Volume-I

A COMPREHENSIVE ASSESSMENT OF THE AVAILABILITY AND USE OF BIOMASS FUELS FOR VARIOUS END-USES WITH SPECIAL ATTENTION TO POWER GENERATION

Final Report

(Ref: UNDP-BD-CPS-2018-009)

Submitted to

National Project Director
SREPGen Project
Attention: Project Manager, SREPGen Project
UNDP Bangladesh

Submitted by

NATURE CONSERVATION MANAGEMENT (NACOM)

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June 2019

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Rashiduzzaman Ahmed
Director, NACOM

A COMPREHENSIVE ASSESSMENT OF THE AVAILABILITY AND USE OF BIOMASS FUELS FOR VARIOUS END USES WITH SPECIAL ATTENTION TO POWER GENERATION

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ACRONYMS AND ABBREVIATIONS

ADB = Asian Development Bank
AE = Agricultural Expert
AFCL = Annual Forest Cover Loss
AIS = Agricultural Information Services
BARI = Bangladesh Agricultural Research Institute
BADC = Bangladesh Agricultural Development Corporation
BAU = Bangladesh Agricultural University
BBDF = Bangladesh Biogas Development Foundation
BBS = Bangladesh Bureau of Statistics
BCAS = Bangladesh Centre for Advanced Studies
BCCSAP = Bangladesh Climate Change Strategy and Action Plan
BCCT = Bangladesh Climate Change Trust
BCIC = Bangladesh Chemical Industries Corporation
BCSIR = Bangladesh Council of Scientific and Industrial Research
BERC = Bangladesh Energy Regulatory Commission
BREB = Bangladesh Rural Electrification Board
BSFIC = Bangladesh Sugar and Food Industries Corporation
BEPP = Bangladesh Energy Planning Project
BES = Bangladesh Energy Study
BF = Biomass Fuel
BFD = Bangladesh Forest Department
BFE = Biomass Fuel Expert
BFIDC = Bangladesh Forest Industries Development Corporation
BFRI = Bangladesh Forest Research Institute
BGF = Biomass Gain Factor
BGDCL = Bakhrabad Gas Distribution Company Limited
BioSNG = Bio-Synthetic Natural Gas
BJRI = Bangladesh Jute Research Institute
BLRI = Bangladesh Livestock Research Institute
BLGCC = Black Liquor Gasification Combined Cycle
BLGMF = Black Liquor Gasification for Motor Fuels
BMDA = Barind Multipurpose Development Authority
BNH = Bangladesh National Herbarium
BPC = Bangladesh Petroleum Corporation
BPDB = Bangladesh Power Development Board
BRAC = Bangladesh Rural Advancement Committee
BRRI = Bangladesh Rice Research Institute
BSV = Baseline Stock Volume
BSTI = Bangladesh Standard and Testing Institute
BTU = British Thermal Unit
BUET = Bangladesh University of Engineering and Technology
B_{LA} = Bran from Local Aus
BVC = Bangladesh Veterinary Council
CAM = Conceptual Analytical Model

CAP = Country Action Plan for Clean Cookstoves
CCAC = Climate and Clean Air Coalition
CCTF = Climate Change Trust Fund
CDB = Cotton Development Board
CDM = Clean Development Mechanism
CEGIS = Center for Environmental and Geographic Information Services
Cft/cft = Cubic Feet
CHP = Combined Heat and Power
CHT = Chittagong/Chattagram Hill Tracts
CV = Commercial Volume
CO_2 = Carbon dioxide
CH_4 = Methane
D = Bulk Density of MSW waste in ton/cubic meter
DAE = Department of Agricultural Extension
DAM = Department of Agricultural Marketing
D_n = Other use
D_1 = Sludge Used in the Sewage Sludge Based Biogas Plant in ton/year
DBH = Diameter at Breast Height
DCRMA = Disaster and Climate Risk Management in Agriculture
DESCO = Dhaka Electric Supply Company Limited
DF = Waste Disposal factor
DFO = Divisional Forrest Officer
DFR = Draft Final Report
DFLS = Districts with Forest Land-use System
DLS = Department of Livestock Services
DME = Data Management Expert
DNFLS = District with No Forest Land-use System
DoE = Department of Environment
DPDC = Dhaka Power Distribution Company Limited
DTL = Deputy Team Leader
D_1 = Ton of MSW used in the MSW based biogas plant
D_n = Other use
EBT = Energy Balance Tables
ef = Extraction Factor
EIA = The U.S. Energy Information Administration
EU = European Union
FAO = Food and Agriculture Organization of the United Nations
FD/BFD = Bangladesh Forest Department
FDC = Forest Dependent Communities
FE = Forestry Expert
FMP = Forest Management Plan
FRA = Forest Resource Assessment
FY = Fiscal Year
GCF = Green Climate Fund
GDP = Gross Domestic Product
GEF = Global Environment Facility

GIAHS = Globally Important Agricultural Heritage System
GIZ = German development agency
GHG = Green House Gas
GJ = Giga (10^9)Joules
GNI = Gross National Income
GOB = Government of Bangladesh
GPS = Global Positioning System
GS = Grameen Shakti
GW = Gigawatt
GWh = Gigawatt Hour
ISWM = Integrated Solid Waste Management
Ha = Hectare (2.471 acres or 10,000 square meters)
HES = Households Expenditure Survey
HF = Hortex Foundation
HIES = Household Income & Expenditure Survey
HH = Households
HHK = Hybrid Hoffman Kiln
HYV = High Yielding Varity
H_2 = Hydrogen
ICS = Improved Cook Stove
IEA = International Energy Agency
IDCOL = Infrastructure Development Company Limited
IDRC = International Development Research Foundation
IPCC = Intergovernmental Panel on Climate Change
IUCN = International Union for Conservation of Nature
IUT = Islamic University of Technology
IW = Industrial Waste
JGTDSL = Jalalabad Gas Transmission and Distribution Systems Ltd.
JICA = Japan International Cooperation Agency
KfW = Kreditanstalt für Wiederaufbau ("Credit Institute for Reconstruction").
KG = Kilogram
kgoe = Kilogram of Oil Equivalent
KGDCL = Karnaphuli Gas Distribution Company Limited
KM = Kilo Meter
KTOE = Kilotonne of Oil Equivalent
KUET = Khulna University of Engineering and Technology
Kw/KW = Kilowatt
Kwh = Kilowatt hour
LCV = Lower Calorific Value
LGED = Local Government Engineering Department
LHV = Lower Heating Value
LPE = Livestock and Poultry Expert
LPG = Liquefied Propane Gas
m^3 = Cubic Meter
MC = Middle Canopy
MJ = Mega Joule

MNRE = The Ministry of New and Renewable Energy
MoA = Ministry of Agriculture
MoEFCC = Ministry of Environment, Forest and Climate Change
MoFL = Ministry of Fisheries and Livestock
MoP = Ministry of Planning
MoPEMR = Ministry of Power, Energy and Mineral Resources
MSW = Municipal Solid Waste
MSWE = Municipal Solid Waste Expert
MTOE = Megaton of oil equivalent
MW = Mega Watt
MW_e = Mega Watt Electric
M.Ton = Metric Ton (1000 KG)
M_{HA} = Production of Hybrid Aus
M_{HB} = Production of Hybrid Boro
M_{LA} = Production of Local Aus
M_{LB} = Production of Local Boro
M_{MZ} = Production of Maize
M_W = Production of Wheat
M_{PL} = Production of Pulses
M_{OL} = Production of Oil Seeds
M_{SC} = Production of Sugarcane
M_{PT} = Production of Potato
M_{BA} = Production of Banana
M_{JU} = Production of Jute
NACOM = Nature Conservation Management
NAPA = National Adaptation Programme of Action
NEP = National Energy Policy
NFA = National Forest Assessment
NFI = National Forest Inventory
NT = Numbers of Truck used to dispose MSW per day
NG = Natural Gas
NGL = Natural Gas Liquids
NGO = Non-government Organizations
$N_{buffalo}$ = Number of Buffalo
N_{cow} = Number of Cow
N_{goat} = Number of Goat
O_2 = Oxygen
PAB = Practical Action Bangladesh
PC = Project Coordinator
PCFC = Per Capita Fuel Consumption
PDD = Project Design Document
PER = Primary Energy Resource
PCFC = Per Capita Fuel Consumption
PGCL = Pashchimanchal (West Region) Gas Company Limited
PJ = Peta (10^{15}) Joule
PKSF = Palli Karma Sahayak Foundation

PPP = Public Private Partnership
PROD = Total production in particular sector
PR_{LA} = Mass of Plant Residue (straw)
PR_{LAR} = Mass of Plant Residue (root)
PR_{RW} = Weight of plant Root
PR_{W} = Weight of Plant Residue
P_{opD1} = Population of the District
PSTP = Pagla Sewerage Treatment Plant
pV/PV = Photovoltaic
QTY = Amount of waste in Ton per truck
RE = Renewable Energy
REB = Rural Electrification Board
PRIM = Rubber Research Institute of Malaysia
RIMS = Resource Information Management System
RRDD+ = Reducing Emissions from Deforestation and Forest Degradation Plus
RSF = Rural Services Foundation
SDG = Sustainable Development Goals
SDS = Sustainable Development Scenario
SHS = Solar Home System
SGCL = Sundarban Gas Company Limited
SID = Statistics and Informatics Division, Government of Bangladesh
SIDA = Swedish International Development Authority
SNC = Second National Communication
SNFA = Second National Forest Assessment
SNV = The Netherlands Development Organization
SREDA = Sustainable and Renewable Energy Development Authority
SREPGen = Development of Sustainable Renewable Energy Power Generation
SS = Sewage Sludge
SUST = Shahjalal University of Science and Technology
SWDS = Solid Waste Disposal Site
SYB = Statistical Year Book
S_n = Other Sources of MSW
S_{sludge} = Surplus Sewage Sludge
S_1 = MSW deposited in City corporation/ Municipal MSW dumpsite (ton/yr)
TC = Top Canopy
TGTDCL = Titas Gas Transmission and Distribution Company Ltd.
TJ = Tera (10^{12}) joules
TL = Team Leader
TNC = Third National Communication
ToR = Terms of Reference
TP = Transport Permission
TPES = Total Primary Energy Supply
TWh = (Tera 10^{12} watt-hours)
$T_{brick\ kiln}$ = District wise Total wood-lot Biomass fuels used in Brick kiln
T_{BU} = District wise Total Fire Wood Supply from Built up Area
$T_{BU(F)}$ = District wise Total Biomass Fuel Supply from Built up Area

T_{CL} = District wise total fire-wood supply from the cultivated land
$T_{CL(F)}$ = District wise total Biomass Fuel supply from the cultivated land
$T_{firewood}$ = Total Biomass Fuels used for Cooking
$T_{l(Dung)}$ = District Wise Total Dung Supply
$T_{l(Supply)}$ = District wise Total Livestock Biomass Supply
Tl(litter) = District wise Total Litter Supply
$T_{leaves+twigs}$ = Total Biomass from Leaves and Twigs
$T_{LF(supply)}$ = District wise Total Livestock Biomass Fuel Supply
$T_{IW(F)}$ = District wise Total Industrial Waste biomass fuel supply
$T_{MSW(F)}$ = Total Energy Value of MSW
TNC = Third National Communication
$T_{SS(F)}$ = Total District wise Sewage Sludge Biomass Fuel Supply
T_{VL} = Total Fire Wood Supply from Village Level
$T_{VL(F)}$ = Total Biomass Fuel Supply from Village Level
T_{LA} = Total Biomass Supply from Local Aus
T_{HA} = Total Biomass Supply from Hybrid Aus
T_{LAM} = Total Biomass Supply from Local Aus
T_{LB} = Total Biomass Supply from Local Boro
T_{HB} = Total Biomass Supply from Hybrid Boro
TJ_{U} = Total Biomass Supply from Jute
T_{BA} = Total Biomass Supply from Banana
T_{PT} = Total Biomass Supply from Banana
T_{SC} = Total Biomass Supply from Sugarcane
T_{OL} = Total Biomass Supply from Oil Seeds
T_{PL} = Total Biomass Supply from Pulses
T_{MZ} = Total Biomass Supply from Maize
T_{W} = Total Biomass Supply from Wheat
UK = United Kingdom
UN = The United Nations
UNDP = United Nations Development Programme
UNFPA = United Nations Population Fund
UNFCCC = United Nations Framework Convention on Climate Change
USA = The United States of America
USF = Un-classed State Forest
V = Volume
vf = Village Forest
WB = World Bank
VERC = Village Education Research Center
VOL = Cubic Meter of Waste Handled per Truck
WEEE = Waste Electrical and Electronic Equipment
WGF = Waste Generation Factor per unit production
WPC = Waste generation Per Capita per year (ton/yr)
WRI = World Resource Institute
WZPDCL = West Zone Power Distribution Company Limited
W_{wet} = Mass of Wet Dung
ϱ = Mass Density (Tons/$m^{3)}$

Summary

A Comprehensive Assessment of the Availability and Use of Biomass Fuels for Various End Uses with Special Attention to Power Generation

Introduction

Biomass Fuels are generated on earth's surface by photosynthesis process; these are the most ancient type of energy resources observed on earth's surface. Analyses of empirical data on accumulated carbon dioxide in earth's atmosphere revealed their presence millions of years ago. Fossilization of biomass resources below earth's surface created coal, petroleum fuels and natural gas. Level of carbon dioxide concentration in earth's atmosphere varied between 200 ppm to 300 ppm for 800,000 years (World Bank, 2010). Since the initiation of Industrial Revolution remarkable changes have taken place on the invention of different technologies including Energy Technologies. This resulted in transition of energy use from Biomass Fuels to Fossil Fuels to Electricity. As a result, concentration of carbon dioxide in earth's atmosphere gradually increased from 300 ppm in 1880 to 410 ppm in 2019 due to accelerated use of fossil fuels.

This resulted in increase of earth's temperature causing Climate Change at global level different type of institutions were established (UNFCCC, IPCC, GEF, GCF etc.) and mitigation strategies were adopted (Kyoto Protocol, the Paris Agreement) to combat the effects of Greenhouse gas (GHG) Emissions.

The main objective of the project is to reduce the annual growth rate of GHG emissions (152 million tons carbon dioxide in 2012) from the fossil fuel-based power generation by exploiting Bangladesh's biomass fuels resources for electricity generation, (GOB 2018). The basic approach of the project will be to promote renewable energy through the Sustainable and Renewable Energy Development Authority (SREDA).

Objective

The objective of the present study is to make "A Comprehensive Assessment of the Availability and Use of Biomass Fuels for Various End Uses with Special Attention to Power Generation". As per TOR the study is mandated to

- Assess the Availability of Biomass Fuels;
- Assess the existing use of Biomass Fuels;
- Assess the Prospects of Power Generation in Different Districts up to the year 2040.

Biomass fuels based power generation has been considered to reduce emission of carbon dioxide by substituting the use of fossil fuel based power generation. Biomass fuels are recognized as carbon neutral, with no net emission of carbon dioxide in earth's atmosphere. Specific objectives of the study as per ToR have been presented below.

Component 1: Assessment of the Roles of Biomass Fuels in Total Energy Consumption in Bangladesh and in Selected Developed and Developing Countries

Component 2: Development of a Conceptual and Analytical Model to Estimate Supply and Demand of Biomass Fuels for 64 Districts of Bangladesh

Component 3: Assessment of Supply of Biomass Fuels from Tree Resources for 64 Districts of Bangladesh

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Component 6: Assessment of Supply of Biomass Fuels from Municipalities and Industrial Units for 64 Districts

Component 7: Assessment of Consumption of Biomass Fuels for Cooking and other End-uses Including Power Generation for 64 Districts

Component 8: Compilation of Data of Total Supply and Demand of Biomass Fuels for the Base year 2015 and Future Projections of Biomass Fuels up to 2040

Conceptual Issues

Some conceptual issues related to Assessment of Supply and Demand of Biomass Fuels for Various End Uses with Special Attention to Power Generation are shown in Box-1.

Box-1: Some Conceptual Issues Related to Assessment of Supply and Demand of Biomass Fuels for Various End Uses with Special Attention to Power Generation

Biomass and Biomass Fuels Resources: Plant materials grow on land and water by photo-synthesis process using carbon dioxide and water from the environment. Biomass is used for multiple purposes. As for example, paddy crop is grown on paddy plants. Bran and husks are produced as crop residues during processing of paddy to rice. Rice is the main product used for food, bran is used for extraction of rice-bran-oil, and husks are used as fuel. Plant residues are obtained from paddy plants, of which top portion (fine straw) is used as fodder and bottom portion (rough straw) is used as building materials, mulch and fuels. When a tree biomass is extracted timber is obtained as main product and tree residues (e.g. branches & leaves, saw logs, saw dust) are used as fuel. From jute plant, extracted fiber is the main product used in jute and textile industries and plant residue (e.g. jute sticks is used as building materials and fuels). In livestock sector; milk, meat and hide are the main products and animal dung is the byproduct; which is used as building materials, manure and fuel. All the biomass products mentioned above (grain, timber, milk, meat and hide) are considered as resources in National Accounting System to compute Gross Domestic Products (GDP).

Tree residues, agricultural residues (e.g. crop residues and plant residues), animal and poultry residues are assumed as wastes and not considered in national accounting system to compute GDP. As these residues are generally used as fuels; are defined as biomass fuels. Major portion of total biomass fuels are used in rural areas, they are also called rural energy. It may be noted that part of total biomass fuels are also used in urban areas for cooking and heating and also in rural industries. As biomass fuels are used in household cooking, both in rural and urban areas using traditional technologies; sometimes biomass fuels are also called traditional fuels. As most of biomass fuels is obtained by gathering from local sources; they are also called non-commercial fuels. It may be noted that part of biomass fuels (e.g. fuel wood) is transacted commercially both in urban and rural areas even then they are mentioned in the literature as non-commercial fuel.

Resources & Wastes: Materials and substances occurring in nature which can be exploited for economic gain are considered as natural resources. In this context, both biomass and biomass fuels are natural resources. Crops and main products of natural resources has been considered as natural resources under the national accounting system and residues type biomass fuels are not recognized as resources. Although some of the residues used as biomass fuels (e.g. fuel wood, rice husk, oil cakes and animal dung) are being transacted commercially in the local markets; they are not recognized by the national accounting system as resources. Even then in specific locations, to an individual owner, when the economic costs of residues are more than economic gain through its use, it is considered as wastes. On the other hand, when the economic gains of using residues are more than the economic cost of extraction and supply cost; it is considered as resource or wealth. At the present economic condition, in Bangladesh residues available from the crops harvested in rainy season, animal dung produced in rainy season; Municipal Solid Wastes (MSW) are considered as wastes (left unutilized at dumpsite), because the economic cost for its collection to its dump site is higher than its economic value. In future when these waste materials can be transformed into energy by using appropriate conversion technologies, these waste materials may also be considered as resources.

Bio-Fuels: Liquid fuels may be obtained directly from crops and also by processing biomass and are used to substitute petroleum fuels are defined as bio-fuels. Biofuels (alcohol) are renewable and petroleum fuels are non-renewable fossil fuels. Liquid fuels may be extracted directly from oil seed crops (e.g. mustard, soybean, sunflower, palm, coconut etc.) and can be produced by processing (fermentation) of crops (e.g. alcohol is produced by processing of sugarcane and sugar beet).

Biogas: Gaseous fuel may be obtained by anaerobic digestion of biomass (e.g. animal dung, plants etc.). Bio-fuels (liquid) and biogas are used in transport sector to substitute non-renewable petroleum fuels (e.g. diesel, octane etc.).

Rural Energy: As major portion of biomass fuels is consumed in rural areas, sometimes biomass fuels are assumed synonymous to rural energy; which is not correct. In rural areas different type of energy sources used for various end-uses are: (a) biomass fuels, kerosene, LPG for household cooking; (b) kerosene, grid electricity, photo-voltaic electricity for household lighting; (c) biomass fuels, kerosene, LPG for cooking in commercial units (e.g. hotel, restaurant); (d) biomass fuels, kerosene, LPG in rural industries; (e) animal power & petroleum fuels in ploughing; (f) diesel and solar PV and grid electricity for irrigation; (g) animal & human muscle power, diesel, electricity in rural transport. Biomass fuels meet the needs of a substantial part of the total energy consumed in rural areas. It means total rural energy needs cannot be met by biomass fuels only.

Renewable Energy Sources (RES): Different types of Renewable Energy Sources used in the country are: (a) biomass fuels, (b) hydro power, (c) solar PV and (d) wind power. Biomass fuels are (a) particular type of renewable energy; which supply a major portion of total renewable energy consumed in the country. But biomass fuels and renewable energy are not synonymous.

Renewable Energy Technologies (RETs): Electricity is the best form of energy; government has given priority attention to deliver electricity to the total population by 2020. Electricity can be generated by all types of renewable sources (such as solar PV, wind power, hydro power, biomass fuels) by using technologies specific to Renewable Energy Sources (RES). It requires specialized technical knowledge to design and develop technologies specific to RES & Renewable Energy Technologies (RETs). In Bangladesh, major portion of total electricity is generated by using fossil fuels; which release greenhouse gases to earth's atmosphere. Generation of electricity by using RETs and nuclear energy do not contribute emission of greenhouse gases (GHGs). Government is committed to generate at least 10 percent of total electricity by using renewable energy sources. Biomass fuels is carbon neutral, generation of electricity by using biomass fuels does not contribute in emission of carbon dioxide. This is why; the objective of the present study is to make "A Comprehensive Assessment of the Availability and Use of Biomass Fuels for Various End Uses with Special Attention to Power Generation". It has been discussed above that at present large portion of biomass fuels is used for different end uses. Systematic and pragmatic assessments of supply and demand of biomass fuels are to be made to identify areas for establishment of power plants in specific locations. Use of biomass fuels for power generation is to be location specific. Because cost of transport of biomass fuels is a barrier for establishing large size power plants based on biomass fuels.

Scope of the Work

Details Terms of Reference of this assignments and scope of work is included in the Annex-I of the Volume-I.

Study Team

The Study Team is composed of following Members. One Individual Consultant has been appointed by the UNDP/SREDA to guide the team and review the deliverables of the assignments.

Individual Consultant: Prof. Dr. M. Nurul Islam, Former Professor, Chemical Engineering Department and Institute of Appropriate Technology (IAT), BUET.

Assignments	Name
Team Leader	Professor Ijaz Hossain
Deputy Team Leader and Energy Expert	Mr. Utpal Bhattacharjee
Biomass Fuel Expert-1	Dr. Md. Ali Ahammad Shoukat Choudhury
Biomass Fuel Expert-2	Dr. Shoeb Ahmed
Forestry Expert	Dr. Paramesh Nandi
Agricultural Expert	Dr. Abu Wali Raghib Hassan
Livestock and Poultry Expert	Dr. Md. Rafiqul Islam
Municipal Solid Waste (MSW) and Industrial Wastes Expert	Mr. Shaymal Barman
Project Coordinator	Mr. Rashiduzzaman Ahmed

Organization of the Report

The report has been organized in three volumes.

Component wise summary of this study are mentioned below**:**

Component 1: Assessment of the Roles of Biomass Fuels in Total Energy Consumption in Bangladesh and in Selected Developed and Developing Countries

1.1 Introduction

Biomass fuels are used both in developing and developed countries. In developing countries, it plays a big role because it often constitutes more than 90 percent of the rural energy consumptions. As per capita GNI of the country increases through industrialisation, share of commercial energy increases and the share of biomass fuels decreases. In addition, as rural households move up the energy ladder as a result of increasing standard of living, the role of biomass fuels decreases. This decreasing share of biomass fuels in the total primary energy is the result of increasing use of commercial energy for driving industrial growth and urban development. In developed countries, the share of biomass fuels in the Total Primary Energy (TPE) is generally less than 10 percent.

The areas of application of biomass fuels in developed and developing countries also varies. Biomass fuels are predominantly used for cooking and space heating in developing countries. In developed countries biomass fuels is mainly used to produce liquid biofuels for the transport sector and to generate electricity.

1.2 Objective

The Objective of this component is to assess the roles of biomass fuel in total energy consumption in Bangladesh and in selected developed countries and developing countries.

1.3 Organizations

Organizational issues are important for planning and development of biomass fuels development program. Important roles and the functional aspects of organizations are presented below.

Biomass Fuels Planning: During last forty years two major studies have been carried out for sustainable development of biomass fuels; due to absence of appropriate organizations these initiatives have not been transformed into actions. In Bangladesh, sub-sectoral Master Plans are generally initiated by respective national organizations (e.g. Forestry Master Plan by Department of Forest, Gas Master Plan by Petrobangla, Power Sector Master Plan by Bangladesh Power Development Board etc.); With the initiative of the Energy Division of the Planning Commission two Energy Master Plans (Bangladesh Energy Study and Bangladesh Energy Planning Project) were completed in 1976 and 1987. Both the Maser plans highlighted the important roles of biomass fuels in meeting energy demand of the country.

Data Management: Bangladesh Bureau of Statistics (BBS) is the apex national organization responsible for collection and publication of data required for planning and development of different sub-sectors (e.g. biomass fuels). BBS started publishing, the data of traditional fuels originally presented in BES in Statistical Year Book (GOB 1979) and continued publishing

up to 2009 (GOB 2009). In addition, quantity of biomass fuels supplied per year in 1992 was reported as 25.17 million tons which was increased to 43.7 million tons in 1993. No explanation was given in Statistical Year Book published in subsequent years about the sudden increase in supply of traditional and discontinuation of publication of yearly supply data of traditional fuels.

Census of Agriculture: Under Agricultural Census Act of 1958 (as amended in 1983), the country has carried out Agriculture Censuses in 1960, 1977, 1983-84, 1996 and 2008 and subsequently published their report accordingly. Data published in Agriculture Census Reports consist land use data of Forest, Crops, Livestock & Poultry and Fisheries. Since independence, the first round of Household Expenditure Survey (HES) was carried out 1973-74 and the Preliminary Report of the 16th round HIES (GOB 2017) has been published by BBS.

Consumption of Biomass Fuels: Per capita consumption of biomass fuels is a basic parameter required for future planning and development of biomass fuels and rural energy. A number of studies were carried out in the country since 1976; a comprehensive review of these have been presented in BEPP report (GOB 1987), which have been presented in present study report.

Research on biomass fuels consumption and development of related technologies (e.g. improved biomass fuels using cook-stoves, biogas technology) have been carried out by a number of national R&D organizations and Universities. Outcomes of these research had limited applications due to lack of continuity of funding and policy support. Masters and PhD degrees on various aspects of biomass fuels are being awarded from BAU, BUET and other Universities.

1.4 Review and Analysis

Biomass fuels currently contribute 10% of global primary energy supply. In EU and USA, biomass fuels' contribution to the total primary energy supply (TPES) is 8.9 percent, and 4.3 percent respectively. In 2015, 4 percent of TPES of China came from biomass fuels. Lower income developing countries are more reliant on biomass fuels; India's TPES included 21 percent share of biomass fuels (IEA, 2019).

It is, however, be noted that China's share is much lower than that of the EU even though EU has no demand for biomass fuels for cooking needs. This indicates that China is lagging behind the EU in developing Modern Biomass, i.e. applications in liquid biofuels production, electricity generation and process heating

Power generated from biomass fuels as a percent of total generated power; EU 6.18 percent, USA 1.86 percent, China: 0.9 percent, India 1.94 percent and Bangladesh-negligible.

Biomass fuels conversion technologies for power generation and biomass fuels action program in selected countries have been reviewed. Percent of Biomass Fuels in Total Energy Sources in Selected Developed and Developing Countries were reported as follows:

EU 9.47percent, USA 4.67percent, China 3.8percent, India 21.49percent and Bangladesh 24.69 percent.

Previous studies on biomass fuels in Bangladesh has been reviewed. Historical relationship between biomass fuels consumption and GNI percapita has been studied, which indicates share of biomass fuels in the total energy mix varied from 54 percent, 1990 (GNI per capita US$ 310) and 24 percent in 2016 (GNI percapita US$ 1330).

On the basis of analysis of data of traditional fuel supply percent of biomass fuels in Bangladesh, historical relationship between biomass fuels consumption and GNI per capita of another data set has been studied; which indicates share of biomass fuels in the total energy mix varied from 48.5 percent in 1993 (GNI per capita US$ 320) and 40.1 percent in 2005 (GNI per capita US$ 530).

Electricity generation capacity of biomass fuels based power plants in Bangladesh is 42.5 MW (including 40 MW in Sugar Mills by burning bagasse).

Law, rules and policies related to use of biomass fuels have been reviewed. An Energy Balance Table for the country has been prepared for the year 2015; it indicates that 36 percent of Total Primary Energy was supplied by Biomass Fuels.

1.5 Projection

The projection of biomass fuels use is very difficult because many factors impact its use. In developed countries the use of biomass fuels is being promoted because it is a renewable fuel and lowers the emission of greenhouse gases. In developing countries most governments are striving to decrease the role of biomass fuels in rural areas because it is perceived as a sign of underdevelopment. However, as part of the global community facing the challenges of Climate Change, Bangladesh has an interest in promoting use of biomass fuels especially for power generation.

1.6 Conclusion and Suggestions

At present in Bangladesh no organization is responsible for collection and publication of data on supply and consumption of biomass fuels for its sustainable development. Appropriate actions should be taken in this respect for sustainable development and management.

- At present bagasse based power plants are operated in sugar mills for 120 to 180 days per year. A feasibility study may be undertaken to assess the prospect of operating power plants of sugar mills to operate throughout the year, using alternative fuels.
- BBS published data of yearly supply of traditional fuels (biomass fuels) from 1974 to 2005. On the basis of the present study, BBS should regularly publish data of biomass fuels supply starting from 2016.
- SREDA should interact with BBS to harmonize the publication of Census of Agriculture data of 2019 in order to estimate the supply of biomass fuels from different categories of land. And also publish data of livestock and poultry resources to facilitate the establishment of domestic and commercial biogas plants based on animal and poultry dung.
- Energy Balance Tables (EBT) of Commercial Fuels used to be published by BBS as a part of Energy Data Base. Since 2005, BBS has discontinued publication of EBT.

This important task needs to be undertaken urgently. SREDA / BBS should consider publishing EBT similar to present study.

- At present Household Income Expenditure Survey (HIES) of BBS publishes data of different categories of household expenditures including energy and lighting. HIES should consider in publishing the type (e.g. fuelwood, kerosene, LPG, electricity etc.) and quantity (e.g. kg, litter, kg, kWh etc.) of energy consumed along with energy expenditures.

Component 2: Development of a Conceptual and Analytical Model to Estimate Supply and Demand of Biomass Fuels for 64 Districts of Bangladesh

2.1 Introduction

The conceptual framework is the core element for comprehensive assessment for supply and demand of biomass fuels for 64 Districts of Bangladesh. Dis-aggregated data on supply-demand of biomass fuels at a district level is the first step towards planning and development of biomass fuels. In future, when it become necessary data can be analysed at Upazila and Union level.

2.2 Objective

The objective of Component 2 is to develop a Conceptual and Analytical model (CAM) to estimate Supply and Demand of biomass Fuels for 64 districts of Bangladesh to be followed by all the components of the present study.

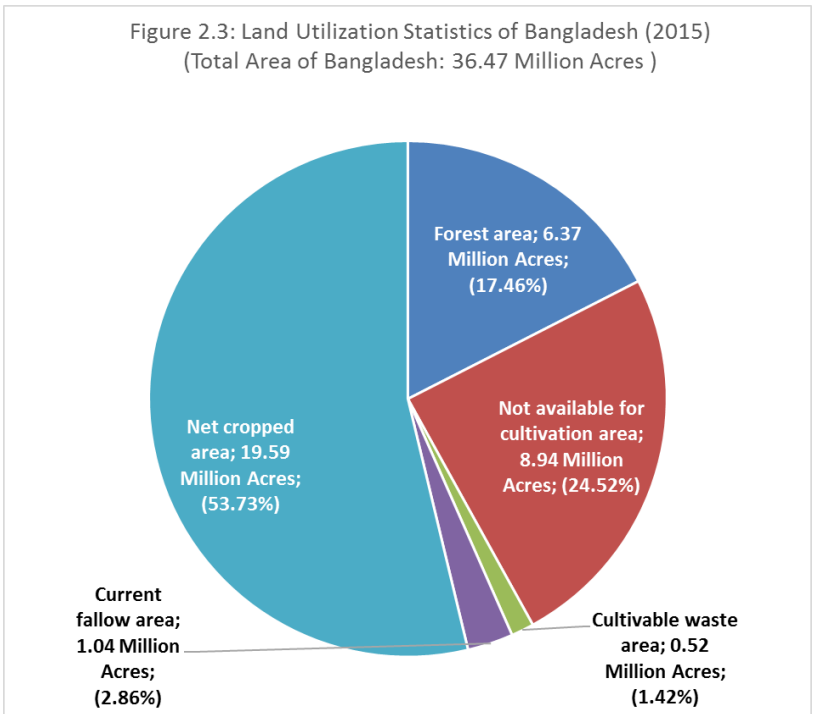
2.3 Conceptual Framework and Analytical Model

A Conceptual Framework has been developed; which indicates the linkages for assessment of supply and demand of biomass fuels. Equations required for computation of different parameters have been presented in the Component 2.

2.4 Primary Data Source

Agricultural censuses carried out by BBS periodically, provides primary data related to tree resources, crops and animal resources. Land use Analysis data for the year 2015 has been used for the analyses of the present study, except MSW and Industrial Wastes. Land use data of BBS for the year 2015 is shown below.

Figure 2.3: Land Utilization Statistics of Bangladesh (2015)
(Total Area of Bangladesh: 36.47 Million Acres)



Source: BBS Statistical Yearbook, 2017

In the present study, assessment of supply of biomass residues has been made for the following classes of lands: Forest Land (6.37 million acres) and Net Cropped Area 19.59 million acres; which cover 71.2percent of the total area of the country.

Due to unavailability of data of biomass production, it has not been possible to assess supply of biomass residues from the following classes of land: Cultivable waste (0.52 million acres), Current fallow (1.04 million acres) and Not Available for Cultivation (8.94 million acres); which covers 28.7 percent of the total area of the country. It is known that some of these lands are being used for grazing of livestock and growing of fodders and also for growing trees. Considering their functional use from biomass supply point of view, these lands may be broadly classified as "Non-cropped land" for fodder and "Non-forest land" for growing trees. On the basis of these analysis, possibility of revising existing BBS land use analyses (Not Available for Cultivation, Cultivable Waste Area and Current Fallow Area) should be considered for future estimation of supply of biomass fuels.

Of the total area Not Available for Cultivation (8.94 million acres), 13.1 percent of total area of the country is covered by different water bodies; which are not available for growing biomass to be used as fuels. 9.93 percent of the country is covered by other categories of land. It has been estimated that among the other categories of land, village forest covering 0.67 million acres (1.84 percent of the total area of the country) supply more than 99 percent of the tree residues (biomass fuels). On the other hand, Government forest land covering 6.37 million acres (17.46 percent of total area of the country) supplies about 1 percent of tree residues (biomass fuels).

On the basis of land use data of BBS and Banglapedia, an attempt has been made to disaggregate 9.93 percent of other lands for future assessment of biomass fuels (tree residues).

Component 3: Assessment of Supply of Biomass Fuels from Tree Resources for 64 Districts of Bangladesh

3.1 Introduction

Tree resources are recognized as the cheapest means of capturing carbon dioxide from earth atmosphere. Environmental benefit of carbon capture is enjoyed by the Global community. Economic benefits of tree resources in the form of fruits, timber, fuel, balancing of micro environment are enjoyed by the country, local communities, institutions and individuals. The contributions of Forest and related services in GDP in 2015 were 1.42 percent of GDP (at current market price).

3.2 Objective

The objective of Component 3 is to assess the Biomass fuels supply from the Tree Resources for 64 districts.

3.3 Conceptual Diagram

A Conceptual diagram of the Component 3 has been considered as an integral part of the conceptual and analytical model of the study presented in Component 2.

3.4 Organizations

The Ministry of Environment and Forests (MoEF) was renamed as the Ministry of Environment, Forests and Climate Change (MoEFCC) on May 14, 2018. Different Organizations under the Ministry are: Bangladesh Forest Department (BFD), Bangladesh Forest Research Institute (BFRI), Bangladesh Forest Development Industries Cooperation (BFIDC), Department of Environment (DoE), Bangladesh National Herbarium (BNH) and Climate Change Trust (CCT). Data supplied by Bangladesh Forest Department (BFD) and BBS have been used for the study of Component 3.

3.5 Data Collections & Analyses

In Bangladesh, total quantity of biomass fuels obtained from tree resources in 2015 was estimated as 16.19 million tons, of which the shares of Village Forest and Government Forest were 16.18 million tons (99.7 percent) and 0.01 million tons (0.3 percent) respectively. The shares of land under village forests and Government forest were 0.27 million hectares and 2.26 million hectares respectively. It means that village forests are highly productive (59.93 tons/hectare) in comparison to Government forest (0.0044 tons/hectare). It may be mentioned that extraction of trees from Government forest has been banned since 2015. Whereas there is no such restriction on the extraction of tree residues obtained from Village Forests by tree felling and pruning. It has been estimated that in 2017, biomass stock in Village Forest is 260.48 million ton, which is 60 percent of total biomass stock (434.16 million ton).

The total supply of tree residues (as fuel) in 2015 was estimated as 16.19 million tons, which will gradually decrease to 10.24 million tons in 2050.

3.6 Projection

It has been projected that in future, extraction and consumption of wood fuel will decline while the extraction of round wood or timber wood may increase.

Component 4: Assessment of Biomass Fuel Supply from Agricultural Crop Lands and Other Type of Lands for 64 Districts of Bangladesh

4.1 Introduction

In Bangladesh, Agriculture sector consist of four major sub-sectors; Forestry, Crops , Livestock and Fisheries. The contribution of Agriculture sector in GDP in 2015 was 12.21 percent and the share of crops sub-sector in GDP was 8.73 percent at current market price (GOB 2016).

4.2. Objectives

The objective of the Component 4 is to assess the potential supply of biomass fuels from the Agricultural residues available from different crops according to 64 districts of Bangladesh.

4.3 Conceptual Diagram

A Conceptual diagram of the Component 4 has been considered as an integral part of the conceptual and analytical model of the study presented in Component 2.

4.4 Organizations

Ministry of Agriculture (MoA) is responsible for overall development and management of agricultural lands and crops. Different organizations involved with the development and management of Agriculture Sector are: Department of Agricultural Extension (DAE), Bangladesh Agricultural Development Corporation (BADC), Department of Agricultural Marketing (DAM), Cotton Development Board (CDB), Barind Multipurpose Development Authority (BMDA), Agriculture Information Services (AIS), Hortex Foundation (HF). In addition many reaearch and training organizations are also involved in development and management of crop sub-sector.

4. 5 Data Collections & Analyses

For the present study, information on crop calendar is important, because the residues obtained during rainy season cannot be used directly as fuels. Whereas, most of the residues obtained during dry season are used for various end uses, such as fodder, building materials, mulching, fuels etc.. For a particular location (District) specific uses of agricultural residues depends on local agro-ecological conditions and ownership of the resources.

In the present study of 2015, out of total gross cropped area of 37.67 million acres, potential supplies of agricultural residues have been estimated for different crops grown in 34.90 million acres (92.7 percent of gross cropped area). Minor crops have been grown in balance 6.3 percent areas.

