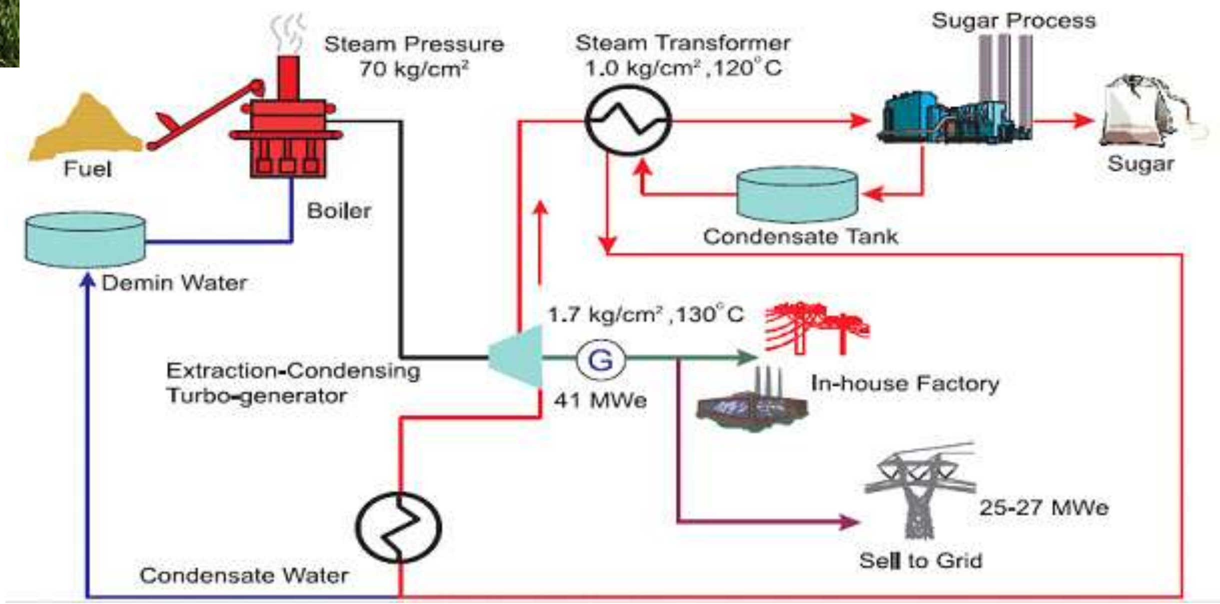
SOUTH ASIAN ASSOCIATION FOR REGIONAL COOPERATION

STUDY ON

COGENERATION OPPORTUNITIES IN SUGAR AND PAPER INDUSTRIES IN SAARC MEMBER STATES



SAARC ENERGY CENTRE

ISLAMABAD

2013

SOUTH ASIAN ASSOCIATION FOR REGIONAL COOPERATION

STUDY ON

COGENERATION OPPORTUNITIES IN SUGAR AND PAPER INDUSTRIES IN SAARC MEMBER STATES

SAARC ENERGY CENTRE

ISLAMABAD

2013

Table of Contents

EXECUTIVE SUMMARY 1

LIST OF ABBREVIATIONS 3

1 INTRODUCTION 1

1.1 Background 1
1.2 Objectives 2
1.3 Methodology 2
1.4 Scope of work 2

2 PART A: COGENERATION 3

2.1 Concept of Cogeneration 3
2.1.1 Principles of Cogeneration 3
2.1.2 Important Technical Parameters for Cogeneration 5
2.2 International Best Practices 7
2.2.1 United States of America 7
2.2.2 Denmark 8
2.2.3 France 9
2.2.4 Spain 9
2.2.5 United Kingdom 10
2.2.6 Japan 10
2.2.7 Republic of Korea 11
2.3 Regional Best Practices 11
2.3.1 Thailand 12
2.3.2 Indonesia 12
2.3.3 Philippines 13
2.4 Operational Processes of the Target Industries 14
2.4.1 Sugar Industry 14
2.4.2 Pulp and Paper Industry 16
2.5 Economic Drivers 19
2.6 Environmental Benefits - CDM 21

3 PART B: SUGAR INDUSTRY 24

3.1 Bangladesh 24
3.1.1 Industry Structure 24
3.1.2 Current Cogeneration Situation 26
3.1.3 Cogeneration Potential 29
3.1.4 Institutional Facilitators 39
3.1.5 Government Initiatives and Legal Frameworks 39
3.1.6 Barriers and Constraints 39
3.1.7 Cost Benefit Analysis 42
3.1.8 Recommendations 42
3.2 India 44
3.2.1 Industry Structure 45
3.2.2 Current Cogeneration Situation 46
3.2.3 Cogeneration Potential 47
3.2.4 Institutional Facilitators 50
3.2.5 Government Initiatives and Legal Frameworks 51

3.2.6 Barriers and Constraints 53
3.2.7 Cost Benefit Analysis 56
3.2.8 Recommendations 59

3.3 Pakistan 61

3.3.1 Industry Structure 61
3.3.2 Current Cogeneration Situation 61
3.3.3 Cogeneration Potential 62
3.3.4 Institutional Facilitators 67
3.3.5 Government Initiatives and Legal Frameworks 67
3.3.6 Barriers and Constraints 67
3.3.7 Cost Benefit Analysis 69
3.3.8 Recommendations 70

3.4 Sri Lanka 71

3.4.1 Industry Structure 71
3.4.2 Current Cogeneration Situation 72
3.4.3 Cogeneration Potential 73
3.4.4 Institutional Facilitators 73
3.4.5 Government Initiatives and Legal Frameworks 73
3.4.6 Barriers and Constraints 74
3.4.7 Cost Benefit Analysis 74
3.4.8 Recommendations 74

4 PART C: PULP AND PAPER INDUSTRY 75

4.1 Bangladesh 75

4.1.1 Industry Structure 75
4.1.2 Current Cogeneration Situation 75
4.1.3 Cogeneration Potential 75
4.1.4 Institutional Facilitators 76
4.1.5 Government Initiatives and Legal Frameworks 76
4.1.6 Barriers and Constraints 76
4.1.7 Cost Benefit Analysis 77
4.1.8 Recommendations 77

4.2 India 78

4.2.1 Industry Structure 79
4.2.2 Current Cogeneration Situation 80
4.2.3 Cogeneration Potential 80
4.2.4 Institutional Facilitators 81
4.2.5 Government Initiatives and Legal Frameworks 81
4.2.6 Barriers and Constraints 82
4.2.7 Cost Benefit Analysis 82
4.2.8 Recommendations 83

4.3 Pakistan 84

4.3.1 Industry Structure 84
4.3.2 Current Cogeneration Situation 86
4.3.3 Cogeneration Potential 87
4.3.4 Institutional Facilitators 87
4.3.5 Government Initiatives and Legal Frameworks 87
4.3.6 Barriers and Constraints 87
4.3.7 Cost Benefit Analysis 87
4.3.8 Recommendations 87

4.4 Sri Lanka 89

4.4.1 Industry Structure 89
4.4.2 Current Cogeneration Situation 89

4.4.3 *Cogeneration Potential* 89
4.4.4 *Institutional Facilitators* 89
4.4.5 *Government Initiatives and Legal Frameworks* 90
4.4.6 *Barriers and Constraints* 90
4.4.7 *Cost Benefit Analysis* 90
4.4.8 *Recommendations* 91

5 PART D: SUMMARY AND RECOMMENDATIONS 92

5.1 Summary of Cogeneration Situation and Potential 92

5.2 Recommendations and Way Forward 94

5.2.1 *Recommendations* 94
5.2.2 *Way Forward* 95

5.3 Conclusions 97

List of Annexures

Annex A: List of Reference Documents 99

List of Tables

Table 3.1: Sugar Mills with year of installation & crushing capacity (ton/day) 25
Table 3.2: Comparison of Generators and Transformer for the selected Sugar Mills 36
Table 3.3: Comparison of Boilers for the selected Sugar Mills 37
Table 3.4: Comparison of Turbines for the selected Sugar Mills 37
Table 3.5: Results of analysis for different options with coal as the fuel 38
Table 3.6: State wise Potential for Exportable Surplus Electricity 48
Table 3.7: Estimated Co-generation @ 6000 Tons per day Cane Crushing Rate 63
Table 3.8: Estimated Co-Generation @ 9600 Tons per day Cane Crushing rate 64
Table 3.9: Bagasse Balance 64
Table 3.10: Electricity Generation cost by different sources 65
Table 5.1: Summary of Cogeneration Situation and Potential 92

List of Figures

Figure 2.1: Combined Cycle Topping System 3
Figure 2.2: Steam Turbine Topping System 4
Figure 2.3: Gas Engine Topping System 4
Figure 2.4: Gas Turbine Topping System 5
Figure 2.5: Steam Turbine Bottoming System 5
Figure 2.6: Sugarcane Processing Flowchart 15
Figure 2.7: Overview of Bagasse Cogeneration 16
Figure 2.8: Overview of Cogeneration in Paper Mills 19
Figure 3.1: Sugar Mills of Bangladesh under BSFIC 26
Figure 3.2: Steam and Condensate Flow Diagram 29
Figure 3.3: Map of Natore district showing the location of North Bengal Sugar Mill 31
Figure 3.4: Map of Rajshahi district showing the location of Rajshahi Sugar Mill 32
Figure 3.5: Map of Joypurhat district indicating the position of Joypurhat Sugar Mills 33
Figure 3.6: Map of Jhenaidah district showing the location of Mobarakgang Sugar Mill 34
Figure 3.7 : Map of Rangpur district showing the location of Shampur Sugar Mill 35
Figure 3.8: Showing state wise sugarcane production in India 44
Figure 3.9: Showing location of Sugar Mills of India 45
Figure 4.1: Indian Map Identified the Location of Paper Mills 78
Figure 4.2: Paper Manufacturing in Pakistan 84
Figure 4.3: Eucalyptus trees in Pakistan- Source of Raw material Paper Pulp 85
Figure 4.4 : Wheat Straw used in enrichment in Pakistan. 86
Figure 5.1: Flow Chart of Cogeneration Implementation Strategy 96

EXECUTIVE SUMMARY

Industrial sectors including sugar and pulp and paper mills are increasingly adopting cogeneration units and are acquiring substantial benefits from such facilities.It is observed that bagasse, fibrous residue remaining after the extraction of juice from sugarcane, typically has been used as an input to produce electricity and steam in sugar mills of South Asia. However, most of the mills have not attained true energy potential of bagasse because of outdated equipment, using conventional thermal steam technologies. Wood waste and sludge collected as residues from these industries are converted to useful thermal energy by burning in industrial boilers to generate electricity and steam for many years reducing requirement of energy sources.

This report commissioned by the SAARC Energy Centre (SEC) has been prepared based on desk studies collecting data, information, reports, papers, etc. as required in the context of the ToR. Some observations presented in the report are made extracting relevant information from available studies conducted earlier by different experts, institutions, etc.

The results of the study for the four SAARC Member states studied are summarized below:

<u>Bangladesh</u>

- All the sugar mills have cogeneration facilities while these mills are operating in the crushing season for 150 days. With the bagasse available, cogeneration potential can produce over **100 MW** round the year.
- The pulp and paper industry has about 35 MW being generated from cogeneration and this is expected to increase to more than **50 MW**.

<u>India</u>

- Sugar mills cogenerate their own requirements of steam and power while surplus is being sold to grid. The potential for cogeneration in the sugar industry is estimated to over **5,000 MW**.
- Paper mills are using agro-industrial residue based cogeneration to meet all their energy requirements and the cogeneration potential has been estimated to be about **750 MW**.

<u>Pakistan</u>

- All operating sugar mills have potential to produce excess electricity and the potential from these mills has been estimated around **1,000 MW** and if coal is added as an alternative/additional fuel, this may go up to 2,000 MW**.**
- It is estimated that total potential in the pulp and paper sector will range between **200 MW** to **300 MW** provided majority of paper mills install cogeneration plant

<u>Sri Lanka</u>

- Information on cogeneration was not readily available.

Collection of information/data on sugar industry for Bangladesh, India and Pakistan was available for analysis but for Sri Lanka it was not possible due to unavailability of required information. Similarly for paper industry information for Bangladesh and India was available but for Pakistan and Sri Lanka, information was not available. Unavailability of information/data limited the scope of analysis required for presenting cogeneration situation and potential along with barriers and constraints regarding Pakistan in Paper Industry and Sri Lanka for both sugar and paper industries.

Since cogeneration development seems to be very promising, the hurdles (institutional structure, policy and planning, energy pricing and tariff, investment and financing etc.) in this sector may be reviewed for its further propagation. Regulatory measures are needed for the sale of excess electricity to the grid or third party, and back-up power supply from the grid as and when necessary.

Co-ordination among the users, suppliers, financiers, developers, etc., is very important and there is a need to have a facilitator or an intermediary body. Cogeneration promotion activities should be combined with energy conservation and efficiency activities. SAARC Energy Centre (SEC) may take the responsibility of 'Facilitator' towards promotion of cogeneration within the SAARC region, by arranging seminars/workshops for awareness about opportunities and potential of each country to others. They may come up with the assistance of India (as they are experienced in this region) for bilateral and international support for setting up cogeneration demonstration projects using recent technologies in various sectors of activities in order to achieve rational use of energy within the country and the region.

The development of cogeneration is basically a policy issue, and therefore, the first prerequisite is an establishment of ideal policy framework. There should be certain regulations that clearly define the cogeneration system by specifying the fuel to be used, energy efficiency, minimum or maximum ratio of heat to power, etc. Regulations should allow the purchase and sale of power between cogenerators and electric utilities. The obligations and rights of cogenerators and electricity utilities must be clearly defined as well as the interaction between them. Overall, a suitable investment climate should be created in order to attract local and foreign investment into the field of cogeneration.

LIST OF ABBREVIATIONS

ABT	:	Availability Based Tariff
ADB	:	Asian Development Bank
AEDB	:	Alternative Energy Development Board, Pakistan
AP	:	Andhra Pradesh
BCIC	:	Bangladesh Chemical Industries Corporation
BUET	:	Bangladesh University of Engineering And Technology
CAA	:	Clean Air Act, USA
CEA	:	Clean Energy Alternatives
CEB	:	Ceylon Electricity Board
CERC	:	Central Electricity Regulatory Commission
CES	:	Centre for Energy Studies
CHP	:	Combined Heat And Power
CO_2	:	Carbon Dioxide
DOE	:	The Department of Energy, USA
EMCC	:	Energy Monitoring And Conservation Centre
ESCAP	:	Economical Social Cooperation in Asia Pacific
GHG	:	Greenhouse Gases
GJ	:	Gujarat
GWh	:	Gigawatt Hour
HP	:	Himachal Pradesh
HUDCO	:	Housing and Urban Development Corporation Limited
ICICI	:	Industrial Credit and Investment Corporation of India Limited
IPP	:	Independent Power Producer
IREDA	:	The Indian Renewable Energy Development Agency Limited
IRR	:	Internal Rate of Return
J&K	:	Jammu And Kashmir
KA	:	Karnataka
KNM	:	Khulna News Mills
KPML	:	Karnaphuly Paper Mills Limited
KR	:	Kerala
MERCs	:	Maharashtra Electricity Regulatory Commissions
MH	:	Maharashtra
MNES	:	Ministry of Non-Conventional Energy Sources
MNRE	:	Ministry of Non-Renewable Energy
MW	:	Megawatt
NBPM	:	North Bengal Paper Mill
NE	:	North Eastern States

NEPRA	:	National Electric Power Regulatory Authority
NPV	:	Net Present Value
O&M	:	Operation and Maintenance
OR	:	Orissa
PBP	:	Pay Back Period
PEC	:	Power Finance Corporation Limited
PIDC	:	Pakistan Industrial Development Corporation
PPIB	:	Private Power And Infrastructure Board
REC	:	Rural Electrification Corporation of India Limited
SAARC	:	South Asian Association for Regional Cooperation
SDF	:	Sugar Development Fund
SEB	:	State Electricity Board
SEC	:	SAARC Energy Centre
SERC	:	State Electricity Regulatory Commission
SPP	:	Small Power Producer
SPPA	:	Standardized Power Purchase Agreement
SPPM	:	Sylhet Pulp And Paper Mill
SSEA	:	Sri Lanka Sustainable Energy Authority
TG	:	Turbine Generators
TN	:	Tamil Nadu
UA	:	Uttaranchal
UIT	:	Unexpected Interchange Tariff
UNDP	:	United Nations Development Program
UNESCO	:	United Nations Educational, Scientific and Cultural Organization
UNICEF	:	United Nations International Children's Emergency Fund
USAID	:	U.S. Agency for International Development
WB	:	West Bengal
WTO	:	World Trade Organization

1 INTRODUCTION

1.1 Background

A cogeneration system is the sequential or simultaneous generation of multiple forms of useful energy (usually mechanical and thermal) in a single, integrated system. Mechanical energy, generated from the system, is typically used for driving electrical generators to produce electricity, or to rotate equipment such as motors, compressors, pumps as required to run an industry. On the other hand, thermal energy produced from the system can be used directly for processing applications or indirectly to produce steam, hot water, hot air for dryer or chilled water for process cooling. Similarly, industries integrating cogeneration system produces thermal energy for industrial processes, space heating, water heating, dehumidification, refrigeration and air conditioning. Air conditioning and refrigeration is carried out through the use of commercially available absorption chillers requiring either low-pressure steam or hot water.

Cogeneration provides a wide range of technologies for application in various domains of economic activities. The major benefit of cogeneration is that it offers the potential for achieving substantial energy cost savings. Overall energy conversion efficiencies greater than 80% are typical for many existing industrial cogeneration systems. This compares to an overall conversion efficiency of 30 to 40% for conventional power generating systems, which reject heat directly into the environment. Along with the saving of fossil fuels, cogeneration also allows reduction of emission of greenhouse gases (particularly CO_2 emission) per unit of useful energy output. It makes power available closer to load centers and improves reliability of the electrical energy supply by adding generation capacity. The production of electricity being on-site, the burden on the utility network is reduced and the transmission line losses eliminated. As a result, industrial cogeneration operators can realize revenues from the sale of surplus electricity to the electrical grid and/or from the sale of surplus steam and hot water to neighboring users.

It is observed that bagasse, fibrous residue remaining after the extraction of juice from sugarcane, typically has been used as an input to produce electricity and steam in sugar mills of SAARC region. However, most of the mills have not attained true energy potential of bagasse because of outdated equipment using conventional thermal steam technologies.

In pulp and paper industries, wood waste and sludge collected as residues are burned in boilers reducing requirement of other energy sources.

In early days, most of cogeneration systems failed in industries such as sugar mills or pulp and paper mills. The reason was that the industries were purposely designed with lower efficiency for cogeneration in order to get rid of all the wastes produced. However, the interest in cogeneration revived because of rapidly increasing demand for electricity, constraints faced by the national authorities to finance additional power generating capacities, and the growing concern to limit the environmental emissions associated with the use of energy. Cogeneration is presently being recommended when there is plan for expansion of existing facilities, development of new industrial zones, replacement of outdated steam generation systems, or when the cost of energy is high and there is scope for selling power.