Agricultural residues have two major components: plant residues and crop residues.

There are multiple uses of plant residues (e.g. straw, stalks and sticks etc.) such as fodder, building materials and fuels. Crop residues (e.g. bran, oil cake etc.) are generally used as cattle and poultry feed. Rice husk also has multiple uses like poultry bedding materials and fuels.

There are hierarchical gradation of plant and crop residues depending on their economic value. Fodder, feed and building materials are higher value usages than fuel. It means to an individual owner if there is opportunity to use available residues for higher value product, they will not be used for lower valued usage (fuel). Considering these local practices in mind, supply of crop residues except rice husk has not been made in estimating the supply of agricultural residues.

In 2015, total supply of agricultural residues has been estimated as 115 million tons; of which 4 million tonnes Aus straw harvested during rainy season and the portion (39 million tonnes estimated in component 8) used as fodder have not been considered in the heat balance computation. It means that 43 million tonnes agricultural residues has been used as fuel.

4.6 Projection

Data on projection on Agricultural Crops up to 2040 are not available. The supply of agricultural residues for the base year 2015 may be assumed as constant up to year 2040.

4.7 Conclusion & Suggestions

A substantial portion of agricultural residues available in dry season is used as cooking fuels. There is scope to save these resources through promotion of processed residues (e.g. briquets, pellets) and improved cookstoves. Saved biomass fuels may be used in future for power generation. Agricultural residues available in wet season are not used at present. Possibility of using these resources for biogas production to generate electricity may be assessed.

The scope of the present study was limited to assess the supply of land based biomass fuels. It has been observed during field observations that aquatic biomass (water hyacinth) are used in floating agriculture, which may be helpful in adapting climate change effects on agricultural production. Assessment of water-based (aquatic) biomass resources may be considered in future.

Component 5 : Assessment of the Biomass Fuels Supply from Livestock and Poultry Resources for 64 Districts of Bangladesh

5.1 Introduction

Livestock and poultry subsector plays an important role in the economy of Bangladesh. According to DLS (www.dls.gov.bd), the contribution of livestock and poultry sector in the Gross Domestic Product was 2.07 (current price) in 2015.

The household based report consists of data on the number of livestock and poultry birds by category, their composition in terms of age, sex and breeds, quantity of milk and eggs produced, food and health expenditure, man power engaged in rearing up livestock and poultry birds. The firm based survey report provides elaborate information from the types and characterises and livestock and poultry farms operating in Bangladesh such as, output, input, employment, fixed assets, receipts and expenditure, change in inventory. In the present study, data presented in the Livestock and Poultry surveys reports and Census of Agriculture reports have been reviewed for the collection and compilation.

5.2 Objective

The objective of the present component is Assessment of the Biomass fuels supply from the Livestock and Poultry Resources for 64 districts.

5.3 Conceptual Diagram

Livestock and Poultry resources component of the integrated conceptual diagram is presented in Figure 5.1. in the Volume II of the report.

5.4 Organizations

Ministry of Fisheries and Livestock (MoFL) is responsible for overall development and management of Livestock and Poultry Resources of the country. There are three organizations under the MoFL related to Livestock and Poultry Resources. Department of Livestock Services (DLS), Bangladesh Livestock Research Institute (BLRI) and Bangladesh Veterinary Council (BVC).

5.5 Data Collections & Analyses

Distribution of cattle at household and farm level were as follows 23 million (97.3 percent) and 0.64 million (2.7 percent) respectively. Sirajganj district had the highest number of cattle and buffalo (9,09,740) and Feni District had the lowest number of cattle and buffalo (105720) at household level. Chittagong district had the highest number of cattle (22,309) and Bandarban district had the lowest number of cattle (2,470) at Farm level.

It may be observed that in Bangladesh, 48.3 percent housholds owned livestock, which means that 51.7 percent households did not own any cattle. Distribution of percent livestock owning household among different divisions were as below. Barisal-62.5 percent, Chittagong-45.15 percent, Dhaka-40.75 percent, Khulna-56.64 percent Rajshahi-52.46 percent, Rangpur-54.29 percent and Sylhet- 47.92 percent. Among the districts, Meherpur, had highest percent of

(67.20 percent) and Sylhet has the lowest percent (42.07 percent) livestock owning housholds.

Average Biomass (dung) from livestock species at households level is @ 10kg per day and at Farm level for hybreed animals is @15 kg per day. Dry dung weight is 25% of the weight of the wet dung. By observing local practices availability of dry dung as fuel at household level was estimated as 8 million tonnes per year. Considering the prospects of using dung for production of biogas, the quantity has estimated in tonne of raw dung perday.

Total available raw dung from cattle (both at household and farm level) has been estimated as 0.119 million tonnes per day (43.4 million tonnes per year); which is about 10.9 million tonnes (dry) dung per year. Traditional processes of making dung-sticks and dung-cakes are shown in pictures. Quantity of dry dung has been considered as an input for the supply of biomass fuel. As poultry litters are not used as fuel, which has not been used for energy balance.

Biogas Potential

Biogas generation potential has been estimated on the basis of raw dung. It is reported in the draft Biogas Guidelines that on the basis of households having 5 heads of cattle can establish about 1.27 million Domestic Biogas Plant; which will require dung from 6.35 million cattle. Potential biogas generation capacity of 1.27 million biogas plants may be estimated as 2.54 million cubic meter per day [6.35 million x10 kg/day x 0.04 cubic meter/kg of dung]. Generated gas may be used for domestic cooking of 1.27 million households. It may be noted that generated biogas from small size biogas plant is used for domestic cooking not for generation of electricity.

It has been estimated that total amount biogas may be generated in 10 (ten) large Government owned cattle farms was 3,817 cubic meter per day, which may be used to generate 5,464 kWh of electricity per day. If the generators are operated for 8 hours a day, it would require generation capacity of 683 kW. For computational purpose, the size of the generator have been estimated on the basis of total number of animals in a farm. It has been observed during field visits that the farm management sometimes prefer to install biogas plant and generator attached to animal sheds. In order to facilitate computation of small number of biogas units; biogas generation capacity and the size of the generators has been estimated for 25, 50 and 100 cattle. Distribution of potential number of biogas plants in Government owned cattle farms according to districts are: Bagerhat, Bogra 1, Barisal 1, Chattogram 1, Dhaka 3, Faridpur 1, Rajshahi and Sylhet 1. It may be noted that Bangladesh Livestock Research Institute (BLRI) has already established two biogas plants in two cattle sheds to generate electricity.

Total amount biogas may be generated in 47 (forty seven) privately owned large cattle farms registered with dairy association of Bangladesh was 7,330 cubic meter per day, which may be used to generate 11,694 kWh of electricity per day. If the generators are operated for 8 hours a day, it would require generation capacity of 1,462 kW. For computational purpose, the size of the generator have been estimated on the basis of total number of animals in a farm. It has been observed during field visits that the farm management sometimes prefer to install biogas plant and generator attached to animal sheds. In order to facilitate computation of small

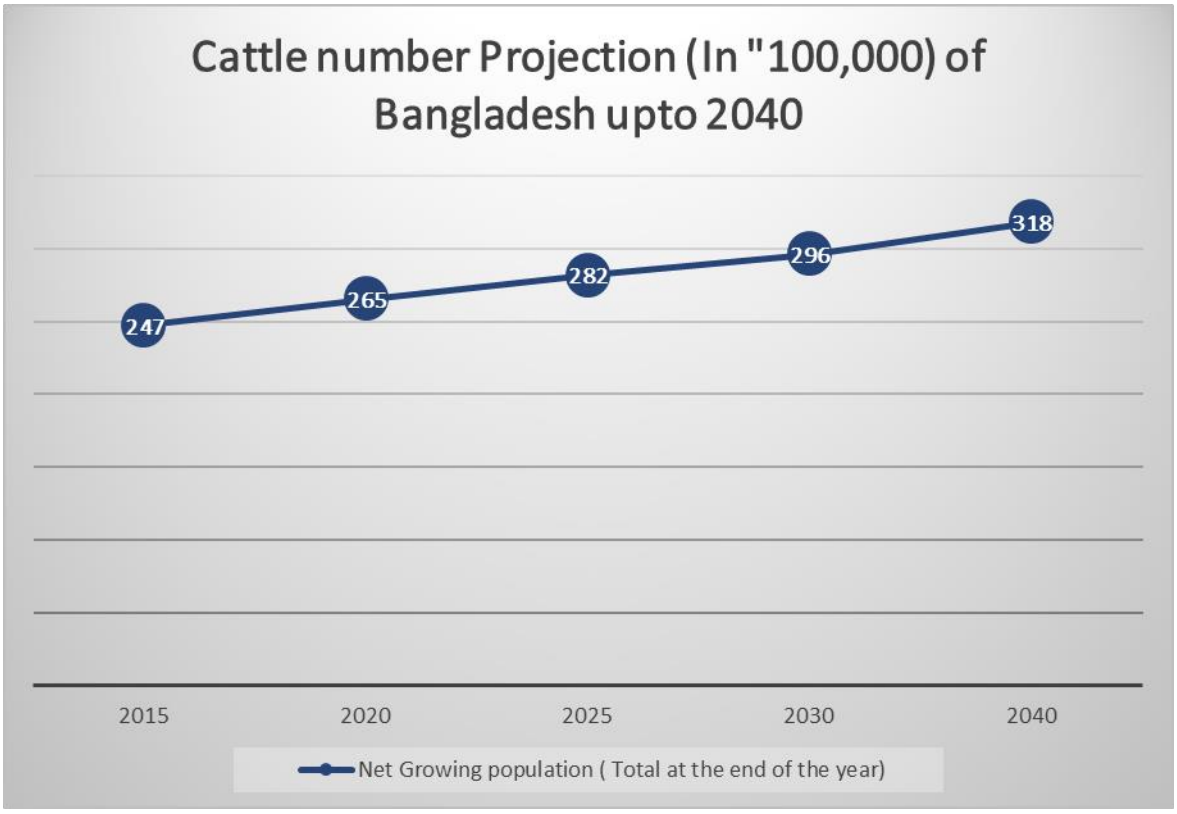
number of biogas units; biogas generation capacity and the size of the generators has been estimated for 25, 50 and 100 cattle. Distribution of number of biogas plants according to districts are: Chottogram 12, Dhaka 11, Dinajpur 1, Gazipur 3, Jamalpur 1, Jessore 2, Keraniganj 1, Kishorganj 1, Kustia 1, Magura 1, Moulovibazar 1, Munshiganj 1, Narayanganj 1, Norshindhi 1, Noakhali 1, Pabna 1, Rangpur 1, Sylhet 2 and Tangail 1.

Total amount of biogas may be generated in 64,073 privately owned cattle farms (located in 64 districts) has been estimated as 4,00,554 cubic meter per day, which may be used to generate 5,72,952 kWh of electricity per day. If the generators are operated for 8 hours a day, it would require generation capacity of 71,619 kW (about 72 MW) in 64 districts. This computation has been made on the basis of 10 cattle per farm. It would be necessary to undertake a feasibility study to assess total number of biogas plants and their size (cubic meter/day) may be established in different Private Livestock Farms.

Total amount of biogas may be generated in 760 privately owned poultry farms was 22,522 cubic meter per day, which may be used to generate 32,215 kWh of electricity per day. If the generators are operated for 8 hours a day, it would require generation capacity of 4,027 kW (about 4 MW) in 64 districts. This computation has been made on the basis of 10,000 birds per farm. It would be necessary to undertake a feasibility study to assess the number of biogas plants and their size (cubic meter/day) may be established in different Private Poultry Farms.

5.7 Projection

A projection on the number of cattle from 2015 to 2040 has been made and is shown below.



5.8 Conclusion & Suggestions

Following traditional practices, at present major portion of animal dung produced by livestock resources are used as biomass fuels (dry dung). Total available raw dung from cattle (both at household and farm level) has been estimated as 0.119 million tonne per day (43.4 million tonnes per year); which is about 10.9 million tonnes (dry) dung per year.

Under traditional practice animal dung is used either as fuel or as manure. Use of animal dung and poultry litters in Biogas technology is recognized as an efficient method of use of dung, because it can provide both fuel and manure. Moreover, it can dispose off large quantity of animal residues (from farms) in environment friendly way. In this context, Government of Bangladesh has taken appropriate measures for the promotion of biogas technology to generate gas and electricity. Recently, SREDA has prepared a Guidelines on Biogas Technology for Energy. Summary of biogas generation potential from animal dung and poultry litter are presented in Table 1.

Table 1: Potential Biogas and Electricity Generation from Dung and Poultry Litters.

Particulars	Number of units	Number of animals	Biogas generation (cubic meter per day)	Number of beneficiaries	Electricity Generation (kWh/day)	Generation Capacity (kW)
1	**2**	**3**	**4**	**5**	**6**	**7**
Family size biogas plants based on dung from 5 cattles.	1.27×10^6	6.35×10^6	2.5×10^6	1.27×10^6 Families	Not Applicable	Not Applicable
Domestic	1.27×10^6	6.35×10^6	2.5×10^6	1.27×10^6 Families	Not Applicable	Not Applicable
Government Farms	10	6,059	3,817	Not Applicable	5,464	683
Dairy Farms	47	7,923	7,330	Not Applicable	11,694	1,462
Small Farms	64073	6,40,730	400,554	Not Applicable	572,952	71,619
Poultry Farms	760	76,00,000	22,522	Not Applicable	32,215	4,027
Commercial	64,890	13,982	434223		622,325	77,791

Component 6: Assessment of Supply of Biomass Fuels from Municipalities and Industrial Units for 64 Districts

6.1 Introduction

Component 6 covers Municipal Solid Wastes (MSW), Municipal Sewage Sludge and Industrial wastes. The report describes Activities, Approaches and Methodologies of Component 6 and Conceptual Framework to achieve the outcome.

The Component provides district wise supply of biomass fuels from Municipalities and Industrial units in 2015. The assessment of this component is limited to 12 city corporations and all other Municipalities located at district headquarter of the remaining districts.

6.2 Objective

The objective of the Component 6 is the assessment of Biomass fuels supply from Municipalities and Industrial Units.

6.3 Conceptual Diagram

A conceptual framework considers the district wise waste biomass resources from mainly in the following categories: City corporation/Municipal MSW of 64 districts (district headquarter level only), Sewer sludge from Municipal wastewater Treatment facility only, Major sources of Industrial wastes.

6.4 Organizations

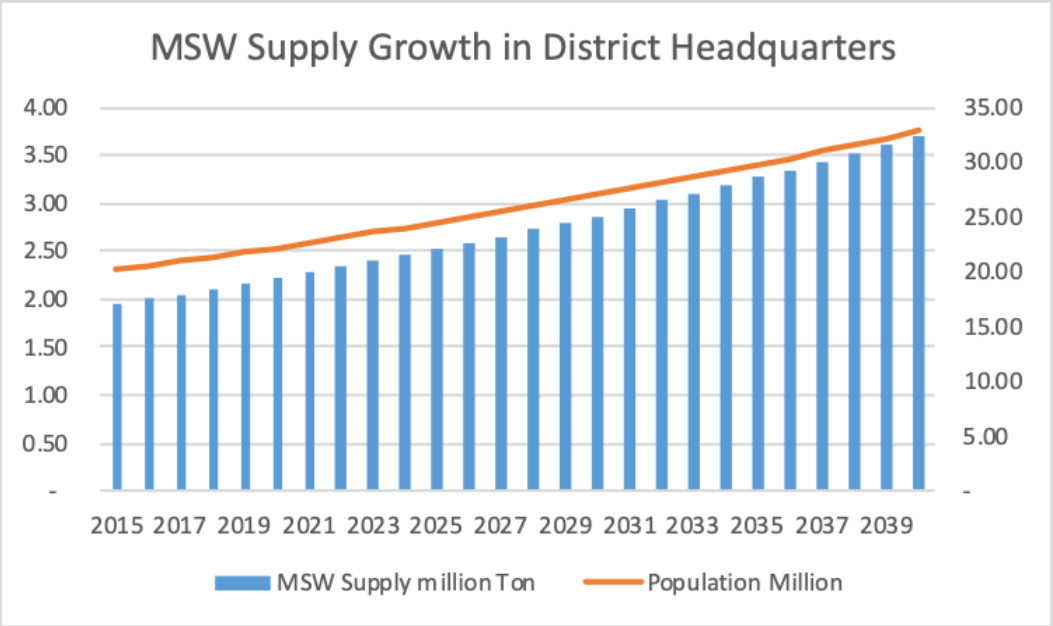
Twelve large City Corporations and the Municipalities of the rest of the districts are responsible for management of MSW. Wastes available from different industries are managed by their respective units.

6.5 Data Collection and Analyses

Availability of different type of wastes, their composition and characteristics have been assessed according to districts. At present MSW are considered as wastes material; these have no economic value. Respective Municipalities collect this waste and dispose off in landfill sites. In Bangladesh, Practical Action has established 4 MSW based biogas plants at Faridpur, Gaibandha, Mymensingh and Sathkhira. A SREDA study on waste to energy generation has suggested to establish MSW based electricity plant via biogas at the following 6 Municipalities: Cox's Bazar, Dinajpur, Habiganj, Jessore, Mymensingh and Sirajganj. In this context, it has been decided to make approximate estimation of potential biogas generation from MSW in 64 districts. Total amount of biogas may be generated in 2015 has been estimated as 3,26,319 cubic meter per day, which may be used to generate 4,67,080 kWh of electricity per day. If the generators are operated for 8 hours a day, it would require generation capacity of 17,986 kW (about 18 MW) in 64 districts. It would be necessary to undertake a feasibility study to assess the number of biogas plants and their size (cubic meter/day) that may be established in different Municipalities.

6.6 Future Projection of Biomass Fuels Supply

The MSW supply in 2015 has been estimated as 1.91 million tons, which is expected to grow to 3.63 million tons in 2040. Future Projections of MSW Supply in District Headquarters in Bangladesh is shown below.



6.7 Conclusion

In 2014 waste generation in urban areas in Bangladesh is around 8.646 million tonnes per year (Waste Concern 2014) or 0.56 kg/cap/day. There is an increasing rate of waste generation in Bangladesh and it is projected to reach 47, 064 tonnes per day by 2025. The rate of waste generation is expected to increase to 0.6 kg/cap/day in 2025 (Waste Concern 2014). A significant percentage of the population has zero access to proper waste disposal services, which will in effect lead to the problem of waste mismanagement.

Industrial waste is not significant in Bangladesh while municipal solid waste will grow from 1.9 million tonnes per year in 2015 to 3.15 million tonnes per annum in 2040. Sewage sludge will also grow from 0.67 million tonne in 2015 to 15.10 million tonnes in 2040.

Component 7: Assessment of Consumption of Biomass Fuels for Cooking and other End-uses Including Power Generation for 64 Districts

7.1 Introduction

Broad objective of the present study is Comprehensive Assessment of the Availability and Use of Biomass Fuels for various End-uses with Special Attention to Power Generation. In this context, previous four Components (Component 3, Component 4, Component 5 and Component 6) have considered the assessment of supply of biomass fuels from different sources. Component 7 is aimed to "Assess Total Consumption of Biomass Fuels for Domestic Cooking and other End-use"; in order to facilitate a supply-demand balance of biomass fuels according to 64 districts.

7.2 Objective

The main objectives of the Component 7 are to estimate consumption of biomass fuels for rural household cooking, rice parboiling, urban household cooking, urban commercial units, rural agro processing and rural non-agro processing industries.

7.3 Conceptual Diagram

A Conceptual diagram of the Component 7 has been considered as an integral part of the conceptual and analytical model of the study presented in Component 2.

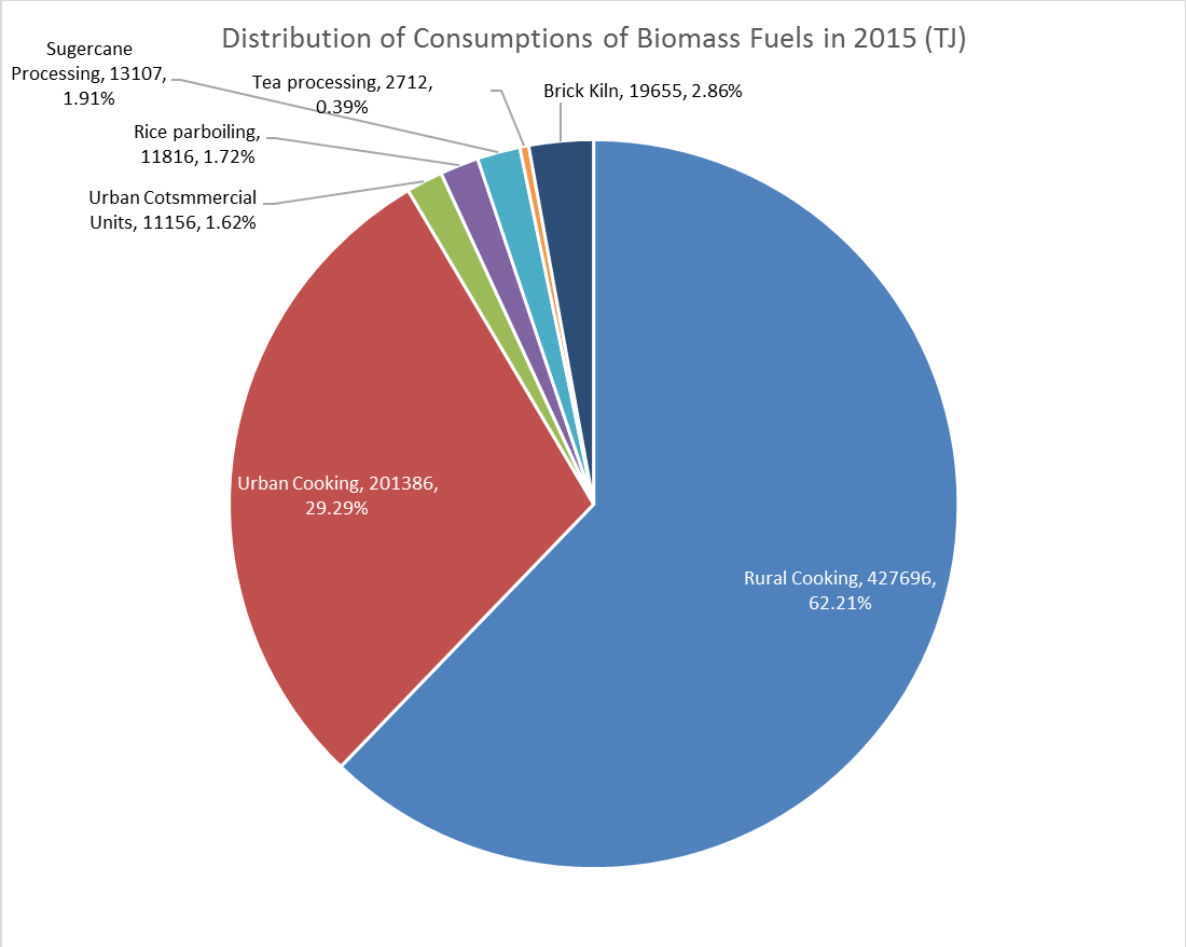
7.4 Organizations

At present no organization is responsible for collection, analysis and presentation of data on consumption of biomass fuels. For planning and sustainable development of biomass fuels, it would be necessary to establish permanent institutional system to perform the above responsibilities.

7.5 Distribution of Biomass Fuels Consumption in Different Sectors in 2015

Biomass fuels consumption in each of the five sectors namely rural household cooking, urban household cooking, urban commercial units, rural agro processing and non-agro processing industry have been calculated for each district. The total amount of biomass fuels consumption in 2015 was calculated as 6,87,533 TJ (51.3 million ton).

The shares of different end uses were as follows: rural cooking 62.2 percent, urban cooking 29.3 percent, brick kiln 2.86 percent, sugar processing 1.91 percent, rice parboiling 1.7 percent, urban commercial unit 1.62 percent and tea processing 0.39 percent. are shown in Figure below. It may be noted that in order to reduce the amount of biomass fuel consumption, promotion of efficient energy conversion technologies is a recognized policy option. Among the different end uses the following projects/have been undertaken to reduce consumption of biomass fuels: SREDA has been implementing Country Action Plan (CAP) to promote clean cook stoves for urban and rural households, GIZ has been continuing efficient parboiling technologies in rice mills, ADB and World Bank is promoting energy efficient brick kilns. There is a need to assess the impacts of these projects periodically in terms of the quantity of fuel saved. Distribution



Out of the seven divisions, Dhaka was the highest biomass fuels consuming division (30%) followed by Rajshahi (16%) and Chittagong (16%). Barisal and Sylhet consumed the least amount of biomass fuels (only 6% each). Number of households and population of these divisions were also less compared to other divisions.

Districtwise biomass consumption pattern also followed the trend of population and households. Dhaka district consumed the highest amount of biomass fuels in 2015 (34696 TJ), followed by Chittagong (26686 TJ) and Mymensingh (25743 TJ). On the other hand, Bandarban consumed the lowest biomass fuels (1776 TJ) in 2015. In general, the hill tracts area was relatively lower biomass fuel consuming districts mainly because of lower population density.

On an average per capita biomass fuels consumption for Bangladesh was found to be 4.27 GJ (19.10 GJ per household). However, Natore had the highest per capita biomass fuels consumption (6.40 GJ), equivalent to 28.60 GJ per household and Dhaka had the lowest per capita biomass fuels consumption (2.49 GJ), which is equivalent to 11.13 GJ per household. Although, the total biomass fuels consumption was lower for the three hill tract district, the per capita consumption was almost similar to the national average. This reconfirms that the lower overall biomass fuels consumption in these hill tract districts was because of lower population density, not because of the consumption pattern.

7.6 Projection of Biomass Fuels Consumption

Since more than 90 percent biomass fuels consumption was found in the rural and urban households cooking, the future projection of the biomass fuels consumption was performed for households cooking only. From the baseline data of 2015, projections were made for the years 2020, 2030 and 2040 for two different scenarios. Scenario 1 assumes the household LPG growths is at the rate of 15 percent of current domestic LPG consumption per annum up to 2020 and then reduce to 12 percent for the period 2021-2030 and 8 percent afterwards till 2040. On the other hand, scenario 2 assumes a higher penetration rate of LPG in the households and considers these growth rates as 20 percent till 2020, 15 percent for 2021-2030 and 10percent afterwards.

Component 8: Compilation of Data of Total Supply and Demand of Biomass Fuels for the Base year 2015 and Future Projections of Biomass Fuels up to 2040

8.1 Introduction

On the basis of the data gathered by the respective components, Supply- Demand Balance of Biomass fuels are to be established for 64 districts for the base year 2015 and to be projected up to 2040. Potential districts for Biomass fuels based power generation are to be identified and 10 sites will have to be selected for establishing biomass fuels based power generation (pilot) plants.

8.2 Objective

The objective of Component 8 is the compilation of data of total supply and demand of biomass fuels according to 64 districts for the base year 2015 and projections up to the year 2040.

8.3 Conceptual Diagram

In order to estimate and compile the district wise supply and demand of all categories of biomass fuels has been presented in line with a Conceptual Framework and analytical model presented in Component 2. A Simplified Conceptual Diagram has also been included in this Component.

8.5 Data Collection and Analysis

Data collected and analyzed under the following components for estimating the supplies of biomass fuels (**Component-3, Component-4, Component-5, Component-6**); and the data have been presented in this Component. It may be noted that Agricultural residues available during the wet season have been excluded from biomass fuels supply data.

Both supply and demand data of biomass fuels have been converted to uniform heat units (TJ). Supply and Demand balance indicate that in some of the districts biomass fuels are in excess and in some districts they are in deficit.

Total supply of biomass residues from different sources has been estimated as follows: tree residues (16.18 million tons), agricultural residues (111 million tons), animal dung (dry) (10.9 million tons). It means total biomass residues in year 2015 was estimated as 138 million tons.

On the basis of Supply-Demand balance per capita **deficit** of biomass fuels in the deficit Districts: (**Chittagong, Dhaka**, **Gazipur, Munsiganj, Narayanganj** and **Narsingdhi)**. It means that the Districts having negative balance of biomass fuels may possibly meeting their demands from the districts located within economic distance of transport. Organization involved with the promotion of Improved Cookstoves may consider this assessment in implementing their program. LPG marketing companies may also consider these districts for increasing their market penetration.

Excess availability of biomass fuels have been found in the following Districts (**Barisal, Faridpur, Jamalpur, Netrokona, Chuadanga, Jhenaidah, Kusthia, Bogra, Naogaon, Pabna, Dinajpur, Lalmonirhat, Thakurgaon and Habiganj**). Districts having more than 4.44 GJ/person/year are in a better position in terms of supply of biomass fuel sources.

SREDA may consider in sending a multidisciplinary team of experts to visit the districts identified as excess and deficit supply of biomass fuels in rainy season to assess the practical situation of biomass availability.

Total consumption of biomass fuels in 2015 estimated by the present study was 687,533 TJ (51.3 million tons). It may be noted that estimated consumption of biomass fuels in 2015 is closer to high scenario supply data BBS.

Tree biomass fuels are considered as best because of quality, animal residues are second best because of nearness of availability and agricultural residues are considered as the least preferred options because of quality. According to this assumption, composition of biomass fuels consumed in 2015 has been estimated as follows: tree biomass fuels-16.8 million tonnes (2,44,379 TJ, 35.5%); animal residues -10.9 million tonnes (1,26,417 TJ, 18.4%) and balance agricultural residues (3,16,736 TJ, 46.1%). However, choice of particular type of biomass fuels would vary according to locations, season, availability and affordability.

Analyses of past data of supply of TPES indicated that the share of biomass fuels in TPES in 1976 was about 70 percent, which has gradually decreased to 36 percent in 2015. Total biomass fuel consumption in 2015 was estimated as 51.3 million tonnes of which 90% is used for domestic cooking. Considering 10% efficiency of biomass fuel cookstoves, if it is replaced by petroleum fuel for cooking (50% efficiency), it would require about 10 million tonnes of liquid fuel. In 2018-19, Bangladesh imported total 6.7 million tons of petroleum fuels at a cost of $4.8 billion (the Daily star, 28 September 2018). Accordingly, the contribution of biomass fuel in country's economy would have been about US$ 7.16 billion.

8.6 Projections

Projections of supplies of different types of biomass fuels (tree residues, agricultural residues, dung and poultry litter and MSW and industrial wastes etc.) and demand of biomass fuels according to Districts have been presented in the reports of the respective components. Considering the large volume of data and uncertainties to estimate future situations, it is decided to make projections of supply and demand of biomass fuels for years 2020, 2025, 2030 and 2040 at the country level. Summary of observations of the Projections are presented below.

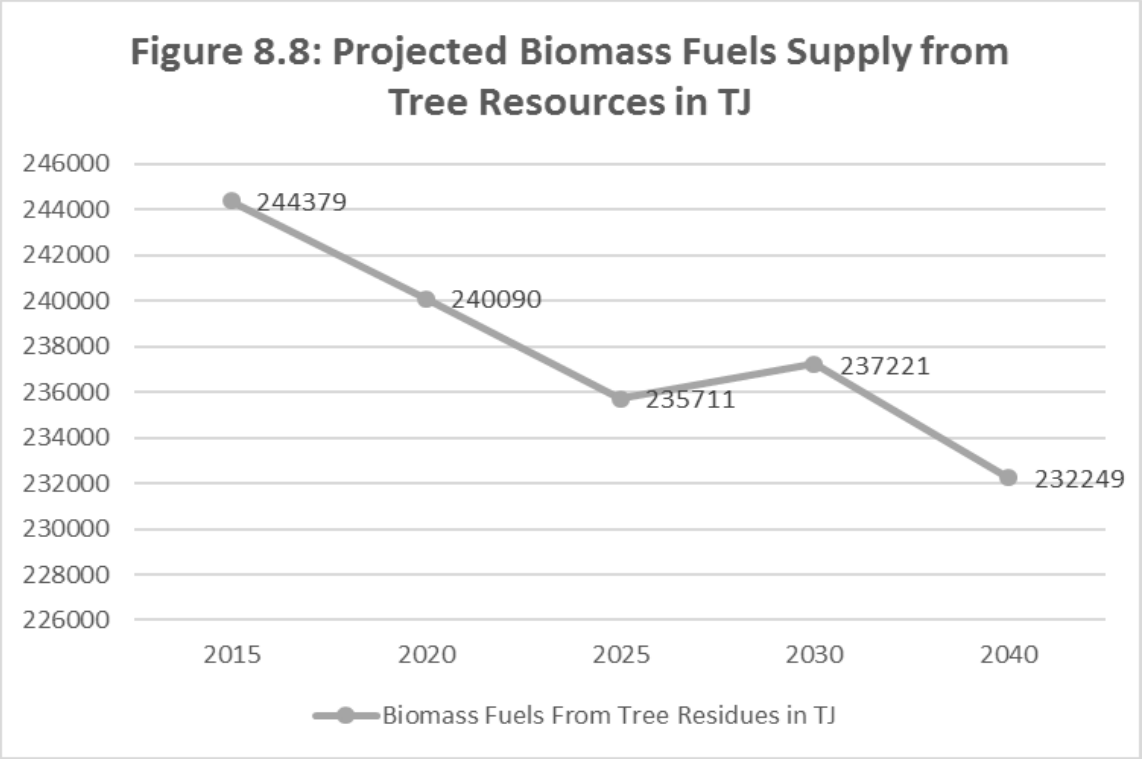


Figure 8.8: Projected Biomass Fuels Supply from Tree Resources in TJ
246000
244000
242000
240000
238000
236000
234000
232000
230000
228000
226000
244379
240090
235711
237221
232249
2015
2020
2025
2030
2040
Biomass Fuels From Tree Residues in TJ

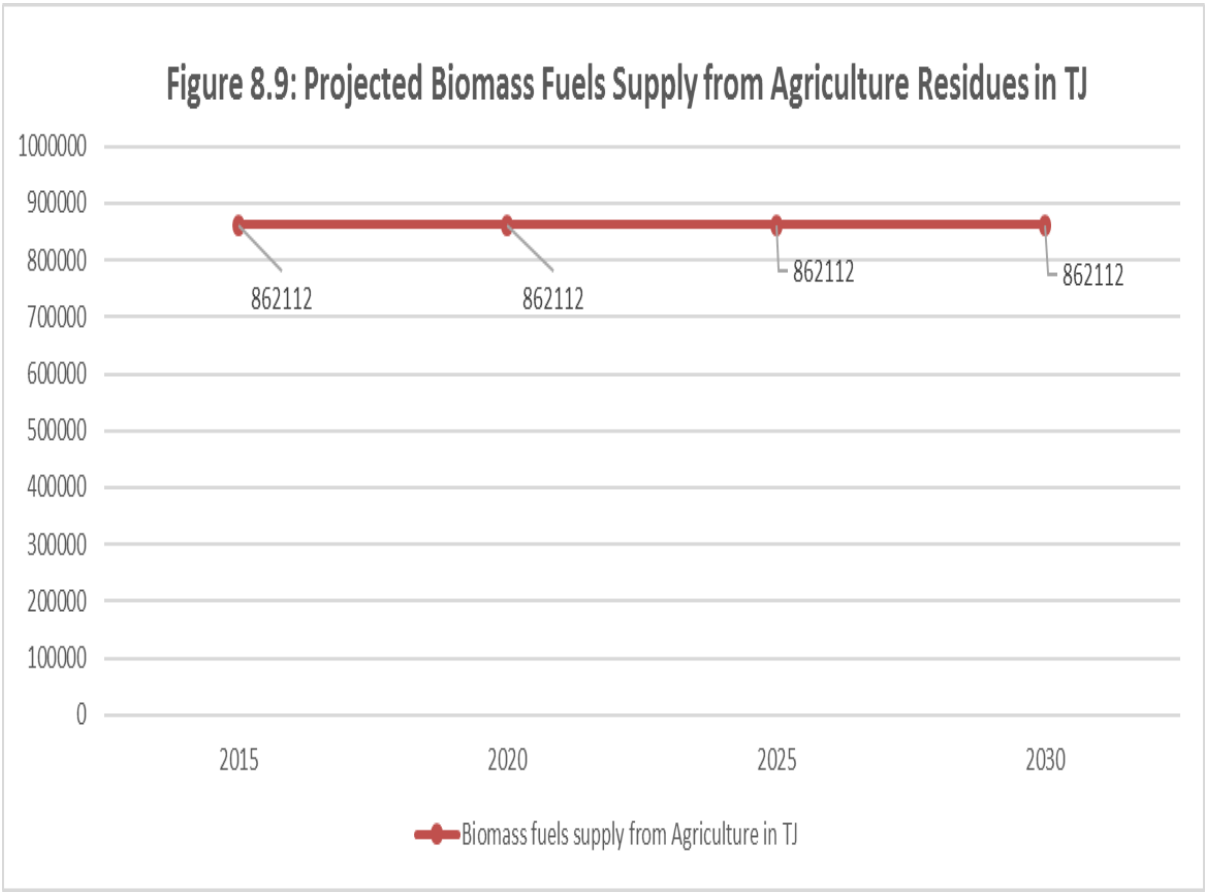


Figure 8.9: Projected Biomass Fuels Supply from Agriculture Residues in TJ
1000000
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
862112
862112
862112
862112
2015
2020
2025
2030
Biomass fuels supply from Agriculture in TJ

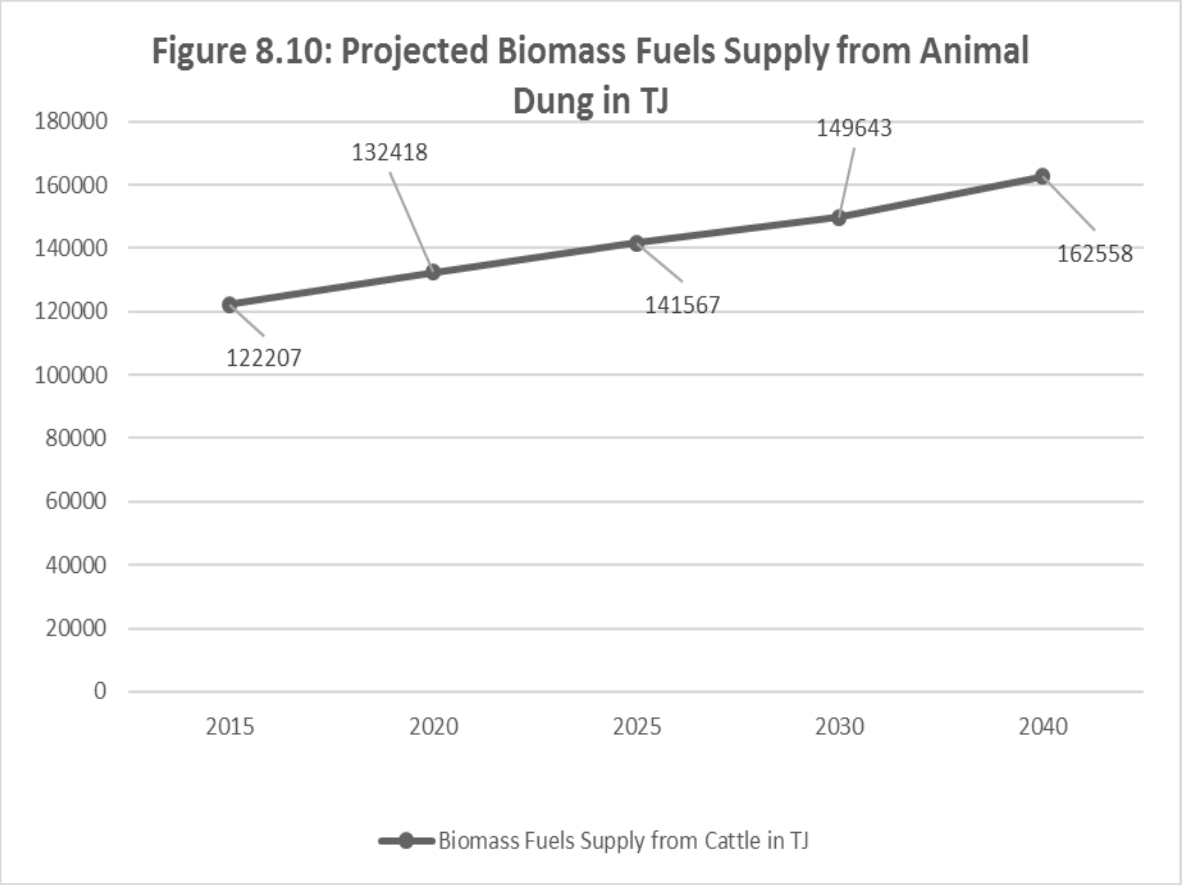


Figure 8.10: Projected Biomass Fuels Supply from Animal Dung in TJ
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
132418
149643
162558
141567
122207
2015
2020
2025
2030
2040
Biomass Fuels Supply from Cattle in TJ