1.2 Objectives

The main objective of this study is to review existing cogeneration potential in sugar and pulp & paper industries in four SAARC member countries with a view to assess the current cogeneration situation, potential, government initiatives and legal framework. The study also covers the technical aspects, economic drivers and environmental benefits, barriers and constraints and proposes the way forward for the implementation of cogeneration in SAARC member states.

1.3 Methodology

A detailed country-wise review of available reports and literatures related to cogeneration in sugar and pulp & paper industries was carried out by contacting relevant web sites, authors and peers. As it was a desk-top study, the consultant paid visits to the concerned government agencies/corporations, mills owners association, academic institutions & academicians as well as donor agencies like the World Bank, ADB, UNESCO, ESCAP, UNICEF, etc only in Bangladesh; but for Pakistan, India and Sri Lanka, the method was to visit websites, telephone calls and email correspondences with similar types of agencies.

This report has been prepared based on the data, information, reports, papers, etc. as mentioned above. Some observations presented in the report are made extracting relevant and taking pertinent information from the available studies conducted earlier by different experts, institutions, etc.

1.4 Scope of work

The study will cover, but not be limited to, the following aspects:

a) Analyze the potential, technical aspects, economic drivers and environmental benefits for cogeneration in sugar and pulp & paper industries;

b) Identify the barriers and constraints in implementation of cogeneration in SAARC member states;

c) Cost benefit analyses for improving the efficiency of existing plants and replacing inefficient machineries with the new efficient technology options for cogeneration in sugar and pulp & paper industries;

d) Review the government initiatives and, legal framework for energy cogeneration in SAARC Member States;

e) Review of regional and international best practices in energy cogeneration;

f) Recommend the way forward for successful implementation of Cogeneration in sugar and pulp & paper industries in SAARC member states.

2 PART A: COGENERATION

2.1 Concept of Cogeneration

2.1.1 Principles of Cogeneration

Cogeneration or combined heat and power (CHP) is defined as the sequential generation of two different forms of useful energy from a single primary energy source, typically mechanical energy and thermal energy. Mechanical energy may be used to drive an alternator for producing electricity, or rotating equipment such as motor, compressor, pump or fan for delivering various services. Thermal energy can be used either for direct process applications or for indirectly producing steam, hot water, hot air for dryer or chilled water for process cooling.

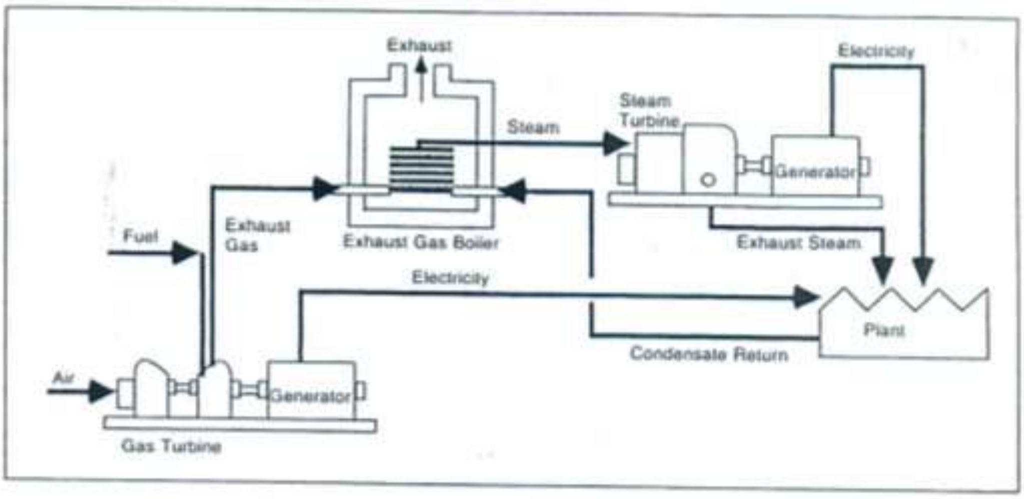
There are two basic cogeneration configurations or operating cycles depending on whether mechanical/electrical power is produced before or after heat is extracted for thermal application.

The system in which electrical power is produced first, followed by extraction of heat, is known as a topping cycle and the system in which thermal energy is produced first followed by producing electricity is known as bottoming cycle.

<u>Topping Cycle</u>

The primary fuel is used to produce electricity and the thermal energy exhaust is used for process heating. Topping cycle cogeneration is widely used and is the most popular method of cogeneration. A gas turbine or diesel engine producing electrical or mechanical power followed by a heat recovery boiler to create steam to drive a secondary steam turbine.

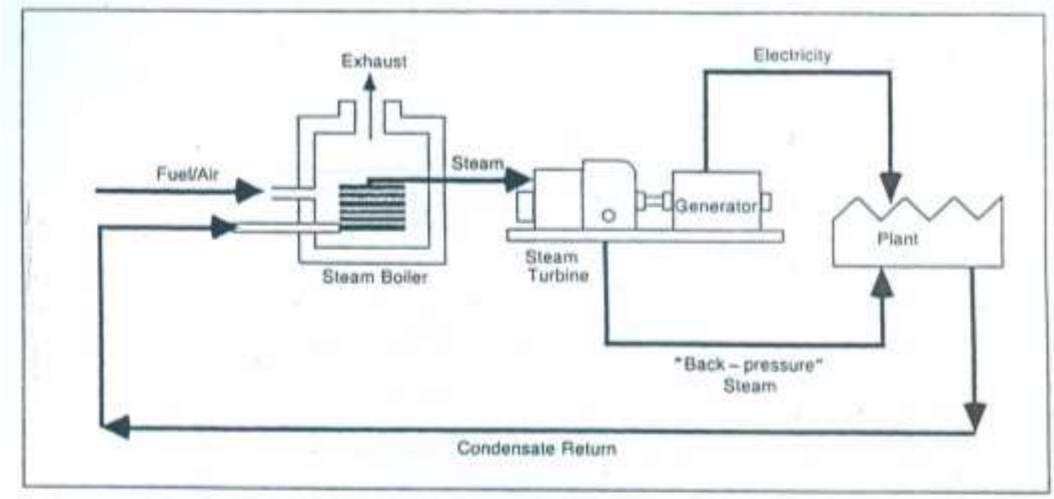
Figure 2.1: Combined Cycle Topping System



Steam-Turbine Topping System

The second type of system burns fuel (any type) to produce high-pressure steam that passes through a steam turbine to produce power, with the exhaust providing low-pressure process steam used in the plant.

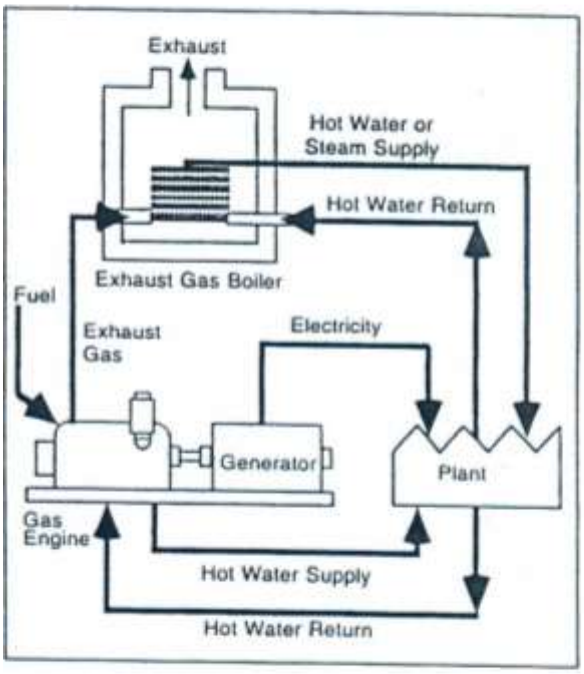
Figure 2.2: Steam Turbine Topping System



Gas Engine Topping System

A third type employs heat recovery from an engine exhaust and/or jacket cooling system flowing to a heat recovery boiler, where it is converted to process steam / hot water for further use.

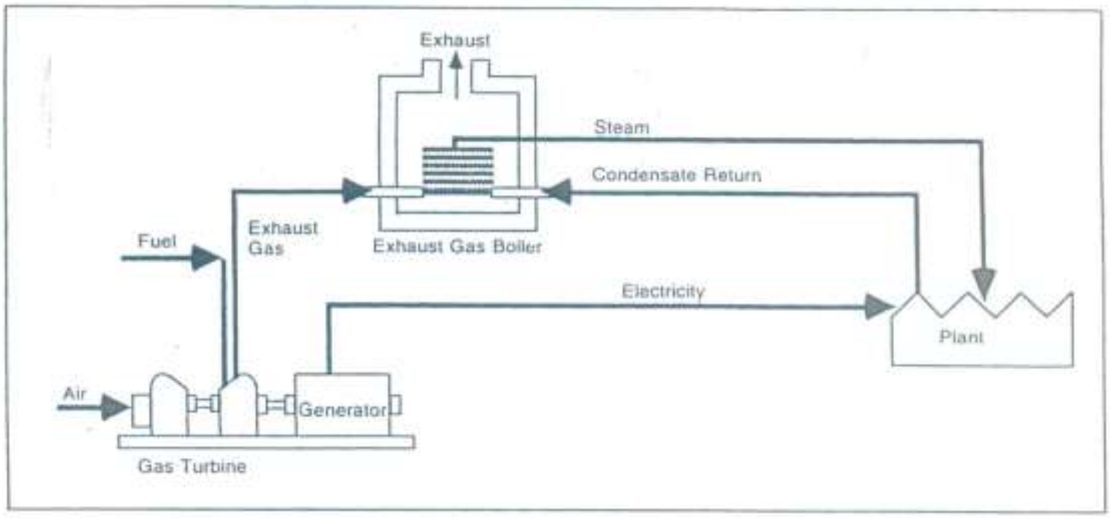
Figure 2.3: Gas Engine Topping System



Gas-Turbine Topping System

A natural gas turbine drives a generator. The exhaust gas goes to a heat recovery boiler that makes process steam and process heat.

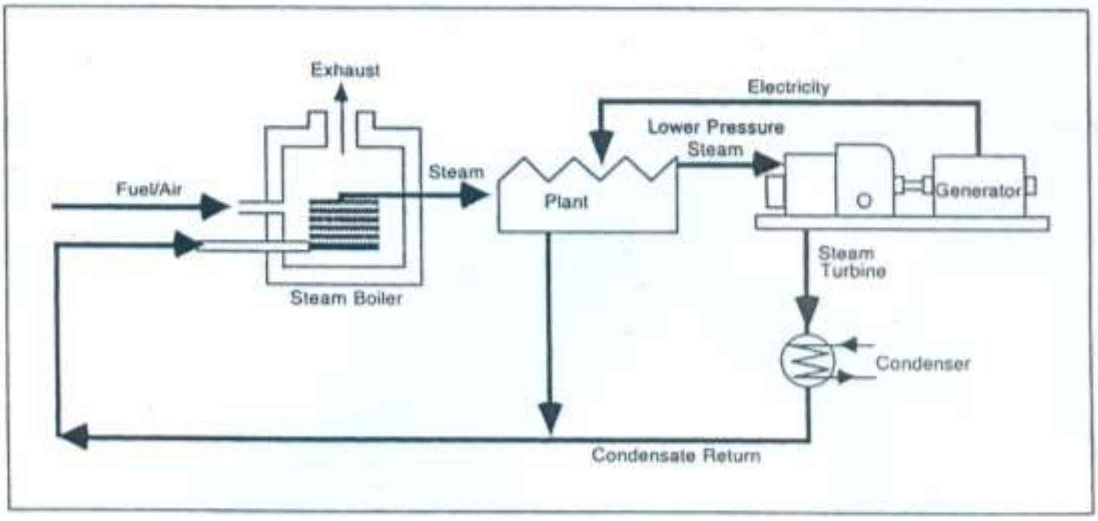
Figure 2.4: Gas Turbine Topping System



Bottoming cycle

The primary fuel is used to produce high temperature steam that is used in the process plant. The lower pressure exhaust steam is subsequently used to produce electrical energy through waste heat boiler and turbine generator system. Bottoming cycles are suitable for manufacturing processes that require heat at high temperature in furnaces and kilns, and reject heat at significantly high temperatures.

Figure 2.5: Steam Turbine Bottoming System



2.1.2 *Important Technical Parameters for Cogeneration*

While selecting cogeneration systems, one should consider some important technical parameters that assist in defining the type and operating scheme of different alternative cogeneration systems to be selected.

Heat-to-power ratio

Heat-to-power ratio is one of the most important technical parameters influencing the selection of the type of cogeneration system. The heat-to-power ratio of a facility should match with the characteristics of the cogeneration system to be installed.

It is defined as the ratio of thermal energy to electricity required by the energy consuming facility.

Quality of thermal energy needed

The quality of thermal energy required (temperature and pressure) also determines the type of cogeneration system. For a sugar mill needing thermal energy at about 120°C, a topping cycle cogeneration system can meet the heat demand. On the other hand, for a cement plant requiring thermal energy at about 1450°C, a bottoming cycle cogeneration system can meet both high quality thermal energy and electricity demands of the plant.

Load patterns

The heat and power demand patterns of the user affects the selection (type and size) of the cogeneration system.

Fuels available

The availability of cheap fuels or waste products that can be used as fuels at a site is one of the major factors in the technical consideration because it determines the competitiveness of the cogeneration system.

A rice mill needs mechanical power for milling and heat for paddy drying. If a cogeneration system were considered, the steam turbine system would be the first priority because it can use the rice husk as the fuel, which is available as waste product from the mill.

System reliability

Some energy consuming facilities require very reliable power and/or heat; for instance, a pulp and paper industry cannot operate with a prolonged unavailability of process steam. In such instances, the cogeneration system to be installed must be modular, i.e. it should consist of more than one unit so that shut down of a specific unit cannot seriously affect the energy supply.

Grid dependent system versus independent system

A grid-dependent system has access to the grid to buy or sell electricity. The grid independent system is also known as a “stand-alone” system that meets all the energy demands of the site. It is obvious that for the same energy consuming facility, the technical configuration of the cogeneration system designed as a grid dependent system would be different from that of a stand-alone system.

Retrofit versus new installation

If the cogeneration system is installed as a retrofit, the system must be designed so that the existing energy conversion systems, such as boilers, can still be used. In such a circumstance, the options for cogeneration system would depend on whether the system is a retrofit or a new installation.

Electricity buy-back

The technical consideration of cogeneration system must take into account whether the local regulations permit electric utilities to buy electricity from the cogenerators or not. The size and type of cogeneration system could be significantly different if one were to allow the export of electricity to the grid.

Local environmental regulation

The local environmental regulations can limit the choice of fuels to be used for the proposed cogeneration systems. If the local environmental regulations are stringent, some available fuels cannot be considered because of the high treatment cost of the polluted exhaust gas and in some cases, the fuel itself.

2.2 International Best Practices

There is no standard procedure or method to gather reliable and up-to-date data on cogeneration-based power generation and installed capacity in each country on a basis comparable with the others. Based on data available in literature, north European countries are presently the leaders in the field of cogeneration, having between 30 to 40% of their power generating capacities as cogeneration. In the case of the European Union of 15 countries, cogeneration represented more than 15 per cent of the total gross electricity generation and countries like Denmark, Finland and the Netherlands far exceed the others. Next in line are the central European countries and China, which have an average of 10 to 15%. The United States has less than 10% of electricity coming from cogeneration whereas the figure for Australia is just over five per cent. Worldwide trends indicate that a significant increase in cogeneration is likely to occur over the next 20 years. There is a general consensus that the importance of cogeneration technology is linked with its potential for rendering higher energy efficiency, more stable energy supply, and reduced environmental impact.

In many industrialized countries, cogeneration is playing an increasingly important role in industry and in the residential and service sector. It is being perceived not as a competitor to the conventional power generation system, but as an advanced technology that can be applied to hospitals, hotels, shops and offices. Another area where cogeneration has become popular is the district heating network, and more recently district cooling in tropical climates.

Cogeneration experiences of selected countries around the world, focusing mainly on the United State of America and Europe where cogeneration is better organized and data for most countries are more easily accessible are summarized below:

2.2.1 *United States of America*

The United States of America has been widely recognized as the first country for having set up policy for promoting cogeneration. The Public Utility Regulatory Policies Act of 1978 was signed into law in November 1978. Enacted as part of a package of legislation to combat the "energy crisis," and the perceived shortage of natural gas, primary purposes of the policy were to promote conservation (through cogeneration of both steam and electricity) and to encourage greater use of alternative sources of power generation.

Cogeneration is now used extensively by several energy-intensive industries, including pulp and paper, chemicals, and petroleum refining. Following are the developments that have renewed interests of both government and industry in expanding cogeneration applications to other industries as well as other sectors of the economy. Recent advances in technologies such as combustion engines, steam turbines, reciprocating engines, fuel cells, and heat-recovery equipment have decreased the cost and improved the performance of cogeneration systems;

Although the technical performance and costs of cogeneration systems have improved, there are significant barriers to their widespread use, which include the following aspects:

a) Environmental permission for cogeneration systems where current environmental regulations do not recognize the overall energy efficiency of cogeneration, or credit the emissions avoided from displaced electricity generation;
b) Utility policies for utilities currently charge backup rates and require complex interconnection arrangements for cogeneration systems; and
c) Tax Policies on depreciation schedules for cogeneration investments.

The Department of Energy (DOE) is undertaking its efforts in co-ordination with the United States of Environmental Protection Agency, which is focusing on environmental permit issues such as application of output based emissions standards to CHP systems, and the inclusion of cogeneration as a strategy in State Implementation Plans for the Clean Air Act.

2.2.2 *Denmark*

Cogeneration was widely used in large towns by the end of 1980 and fresh initiatives were taken in 1986 to develop around 450 MW of small scale cogeneration programmes in about 300 small towns with the power utilities playing a major role. In 1988, guidelines were issued by the Ministry of Energy, which required all municipalities to ban the use of electric heating in new buildings in areas having collective heat supply facilities.

By the end of 1993, utility generation accounted for 29,782 GWh of electricity and 19,546 GWh of heat. The energy efficiency of conversion was 58 per cent that would have been 40.3 per cent without cogeneration. Non-utility cogeneration accounted for only 607 GWh of production. On the whole, over 10 per cent of fuel is saved through cogeneration in Denmark. This figure is a little low because of the low load factor, i.e. cogeneration plants often operate in non-cogeneration mode due to the low heat demands. Heat from cogeneration plants accounted for 64 per cent of the total heat supply to district heating network, and almost half of this was for space heating alone.