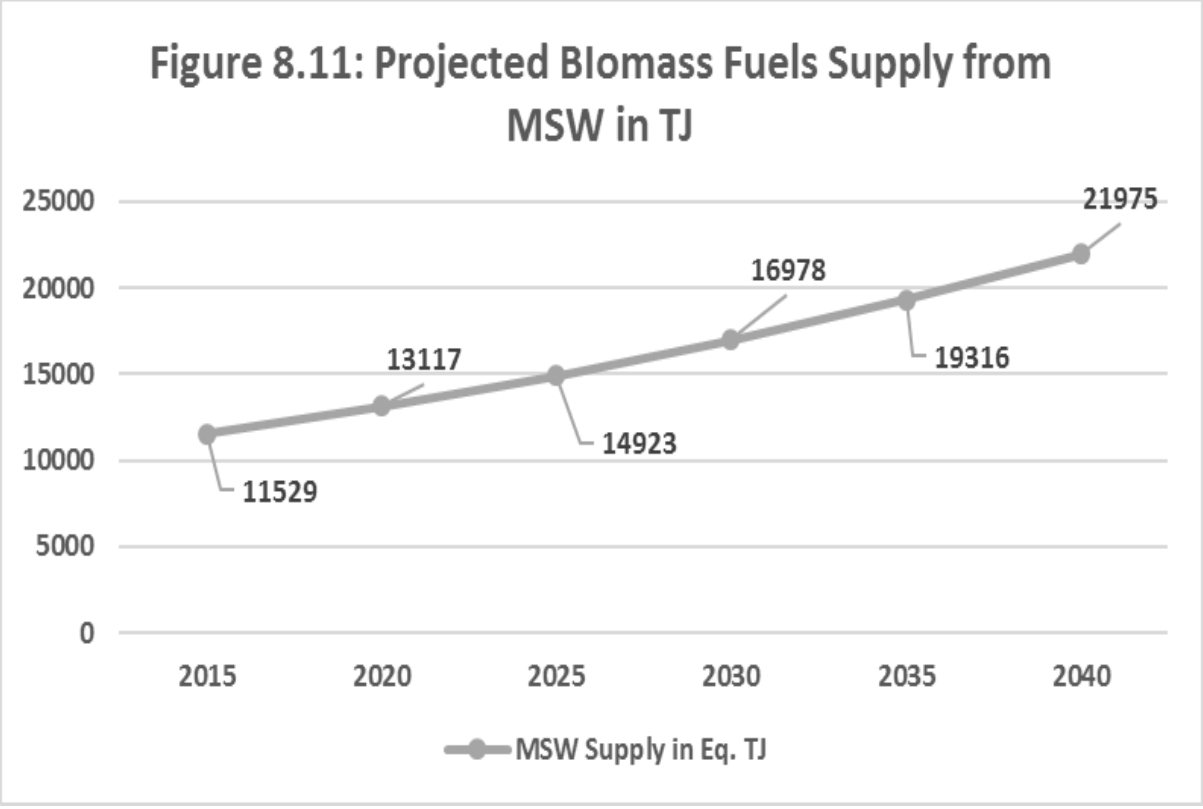
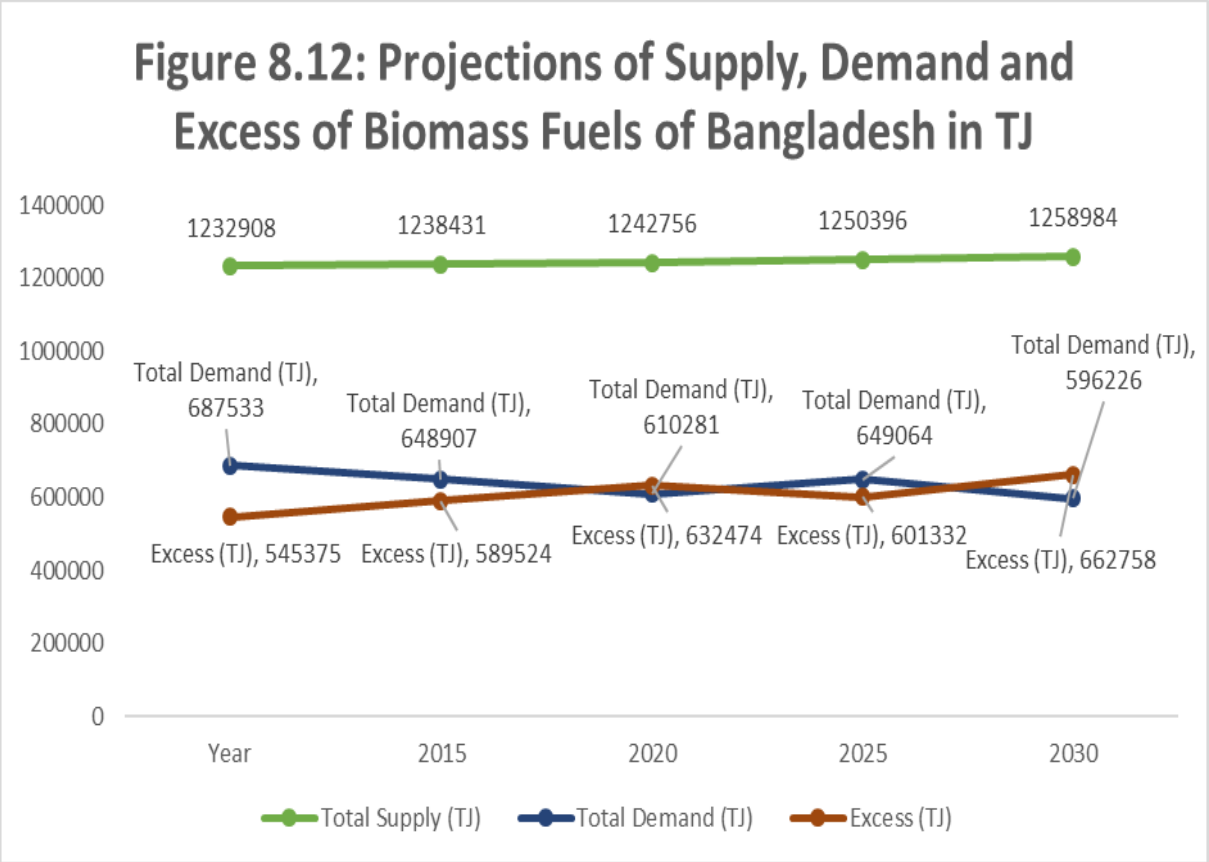


Figure 8.11: Projected Biomass Fuels Supply from MSW in TJ
25000
20000
15000
10000
5000
0
21975
16978
13117
19316
14923
11529
2015
2020
2025
2030
2035
2040
MSW Supply in Eq. TJ



8.8 Biomass Fuels Action Plan (BFAP)

Improved Cookstove Program

CAP program of SREDA can use district wise data base on supply and demand balance of biomass fuels in deciding appropriate studies for the districts having negative biomass fuel balance (biomass fuels scarcity) and excess supply of biomass fuels.

Biogas Based Electricity Generation

Total number of Biogas Plant may be considered for electricity generation has been listed in Table 8.6. Following observations may be made on the basis of data. presented in the Table

(1) Biogas based electricity generation potential in 10 Government owned livestock farms with 6059 cattle has the potential to generate biogas 3,817 cubic meter per day, which may be used to generate 5,464 kWh of electricity per day. If the generators are operated for 8 hours a day, it would require generation capacity of 683 kW.

(2) Total amount biogas may be generated in 47 (forty seven) privately owned large cattle farms registered with dairy association of Bangladesh with 7,923 cattle has the potential to generate biogas 7,330 cubic meter per day, which may be used to generate electricity 11,694 kWh per day. If the generators are operated for 8 hours a day, it would require generation capacity of 1,462 kW.

(3) Total amount biogas may be generated in 64,073 privately owned small cattle farms with 640,073 cattle has the potential to generate biogas 400,334 cubic meter per day, which may

be used to generate 5,72,952 kWh of electricity per day. If the generators are operated for 8 hours a day, it would require generation capacity of 71,619 kW (about 72 MW) in 64 districts

(4) Total amount biogas may be generated in 760 privately owned poultry farms with 76,00000 birds has the potential to generate biogas 22,522 cubic meter per day, which may be used to generate 32,215 kWh of electricity per day. If the generators are operated for 8 hours a day, it would require generation capacity of 4,027 kW (about 4 MW) in 64 districts.

Among the above mentioned four groups of beneficiaries, 10 Government farms may be selected on priority basis for implementation of pilot project., Investment requirement for this 10 Government Farms have been estimated in Table 8.7 (Taka 74.23 million).

At the next stage, SREDA may consider establishing biogas plants for the rest three groups shown in Table 8.6 (privately owned registered dairy farms, small dairy farms and poultry farms). Feasibility studies are to be undertaken to implement those projects. Policy recommendations mentioned in Guidelines on Biogas Technology for Energy may be given due consideration.

It is recommended that at the initial stage SREDA should pay attention to generation of electricity by using Biogas Technology. In subsequent stage by further analyses of the data of the present study, SREDA may consider other biomass to energy conversion technologies for heat and electricity generation (e.g. combined heat and power).

8.9 Conclusions & Suggestions

For the first time in Bangladesh supply and demand of biomass fuels have been estimated according to districts for the base year 2015 and projected as follows: 2020, 2025, 2030 and 2040.

- Composition of the total supply of biomass fuels have been estimated as 99 million tons and the shares of tree residues, agriculture residues and animal dung are as follows: tree residues 19.8 percent, agriculture residues 69.9 percent, animal dung 10.2 percent.
- It has been identified that the following districts have negative balance of biomass fuels: **Chittagong, Dhaka**, **Gazipur, Munsiganj, Narayanganj** and **Narsingdhi.**
- It has been identified that the following districts have excess supply of biomass fuels: **Barisal, Faridpur, Jamalpur, Netrokona, Chuadanga, Jhenaidah, Kusthia, Bogra, Naogaon, Pabna, Dinajpur, Lalmonirhat, Thakurgaon and Habiganj.** District level data of excess supply of biomass fuels are to be further analysed at Upazila level to identify the locations for establishing biomass based power plants.
- SREDA may consider in sending a multidisciplinary team of experts to visit the districts identified as deficit and excess supply of biomass fuels in rainy season to assess the practical situation of biomass availability.
- Availability of plant residues from Aus Paddy should be estimated at Upazila/Union level to identify the location for biogas based power generation units.

- Biogas based electricity generation potential in 10 Government owned livestock farms may be considered on priority basis to generate electricity. Potential installed capacity of this power plants may be 683 kW considering 8 hours of average plant running time. Total electricity generation potential has been estimated as 5,464 kWh. A Feasibility studies should be undertaken to assess the size and locations of biogas plants within the Farms.

- Biogas based electricity generation potential in 47 Private livestock farms, registered with Dairy Associations may be considered to generate electricity on priority basis. Potential installed capacity of this power plants may be 1,462 kW considering 8 hours of average plant operation time. Total electricity generation potential has been estimated as 11,694 kWh. A Feasibility studies should be undertaken to assess the size and locations of biogas plants within the Farms.

- Biogas based electricity generation potential in 64,073 private livestock farms according to districts have been estimated. Potential installed capacity of this power plants may be 71,619 kW considering 8 hours of average plant operation time. Total electricity generation potential has been estimated as 5,72,952 kWh. A Feasibility studies should be undertaken to assess the size and locations of biogas plants within the Farms.

- Biogas based electricity generation potential in 760 private Poultry farms according to districts have been estimated. Potential installed capacity of this power plants may be 4,072 kW considering 8 hours of average plant operation time. Total electricity generation potential has been estimated as 32,215 kWh. A Feasibility studies should be undertaken to assess the size and locations of biogas plants within the Farms.

- Municipal solid wastes based power plants may be established in six Municipalities identified in the SREDA study on waste to electricity generation. Both Co-firing and Digestors technologies may be considered for power generation.

- Practical Action Bangladesh has established four MSW based biogas plants in some Municipalities. Possibility for application of this technologies in large size biogas plants should be considered.

A huge quantity of data on supply and demand of biomass fuels have been gathered and analyzed in this project. SREDA should undertake necessary measures in assigning the management, updating and publication of biomass fuels database to a competent national institution with good historical record of biomass fuels research.

A Comprehensive Assessment of the Availability and Use of Biomass Fuels for Various End Uses with Special Attention to Power Generation

A Comprehensive Assessment of the Availability and Use of Biomass Fuels for Various End Uses with Special Attention to Power Generation

1. Introduction

Biomass Fuels are generated on earth's surface by photosynthesis process; these are the most ancient type of energy resources observed on earth's surface. Analyses of empirical data on accumulated carbon dioxide in earth's atmosphere revealed their presence millions of years ago. Fossilization of biomass resources below the earth created coal, petroleum fuels and natural gas. Level of carbon dioxide concentration in earth's atmosphere varied between 200 ppm to 300 ppm for 800,000 years (World Bank, 2010). Since the initiation of Industrial Revolution remarkable changes have taken place on the invention of different technologies including Energy Technologies. This resulted in transition of energy use from Biomass Fuels to Fossil Fuels to Electricity. As a result, concentration of carbon dioxide in earth's atmosphere gradually increased from 300 ppm in 1880 to 410 ppm in 2019 due to accelerated use of fossil fuels.

This resulted in increase of earth's temperature causing Climate Change. At global level different type of institutions were established (UNFCCC, IPCC, GEF, GCF etc.) and mitigation strategies were adopted (Kyoto Protocol, the Paris Agreement) to combat the effects of Greenhouse Gas (GHG) Emissions. The global community has reached a Common Platform to adopt a Low Carbon Path for development. In agreement with global actions, similar institutional reforms have also been made in Bangladesh. Name of the Ministry of Environment and Forest (MoEF) has been changed to the Ministry of Environment Forest and Climate Change (MoEFCC) and assigned with the tasks of acting as the focal point of UNFCCC on Climate Change issues. Establishment of the Rooppur Nuclear Power Plant under the Ministry of Science and Technology and Sustainable Renewable and Energy Authority (SREDA) under the Power Division of the Ministry of Power, Energy & Mineral Resources (MoPEMR) is implementing GEF-Funded Project on Development of Sustainable Renewable Energy Power Generation (SREPGen) supported by UNDP. The Nationally Determined Contribution (NDC) of Bangladesh has adopted an unconditional GHG emission reduction target of 5 percent and another 10 percent GHG emission reduction target conditional upon availability of international funding and technology supports (GOB, 2015).

The main focus is to reduce the annual growth rate of GHG emissions from the fossil fuel-based power generation by exploiting Bangladesh's renewable energy resources for electricity generation. The basic approach of the project is to promote renewable energy through the Sustainable and Renewable Energy Development Authority (SREDA). The SREPGen project are expected to support activities that will-

(i) transform SREDA into a strong RE project facilitation center to bring confidence to private investors and increase the number of approved Renewable Energy (RE) projects;

(ii) increase the capacities of appropriate government and private sector agencies to generate, process, obtain and disseminate reliable Renewable Energy (RE) resource information for use by potential project developers and investors; and

(iii) increase the share of Renewable Energy in Bangladesh's power mix through facilitating the financing, implementation and operator of Pilot Renewable Energy (RE) projects using Biomass fuels.

The lessons learned from the pilot projects will be utilized to scale-up the dissemination and investment in on-grid & off-grid biomass fuels based Renewable Energy (RE) projects and RE technologies.

- The Renewable Energy Policy, 2008 obligates renewable energy share in power generation to be 10 percent by 2020, which is about 2000 MW. To achieve this goal, government has set a target to generate 3168 MW electricity during 2015 to 2021 by different renewable sources of energy. Contributions of different type of renewable energy sources have been estimated by SREDA as follows:
    - solar 1740 MW (54.9%),
    - wind 1370 MW (43.2%),
    - biomass fuels 47 MW (1.5%),
    - biogas 7 MW (0.22%) and
    - hydro 4 MW (0.13%).

2 Objective

The objective of the present study is to make 'A Comprehensive Assessment of the Availability and Use of Biomass Fuels for Various End Uses with Special Attention to Power Generation'. As per TOR the study is mandated to-

- Assess the Availability of Biomass fuels,
- Assess the use of Biomass fuels,
- Assess the Prospects of Biomass Fuels based Power Generation in Different Locations.

Biomass fuels based power generation has been considered to reduce emission of carbon dioxide by substituting the use of fossil fuels based power generation. Biomass fuels are recognized as carbon neutral, with no net emission of carbon dioxide in earth's atmosphere. Specific objectives of the study as per ToR have been presented below.

Component 1: Assessment of the Roles of Biomass Fuels in Total Energy Consumption in Bangladesh and in Selected Developed and Developing Countries

Component 2: Development of a Conceptual and Analytical Model to Estimate Supply and Demand of Biomass Fuels for 64 Districts of Bangladesh

Component 3: Assessment of Supply of Biomass Fuels from Tree Resources for 64 Districts of Bangladesh

Component 4: Assessment of Biomass Fuel Supply from Agricultural Crop Lands and Other Type of Lands for 64 Districts of Bangladesh

Component 5: Assessment of the Biomass Fuels Supply from Livestock and Poultry Resources for 64 Districts of Bangladesh

Component 6: Assessment of Supply of Biomass Fuels from Municipalities and Industrial Units for 64 Districts

Component 7: Assessment of Consumption of Biomass Fuels for Cooking and other End-uses Including Power Generation for 64 Districts

Component 8: Compilation of Data of Total Supply and Demand of Biomass Fuels for the Base year 2015 and Future Projections of Biomass Fuels up to 2040

3. Conceptual Issues

Some conceptual issues related to Assessment of Supply and Demand of Biomass Fuels for Various End Uses with Special Attention to Power Generation are shown in Box-1.

Box-1: Some Conceptual Issues Related to Assessment of Supply and Demand of Biomass Fuels for Various End Uses with Special Attention to Power Generation

Biomass and Biomass Fuels Resources: Plant materials grow on land and water by photo-synthesis process using carbon dioxide and water from the environment. Biomass is used for multiple purposes. As for example, paddy crop is grown on paddy plants. Bran and husks are produced as crop residues during processing of paddy to rice. Rice is the main product used for food, bran is used for extraction of rice-bran-oil, and husks are used as fuel. Plant residues are obtained from paddy plants, of which top portion (fine straw) is used as fodder and bottom portion (rough straw) is used as building materials, mulch and fuels. When a tree biomass is extracted timber is obtained as main product and tree residues (e.g. branches & leaves, saw logs, saw dust) are used as fuel. From jute plant, extracted fiber is the main product used in jute and textile industries and plant residue (e.g. jute sticks is used as building materials and fuels). In livestock sector; milk, meat and hide are the main products and animal dung is the byproduct; which is used as building materials, manure and fuel. All the biomass products mentioned above (grain, timber, milk, meat and hide) are considered as resources in National Accounting System to compute Gross Domestic Products (GDP).

Tree residues, agricultural residues (e.g. crop residues and plant residues), animal and poultry residues are assumed as wastes and not considered in national accounting system to compute GDP. As these residues are generally used as fuels; are defined as biomass fuels. Major portion of total biomass fuels are used in rural areas, they are also called rural energy. It may be noted that part of total biomass fuels are also used in urban areas for cooking and heating and also in rural industries. As biomass fuels are used in household cooking, both in rural and urban areas using traditional technologies; sometimes biomass fuels are also called traditional fuels. As most of biomass fuels is obtained by gathering from local sources; they are also called non-commercial fuels. It may be noted that part of biomass fuels (e.g. fuel wood) is transacted commercially both in urban and rural areas even then they are mentioned in the literature as non-commercial fuel.

Resources & Wastes: Materials and substances occurring in nature which can be exploited for economic gain are considered as natural resources. In this context, both biomass and biomass fuels are natural resources. Crops and main products of natural resources has been considered as natural resources under the national accounting system and residues type biomass fuels are not recognized as resources. Although some of the residues used as biomass fuels (e.g. fuel wood, rice husk, oil cakes and animal dung) are being transacted commercially in the local markets; they are not recognized by the national accounting system as resources. Even then in specific locations, to an individual owner, when the economic costs of residues are more than economic gain through its use, it is considered as wastes. On the other hand, when the economic gains of using residues are more than the economic cost of extraction and supply cost; it is considered as resource or wealth. At the present economic condition, in Bangladesh residues available from the crops harvested in rainy season, animal dung produced in rainy season; Municipal Solid Wastes (MSW) are considered as wastes (left utilized at dumpsite), because the economic cost for its collection to its dump site is higher than its economic value. In future when these waste materials can be transformed into energy by using appropriate conversion technologies, these waste materials may also be considered as resources.

Bio-Fuels: Liquid fuels may be obtained directly from crops and also by processing biomass and are used to substitute petroleum fuels are defined as bio-fuels. Biofuels (alcohol) are renewable and petroleum fuels are non-renewable fossil fuels. Liquid fuels may be extracted directly from oil seed crops (e.g. mustard, soybean, sunflower, palm, coconut etc.) and can be produced by processing (fermentation) of crops (e.g. alcohol is produced by processing of sugarcane and sugar beet).

Biogas: Gaseous fuel may be obtained by anaerobic digestion of biomass (e.g. animal dung, plants etc.). Bio-fuels (liquid) and biogas are used in transport sector to substitute non-renewable petroleum fuels (e.g. diesel, octane etc.).

Rural Energy: As major portion of biomass fuels is consumed in rural areas, sometimes biomass fuels are assumed synonymous to rural energy; which is not correct. In rural areas different type of energy sources used for various end-uses are: (a) biomass fuels, kerosene, LPG for household cooking; (b) kerosene, grid electricity, photo-voltaic electricity for household lighting; (c) biomass fuels, kerosene, LPG for cooking in commercial units (e.g. hotel, restaurant); (d) biomass fuels, kerosene, LPG in rural industries; (e) animal power & petroleum fuels in ploughing; (f) diesel and solar PV and grid electricity for irrigation; (g) animal & human muscle power, diesel, electricity in rural transport. Biomass fuels meet the needs of a substantial part of the total energy consumed in rural areas. It means total rural energy needs cannot be met by biomass fuels only.

Renewable Energy Sources (RES): Different types of Renewable Energy Sources used in the country are: (a) biomass fuels, (b) hydro power, (c) solar PV and (d) wind power. Biomass fuels are (a) particular type of renewable energy; which supply a major portion of total renewable energy consumed in the country. But biomass fuels and renewable energy are not synonymous.
Renewable Energy Technologies (RETs): Electricity is the best form of energy; government has given priority attention to delivered electricity to the total population by 2020. Electricity can be generated by all types of renewable sources (such as solar PV, wind power, hydro power, biomass fuels) by using technologies specific to Renewable Energy Sources (RES). It requires specialized technical knowledge to design and develop technologies specific to RES & Renewable Energy Technologies (RETs). In Bangladesh, major portion of total electricity is generated by using fossil fuels; which release greenhouse gases to earth's atmosphere. Generation of electricity by using RETs and nuclear energy do not contribute emission of greenhouse gases (GHGs). Government is committed to generate at least 10 percent of total electricity by using renewable energy sources. Biomass fuels is carbon neutral, generation of electricity by using biomass fuels does not contribute in emission of carbon dioxide. This is why; the objective of the present study is to make "A Comprehensive Assessment of the Availability and Use of Biomass Fuels for Various End Uses with Special Attention to Power Generation". It has been discussed above that at present large portion of biomass fuels is used for different end uses. Systematic and pragmatic assessments of supply and demand of biomass fuels are to be made to identify areas for establishment of power plants in specific locations. Use of biomass fuels for power generation is to be location specific. Because cost of transport of biomass fuels is a barrier for establishing large size power plants based on biomass fuels.

4. Approaches and Outcomes

On the basis of literature review an assessment of contribution of biomass fuels in total energy consumption of selected developed (EU & USA) and developing countries (China & India) and Bangladesh have been made and findings have been presented under Component 1.

On the basis of literature review and study of the reports of the Bangladesh Energy Planning Project (GOB 1987) an Integrated Conceptual Framework has been developed to indicate the relations among different components of the present study. Analytical equations for computation of different output parameters have been developed. Land use data gathered by the Census of Agriculture have been used as the basic source of data for the present study. Conceptual model, analytical equations and basic data sources have been incorporated under Component 2.

Data sources, data gathering procedures and analyses of data to estimate the supply of biomass fuels from tree resources grown in designated Forest Areas and in Non-Forest Areas for 64 districts have been described and findings have been presented under Component 3.

Land areas under major crops, production of crops, coefficients of agricultural residues have been used to compute the supply of agricultural residues for dry and wet season for 64 districts and findings have been presented under Component 4.

Supply of biomass fuels from livestock and poultry resources for 64 districts have been estimated and tabulated at Household and Farm levels. Potential quantity of biogas and electricity that can be generated by installing Biogas Plants have been estimated and presented under Component 5.

Supply of biomass fuels from Municipalities (at district level), City Corporations and industrial units for 64 districts have been presented under Component 6.

Consumption of biomass fuels for cooking and other end uses including power generation for 64 districts have been computed and presented under Component 7.

Supply and Demand balance of biomass fuels for 64 districts have been estimated and presented under Component 8, and the districts having excess supply of biomass fuels have been identified.

5. Scope of the Work

Details Terms of Reference of this assignments and scope of work is included in the Annex-I of the Volume-I.

6. Study Team

The Study Team is composed of following Members. One Individual Consultant has been appointed by the UNDP/SREDA to guide the team and review the deliverables of the assignments.

Individual Consultant: Prof. Dr. M. Nurul Islam Former, Professor, Chemical Engineering Department and Institute of Appropriate Technology (IAT), BUET

Assignments	Name
Team Leader	Professor Ijaz Hossain
Deputy Team Leader and Energy Expert	Mr. Utpal Bhattacharjee
Biomass Fuel Expert-1	Dr. Md. Ali Ahammad Shoukat Choudhury
Biomass Fuel Expert-2	Dr. Shoeb Ahmed
Forestry Expert	Dr. Paramesh Nandi
Agricultural Expert	Dr. Abu Wali Raghib Hassan
Livestock and Poultry Expert	Dr. Md. Rafiqul Islam
Municipal Solid Waste (MSW) and Industrial Wastes Expert	Mr. Shaymal Barman
Project Coordinator	Mr. Rashiduzzaman Ahmed

7. Organization of the Report

The Reports of the Study have been presented in 3 Volumes as below.

Volume- 1	Volume- 2	Volume- 3
Summary Summary of the Different Components of the Study on Comprehensive Assessment of the Availability and Use of Biomass Fuels for Various End Uses with Special Attention to Power Generation **Introduction** **Component 1:** Assessment of the Roles of Biomass Fuels in Total Energy Consumption in Bangladesh and in Selected Developed and Developing Countries. **Appendix-I** **Annex-I- ToR**	**Component 2:** Development of a Conceptual and Analytical Model to Estimate Supply and Demand of Biomass Fuels for 64 Districts of Bangladesh. **Appendix-II** **Component 3:** Assessment of Supply of Biomass Fuels from Tree Resources for 64 Districts of Bangladesh. **Appendix-III** **Annex-III** **Component 4**: Assessment of Biomass Fuel Supply from Agricultural Crop Lands and Other Type of Lands for 64 Districts of Bangladesh. **Appendices-IV** **Component 5**: Assessment of the Biomass Fuels Supply from Livestock and Poultry Resources for 64 Districts of Bangladesh. **Appendices-V** **Component 6**: Assessment of Supply of Biomass Fuels from Municipalities and Industrial Units for 64 Districts. **Appendices-VI**	**Component 7:** Assessment of Consumption of Biomass Fuels for Cooking and other End-uses Including Power Generation for 64 Districts. **Appendices VII** **Component 8:** Compilation of Data of Total Supply and Demand of Biomass Fuels for the Base year 2015 and Future Projections of Biomass Fuels up to 2040. **Appendix- VIII**

6. References

GOB 2015, Nationally Determined Contribution (NDC), MOEFCC, Government of the People's Republic of Bangladesh, Dhaka, 02 pp.

GOB 1987, Final Report, Bangladesh Energy Planning Project, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh

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COMPONENT- 1

Assessment of the Roles of Biomass Fuels in Total Energy Consumption in Bangladesh and in Selected Developed and Developing Countries

Component 1: Assessment of the Roles of Biomass Fuels in Total Energy Consumption in Bangladesh and in Selected Developed and Developing Countries

1.1 Introduction

Biomass fuels are used both in developing and developed countries. In developing countries, it plays a big role because it often constitutes more than 90 percent of the rural fuel consumptions. As per capita GNI of the country increases through industrialisation, share of commercial energy increases and the share of biomass fuels decreases. In addition, as rural households move up the energy ladder as a result of increasing standard of living, the role of biomass fuels decreases. This decreasing share of biomass fuels in the total primary energy is the result of increasing use of commercial energy for driving industrial growth and urban development. In developed countries, the share of biomass fuels in the Total Primary Energy (TPE) is generally less than 10 percent.

The areas of application of biomass fuels in developed and developing countries also varies. Biomass fuels are predominantly used for cooking and space heating in developing countries. In developed countries biomass fuels is mainly used to produce liquid biofuels for the transport sector and to generate electricity.

In order to limit greenhouse gases (GHG) emissions, all types of renewable energy sources including biomass fuels has been brought into focus. In the past, the mindset was to move from traditional biomass fuels to commercial fuels, which has been considered as an indicator of development. In many developing countries, more than 90 percent of the rural population depends on biomass fuels for cooking; for them it is very difficult for the poor to shift from biomass fuels to commercial fuels.

In the new mindset where the uses of biomass fuels are being promoted, it is important to evaluate the potential of sustainable biomass fuels-based energy production. In recent years in developed countries there has been an increase in the use of biomass fuels for generating electricity, for producing heat and for producing liquid biofuels.

Renewable energy other than hydropower is a diffuse form of energy that ultimately depends on the Sun. To derive a significant proportion of the total energy in a country from renewable sources, all forms of renewable energy must be exploited. Therefore, along with solar and wind, biomass fuels must also be considered with due importance. The most important consideration, when considering biomass fuels is to ensure that it is used on a sustainable basis.

1.2 Objective

The Objective of this component is to assess the roles of biomass fuel in total energy consumption in Bangladesh and in selected developed countries and developing countries. The major activities, methodologies and approaches have been presented in Table 1.1.

Table 1.1: Activities, Methodologies and Approaches

Activities	Methodologies and Approaches
1.1 Review status of studies on Biomass fuels resources potential and their use in selected developed (EU and USA) and in selected developing countries (China, India) and Bangladesh with attention to study methodology, type of biomass resources, technologies, future projections, policy supports etc., for sustainable use of Biomass fuels.	Desktop research was conducted to collect the information on study methodology, type of biomass resources, technologies, future projection and policy support. In addition, published journal papers, project reports were also reviewed. Systematic country specific literature reviews were carried out for the present study to assess the status of biomass fuels use for different end uses including cooking.
1.2 Review status of Biomass fuels conversion technologies for power generation (e.g. steam power plant, combustion/gasifier-based power plant, biogas-based power plant) used in different developed and developing countries with attention to size, conversion efficiency and price etc. Present the data of selected developed and developing countries according to given Tables.	Desktop research and published reports and journal publications have been consulted and a status report has been developed which fitted into the overall assessment. Information on the biomass conversion technologies such as cooking, heating, power generations etc. for all the selected countries were considered. The information is present in Tables 1.3 to 1.5 as suggested in the ToR.
1.3 Compile Biomass fuels Action Plans of the Selected Countries up to 2040.	Action Plans of different countries were reviewed and illustrated in the section 1.4.3. Relevant findings have been incorporated in the Bangladesh Action Plan.
1.4 Review status of previous studies on Biomass fuels carried out in Bangladesh indicating the shares of commercial energy and Biomass fuels.	Bangladesh Energy Study (BES), carried out during 1974 and the BEPP study conducted in 1984 and other studies done in Bangladesh were consulted and reviewed.
1.5 Review the status of Biomass fuels conversion technologies (e.g. improve cookstoves, steam power plants, biogas-based power plants, gasifier-based power plants, (or any other) used in Bangladesh.	Desktop research and secondary information on the biomass fuels use in ICS, steam power plants, biogas, gasifier-based power plants were documented. Technology providers (e.g. for biogas plants, biogas to electricity, brick kilns) and various associations (e.g. poultry, sugarcane) have been consulted. In addition, donor reports were consulted for finding the use of different biomass technologies in Bangladesh.
1.6 Identify the institutions involved with surveys, analyses and publication of Biomass fuels resource data; research, development, demonstration and diffusion on different biomass technologies; financing of biomass projects/program	A list was developed after identifying the institutions who are involved on biomass related activities. Institutions such as BCSIR, BUET, BARC, BARI, BIRI, BJRI and similar organization like IDCOL, and NGOs were also considered.
1.7 Compile laws, rules and policies related conservation and sustainable development of Biomass fuels resources in Bangladesh.	Relevant information was collected from government publications and from MoPEMR, SREDA. Ministry of Agriculture, Bangladesh Forest Department, Department of Environment, Energy and Power Research Council, etc. were also contacted for information on policy issues.
1.8 Prepare a Total Energy Balance Table of Bangladesh including both Biomass fuels and Commercial Energy Sources for 2015. Indicate total BF as percent of Total Primary Energy (TPE).	Data on commercial fuels were collected from relevant organizations (Petrobangla for gas and coal, BPC for oil and LPG, BPDB for electricity,). Data on traditional fuels have been taken from the study. Data gaps were filled using expert judgment after consultation with SREDA. Based on the gathered information total energy balance tables (in physical units and energy units) were prepared including both biomass energy and commercial energy sources for 2015 indicating total Biomass Fuels (BF) as a percent of TPES.

1.3 Organizations

Organizational issues are important for planning and development of biomass fuels program. Important roles and the functional aspects of organizations are presented below.

Biomass Fuels Planning

During the last forty years two major studies have been carried out in Bangladesh for sustainable development of biomass fuels; due to absence of appropriate organizations these initiatives have not been transformed into actions. In Bangladesh, sub-sectoral Master Plans are generally initiated by respective national organizations (e.g. Forestry Master Plan by Department of Forest, Gas Master Plan by Petrobangla, Power Sector Master Plan by Bangladesh Power Development Board etc.); after completion of the studies respective national agencies implement their recommendations. With the initiative of the Energy Division of the Planning Commission two Energy Master Plans (Bangladesh Energy Study and Bangladesh Energy Planning Project) were completed in 1976 and 1987 (GOB 1976, GOB 1987). Both the Master Plans highlighted the important roles of biomass fuels in meeting energy demand of the country. Due to absence of relevant national executing agency no follow up actions were taken. It was not possible for the consultants of the present study to access the reports of those two studies from the relevant section and the Library of the Planning Commission. However, subsequently the reports were accessed at the libraries of Department of Chemical Engineering and the Institute of Appropriate Technology, BUET.

Data Management

Bangladesh Bureau of Statistics (BBS) is the apex national organization responsible for collection and publication of data required for planning and development of different sub-sectors including biomass fuels. BBS started publishing, the data of traditional fuels originally presented in BES reports, in Statistical Yearbook (GOB 1979) and continued publishing up to 2009 (GOB 2009). Quantity of biomass fuels supplied per year in 1992 was reported as 25.17 million tons which was increased to 43.7 million tons in 1993. No explanation was given in Statistical Yearbook published in subsequent years about the sudden increase in supply of traditional fuels and discontinuation of publication of data on yearly supply of traditional fuels. Present study has made further analysis and observation in later sections of the report.

Census of Agriculture

Under Agricultural Census Act of 1958 (as amended in 1983), National Statistical Office (BBS) has carried out Agriculture Censuses in 1960, 1977, 1983-84, 1996 and 2008 and subsequently published the Census Reports accordingly. Data published in Agriculture Census Reports consist of land use data of Forest, Crops, Livestock & Poultry and Fisheries. In between Census years, BBS publishes updated data in the Yearbook of Agricultural Statistics on a regular basis. In the present study, data published in the Agricultural Census Reports and Yearbook of Agricultural Statistics have been used to estimate the supply of biomass fuels (e.g. tree residues, agricultural residues, animal residues etc.).

It may be noted that the latest (2019) Census of Agriculture has been initiated on 19 May 2019 and field data gathering process has taken place from 9-20 June 2019. After necessary processing, Census of Agriculture 2019 reports are expected to be published in 2021. It is

reported that at the request of SREDA, BBS may tabulate specific data of Agriculture Census 2019 for estimating the supply of different residues (e.g. tree residues, agricultural residues, animal residues etc.).

Since independence, the first round of Household Expenditure Survey (HES) was carried out in 1973-74 and the Preliminary Report of the 16th round HIES (GOB 2017) has been published by BBS. Along with other data of household expenditures, HIES also publishes expenditure on account of fuel & lighting. SREDA may interact with HIES project authority to publish the data of quantity of energy consumption along with the expenditures.

It may be inferred from previous presentation that close interactions between SREDA and BBS are necessary to gather and publish data on supply and consumption of biomass fuels on a regular basis.

Consumption of Biomass Fuels

Per capita consumption of biomass fuels is a basic parameter required for future planning and development of biomass fuels and rural energy. A number of studies were carried out in the country since 1976; a comprehensive review of these have been presented in BEPP report (Volume IV); these reports have been reviewed by the present study. Reports of studies carried out by World Bank, other Development Partners, Bangladesh Forest Department and individual researchers working in academic and research institutions have also been reviewed.

Research on Biomass Fuels Using Technologies

Research on biomass fuels consumption and development of related technologies (e.g. improved biomass fuels using cook-stoves, biogas technology) have been carried out by a number of national R&D organizations and Universities. Outcomes of these research had limited applications due to lack of continuity of funding and policy support. Masters and PhD degrees on various aspects of biomass fuels are being awarded from BAU, BUET and other Universities.

Activities of Different Organizations Related to Biomass Fuels

Sustainable and Renewable Energy Development Authority: SREDA under the Power Division is the principal organization in the country entrusted for research, survey, demonstration and diffusion of different biomass fuels technologies. Along with energy efficiency, SREDA is promoting all forms of renewable energy technologies. SREDA is responsible for implementing the Country Action Plan for Clean Cook-stoves (CAP) and the Guidelines for the standardization of improved cook-stoves (ICS). SREDA has prepared a Guidelines for the promotion of Biogas Technology. The present biomass fuels study is a part of the efforts of SREDA to promote the sustainable use of biomass fuels in the country through the development of a database of supply and demand of biomass fuels.

Infrastructure Development Company Ltd.: IDCOL, a non-banking financial institution has taken initiatives for the promotion of biomass fuels technologies (e.g. Biogas, ICS). In recent years, a number of private Livestock and Poultry Industries have established few large size biogas plants with the objective of safe disposal of wastes and to generate biogas fuel and organic manure.

Bangladesh Bank has declared Green Banking Policy to provide funds with financial incentives to private entrepreneurs for promotion of biomass fuels programs.

1.4 Review and Analysis

1.4.1 Review of Biomass Fuels Consumption Status and their Uses in Bangladesh and Selected Developed and Developing Countries

General

Biomass fuels currently contribute approximately 10 percent of global primary energy supply. In EU and USA, biomass fuels' contribution to the total primary energy supply (TPES) is 8.9 percent and 4.3 percent, respectively. In 2015, 4 percent of TPES of China came from biomass fuels. Lower income developing countries are more reliant on biomass fuels; India’s TPES included 21 percent share of biomass fuels (IEA, 2019a).

Table 1.2 shows the consumption of biomass fuels for energy in EU, USA, China and India in 2015. Primary biomass fuels consumption to produce secondary products in these selected countries in 2015 is also shown in Table 1.2. India was the highest consumer of biomass fuels with a total consumption of 179.8 MTOE. A major fraction of this is used in household cooking. The other major use is the production of electricity. Only a small fraction of the biomass fuels in India was used for production of various liquid biofuels. On the other hand, in EU and USA the use of biomass fuels for the production of liquid biofuels is significant.

The EU countries together produced 177.8 TWh of electricity from biomass fuels in 2015. Some of the power generation facilities are cogeneration plants, where heat was also produced; 547 TJ of heat was a by-product from these facilities. Among the EU countries, Germany is the leading country in the use of biomass fuels, followed by Sweden and UK. In USA, the major fraction of biomass fuels was used for the production of various liquid fuels, such as bioethanol and biodiesel. Among all the countries listed in Table 1.2, China had the lowest share of biomass fuels in their energy mix even though biomass fuels are extensively used in rural areas. The principal reason behind this is the large use of coal for domestic cooking and space heating and in low efficiency power plants.

Although developed (EU and USA) and developing (China and India) countries all consume large quantities of biomass fuels, the outputs of China and India as commodities such as electricity, biofuels and heat are significantly lower. This is due to the extensive use of biomass fuels in traditional cookstoves in rural areas. The very large heat output of EU is the result of the extensive use of heat from cogeneration plants, where the waste heat of electricity generation plants is used. District heating (space heating) using outputs of cogeneration plants is a common practice in many European countries.

Table 1.2: Primary Biomass Fuels Consumption to Produce Secondary Products in Selected Countries in 2015

Country	Reference	Primary Biomass Fuel Consumption MTOE			Secondary Energy		
		Wood and Wood Waste	Waste (Industrial waste, landfill gas etc.)	TPES	Electricity TWh	Biofuel MTOE	Heat PJ
1	2	3	4	5	6	7	8
EU 28	EU (2017)			136.8	177.8	13.6	547
Germany				25.7	50.3	3.3	64.1
Sweden				11.2	10.8	0.3	125.6
UK				10	29.2	0.3	0.7
USA	EIA (2018)	110.5	13.1	123.6	63.6	35.7	38.6
China	China Energy Portal (2015) & Qin et al. (2018)	101.5	12.2	113.7	52.7	2	45.4
India	MNRE (2017)	178.7	1.1	179.8	26.9	0.3	-

Compiled by: Ijaz Hossain (2019)

The installed power generation capacities for selected countries/region are given in Table 1.3. European countries together have an installed capacity of more than 37,000 MW. Germany, Sweden and UK have the major share of the installed capacity in Europe. Germany has the major share of biogas/landfill gas to electricity, while Sweden leads in wood/wood residue to electricity. USA also has a significant number of electricity producers using wood and wood wastes with a combined capacity of more than 9,000 MW.

India has a combined capacity of 5,940 MW of biomass fuels to electricity. These facilities use both gasification and combustion of biomass fuels for power generation. All sugar mills have facilities using bagasse as the fuel for electricity production. Very favorable feed-in tariff for cogenerated electricity allowed the Indian sugar mills to increase and improve their power generation facilities. In fact, many sugar mills in India consider electricity as their main product, and sugar as their by-product. In China the share of biomass fuels to electricity and waste to electricity are nearly equal; approximately 7,000 MW each.

In developed countries – EU and USA – the energy statistics over a decade show that the production capacities are almost similar or have changed insignificantly. This indicates that a lot of the easy to exploit potential has already been used. On the other hand, developing countries such as China and India still have significant unused potential. The total installed capacity of biomass fuel to power in India in 2015 was 5,940 MW, out of which approximately 5,000 MW is from the cogeneration plants using bagasse (MNRE 2019). Therefore, India's biomass to electricity is predominantly linked to the sugar mills; all other sources contribute only about 1,000 MW. The total potential is more than 22,000 MW. The waste to energy potential is approximately 2,500 MW. China with a larger geographical area has almost five times of India’s biomass to energy potential; approximately 100,000 MW.

Table 1.3: Biomass Fuels Power Generation in Selected Countries in 2015

Country	Reference	Installed Capacity (MW)				Potential (MW)	
		Biomass fuels and Biofuels to Power	Waste to Energy	Biogas/ Landfill Gas	Total	Biomass Fuels to Power	Waste to Energy
1	2	3	4	5	6	7	8
EU 28	EU (2017)	17352	8309	11413	37074		
Germany		1592	1924	5643	9159		
Sweden		3700	876	2	5278		
UK		2738	925	1615	4578		
USA	EIA (2016)	9475	2441	2370	14286		
China	China Energy Portal (2015) & Qin et al. (2018)	7009	7253	500	14762	100700	
India	MNRE (2017)	5665	275		5940	22536	2554

Compiled by: Ijaz Hossain (2019)

Summary of Biomass fuels consumption status and their uses in Bangladesh and selected developed and developing countries

As per the TOR of this component, the review of the status of biomass fuels consumption and their uses in selected developed and developing countries and Bangladesh are presented in Table 1.4, Table 1.5 & Figure 1.1 and Table 1.6. The percent of biomass fuels in TPES in Bangladesh and India are more than 20 percent because rural households in these two counties are still dependent on biomass fuels and are thus low in the energy ladder. The transition from traditional fuels to commercial fuels has not progressed far enough. On the contrary in China, where the transition to commercial fuels is advanced, the percent of biomass fuels in TPES is low. It is, however, to be noted that China's share is much lower than that of the EU, even though in EU there is almost no demand for biomass fuels for cooking. This indicates that China is lagging the EU in developing applications such as liquid biofuels, electricity generation and process heating.

An important aspect of biomass used as fuels in developing countries is the efficiency of combustion. In counties such as Bangladesh, China and India the use of biomass fuels for cooking has very low efficiency because traditional cookstoves are used. If the efficiency of fuel use can be increased, then the total use of biomass fuels will decrease drastically – by as much as 50 percent. Since biomass fuels are not used for cooking and household heating in developed countries, these are put to different uses where these are called "Modern Biomass". In developed countries the drive to use biomass fuels is essentially to increase the share of renewables in the primary energy mix and to deal with industrial and agricultural waste in a sustainable manner. In recent years the need to limit emission of greenhouse gases resulting from the extensive use of fossil fuels is also driving the use of biomass fuels.

Electricity generated from biomass fuels in Bangladesh is negligible compared to even India which is also at a similar level of economic development. In terms of resources on a per capita basis Bangladesh's biomass fuels potential is as good as any other country. This is why present study is undertaken to assess the potential of biomass fuels-based electricity generation.

Table 1.4: Status of Biomass Fuels in Selected Developed and Developing Countries and in Bangladesh in 2015

Name of the Country	Reference	Area of the Country km^2	Area Covered by Tree resources km^2	Area Covered by Agricultural Crops (Net/total cropped area) km^2	Supply of Biomass Fuel, Terajoules						Biomass Fuels			
					Tree Residues	Agricultural Residues	Animal Residues	Industrial Wastes	Municipal Wastes	Liquid and Gaseous Biofuels	Amount of BF used for heating, TJ	Amount of BF used for power generation, TJ	BF based Installed power plants (MW)	Power generated (GWh) by using BF
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
EU	IEA (2017) UN (2015)	4,475,757	1,647,764	969,643	2,973,628	10,496	343,621	665,587	781,861	1,216,057	3,099,069	2,625,123	39,497	200,900
USA	IEA (2017) UN (2015)	9,833,520	3,625,283	1,577,021	434,061	696,343	353,073	783,884	2,94,282	1,391,021	1,789,341	929,649	14,286	80466
China	IEA (2017) UN (2015)	9,478,000	2,530,000	1,350,000	1,623,834	258,327	-	200,666	1,580,328	350,436	3,688,152	917,746	14,762	52,700
India	IEA (2017) UN (2015)	3,287,469	717,940	1,983,600	4,149,351	4,572,192	-	-	46,000	-	7,400,587	620,902	5,940	26,900
Bangla-desh	IEA (2017) UN (2015)	1,47,570	25,770	91,622	156,300	234,455		-		0.4	-	-	-	-

Source: Data for columns 3, 4 and 5 – Statistical Yearbook 2015 (for India and China); Eurostat 2015 (for EU); US Census of Agriculture 2015 - land usage pattern (for United States); Statistical Yearbook 2015 (for Bangladesh)

Compiled by: Ijaz Hossain (2019)

Table 1.5: Contribution of Biomass Fuels in Selected Developed and Developing Countries and in Bangladesh in 2015

Name of the Country	Refer-ence	Popula-tion[1] (million)	Per capita GNI[2] (US$ per person PPP)	Million Ton Oil Equivalent (MTOE)									Biomass Fuels Percent in Total Primary Energy
				Primary Energy Mix									
				Fossil Fuels			Renewable Energy Sources					Total Primary Energy	
				Coal	Oil	Natural Gas	Hydro-power	Wind	Solar	Nuclear	Biomass fuels		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
EU	IEA (2017)	508.54	38,163	262.83	518.01	357.74	29.33	25.96	0.48	223.41	150.50	1589.52	9.47
USA	IEA (2017)	321.70	57,880	374.04	789.54	646.77	21.54	16.59	2.76	216.34	102.3	2187.66	4.67
China	IEA (2017)	1374.62	14,400	1996.62	533.74	158.59	95.83	15.97	3.85	44.50	113.66	2991.43	3.80
India	IEA (2017)	1254.02	6,060	379.67	207.31	43.22	11.66	3.58	0.90	9.75	179.77	836.53	21.49
Bangladesh	IEA (2017)	158.9	1,465	2.27	4.98	21.14	0.05	0.0003	0.013	-	9.33	37.78	24.69

Source: 1. Population data taken from – Statistical Yearbooks (India, China, Bangladesh); Eurostat (EU); United States Census Bureau (United States)

2. GNI data taken from World Bank online database downloaded 15 March 2019

Compiled by: Ijaz Hossain (2019)

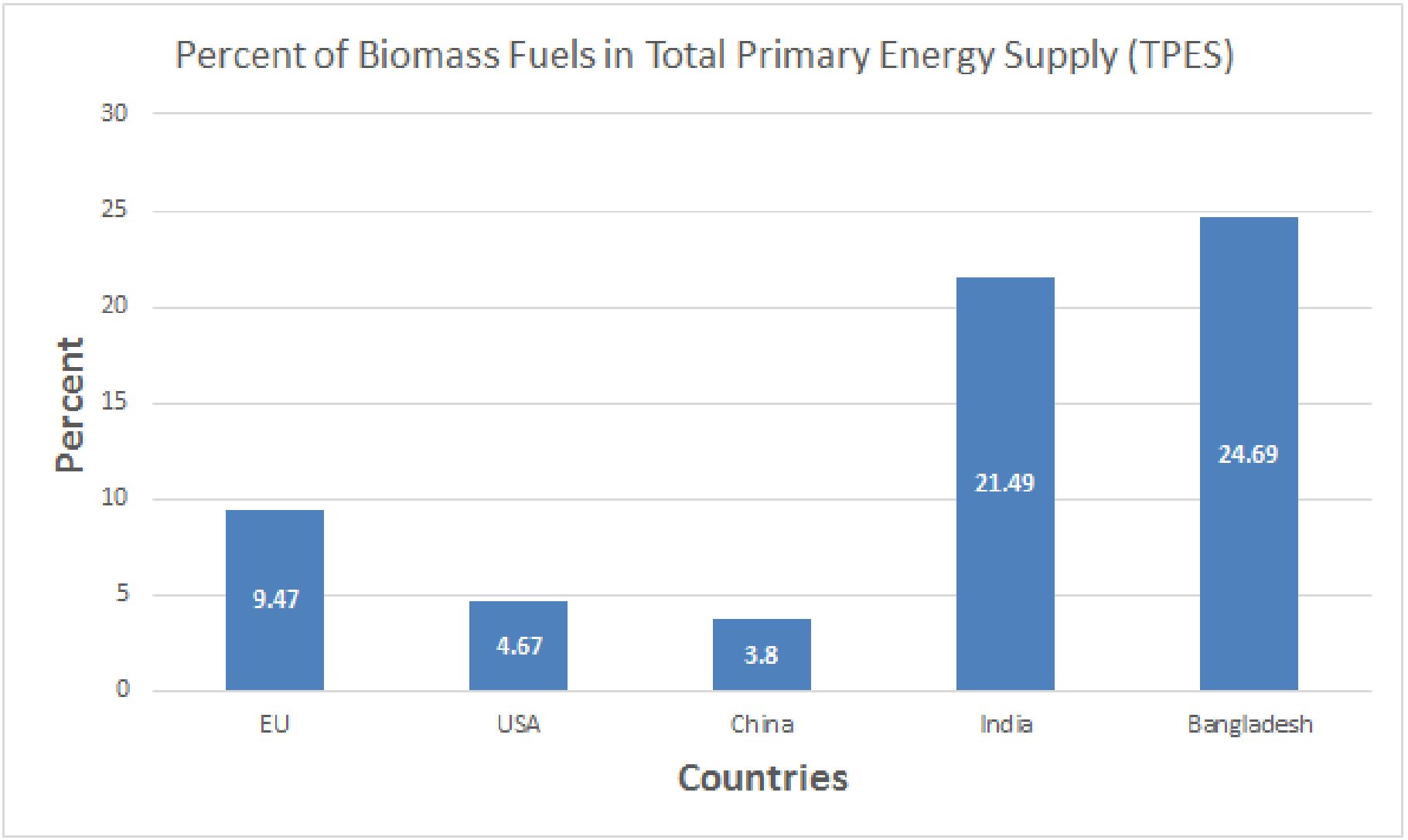


Figure 1.1: Percent of Biomass Fuels in Total Energy Sources in Selected Developed and Developing Countries

Table 1.6: Fuel Mix for Power Generation in Selected Developed and Developing Countries and in Bangladesh in 2015

Name of the Country	Refer-ence	Total Energy Used for Power Generation MTOE	Percent of Total Primary Energy Used for Power Generation	Energy Mix for Power Generation Gigawatt hour (GWh)							Power Generated by Biomass Fuels as % of Total Generated Power
				Power Generated by Fossil Fuels	Power Generated by Renewable Energy Sources					Total Power Generated	
					Power Generated by Hydropower	Power Generated by Wind Resources	Solar Power	Nuclear Power	Power Generated by BF		
1	2	3	4	5	6	7	8	9	10	11	12= (10/11)×100
EU	IEA (2017)	649.17	40.8	1,384,373	371,167	301,876	107,897	857,020	200,900	3,235,113	6.18
USA	IEA (2017)	880.44	40.3	2,882,404	271,129	192,992	35,635	830,288	80,466	4,317,159	1.86
China	IEA (2017)	1218.59	40.7	4,265,019	1,130,270	185,766	44,809	170,789	52,700	5,859,515	0.90
India	IEA (2017)	315.63	37.7	1,120,967	135,609	41,663	10,478	37,414	26,639	1,372,770	1.94
Bangla-desh	IEA (2017)	13.64	36.1	58,287	566	4	154	-	96[1]	59,107	0.0016

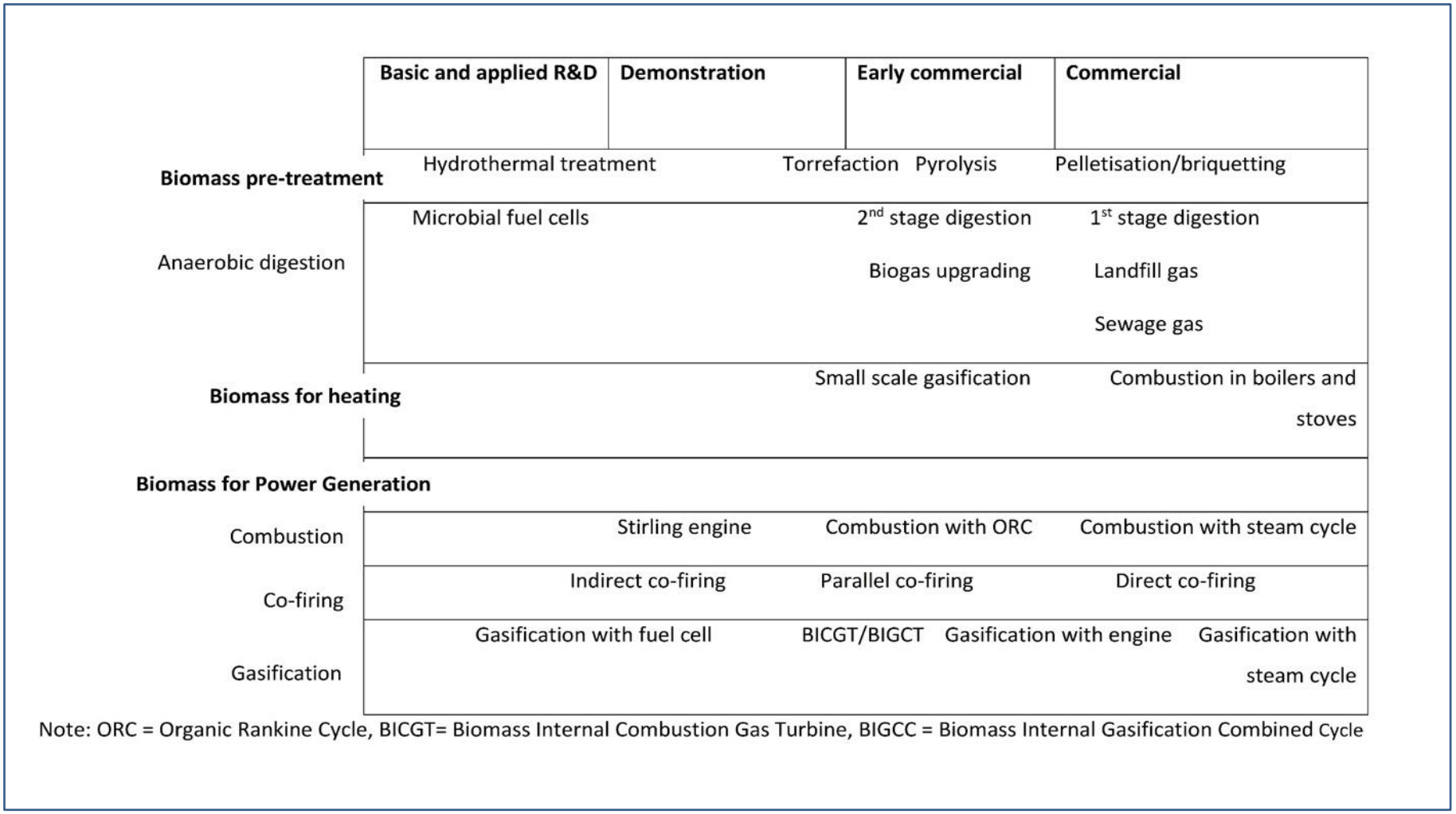
Note: (1) Estimated by author from sugar mill power generation capacity.

Compiled by: Ijaz Hossain (2019)

1.4.2 Review of Biomass Fuels Conversion Technologies for Power Generation

World energy demand is affected by the increasing population in developing countries. To meet the increasing energy demand, energy sources will be needed which are sustainable and indigenous. The reason behind this is not only the limited resource of fossil fuels but also the mitigation of carbon dioxide emission. For this, International Energy Agency has set goals and specific tasks to increase the use of biomass fuels and other renewable energy sources (IEA Bioenergy 2017).

The simplest way to consume the energy from biomass fuels is to use the existing conversion technologies for solid fossil fuels. These technologies could entail both thermochemical and biochemical pathways based on maturity. The current state of the available technologies is provided in Figure 1.2. Some of the newer technologies to convert biomass have reached the commercialization phase. The pre-treatment technologies such as torrefaction and pyrolysis are in the early commercial stage. In fact, torrefaction before combustion is becoming very popular as it removes the oxygenated groups from biomass to make it energy dense and increases the storage life of biomass. There are some upcoming biotechnologies which are in the laboratory stage, i.e. microbial fuel cell (uses bacteria to release electron at anode). However, it should be noted that microbial fuel cells cannot be used for traditional power generation as the energy density is very low. These are targeted mainly towards replacing small scale power needs like batteries and biosensors. For bioelectricity, energy is harnessed from biomass fuels through direct combustion or, secondary combustion of derived products. Biomass fuels meet a significant portion of the primary energy demand in several developing countries, however, not through power generation. On the other hand, biomass fuels are generally used for biofuel production and heat/power generation in developed countries to increase the share of renewables in their energy mix. Among them, co-firing and, cogeneration (also known as Combined Heat and Power–CHP) plants are the major contributors for power generation from biomass fuels. An overview of the available technologies for biomass fuels-based power generation is given in Figure 1.3. In the following paragraphs, brief description of the conversion technologies for biomass fuels is given. Additional information on price of energy conversion technologies has been shown in Appendix I.I.



Source: IEA 2012

Figure 1.2: Technological Maturity of Different Types of Biomass Conversion Technologies

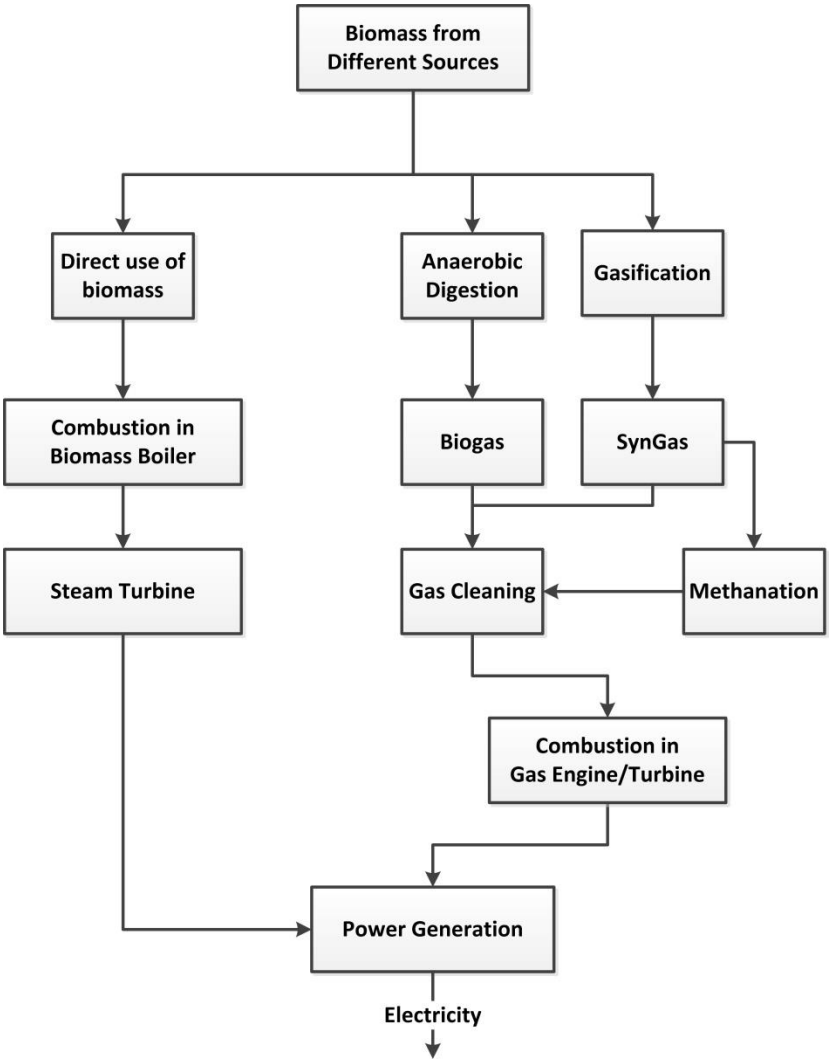


Figure 1.3: Biomass Fuels Conversion Technologies Focused on Power Generation

Co-firing: Direct co-firing (in existing solid fuels furnaces such as coal, peat, MSW and industrial wastes) has been the most economical way of utilizing biomass fuels for power generation to deal with the issue with collection and transportation of biomass fuels. The size of biomass fuels only power plants is greatly limited by the biomass fuels supply (typical size is below 100 MW). These tend to have low efficiencies between 20 to 25%. In case of biomass fuels co-fired plants, existing fossil fuel-based power plants of high capacity can be utilized for co-firing with minor modifications instead of constructing a new one. In USA, co-fired plants are major contributors for biomass fuels-based power generation. However, the direct co-firing levels are still within 5 to 20% by mass considering continuous operation of plants (Agbor et al. 2014). Canada, China, EU countries, Japan and South Korea are also using co-firing to reduce the carbon footprint from power generation. It is to be noted that co-firing is only recently being trialed in India for future implementation.

Co-generation: Combined Heat and Power (CHP) plants are the most common ways for power generation from biomass fuels in developed countries. Due to the smaller capacity of CHPs, it is important to have other uses of the energy produced (i.e. space heating) for economic reasons. In cogeneration mode, overall efficiency of CHPs varies between 70-90 percent (IEA 2012). This process generates electricity through steam turbine while the exhaust steam is used for space heating and other heating purposes. A schematic diagram of this type of plants is shown in Figure 1.4. European countries encourage renewable energy

generation from CHP plants through subsidy and other policy support in national level (IEA 2012). In developing countries like Bangladesh and India, cogeneration has been practiced only in the sugar mills which consume the bagasse from cane for heat and power generation.

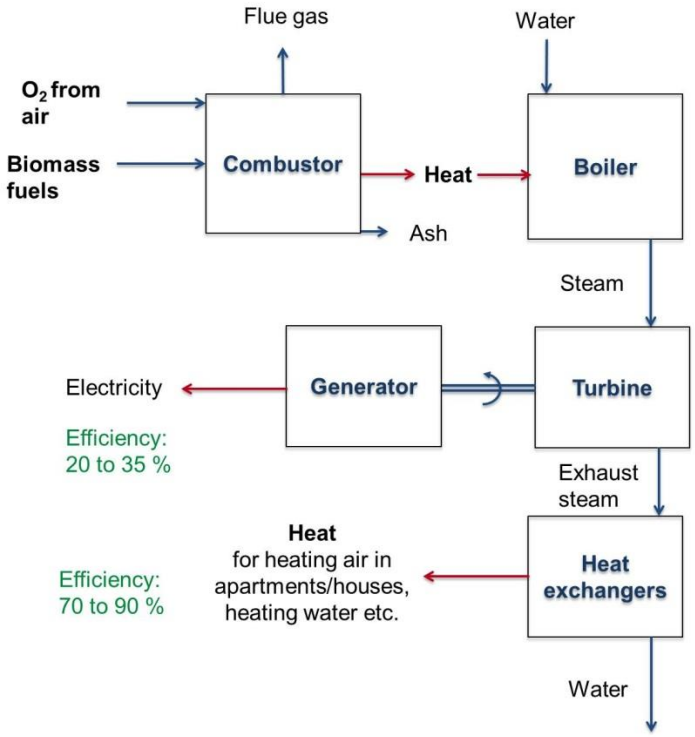


Figure 1.4: General Configuration of a CHP Plant Based on Biomass Fuels

Gasification: After direct combustion, gasification has been the most popular option for power generation from biomass fuels. Gasification uses a lower amount of oxygen than the stoichiometric requirement for complete combustion. This incomplete combustion results in a mixture of CO, H_2, CO_2, CH_4 and some pollutants. After cleaning, this Syngas is either directly combusted to produce energy in a gas engine/turbine or further converted to methane (also known as methanation) for BioSNG generation. Based on the BioSNG concept, there has been a recent development in Gothenburg, Sweden known as GoBiGas project (Phase-1: 20 MW and Phase-2: 100 MW) (Chemicals Technology 2019, Thunman et al. (2015). The process uses circulating fluidized bed gasification technology utilizing wood derived biomass fuels to produce methane (BioSNG) for power generation and heating purpose. Based on a similar technology, a 140 MW BioSNG plant was commissioned by Valmet in Vaasa, Finland (Valmet 2019). This plant used syngas to co-fire in boilers to replace up to 40% of the coal consumption by mass. In developing countries such as India, gasification plants for power generation have greatly increased in recent years to meet both on and off-grid demands (Indian Ministry of Statistics and Programme Implementation 2015).

Biomass Conversion Technology: Gasification

Source – Practical Action 2012

Photo: Acacia Logs in Nakuru County; A simple gasifier assembly that can be used to produce both mechanical and electrical power in stationary installation that comes in either 10 kW or 20 kW output

Anaerobic digestion: Anaerobic digestion is a process that takes place in absence of air/oxygen to convert organic matter through biological process for producing a mixture of CH_4 and CO_2 (also known as biogas). Using proper gas cleaning methods to remove the undesired gases including CO_2, biogas can be converted to biomethane. This biomethane can be combusted to produce power/electricity. Due to its simplicity and low-cost nature, biogas plants have seen an exponential growth all over the world. Among all the countries, Germany leads world biogas production with installed electricity generating capacity of 5643 MW_e as of 2015 (EU 2018). A close competitor to Germany is Brazil with 2513 MW capacity with biogas. Among the Asian countries, Republic of Korea had approximately 1320 MW electricity generation capacity from anaerobic digestion of biomass fuels in 2015 (IEA 2015).

Other than the above-mentioned major technologies, fast pyrolysis has also been developed during the past decade which can now produce stable pyrolysis oil in commercial scale for various uses including power generation (Bridgwater 2012). However, the contribution to bio-electricity is relatively small from this technology. Charcoal production from biomass fuels has also gained interest for mainly co-firing purpose in different industries such as steel mills.

In 2015, total electricity generation from biomass fuels was led by USA followed by Germany, China, Brazil and Japan (EU 2018, REN21 2015a, REN21 2015b). However, over the past years, the development slowed down in USA. China and USA are contributing to bioelectricity through co-firing and CHPs, while Germany's main contribution towards bioelectricity is through anaerobic digestion (REN21 2015a, REN21 2015b). Table 1.7 shows the efficiencies for electricity generation using co-firing, CHP and anaerobic digestion-based CHP.

Table 1.7: Efficiencies of Bioelectricity Production from CHPs and Co-Firing

Technology	Electric Efficiency (%)
1	2
Biomass fuels-CHP	16-36
Anaerobic Digestion based CHP	26-32
Co-firing with Coal Fired Boilers (retrofit)	36-44

Source: REN21 2015a, REN21 2015b

In all cases, the choice of technology will be determined by the type of biomass fuels available for electricity generation. Biomass fuels composition and characteristics will greatly determine the most appropriate technology for biomass fuels-based power generation for a country. Further discussion on the technology selection for Bangladesh is undertaken in section 1.4.5

Biomass Conversion Technology: Combustion

Source: Power Technology 2019

Photo: Cogeneration Biomass Power Plant (30 MW) Using Bagasse and Wood at Rocky Point Sugar Mill, Brisbane, Queensland, Australia

1.4.3 Biomass Fuels Action Plans of Selected Countries

Many countries have set biomass fuels targets to achieve a greater penetration of biomass fuels. The timeline of these targets varies from country to country – some only go up to 2020, e.g. China, while others have a plan up to 2030. REN21 has compiled a set of targets for biomass fuels-based power generation of some countries shown in Table 1.8. There are basically two types of targets – those that specify the total and those that specify additional capacity to be built. Targets set in power units (MW) can be misleading because it gives no indication of the annual load factor. Because biomass fuels availability is heavily dependent on location, many of these targets are specific to particular states and regions. For example, several states of the USA have their own biomass fuels action plans. Similarly, the EU has an action plan for biomass fuels for a specific region where biomass fuels availability is high.

Table 1.8: Biomass Power Generation Targets in Selected Asian Countries

Country	Biomass and Waste Targets
1	2
China	30 GW by 2020
India	1,700 MW of additional biomass cogeneration capacity by 2012
Indonesia	810 MW by 2025
Malaysia	1,065 MW by 2020
Philippines	267 MW by 2030
Thailand	3,700 MW by 2022
Viet Nam	5% (30 MW) renewable energy by 2020 including biomass

Source: BE Sustainable 2019

The biomass fuels action plans of EU, USA, China and India have been reviewed, and the salient features are presented below in brief.

EU

The EU has several biomass fuels programs. Some deal with biofuels, while others try to promote the use of biomass fuels for heating. Electricity generation from biomass fuels is low priority in the EU. Recent studies have shown that in terms of greenhouse gas emission reduction, biomass fuels derived from energy crops are not very attractive. The use of chemical fertilizers and farm machinery that run on fossil fuels lower the GHG reduction benefits of biomass fuels. There are also issues of deforestation, depletion of soil fertility and water sustainability. However, biomass wastes properly sourced and utilized can be sustainable renewable energy.

EU biomass fuels action plans mainly deal with biofuels and heating. The biomass fuels to power programs are of low priority. The biomass fuels to electricity option that is promoted is co-firing (using biomass fuels as a supplement to other solid fuels). Thus, surplus biomass fuels, if it cannot be used otherwise are usually earmarked for co-firing in either coal-fired or MSW-fired boilers.

EU's biomass action plan was prepared in 2005, and the plan has targets only up to 2020, which means the timeline of these targets are very close to their end. However, there are studies included in the biomass action plan that deal with projection of the potential of biomass energy. Table 1.9 shows the potential of biomass energy in the EU25 countries. Since the study was done prior to 2005, it does not include the potential of the Eastern European countries, which became members after 2005. As can be seen there exists huge potential of biomass energy in the EU up to 2030. The report further states that the table does not include the potential of Bulgaria and Romania, which have large per capita availability of land; 0.7 hectares as opposed to 0.4 hectares in the EU25 countries.

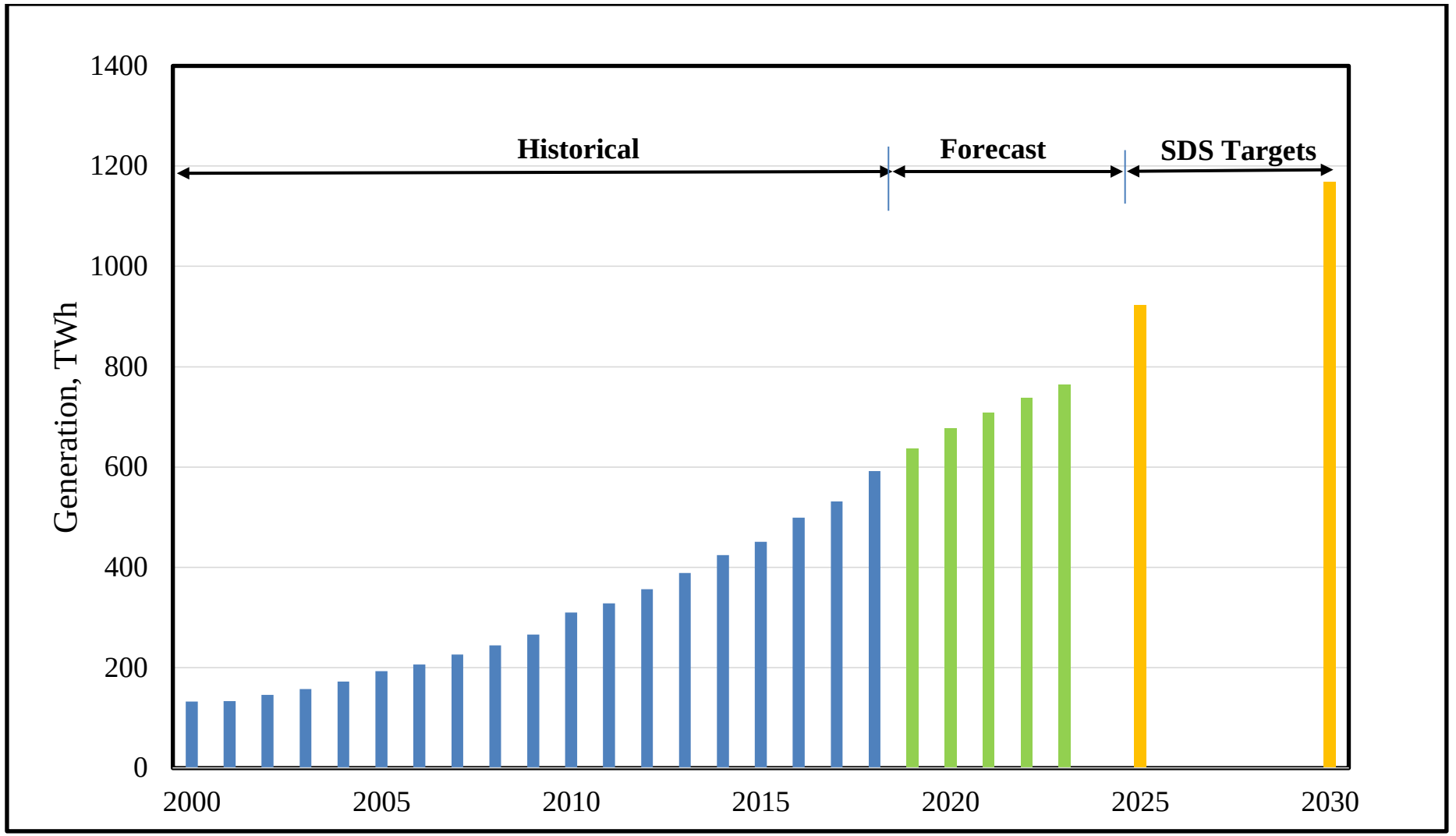
Table 1.9: Consumption and Potential of Biomass for Energy Purposes in the 25 Member States of the EU

Type of Biomass	**MTOE**			
	Consumption 2003	**Potential 2010**	**Potential 2020**	**Potential 2030**
1	2	3	4	5
Wood direct from forest (increment and residues)	67	43	39-45	39-72
Organic wastes, wood industry residues, agricultural, food processing residues, manure		100	100	102
Energy crops from agriculture	2	43-46	76-94	102-142
Total	**69**	**186-189**	**215-239**	**243-316**

Source: (EU 2005)

With regard to electricity generation the targets are country specific. For example, Sweden and UK have targets to produce approximately 18 and 50 TWh of electricity from biofuels by 2020 respectively (EC 2019, DECC 2011). There are however studies dealing with the projection of biomass fuels to electricity in the EU region. Figure 1.5 shows the historical trend, the forecasted trend and the Sustainable Development Scenario (SDS) target for power

generation. SDS is defined by IEA as: “Based on existing and announced policies – as described in the IEA New Policies Scenario – the world is not on course to achieve the outcomes of the UN SDGs most closely related to energy. The SDS sets out an ambitious but pragmatic vision of how the global energy sector can evolve in order to achieve these critical energy-related SDGs” (IEA 2019b). As can be seen from Figure 1.5 in 2015 the biomass fuels-based electricity generated in the EU was 451 TWh. This is projected to go up to 677 TWh in 2020 and 1,168 TWh in 2030.