By 2005, district heating is expected to account for 60 per cent of the total heat demand (47 per cent in 1990) and 90 per cent of this demand (55 per cent in 1990) would be met by cogeneration. This achievement is only possible with a very conducive policy framework set by the national authorities, active involvement of the utilities and a combination of legislation, grants and subsidies, tariffs and tax incentives.

2.2.3 *France*

The role of cogeneration has been marginal up to 1980 and in 1995, cogeneration represented only around 1.4 per cent of the total power production in France. According to a study conducted in 1996 for the Ministry of Industry, the total installed cogeneration capacity at the end of 1995 was 3,200 MW. The Ministry of Industry had forecasted this figure to rise to 5 GW by the year 2005. However, recent policy and tariff changes have favoured much rapid development of cogeneration, proven by the fact that in 1997 alone, the installed capacity had doubled the figure of 1996, attaining 500 MW. If a few of the planned big projects are actually implemented, the figure could easily surpass 1,000 MW in 1998.

Recent policies regarding financial assistance for cogeneration include tax holiday on natural gas for 5 years, reduced tax on investment costs, 50 per cent reduction in professional tax, etc. For facilitating further development, the "Cogeneration Mission" of Gaz de France started offering package of services in 1991:

The Club Cogénération, was created by groups of many important French entities concerned with cogeneration. The Club proposes to public authorities regulatory measures that can favour the growth of cogeneration. It participates in working groups and gives opinion on the texts prepared in France as well as in Europe. It plays the role of a catalyst for exchanging experiences and information among professionals. The Club organizes training workshops and seminars periodically. The club also assures the follow-up on technological developments in cogeneration: new models and systems, efficiency improvements, impact of the installations on the economy and environment.

2.2.4 *Spain*

The policies developed by the national authorities in the late 1980 sent a very positive signal to the market and favoured cogeneration to an extent beyond what was projected in 1990. Cogeneration appeared to have become such a lucrative activity that some cogenerators sold all the electricity generated in their plant to the grid and met their own power needs by buying it from the grid at a cheaper rate than their selling price.

The new law of 1995 is expected to have some regressive impact on the extent of new cogeneration development in Spain. This legislation intends to harmonize self-generation with the central system and develop a uniform tariff. A major blow on the cogenerator has been the reduction of the tariff of exported electricity in steps by 30 per cent after 5 years of commissioning. Accordingly, the payback periods are expected to be much longer, as much as 15 years. The minimum purchase contract period has been specified for five years. The cogenerator is allowed to sell only the electricity produced in excess. Penalties for non-supply of guaranteed electricity have become so high that the cogenerator is likely to choose a programmed tariff that has a lower rate. The law appears more favourable to the power sector which will become a major player in cogeneration investment in the future as it is highly unlikely that lower returns and higher risks involved in cogeneration projects can attract private sector investment any longer.

2.2.5 *United Kingdom*

Most recent cogeneration figures available show that there are a total of 1,336 cogeneration schemes in operation throughout the United Kingdom with a total capacity of 3,562 MW. Almost three-quarter of the total number of installations was for commercial, residential and public sector buildings. On the other hand, the industrial sector dominates the cogeneration market, accounting for 89% of the total installed capacity. From this information, one can conclude that industrial cogeneration schemes had much bigger power generating capacities than those in the other sectors did.

Privatization of the public utilities and the on-going liberalization of the energy market have given a boost to the cogeneration business. The majority of the small cogenerators does not require getting a license and have been exempted from the fossil fuel levy. Even export of power up to 500 kW is allowed with the need to have a supply license.

Government has set an objective to establish an undistorted market for cogeneration and to eliminate any unnecessary barriers. To start with, government seeks cost effective options for applying cogeneration to its own estate and to persuade the public sector to follow. Currently over a half of all cogeneration installations are in the public sector.

Government is also working with the cogeneration industry and other partners in order to develop new cogeneration market where there is unrealized potential. Efforts are being made to replicate the experience already gained in industries and buildings where cogeneration is well accepted.

Lastly, government intends to continue the promotion of this technology by keeping the decision-makers informed through the “Energy Efficiency Best Practice” programme and other environmental and energy management initiatives.

2.2.6 *Japan*

Cogeneration is a well known concept in Japan, and the total cogenerating capacity of public power plants and industrial and commercial cogenerators represents 1.8 % of the total power generation capacity of the country. As of March 1998, there were 1,490 units totaling 789 MW installed for commercial use and 1,051 units totaling 3,507 MW for industrial applications. As can be observed, industrial cogeneration plants with an average power generation capacity of 3.34 MW tend to be much bigger in size compared to the ones used for commercial applications, typically around 0.5 MW.

After a sharp rise in 1990, the growth rate slowed down in 1992 due to recession and decline of energy price. There has been a renewed interest in cogeneration, the number of installations as well as the capacity has been steadily increasing over the last decade. Among commercial applications, hotels rank first in terms of number and total capacity, followed by shopping centres and offices. The main features of these sites include long and continuous operating hours, constant demand of thermal energy for hot water, steam and chilled water. Though few in number, district heating and cooling network projects with much higher average sizes, contribute significantly to the total capacity. Among industrial uses, pharmaceutical and chemical industries have the largest share in terms of number and capacity. Other subsectors having high cogeneration capacities are oil and gas, pulp and paper, iron and metals, and machinery. In contrast, the food industry uses many smaller systems.

Lastly, grants can be obtained for development of new generation environment-friendly technologies such as ceramic gas turbines, ceramic natural gas engines, large-scale high efficiency fuel cells, etc.

2.2.7 *Republic of Korea*

Cogeneration development that has taken place in the Republic of Korea can be classified into 4 distinct categories: industries, high-rise buildings, industrial estates, and district heating networks. The total number of cogeneration plants in these four areas was 90 units in 1995, with a cumulative power generation capacity of 6,225 MW.

The most important cogeneration development has been in connection with district heating system in the outskirts of Seoul Metropolitan City. Government set up an ambitious plan to provide two million residential units, mostly apartment buildings, outside Seoul city during late 1980s and early 1990s, in order to disperse the population in newly developed towns. Ten such projects were commissioned by 1995 in the satellite cities that have a great demand for heat during the cold season. Cogeneration plants were jointly built by two public sector enterprises; the Korea Electric Corporation assured the electric power supply, while district heating was handled by the Korea District Heating Corporation. A total power generating capacity of 3,013 MW was already in place by 1995. Further expansion plans included the southern part of Seoul city, which included residential areas for over three million people. An example of cogeneration and district heating project that has been developed recently is the one in the town of Bundang. In order to supply electricity and other forms of energy to approximately 100,000 households in mostly apartment buildings, natural gas fired combined cycle cogeneration plants were installed with a total capacity of 600 MW of power and 560 GCal/hour of heating facility.

2.3 Regional Best Practices

The concept of cogeneration is not new in this region. But presently, interest in cogeneration is being renewed due to the recent changes in government policies regarding the role of private sector in the power sector. Deregulation of the power sector has given the right thrust towards revitalization of the cogeneration concept and has provided an excellent opportunity for cogeneration to flourish. Experience in some countries have shown that while independent power producers (IPPs) are facing some teething problems, the small to medium sized cogeneration projects, despite their relatively small scale, have been more successful under the small power producer (SPP) programme. Based on location, environment and small-scale advantages, these projects have been capable of providing surplus power at highly attractive rates. Cogeneration experiences of some selected countries of this region are summarized below:

2.3.1 *Thailand*

Thailand can be considered as an excellent showcase for many of the Asian developing countries as far as the promotion of small power generation and cogeneration is concerned. The government of Thailand approved a policy in October 1988 to encourage private sector involvement in power generation through cogeneration, renewable energies and waste fuels.

The National Energy Policy Office, Thailand has estimated the technical potential for cogeneration in about 20 industrial estates alone to be as high as 5,000 MW.

Apart from the government's policy to encourage private sector participation in power generation in the form of independent power producers (IPPs), the energy authorities of the country recognize energy generation from non-conventional energy, waste or residual fuels, and cogeneration by:

i) promoting the use of indigenous by-product energy sources and renewable energy for electricity generation;

ii) increasing the efficiency in the use of primary energy;

iii) encouraging the participation of small power producers (SPPs); and

iv) reducing the financial burden on the public sector with respect to investment on electricity generation and distribution.

The power utility has the obligation to purchase electricity from any SPP who cogenerates using any type of fuel, meeting certain requirements. These include the type of thermal cycles to be used, the minimum amount of thermal energy to be used from the cogeneration plant, and the minimum overall efficiency on the basis of the type of fuel used.

2.3.2 *Indonesia*

In Indonesia, cogeneration technology has been traditionally associated with major process industries having high steam demand, such as paper, chemicals, refineries, and food and beverage industries. However, not many industries are presently utilizing cogeneration technology due to two main reasons. The industrial decision-makers are little aware of the technology and its economic merits. Secondly, the energy price does not reflect its actual cost.

On the other hand, captive power plants are commonly employed in Indonesia due to the geographical characteristics of the country and inability of the national grid system to supply the amount of energy required by the users. The share of energy from captive power plants represented 36% of the total requirement.

There are two relevant documents that reflect government's policy on cogeneration. The first regulation issued in 1993 allows the industries to adopt cogeneration technology for their own use within utility's concession area, and sell the excess power from the cogeneration facility to the utility. The Ministry of Mines and Energy published the tariff for purchase of electricity from small power producers. After power generation from solar, mini-hydro and wind energies, cogeneration from agricultural and industrial wastes was given the next priority, allowing sale of up to 30 MW for Java-Bali grid system, and up to 15 MW for the other grids.

The third priority was given to cogeneration using conventional fuels, followed by power generation alone with conventional fuels. In line with the energy policy, government will look into some factors while issuing permits to private generators and cogenerators who intend to produce energy for their own use and for selling excess to others. These include the local grid capability, primary energy source used, pricing mechanism, security of energy supply, and environmental impact.

2.3.3 *Philippines*

The government of Philippines has manifested a growing interest to promote industrial cogeneration, with the following rationale:

Development Policy: Recognizing that adequate power supply is one of the basic prerequisites for sustained economic growth, decision was taken to allow private sector participation in the power sector;

Additional Resources: The private sector can be expected to bring additional resources or equity funds;

Efficiency Improvement: Many industries with continuous demand for low quality steam can install power generation units and use the waste steam for industrial process needs, thus high fuel use efficiency can be achieved;

Environmental Benefits: Cogeneration offers substantial reductions in exhaust gas emissions. Government has therefore instituted policies, incentives and programs for supporting cogeneration along with renewable energy technologies; and

Fiscal Incentives: Extended to the cogenerators include income tax holiday for six years, reduced duty of only 3 per cent on imported capital equipment and spare parts, tax credit on domestic capital equipment and spare parts and tax deduction for labour expenses.

For purchase of power from cogenerators having less than 10 MW capacity, standard power purchase rates are adopted which reflect the structure of capacity and energy costs of the national utility for varying levels of power availability and dispatchability. The electric utility shall sell power to the cogenerator upon request. The back-up power provided by the utility will be at a rate approved by the Energy Regulatory Board.

The host utility is obliged to interconnect and wheel the electricity generated to a third party; for cogeneration with less than 10 MW capacity, the utility will shoulder all the costs. For cogeneration facility of any size, maintenance cost of the interconnection facility shall be borne by the electric utility.

2.4 Operational Processes of the Target Industries

2.4.1 *Sugar Industry*

The sugar production process comprises of two main processes. First process is the extraction of juice from sugar cane and the second process is the crystallization of sugar from the juice.

First process

The first process comprises of carrying sugar cane to the mill, chopping the sugar cane, fiberizing the chopped cane and crushing the fiber so that the juice present in the sugar cane will come out. The juice thus obtained contains sucrose, some other dissolved materials and water. During crushing, to ensure proper extraction of sucrose from the sugar cane, water is mixed with crushed fiber and again re-crushed. This process is repeated 3-5 times depending on the system involved. This process is called imbibition. After crushing the juice is carried to other place for further process and the residue of the crushed cane called *bagasse* is directly fed to the boiler as fuel. The bagasse thus contains about 51% moisture.

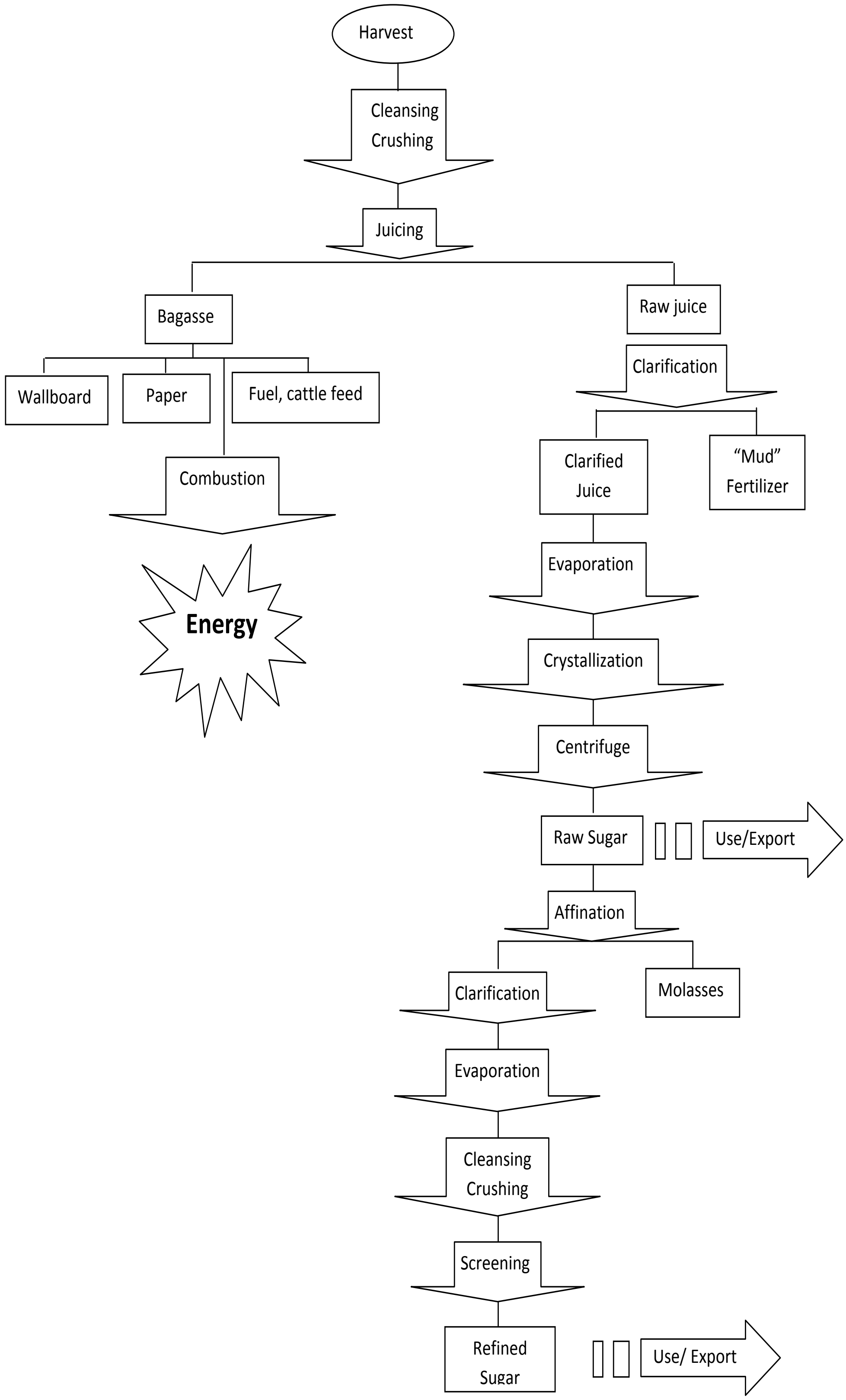
Second process

The second process starts with the formation of crystal of the sugar. It comprises of clarification of sugar, heating of juice for evaporating the water to make the juice supersaturated with sugar, cooling the juice for crystallization and finally centrifuging the magma to get the sugar. The processes involved are the sulphitation, decantation, filtration, heating, evaporation, crystallization and centrifuging. During the process the energy is supplied to the juice by steam and through motors for transferring the juice at different locations. Due to chemical stability the juice cannot be heated more than 110^{o}c and to evaporate the water effectively evaporation is done in vacuum and the vacuum is generated mainly by condensing the evaporated steam from the evaporator. For process heating some steam is used directly from the boiler.

It is well known that sugar process is a combined heat and power (CHP) process that it is a cogeneration process. Steam from the boiler is initially used for generating power and after that it is used for process heating. Finally this steam is condensed by the process itself and therefore no extra condensing system is present in the sugar mills. The condensate is then fed to the boiler again. A small amount of water is required to be treated for boiler which is the makeup water. During heating in the evaporator, steam is produced and this steam is condensed by barometric condenser using water spray which in turn is passed to the spray pond for cooling. A portion of the steam is used for running the crusher driven by crusher turbine.

Generally, sugar mills are using spray for cooling water supply. At the time of starting the mill, spray pond is filled up with water collected from underground water. This water along with the makeup water needed for condensing the steam to create vacuum, is supplied from the condensing steam coming from the evaporator. As there is a continuous supply of water from the process itself therefore no extra water is needed for condensing purpose. The water needed for the process is supplied from underground source.

Figure 2.6: Sugarcane Processing Flowchart

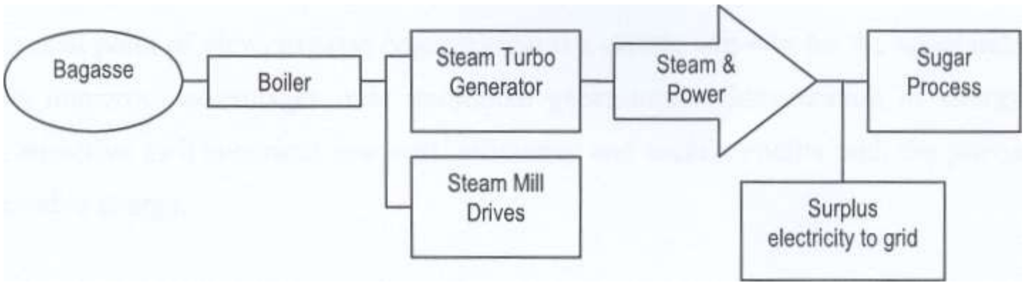


***Cogeneration in Sugar Industry*:**

Bagasse is the fibrous residue of cane stalk obtained after crushing and the extraction of juice. Each ton of sugarcane can yield 250kg of bagasse. The composition of bagasse varies with variety and maturity of sugarcane as well as with harvesting methods used and efficiency of the sugar mill in processing the sugarcane.