Source: IEA 2019c

Figure 1.5: Targets for Electricity Generation from Biomass Fuels in the EU

USA

There is no biomass action plan of USA for the entire country. The biomass action plans of the United States of America are contained in the respective state programs. In most states of the United States there is a compulsory requirement of blending bioethanol with gasoline. In California the bioethanol blending requirement is 10 percent, and they are considering increasing it to 20 percent. A 20 percent blending requirement across USA will create huge demand for liquid biomass fuels.

The most ambitious action plan for biomass is that of the State of California, which has large untapped biomass resources, including residues from forestry, urban and agricultural wastes. According to the action plan – "The production and use of the state's considerable biomass resources can achieve progress toward meeting the state's petroleum reduction, climate change and renewable energy goals, while providing strategic social, economic and environmental benefits to California. Using biomass for energy production can significantly reduce the waste stream in California's forests, landfills and farmlands, and improve forest health while reducing the risk of catastrophic wildfires" (Schwarzenegger, undated).

On April 25, 2006, Governor Arnold Schwarzenegger issued Executive Order S-06-06, establishing targets for the use and production of biofuels and biopower and directing state agencies to work together to advance biomass programs in California while providing environmental protection and mitigation (Schwarzenegger, undated). In Executive Order S-06-06, Governor Schwarzenegger established the following targets to increase the production and use of bioenergy, including ethanol and biodiesel fuels made from renewable resources:

- Regarding biofuels, the state shall produce a minimum of 20 percent of its biofuels within California by 2010, 40 percent by 2020, and 75 percent by 2050.
- Regarding the use of biomass for electricity, the state shall meet a 20 percent target within the established state goals for renewable generation for 2010 and 2020.

The action plan emphasizes the importance of multi-agency collaboration and lists the responsibilities of the individual agencies to make the action plan work. The legislative options to carry forward the action plan are also listed.

China

China's main biomass fuels target, set in 2010, only extends up to 2020 and is 30 GW of biomass fuels-based power generation. In 2010, when this target was set, the power generation from biomass fuels was approximately 5 GW. Thus, a six-fold increase in power generation from biomass fuels is envisaged. No new target for biomass fuels has been set. Like India and many other countries, China is concentrating on wind and solar energy. The many issues surrounding biomass fuels use as an energy source has prompted this slowdown. The Climate Change negotiations including the obligation under the Paris Agreement has also meant China is re-evaluating all its renewable energy targets.

India

India's biomass fuels action plan encourages biofuels and electricity generation principally through biomass fuels gasification. The biofuel program is concentrated on bioethanol, and 10 percent blending of bioethanol with gasoline is in force in many states. India's target is to

reach E20, i.e. 20 percent bioethanol blend for gasoline. The large sugar industry of India acts in favor of the gasoline blending. India also hopes to blend 20 percent biodiesel with diesel. These targets have, however, been given no end dates.

The electricity generation program from biomass fuels is an old one, and India is one of the pioneering countries in the gasification technology having solved many of the gasification technology's nagging technical problems. Rural electrification especially in areas where the grid cannot reach easily was the main aim of the program. India currently has 4000 MW of biomass fuels gasification-based electricity generation. The other large focus is bagasse-based sugar cogeneration (electricity + process heat) which is an intrinsic part of the sugar industry. India's biomass fuels-based electricity generation target is 10 GW by 2022.

The biomass fuels action plans of selected countries are summarized in Table 1.10.

Table 1.10: Biomass Fuels to Electricity and Biofuels in Selected Countries

Country	Biomass Fuels to Electricity	Biofuels (Liquid)
1	2	3
EU	1,100 TWh (SDS Target by 2030)	Limited to 7% of Renewable Energy (RE) target by 2030
USA	Contained in state-level Renewable Portfolio Standards	
China	30 GW by 2020	
India	10 GW by 2022	E20 – 20% bioethanol blend in gasoline B20 – 20% biodiesel blend in diesel (no time given for both the targets)

Compiled by Ijaz Hossain

1.4.4 Review of Previous Studies on Biomass Fuels in Bangladesh

BES, BEPP studies and BBS database

Assessment of biomass fuels in the total energy need of Bangladesh was first conducted by the Bangladesh Energy Study (BES), carried out during 1974 (GOB 1976) shown in Table 1.11. This study, therefore, can be considered to be the first study dealing with biomass fuels in Bangladesh. Since then Statistical Yearbooks of Bangladesh have been publishing estimated supply of biomass fuels naming it as “Traditional Fuels”. Their data is available for the years 1974 to 2005 and were published in SYB 1979 to SYB 2009 (GOB 1979; GOB 1986, GOB 1991; GOB, 1996; GOB, 2001; GOB, 2006, GOB, 2010) as shown in Table 1.12 and Figure 1.6. Data presented in Table 1.12 have been converted to energy unit and shown in Table 1.13. It is to be noted that BBS made a large adjustment in their "Rice Straw" data; in 1991-92 the reported quantity is 3.3 million tonnes, but in 1992-93 it is abruptly increased to 20.3 million tonnes. One logical explanation is a change in methodology of reporting rice straw used as a fuel. Alternatively, it may be that this item was being wrongly reported, and that the correct quantity was much larger than used to be reported earlier. As a result of this adjustment the total biomass fuels consumption in Bangladesh went up from approximately 25 to 44 million tonnes.

Data presented in Figure 1.6 has been extrapolated up to the base year of the present study, 2015. It indicates that in 2015, consumption of traditional fuels should be in between 32 million tons and 57 million tonnes.

Following the BES, another study titled Bangladesh Energy Planning Project (BEPP), conducted in the early 1980s by a consortium of national and international consulting companies for the Government of Bangladesh, was undertaken (GOB 1987). This was a very detailed study which resulted in the development of biomass energy related parameters, some of which are still used by researchers and planners. The present study has also used some of these parameters as well as some data presentation formats. Biomass fuels supply data reported in BEPP is shown in Table 1.14. Other than these two studies there are no comprehensive studies on biomass fuels in Bangladesh.

Table 1.11: Rough Estimates of Consumption of Energy Supplied by Traditional Fuels, 1974

Fuel	**Percent of total production used as fuel**	**Amount used as fuel, 10^6 long tons**	**BTU per 1b.**	**BTU per long ton, 10^6**	**Total BTU content, 10^{18}**	**Total MTOE**
1	2	3	4	5	6	7
Cow dung	35	6	3700	8.3	50	1.26
Jute stick	50	1	5400	12.1	12	0.30
Rice straw	10	3	5400	12.1	36	0.91
Rice bulls	80	4	5400	12.1	48	1.21
Bagasse	75	1.5	3200	7.2	11	0.28
Firewood	…	0.5	6500	14.6	7	0.18
Twigs, leaves	…	1.5	5400	12.1	18	0.45
Other waste	…	1.5	5400	12.1	18	0.45
All fuels	…	**19.1**	**4700**	**10.6**	**200**	**5.04**

Notes: BTU – British Thermal Unit, MTOE- Million Ton Oil Equivalent

Source: Bangladesh Energy Study, 1976 (Reproduced from Statistical Yearbook of Bangladesh 197980, GOB, 1979)

Table 1.12: Supply of Traditional Fuels in Bangladesh from 1973-74 to 2004-05

(In Million Metric Tons of Physical Units)

Year	Cow Dung	Jute Stick	Rice Straw	Rice Hull	Bagasse	Firewood	Twigs, Leaves	Other Wastes	Total
1	2	3	4	5	6	7	8	9	10
1973-74	6.64	1.09	3.26	4.03	1.61	0.50	1.50	1.50	20.13
1974-75	6.71	0.63	3.22	3.81	1.68	0.52	1.57	1.57	19.71
1975-76	6.75	0.72	3.41	4.48	1.49	0.56	1.69	1.69	20.79
1976-77	6.80	0.87	3.30	4.26	1.62	0.57	1.72	1.72	20.86
1977-78	7.20	1.00	3.40	4.60	1.80	0.60	1.90	1.90	22.40
1978-79	8.40	1.20	3.40	4.60	1.70	0.70	2.00	2.00	24.00
1979-80	5.20	1.10	3.50	4.00	2.30	0.70	2.10	2.10	21.00
1980-81	5.20	0.90	3.60	4.30	2.20	0.70	2.20	2.20	21.30
1981-82	5.30	0.80	3.60	4.20	2.40	0.70	2.20	2.20	21.40
1982-83	5.30	0.90	3.60	4.40	2.50	0.80	2.50	2.50	22.50
1983-84	5.50	0.90	3.30	4.90	2.40	0.80	2.30	2.30	22.40
1984-85	5.60	0.80	3.20	4.90	2.30	0.80	2.40	2.40	22.40
1985-86	5.70	1.20	3.30	5.00	2.20	0.90	2.60	2.60	23.50
1986-87	5.70	1.20	3.50	3.20	2.30	0.80	2.30	2.30	21.30
1987-88	6.00	1.20	3.30	4.50	2.40	0.90	2.40	2.40	23.10
1988-89	6.40	1.30	3.50	4.60	2.30	0.90	2.40	2.40	23.10
1989-90	6.20	0.90	3.50	5.90	2.50	0.80	2.50	2.50	23.80
1990-91	6.30	1.00	3.40	5.90	2.60	0.90	2.50	2.50	24.80
1991-92	6.60	0.90	3.30	6.10	2.50	1.00	2.40	2.40	25.10
1992-93	6.70	1.00	20.33	6.20	2.60	1.90	2.50	2.50	43.73
1993-94	6.60	0.90	19.97	6.20	2.40	2.00	2.60	2.60	43.27
1994-95	6.70	1.00	18.14	6.20	2.30	3.50	2.70	2.70	43.24
1995-96	7.80	1.50	18.75	6.20	1.30	3.60	2.70	2.60	44.45
1996-97	8.00	1.80	18.95	6.30	1.40	3.90	2.80	2.60	45.75
1997-98	7.70	2.10	15.18	6.30	1.40	5.00	2.90	2.60	43.18
1998-99	7.90	1.90	16.12	6.30	1.20	5.60	3.00	2.50	44.52
1999-00	8.10	2.10	18.04	6.40	1.20	6.00	3.00	2.70	47.54
2000-01	8.20	2.20	18.75	6.40	1.30	6.20	3.10	2.80	48.95
2001-02	8.20	2.30	18.49	6.50	1.40	6.40	3.10	2.90	49.29
2002-03	8.20	2.20	18.60	6.60	1.40	6.60	3.20	3.00	49.80
2003-04	8.30	2.10	18.60	6.50	1.60	7.20	3.20	3.10	50.60
2004-05	8.40	2.00	18.50	6.50	1.50	7.80	3.30	3.20	51.20

Source: Statistical Yearbook of Bangladesh 1979, 1985, 1990, 1995, 2000 and 2009

Compiled by: Ijaz Hossain

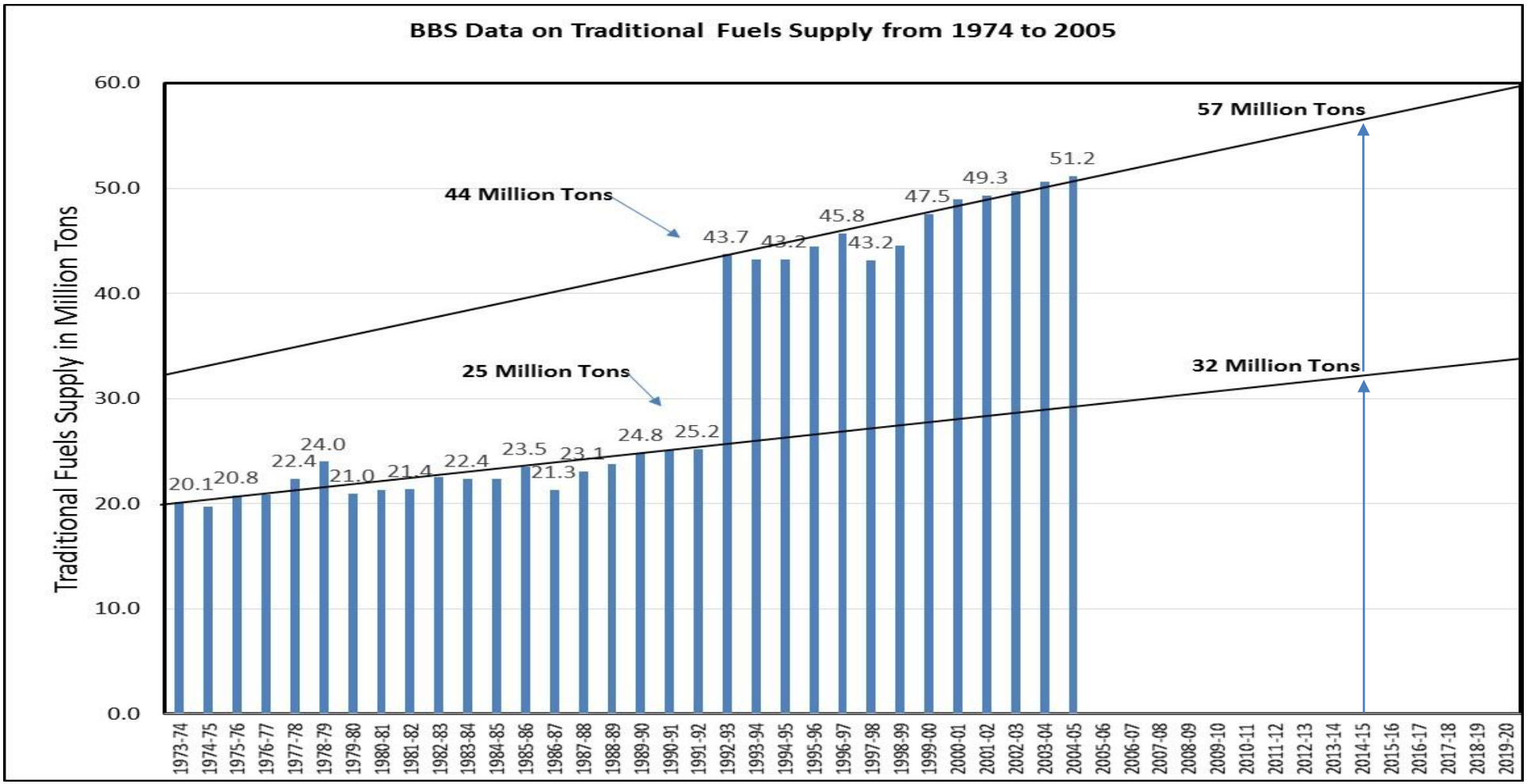


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Figure 1.6: BBS Data on Traditional Fuels Supply from 1973-74 to 2004-2005

Table 1.13: Supply of Traditional Fuels in Bangladesh from 1973-74 to 2004-05

(in MTOE)

Year	Cow Dung	Jute Stick	Rice Straw	Rice Hull	Bagasse	Firewood	Twigs, Leaves	Other Wastes	Total
1	2	3	4	5	6	7	8	9	10
1973-74	1.84	0.33	0.97	1.20	0.48	0.18	0.45	0.45	5.90
1974-75	1.86	0.19	0.96	1.14	0.50	0.19	0.47	0.47	5.77
1975-76	1.87	0.21	1.02	1.34	0.44	0.20	0.50	0.50	6.10
1976-77	1.88	0.26	0.99	1.27	0.48	0.21	0.51	0.51	6.12
1977-78	1.99	0.30	1.02	1.37	0.54	0.22	0.57	0.57	6.57
1978-79	2.33	0.36	1.02	1.37	0.51	0.25	0.60	0.60	7.03
1979-80	1.44	0.33	1.04	1.19	0.69	0.25	0.63	0.63	6.20
1980-81	1.44	0.27	1.07	1.28	0.66	0.25	0.66	0.66	6.29
1981-82	1.47	0.24	1.07	1.25	0.72	0.25	0.66	0.66	6.32
1982-83	1.47	0.27	1.07	1.31	0.75	0.29	0.75	0.75	6.65
1983-84	1.52	0.27	0.99	1.46	0.72	0.29	0.69	0.69	6.62
1984-85	1.55	0.24	0.96	1.46	0.69	0.29	0.72	0.72	6.62
1985-86	1.58	0.36	0.99	1.49	0.66	0.32	0.78	0.78	6.95
1986-87	1.58	0.36	1.04	0.96	0.69	0.29	0.69	0.69	6.29
1987-88	1.66	0.36	0.99	1.34	0.72	0.32	0.72	0.72	6.82
1988-89	1.77	0.39	1.04	1.37	0.69	0.32	0.72	0.72	7.02
1989-90	1.72	0.27	1.04	1.76	0.75	0.29	0.75	0.75	7.32
1990-91	1.75	0.30	1.02	1.76	0.78	0.32	0.75	0.75	7.41
1991-92	1.83	0.27	0.99	1.82	0.75	0.36	0.72	0.72	7.44
1992-93	1.86	0.30	6.07	1.85	0.78	0.69	0.75	0.75	13.03
1993-94	1.83	0.27	5.96	1.85	0.72	0.72	0.78	0.78	12.90
1994-95	1.86	0.30	5.42	1.85	0.69	1.26	0.81	0.81	12.98
1995-96	2.16	0.45	5.60	1.85	0.39	1.30	0.81	0.78	13.33
1996-97	2.22	0.54	5.66	1.88	0.42	1.41	0.84	0.78	13.73
1997-98	2.13	0.63	4.53	1.88	0.42	1.80	0.87	0.78	13.04
1998-99	2.19	0.57	4.81	1.88	0.36	2.02	0.90	0.75	13.47
1999-00	2.24	0.63	5.39	1.91	0.36	2.16	0.90	0.81	14.39
2000-01	2.27	0.66	5.60	1.91	0.39	2.24	0.93	0.84	14.82
2001-02	2.27	0.69	5.52	1.94	0.42	2.31	0.93	0.87	14.94
2002-03	2.27	0.66	5.55	1.97	0.42	2.38	0.96	0.90	15.10
2003-04	2.30	0.63	5.55	1.94	0.48	2.60	0.96	0.93	15.37
2004-05	2.33	0.60	5.52	1.94	0.45	2.81	0.99	0.96	15.59

Source: Statistical Yearbook of Bangladesh 1979, 1985, 1990, 1995, 2000 and 2008

Compiled by: Ijaz Hossain

Table 1.14: Biomass Fuels Consumption in Bangladesh in the Year 1981

Type of Land	Area (million acre)	Percent (%)	Biomass Fuels		
			Million Tons	Peta Joule	Percent
1	2	3	4	5	6
Forests	5.41	15.30	0.68	10.30	2.15
Not available for cultivation	6.36	18.00	0.08	1.20	0.25
Village Forests	0.74	2.10	4.66	65.60	13.70
Cultural Wastes	0.62	1.80	0.15	2.00	0.41
Current Fallow	1.40	4.00	0.33	4.70	0.98
Net Crop	20.77	58.80	23.08	288.48	60.20
Total Area	**35.33**	**100.00**	**29.00**	**372.28**	**77.69**
Livestock (2.5 million head)			6.70 (Dung)	77.72	16.21
Recycle Biomass			2.30	29.30	6.10
Total			**38.00**	**479.30**	**100.00**

Source: GOB 1987

Recent studies on biomass fuels in Bangladesh

The scopes of the available studies are very limited even though many claim to cover the entire country. Many of these studies deal only with potential of biomass fuels. The consumption or supply of biomass fuels is the subject matter of very few studies and are generally limited to household consumption of biomass fuels. These studies are not comprehensive enough to demand consideration in the context of this project. Moreover, there are large variations in the estimates. Nevertheless, for the sake of completeness, the important studies dealing with biomass fuels are reviewed here. These studies can be divided into three categories:

- Studies of biomass fuels consumption/supply
- Studies on the potential of biomass fuels in Bangladesh
- Miscellaneous studies on biomass fuels

BES and BEPP are the main studies in the first group. These two studies have been reviewed in the previous sub-section, and their findings relevant to this study are summarized in Table 1.11 and Table 1.14 respectively. No studies since BEPP have dealt with biomass fuels in such great depth. Recent studies that have conducted some primary data collection through direct questionnaire-based surveys are listed in Table 1.15. After BES and BEPP study, BIDS has carried out a rural energy study in 2005, which has been subsequently published by World Bank (Asaduzzaman and Latif 2005, Asaduzzaman, Barnes and Khandker 2010).

The data from the limited study targeting a few villages has been used through extrapolation to develop a demand and supply scenario of biomass fuels for the entire country. The JICA study (JICA 2012) on biomass fuels have been collected from a researcher at Bangladesh Agriculture University. The principal limitation of these studies is that these are based on data collected from a few villages, and it is well known that there are wide variations in both the type and quantity of biomass fuels consumption depending upon the availability of biomass and the economic condition of the area. The Agriculture Census conducted by the Bureau of Statistics under the Ministry of Planning is an excellent source of data on biomass availability from various sources including livestock and homestead forestry. The data of

these censuses are published, and this study has used many of the 2008 census results (GOB 2010).

Table 1.15: Studies of Biomass Fuels Consumption/Supply

Study/Report	Salient Features
Bangladesh Energy Study (BES) Government of Bangladesh GOB, 1976	A study undertaken by the Government of Bangladesh to assess the energy requirement in Bangladesh, both traditional and commercial fuels. First detailed study on Energy in Bangladesh. Data table presented earlier for the year 1973-74
Bangladesh Energy Planning Project (BEPP) Government of Bangladesh GOB, 1987	A comprehensive study involving field surveys to assess the energy consumption pattern in Bangladesh. The study has provided extensive data and information on biomass fuels. Many of the factors and parameters developed in the BEPP are still used for estimating biomass fuels consumption in Bangladesh.
Census of Agriculture 2008 Bangladesh Bureau of Statistics (BBS) GOB, 2010	Agriculture censuses are carried out under legal mandates of the Agriculture Census ACT NO. XL1 of 1958 (as amended in 1983). The Act also makes binding on the part of the respondents to answer questions asked by authorized census enumerators or census officials.
Restoring Balance Bangladesh's Rural Energy Realities M. Asaduzzaman Douglas F. Barnes Shahidur R. Khandker ESMAP, World Bank, 2010	World Bank, through a consultative process, initiated two surveys—one focused on rural households and the other on village microenterprises and rural growth centers—to elicit information on energy-using behavior and characteristics. Subsequently, the Bank commissioned studies on the market structure for energy and the macro-level dimensions of biomass fuels supply and demand. Much of this study's analytical underpinning was based on several background studies including these two studies
Preparatory Survey on Renewable Energy Development Project JICA and Mitsubishi Research Institute, Inc. Final Report, November 2012	Report is principally based on unpublished data from Dr. Md Golam Rabbani of Bangladesh Agricultural University. The report concludes – "Rabbani's data show that 70 percent of the total energy consumption comes from biomass fuels. This comes with the fact that around 65 percent of the country's economic activities are based on agriculture. It is estimated that about 40 million tons of biomass fuels (timber, crop residues, cow dung) are used per year for cooking only"
Fuel Wood Consumption in Four Districts of Bangladesh Kazi Ali Toufique Debi Narayan Rudra Paul Tahreen Tahrima Chowdhury Sami Farook Draft Report, BIDS, 2018	The main objectives of the study are to quantify the consumption of fuel wood by households in the rural and urban areas of four districts of Bangladesh (Barisal, Barguna, Satkhira and Bagerhat) in a statistically representative manner. Fuel wood consumption in the dry season was found to be highest in Bagerhat amounting to 1.87 kg/day/AdEq and lowest in Satkhira amounting to 1.25 kg/day/AdEq. In the dry season fuel wood consumption in Barisal and Barguna was the same, 1.80 kg/day/AdEq. In the wet season, fuel wood consumption was also the highest in Bagerhat (2.50 kg/day/AdEq) and lowest in Satkhira (1.99 kg/day/AdEq). AdEq = Adult Equivalent

Compiled by: Ijaz Hossain

Critical Review of Some Studies on Biomass Fuels Consumption

Per capita consumption of biomass fuels is an important parameter for the present study. Per capita consumption of biomass fuels estimated by some studies in Bangladesh during last forty years have been tabulated in Table 1.16. Some of these were previously reviewed by Islam, Morse & Soesastro 1984) and (the BEPP study,GOB 1987).

Table 1.16: Estimated Biomass Fuel use for Cooking

Reference	Composition of Sources of Biomass Fuels (%)				Per Capita Fuel Consump-tion (GJ/Year)	Bangladesh	Division	Location in the Districts
	Tree	Agriculture Residues	Animal Residues	Total				
1	2	3	4	5	6	7	8	9
GOB 1976	12.5	62.5	25.0	100	2.8	Bangladesh		
Tyers 1978	7.0	66.0	27.0	100	5.0	Bangladesh		
Briscoe 1979	36.0	61.	3.0	100	6.8			Comilla
Hughart 1979	-	-	-	-	4.3-7.6	Bangladesh		
Islam 1980	71.0	24.0	5.0	100	4.9			Jhalkathi
Douglas 1981	63.0	37.0	-	100	4.44	Bangladesh		
Rahman 1982	57.0	38.0	5.0	100	1.6	Bangladesh		
Quader, Omar 1982	59.0	38.0	3.0	100	8.1			Rangpur
GOB 1987	10.28	66.66	23.06	100	4.44	Bangladesh		
Asaduzzaman, Barnes and Khandker 2010	80.99	12.74	6.27	100	9.9		Chitta-gong	
	62.31	21.77	15.91	100	7.9		Dhaka	
	56.85	25.68	17.46	100	10.18		Khulna	
	38.03	34.08	27.88	100	6.9		Rajshahi	
	58.94	21.94	19.10	100	9.06	Bangladesh		

Notes: (1) Tree: firewood, branches, twigs and leaves; (2) Agri Residue: straw, rice hulls, jute stick, bagasse and other crop residues; (3) Animal Residue: dry cow dung

Source: de Lucia et. al. 1982, Islam, Morse & Soesastro 1984; GOB 1987; Asaduzzaman and Latif 2005; Asaduzzaman, Barnes and Khandker 2010

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An up to date review of different biomass fuels consumption studies are presented below –

- Assessment of supply of traditional fuels for the entire country was made by Bangladesh Energy Study with the support of aerial photographs. Per capita supply of biomass fuels was estimated as 2.8 GJ per person per year (GOB 1976, de Lucia et al. 1982);
- On the basis of secondary data per capita consumption of biomass fuel was estimated as 5 GJ per person per year (Tyers 1978);
- A study was carried out in 48 households of a village in Cumilla district and per capita consumption of biomass fuels was estimated as 6.8 GJ per person per year (Briscoe 1979);
- In order to assess village energy balance, a study was carried out in 77 households of a village (location & the name of the village not known) in Bangladesh. Estimated consumption of biomass fuels varied between 4.3-7.6 GJ per person per year (Hughart 1979);
- A census of 2,820 households in 23 villages of Nabagram Union of Jhalokhati District was carried out in 1980 in order to assess rural energy need and potential for

introducing new energy technologies. Consumption of biomass fuels was estimated as 4.9 GJ per person per year (Islam 1980);

- A field survey was carried out in 6,000 households from 430 villages of 18 Districts. In order to assess supply and demand of forest products per capita biomass fuels consumption was estimated as 4.44 GJ per person per year (Douglas 1981);
- In order to assess rural energy need, a survey was carried out in 760 households from 23 villages of 9 districts and consumption of biomass fuels was estimated as 1.6 GJ per person per year (Rahman 1982),
- In order to assess rural energy need and potential for new energy technology census was carried out in 954 households of 4 villages of Kulaghat Union of Rangpur District. Consumption of biomass fuels was estimated as 8.1 GJ per person per year (Quader, Omar 1982);
- BEPP Study estimated consumption of biomass fuels as 4.44 GJ per person per year and used the data for estimation of total biomass fuels consumptions of the country for National Energy Planning (GOB 1987).

Researchers of BIDS carried out a rural energy survey in 2005 (Asaduzzaman and Latif 2005). The findings of the study were subsequently published in a World Bank Report (Asaduzzaman, Barnes and Khandker 2010). The survey gathered data and information of 2,391 households of 119 villages located in 40 Upazilas of 4 Divisions (Chittagong, Khulna, Dhaka and Rajshahi) and presented the results in terms of weight of biomass fuels (kg per household per year).

For the purposes of comparison of BIDS results with the findings of previous studies the present study has analysed the BIDS study as follows: Per capita biomass fuels consumption estimated by BIDS in weight basis (kg/household/year), have been converted to per capita heat energy consumption (GJ per person per year) and the data presented in the Table 1.16 according to Divisions and Bangladesh: Per capita biomass fuels consumption as below. Chittagong-9.9 GJ per person per year, Dhaka-7.9 GJ per person per year, Khulna-10.18 GJ per person per year, Rajshahi-6.9 GJ per person per year and Bangladesh as 9.06 GJ per person per year.

It may be observed from Table 1.16 that per capita biomass fuels consumption estimated by BIDS study is much higher (6.9 GJ per person per year to 10.1 GJ per person per year) than previous studies carried out in Bangladesh (1.6 GJ per person per year to 7.6 GJ per person per year). Various factors contributing to variations of per capita biomass fuels consumption have been discussed in previous two publications (Islam, Morse & Soesastro 1984 and GOB 1987); it is beyond the scope of the present study to discuss those factors.

World Bank Report (Asaduzzaman, Barnes and Khandker 2010) has made the following observations on higher per capita consumption of biomass fuels.

> "Estimated annual energy consumption by rural households is 1,049 kgoe or 8.9 gigajoules (GJ) per persons – a vast increase from the 5 GJ per persons consumed 25 years ago. Over the same period, the annual growth rate was more than 2.6 percent, higher than the average growth rate in per capita income. Indeed, when only biofuels are considered, growth appears even more remarkable. Leach (1987), using figures based on Islam (1980, 1986), reported that rural households used an estimated 4.2 GJ of biofuels. The corresponding figure for biomass in the current study's household survey is 8.6 GJ per person; this figure translates into an average growth rate of 3.2 percent, outstripping even population growth rate. These findings

highlighted the critical role that biomass continues to play in the rural energy balance; today it is just as important, if not more so, than 25 years ago".

From biomass fuels survey methodology point of view, the above explanations may be acceptable when the same survey is repeated after an interval of 25 years under the same sample framework and by involving same group of researchers. Probable reasons for such wide variations may be found by studying the previous two reviews (Islam, Morse & Soesastro 1984 and GOB 1987). Moreover, World Bank Report mentioned 'per capita consumption of biomass fuels as 1,049 kgoe or 8.9 gigajoule per person', actually it should be 1,049 kg biomass fuels or 8.9 gigajoule per person.

Data presented in the Table 1.16 have been disaggregated for Bangladesh, Divisions and Villages in Districts. It was decided to consider country specific data of per capita biomass fuels consumption. For the first time in Bangladesh, BEPP made biomass fuels development program on the basis of their estimated data on per capita consumption of biomass fuels. This is why per capita consumption of biomass fuels estimated by BEPP (4.44 GJ/person/year) has been used in the present study in Component 7.

Studies on the Potential of Biomass Fuels in Bangladesh have been shown in Table 1.17.

Table 1.17: Studies on the Potential of Biomass Fuels in Bangladesh

Authors/ Year	Source	Title	Brief Description
1	2	3	4
Islam, M.N. 2001	Renewable Energy Application for Rural Areas of Bangladesh, IAT, BUET	Energy context in Bangladesh	An assessment of the biomass fuels-based energy applications in rural Bangladesh including sustainability analysis of biomass fuels use
Asaduzzaman M. and Latif A. 2005	Bangladesh Institute of Development Studies, Dhaka	Energy for Rural Households: Towards rural energy strategies in Bangladesh	Discussed in detail in main text
Mamun, Md. R.A. 2007	M.Sc. Thesis, Dept. of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh	Utilization Pattern of Biomass for Rural Energy Supply in Bangladesh	Through a survey of 100 farmers in 8 villages assessed the availability and utilization pattern of crop biomass fuels in rural Bangladesh. The potential biomass availability in the study areas was about 291.47 GJ/yr-household of which the share of field crop biomass is about 229.61 GJ/yr-household
Wazed, M.A. and Islam, M.A. 2010	Engineering e-Transaction	Prospect and future of biomass fuel: a review in Bangladesh	The study estimates the energy supply from different types of biomass fuels. According to this study "At present Bangladesh meet 46.15 percent of its energy need by agricultural residue, 10.5 percent by fuel wood and 33 percent by tree residue"
Miah, M.D., Kabir, R.R.M.S., Koike, M., Akther, S. and Shin, M.Y. 2010	Energy Policy	Rural household energy consumption pattern in the disregarded villages of Bangladesh	An extensive survey on household energy consumption pattern using stratified random sampling technique of 120 households. The study shows that 92% households use biomass, 28% LPG, 89% kerosene, 78% electricity and 27% candle as fuel types. It was found that 56%

Authors/ Year	Source	Title	Brief Description
1	2	3	4
			households collected biomass from their own homesteads and/or agricultural lands.
Huda, A.S.N, Mekhilef, S. and Ahsan, A. 2014	Renewable and Sustainable Energy Reviews. 30. 504–517	Biomass energy in Bangladesh: Current status and prospects	Limited scale research work based on secondary and proxy data and indirect calculations, and presents the scope, potential and technologies related to the use of biomass fuels resources. The study also discusses strategies to promote biomass fuels technologies in Bangladesh.
Hassan, M.K. 2015	DissertationesForestales210.62p Available at: http://dx.doi.org/10.14214	Supply and demand of biomass based energy: rural people's perspectives in Bangladesh	Study examines: bioenergy potential, energy consumption patterns of rural households, preferences and attitudes of rural households towards biomass fuels, and their knowledge and perceptions of sustainable energy development
Hossen, M.M., Rahman, A.H.M.S., Kabir, A., Hasan, F., and Ahmed, S. 2017	Renewable and Sustainable Energy Reviews, 67:94-105	Systematic Assessment of the Availability and Utilization Potential of Biomass in Bangladesh	Based on calculation from biomass fuels-based renewable sources, such as wood, agricultural residues, municipal solid wastes. Presents a realistic assessment of available biomass fuels as a prominent source of useful energy and chemicals

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In the third group, listed in Table 1.18, several studies can be found that have dealt with only one sub-sector. For example, in the UNDP and World Bank brick CDM projects, the consumption of wood for brick making has been assessed (J P Morgan Climate Care 2015). In a GIZ study (GIZ 2017) the availability and consumption of rice husk has been assessed for designing a CDM project for the efficiency improvement of rice husk fired parboilers. In another study (UNFCCC 2019) the consumption of biomass fuels for cooking was assessed to develop the Project Design Document (PDD) of a CDM project dealing with the improved cookstove called "Bondhu Chula".

Table 1.18: Miscellaneous Studies on Biomass Fuels in Bangladesh

Study/Report	Salient Features
1	2
Forest resources of Bangladesh, Country report Food and Agriculture Organization (FAO) Forest resources assessment programme, Working Paper No. 15. FAO, Rome (2000)	FAO regularly provides information on forest resources in different countries and at the global level. The FAO project "Strengthening Country Capacity in Forest Resource Assessment for Sustainable Forest Planning in the Asia Pacific Region (GCP/RAS/162/JPN) attempts to supplement these efforts by working at regional and country levels to develop information on status, planning and management of forest resources in South Asian countries
Rice Husk Energy Technologies in Bangladesh Ahiduzzaman, M. Agricultural Engineering International: the CIGRE journal, No. 1. Vol. IX, 2007	Presents data on agricultural residue particularly on rice husk. This data is quoted by many authors as a good set of authentic data. A good compilation of data from all over Bangladesh. The paper focuses on the improvement of rice husk energy and constraints for technologies dissemination in Bangladesh
Non-renewable Biomass Study HED NRB Study 2008 J P Morgan Climate Care	In mid-2008 J P Morgan Climate Care commissioned from a 3rd party consulting firm (HED) a thorough survey of wooded land in Bangladesh. The study compared sustainably managed woody biomass fuels with areas showing indicators of deforestation. No sustainably managed land was found. Further, fuel wood sourcing areas showed more than two of the prescribed indicators of deforestation and non-renewability
Bangladesh Forest Sector Outlook Study Food and Agriculture Organization (FAO) No. APFSOS II/WP/2011/33., Regional Office for Asia & the Pacific FAO, Bangkok, (2011)	The major objective of these outlook studies has been to provide decision makers; especially those dealing with forest and forestry; the required information, data and analyses about the prevailing trends in forestry sectors and present the best possible future projections to appraise the possible future of forestry sectors
Bangladesh National Conservation Strategy Forest Resources Laskar Muqsudur Rahman IUCN and Forest Department, MoEF (2016)	The report highlights forestry issues that needs special attention for conservation related to natural and human induced changes, particularly related to resource depletion and/or degradation or enhancement. In the light of sustainable development goals (SDGs) and criteria and indicators (C&I) for sustainable forest management (SFM) the report identifies challenges for sustainable management of forests. It proposes - "Enact a new Forest Conservation Act to restrict non-forestry use of forest land and protection of trees outside forests, amend the Forest Act"

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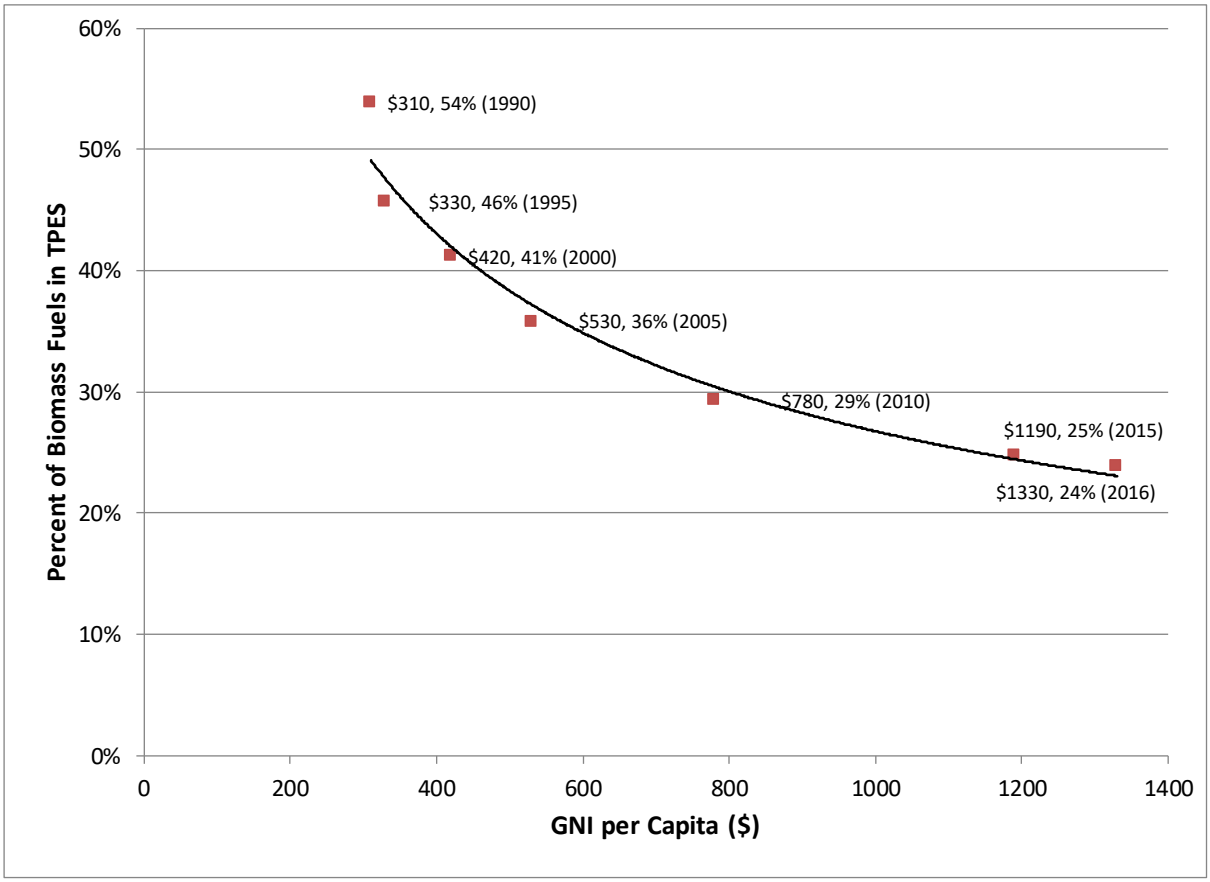
Historical relationship between biomass fuels consumption and GNI per capita

In addition to different studies discussed above energy data and indicators for countries are tabulated by the UN, World Bank, IEA and other international databases. The share of Biomass Fuels in TPES is given by IEA in their online database. An interesting representation of the biomass fuels consumption data can be obtained by plotting these data against GNI per capita. The GNI per capita for most countries are tabulated and reported by the World Bank (World Bank 2019). The percent of biomass fuels in TPES from 1990 to 2015 are plotted against the GNI per capita for the respective year as shown in Figure 1.7. It may be seen that the share of biomass fuels in TPES is steadily decreasing with increasing GNI per capita. Thus, in 1990 the share of biomass fuels was more than 54 percent

corresponding to GNI per capita of $310. In twenty-six years, the GNI per capita had increased to $1,330, while the share of biomass fuels has come down to 24 percent.