The value of bagasse as a fuel depends largely on its calorific value, which in turn is affected by its composition, especially with respect to water content and to the calorific value of the sugarcane crop, which depends mainly on its sucrose content. Every ton of sugar has an energy potential equivalent to that of 1.2 barrels of petroleum. Historically, sugar mills have been designed to meet their energy requirements by burning bagasse: this was seen as an economic means of producing electricity whilst cheaply disposing of bagasse. The process of bagasse cogeneration is sketched out in Figure below.

Figure 2.7: Overview of Bagasse Cogeneration



2.4.2 *Pulp and Paper Industry*

The Pulp and Paper industry converts fibrous raw materials into pulp, paper and board. In a first step raw materials are processed into pulp and in a second step paper and paper products are produced out of this pulp. Different plant categories exist depending on whether they only produce pulp (pulp mills) for further processing or only paper out of purchased pulp and or recycled waste paper (paper mills). The third category, the integrated pulp and paper mills combines the two process and is most common in the paper industry.

<u>The Manufacturing Process</u>

The process whereby timber is converted into paper involves six steps. The first four convert the logs into a mass of cellulose fibres with some residual lignin using a mixture of physical and chemical processes. This pulp is then bleached to remove the remaining lignin and finally spread out into smooth, pressed sheets (often with chemicals added to provide particular properties such as colour or water resistance). For some papers (e.g. cardboards and 'brown paper') the bleaching step is unnecessary, but all white and coloured papers require bleaching.

(a) Wood preparation

Wood is delivered to the mill in one of two ways: whole logs and sawmill chips (residuals from sawmills). The logs have their bark removed, either by passing through a drum debarker or by being treated in a hydraulic debarker. The hydraulic debarker, which uses high pressure water jets, can handle large diameter logs. The removed bark is a good fuel, and is normally burnt in a boiler for generating steam. After debarking, the logs are chipped by multi knife chippers into suitable sized pieces, and are then screened to remove overlarge chips. The thickness of the chips is the most important parameter, as this determines the speed and the thoroughness of the impregnation of the cooking chemicals into the wood chip. Neither debarking nor chipping are usually necessary for sawmill chips.

(b) Cooking

The "cooking process" is where the main part of the delignification takes place. Here the chips are mixed with "white liquor" (a solution of sodium hydroxide and sodium sulphide), heated to increase the reaction rate and then disintegrated into fibres by 'blowing' - subjecting them to a sudden decrease in pressure. Typically some 150 kg of NaOH and 50 kg of Na_2S are required per ton of dry wood. This process is, like any chemical reaction, affected by time, temperature and concentration of chemical reactants. Time and temperature can be traded off against each other to a certain extent, but to achieve reasonable cooking times it is necessary to have temperatures of about 150 - 165^oC, so pressure cookers are used.

There are two different cooking systems; batch and continuous. In batch cooking, chips and white liquor are charged to a pressure vessel and are then heated with steam to a set temperature for a set time. When the correct delignification has been achieved, the cook is "blown" (the pressure is suddenly released so that the cooked chips disintegrate into fibres). In the continuous process, chips and white liquor are fed continuously to the top of a tall pressure vessel. The chips move down the 'digester' by gravity (as a plug) to be finally blown from the bottom of the vessel. The cooking time cannot be varied in this case (it is set by the production rate) and only the temperature and the chemical charge can be controlled. Many developments have taken place during the last decade to improve the 'science' of kraft pulping. The challenge has been to remove as much of the lignin as possible with out degrading the cellulose and without losing too much yield. It is now well known that the concentrations of NaOH, Na_2S and dissolved lignin during the various phases of the delignification are of crucial importance for the pulp strength. Generally speaking, it is desirable to have a high sulphide concentration in the beginning of the cook, a low lignin concentration in the liquid phase towards the end of the cook, and an even alkali concentration during most parts of the cook. How to achieve this in practice under conditions of high temperature and high pressures has been a challenge, and much development is still going on.

(c) Pulp washing

Because of the high amounts of chemicals used in the cooking wood in pulping, the recovery of the chemicals is of crucial importance. The process where the chemicals are separated from the cooked pulp is called pulp washing. A good removal of chemicals (inorganic and organic) is necessary for several reasons:

- The dissolved chemicals interfere with the downstream processing of the pulp
- The chemicals are expensive to replace
- The chemicals (especially the dissolved lignin) are detrimental to the environment. There are many types of machinery used for pulp washing.

Most of them rely on displacing the dissolved solids (inorganic and organic) in a pulp mat by hot water, but some use pressing to squeeze out the chemicals with the liquid. An old, but still common method is to use a drum, covered by a wire mesh, which rotates in a diluted suspension of the fibres. The fibres form a mat on the drum, and showers of hot water are then sprayed onto the fibre mat.

(d) Pulp screening

Apart from fibres, the cooked pulp also contains partially uncooked fibre bundles and knots. Modern cooking processes (together with good chip screening to achieve consistent chip thickness) have good control over the delignification and produce less "rejects". Knots and shives are removed by passing the pulp over pulp screens equipped with fine holes or slots.

(e) Bleaching

Pulp produced by the kraft process is brown. This presents no problem for certain uses, e.g. for sack paper, most corrugated boxes, some bag paper etc. However, a major proportion of the kraft pulp is used for white or coloured papers such as writing and printing papers, and this pulp needs to be bleached.

Bleaching involves removing virtually all of the lignin that still remains after cooking, as the lignin contains the chromophoric groups which make the pulp dark. Strictly speaking, bleaching and cooking are both delignification processes, and modern developments have tended to blur the difference between the two processes. However, traditionally the name 'bleaching' is reserved for delignification that is taking place downstream of the cooking process. In practice, there are two separate "bleaching" process steps: oxygen delignification and final bleaching.

(f) Paper making

Paper making is the process whereby pulp fibres are mechanically and chemically treated, formed into a dilute suspension, spread over a mesh surface, the water removed by suction, and the resulting pad of cellulose fibres pressed and dried to form paper.

The mechanical treatment of the fibre normally takes place by passing it between moving steel bars which are attached to revolving metal discs - the so-called refiners. This treatment has two effects: it shortens the fibre (fibre cutting) and it fibrillates the fibre. The latter action increases the surface area, and as the fibres bond together in the paper sheet by hydrogen bonding, the increased surface area greatly increases the bonding and strength of the paper. Paper strength is dependent on the individual fibre strength and the strength of the bonds between the fibres. It is usually the latter, which is the limiting factor. Refining increases the interfibre bonding at the expense of the individual fibre strength, but the net result will be an increase in paper strength. Pressing and calendering (feeding through rollers) increase density and promote smoothness.

Cogeneration in Paper Industry

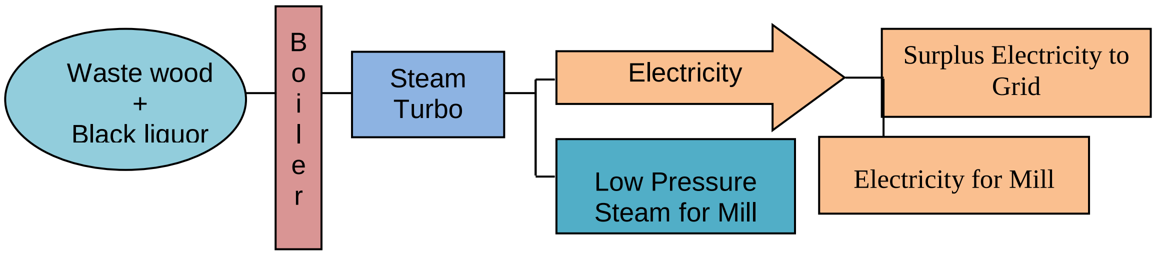
Pulp and Paper production is highly energy intensive with 75-85% of the energy requirement being used as process heat and 15-25% as electric power. The combination of this two energy requirements, qualifies paper production for the use of cogeneration (low pressure steam for process heat and high pressure steam for electricity generation)

In general, most of the energy is used in the form of heat within the pulping process (digester, evaporator and washing) when raw materials have to be cooked and mechanically or chemically treated for further use in the production chain. The pulping process consumes absent a quarter of all primary energy required for paper production.

Furthermore, paper making requires considerable amounts of energy in form of both heat and electricity for pressing and drying of the paper and this process generally produce their own electric power with steam-driven turbo-generators. The waste organic materials e.g waste-wood & black liquorare converted to useful thermal energy by burning these materials in industrial boilers to generate high-pressure steam, which is used to drive the turbo-generators to produce electricity and exhaust low-pressure steam. The remaining thermal energy in the low-pressure steam is used throughout the mill to heat process, concentrate black liquor and dry pulp & paper products. This process is “Cogeneration” having electricity, steam, hot air, hot water or chilled water allowing the mills to better balance their energy needs and costs.

The process of above cogeneration is sketched out in the figure below:

Figure 2.8: Overview of Cogeneration in Paper Mills



2.5 Economic Drivers

Cogeneration: the combined generation of steam and electricity, is an efficient and cost-effective means to save energy and reduce pollution. Cogeneration, or combined heat and power (CHP), can result in primary fuel savings of 35% for a typical system as a result of the increased efficiency of a CHP system, which may be as high as 85%, compared to separate generation of steam and power. Despite the obvious advantages of cogeneration, it remains an untapped potential in most countries, including SAARC member countries.

Cogeneration and, hence, additional income revenues from electricity sales to the national grid may contribute substantially to the economic viability of the sugar sector. Several studies in India, and other parts of the world, point to the sugar industry as a prime candidate for supplying low-cost, non-conventional power via cogeneration. The advantages of sugar mill cogeneration include relatively low capital cost requirements and the use of a renewable, indigenous waste as a "non-polluting" fuel. Furthermore, the number and size of Indian sugar mills are sufficient to make a measurable contribution to local power supplies. In a study conducted by Maharashtra's Commissioner of Sugar, the estimated capital investment to implement cogeneration with power export in the state's existing sugar mills was estimated at $567/kW; for the planned new mills, the incremental investment was estimated at only $320/kW[1] Most studies estimate the total capital cost of new sugar mill cogeneration projects at less than $900/kW[2], which is substantially lower than that for new coal-fired power generation.

Cogeneration is a proven technology that saves fuel resources, but it does not necessarily imply any assurance of economic benefits. Irrespective of all its technical merits, the adoption of cogeneration would principally depend on its economic viability, which is very much site-specific. The equipment used in cogeneration projects and their costs are fairly standard, but the same cannot be said about the financial environment that varies considerably from one site and/or country to another. The best way to assess the attractiveness of a cogeneration project is to conduct a detailed financial analysis and compare the returns with the market rates for investments in projects presenting similar risks.

Well-conceived cogeneration facilities should incorporate technical and economic features that can be optimized to meet both heat and power demands of a specific industry. A comprehensive knowledge of the various energy requirements as well as characteristics of the cogeneration plant is essential to derive an optimal solution. As a first step, the compatibility of the existing thermal system with the proposed cogeneration facility should be determined. Important user characteristics which need to be considered include electrical and thermal energy demand profiles, prevalent costs of conventional utilities (fossil fuels, electricity) and physical constraints of the cogeneration. A factor that should not be overlooked at this stage is the need for reliable energy supply as some industrial processes and commercial entities are extremely sensitive to any disruption of energy supply that may lead to production losses.

[1]Advancing Cogeneration in the Indian Sugar Industry - Three Mills in Tamil Nadu andMaharashtra, U.S. Agency for International Development, Report No. 93-02, May 1993
[2]Eniasivam, S., "India - Utopia Amidst Political Chaos and Myopia?," World Cogeneration,Vol. 7, No. 5, November/December 1995.

To fully exploit the cogeneration installation throughout the year, potential candidates for cogeneration should have the following characteristics:

i) adequate thermal energy needs, matching with the electrical demand;
ii) reasonably high electrical load factor and/or annual operating hours;
iii) fairly constant and matching electrical and thermal energy demand profiles.

Cogeneration may be considered economical only if the different forms of energy produced have a higher value than the investment and operating costs incurred on the cogeneration facility. In some cases, the revenue generated from the sale of excess electricity and heat or the cost of availing stand-by connection must be included. More difficult to quantify are the indirect benefits that may accrue from cogeneration such as avoidance of economic losses associated with the disruption in grid power, and improvement in productivity and product quality.

Following are the major factors that need to be taken into consideration for economic evaluation of a cogeneration project:

i) initial investment;
ii) operating and maintenance costs;
iii) fuel price;
iv) price of energy purchased and sold.

Regardless of whether the cogeneration project is a totally new facility or a retrofit of an existing operation, the project will materialize only if it is financially attractive. The sizing of the cogeneration system is sometimes carried out by financial analysis in grid dependent cases where there is an option for importing electricity instead of self-generation of all the electricity. In such circumstances, the optimum size of cogeneration would correspond to a system that has the minimum annual total cost (or maximum annual net profit).

The best cogeneration system would be identified after the sensitivity analysis is carried out to make sure whether the selected cogeneration system is still financially attractive with possible variations in the values of some critical parameters. To summarize, assessment of the feasibility of a cogeneration project involves four distinct steps, as follows:

i) Analysis of the energy demand pattern (electricity, thermal energy);
ii) Identification of the different technical options (considering technical constraints, equipment availability, space constraints, etc;
iii) Optimization of each technical option (overall efficiency, part load performance);
iv) Financial analysis for selecting the best option (payback period, internal rate of return).

2.6 Environmental Benefits - CDM

Bagasse-based energy is totally renewable and does not involve mining, extraction and long-distance transportation expenses of fossil fuel. It is regarded as a clean fuel with respect to the environment. As a biomass, bagasse supplies raw material for the production of natural, clean and renewable energy, reducing needs for and use of fossil fuels. Bagasse is a waste product that needs to be disposed of in two ways – either by combustion or decomposition (composting). Both of them would release, as CO_2, the carbon contained in bagasse. Very little fly ash and almost no sulphur are produced during the combustion process.

In other words, the environmental advantages of bagasse cogeneration are lower emission of particles, CO_2 and other green house gases (GHGs) compared to carbon-intensive fossil fuels, as well as lower emission as against that during composting. Besides, if the bagasse was to be composted, it would also release methane, a GHG which is 27 times more potent than CO_2.[3]

If the surplus energy is supplied to the national grid, it would substitute fossil fuel burned in conventional thermoelectric plants. The reduction of emissions is estimated to be about *0.55 tons of CO_2 equivalent per ton of used bagasse*[4]*.* Such reductions in greenhouse gas emissions qualify for carbon credits if they constitute "additionality" (the reduction should exceed those emissions that would occur in the absence of the activity), and could be used for obtaining CER credits within the terms of the Clean Development Mechanism (CDM) established by the Kyoto Protocol[5]. The extent of emission reduction and associated carbon credits differ substantially across the projects depending on the size and efficiency of power plants, captive consumption of sugar mills, amount of replaced electricity generated by thermoelectric plants, etc.

So far, the cumulative capacity of renewable energy systems such as bagasse cogeneration in India is far below their theoretical potential despite government subsidy programmes. One of the major barriers is the high investment cost of these systems.

The CDM provides industrialized countries with an incentive to invest in emission reduction projects in developing countries to achieve a reduction in CO_2 emissions at lowest cost that also promotes sustainable development in the host country. Bagasse cogeneration projects could be of interest under the CDM because they directly displace greenhouse gas emissions while contributing to sustainable rural development.

Estimates in India[6] indicate that there is a vast theoretical potential of CO_2 mitigation by the use of bagasse for power generation through cogeneration process in India.

[3]Bagasse Cogeneration – Global Review and Potential. WADE, June 2004

[4] Sugarcane-based Bio-ethanol-Energy for sustainable Development. BNDES, Rio de Janerio, November 2008

[5] For more details see MECAS(04)04

[6]Pallav Purohita and Axel Michaelowa, CDM Potential of Bagasse Cogeneration in India, Research Programme on International Climate Policy, Hamburg Institute of International Economics, Neuer Jungfernstieg 21, D-20347 Hamburg, Germany,

The preliminary results indicate that the annual gross potential availability of bagasse in India is more than 67 million tons (MT). The potential of electricity generation through bagasse cogeneration in India is estimated to be around 34 TWh i.e. about 5575 MW in terms of the plant capacity. The annual CER potential of bagasse cogeneration in India could theoretically reach 28 MT. Under more realistic assumptions about diffusion of bagasse cogeneration based on past experiences with the government-run programmes, annual CER volumes by 2012 could reach 20–26 million. The projections based on the past diffusion trend indicate that in India, even with highly favorable assumptions, the dissemination of bagasse cogeneration for power generation is not likely to reach its maximum estimated potential in another 20 years. CDM could help to achieve the maximum utilization potential more rapidly as compared to the current diffusion trend if supportive policies are introduced.

3 PART B: SUGAR INDUSTRY

3.1 Bangladesh

3.1.1 *Industry Structure*

In Bangladesh, 15 (fifteen) sugar mills owned by government are controlled and managed by 'Bangladesh Sugar and Food Industries Corporation (BSFIC)'. The main products of these mills are sugar, spirit/alcohol drinks and spare parts while molasses and bagasse are important by-products. Total cane crushing capacity of the operating sugar mills is 21,044 tons per day (TCD) and annual total sugar production capacity is 2,10,440 tons. This capacity is estimated considering 125 effective crushing days and 8% sugar recovery from cane. It requires approximately 2.50 million tons of sugarcane per annum for the full capacity utilization of the sugar mills. Annual average sugar production during the last 37 years was 1,46,603 tons with an average(weighted) sugar recovery rate of 7.60%.

Sugarcane is one of the main dependable cash crop in the low rainfall belt of the north-west and south-west parts of Bangladesh. Based on sugarcane, the sugar and 'gur' industries of Bangladesh have developed in the country.

At present, 7.3 million ton sugarcane is produced from 0.18 million hectares (roughly 0.1 million hectares in sugar mill zones and 0.08 million hectares in non-mill zones for gur production) of land per year. The yield of sugarcane is 40.52 tons/hectare (46 tons/hectare in sugar mill areas and 36 tons/hectare in gur areas). To meet the demand of sugar and gur, 11.1 million tons of sugarcane requires to be produced per year.

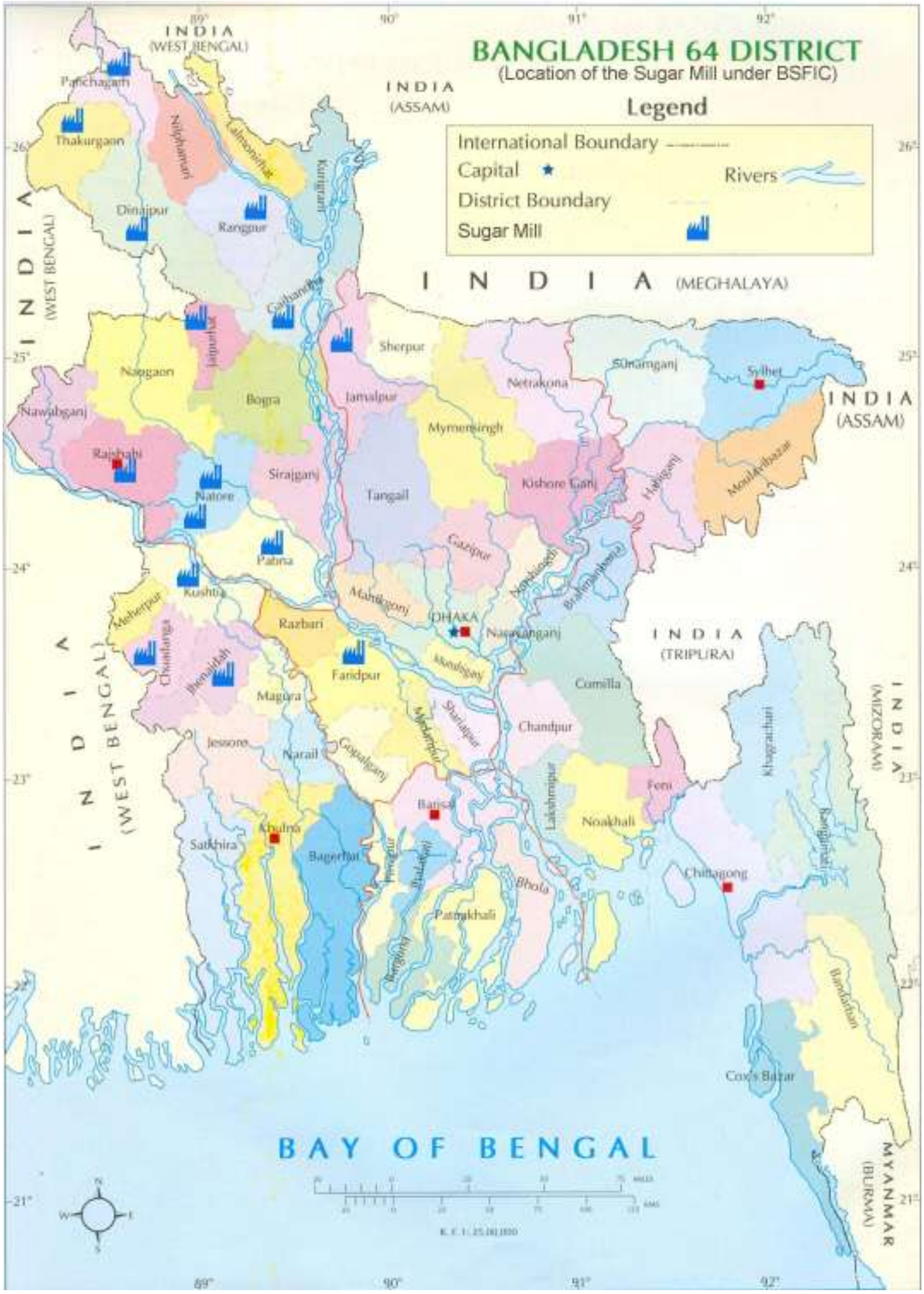
The BSFIC sugar mills have capability of daily sugar cane crushing ranging from 300 tons to 2,000 tons. These mills are scattered thought the country but the main cogeneration is in the Northwest part of the country. Generally, a 1500 tons per day crushing mill requires from 50 to 70 metric ton/ hour of steam and the power demand ranges from 1.2 to 1.9 MW. Each mill has several boilers which use bagasse as the main fuel and either liquid fuel or gas for ignition. The age of these boilers varies from 16 to 68 years old. This implies that several boilers should be replaced in the very near future. Each of the mills has several electrical generators and these range in size from 0.9 to 1.5 MW. The average age of these is 25 years and this also indicates that some of the generators should be replaced in the near future.

Usually during the crushing season, the mills produce steam that is used to make the electrical generators run and supply process steam. During the off crushing season, the mills import their minimal power requirements from the grid at a supply voltage of 415 V. Table 3.1 shows name of the sugar mills with year of installation and crushing capacity (ton/day) and Figure 3.1 shows the location of the Sugar Mills in Bangladesh.

Table 3.1: Sugar Mills with year of installation & crushing capacity (ton/day)

Name of sugar mills	Year of Installation	Crushing capacity (ton/day)
North Bengal	1933	1500
Setabgonj	1933	1250
Carew & Co.	1938	1150
Rangpur	1958	1500
Thakurgaon	1959	1524
Zealbangla	1959	1016
Joypurhat	1963	2023
Rajshahi	1966	2000
Kushtia	1966	1524
Mobarakgonj	1966	1500
Shampur	1668	1016
Panchagar	1970	1016
Faridpur	1977	1016
Nator	1985	1500
Pabna	1997	1500

Figure 3.1: Sugar Mills of Bangladesh under BSFIC



3.1.2 *Current Cogeneration Situation*

In the sugar mills, juice is extracted from sugar cane by crushing it. Imbibition is done during crushing to ensure proper extraction of sucrose present in the sugar cane. The juice obtained by crushing the cane contains some dissolved solids including sucrose. This juice is heated to evaporate the water of the mixture such that it becomes supersaturated by sucrose. Due to chemical stability of the sucrose mixed in the juice, the mixture is heated not more than 110^0C during the process. It is a convention that juice is heated by low pressure steam. The steam needed in this process is produced in a boiler by burning the bagasse, which is the portion of the sugar cane left after crushing. The burning temperature in the furnace of the boiler is about 1000^0C. Production of steam at higher temperature and pressure is thermodynamically essential for better system efficiency in power generation. But steam required for sugar production process is at low temperature and pressure. Therefore, for the sake of efficiency, the sugar production process always works on CHP (combined heat and power) production process called cogeneration system.

In Bangladesh, due to the seasonal availability of the sugar cane, the sugar production lasts for few months in a year. Normally, on an average, it is about 3 (three) months and for rest 9 (nine) months of the year, sugar mills remain closed and some maintenance works are conducted.

During the crushing season, sugar mills collect sugar cane from the farmers from the adjacent area, of the sugar mill. The amount of sugar cane that a mill can normally collect is only about 25%-30% of the sugar cane grown near the mill area. The remaining portion of the sugar cane is used for the production of gur. The collected sugar cane is crushed in the mill and juice is extracted. During extraction some extra water is added for the proper extraction (called imbibition) as mentioned in the previous section. The average dissolved solid particle in the juice thus found is about 11% and it varies a little from mill to mill in Bangladesh. This juice thus collected is used for the production of sugar.

During sugar production, steam used are either at low pressure (below 15 bar) or at medium pressure (20 to 30 bar). This low pressure steam is initially used in the back pressure turbine for power production and the exhaust steam from it is used for process heating necessary for sugar production. The power thus produced is used by the sugar mill for its own consumption. Since the sugar mills of Bangladesh are very old and due to some other reason, the cost of sugar production is tremendously high because of higher steam consumption. For example, the steam consumption in sugar mill of Bangladesh is as high as 65-75% on cane (i.e. mass of steam as a percentage of the mass of cane processed) compared to as low as 50-55% in India and 40% in modern sugar mills.

But in the modern sugar mill, steam is produced at high pressure (40 to 50 bar). It is well known that the higher the pressure and temperature of the boiler, the better the thermodynamic efficiency. In the modern sugar mills, steam with high temperature and pressure is used for power production and the exhaust steam from the back pressure turbine is used for sugar production. The power thus produced is sufficient enough to serve its own use as well as for the supply to the nation grid. Therefore, in the modern sugar mills power and sugar are simultaneously produced with higher efficiency and such mills operate as profit generating industries.

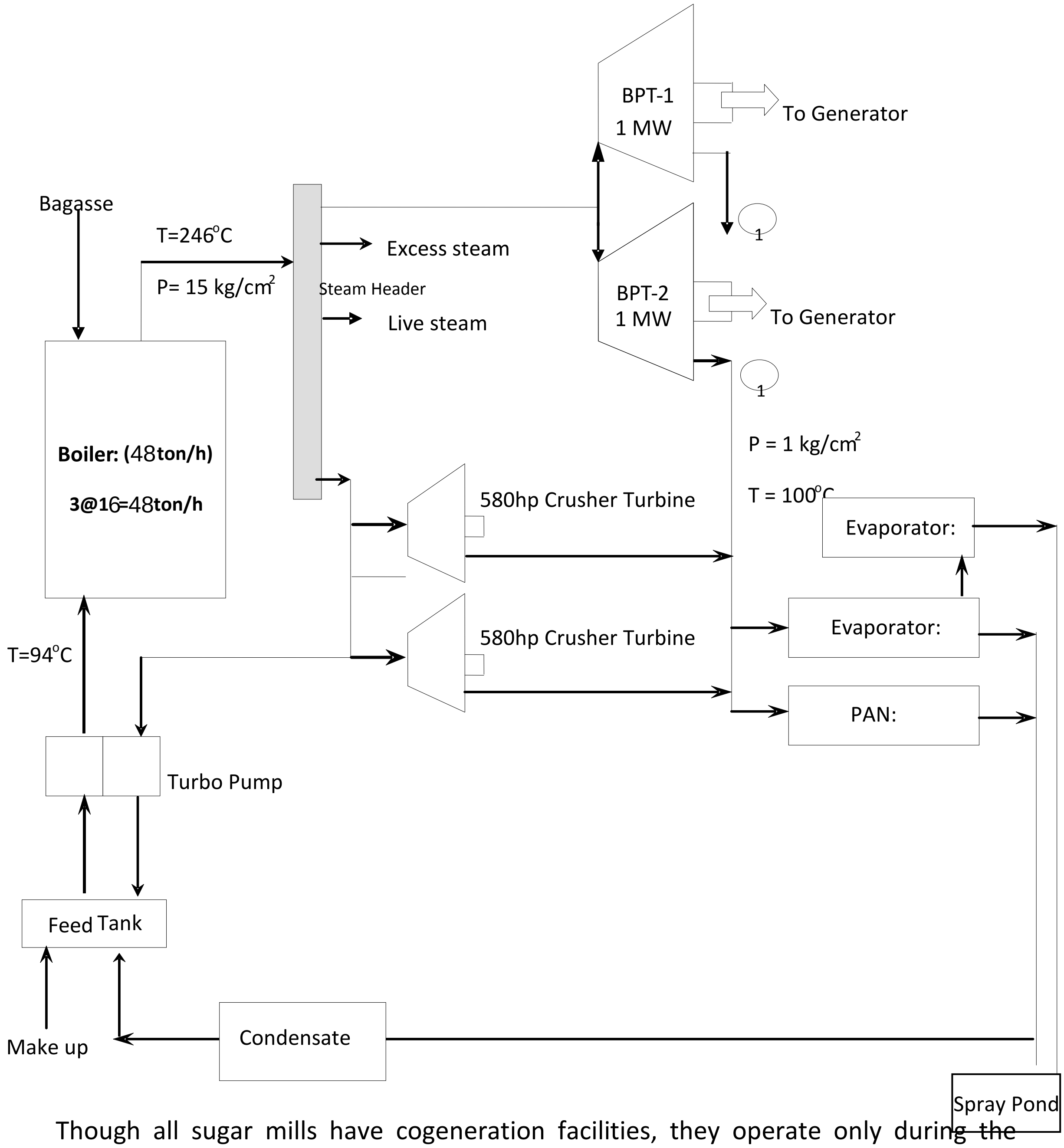
In the sugar mill of Bangladesh, the fuel used in the boiler for generating steam is bagasse, which is a by-product of their sugar cane as mentioned earlier. The scenario of the amount of bagasse thus produced and the amount of bagasse needed for their own sugar production is such that when the sugar production is less, the amount of bagasse is less than the amount they actually needed. In that case it is observed that some sugar mills collect bagasse from other mills. When the amount of sugar production is high, the sugar mill can have some excess bagasse. But this excess bagasse is not that much to be used for rest of the year for steam production. Normally modern mills have bagasse drying facility, which increases boiler efficiency, but it is not practiced in Bangladesh.

The sugar cane season normally does not last more than 3 (three) months in Bangladesh. In some very special case it is extended up to 5 (five) months in some sugar mills. Therefore, in general, the sugar mills of Bangladesh cannot be run using its own bagasse as a fuel beyond its own capacity of sugar production. In other words, during the crushing season it cannot produce more amount of steam for the extra power generation. If new boiler is procured for generating steam at higher pressure and temperature, only then it may produce some extra power for national grid during crushing season.

Bagasse is the primary source of fuel which is burnt in boiler furnace to generate steam which in turn is used to drive steam turbine generators for electricity generation required for motor drives, driving mill drive turbines and for meeting process steam needs. As most sugar mills have similar configurations, one of them is described here with more details (flow diagram is shown in Figure). The mill has three water tube boilers, each with a steam generating capacity of 16 ton/hr. The pressure and temperature of the steam are 15 kg/cm^2 and 246°C respectively. One steam turbine generator is normally operated during milling season to meet the entire electric demand. One standby diesel generator is also available and run during emergency. Electricity is purchased from Bangladesh Power Development Board (BPDB) as required during cleaning days and during off-season. There are also two crusher drive steam turbines, each of 580 HP capacity and two steam turbine generators, each of 1 MW capacity. About 30 tons/hour of steam is produced in the boiler that has an average efficiency of 56 per cent. High-pressure steam is mainly used for steam turbine generator and crusher drive turbines.

An automatic pressure reduction valve reduces steam from 15kg/ cm^2 pressure to 3kg/cm^2 that is mainly used in centrifugals for purging molasses and washing/cleaning heaters, evaporators and pans, etc. Turbine exhaust steam is used in processing juice, i.e mainly heating purposes. Another automatic steam reduction valve reduces 3 kg/cm^2 steam to 1 kg/cm^2 to supply make up steam. Totally 80 per cent of the condensate is recovered and about 20 per cent make up water is needed for the boiler. Steam used in heating air of 6 forced air supply units of sugar dryer are being operated with an open bypass valve of traps causing live steam discharge to drains.

Figure 3.2: Steam and Condensate Flow Diagram



Though all sugar mills have cogeneration facilities, they operate only during the season, i.e. 150 days per year. If they can be operated during off-season by applying balancing, modernization, rehabilitation & expansion (BMRE) programme, more power could be generated which can alleviate the power shortage in the country.

3.1.3 *Cogeneration Potential*

Recently, Mechanical Engineering Department of the Bangladesh University of Engineering and Technology (BUET) conducted a feasibility study on cogeneration in sugar mills in Bangladesh under Bangladesh Sugar and Food Industries Corporation (BSFIC), a sector Corporation under the Ministry of Industries.

BUET selected five sugar mills out of fifteen for the said feasibility study based on the capacity of the sugar mills, location, road, railways and river connectivity, electric power grid connectivity and availability of fuel.

The selected five sugar mills are

i) North Bengal Sugar Mills (NBSM)

ii) Rajshahi Sugar Mills (RJSM)

iii) Joypurhatypurhat Sugar Mills (JSM)

iv) Mubarakganj Sugar Mills (MKSM)

v) Shampur Sugar Mills (SHSM)

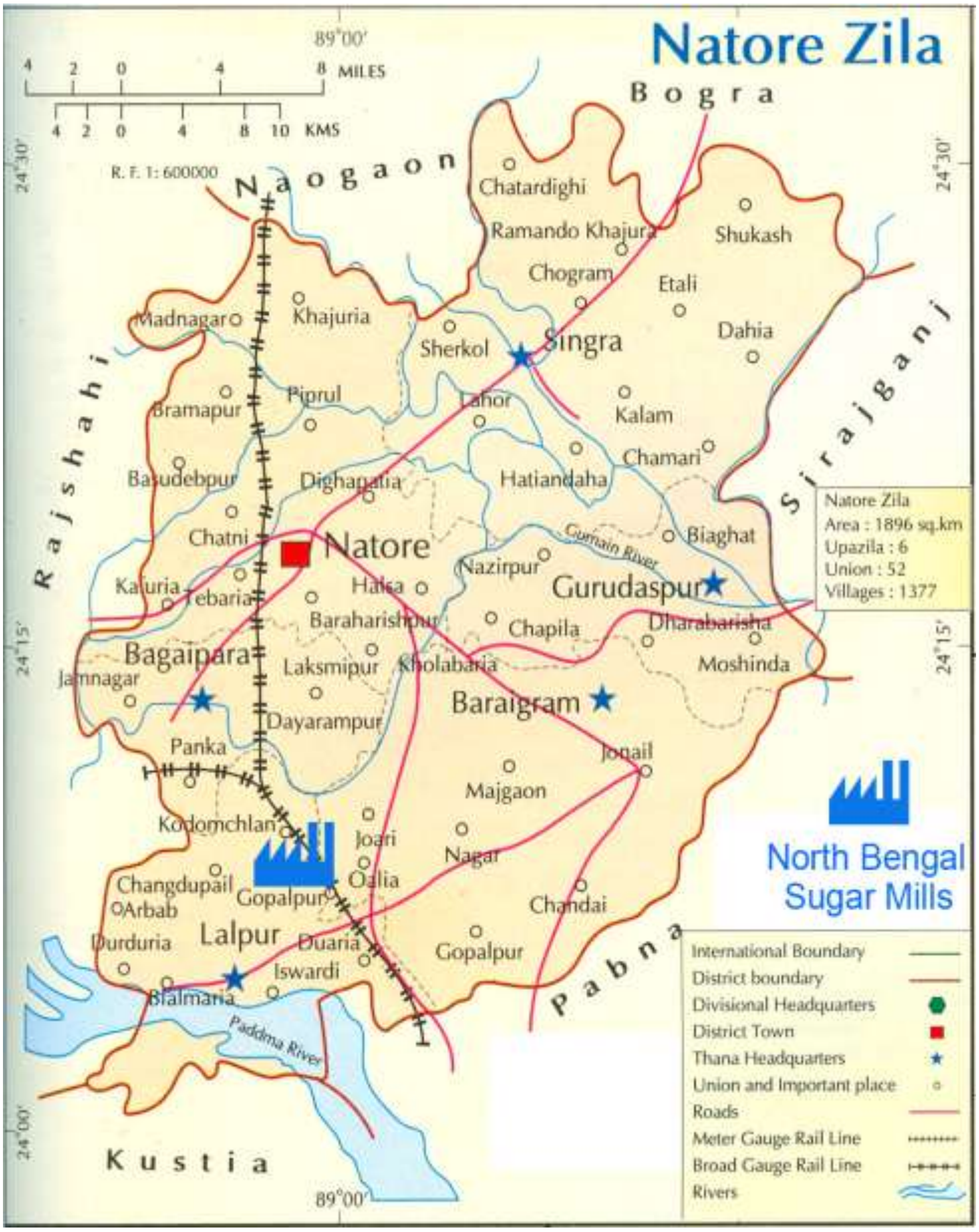
Comparison of important equipment of the above 5 (five) sugar mills are presented in the Table: 3.2 to 3.4 after the descriptions of these mills and their locations

North Bengal Sugar Mills

It is situated at Gopalpur in Lalpur upozilla of Natore district. This sugar mill was established in 1933 by private entrepreneurs and is one of the oldest sugar mills that is still operating in the country. Machinery and equipment of the sugar mills were supplied by M/S. Faweet Presten of UK.