Energy Data Source: IEA (2019); GNI Data Source: World Bank (2019)
Compiled by: Ijaz Hossain

Figure 1.7: The Percent of Biomass Fuels in TPES versus GNI Per Capita in US $, Based on IEA Data

Plots like Figure 1.7 can also be made using data of Traditional Fuels Supply published by BBS (Tables 1.12 and 1.13). The data published by BBS as shown in Table 1.12 has been plotted in Figure 1.6. As can be seen there is a large anomaly in the data for Rice Straw for the year 1992. Probably due to a change in methodology or a change in the definition of this biomass fuel, the supply of traditional fuels has nearly doubled in 1992. As a result, it is not possible to consider the full range of data from 1974 to 2005 for the type of analysis displayed in Figure 1.7. Therefore, only the data from 1992 to 2005 have been used to construct a plot like Figure 1.7; the data for the plot is shown in Table 1.19. The new plot is shown in Figure 1.8. The downward trend can be clearly observed; from 48% of TPES in 1992, Traditional Fuels Supply has declined to 40% of TPES in 2005. It is instructive to compare the 2005 value with that given by Figure 1.8, which uses IEA data for percent of biomass fuels in TPES. According to IEA data, the percent of biomass fuels in TPES in 2005 is 36%. Considering the long time interval involved and the other uncertainties inherent in biomass fuels data, this is indeed a good agreement.

Table 1.19: Share of Biomass Fuels in TPES from 1993 to 2005

Year	GNI per Capita (US $)	MTOE			Share of Biomass Fuels in TPES
		Commercial Energy	Traditional Fuels Energy	Total	
1	2	3	4	5 = (3+4)	6 = (4/5) × 100
1992-93	320	13.82	12.99	26.81	48.5%
1993-94	320	14.62	12.86	27.48	46.8%
1994-95	330	15.79	12.94	28.73	45.0%
1995-96	360	15.92	13.28	29.2	45.5%
1996-97	380	16.62	13.69	30.31	45.2%
1997-98	400	17.13	13.00	30.13	43.1%
1998-99	410	17.8	13.43	31.23	43.0%
1999-2000	420	18.52	14.35	32.87	43.7%
2000-01	430	20.31	14.78	35.09	42.1%
2001-02	420	20.81	14.89	35.7	41.7%
2002-03	450	21.59	15.05	36.64	41.1%
2003-04	490	22.26	15.33	37.59	40.8%
2004-05	530	23.25	15.54	38.79	40.1%

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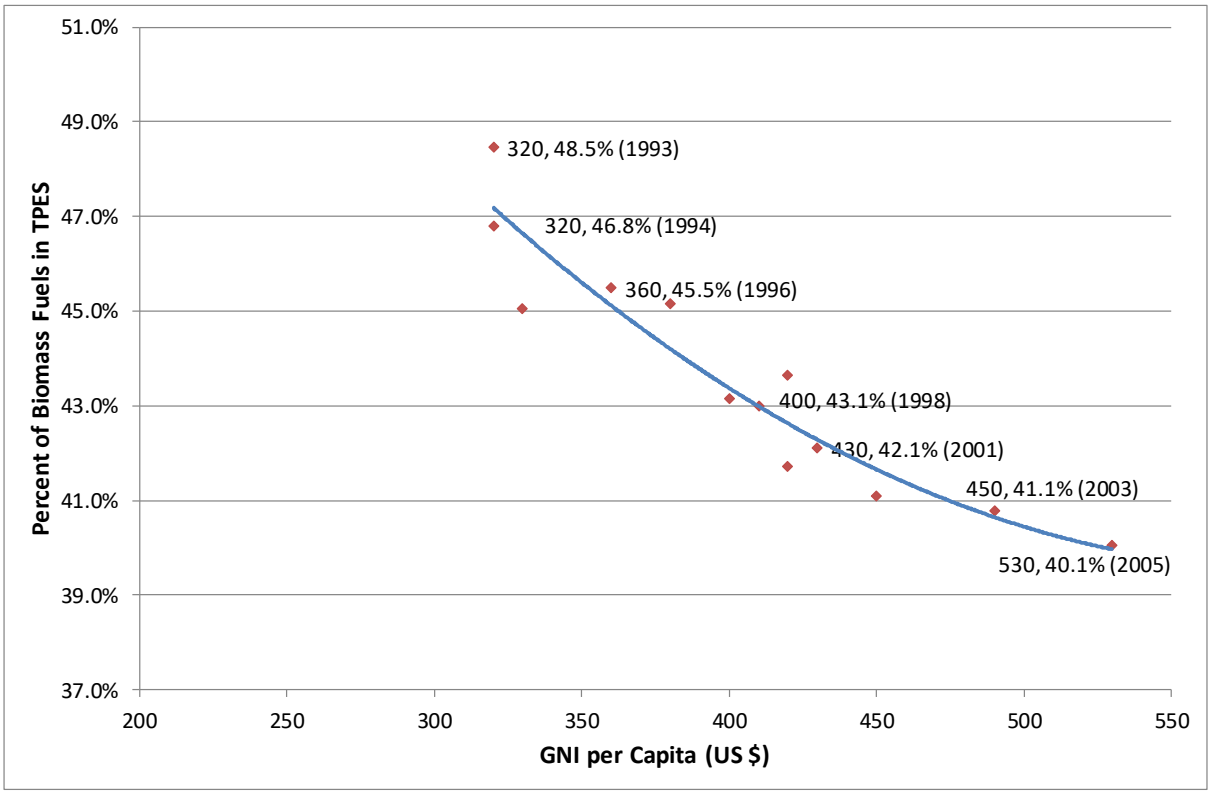

Compiled by Ijaz Hossain (2019)

Figure 1.8: Percent of Biomass Fuels in TPES Versus GNI Per Capita (US $) Using BBS Data of Traditional Fuels Supply

Another interesting comparison can be performed with the assumption of renewable energy made in the Renewable Energy Policy, 2008. The comparison for the year 2008 is shown in Table 1.20. Due to the lack of good data and/or authoritative study, the policymakers had to

assume a very large range for the share of biomass fuels in TPES. This also reflects the confusion that exists surrounding the share of biomass fuels in Bangladesh. However, the lower value assumed in REP, 2008 is in good agreement with data available in literature (IEA and BBS). The valuable revelation is that in Bangladesh the share of biomass fuels in the primary energy supply has decreased indicating a transition to commercial fuels.

Table 1.20: Share of Renewable Energy in TPES in REP 2008 Compared to IEA Data and BBS (extrapolated) Prediction

Source	Share of Renewables/ Biomass Fuels in TPES in 2008	Remarks
1	2	3
REP 2008 (GOB 2008)	35% - 60%	A wide range was assumed in the REP 2008
IEA	32%	Estimated by interpolation between 2005 and 2010 values in Figure 1.7
BBS	36%	Estimated by extrapolation beyond 2005 in Figure 1.8

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1.4.5 Review of Biomass Fuels Conversion Technologies in Bangladesh

In developed countries, the main motivation nowadays for converting biomass is to produce liquid biofuels (e.g. transport fuel). However, the biomass required for this process are high value products such as corn and beet. The incentive for liquid biofuel production is highly dependent on the technology (how advanced it is) and fossil fuel price. In developing countries, the heavy requirement for food crops to feed its often-large population prevents this route of biomass fuels utilization. Therefore, the biomass fuels in developing countries available for fuel use are residues – mainly agricultural residues and animal residues. Also, scarcity of land means that wood cannot be sustainably harvested in these countries for biomass fuels-based power plants. Apart from use of bagasse combustion to produce electricity in sugar mills, all current practices for biomass fuels conversion for electricity production in Bangladesh are through Anaerobic Digestion, that too only in small scale. There is however extensive use of biomass fuels to produce heat (cooking, rice parboiling, brick making, etc.). As the biomass fuels characteristics can dictate the choice of technology, the technologies that may be used in Bangladesh are listed in Table 1.21 outlining their applicability, strengths and limitations.

Table 1.21: Comparison of Commercially Matured Technologies for Power Generation Using Biomass Fuels

Criteria	Anaerobic Digestion	Gasification	Combustion
1	2	3	4
Feedstock	Suitable for wet feedstock	Suitable for dry to semi-dry feed, both solid and slurry can be fed	Suitable for dry feedstock
Inorganic content	Feed with Low to high inorganic content can be fed	Feed with low to high inorganic content can be fed	Feed with low to high inorganic content can be fed
Temperature and pressure	Requires low temperature and pressure	Requires medium to high temperature for processing (>700^{o}C, up to 1500^{o}C)	Requires medium-high temperature (800-900^{o}C)
Reaction atmosphere	Reaction takes place in absence of Oxygen	Oxygen/air is supplied. Steam and CO_2 is supplied or produced in situ	Oxygen/Air is supplied for combustion
Product	Product is mainly Methane and Carbon Dioxide	Product is syngas, can be combusted to produce energy or, synthesize methane or, transport fuel	Product is energy for burning the feedstock, can be used as heat or to produce electricity
Possible processing step	First step of biomass fuels processing	Can be first, second or the last step of processing	Most likely, the last step in biomass fuels conversion
Limiting factors	Land and (residence) time requirements are high for this process	Might need high temperature to reach desired conversion. Solid feeding could be problematic	Final product can be used only as energy/heat. Corrosion might take place for inorganics

Source: Kirtania (2018)

The major contribution to biomass fuels-based power generation in Bangladesh is using bagasse in the sugar mills for cogeneration. While there is potential to use biomass fuels in Bangladesh for co-firing (burning with other solid fuels) in coal-based power plants, this has not been practiced.

Being an agricultural country, significant amount of agro-based waste is generated in Bangladesh. There exist possibilities to utilize those biomass fuels for power generation through both combustion and gasification (see Table 1.21). In recent years, there have been some initiatives with rice husk gasifiers (between 100-400 kW) (Huda et al. 2014). With financial support from IDCOL (Infrastructure Development Company Limited), two rice husk-based gasifiers for power generation have been set up at Kapasia (250 kW) and Thakurgaon (400 kW) (IDCOL 2016). However, considering the high silica and alkali content in the agro-based residues, gasification is not recommended because of slag formation and corrosion. For biomass fuels conversion using thermochemical pathways, direct firing remains the most viable option for Bangladesh. If heat can be utilized, to improve the economics, combined heat and power (CHP) or cogeneration is the preferred mode of operation. Where the supply of biomass fuels is an issue, co-firing with coal can be considered.

In Bangladesh, bagasse-based power generation are in operation in government owned sugar industries. Bagasse, a by-product of sugar refining, is combusted in a biomass fuels boiler to raise high pressure steam. The high-pressure steam is used for power generation in an extraction turbine, which allows low pressure steam to be used for process heat. Cogeneration in sugar industries is an old and mature technology. There is plenty of capacity in the country to operate, maintain and troubleshoot this technology. Table 1.22 shows the current capacities of the sugar mills for power generation. The major limitation of bagasse based power generation is seasonal availability of bagasse for 120 to 180 days per year; rest of the period the system remain in operation. A feasibility study may be undertaken to study the prospect of running the system throughout a year by using some alternative fuels.

Table 1.22: Sugar Mills Capacities for Power Generation in Bangladesh
(Number of day's operation in a year: 90-120)

Name of Sugar Mills	Installed Capacity (t/day crushed)	Electricity Generation Capacity (MW)
1	2	3
Panchagor	1016	2.0
Thakurgaon	1524	3.0
Setabganj	1250	4.0
Shyampur	1016	2.0
Rangpur	1321	2.6
Jaypurhat	2032	2.5
Rajshahi	2000	3.5
Natore	1500	4.0
North Bengal	1500	2.0
Kushtia	1524	3.0
Carew	1150	3.0
Mobarakganj	1500	2.0
Faridpur	1016	2.0
Zeal Bangla	1016	2.0
Total		**37.6**

Source: BSFIC (2016)

Other than direct combustion and gasification, animal and poultry wastes are being processed using anaerobic digestion for biogas production. More than 100,000 small biogas plants have been set up in different parts of Bangladesh. Some of these biogas plants, especially the large ones, are for electricity production. IDCOL has financed some poultry litter-based biogas power plants with capacities ranging between 5 kW and 400 kW (IDCOL 2016). Three biogas-based electricity plants have been set up (100 kW each) in Mymensingh and Gazipur, for which the poultry litter is supplied by Paragon Poultry Limited (Huda et al. 2014). These initiatives are enabling the poultry farms to generate a portion of their electricity demand and be less dependent on the national grid especially in rural areas. In addition to providing electricity to poultry industries, the major benefit of biogas plant are hygienic disposal of poultry litters to control environmental pollution. Apart from animal and poultry wastes, , municipal solid wastes are also processed through anaerobic digestion. Practical Action Bangladesh has established some pilot biogas plant based on MSW; however, no commercial venture is reported yet.

Waste to energy potential of six municipalities has been studied by SREDA. The report titled Draft Biogas Guidelines for Energy (SREDA 2019) estimates that there is good potential of generating power in several municipalities. Waste to energy projects are also being pursued by LGED, MoEFCC and MoPEMR. The summary of all the technologies being used in Bangladesh is provided in Table 1.23.

Table 1.23: Summary of Biomass Fuels Technology Application in Bangladesh

Technology	Raw Material	Remarks
1	2	3
Combustion – Steam Turbine	Bagasse	Approximately 40 MW during sugar crushing season (90 – 120 days annually) in different sugar mills of Bangladesh.
Combustion (Fluidized bed Technology) – Steam Turbine	Rice Husk	1.5 MW Rice Husk fired Power Plant at Rashid Rice Mills Ltd at Rajshahi
Combustion – Steam Turbine	Press mud	Collected from sugar mills of Bangladesh (under implementation)
Anaerobic Digestion – Gas Engine	Poultry Waste	700 – 800 kW total; small (5 kW) to medium (400 kW) sized units
Gasification – Gas Engine	Rice Husk	650 kW total; 2 units, one at Kapasia, Gazipur, other at Panchagarh; both not operational presently

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1.4.6 Institutions

Institutions involved with biomass fuels in different capacities can conveniently be put into four categories, namely –

- Government and Semi-government institutions
- Autonomous institutions
- NGOs and Developmental institutions
- Development Partners

The functions and activities of organisations under these four categories are described below.

Government and Semi-government Institutions

- Ministry of Power, Energy and Mineral Resources (MoPEMR) oversees all energy and power related matters including renewable energy. Power Division of the MoPEMR is entrusted with the role of promoting renewable energy in Bangladesh. Even though its roles in biomass fuels energy utilisation are small, it nevertheless has the legal authority over biomass fuels-based power generation especially if electricity is supplied to grid. As a result of the authority vested in this ministry, the Power Division is coordinating several activities of biomass fuels supply and consumption.

- Ministry of Environment, Forests and Climate Change (MoEFCC) is involved along with MoPEMR in promoting sustainable energy. In its role in promoting sustainable development and greenhouse gas emission reduction, MoEFCC is actively engaged in promoting Municipal Solid Waste (MSW) to energy and clean brick production programs.

- Sustainable and Renewable Energy Development Authority (SREDA) under Power Division is the principal organisation in the country entrusted with the responsibility for research, survey, demonstration and diffusion of different biomass fuels technologies and finance. Along with energy efficiency, SREDA is promoting all forms of renewable energy technologies. SREDA is responsible for the Country Action Plan for Clean Cookstoves (CAP). This report is part of the efforts of SREDA

to promote the sustainable use of biomass fuels in the country through the development of a database of supply and demand of biomass fuels.

- Bangladesh Council of Scientific and Industrial Research (BCSIR) is a government owned research and development organization under the Ministry of Science and Technology that is engaged in developing various biomass fuels-based technologies. BCSIR is best known for its research on biogas and clean cookstoves technologies. The original design of the Bondhu Chula "improved cookstove" that is now being promoted by GIZ and MoEFCC is due to BCSIR. The pioneering work on biogas digesters is due to the BCSIR scientists.

- Bangladesh Standards and Testing Institute (BSTI) is responsible for setting standards and testing procedures for different biomass fuels technologies including those for clean cookstoves.

- Local Government Engineering Department (LGED) has been created mainly to provide technical support to the local government institutions. The first biogas plant based on night soil was constructed by LGED in Faridpur Muslim Mission. Small bore sewerage system, in conjunction with biogas plant installed by LGED in Bauniabad slum in Dhaka proved to be a cheaper and better solution for sewage disposal. LGED has trained a lot of professional engineers on biogas technology; some of them received higher training in China.

- Palli Karma Sahayak Foundation (PKSF) has been established by the Government of Bangladesh and is undertaking nationwide programs for poverty alleviation through employment generation. The principal objective of PKSF is to provide funds to various organizations for their microcredit programme with a view to help the poor who have no land or any credible material possession.

Autonomous Institutions

Infrastructure Development Company Limited (IDCOL) is a non-banking financing autonomous government-owned company. It was set up to finance all types of infrastructure projects in Bangladesh including renewable energy projects. IDCOL has shown remarkable success in Solar PV dissemination. With biomass fuels projects it has had limited success having first promoted two biomass fuels gasification power projects, both of which failed, and later several biogas projects, some of which are facing various operational and logistical difficulties. The biogas projects were supported by KfW and SNV. IDCOL has recently taken steps to establish a testing and certification laboratory for stoves

In this group are also the various government universities and institutes. Many of these organizations are involved in research and survey of biomass fuels. The most active in biomass fuels research is the Bangladesh Agricultural University (BAU). On a regular basis Master's and PhD degrees on various aspects of biomass fuels are being awarded from BAU. Other universities and institutes engaged in biomass fuels research are:

- Bangladesh Agriculture Research Institute (BARI)
- Bangladesh Jute Research Institute (BJRI)
- Chemical Engineering Department, Bangladesh University of Engineering and Technology (BUET)

- Institute of Energy, Dhaka University
- Islamic University of Technology (IUT)
- Khulna University of Engineering and Technology (KUET)
- Rajshahi University
- Shahjalal University of Science and Technology (SUST)

Among the above-mentioned research organizations, the Chemical Engineering Department, BUET has a long record on research related to biomass fuels. Pioneering role in this regard was played by Prof. M. Nurul Islam in the late nineteen seventies. Prof. Islam was also involved with the well-known BEPP study conducted in the early nineteen eighties. Several important publications on biomass fuels have emerged from the Chemical Engineering Department, BUET. Starting from estimating potential of biomass fuels, the Department has worked in most aspects of biomass fuels which include surveys, assessment and development of technologies. The following experts of the Chemical Engineering Department, BUET are involved with the current project – (1) Prof M. Nurul Islam, Individual Consultant of UNDP/SREDA; (2) Prof Ijaz Hossain, Team Leader, Prof M.A.A. Shoukat Choudhury, Biomass Fuels Expert, Dr. Shoeb Ahmed, Associate Biomass Fuels Expert.

The Chemical Engineering Department has maintained the tradition of biomass fuels study. A new group of researchers have successfully carried forward the good work started by Prof. M. Nurul Islam and his team. Young researchers of the Department are now working in new research areas of upgrading biomass fuels (torrefaction and pyrolysis) and energy production from MSW using innovative techniques. The biochemical engineering researchers are looking into energy from microalgae and microbial fuel cells. The Chemical Engineering Department, BUET has the full capability of maintaining a database of supply and demand of biomass fuels and to provide guidance in technology selection for different types of biomass fuels. The highly trained researchers at the Department are working to continue the legacy of studies on biomass fuels. List of Biomass Fuels Related Publications of Chemical Engineering Faculties are shown in Box 1.

Box 1: List of Some Publications by Chemical Engineering Faculties Related to Biomass Fuels

1. Study of the Problems and Prospects of Biogas Technology as a Mechanism for Rural Development – Study in a Pilot Area of Bangladesh (Village Resources Survey for the Assessment of Alternative Energy Technology), Report prepared by M. Nurul Islam, Department of Chemical Engineering, BUET, Bangladesh for International Development Centre (IDRC), Ottawa, Canada, September, 1980.

2. Resources and Energy Potentials in Rural Bangladesh- A Case Study of Four Villages, Report prepared by A.K.M. Abdul Quader and K. Ikhtyar Omar, Chemical Engineering Department, BUET, Bangladesh for Commonwealth Science Council. London, UK, June, 1982.

3. Rural Energy to Meet Development Needs: Asian Village Approaches, Book Edited by M. Nurul Islam, Richard Morse and Hadi Soesastro, Westview Special Studies in Social, Political and Economic Development, East-West Centre, Hawaii & Westview Press, USA, 1984 [scanned copy of the Book is available at PN-AAT-08740627]

4. Energy and Rural Development: Critical Assessment of the Bangladesh Situation by M. Nurul Islam, Chapter 2 of the Book Rural Energy to Meet Development Needs: Asian Village Approaches, Book Edited by M. Nurul Islam, Richard Morse and Hadi Soesastro, East-West Centre, Hawaii & Westview Press, USA,1984.

5. Field-Based Assessment and Development of Improved Stoves by M. Nurul Islam, Chapter 8 of the Book Rural Energy to Meet Development Needs: Asian Village Approaches, Book Edited by M. Nurul Islam, Richard Morse and Hadi Soesastro, East-West Centre, Hawaii & Westview press, USA, 1984.

6. Rural Energy and Biomass Supply, Volume IV Report of Bangladesh Energy Planning Project (BEPP), Prepared by Sir Halcrow and Partners, Motor Columbus Consulting Engineering, Inc., Petronous Consultants in Association with TSL and PSL, Government of the Peoples' Republic of Bangladesh.1987. Volume IV was prepared by M. Nurul Islam, Draft Final Report submitted in 1985.

7. Energy Planning for Rural Bangladesh: Comparative Assessment of Energy Situation in an Electrified and Non-Electrified Village of Mymensingh District, by Md. Azaharul Islam, MURP Thesis, Department of Urban & Regional Planning, BUET, Bangladesh, March. 1987. Thesis Supervisor M. Nurul Islam.

8. Rural Energy Systems in the Asia-Pacific: A Survey of their Status, Planning and Management, Book, Edited by K.V. Ramani; M.N. Islam and A. K. N. Reddy, Published by the Asian and Pacific Development Centre, Kuala Lumpur, Malaysia, 1993.

9. Country Status Report on Bangladesh, Chapter of the Book on Rural Energy Systems in the Asia-Pacific: A Survey of their Status, Planning and Management, Book, Edited by K.V. Ramani; M.N. Islam and A.K.N. Reddy, Published by the Asian and Pacific Development Centre, Kuala Lumpur, Malaysia, 1993.

10. Rural Energy Planning – A Government Enabled Market Based Approach, Book Edited by K.V. Ramani; A.K.N. Reddy and M.N. Islam, Published by the Asian and Pacific Development Centre, Kuala Lumpur, Malaysia, 1995.

11. Rural Development, Energy and Environment; Prevailing Paradigms for Rural Energy Planning; GEMBASED Approach to Rural Energy Planning; Rural Energy Projects Formulation; Co-Author of the Chapters of the Book Rural Energy Planning – A Government Enabled Market Based Approach, Book, Edited by K.V. Ramani; A.K. N. Reddy and M.N. Islam, Published by the Asian and Pacific Development Centre, Kuala Lumpur, Malaysia, 1995.

12. Review of Rural Energy Issues in Bangladesh, Prepared by M. Nurul Islam in 2000 for the World Bank Study on Restoring Balance – Bangladesh's Rural Energy Realities 2010.

13. Distributed Renewable Energy, Produced a study report for IISD, Canada in collaboration with five other developing countries on the prospects of Distributed Renewable Energy technologies for CDM. Report prepared by Ijaz Hossain, 2003.

Box 1: List of Some Publications by Chemical Engineering Faculties Related to Biomass Fuels (continued)

14. Country Study: Bangladesh, chapter in *SEEING THE LIGHT – Adapting to climate change with decentralized renewable energy in developing countries* – Ijaz Hossain, M. Tamim and Edmond Gomes, edited by Henry David Venema and Moussa Cisse, IISD, 2004.
15. Energy and Sustainable Development in Bangladesh, Ijaz Hossain and M. Tamim, HELIO International, 2005/2006.
16. Improving energy efficiency and emission characteristics of biomass cooking stoves by incorporating beneficial aspects of different kilns under institutional strengthening of climate change study cell at BUET for knowledge generation and human resource development project. Biomass Briquette Making Process Development for use in ICS and their Test Marketing under Rural Electrification and Renewable Energy Development II (RERED II) Project of IDCOL, Team Leader: Moninur Rahman, Funder: Bangladesh Climate Change Trust (BCCT), MoEF, GoB 2011-2013.
17. Categorical assessment and characterization of conventional and unconventional biomass resources in Bangladesh, MM Hossen, AHMS Rahman, Dr. Shoeb Ahmed, Chemical Engineering Research Bulletin; 17(1) 2015.
18. Erik Furusjö, Kawnish Kirtania, Yawer Jafri, Albert Bach Oller, Kentaro Umeki, Joakim Lundgren, Elisabeth Wetterlund, Ingvar Landläv, Rikard Gebart and Esbjörn Pettersson, "Co-gasification of pyrolysis oil and black liquor - a new track for production of chemicals and transportation fuels from biomass", International conference on thermochemical (TC) biomass conversion science, Chicago, Illinois, USA, November 2-5, 2015.
19. Improved Cookstoves (ICSs) Related Development and Characterization under Rural Electrification and Renewable Energy Development II (RERED II) Project of IDCOL. Team Leader: Mominur Rahman, Sponsored by World Bank July, 2014 – August, 2016.
20. Biomass Briquette Making Process Development for use in ICS and their Test Marketing under Rural Electrification and Renewable Energy Development II (RERED II) Project of IDCOL, Team Leader: Mominur Rahman, Sponsored by World Bank July, 2014 – August, 2016.
21. Characterization and Assessment of the Potential of Local Biomass as Feedstock of Synthetic Fuels and Chemicals'; M.Sc. Thesis of MG Rasul supervised by Dr. Shoeb Ahmed 2016.
22. Systematic Assessment and Characterization of Biomass Resources for Energy Applications in Bangladesh, Dr. Shoeb Ahmed, prepared for Committee for Advanced Studies and Research (CASR), BUET, December 2016.
23. Systematic Assessment of the Availability and Utilization Potential of Biomass in Bangladesh – Shoeb Ahmed and others, Renewable and Sustainable Energy Reviews, 2017.
24. Pre-study: Liquefaction and upgrading of industrial by-products, wastes and residues, submitted to Swedish Energy Agency (Energimyndigheten), Kawnish Kirtania, 2017.
25. Techno-economic Assessment of Catalytic Gasification of Biomass Powders for Methanol Production, Kawnish Kirtania and others, Bioresource Technology 237, 167-177, 2017.
26. Thermochemical Conversion Processes for Waste Biorefinery by Kawnish Kirtania chapter of a Book 'Waste Biorefinery*: Potential and Perspectives'* – Elsevier, 2018.
27. Resource Recovery and Reuse Potential of Pit Sludge for Sustainable Agriculture and Environment'; Ph.D. Thesis, Chemical Engineering, BUET of Mominur Rahman supervised by Dr. Shoeb Ahmed 2018.
28. Integrated Concept for Converting Solid Waste to Energy (InConSolE) – Waste to Biocoal for Power Generation, EPRC/58-2018-001-01, Team Leader: Dr. Mominur Rahman Sponsored by Ministry of Power, Energy and Mineral Resources, GOB 2018-2021.

Developmental Institutions and NGOs

- Bangladesh Biogas Development Foundation (BBDF) conducts research, training and awareness programs on the benefits of biogas especially in terms of public health. BBDF offers guidance to set up manufacturing plants of biogas to electricity. BBDF Research Cell, Design Cell and Monitoring Cell assists in the development of Biogas-based energy conversion in the country.
- Bangladesh Centre for Advanced Studies (BCAS): A Climate Change NGO that conducts research and field work on climate resilience and adaptation.
- Bangladesh Rural Advancement Committee (BRAC): One of the biggest NGOs in the world and internationally active. The focal areas are wide; in Bangladesh they comprise of poverty alleviation, micro-finance, health, environmental protection and social empowerment through provision of improved energy services with a focus on solar household systems.
- Bandhu Foundation: It is one of the NGOs working on dissemination of ICS in Bangladesh.
- Grameen Shakti (GS): The biggest NGO involved in the dissemination of renewable energy technologies in Bangladesh. GS has installed approximately 750,000 ICS (January 2014). GS is managing their activities through branch offices (sales point) and manufacturing centres.
- Rural Services Foundation (RSF) is one of the largest NGOs in the country and is involved in the dissemination of renewable energy technologies in general.
- Practical Action (PA): PA is active in infrastructure and livelihood improvement in poor urban areas. As part of their efforts to provide energy access to the poor, they are interested to cooperate with SED in the promotion of improved cookstove as well as related monitoring and evaluation activities.
- The Village Education Resource Center (VERC) is implementing improved stove projects.

Development Partners and Initiatives

- Asian Development Bank (ADB): All international donor activities in the energy sector are coordinated by the Local Consultative Group led by ADB. ADB is providing funds to the RERED program implemented by IDCOL.
- Climate and Clean Air Coalition (CCAC): CCAC is a new partnership represented by the USA, Canada, Sweden, Mexico, Ghana and Bangladesh. This group is focusing on the reduction of short-lived pollutants such as black carbon and methane by promoting new environmentally friendly technologies and processes like improved cookstoves, brick kilns and rice parboiling systems. Detailed discussions for cooperation have taken place in Toronto and Paris recently.
- GIZ: The German aid agency is very active in Bangladesh energy sector. It has extensive programs in energy efficiency and renewable energy. It is the principal actor in the introduction of the "Bondhu Chula" and improved rice parboilers. Both these programs are aimed at efficient use of biomass fuels.
- SNV Netherlands Development Organization: SNV has been active in the field of biogas technology dissemination and is showing interest in improved cookstoves
- UNDP: Along with other donor agencies, UNDP facilities the introduction of sustainable energy in Bangladesh.
- Urban Partnership for Poverty Reduction (UPPR): Under UNDP initiative, UPPR is collaborating with SED in the cookstove sector and is also open for cooperation in biogas plants in urban settings.
- U.S. Agency for International Development (USAID): Currently, USAID has approved a 50 million USD program for energy; 35 million are earmarked for energy efficiency measures and 15 million for improved cookstoves.
- Swedish International Development Agency (SIDA): SIDA is planning to start improved cookstove activities in Bangladesh. It has not yet been decided whether this will happen in cooperation with GIZ.
- UK Department for International Development (DFID): DFID has made funds available for improved cookstove activities.
- The World Bank (WB): The WB is a major player in the energy sector of Bangladesh. It has several programs dealing with renewable energy including biomass fuels.

1.4.7 Review of Laws, Rules and Policies

General

Bangladesh is a small landmass country with a high population density. Therefore, the per capita availability of forest resources is low. In addition, being a developing country, where the entire rural population depend on biomass fuels for cooking, the demand for biomass fuels is very high. Preserving the natural forests is a difficult task for the Government. In the last fifty years the proportion of land covered by forests has fallen. As a result, strict conservation laws are in place to protect forests. Afforestation and roadside tree-planting

have been given high priority. Social forestry is also vigorously promoted. City Corporation Laws, Pourashava Laws, Union Parishad Laws and the Laws on Hill Districts all have clauses that restrict cutting down trees and encourage planting new trees.

The issue of all tree resources depleting due to a variety of reasons is dealt with in the Bangladesh Poverty Reduction Strategy Paper (PRSP), 'Conservation of Nature': "Population pressure on land has been leading to conversion of forest land and land under tree cover into other uses. This at the same time further lowers the supply of biomass and fuel wood for cooking raising their market value including further deforestation and cutting down of trees. Smoke due to fuel wood burning also is a major cause of a significant rise in the level of indoor air pollution affecting adversely the health of women and children" (GOB 2005b). The Bangladesh PRSP document outlines a strategy to deal with conservation of biomass resources considering poverty reduction.

One of the most important laws towards conservation of woody biomass fuels enacted in 1989 is the prohibition on the use of firewood for brick burning (Bangladesh Gazette 1989). The brick industry used to consume large quantities of firewood, and this biomass fuel use was identified as one of the major causes of deforestation. Even after the ban brick kilns continue to illegally use firewood, but the use has declined significantly. The ban was strengthened through – The Brick Manufacturing and Brick Kilns Establishment (Control) Act, 2013 (Act no. 59 of 2013) Clause 6 – Using fuel wood is prohibited –"Notwithstanding anything contained in any other law for the time being in force, no person shall use fuel wood as fuel in brick kilns for burning brick." (Bangladesh Gazette 2013).

The protection of forests is high priority in Bangladesh. Table 1.24 gives a snapshot view of the laws that govern this protection. However, despite the strict laws, illegal felling of trees from protected forests continues.

Table 1.24: Policies and Laws Governing Conservation and Sustainable Development of Biomass Fuel Resources in Bangladesh

Legal Instruments	Salient Feature
1	2
1927 Forest Act	The first set of forestry laws to protect forests
Acquisition of Waste Land Act (1950)	Afforestation of waste land is advocated
National Forest Policy in 1979	First comprehensive policy document
Forest Policy (1994)	Updated forestry policy
Social Forestry Rules (2004)	To elaborate on the social forestry procedure under the Forest Act, 1927
Forestry Sector Master Plan, 1995-2015	Through social and participatory forestry, to raise the total forest cover to 20% by 2015
National REDD+ Readiness Roadmap	National REDD+ Readiness Roadmap was approved in 2012 by the MoEFCC
BCCSAP (MOEF 2009)	A plan to replant the mangrove and forest belt that once covered much of the coastline
Bangladesh Forestry Master Plan 2017-2036 (Draft Final) December 2016	Updating of the Forestry Master Plan for Bangladesh Incorporates Climate Resilient Participatory Afforestation and Reforestation Project
SREDA Act, 2012	Promote renewable energy technologies
Energy Efficiency and Conservation Rules, Draft 29 October 2012	Rules and regulations for promoting energy conservation and efficiency
Renewable Energy Policy, 2008	Set targets for renewable energy
Draft Biogas Guidelines (SREDA, 2019)	Discusses potential of biogas and sets out guidelines for biogas plant developers

Compiled by: Ijaz Hossain (2019)

Forestry Acts

The Department of Forests under the Ministry of Environment, Forests and Climate Change is responsible for the protection of forests including controlled extraction, afforestation and reforestation. The Department from time to time enacts laws and regulation to protect forests and other woodlands in Bangladesh. Some important laws and regulations relevant to this study are listed below –

- The Forest Act of 1927 (Act XVI of 1927) provide legal protection of forests. The Forest Act of 1927 was amended in 1989 to provide deterrent penalties for certain forest offences and further modified in 2000 to provide for social forestry.
- Forest Transit Rules were framed in 2011 under the provision of the Brick Burning (Control) Act, which came into force for the first time in July 1989 to ban firewood for brick burning.
- The above rules have been substituted by the Brick Manufacturing and Kiln Construction (Control) Act, 2013 (Act No. 59 of 2013) with effect from July 1, 2014 to meet the current context.
- Similarly, the earlier Sawmill (License) Rules, 1998 were substituted in 2012.

Renewable Energy Policy and Rural Energy

The National Energy Policy (NEP) of 1996 is the first document to address renewable energy, especially biomass fuels energy in rural areas, but the policy document dealing with renewable energy applications was formulated much later in 2008. The Renewable Energy Policy lays down some targets for renewable energy application for 2015 and 2020 mainly to promote wind and solar energy. It does not deal specifically with biomass fuels energy other than mentioning that it must be sustainable.

Since the Renewable Energy Policy is the principal legal document dealing with biomass fuels, relevant sections of that policy are reproduced below especially those dealing with promotion and conservation of biomass fuels.

- Renewable energy in the form of traditional biomass is the main source of primary energy in the country comprising some 35-60% percent of total primary energy use.
- Biomass: Bangladesh has strong potential for biomass gasification-based electricity. More common biomass resources available in the country are rice husk, crop residue, wood, jute stick, animal waste, municipal waste, sugarcane bagasse etc. This technology can be disseminated on a larger scale for electricity generation.
- Biogas: Biogas mainly from animal and municipal wastes may be one of the promising renewable energy resources for Bangladesh. Presently there are tens of thousands of households and village-level biogas plants in place throughout the country. It is a potential source to harness basic biogas technology for cooking, and rural and peri-urban electrification to provide electricity during periods of power shortfalls.
- Provide fund for the development of standardized renewable energy configurations to meet common energy and power applications, such as solar, biogas and biodiesel for mechanical irrigation and improved community practices for forest management and conversion and use of fuel wood by using grant, subsidy and/or carbon/CDM fund;
- Stimulate market development for sustainable energy technologies, such as improved cook stoves and household biogas digesters;
- For large biomass electricity project (i.e. greater than 1 MW) the project developer must demonstrate that the biomass is being sustainably harvested and that no adverse social impact will result from that development.
- Production and use of biofuels will be encouraged in limited scale without jeopardizing the existing crops.

1.4.8 Energy Balance Table of Bangladesh

As per TOR, an Energy Balance Table (EBT) for the year 2015 has been established by including both Commercial and Renewable energy sources. Energy data have been shown in Table 1.25 in physical units & Table 1.26 in energy units (PJ) and in Table I.II in MTOE. Biomass fuels consumption data estimated in Component 7 have been included in the above-mentioned tables. All other data have been collected from either the annual reports or the official websites of the relevant organisations (BPC 2019, BPDB 2015, Petrobangla 2015) except for the coal data, which has been taken from the World Bank database (World Bank 2019).

Supply of Total Primary Energy and Final Energy Consumption of Bangladesh in 2015 are shown in Figure 1.9 and Figure 1.10 respectively.

According to the findings of this study the share of biomass fuels in 2015 was 35.55 percent, while IEA data shown in Figure 1.7 puts this value at 25 percent. Multilateral organizations such as World Bank, UN and IEA generally collect their data from national organisations responsible for the data. Since the national organization (BBS) that used to disseminate biomass fuels data stopped doing that in 2005, it is unclear where IEA collected their biomass fuels data from. Therefore, short of a full detailed survey of biomass fuels consumption, it is not possible to resolve this difference. This study has followed a rigorous methodology to estimate the biomass fuels consumption.

The Energy Balance Table (EBT) for Bangladesh has recently been constructed by SREDA (2018) and presented in the Figure 1.11. It may be seen that EBT of SREDA does not include biomass fuels. In the future EBT will have to be prepared by including biomass fuels and renewable energy sources. SREDA should request BBS to publish EBT tables for every year on a continuing basis.

Table 1.25: Bangladesh Energy Balance for 2015 (in physical units)

		Natural Gas	NGL	Crude Oil	Petroleum Products + LPG	Coal	Electricity	Hydro-electricity	Renewables (solar, wind, etc.)	Biomass Supply
		Bcf	Bbl	Ton	Ton	Ton	GWH	GWh	GWh	Million Ton
I. SUPPLY										
Primary Production		892.17	3233863			675775		566	329	50.4
Imports				1092673	4111357	1624200	3380			
Exports			-1643334		-48705					
Stock Changes										
Total Primary Supply		892.17	1590529	1092673	4062652	2299975	3380	566	329	50.4
II. TRANSFORMATION										
Refinery			-1590529	-1092673	2629538					
Thermal Power Stations		-360.79			-1094478	-675775	45836			
Primary Electricity							895	566	329	
Losses & Own Use			-31811	-21853	-26295	-13516	-6212			
Total Final Supply		531.38			5571416	1610685	43004			50.4
III. CONSUMPTION										
Domestic		120.18			511342		22216			33.8
Industrial		302.80			347537	1610685	14441			11.6
Commercial		10.08					3999			5.0
Transport		43.63			3530199					
Agriculture					1122082		1776			
Others					60568		568			
Non-energy Use		54.69								
Total Demand		**531.38**			**5571729**	**1610685**	**43000**			**50.4**

Data Source: Natural gas and NGL – Petrobangla Annual Report; Crude oil and Petroleum products – BPC Annual Report; LPG - LPG Producers' Association; Coal – IEA Energy Database; Electricity and Hydroelectricity – BPDB Annual Report; Renewables – Estimated from SREDA Database; Biomass – This study
Prepared by: Ijaz Hossain

Table 1.26: Bangladesh Energy Balance Table for 2015 (in energy units)

	Natural Gas	NGL	Crude Oil	Petroleum Products + LPG	Coal	Electricity	Total Comm. Energy	Hydro-electricity	Renewables (solar, wind, etc.)	Biomass Supply	Total Renewable Energy	TOTAL ENERGY
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	**PJ**
I. SUPPLY												
Primary Production	883.25	19.95			18.25		921.45	2.04	1.18	660.00	663.22	**1585**
Imports			46.66	175.55	43.85	12.17	278.23					**278**
Exports		-10.14		-2.08			-12.22					**-12**
Stock Changes												
Total Primary Supply	**883.25**	**9.81**	**46.66**	**173.48**	**62.10**	**12.17**	**1187.46**	**2.04**	**1.18**	**660.00**	**663.22**	**1851**
Percent of Total Energy Supply	47.73%	0.53%	2.52%	9.37%	3.36%	0.66%	**64.16%**	0.11%	0.06%	**35.66%**	**35.84%**	**100%**
II. TRANSFORMATION												
Refinery		-9.81	-46.66	55.34								**-1**
Thermal Power Stations	-357.19			-46.73	-18.25	165.01						**-257**
Primary Electricity						3.22		2.04	1.18			
Losses & Own Use	-1.48	-0.20	-0.93	-0.55	-0.36	-22.36						**-23**
Total Final Supply	**526.06**			**181.53**	**43.49**	**154.81**	**905.89**			**660.00**		**1566**
III. CONSUMPTION												
Domestic	118.97			20.09		79.98	219.04			442.20		**661**
Industrial	299.77			11.09	43.49	51.99	406.34			151.80		**558**
Commercial	9.98					14.40	24.38			66.00		**90**
Transport	43.19			112.63			155.82					**156**
Agriculture				35.80		6.39	42.19					**42**
Others				2.11		2.04	4.15					**4**
Non-energy Use	54.14						54.14					**54**
Total Demand	**526.06**			**181.71**	**43.49**	**154.80**	**906.06**			**660.00**		**1566**
Percent of Total Energy Consumption	33.59%			11.60%	2.78%	9.88%	57.86%			42.14%		**100%**

Natural Gas: 1 MMCF = 0.00099 PJ; Crude Oil: 1000 Tonnes = 0.427 PJ; Petroleum Products (average): 1000 Ton = 0.427 PJ; Coal: 1000 Ton = 0.0270 PJ; Biomass (average) 1000 Ton = 0.0131 PJ; Electricity: 1 GWh = 0.0036

Prepared by: Ijaz Hossain

Table 1.27 and Figure 1.9 show the Total Primary Energy (Fossil Fuels and Renewables) Supply in both Petajoule (PJ) and MTOE in 2015.

Table 1.27: Total Primary Energy (Fossil Fuels and Renewables) Supply in both Petajoule (PJ) and MTOE in 2015

Primary Energy Supply (PES)	NG & NGL	Crude Oil, Petroleum & LPG	Coal	Electricity Import	Hydro, Solar & Wind	Biomass	Total
1	2	3	4	5	6	7	8=2+3+...+7
PJ	893	220	62	12	3.2	660	1851
MTOE	20.9	5.2	1.5	0.3	0.1	15.5	43.34
Percent	48%	12%	3%	1%	0.2%	36%	100%

Note: 42.7 PJ/MTOE

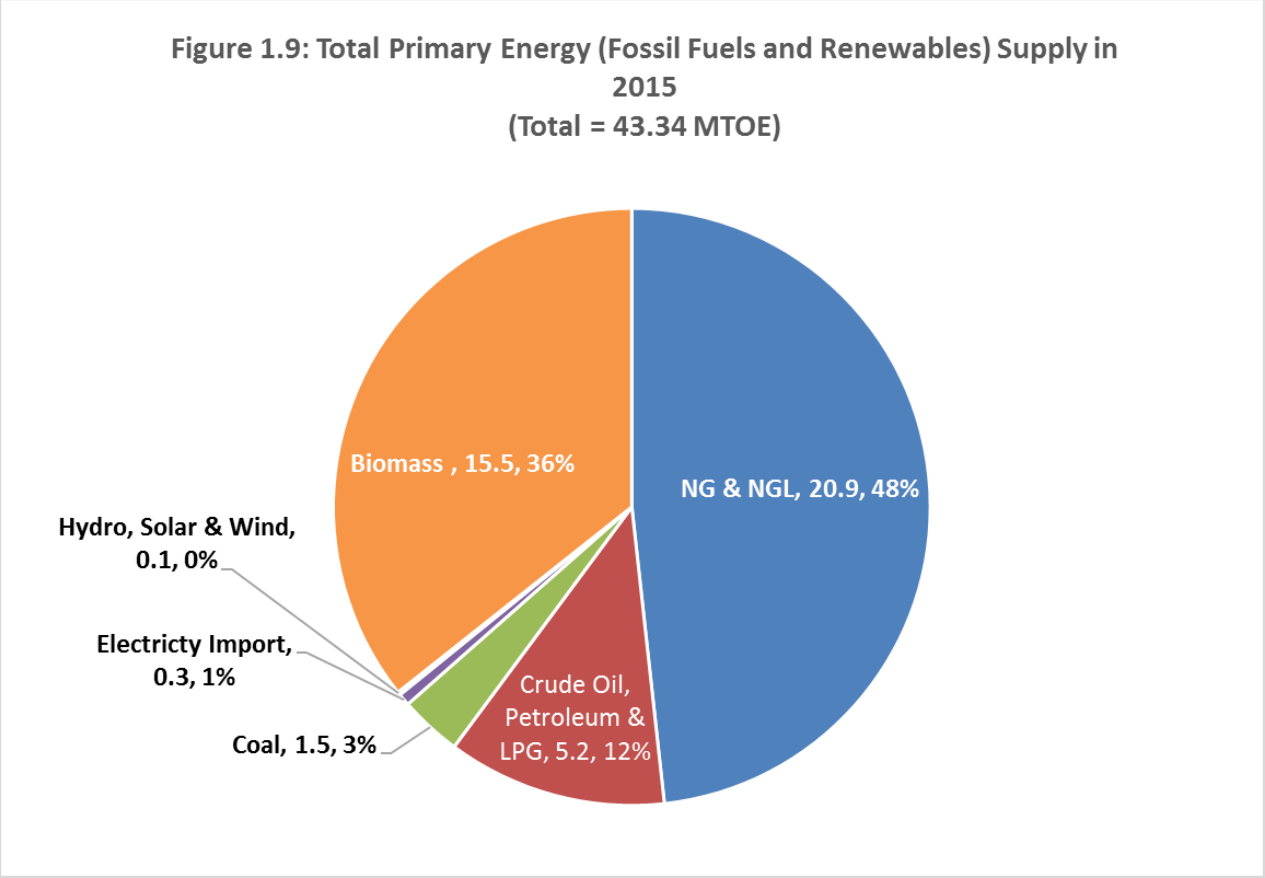
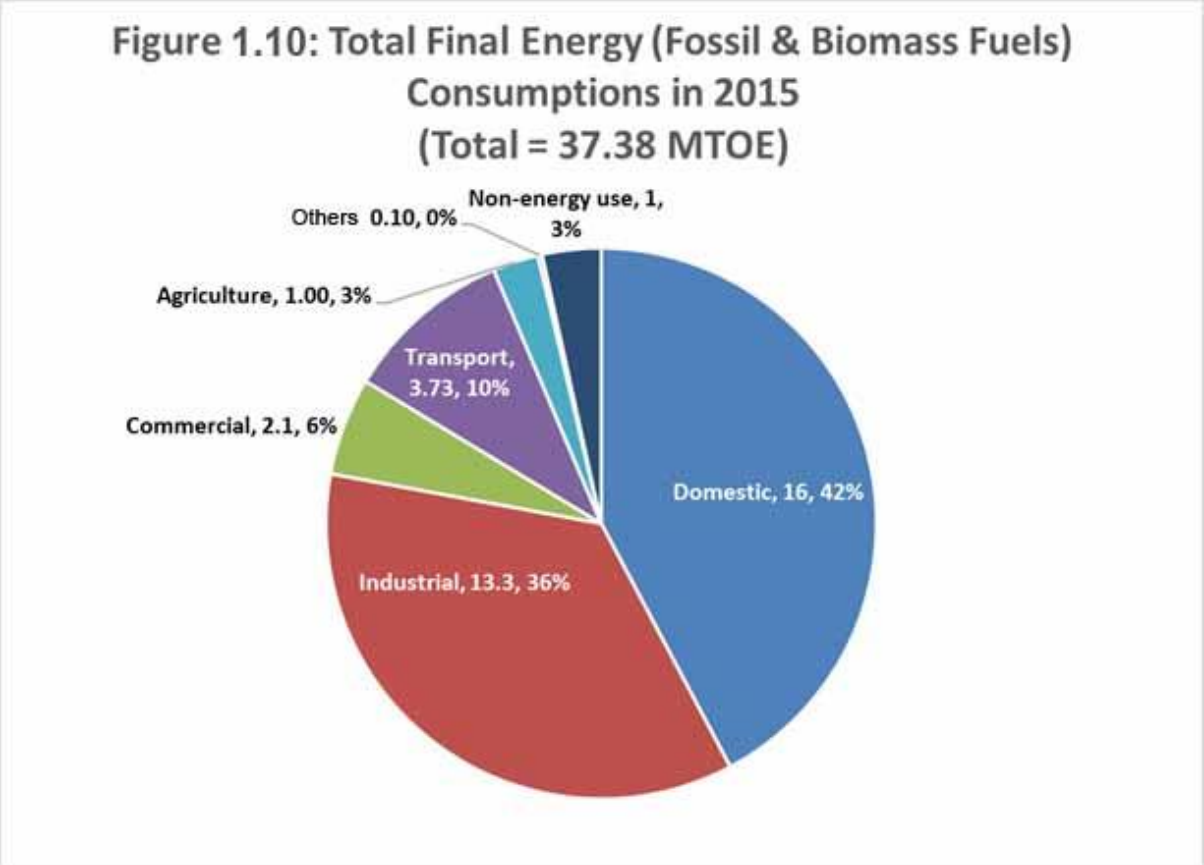
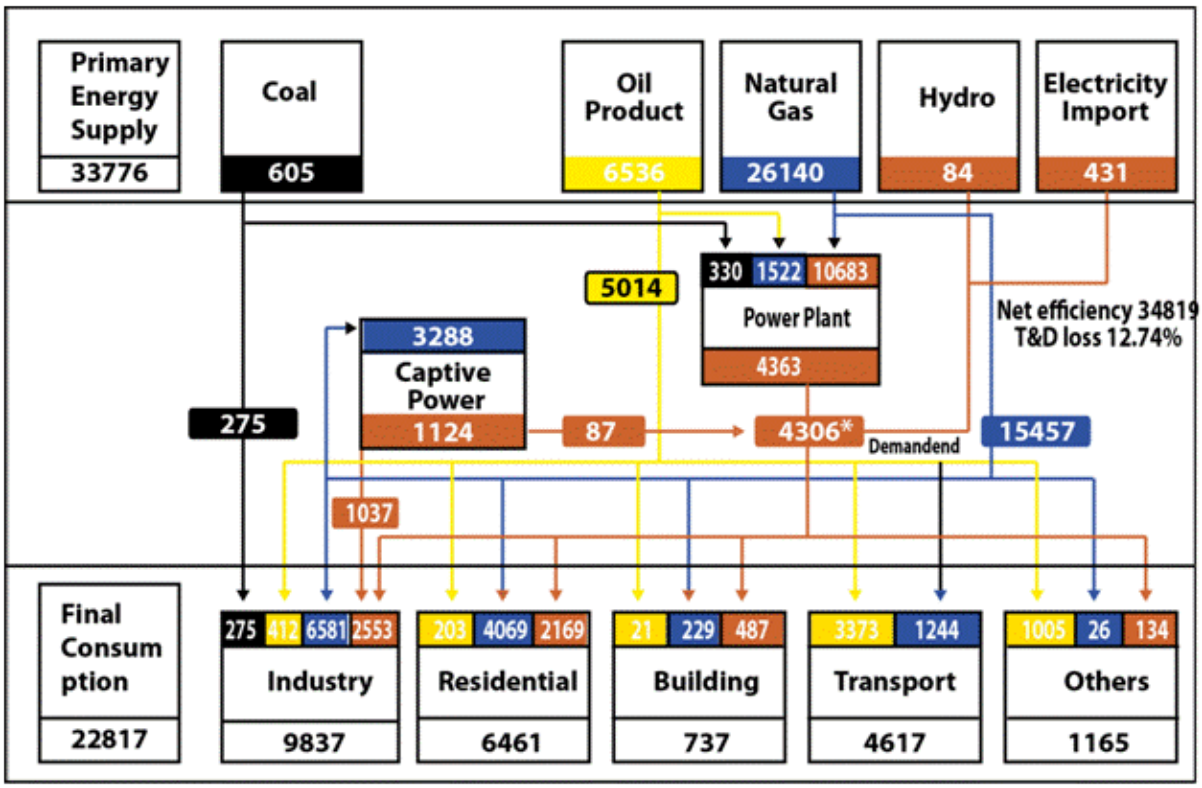


Table 1.28 and Figure 1.10 show the Total Final Energy (Fossil & Biomass Fuels) Consumptions in 2015.

Table 1.28: Total Final Energy (Fossil & Biomass Fuels) Consumptions in 2015

Consumption of Energy	Domestic	Industrial	Commercial	Transport	Agriculture	Others	Non-energy use	Total
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9=2+..+8**
PJ	661	558	90	156	42.0	4	54	1565
MTOE	16	13.3	2.1	3.73	1.00	0.10	1	37.38
Percent	42%	36%	6%	10%	3%	0.3%	3%	100%





Note: Unit = KTOE; excluding biomass & solar

Figure 1.11: National Energy Balance FY2016-17 in KTOE Published by SREDA

The Energy Balance Table (EBT) is a very useful tool to understand the energy supply and demand of a country. It provides a snapshot view of the supply of all fuels, the transformation of those fuels to electricity and other secondary products and the demand of those products and electricity in the various consumption sectors. It also shows where the fuel or primary electricity is coming from, i.e. whether it is domestically produced or imported. The beauty of the EBT is that it gives a full balance in energy units of all the fuels supplied and all the fuels consumed in the various demand sectors. The EBT is an extremely useful tool for policymakers for energy planning. Policymakers can plan fuel substitution, take decision whether to increase or decrease fuel supply and allocate resources to facilitate sustainable energy development by studying the EBT.

The EBT along with all other energy statistics need to be published on a regular basis. Several organizations locally and internationally need good reliable data presented in a recognized format. Such data availability is essential for economic development of a country.

Chemical Engineering Department, BUET has a long association with biomass energy in Bangladesh. They possess full capability of managing such data, and can if required provide training and technical support to the government for collecting, analyzing and disseminating biomass energy data.

1.5 Projections

The projection of biomass fuels use is very difficult because many factors impact its use. In developed countries the use of biomass fuels is being promoted because it is a renewable fuel and lowers the emission of greenhouse gases. In developing countries most governments are striving to decrease the role of biomass fuels in rural areas because it is perceived as a sign of underdevelopment. However, as part of the global community facing the challenges of Climate Change, Bangladesh too has an interest in promoting the use of biomass fuels especially for power generation.

The projection of biomass fuels in Bangladesh must consider at least the following:

- The diffusion of modern fuels such as kerosene, LPG and electricity
- The extent of diffusion of Improved Biomass Cookstoves
- The price of biomass fuels in comparison to commercial fuels

In other components of this report the potential supply of different types of biomass and their consumption have been projected. Factors which will impact the future availability of biomass in Bangladesh are:

- Agricultural land availability and cropping intensity
- Reforestation and Afforestation
- Increase in livestock population
- Climate Change impacts on agriculture of Bangladesh

There is no new land to expand agricultural activity; and strong evidence that every year a small percentage of land is being lost due to industrialization and urbanization. Even in rural areas, the increase in the number of households implies that agricultural land is being lost. Through increase in cropping intensity there will be some increase in agricultural output, but the country is already on a high cropping intensity. Therefore, there is little possibility of the supply of biomass increasing in the future.

Analyses of available data indicate that in the future the share of biomass fuels may decrease and reach a constant level. However, the total quantity of biomass fuels consumed may increase as a result of increasing population. This increasing trend will be moderated by rural households moving to modern cooking fuels such as kerosene, LPG and electricity with increasing standard of living. Thus, the share of biomass fuels in TPES, or more specifically the quantity of biomass fuels used by rural households will critically depend on the pace of transition to commercial energy from traditional energy. This type of transition has been observed in many countries around the world and will inevitably happen in Bangladesh.

According to the data presented in Figure 1.7, the share of biomass fuels in total primary energy had already come down to 24 percent in 2016. The analysis of this report, however, shows that in the year 2015 the share of biomass fuels was around 36 percent. Whatever the actual percentage may be, there is already clear evidence that transition to modern fuels is taking place implying biomass fuels used for cooking in rural areas will decrease. A large segment of people may, however, need to continue using biomass fuels because they may not be able to afford modern fuels. The principal reason for this is that these people do not buy their fuel; they collect those from homestead trees.

The rapid economic growth that Bangladesh has experienced in the last 10 years implies that the use of commercial fuels will increase. This will naturally force the share of biomass fuels to decrease further.

1.6 Suggestions and Conclusions

On the basis of presentation and discussions made in previous paragraphs, following suggestions are made for consideration of the Government.

- At present bagasse based power plants are operated in sugar mills for 120 to 180 days per year. A feasibility study may be undertaken to assess the prospect of operating power plants of sugar mills to operate throughout the year, using alternative fuels.
- BBS published data of yearly supply of traditional fuels (biomass fuels) from 1974 to 2005 (Table 1.13). On the basis of the present study, BBS should regularly publish data of biomass fuels supply starting from 2016.
- SREDA should interact with BBS to harmonize the publication of Census of Agriculture data of 2019 in order to estimate the supply of biomass fuels from different categories of land. And also publish data of livestock and poultry resources to facilitate the establishment of domestic and commercial biogas plants based on animal and poultry dung.
- Energy Balance Table (EBT) is a vital energy data table required for overall energy planning of the country. BBS has stopped publication of EBT in Statistical Year Book since 2005. On the basis of the estimate of the present study, BBS should start publishing yearly EBT data (Table 1.25, Table 1.26 and Table I.II) on a regular basis starting from 2016; which should include data on both commercial energy and biomass fuels sources
- At present Household Income Expenditure Survey (HIES) of BBS publishes data of different categories of household expenditures including energy and lighting. HIES should consider in publishing the type (e.g. fuelwood, kerosene, LPG, electricity etc.) and quantity (e.g. kg, liter, kg, kWh etc.) of energy consumed along with energy expenditures.

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APPENDIX-I

Appendix I

Cost of Different Biomass Fuels Technologies

Table I.I Estimated Equipment Costs for Different Biomass Power Generation Technologies from Different Studies

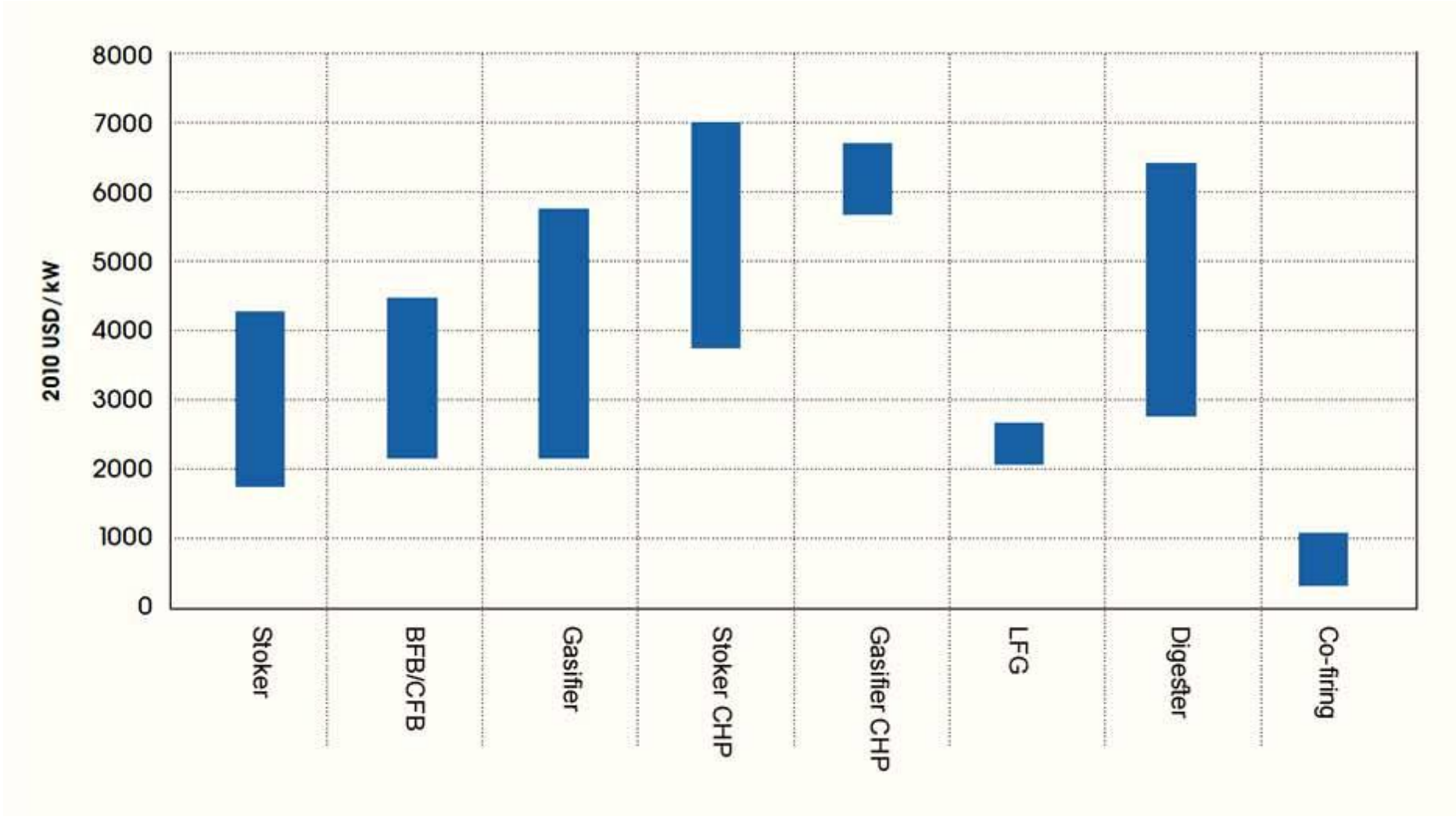
	O`Connor, 2011	Mott MacDonald, 2011	EPA, 2007 and EIA, 2010	Obernberger, 2008
	(2010 USD/kW)			
Stoker boiler	2 600 – 3 000	1 980 – 2 590	1 390 – 1 600	2 080
Stoker CHP	2 500 – 4 000		3 320 – 5 080*	3 019
CFB	2 600 – 3 000	1 440	1 750 – 1 960	
CFB CHP			4 260 – 15 500	
BFB		2 540	3 860	
Co-firing	100 – 600			
100% biomass repowering	900 – 1 500			
MSW	5 000 – 6 000			
Fixed bed gasifier ICE		4 150	1 730	4 321 – 5 074
Fixed bed gasifier GT	3 000 -3 500			
Fluidised gasifier GT			2 470-4 610	
BIGCC	3 500 – 4 300		2 200-7 894	
Digester ICE	1 650 – 1 850	2 840 – 3 665		
Digester GT	1 850 – 2 300			
Landfill gas ICE	1 350 – 1 500		1 804	

Note:

* = CHP back pressure steam turbine. ICE = internal combustion engine.
GT = gas turbine. MSW = municipal solid waste.

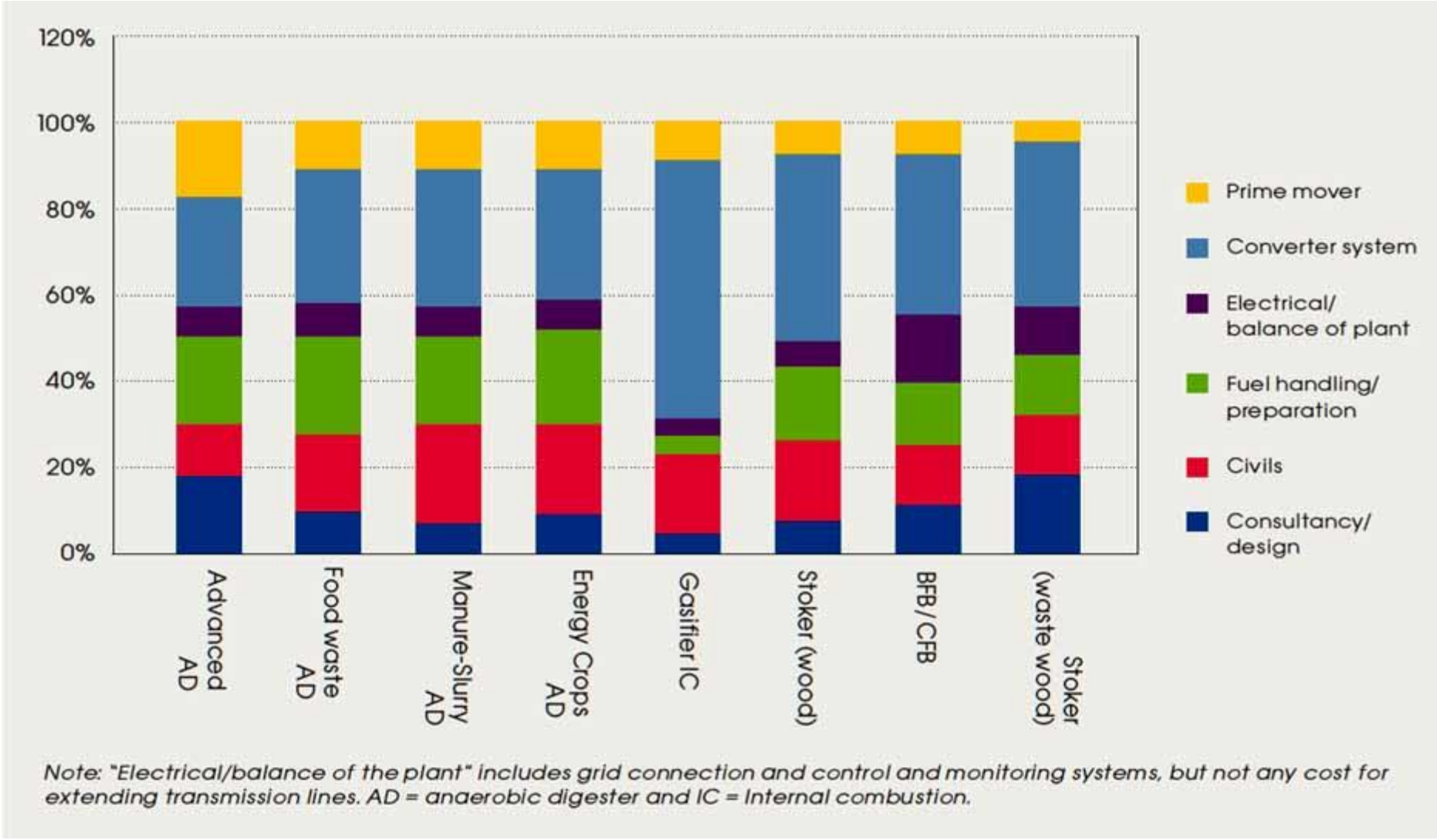
Source: IRENA 2012

Figure I.I: Installed Capital Cost ranges by Different Biomass Power Generation Technologies



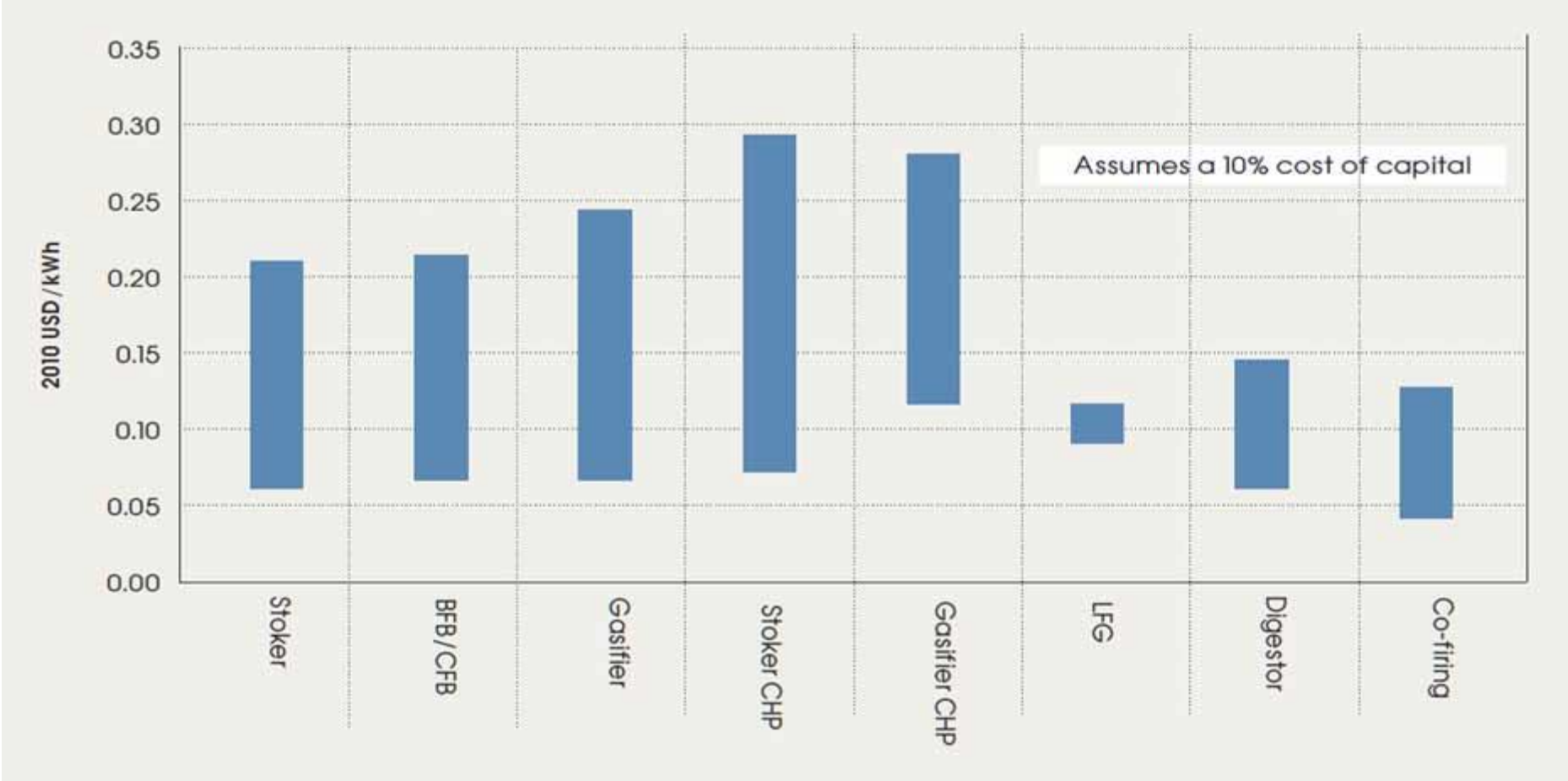
Source: IRENA 2012

Figure I.II: Capital Cost Breakdown for Different Biomass Power Generation Technologies



Source: Mott Macdonald 2011

Figure I.III: Levelized Cost of Generation (LCOE) Ranges for Different Biomass-fired Power Generation Technologies



Source: IRENA 2012

Table I.II: Bangladesh Energy Balance Table for 2015 in MTOE

	Natural Gas	NGL	Crude Oil	Petroleum Products + LPG	Coal	Electricity	Total Comm. Energy	Hydro-electricity	Renewables (solar, wind, etc.)	Biomass Supply	Total Renewable Energy	TOTAL ENERGY
	MTOE	MTOE	MTOE	MTOE	MTOE	MTOE	MTOE	MTOE	MTOE	MTOE	MTOE	**MTOE**
I. SUPPLY												
Primary Production	20.68	0.47			0.43		21.58	0.05	0.03	15.46	15.53	**37.11**
Imports			1.09	4.11	1.03	0.28	6.52					**6.52**
Exports		-0.24		-0.05			-0.29					**-0.29**
Stock Changes												
Total Primary Supply	**20.68**	**0.23**	**1.09**	**4.06**	**1.45**	**0.28**	**27.81**	**0.05**	**0.03**	**15.46**	**15.53**	**43.34**
Percent of Total Energy Supply	47.73%	0.53%	2.52%	9.37%	3.36%	0.66%	**64.16%**	0.11%	0.06%	**35.66%**	**35.84%**	**100.00%**
II. TRANSFORMATION												
Refinery		-0.23	-1.09	1.30								**-0.03**
Thermal Power Stations	-8.37			-1.09	-0.43	3.86						**-6.02**
Primary Electricity						0.08		0.05	0.03			
Losses & Own Use	-0.03	0.00	-0.02	-0.01	-0.01	-0.52						**-0.53**
Total Final Supply	**12.32**			**4.25**	**1.02**	**3.63**	**21.22**			**15.46**		**36.67**
III. CONSUMPTION												
Domestic	2.79			14.61		1.87	19.27			10.36		**29.63**
Industrial	7.02			-0.71	1.02	1.22	8.54			3.56		**12.10**
Commercial	0.23					0.34	0.57			1.55		**2.12**
Transport	1.01			-7.23			-6.22					**-6.22**
Agriculture				-2.30		0.15	-2.15					**-2.15**
Others				0.05		0.05	0.10					**0.10**
Non-energy Use	1.27						1.27					**1.27**
Total Demand	**12.32**			**4.42**	**1.02**	**3.63**	**21.39**			**15.46**		**36.84**
Percent of Total Energy Consumption	33.44%			12.01%	2.76%	9.84%	58.05%			41.95%		**100.00%**

Notes: 42.7 PJ/MTOE

Annex-I

Terms of Reference (ToR)

Annexure-II

TERMS OF REFERENCE
FOR CONSULTANCY FIRM CONTRACT
for

HIRING A FIRM FOR COMPREHENSIVE ASSESSMENT OF THE AVAILABILITY AND USE OF BIOMASS FUELS FOR VARIOUS END-USES WITH SPECIAL ATTENTION TO POWER GENERATION; UNDER THE DEVELOPMENT OF SUSTAINABLE RENEWABLE ENERGY POWER GENERATION (SREPGEN) PROJECT.
TERMS OF REFERENCE (TOR)

A. Background/Context:

Power Division is implementing GEF-Funded Project "Development of Sustainable Renewable Energy Power Generation (SREPGen)". The objective of the Project is to reduce the annual growth rate of GHG emissions from the fossil fuel-based power generation by exploiting Bangladesh's renewable energy resources for electricity generation. The basic approach of the Project will be to promote renewable energy through the Sustainable and Renewable Energy Development Authority (SREDA).

For Bangladesh to achieve a greater share of renewable energy (RE) in its energy mix, the Project will support activities that will (i) transform SREDA into a strong RE project facilitation center to bring confidence to private RE investors and increase the number of approved RE projects; (ii) increase the capacities of appropriate government and private sector agencies to generate, process, obtain and disseminate reliable RE resource information for use by potential project developers and investors; and (iii) increase the share of RE in Bangladesh's power mix through facilitating the financing, implementation and operation of pilot (RE) projects using Biomass fuels. The lessons learned from the pilot projects will be utilized to scale-up the dissemination and investment in on-grid & off-grid biomass based RE projects and RE technologies.

Bangladesh is an agriculture-based country (57.6% of total land area is under cultivation, 17.5% under forest and 25.0% not available for cultivation). More than 65 percent of the people live in rural areas and major portion of primary energy consumed in rural area is supplied by Biomass fuels, mainly agricultural residues, animal dung and wood fuels (tree residues).