Figure 3.3: Map of Natore district showing the location of North Bengal Sugar Mill.The mill is about 10 km from the Natore-Dhaka highway

Figure 3.3: **Map of Natore district showing the location of North Bengal Sugar Mill**

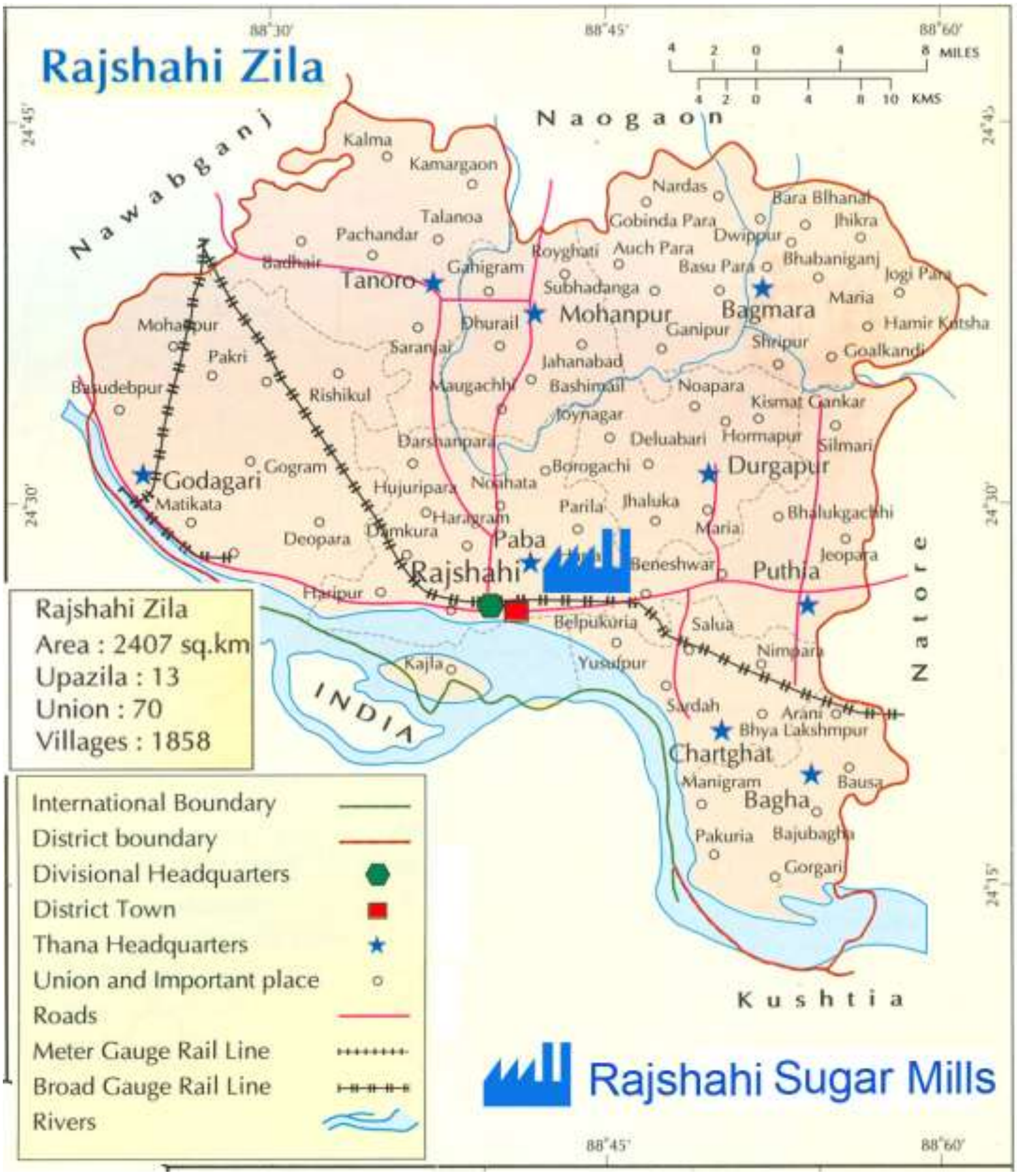


<u>Rajshahi Sugar Mills</u>

It is situated at Harian near Rajshahi Town. It was set up by the Government in 1962-65 at a cost of Tk.23.35 million with an initial cane crushing capacity of 1016 M.Tons per day. Machinery and equipment of the sugar mill were supplied by M/S. Mirrless and Watson of UK. The sugar mill started trial production in 1965-66.

Figure 3.4: Map of Rajshahi district showing the location of Rajshahi Sugar Mill.The mill is about 5km from the Rajshahi Dhaka highway.

Figure 3.4: Map of Rajshahi district showing the location of Rajshahi Sugar Mill



Joypurhat Sugar Mills

It is located at heart of Joypurhat district. It was set up by the Government in 1963 at a cost of Tk.23.50 million. The sugar mill started trial production in 1962-63. Since independence of Bangladesh, the sugar mill has produced 14,227 M.Tons of Sugar per annum on average at an average sugar recovery rate of 7.58% from sugarcane. Highest sugar production was 22,735 M.Tons in 1977-78.

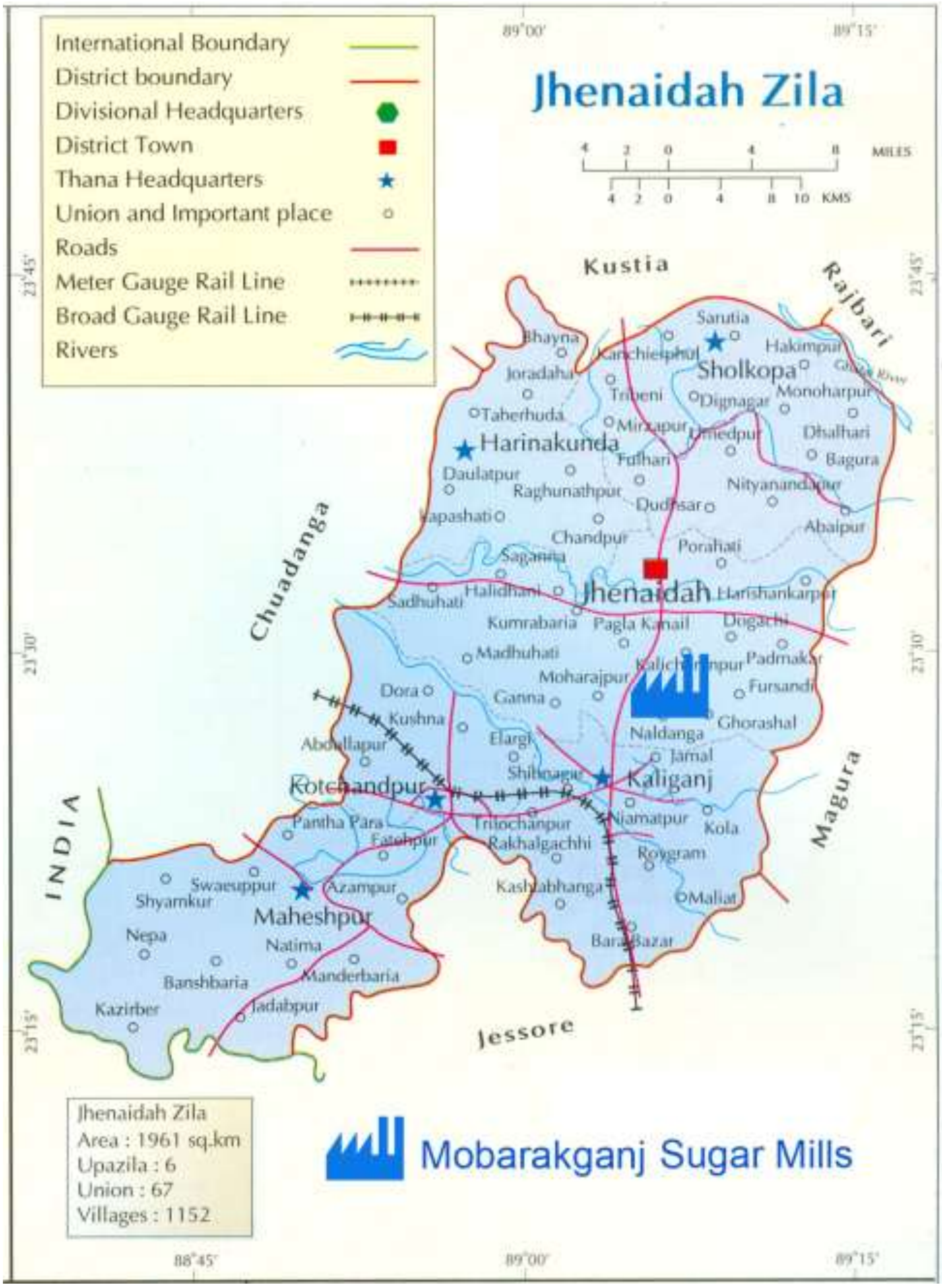
Figure 3.5: Map of Joypurhat district indicating the position of Joypurhat Sugar Mills

<u>Mobarakgonj Sugar Mill</u>

It is situated at Naldanga under Khaliganj Upazilla of Jhenaidah District and was set up by the Government in 1968 at a cost of Tk.35.09 million. Machinery & equipment of the sugar mill were supplied by M/S Stork-Werks poor of Holand.The sugar mill started trial production in 1967-68.

Figure 3.6: Map of Jhenaidah district showing the location of Mobarakgang Sugar Mill which is around 1.5 km from the Mobarakganj Railway Station.

Figure 3.6: Map of Jhenaidah district showing the location of Mobarakgang Sugar Mill



<u>Shampur Sugar Mill</u>

It is situated at Shampur under Bodorganj Upazilla of Rangpur District and was set up by the Government in 1968. Machinery and equipment of the sugar mills were supplied by Mitsubishi Heavy Industries of Japan.

Figure 3.7: Map of Rangpur district showing the location of Shampur Sugar Mill. The broad guage railway line connecting Rangpur to Parbotipur runs right by the side of the sugar mill.

Figure 3.7: Map of Rangpur district showing the location of Shampur Sugar Mill

Table 3.2: Comparison of Generators and Transformers for the selected Sugar Mills

Mill	Generator				Transformer	
	Steam		Diesel			
	Capacity (kW)	Year of installation	Capacity (kW)	Year of installation	Capacity (kVA)	Year of installation
NBSM	1000	1982	324	1954	500	Not Available
NBSM	1000	1982	192	1968	500	Not Available
RJSM	1500	1991	250	1987	500	Not Available
RJSM	1000	1964	250	1987	500	Not Available
RJSM	1000	1964	150	1964	500	Not Available
JSM	1000	1962	360	1998	250	1983
JSM	1000	1962	240	1966	250	1983
JSM	1500	1966	240	1966	250	1983
MKSM	1000	1965	185kVA	Not Available	500	Not Available
MKSM	1000	1965	400kVA	Not Available	500	Not Available
SHSM	1000	1967	200	Not Available	200	Not Available
SHSM	1000	1967	100	Not Available	200	Not Available

Source: BUET Study

Table 3.3:Comparison of Boilers for the selected Sugar Mills

Mill	Capacity (Ton/hr)		Year of installation
	Rated	Current	
NBSM	30	26 M	1987
	12.5 x 4	7 x 4 M	1933
	40	38 M	2002
RJSM	15 x 4	15 x 4	No. 1-3: 1964 No. 4: 1969
	30	30	1991
JSM	16 x 4	13 x 4	No. 1-3: 1961-62 No. 4: 1966
MKSM	16 x 3	16 x 3	1965
	30	30	1987
SHSM	15 x 3	10-12 M x 3	1965

Source: BUET Study

Table 3.4: Comparison of Turbines for the selected Sugar Mills

Mill	Rated Capacity	Year of installation
NBSM	1500 HP	1982
RJSM	1500 kW	1991
JSM	2 x 1000 kW	1965-66
	1 x 1.5 MW 2 x 1 MW	1966
MKSM	1 MW	1965
SHSM	1 MW	1965
	2 x 1 MW	1965

Source: BUET Study

In the said study, cogeneration potential has been analyzed considering physical and thermodynamic aspects of equipment, amount of power generation for the plant itself as well as supplying to the national grid along with the production of sugar from sugarcane as well as raw sugar on the basis of partial cogeneration (3 months) and complete cogeneration scheme (12 months).

The result of the analysis is presented in the Table 3.5below.

Table 3.5: Results of analysis for different options with coal as the fuel

Name of the mills	Items		Crushing Period (3 months)	Non-Crushing Period (9 months)
North Bengal Sugar Mills (NBSM)	Power Generation (MW)	Plant	1.0	0.0
		Grid	6.2	10.8
Rajshahi Sugar Mills (RJSM)	Power Generation (MW)	Plant	2.0	0.0
		Grid	6.3	11.8
Joypurhat Sugar Mills (JSM)	Power Generation (MW)	Plant	1.0	0.0
		Grid	2.9	7.1
Mobarakganj Sugar Mills (MKSM)	Power Generation (MW)	Plant	1.0	0.0
		Grid	4.5	8.7
Sampur Sugar Mills (SHSM)	Power Generation (MW)	Plant	1.0	0.0
		Grid	2.3	5.4
	Total	Grid	22.2	43.8

Source: Compiled from BUET Study

As per another study, on potential for cogeneration in Bangladesh conducted in 2001by Canada Bangladesh Infrastructure Consultants under CIDA for IIFC, most sugar mills in Bangladesh have some form of cogeneration and estimated that the 15 mills have some 40 MW power from cogeneration to meet their own power requirements during the cane crushing season. By replacing the equipment, in order to make full use of all the bagasse available for power generation, it was estimated that an additional 100 MW could be generated and sold directly to the grid. From BUET study it is also noted that individual sugar mills can produce an average of 10 MW additional power for national grid.

Another study, carried out earlier by the Bangladesh Centre for Advanced Studies (BCAS)on the potential of cogeneration in the sugar sector concluded that with the bagasse available power generation could achieve in excess of 100 MW for all the sugar mills. This may be achieved with an average installation of 10 MW at individual sugar mills.

Most sugar factories have low-pressure (15 bar) boilers. By installing high-pressure boilers, these can produce more power efficiently. The choice of boiler pressure of 64 kg/ cm^2 and above appears inevitable for mills intending to sell power to the national grid. Typically, a well-designed 2,500 tons crushed/day plant can sell 10 MW of power to national grid.

3.1.4 *Institutional Facilitators*

The Bangladesh Government is very keen to develop the cogeneration potential in the country. The following institutions support the development of the sector through its administrative or financing roles:

1. Sustainable and Renewable Energy Development Agency (SREDA)
2. Infrastructure Development Company Ltd (IDCOL)
3. IPFF and BIFFL (for financing)

3.1.5 *Government Initiatives and Legal Frameworks*

In order to give impetus to renewable energy, the Government of Bangladesh published the Renewable Energy Policy of Bangladesh in the 2008. The policy provides for:

- Establishment of SEDA
- Investment and fiscal incentives
- Preparing projects for accessing CDM funds
- Utilise PPP for developing renewable energy projects
- Scaling up contributions of renewable energy – both electricity and heat energy

3.1.6 *Barriers and Constraints*

This section provides a brief overview of the barriers and constraints related to cogeneration development. In Bangladesh industrial/commercial cogeneration could be developed considering the following points:

(i) An industrial/commercial installation that requires electricity and steam/heat but currently does not use cogeneration.

(ii) An industrial/commercial installation that requires electricity and steam/heat but currently only uses cogeneration to produce part of its internal requirements for these commodities.

(iii) An industrial/commercial installation that uses cogeneration to produce some or all of its requirements for electricity and steam/heat but does so using equipment that has reached the end of its life and needs to be replaced.

(iv) An industrial/commercial installation that would like to sell excess electricity and steam/heat produced via its cogeneration facilities in order to achieve sufficient return on its investment.

The barriers confronting the development of economic cogeneration can be classified into following four main categories e.g market, institutional, regulatory and other barriers:

Market Barriers

(a) Price of electricity

Market pricing mechanisms in cogeneration are not available. Thus there is uncertainty on the market prices with which cogeneration will have to compete. Price setting by a major player could preclude cogenerators from entering the market if they envisaged selling to the grid. Public power generating entities could offer heavily discounted rates to large consumers to ensure that they retain them as consumers and keep their load base.

(b) Cost of generation technology

With the advancement in cogeneration technology that result in lower cost per unit of power produced and/or increased efficiency, the cost remains high for some applications. Future efficiency improvements can result in lower costs per kWh of electricity that is generated. It is expected that this barrier will be reduced if the market demand for cogeneration technology increases in the future. This increased demand will lead to further investments in R&D and larger, more efficient production facilities which, in turn, would lead to higher operating efficiencies and lower cost for the equipment. Government can reduce costs through tax or other policies and an example has already been set in Bangladesh for IPPs.

Institutional Barriers

(a) Management involvement

The barriers can basically be divided into following three categories:

(i) long-term commitments,

(ii) competition for limited funds, and

(iii) attitudes of senior management

It is noted that the management of potential large consumers of many of the most attractive cogeneration sites with a sufficiently high steam and electricity demand will be reluctant to make the long-term commitment required to construct a cogeneration plant. This reluctance could become an issue as the electricity market opens up and the future price of electricity is unknown. The management used to compare the return/pay-back period of potential cogeneration facilities against other potential capital projects. Other projects may have higher potential returns and a faster payback period compared to the cogeneration facility.

Related to the first two barriers are attitudes of management of the most attractive potential cogeneration sites. These attitudes are based on the fact that power supply is not part of their core business. However, in cases where managers are concerned about the reliability and quality of power supply from the grid, those factors would be mitigated.

(b) Government Ownership

Most of the industrial facilities in Bangladesh are owned by the government. Due to constraints on the availability of investment capital, many governments owned facilities are unable to obtain funding to improve their efficiency or energy utilization via cogeneration.

(c) Lack of Information

Although not a new technology, there is generally a lack of information, understanding and confidence in cogeneration technologies both by potential users as well as investors. This barrier results in the need by both potential customers and investors to spend time and cost to qualify themselves about this technology.

Information costs may be one of the most important institutional barriers and lack of information, understanding and confidence are effectively relate to information costs.

(d) *Transmission Access*

The design of any cogeneration installation is very specific to the characteristics of the site: the size of the electricity load, the size of the heat load, and the time patterns of their usage (the load durations). In many cases, a cogeneration facility which can meet the heat load efficiently will produce more electricity than the steam host requires. For the cogeneration application to maximize value, and perhaps even to be economic, it requires access to the electricity market for the surplus power. Access to the market will be provided in the coming competitive environment. However, there remains uncertainty as to the rules and regulations that will apply to such access.

Regulatory Barriers

Some of the regulatory issues concern fulfilling of technical requirements, licensing arrangements, ability to "wheel" (i.e. allowing cogenerators to sell electricity and heat directly to energy consumers, not through utilities), etc. While the principle of authorization sounds reasonable, procedures can be bureaucratic, complex and time consuming, thus perceived as a disincentive for potential cogenerators with little experience in the power sector.

As a relatively low emission technology, it will be important to ensure that potential cogeneration projects are reviewed efficiently and promptly:

The environmental authorities should set procedures for three categories of projects:

(i) those that require an individual environmental assessment;

(ii) those that would require a screening process; and

(iii) thosethat would not require approval under the existing environmental regulations

In order to make cogeneration attractive to potential investors, the fiscal incentives should be extended to the potential investors and where possible improved.

Other Barriers

Other barriers include the lack of skilled manpower and management. In most cases, both the electric utilities as well as the industrial plants lack skilled manpower and managers to handle the specific task of heat and power production.

3.1.7 *Cost Benefit Analysis*

In this section, analysis has been presented to determine the financial viability of the selected typical cogeneration applications in Bangladesh based on the BUET's feasibility study report as mentioned above (3.1.3).

In the BUET study, the impacts of different options on the investment, production of sugar and generation of electrical energy were financially analyzed. Note that for running the cogeneration throughout the year, the bagasse obtained from cane crashing are not enough. So, for the additional fuels coal, gas and furnace oil have been considered. This financial analysis presents the detailed results obtained with the coal as additional fuel.

The total Power generation capacity of each of the five sugar mills were also evaluated considering the power generation capacity during crushing and non-crushing period. The sugar production capacity due to cogeneration as well as to the raw sugar process of each of the five sugar mills was also evaluated. The annual amount of energy that is expected to be supplied to the grid is also calculated by considering the scheduled maintenance and forced outages of the generating units.

From the study it was estimated that these five sugar mills can contribute around 60 MW of electric energy to the national grid. The annual profit was also calculated considering revenue, investment and productions cost and in total it was Tk. 1,268 crore i.e US$ 158million annually.

This cogeneration applications will not only earn profit by selling sugar and energy but also contribute to the mitigation of energy crisis of the nation.

3.1.8 *Recommendations*

As the sugar mills in Bangladesh are normally operated only in the season time (150 days), to run the mill throughout the year as a cogeneration system, following steps could be taken by the mill authorities.

- Some extra power can be generated for the national grid by using back pressure turbine and also by using condenser turbine where extra boiler capacity is available. Most of the sugar mills in Bangladesh have some extra boiler capacity.
- In addition to the bagasse, the fuel burning system can be modified for continuous burning with coal with indigenous coal supply from the Baropukuria coal mine or imported from neighbouring countries. During the

crushing season, the boiler would be fired on bagasse and during the off-season, possible alternate fuels e.g. peat, coal or natural gas can be considered.

Energy Ministry with the concerned entities responsible for the development of Sugar Sector may establish a co-ordinating committee with a view to:

a) emphasis on use of cogeneration

b) promoting cogeneration technology

c) time to time discussion with regulatory authorities with policy, tariff, etc. for favour the growth of cogeneration

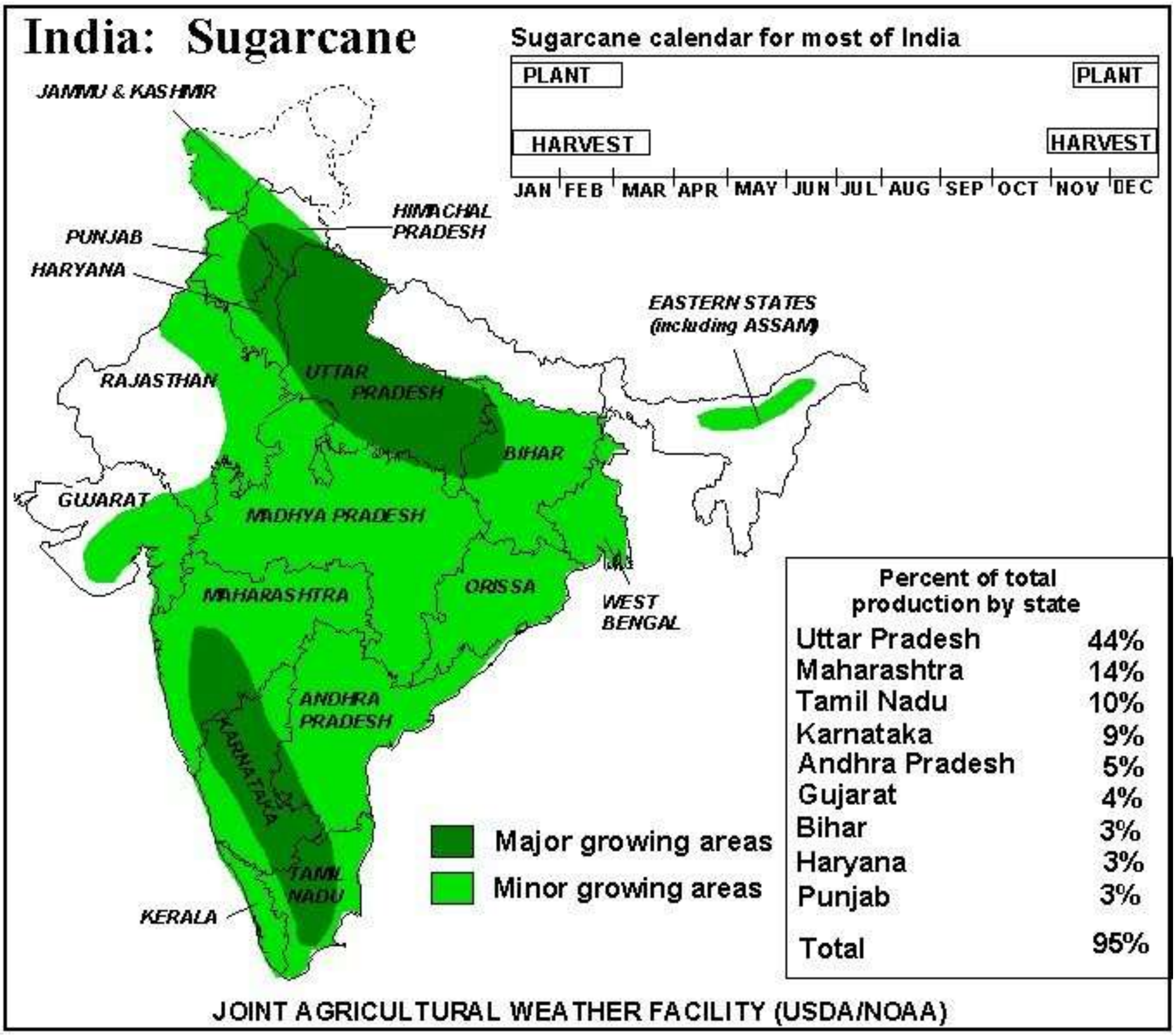
d) organize training workshop/seminars for exchanging experiences and information among other potential industries and SAARC member region.

3.2 India

India has been known as the home of sugar and sugarcane. Indian mythology supports the above fact as it contains legends showing the origin of sugarcane. India is the second largest producer of sugarcane next to Brazil. Presently, about 4 million hectares of land is under sugarcane with an average yield of 70 tons per hectare.[7]

Figure 2.1: Combined Cycle Topping Systemand Figure 3.9: Showing location of Sugar Mills of India"State Wise Sugarcane Production" and "Location of Sugar Mills" in India respectively.

Figure 3.8: Showing state wise sugarcane production in India



[7] www.sugarindustry.com

Figure 3.9: Showing location of Sugar Mills of India

In India, about 60% of the cane produced goes into making refined (centrifugal) sugar, while the remaining 40% is used by the small-scale industry to produce gur and khandsari -- traditional forms of sugar made from an open pan process at atmospheric pressure. In 1989-90, the country produced 222,628,000 tons of sugarcane from 3,405,000 hectares under cultivation or 65,383 kg/hectare. The northern state of Uttar Pradesh is the leading producer of cane, accounting for over 97 million tons or 44.6% of the total. Maharashtra and Tamil Nadu are the second and third ranking sugarcane producers, with 34,008,000 tons or 13.5% of total and 21,918,000 tons or 11.2% of total, respectively. Bagasse, the fibrous residue of the sugarcane used for raising steam in boilers, accounts for approximately 30% of the cane weight. Sugar mills are privately owned, publicly owned, and owned by cooperatives. Of the 491 licensed sugar factories, 288 are in the cooperative sector, accounting for 59% of the factories installed and 62.4% of the national output of sugar. Most of the remaining mills are in private hands.

The size of sugar mills in India is small by international standards. Average mill size is under 2,000 tons crushed per day. Since 1987, however, a minimum 2,500 tons per day standard has been imposed for new mills, and incentives have been created to encourage expansion to up to 5,000 tons per day. Estimates of the potential for cogeneration from the sugar industry vary widely. The ESMAP study on Maharashtra identified 13 mills with a current or expanding capacity of 3,500 tons per day.

3.2.1 *Industry Structure*

The Indian sugar industry uses sugarcane for production of sugar and hence maximum number of the companies is likely to be found in the sugarcane growing states of India including Uttar Pradesh, Maharashtra, Gujarat, Tamil Nadu, Karnataka, and Andhra Pradesh. Uttar Pradesh alone accounts for 24% of the overall sugar production in the nation and Maharashtra's contribution can be totaled to 20%.

The sugar industry can be divided into two sectors including organized and unorganized sector. Sugar factories belong to the organized sector and those who produce traditional sweeteners fall into unorganized sector. Gur and khandsari are the traditional forms of sweeteners.

Several steps are usually followed to produce sugar. These steps are:

- Extracting juice by pressing sugarcane
- Boiling the juice to obtain crystals
- Creating raw sugar by spinning crystals in extractors
- Taking raw sugar to a refinery for the process of filtering and washing to discard remaining non-sugar elements and hue
- Crystallizing and drying sugar
- Packaging the ready sugar

India is the world's largest sugar consuming country and is also the second largest in terms of sugar production. The growth of sugar factories along with the sugar industry segments depicts the sugar industry scenario in India.

Growing population coupled with rising income is providing impetus to the growth in the country's sugar consumption, benefiting the overall sugar industry. India is the world's second largest populated country, representing about 17.31% of the global population. Aggressive growth in the food and beverage industries will lead to the increasing demand for sugar. High sugar content in confectionaries, including chocolates, pastries and ice-creams, will drive the domestic demand for sugar.

By-products, such as ethanol and power via cogeneration provides cross functional and cross business opportunities. Growing pharmaceutical market and low per capita sugar consumption in India provide opportunities for the players to capitalize upon. Oversupply situation coupled with higher cane prices results in declining profit margin for the players in the sugar industry. Cyclical nature of the crop results in volatility in sugar production leading to high cane arrears. The present pricing policy is highly government regulated resulting in limited bargaining power of the sugar millers.

3.2.2 *Current Cogeneration Situation*

In January 2012, the installed capacity of renewable power generation in India was 23 GW, which is equivalent to nearly 12% of total power capacity (MNRE, 2012; CEA, 2012). Bagasse cogeneration contributes 9% capacity represented by 2 GW. The principal fuel used to raise steam in India's sugar mills is bagasse. Bagasse is the fibrous waste that remains after recovery of sugar juice via crushing and extraction. The fiber content of sugar cane varies somewhat but averages about 15% on cane, which is equivalent to approximately 30% by weight of the cane on a mill-wet basis

(48-52%)[8]. The gross heating value of mill-wet bagasse is approximately *2300 kcal/kg (4100 Btu/lb)* — one ton of bagasse is equal to about two barrels of oil on an energy basis.

Industrial cogeneration has been the subject of considerable interest and inquiry in India for over a decade. The main arguments for cogeneration in India have centered on two compelling needs: i) to augment supply of power inexpensively in a regime of endemic power shortages, and ii) to promote energy conversion efficiency and thereby conserve scarce fossil fuels. In other words, the debate, until now, has centered on the use of cogeneration to ensure reliable, continuous delivery of cost effective power and to reduce dependence on fossil fuels.

To date, cogeneration in India has been restricted to the production of electrical energy for own use or "captive power" and has been viewed as a way to meet simultaneous onsite heat and power demands independently of the grid. Industries such as sugar, pulp and paper, and textiles have been "cogenerating" electricity and steam for many years. The location of these industries in regions removed from the grid (e.g., sugar mills and paper plants), the availability of by-product fuels (e.g., bagasse and black liquor), and the steam requirements of the industrial process all combine to favor cogeneration.

Depending on the technology deployed, and the corresponding efficiency, about 75-90% of the bagasse available at Indian mills is used to produce internal steam and electricity; the balance is considered surplus and is either discarded or used for other purposes. The availability of surplus bagasse, or other fuels, is a major issue when considering year-round cogeneration with power export to the grid.

3.2.3 *Cogeneration Potential*

The potential from all operating sugar mills of India spread over 9 major states has been identified at 3,500 MW of surplus power by using bagasse as the renewable source of energy. The project involves employment of extra high-pressure boiler configurations of 67 kg/cm^2 or 87 kg/cm^2 or 105 kg/cm^2 (against the conventional 32 kg/cm^2 or 42 kg/cm^2 pressure boilers used in the sugar mills)[9].

Sugar mills conventionally cogenerate their own requirements of steam and power during the season operation of 150-200 days by using bagasse, the residue of sugarcane generated after crushing. They generally use a number of low-pressure

[8]a)Advancing Cogeneration in the Indian Sugar Industry - Three Mills in Tamil Nadu and Maharashtra, U.S. Agency for International Development, Report No. 93-02, May 1993.

b) Personal communication with the International Fund for Renewable Energy and Energy Efficiency(IFREE) and deLucia and Associates based on work done for the Asian Development Bank, April 1996.

c) Bagasse-Based Cogeneration in India: A Market Primer for U.S. Companies, Prepared by the National BioEnergy Industries Association, March 1995.

d) Eniasivam, S., “India - Utopia Amidst Political Chaos and Myopia?,” World Cogeneration, Vol. 7, No. 5, November/December 1995.

[9]MNES Annual Report 2003 & Estimates from MITCON Cane trash and other agri / forest waste

inefficient boilers for the purpose and consume/waste the entire bagasse during their season operations.

Over the years, due to the expansion and diversification of sugar mills, their energy needs, both during season and off-season, have multiplied. They often require high-cost grid power and additional fuels both during season and off-season.

The high-efficiency cogeneration design not only uses the available bagasse efficiently, but also yields substantial quantities of power for exporting to the grid, over and above their enhanced energy needs. Improved energy efficiency of sugar mill operations to a maximum possible extent is a pre-requisite for building high-efficiency grid-connected cogeneration power plants. Reduced captive steam and power consumptions enhance bagasse availability for extra power generation and for extending their period of operation beyond the crushing season.

The potential of 3,500 MW can be easily increased to over 5,000 MW by employing equipment and systems for reduction of steam and power in sugar processes (from present 50-52% steam on cane and 22 units of electricity per ton of cane crushed to 42-45% steam on cane and 16 units of electricity per ton of cane crushed), as well as for the manufacture of by-products.[10]

The following table gives the state-wise potential for existing conventional and energy-efficient sugar mills in India:

Table 3.6: State wise Potential for Exportable Surplus Electricity

Sr. no.	**State**	**Potential for Exportable Surplus, MW**	
		Conventional Sugar Mills	Energy-efficient Sugar Mills
1.	Maharashtra	1,000	1,250
2.	Uttar Pradesh	1,000	1,250
3.	Tamil Nadu	350	500
4.	Karnataka	300	400
5.	Andhra Pradesh	200	300
6.	Bihar	200	250
7.	Gujarat	200	400
8.	Punjab	150	250
9.	Haryana & others	100	400
	Total	**3,500**	**5,000**

Source: MNES Annual Report 2003

[10]International Sugar Organization: Cogeneration- Opportunities in the world sugar Industries, April 2009

The achievements against this potential, as of December, 2004 cumulate to 432 MW from 56 projects. Additional capacity of about 323 MW from 36 projects is under various stages of construction. Thus, a total of 92 projects, commissioned or under construction, have demonstrated techno-commercial viability. These projects vary in size from 5 MW to 40 MW and mainly use bagasse as fuel with biomass and conventional fuels like coal.

On account of substantial efforts by MNES, bilateral agencies, financial institutions and others, the achievement of 8% of the potential has actually been realized, with another 7% under construction. The barriers for accelerated development of this sector include lack of a sustainable and conducive policy and regulatory framework, innovative financing mechanisms, high risks of fuel linkage, and inadequate capacity.

Cogeneration's market potential depends on a wide range of technical, economic, and institutional considerations, including a plant's steam demand and electric needs, the relative cost of cogenerated power, the fuel used and its cost, tax treatment, rates for utility purchases of cogenerated electricity, and perceived risks such as regulatory uncertainty.

Many Indian sugar mills have recognized the potential for the profitable generation of excess power (i.e., greater than the internal needs of the mill) via cogeneration. Also, many of the State Electricity Boards (i.e., the state-owned utilities) are looking to the sugar mills as economical power sources to meet the growing national demand. As a result, optimum utilization of bagasse and steam within the mills has taken priority. Thus, sugar mills have started looking at alternative schemes to increase power generation. <u>With a higher pressure system, a typical 2500 TPD mill can generate about 11 MW of power of which 8 MW is surplus to the needs of the mill and could be supplied to the grid or a nearby industrial customer</u>. A few industrial plants in India currently wheel excess power through the grid; a similar approach can be pursued by the sugar mills. Larger mills of 5000 TPD capacity can be configured to produce 35-50 MW of which 20-35 MW could be exported.

A study sponsored by the Asian Development Bank suggests that mills crushing at least 200,000 metric tons/year (220,000 tons/year, or about 1100 TPD, or 1200 tons/day, based on an annual crushing season of 180 days) of cane in at least one recent year could consider cogeneration investments[11]. This study concluded that with highly efficient mill operations (i.e., at a steam/cane ratio of about 45%) and using high-pressure steam (42 or 62 ata) systems, the potential for sugar mill cogeneration in India is about 2800 MWin 1996-1997. At more modest conditions (i.e., at a steam/cane ratio of about 55% and using lower pressure boilers), the potential was estimated to be about 1400 MW in 1996-1997. In this study, 174 sugar mills located in the nine primary sugar producing states were thought to have cogeneration potential. The majority of these mills are located in the three largest sugar-producing states: Maharashtra (55 mills), Uttar Pradesh (51 mills), and Tamil Nadu (24 mills). The Government of India's Ministry of Non-Conventional Energy

[11]Personal communication with the International Fund for Renewable Energy and Energy Efficiency(IFREE) and deLucia and Associates based on work done for the Asian Development Bank, April 1996

Sources (MNES) estimated the total cogeneration potential within the sugar industry at 3000-3500 MW[12]. A study by the U.S. Agency for International Development (USAID) estimated the total potential at 3800 MW.