Electricity production in Bangladesh mainly depends on non-renewable fossil fuels having limited local reserves. In 2017, total installed capacity was 13,179MW and distribution according to fuel type is natural gas 62.01%, furnace oil 21.97%, diesel 7.83%, coal 1.90%, hydro 1.75% and power import 4.55%. The government is now focusing on the alternative sources of energy to harness electricity to meet the continuous increasing demand. To reduce the dependency on fossil fuels, conversion of biomass to electricity could play an important role in this regard. The Renewable Energy Policy, 2008 obligates renewable energy share in power generation to be 10 percent by 2020 that it would be about 2000MW. To achieve this goal Government has set a target of generating 3168MW electricity during 2015 to 2021 by different renewable sources of energy. Contributions of different type of renewable energy sources have been estimated by SREDA as follows: solar 1740 MW (54.9%), wind 1370 MW (43.2%), biomass 47 MW (1.5%), biogas 7MW (0.22%) and hydro 4 MW (0.13%).

It is planned to study the availability of different type of Biomass fuels (e.g. tree residue, agriculture residues and animal dung & poultry litters, municipal solid wastes, industrial wastes etc.) and to assess their prospects for generation of electricity. As the supply and demand of Biomass fuels depends on specific locations; data are to be gathered/ compiled according to 64 districts (shown in Annexure-I in Table I.1). The tasks of the project may be grouped under the following 7 (seven) components.

Component 1: Assessment of the Roles of Biomass fuels in Total Energy Consumption in Bangladesh and in Selected Developed (EU & USA) and Developing (China & India) countries.

Component 2: Development of a Conceptual and Analytical Model to Estimate Supply and Demand of Biomass fuels.

Component 3: Assessment of Biomass fuels Supply from Tree Resources.

Component 4: Assessment of Biomass fuels Supply from Agricultural Crop Lands and other Type of Lands.

Component 5: Assessment of the Biomass fuels Supply from Livestock and Poultry Resources.

Component 6: Assessments of Biomass fuels Supply from Municipalities and Industrial Units.

Component 7: Assessment of Total Consumption of Biomass fuels for Domestic Cooking and other End-uses.

B. Objectives:

On the basis of the data gathered by the above seven components Demand-Supply Balance of Biomass fuels are to be established for 64 districts. At first for the base year 2015 and then at 5 years interval up to 2040. Potential districts for Biomass fuels based power generation are to be identified and 10 sites are to be selected for establishing Biomass fuels based power generation (pilot) plants.

The project wants to hire a potential consulting firms to carryout the task of the above 7 (seven) components of the study and analyze the data to identify the districts having potential for biomass based power generation and select 10 (ten) pilot power plant sites of different capacities (MW).

C. Scope of Work

Specific tasks of the 7 (seven) components are detailed with probable activities and are presented below.

Component 1: Assessment of the Roles of Biomass fuels in Total Energy Consumption in Bangladesh and in Selected Developed (EU & USA) and Developing (China & India) Countries. Data are to be presented in Table I.1, Table I.2 and Table I.3 shown in Annexure-I.

(1.1) Review status of studies on Biomass fuels resources potential and their use in selected developed (EU and USA) and in selected developing countries (China, India) with attention to study methodology, type of biomass resources, technologies, future projections, policy supports etc., for sustainable use of Biomass fuels.

(1.2) Review status of Biomass fuels conversion technologies for power generation (e.g. steam power plant, combustion/gasifier based power plant, biogas based power plant) used in different developed and developing countries with attention to size, conversion efficiency and price etc. Present the data of selected developed and developing countries in the following tables.

Table I.1: Status of Biomass fuels in Selected Developed and Developing Countries in 2015 (see Annexure-I).

Table I.2: Contribution of Biomass fuels in Selected Developed and Developing Countries in 2015 (see Annexure-I).

Table I.3: Fuel Mix for Power Generation in Selected Developed and Developing Countries in 2015 (see Annexure-i).

(1.3) Compile Biomass fuels Action Plans of the Selected Countries up to 2040.

(1.4) Review status of previous studies on Biomass fuels carried out in Bangladesh indicating the shares of commercial energy and Biomass fuels.

(1.5) Review the status of Biomass fuels conversion technologies (e.g. improve cook stoves, steam power plants, biogas based power plants, gasifier based power plants, (or any other) used in Bangladesh.

(1.6) identify the institutions involved with surveys, analyses and publication of Biomass fuels resource data; research, development, demonstration and diffusion on different biomass technologies; financing of biomass projects/program.

(1.7) Compile laws, rules and policies related conservation and sustainable development of Biomass fuels resources in Bangladesh.

(1.8) Prepare a Total Energy Balance Table of Bangladesh including both Biomass fuels and Commercial Energy Sources for 2015. Indicate total BF as percent of total Primary Energy Resources (PER).

Component 2: Development of a Conceptual and Analytical Model to Estimate Supply and Demand of Biomass fuels.

(2.1) Present a conceptual framework and analytical model for assessing supply and demand of Biomass fuels with attention to power generation according to districts.
(2.2) Formulate equations to compute supply and demand of Biomass fuels.

(a) As the supply and consumption of biomass are location and season specific; biomass data are to be compiled/collected (if not available in published form) disaggregated at district level (64 districts). It is envisaged that analysis and presentation of district wise disaggregated data of Biomass fuels will facilitate SREDA to develop District level Renewable Energy Plan (DREP) in future. The order of presentation of the districts in tables should be uniform throughout the study (shown in Table I.4).

(b) Biomass fuels available from the following sources are to be assessed:
- (i) Tree covered areas (fuel-wood & tree residues from both forests & village wood lots, and other tree covered lands);
- (ii) Major crops(plant and crop residues) grown in different type of lands;
- (iii) Livestock resources (to estimate availability of dung at household & farm level),
- (iv) Poultry resources (to estimate availability of litter at farm level),
- (v) Cities and municipalities (to estimate municipal solid wastes),
- (vi) Cities and municipalities (to estimate sewage sludge, human excreta etc.),
- (vii) Industrial wastes (solid, semi-solid, liquid etc).

(c) Land use data shown in SYB-2015 and in BEPP reports may be considered for guidance. Land-use classifications in Bangladesh are: Forest, Not available for cultivation (disaggregate data of homestead wood lots from forestry/tree surveys), cultivable waste (some percent may be used for seasonal dhaincha (sesbania grandiflora cultivation and jatropha cultivation), current fallow (some area for dhaincha (sesbania grandiflora) cultivation, net cropped area, area sown more than once, and total cropped area. Compilation of Biomass fuels data will be limited to land based biomass production systems only. Biomass grown in water bodies not to be estimated.

(d) Consumption of Biomass fuels for different end-uses (domestic cooking in rural and urban areas), rural industries, commercial units and other end-uses are to be considered in the conceptual and analytical model.

(e) Future projection(s) supply and demand of Biomass fuels may be made in consultation with SREDA, relevant agencies and Ministries.

Component 3: Assessment of Biomass fuels Supply from Tree Resources.

(3.1) Compile areas, yield, Forest Management Practices, extraction rate of forest trees, method of tree extraction (e.g. uprooting of trees, felling of trees, pruning of trees etc.) and their end uses (e.g. building materials, industrial raw materials, timber, tree residues as fuel etc.) according to districts.

(3.2) Compile tree residues (e.g. sawmill residues, branches, twigs, leaves) data of Forest land according to districts (Forest Inventory Reports prepared by the Department of Forest may be consulted).

(3.3) Compile tree residues data of Village Woodlots (e.g. annual/seasonal pruning of branches of homestead trees, orchard, community forests etc.) according to districts (Village Forest Inventory Reports prepared by the Department of Forest may be consulted)

(3.4) Write a brief description about the local practices of management of forests, privately owned tree resources grown in homestead, village wood lots, orchard & under community forestry projects etc.

(3.5) Prepare a report on Assessment of Tree Residues as Biomass fuels in Bangladesh according to districts for the base year 2015.

(3.6) Future projection(s) of supply of tree residues may be made in consultation with SREDA, relevant agencies and Ministries.

Component 4: Assessment of Biomass fuels Supply from Agricultural Crop Lands and Other Type of Lands.

(4.1) Compile data of cultivation and harvesting period of different crops, present data according to districts. To assess potential use residues during harvesting season, indicate the residues that are available during rainy season (which are of limited use/wastes).

(4.2) Availability of biomass residues from different crops (major crops) to be gathered from Crop-specific research institutes (BRRI, BARI, WRI, BJRI, any other research institute etc.) and also from the Department of Agricultural Extension for different Districts. Data presented in previous studies (e.g. BEPP) may also be tabulated for comparison.
(4.3) Write a brief description about different components of biomass residues [e.g. plant residues (straw), crop residues (husk), crop residues (bran)] and their priority use such as fodder, feed, building materials, fuel, mulch, soil conditioner, no use (may be due to seasonal condition). Available biomass data may be disaggregated as (i) food, (ii) feed, (iii) building materials (iv) industrial raw materials, (v) plant residues, (vi) crop residues, (vii) un-usable residues (due to seasonal character and some other reason-specify). In a particular location, biomass residues considered as waste (no-use) when the benefits (value) of its use is less than cost of their collection, transportation & processing to their respective owners etc.

(4.4) Compile areas, yield, production of major crops (local Aus, HYV Aus, Local Aman, HYV Aman, Local Boro, Hybrid Boro, HYV Boro, Wheat, Maize, Jute, Pulses, Oil Seeds, Sugar cane, Potato etc.) and their respective plant & crop residues according to districts.

(4.5) Make assessment and observations on the possibility of using agricultural residues for mulching/composting or any other useful purpose (specify) and present according to districts.

[4.6] Compile data on cultivation of Dhaincha in cultivable waste and fallow land according to districts.

(4.7) Prepare a Report on Assessment of Agricultural Residues and Agricultural land based Tree Crops as Biomass fuels in Bangladesh according to district for the base year 2015.

(4.8) Future projection(s) supply of agricultural residues and tree crops as Biomass fuels may be made in consultation with SREDA, relevant agencies and Ministries.

Component 5: Assessment of the Biomass fuels Supply from Livestock and Poultry Resources.

(5.1) Compile data of animals, animal dung from Live Stock Resources according to districts for households, government farms, private farms (Livestock Census Report, Department of Livestock Supply, Bangladesh Livestock Research Institute, Livestock and Dairy Industries Association, District Livestock Office etc may be consulted for data) for the base year 2015.

(5.2) Compile data of poultry, poultry litters of poultry firms in consultation with Department of Livestock Supply and Poultry Industries Association according to districts for the base year 2015.

(5.3) Make descriptive assessment and observations on traditional use of animal dung/poultry litters as farm-yard manure and/or compost and their use (seasonal) according to districts. It is generally observed that in order to make rational use of available manpower (e.g. family labor, permanent labor), dung manure is used in homestead garden and in near by crop lands.

(5.4) Prepare a report on Assessment of Livestock Dung and Poultry Litters as Biomass fuels in Bangladesh According to Districts for the base year 2015.

(5.5) Cattle dung is the primary raw material for family size biogas plant and it requires dung from 3 to 5 cattle to operate a family size plant. Make a demand supply balance of cattle dung with 3, 4,5, 6 and more cattle and estimate the potential number of family size biogas plants according to district for the base year 2015.

(5.6) Assess future prospects of Large Size Biogas Plants for power generation in Dairy & Livestock Farms according to districts. Data to be gathered are: Dung available from Livestock and dairy firms may be used for large size biogas plant to generate electricity. Data to be gathered are: total number of animals, daily availability of dung (wet as obtained), current use of dung, monthly fuel requirement of the farm, is there a biogas plant?, if yes then collect technical data related to biogas plants and use of generated biogas of the Dairy Farms. Livestock and Dairy Industries Surveys are to be carried out with GPS and camera.

(5.7) Assess future prospects of Large Size Biogas Plants for Power Generation in Poultry Farms according to districts. Data to be gathered are: total number of birds, daily availability of litters (wet as obtained), current use of litters, monthly fuel requirement of the farm, is there a biogas plant?, if yes then collect

technical data related to biogas plants. Poultry Industries Surveys are to be carried out with GPS and camera.

(5.8) On the basis of surveyed and analyzed data prepare a list of Large Size Biogas Plants may be established in Dairy and Poultry Industries for Power Generation according to districts. Described the business models of large biogas plants for power generation.

Component 6: Assessments of Biomass fuels Supply from Municipalities and Industrial Units.

(6.1) Compile data of quantity and composition Municipal Solid Wastes (e.g. cities & towns) from available MSW survey reports according to districts (information may be gathered from SREDA study reports on Waste to Energy, LGED reports on MSW, any other reports etc.).

(6.2) Assess the experiences of Municipal Solid Wastes (MSW) based biogas plant established in different cities and municipalities (information may be gathered from BCSIR, LGED and Practical Action or any other organizations).

(6.3) Assess supply potential of Sewage Sludge specific to districts (e.g. cities & towns) and their possible usage to produce biogas (information may be gathered from LGED and Practical Action or any other organizations).

(6.4) Compile data (e.g. quantity and districts) of combustible Industrial Wastes (e.g. solid, semi-solid, liquid etc.) [e.g. press mud & bagasse of sugar industries; liquid wastes of agro-processing industries; black-liquor of paper mills etc.] for the base year 2015.

(6.5) Future projection(s) of Biomass fuels supply may be made in consultation with SREDA, relevant agencies and Ministries.

(6.6) Prepare a report on Assessment of Municipal and Industrial Wastes as Biomass fuels in Bangladesh according to districts.

Component 7: Assessment of Total Consumption of Biomass fuels for Domestic Cooking and Other End-Uses.

- The main tasks of Component 7 would be to (i) estimate specific energy consumption for a particular usage and (ii) number of consumption units, according to districts.
- Gathering, analyses, compilation, and tabulation of Biomass fuels consumption for the following end uses are to estimated: cooking in rural households, paddy parboiling at rural households, cooking in urban households, usage in urban commercial units; in rural agro-processing industries (such as paddy processing, tea processing, sugarcane-juice processing to ghur) and in non-agro based industries (such as brick burning, pottery, lime-kiln etc.).
- As the supply and consumption of biomass are location and season specific; biomass consumption data are to be collected/compiled disaggregated at district level (64 districts). First five columns of each table should be as follows: (i) district, (ii) number of urban-households, (iii) urban-population (iv) rural-households, (v) rural population;

- In Bangladesh major portion of Biomass fuels used for household cooking. Following methodology may be considered to compute Biomass fuels for household cooking.

(7.1) Number of households using kerosene for lighting may be computed as follows.

(7.1.1) Name of districts, total number of households, and population may be tabulated in the first three column of the table

(7.1.2) Number of household using electricity for lighting may be compiled by gathering household consumers data from all the Electricity Utilities (e.g. BPDB, DESCO, DPDC, REB, WZPDCL) according to districts.

(7.1.3) Number of households using Solar Home System for lighting may be gathered from IDCOL and other promotional agencies.

(7.1.4) Number of households using kerosene for lighting may be computed by deducting the households using grid and solar electricity for lighting from total households.

- Above computation in [7.1.4] assumes that electricity using households do not use any kerosene for lighting during power failure.

(7.1.5) Amount of kerosene used for household lighting according to districts may be computed according to BEPP data.

(7.2) Kerosene balance is to be compiled to estimate household use of kerosene for cooking as follows.

(7.2.1) Total amount of kerosene used for a particular year (e.g. 2015) may be gathered from BPC according to districts.

(7.2.2) Use of kerosene for power generation *according to districts* may be gathered from BPC/BPDB.

(7.2.3) Amount of kerosene used for household cooking may be computed by kerosene balance [total kerosene = (kerosene for household lighting + kerosene for power generation + kerosene for household cooking)].

(7.2.4) Number households using kerosene for cooking may be computed as per BEPP data [(amount of kerosene used for domestic consumption for cooking)/(specific energy consumption of kerosene for cooking)] .

(7.3) Household using biomass fuels for cooking may be computed as follows.

- Different type of fuels used for domestic cooking are: biomass fuels, kerosene, LPG, natural gas and electricity etc.

(7.3.1) Number of household using natural gas for cooking may be obtained from the natural gas distribution companies (BGDCL, JGTDSL, KGDCL, PGCL, SGCL, TGTDCL etc.) considering some extra (percent) for illegal connections.

(7.3.2) Household using LPG for cooking may be obtained from the LPG marketing companies. LPG use for commercial units may also be obtained from LPG companies.

(7.3.3) Percent of electricity using households using electricity for cooking (e.g. electric heaters by low income group and modern appliances (e.g. Induction cooker, Micro-oven etc. by high income group) may be assumed by discussing with related experts (see the Daily Star, 23 January, 2018).

(7.3.4) Number of households using Biomass fuels may be estimated by difference between total households and sum total of households using modern fuel sources (natural gas, LPG, electricity) for cooking.

(7.3.5) Per Household use of biomass fuels may be estimated by using BEPP data and/or may be estimated by undertaking sample surveys.

(7.4) Consumption of Biomass fuels for other end uses may be computed by using BEPP data and/or undertaking survey.

(7.5) Assess the total consumption of Biomass fuels in all end uses (compute and tabulate) in heat unit (e.g. GJ) for the base year 2015 according to districts.

- Heating values of biomass resources used in BEPP (Table I.5) may be used for continuity of database. Moisture content of all residues should be written. When BEPP data are not used mention moisture content and heating value as given in the respective publications.

(7.6) Future projection(s) on consumption of Biomass fuels may be made in consultation with SREDA, relevant agencies and Ministries.

(7.7) Prepare a Report on Biomass fuels Consumptions for Different End-Uses in Bangladesh according to districts.

Compilation of Data of Total Supply of Biomass fuels for the Base Year 2015

(8.1) Compile (compute & tabulate) the supply of total Biomass fuels available from different sources (tree residues, crop residues, animal dung and poultry litters, MSW, Industrial Wastes) in physical units (tonnes) according to districts (Component 3, Component 4, Component 5, Component 6).

(8.2) Estimate (compute and tabulate) the supply of total Biomass fuels in heat units (e.g. GJ) for the base year (2015) according to districts.

(8.3) Future projection(s) of Biomass fuels supply may be made in consultation with SREDA, relevant agencies and Ministries.

(8.4) Prepare a Report on Total Supply of Biomass fuels from Different Sources in Bangladesh according to districts.

(8.5). Establish a Demand/Supply balance of Biomass fuels disaggregated at district Level for 2015 by comparing Biomass fuels consumption shown in [7.5] and supply data shown in [8.2].

(8.6) Districts having excess supply of biomass fuels may be identified for subsequent decisions on Biomass fuels based electricity generation.

(8.7) Future projections of Demand/Supply Balance of Biomass fuels disaggregated at district level are to be made in consultation with relevant Ministries (e.g. Ministry of Agriculture, Ministry of Environment & Forest) in consultation with SREDA, relevant agencies and Ministries.

(8.8) Estimate the quantity of excess Biomass fuels may be available through demand supply analysis (specific to location and season) and assess their prospects for power generation (specific to technology-biogas technology or any other) according to districts.

(8.9) Identify the districts having potential for biomass based power generation and select at least 10 (ten) pilot power plant sites of different capacities (MW).

(8.10) Future projections of Excess of Biomass fuels Disaggregated at District Level are to be made in consultation with the relevant Ministries (e.g. Ministry of Environment & Forest, Ministry of Agriculture, Ministry of Livestock & Fisheries) in consultation with SREDA).

(8.12) Prepare a Report on Excess Supply of Biomass fuels for Different End-Uses in Bangladesh.

(8.11) Prepare a Biomass fuels Action Plan for Bangladesh with investment requirement up to 2040.

D. Reporting

Selected firm/organization will report and work under the overall supervision of the Project Manager, SREPGen Project and Programme Specialist, Inclusive Growth and Resilience Cluster of UNDP Bangladesh and their nominated supervisors (A consultant has been hired for this purpose already).

E. Activity Timeline Duration

Total duration of the current project is 09 months effective from the date of signing the contract. The study should cover the data base of the whole country disaggregated to 64 Districts. The working location (duty station) is Dhaka, would involve traveling to the selected locations of Bangladesh for gathering /collection of data.

Sl No	Activity/ Deliverables	Timeline
1	Submission of Inception Report (2 print copies & soft copy)	Within 3 weeks after signing the contract.
2	Submission of Mid-term Report (consist of reports of different components prepared by individual consultants after completion of data gathering, entry of data in computer, consisting checking and preparation initial draft) (3 print copies & soft copy). Present the findings of the study in a seminar organized for the stakeholders.	5 months after signing of the agreement.

3	Submission of Draft Final Report-consisting of reports all the deliverables (3 print copies & soft copy). Present the findings and recommendations of the study in a seminar to be organized for the stakeholders.	7 months after signing of the agreement.
4	Submission of Final Report -consisting of reports all the deliverables (5 print copies & soft copies)	At the end of the project.

F. Final Products/Services/Deliverable

The selected firm/organization will produce the following outputs

- Overall output of the study is to make Comprehensive Assessment and Preparation of a Database on the Availability and Use of Biomass fuels for Various End-Uses with Special Attention to Power Generation for 64 districts of Bangladesh. The data base will be used by SREDA for preparation of future Plan and Programs on Biomass fuels Based Power Generation. Overall output may be disaggregated under the following components.

- Assessment of Contribution of Biomass fuels in total Energy Consumption of Bangladesh and the Selected Developed Country and Developing Countries.
- Preparation of a Conceptual and Analytical Model for Supply and Demand Analysis for Biomass fuels for 64 districts & formulation of equations to compile the input & out put parameters.
- Assessment of Supply of Biomass fuels from Tree Resources for 64 districts.
- Assessment of Supply of Biomass fuels from Agricultural Residues for 64 districts.
- Assessment of Supply of Biomass fuels from Livestock and Poultry Resources for 64 districts.
- Assessment of Supply of Biomass fuels from Municipalities and Industrial Units for 64 districts.
- Assessment of Consumption of Biomass fuels for Cooking and other End uses Including Power Generation for 64 districts.
- Assessment of Demand and Supply Balance of Biomass fuels for 64 districts.
- Preparation of an Action Plan for Sustainable use of Biomass fuels for Different End-uses (with special attention to Power Generation) for 64 districts with Investment Costs.
- Develop and Strengthen Capacity of SREDA (technology transfer) on Management of Database of Demand-Supply Balance of Biomass fuels for Sustainable Use Including Power Generation.

G. Schedule of Payment

Activity/ Deliverables	Percent Payment/ Milestone Payment
After Submission of Inception Report	20%
After Submission of Mid-term Report	30%
After Submission of Draft Final Report	25%
After Submission of Final Report	25%

H. Recommended Presentation of Proposal

Interested firms/entities must submit the following detailed proposal made up of documentation to demonstrate the qualifications of the prospective firm, to enable appraisal of competing bids. This should include Technical and Financial proposals details of which are listed below.

1. Technical Proposal

i. Firm information- name of the firm and details of registration address and the bank account; business registration certificate and corporate documents (Articles of Association or other founding authority); description of present activities and most recent annual report (including audited financial statements), if applicable;

ii. Experience- reference at least 2 (two) works and reports of assessments/survey/evaluation undertaking on evaluation and impact assessment in Bangladesh as well as statistical data processing analysis using statistical software.

iii. Process- the technical proposal need to contain a detail description of the process the contractor intends to follow to complete the tasks including a detail work plan and time schedule for completion/delivery of the final product which, after selection of the contractor will be agreed upon by the project.

iv. Human Resources- the technical proposal need to contain a list and CV of the proposed human resources (technical/managerial) which will be utilized for the tasks including their respective qualifications and relevant experience/exposure and required expertise/skill to complete the tasks. Human Resources should also include supporting to be engaged in data entry and preparation of the reports.

v. Tools and Methodologies- the technical proposal must detail tools and methodology that will be used to carryout the study. Major task of the study would involve compilation of various data from published reports according to given format of the 64 districts. In certain cases, it may be necessary to undertake field studies. Field study data are to be authenticated by providing GIS and photographic records.

2. Financial Proposal

The financial proposal shall specify a total delivery amount (in BDT) including all fees and associated field studies, data entry, transport, photocopying, organizing 2 seminars for the stakeholders, overhead etc.

I. Evaluation

In response to the RFP, the firm will have to submit a technical proposal as per the terms of reference and a Financial Proposals separately. The selection committee will first evaluate the technical proposal of the institution/firms. Any institutions/firm getting more than 70% of the maximum achievable points (i.e. 49 points) in the technical proposal will considered for financial appraisal, and ultimately therefore, for contracting. The financial proposal will be evaluated based on lowest price. The scoring points for both the evaluations will be 100; the technical evaluation will be based on 70 points and the rest 30 points are to be allocated to bidder proposing lowest price. A cumulative analysis weighted-scoring method will be applied to evaluate the firm. The award of the contract will be made to the tenderer whose offer has been evaluated and determined as:

(a) Responsive/compliant/acceptable with referent to this TOR, and ;

(b) Having received the highest score out of a pre-determined set of weighted technical and financial criteria specific to this solicitation, with the ratio set at 70:30 respectively.

J. Qualification of Successful Contractor

The firm will be invited to submit a detailed proposal of contents of the following guidelines and methodology of presentation along with CVs of consultants under the firm.

Minimum Eligibility Criteria for firm

- Company Profile, which should not exceed fifteen (15) pages, including printed brochures and product catalogues relevant to the goods/services being procured

- Business Licenses – Registration Papers, Tax Payment Certification, etc.

- Latest Audited Financial Statement – income statement and balance sheet to indicate its financial stability, liquidity, credit standing, and market reputation, etc.; (Last two fiscal years)

- Minimum **10** years working experience of the firm in carrying out socio-economic surveys and **impact** studies (Certification of work completion certificate and work order/ Purchase order must submit for the evidence of vendors qualifications).

- Successful completion of at least two (2) similar assignments in the last 5 years with the evidence of Job Completion Certificate/ Work Order/ Purchase Order from competent authority.

- Statement of Satisfactory Performance/work completion certificate from the Top 2 Clients in the past 3 years.

- Written Self-Declaration that the company is not in the UN Security Council 1267/1989 List, UN Procurement Division List or Other UN Ineligibility List.

- **Demonstrated Organizational Capability:**

  (a) Documental evidence of the organization-Brochures, web address, organogram, core professional staffs, supporting field staffs, supporting office staffs etc.
  (b) Logistic capability- office space, computers, transports, study equipment- GPS, camera etc.
  (c) Financial stability (annual turnover of 2016-2017 and the best performing year during last five years. Supported by Audited reports.
  (d) Intellectual capability (list of 5 socio-economic survey projects completed in the recent past arranged in order of ranking (best project first, better second, good third and so on). Please submit documentary proof.

- Capability to mobilize necessary professional experts, supporting staffs, logistic supports, financial resources to carry out the proposed study during schedule time. Applicant should demonstrate its logistical capability (well-equipped office space at Dhaka with necessary facilities).

K. Team Composition and Qualifications

All the team members are expected to be Bangladeshi nationals. International team members are also welcome. CVs of the Team leader and key expert members containing their experiences on relevant issues must be submitted with detailed proposal. Beside that the evaluation team is expected to fulfil the following qualifications.

Minimum Eligibility Criteria for Key Personnel:

Team Leader Qualification:

- Should have at least a bachelor degree (4 years degree) in any of the following disciplines economics/engineering/or any other related field of study from a recognized university; and should have exposure to renewable energy/rural energy/biomass Fuels.
- 10 years experiences in the field of development study/planning/management.
- Among the stated 10 years, 5 years' experience as team leader/deputy team leader of multidisciplinary study/studies.
- Demonstrated experiences to work in a multi-disciplinary (e.g. engineering, technology, science, statistics, agriculture, animal science, forestry, social science etc.) group of experts.

Energy Expert and Deputy Team Leader:

- Should have at least a bachelor degree (4 years degree) in any of the following disciplines Energy Engineering, Chemical Engineering, Electrical Engineering, and Mechanical Engineering from a recognized university.
- 10 years practical experiences in the field of energy policy/planning/studies.
- Practical experiences on management of energy data/energy research.
- Demonstrated experiences to work in a multi-disciplinary (e.g. engineering, technology, science, statistics, agriculture, animal science, forestry, social science etc.) group of experts.

Data Management Expert:

- Should have at least a bachelor degree (4 years degree) in any of the following disciplines Statistics, Computer Science and Engineering from a recognized university.
- 08 years' experience in data management and evaluation.
- Practical experiences in similar project(s) in preparing conceptual and analytical model for data gathering and used for data management.
- Demonstrated experiences to work in a multi-disciplinary (e.g. engineering, technology, science, statistics, agriculture, animal science, forestry, social science etc.) group of experts.

Forestry Expert:

- Should have at least a bachelor degree (4 years degree) in Forestry or any other relevant discipline from a recognized university.
- Should have 10 years practical experiences in the field of forest management/inventory/ research.
- Practical experience in forest inventory and inventory of village woodlots and uses of forest byproducts as fuel.
- Demonstrated experiences to work in a multi-disciplinary (e.g. engineering, technology, science, statistics, agriculture, animal science, forestry, social science etc.) group of experts.

Agricultural Expert:

- Should have at least a bachelor degree (4 years degree) in Agriculture from a recognized university.
- Should have 10 years practical experiences in the field of agricultural extension/management/research.
- Practical experience on assessment of different type of biomass available from agricultural crops consisting of crops and different type of crop residues and their uses.

- Should have demonstrated experiences to work in a multi-disciplinary (e.g. engineering, technology, science, statistics, agriculture, animal science, forestry, social science etc.) group of experts.

Livestock & Poultry Expert:

- Should have at least a 10 Years Degree in Animal Husbandry or 5 Year Degree in Doctor of Veterinary Medicine or 5 Years in Veterinary and Animal Husbandry from recognized university.
- Should have 10 years practical experiences in the field of livestock and animal science-extension/management/research.
- Practical experience on assessment of different type of animal and poultry residues and their uses.
- Should have demonstrated experiences to work in a multi-disciplinary (e.g. engineering, technology, science, statistics, agriculture, animal science, forestry, social science etc.) group of experts.

Municipal Solid Wastes (MSW) and Industrial Expert:

- Should have at least a bachelor degree (4 years degree) in any of the following disciplines Environmental Engineering, Civil Engineering, Chemical Engineering and Mechanical Engineering from a recognized university.
- Should have 10 years practical experiences in the field of wastes management/research.
- Practical experience on assessment of different type of municipal and industrial wastes and their uses.
- Should have demonstrated experiences to work in a multi-disciplinary (e.g. engineering, technology, science, statistics, agriculture, animal science, forestry, social science etc.) group of experts.

Biomass Fuels Expert:

- Should have at least a bachelor degree (4 years degree) in any of the following disciplines Energy Engineering, Chemical Engineering and Mechanical Engineering from a recognized university.
- Should have 10 years practical experiences in the field of combustion, heat transfer and improved stove research related to biomass Fuels.
- Practical experience on assessment of different type of technologies using biomass Fuels (e.g. improve stoves, biogas technology, gasifier, steam power plant)
- Should have demonstrated experiences to work in a multi-disciplinary (e.g. engineering, technology, science, statistics, agriculture, animal science, forestry, social science etc.) group of experts.

L. Institutional Arrangement

The contracted firm will report to the Project Manager (SREPGen) Project, UNDP

The work will be guided and reviewed by SREDA/UNDP Bangladesh.

M. Duration of the Work and Duty Station

The duration of the assignment will be maximum 09 months, expected beginning in April 2018 and finishing by the end of December 2018.

The study should cover the data base of the whole country disaggregated to 64 Districts. The working location (duty station) is Dhaka, would involved traveling to the selected locations of Bangladesh.

Basis of technical Evaluation

(See Tables below)

Summary of Technical Proposal Evaluation Forms		Score Weight	Points Obtainable
1	Expertise of Firm / Organization	20%	200
2	Proposed Methodology, Approach and Implementation Plan	40%	400
3	Management Structure and Key Personnel	40%	400
	Total		**1000**

Criteria	Weight	Max. Points
Technical	70%	
1. Overall experience and Expertise of the organization/Firm (Form1)		**200**
Organization Reputation and staff credibility and Years of Establishment as a firm-		50
Financial stability (annual turnover for the period of 2016 and 2017)		80
Relevant Experience on Similar Program / Projects		30
Experience on *Climate change mitigation/ renewable energy/ alternative options biomass Fuels*		20
Experience on working with UN organization/ World Bank/ Other international agencies		20
2. Methodology proposed in the technical proposal (Form 2)		**400**
Understanding of the deliverables related to the Terms of Reference		130
Appropriateness and relevance of tools and methodology		90
Risk Management & Overall flexibility		80
Proposed work plan and timeline relevant to the assignment as per the Terms of Reference		100
3. Expertise of Key personnel (Form3)		**400**
Relevant experience of Team Leader:		60
Relevant experience of Energy Expert & Deputy Team Leader		50
Relevant experience of Data Management Expert		40
Relevant experience of Forestry Expert		50
Relevant experience of Agriculture Expert		50
Relevant experience of Livestock & Poultry Expert		50
Relevant experience of Municipal Solid Wastes (MSW) & Industrial Wastes Expert:		50
Relevant experience of Biomass Fuels Expert:		50

Payment Schedule:

1st Tranche: 20% of the total contract value will be paid after submission of an Inception Report (3 printed copies) within 3 weeks after the signing of agreement on 20 March 2018.

2nd Tranche: 30% of the total contract value will be paid after submission of Mid-Term Report (3 printed copies) after completion of Phase-I & Phase-II and the report will be presented in a workshop for discussion with the stakeholders. Transfer all the data and software to persons selected by SREDA. 15 July 2018

3rd Tranche: 25% of the total contract value will be paid after submission of Draft Final Report after completion of Phase-III. On Assessment of the Availability and Use of Biomass fuels for Various End-Uses with Special attention to Power Generation. Draft contents of the report will have to be prepared in consultation with the clients. Three volumes of printed & bound copies and soft copies will have to be submitted. The draft reports will be presented in a workshop for discussion with the stakeholders. Transfer all the data and software to persons selected by SREDA.14 October 2018

4th Tranche: 25% of the total contract value will be paid after submission of three volumes of Final Report (printed & bound copies and soft copies) within 5 weeks by incorporating the comments receive from the stakeholders. 20 December 2018

Annexure-I

Table I.1: Status of Biomassfuels in Selected Developed and Developing Countries in 2015

Column 1: Name of the country
Column 2: Area of the country
Column 3: Area covered by tree resources
Column 4: Area covered by Agricultural Crops (net/total cropped area)
Column 5: Supply of BF
Column 5.1: Tree Residues
Column 5.2: Agricultural Residues
Column 5.3: Animal Residues
Column 6: Biomassfuels
Column 6.1: Amount of BF used for heating
Column 6.2: Amount of BF used for power generation
Column 6.3: BF based Installed power plants (MW)
Column 6.4: Amount of Power generated (GWh) by using BF

Table I.2: Contribution of Biomassfuels in Selected Developed and Developing Countries in 2015

Column 1: Population
Column 2: Per capita GNI (US$ per person)
Column 3: Primary Energy Mix
Column 3.1: Fossil Fuels
Column 3.1.1: Coal
Column 3.1.2: Oil
Column 3.1.3: Natural Gas
Column 3.2: Renewable Energy Sources
Column 3.2.1: Hydropower
Column 3.2.2: Wind
Column 3.2.3: Solar
Column 3.2.4: Nuclear
Column 3.2.5: Biomassfuels
Column 3.3: Total Primary Energy
Column 3.4: BF percent in total primary energy

Table I.3: Fuel Mix for Power Generation in Selected Developed and Developing Countries in 2015.

Column 1: Total Energy Used for Power generation
Column 2: Percent of total Primary Energy used for power generation
Column 3: Energy Mix for power generation
Column 3.1: Power generated by Fossil Fuels
Column 3.2: Power generated by Renewable Energy Sources
Column 3.2.1: Power generated by Hydropower
Column 3.2.2: Power generated by Wind Resources
Column 3.2.3: Solar Power
Column 3.2.4: Nuclear Power
Column 3.2.5: Power generated by BF
Column 3.3: Total Power Generated
Column 3.4: Power Generated by BF as % of total generated power

Table 1.4: Districtwise Data on Supply of Biomassfuels (Tree Residues/ Agriculture Residues/Animal Residues/Municipal Solid Wastes) and Their Demand for Different End-Uses.

Serial No. of District	Division/District	Number of BG Plants
	(1) Barisal Division	
01	Barguna	
02	Barisal	
03	Bhola	
04	Jhallokati	
05	Patuakhali	
06	Pirojpur	
	(2) Chittagong Division	
07	Bandarban	
08	Brahmanbaria	
09	Chandpur	
10	Chittagong	
11	Comilla	
12	Cox's Bazar	
13	Feni	
14	Khagrachari	
15	Lakshmipur	
16	Noakhali	
17	Rangamit	
	(3) Dhaka Division	
18	Dhaka	
19	Faridpur	
20	Gazipur	
21	Gopalgonj	
22	Jamalpur	
23	Kishorganj	
24	Madaripur	
25	Manikgonj	
26	Munshiganj	
27	Mymensingh	
28	Narayanganj	
29	Narshingdi	
30	Netrakhona	

Serial No. of District	Division/District	Number of BG Plants
31	Rajbari	
32	Shariatpur	
33	Sherpur	
34	Tangail	
	(4) Khulna Division	
35	Bagherhat	
36	Chuadanga	
37	Jessore	
38	Jhenaikah	
39	Khulna	
40	Kustia	
41	Magura	
42	Meherpur	
43	Narail	
44	Satkhkhira	
	(5) Rajshahi Division	
45	Bogra	
46	Joypurhat	
47	Naogaon	
48	Natore	
49	Chapai Nawabganj	
50	Pabna	
51	Rajshahi	
52	Sirajganj	
	(6) Rangpur Division	
53	Dinajpur	
54	Gaibandha	
55	Kurigram	
56	Lalmonirhat	
57	Nilphamari	
58	Panchagar	
59	Rangpur	
60	Thakurgaon	
	(7) Sylhet Division	
61	Habiganj	
62	Maulavibazar	
63	Sunamganj	
64	Sylhet	

Table I.5: Heating Values (Lower Heating Values) of Fossil fuels and Traditional Fuels

Fossil fuels			
Fuel Type	**Btu/lb**	**kcal/kg**	**GJ/t**
Crude Oil	18350	10200	42.7
Motor Spirit	20500	11390	47.7
Kerosene	19800	11000	46.1
High Speed Diesel	90200	10600	44.7
Light Diesel Oil	18500	10250	43
Fuel Oil	18000	10000	41.9
Coal (Imported India)	10500	5830	24.4
Coal (Jamalganj)	11600	6450	27
Coal (Barapukuria)			
Peat	6000	3330	13
Methanol	8640	4800	20.1
LPG	20500	11390	47.7
LNG	22700	12600	52.8
Natural Gas	941Btu/scf	990/kJ/scf	0.0351GJ/cum
Traditional Fuels			
Fuel Type	**Btu/lb**	**kcal/kg**	**GJ/t**
Charcoal	12000	6670	27.9
Firewook (20% moisture)	6500	3600	15.1
Twigs & leaves	5400	3000	12.5
Bagasse (50% moisture)	3200	1780	7.5
Bagasse (20% moisture)	6480	3600	15.1
Rice and Wheat Straw	5400	3000	12.5
Rice Husk & Bran	5400	3000	12.5
Jute Sticks	5400	3000	12.5
Animal Dung (Air Dried)	5000	2780	11.6
Other agricultural Residues	5400	3000	12.5

Source: Bangladesh Energy Planning Project, Volume-I

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