3.2.4 *Institutional Facilitators*

The growth of Cogeneration dates back to 1993-94, when the Ministry of Non-Conventional Energy Sources (MNES), Govt. of India, New Delhi, launched National Program on Biomass Power / Bagasse based Cogeneration. This program focused on biomass as renewable energy source since 1992-93. Since then, the Ministry has launched key promotional programs including biomass resource assessment, bagasse- /biomass-based cogeneration, biomass-based power generation, R&D including advanced biomass gasification and industrial cogeneration.

The bagasse cogeneration program focused on the generation of exportable surplus by deploying extra high pressure and temperature applications. This program included:

- capital grant support for demonstration projects,
- interest subsidy schemes for different pressure/temperature configurations with higher levels of interest subsidy for higher configurations,
- a Program Partnership Initiative for promotion across the country,
- guidelines for States for purchase of exportable surplus, promotional efforts for conducive policy/regulatory framework development,
- capacity building and awareness, and fiscal support to industry associations, consultants, etc.

All the above initiatives were updated/revised every year, to suit the market requirements and status of commercialization. The Ministry is likely to announce a back-ended capital subsidy scheme for these projects for the future with lower/reducing levels of capital grants.

United States Agency for Industrial Development (USAID), through its innovative capital grant scheme for nine select bagasse cogeneration projects in the private sector during 1997-2002, as well as through specific technical assistance and capacity building programs in this sector, has also contributed significantly. United Nations Development Program (UNDP), along with the Government of India, has recently cleared an innovative project in this sector named 'Removal of Barriers to Biomass Power Generation in India'. This project is expected to get operationalized in this year. Successful implementations of various activities under this project are expected to accelerate the growth. Under this project, one bagasse cogen project on IPP mode at co-operative sugar mill will be supported.

[12]Indian Sugar Mills Association, Directorate of Economic and Statistical Advisor, Government of India.

State Nodal Agencies, particularly with predominant sugar mills and biomass resources, have also contributed to the development of this sector in their States, through specific programs and activities using available incentives from MNES.

A host of other fiscal and promotional incentives from the Government of India and many States include accelerated depreciation, income tax holidays, concessions and exemption on customs/excise duties, direct/indirect taxes, sales tax, etc. The Electricity Bill 2003 duly enacted by the Indian Parliament and its conducive provisions for renewable energy thereof, will provide further impetus to harness maximum potential from this sector.

The Indian Renewable Energy Development Agency Ltd. (IREDA), a Government of India enterprise and the lending arm of MNES, has provided promotional/development finance for harnessing biomass energy in India over the last 10-12 years. IREDA has made a major contribution in the development and commercialization of bagasse cogeneration projects at sugar mills and other biomass power plants in India (refer IREDA web site http://iredaltd.com for the prevailing lending norms for bagasse cogen and biomass power projects).

A number of other financial institutions such as Housing & Urban Development Corporation Ltd. (HUDCO), Rural Electrification Corporation of India Ltd. (REC), Power Finance Corporation Ltd. (PFC), Industrial Credit & Investment Corporation of India Ltd. (ICICI) at the Central level, and nationalized banks at decentralized locations, have come forward to provide term loan finance to this sector, at attractive lending terms.

3.2.5 *Government Initiatives and Legal Frameworks*

The government initiatives in the Pre-Budget Memorandum 2012-13, includes removal of 10% levy sugar quota, implementation of tax incentives, Cenvat Credit on Bagasse, tax deduction and exemption from both service tax and value-added tax.[13]

Cogeneration of power, sale, and interstate transmission by large IPPs including sugar mills is allowed by regulations of the National Electricity Policy 1991 under the provisions of the Electricity Act. The sugar industry is freed from licensing both for establishment of new units as well as expansion in existing units.

In 1993, the Ministry of Non-conventional Energy Sources constituted a Task Force to assess the potential for cogeneration in the sugar industry. The Task Force assessed the potential for additional cogeneration of power for supplying to the grid at 3500 MW. The Ministry had announced guidelines requiring individual States to fix electricity prices for bagasse-based cogeneration. These were to include escalating feed-in tariff, payment guaranties by the State Electricity Board (SEB) under PPAs, as well as guarantees that SEBs would bear the cost of grid connection[14].

[13]http://www.bharatbook.com/market-research-reports/food-market-research-report/sugar-industry-in-india-2012.html

[14]Bagasse Cogeneration – Global Review and Potential. WADE, June 2004

The Ministry of Non-Conventional Energy Sources also facilitated setting up of cogeneration plants by giving an interest subsidy to the extent of 2 percentage points on institutional loans. Indian Renewable Energy Development Authority (IREDA) is the nodal agency for disbursement of interest subsidy to cogeneration projects besides being a funding agency.

In 2003, the Ministry of Consumer Affairs, Food & Public Distribution created a scheme for funding of cogeneration plants from the Sugar Development Fund (SDF) at a preferential rate of interest.

Also in 2003, the Central Electricity Act was amended. The Act consolidated the laws relating to generation, transmission, distribution, trading, rationalization of tariffs, promotion of efficiency and environmentally benign policies. The Act also permits open access for sale of power. The amended Act lays emphasis on incremental power generation from renewable energy sources through preferential tariffs.

The Act provides for restructuring of SEBs and constitution of State Electricity Regulatory Commissions (SERCs) to determine the tariff for generation of power, transmission, etc. SERCs are guided by the National Electricity Policy of the Central Government under the provisions of the Electricity Act.

The National Electricity Policy 2006 announced tariff guidelines to be followed by SERCs. It provides for an Availability Based Tariff (ABT). Any deviations from the committed supply under this arrangement shall be subject to an U.I. tariff (unexpected inter change) depending on grid frequency. Currently the U.I. tariff ranges from Rs.4/- to Rs.9/- per unit with an average of about Rs.6/50 per unit. In respect of non-conventional sources of energy including cogeneration of power, the policy stipulates that the appropriate commission shall fix a minimum percentage of renewable power to be purchased taking into account the availability of such resources in the region. Uttar Pradesh, Tamil Nadu, Andhra Pradesh Karnataka and Maharashtra have notified compulsory purchase of 5% renewable energy. The purchase of renewable energy is made at tariff rates based on long term agreements between cogeneration units and SERCs as against the bidding process recommended in the tariff guidelines announced in 2006.

There are compulsory purchases (5% of the total energy to come from renewable sources) at low prices established by the SERCs in Uttar Pradesh, Tamil Nadu, Andhra Pradesh Karnataka and Maharashtra. The purchase of renewable energy is made based on long term agreements between cogeneration units and SERCs. The cogeneration units who had no other option, except for sale of power to the SERC initially, had signed the agreements with the SERCs.

Apart from low tariff offered by the State regulatory commissions, even the payments have not been made regularly in time. Several cogeneration units falling under this category approached the Central Electricity Regulatory Commission (CERC), a quasi-judicial authority constituted as per the amended Electricity Act for relief.

The Maharashtra Electricity Regulatory Commission (MERC) gave a landmark tariff order in the year 2002 for bagasse-based cogeneration power plants with 2% compounding escalation, and included other conducive terms such as a 13-year PPA term, infirm power, 50% cost of evacuation to be borne by the SEB, etc. (refer www.mercindia.com for details).

3.2.6 *Barriers and Constraints*

Industrial cogeneration has been the subject of considerable interest in India for over a decade. In general, cogeneration in India has been restricted to the production of electricity for own use (i.e., captive power) and has been viewed as a means to meet simultaneous on-site needs for heat and power independent of the grid. Many Indian industries, including the sugar, pulp and paper, and textile industries, have been cogenerating steam and electricity for many years. In these industries, cogeneration has been favored for several reasons:

a. have significant simultaneous steam and power requirements,
b. by-products or wastes are produced can be used as low-cost fuels,
c. many of the plants are located in areas not connected to the grid, and
d. want to lower their plant operating costs.

Barriers to cogeneration development can be classified into the following: technical, financial drawbacks, poor institutional framework, inadequate regulatory framework, short-sighted electric utility policies, low environmental concern and some other barriers.

a) Technical barriers

First technical barrier is the low level of awareness about the soundness of cogeneration technologies due to the lack of technical information at the level of local utilities, industries, potential cogenerators and governments. In fact, awareness building about cogeneration is the very first step to promote cogeneration systems. Lack of capability to locally manufacture some energy supply equipment can lead to higher investments linked with higher cost of imported equipment. Inferior quality of equipment produced by local manufacturers with poor technologies also hampers the propagation of cogeneration systems. In many developing countries, the technical expertise to design, construct and operate energy efficient cogeneration systems is quite limited. For grid-dependent systems with the option of electricity export to the grid, advanced electrical control systems are necessary for both cogeneration plants and local electric utilities. The local electric utilities must have competent personnel who are capable of operating a more complicated system consisting of utility owned power plants and cogenerators. The cogeneration systems need skilled technicians for regular maintenance and trouble-free operation. Lack of infrastructure is also one of the obstacles in promoting cogeneration systems. For instance, there are natural gas networks in many developed countries. The lack of infrastructure such as gas handling, storage and distribution auxiliaries in some developing countries leads to technically more complicated systems for gas powered cogeneration.

b) Financial drawbacks

Cogeneration systems are somewhat capital intensive. Investments required are sometimes out of reach of energy consuming facilities such as industries, commercial buildings, hospitals, etc., in many developing countries.

Any lack of guarantee for long term availability of fuels can lead to higher risks in investing in cogeneration systems. For example, unlike the developed economies, the availability of fuels in most developing countries depends on the government's policy changes due to the monopoly of the energy sector. There will be uncertainties about the actual energy cost savings unless long-term fuel supply is ensured.

A cogeneration scheme may be found to be a good financial investment and provide reasonable payback period. The hindering factors however are those which limit the income derived from the products (heat and electricity) or increase the cost of inputs (equipment and fuel). Among these, electricity pricing appears to be the deciding factor that is beyond the control of the cogenerator. Some sort of involvement of energy companies and development of third-party financing schemes can help to reduce the financial uncertainties.

In countries where prices of other fuels and electricity are subsidized, cogeneration systems cannot be financially attractive for private or public enterprises if the energy consuming facility has easy access to the grid or can buy other subsidized fuels. The low rate of return on investment would not justify the high capital requirement of a cogeneration system.

Investors may often look for some form of incentives such as reduced fuel prices, investment subsidy, tax benefits and attractive tariffs. In countries having no or inadequate incentives, cogeneration development has been found to be low or marginal. In industrialized countries, cogeneration has been promoted through financial incentives such as soft loans, subsidies, tax credit, etc. Experiences show that these financial incentives are effective tools to enhance the development of cogeneration in industries and utilities.

c) Poor institutional structure

Like other energy efficient technologies, cogeneration can be effectively and rapidly promoted by the government and appropriate institutions working together in harmony. Institutional issues are mainly related to the seriousness of the national authorities in promoting cogeneration in order to achieve conservation of fossil fuels and protection of the environment.

In some instances, existence of a promotional organization for cogeneration has helped to establish policy measures and develop cogeneration market. Some developing countries lack institutions or have inadequate institutions to deal with energy and environment matters. In such instances, there are no energy conservation campaigns and distribution of information on energy efficient technology such as cogeneration.

d) Inadequate regulatory framework

Inadequate regulatory framework can set negative example in the form of poorly planned and designed projects. When foreign investment is involved, the question of allocating sovereign risks and guaranteeing utility payment obligations must be resolved. Lack of experience in planning and lack of transparent power purchase agreement can lead to prolonged process of negotiation between the project developers and the concerned authorities, resulting in unnecessary delays in project implementation and financial losses to the developers.

Some of the regulatory issues concern fulfilling of technical requirements, licensing arrangements, ability to “wheel” (i.e. allowing cogenerators to sell electricity and heat directly to energy consumers, not through utilities), etc. While the principle of authorization sounds reasonable, procedures can be bureaucratic, complex and time consuming, thus perceived as a disincentive for potential cogenerators with little experience in the power sector.

It is also important that the government and institutions themselves must be aware of the benefits of cogeneration in achieving higher overall energy efficiency and lower emission of pollutants. However, the lack of expertise in government body and relevant institutions leads to lower level of awareness on cogeneration and weak policy on the development of cogeneration.

Some developing countries have realized the importance of energy conservation in the economic growth. They have formed a number of institutions to handle the energy matters including promotion of cogeneration. However, the duty and responsibility of each institution is not clearly defined or there is an overlapping of responsibility among the institutions. Such an inefficient institutional structure leads to ineffective cooperation between the government and industries or other energy intensive facilities. Contradictory policies and complicated procedures often frustrate the potential cogenerators.

e) Role of electric utilities

Equally important is the role and attitude of electric utilities towards cogeneration. In spite of the fact that these utilities are being restructured in many parts of the world including Asia, many among them remain monopolistic in nature. Significant investments have been made in the past to develop their generation capacities. As some of these investments have been written off, relatively inexpensive electricity is produced which is not conducive to the development of alternative options of power generation even when they are found economic.

If electricity prices are low, there is little incentive for the users to consider supplying their own power or sell it to the grid with unattractive payback periods. Unhelpful utility attitudes and actions are manifested in the following recurring themes:

- tariffs fixed for purchasing surplus electricity from cogenerator are too low;
- tariffs for stand-by or back-up supplies to the cogenerator are excessive;
- sale of electricity to third parties is rarely permitted or is too expensive;
- technical authorization to new schemes are not always fully transparent; procedure followed can be time consuming and costly.

Where utilities do not consider the cost of additional power generation (system avoided costs) while fixing the power purchase agreement with the cogenerators, they cannot raise enough funds to expand their generating capacities, while they hinder the growth of private investment in power generation or cogeneration. In the process, there is a shortfall between the supply and the demand and there is a slowdown of the national economy

Sometimes, although there are several energy and environment related institutions in some countries, they are not capable of formulating suitable energy policies. For instance, they cannot draft well-structured electricity tariffs. These institutions often imitate the energy policies directly from other countries that are not always suitable for their respective countries. Therefore, the lack of ability to formulate and implement sound energy policies leads to improper dissemination of energy efficient and environmentally sound technologies including cogeneration.

f) Environmental issues

Some developing countries feel that environment is a matter of concern of industrialized countries. They are reluctant to impose environmental restrictions on industries, being afraid that local industries would lose the competitiveness in world market. Such a situation favours the use of cheaper and pollution intensive fuels in inefficient manner. Without energy efficiency standards and environmental regulations, cogeneration systems would not get an advantage over other systems. Therefore, higher environmental concern is necessary to promote cogeneration.

Where emission regulations are used to limit air pollution related to various economic activities, they can be discriminatory against cogeneration installations, as the emission thresholds set do not always recognize the efficiency of energy conversion of the cogeneration process. Though a cogeneration plant may increase the local emissions, it normally displaces even more emissions at the fossil fuel power plant. Any relaxation in the limit of air pollution can help to reduce the investment on cogeneration facilities.

Natural gas is widely recognized as a clean fossil fuel for cogeneration applications. Where it is available and the gas network exists, natural gas can be a promising fuel if it is not too expensive.

g) Other Barriers

Other barriers include the lack of skilled manpower and management. In most cases, both the electric utilities as well as the industrial plants lack skilled manpower and managers to handle the specific task of heat and power production.

3.2.7 *Cost Benefit Analysis*

The main arguments for cogeneration in India have centered on two compelling issues: cogeneration is a relatively inexpensive means to augment conventional power supplies and energy conservation via cogeneration can reduce costs, and possibly increase profits, while reducing or avoiding the pollution attendant with fossil fuel utilization. The need for electrical power in India clearly justifies industrial cogeneration where technically and economically feasible.

A wide range of considerations must be taken into account in deciding whether to invest in an industrial cogeneration system. These include both internal and exogenous economic factors, fuel cost and availability, ownership and financing, tax incentives, utility capacity expansion plans and rates for purchases of cogenerated power, and a variety of perceived risks in such an investment.

Prior to undertaking any economic analysis to assess the commercial benefits of a cogeneration project, attention needs to be given to some important technical parameters which are summarized below:

a) Heat-to-power ratio;
b) Quality of thermal energy needed;
c) Electrical and thermal energy demand patterns;
d) Fuel availability;
e) Required system reliability;
f) Local environmental regulations;
g) Dependency on the local power grid;
h) Option for exporting excess electricity to the grid or a third party, etc.

Cogeneration may be considered economical only if the different forms of energy produced have a higher value than the investment and operating costs incurred on the cogeneration facility. In some cases, the revenue generated from the sale of excess electricity and heat or the cost of availing stand-by connection must be included. More difficult to quantify are the indirect benefits that may accrue from the project, such as avoidance of economic losses associated with the disruption in grid power, and improvement in productivity and product quality.

Following are the major factors that need to be taken into consideration for economic evaluation of a cogeneration project:

a) initial investment;
b) operating and maintenance costs;
c) fuel price;
d) price of energy (electricity and heat) purchased and sold.

Initial investment is the key variable that includes many items in addition to the cost of the cogeneration equipment. To start with, one should consider the cost of pre-engineering and planning. Barring a few exceptional cases, the cogenerator would normally hire a consulting firm to carry out the technical feasibility of the project before identifying suitable alternatives that may be retained for economic analysis. If the cogeneration equipment needs to be imported, one should add the prevailing taxes and duties to the equipment cost. If one plans to purchase cogeneration components from different suppliers and assemble them on site, one should take into account the cost of preparing the site, civil, mechanical and electrical works, acquiring of all auxiliary items such as electrical connections, piping of hot and cold utilities, condensers, cooling towers, instrumentation and control, etc.

Integration of the cogeneration plant into the existing set-up may lead to some `economic losses to the cogenerator (e.g. production downtime). Costs associated with such losses should be included in the total project cost.

The operating and maintenance (O&M) cost should include all direct and indirect costs of operating the new cogeneration facility, such as servicing, equipment overhauls, replacement of parts, etc. The cost of employing additional personnel as well as their training needed for operating the new facility must also be taken into account. Present technology allows complete automation of small pre-packaged and pre-engineered units, helping to reduce the O&M costs considerably.

Annual costs incurred due to the cogeneration plant, such as the insurance fees and property taxes should be included in the analysis. These are often calculated as a fixed percentage of the initial investment.

The price of energy purchased and sold is a decisive parameter. This includes the net value of electricity or thermal energy that is displaced as well as any excess electricity or thermal energy sold to the grid or a third party. A good understanding of the electric utility's tariff structure is important, which may include energy charge and capacity charge, time-of-use tariff, stand-by charges, electricity buy-back rates, etc. As for the fuel, there should be provision to account for electricity price escalation with time. This is particularly true where power utilities depend heavily on fuel in their power generation-mix.

Regardless of whether the cogeneration project is a totally new facility or a retrofit of an existing operation, the project will materialize only if it is financially attractive. There are a number of financial indicators to measure the attractiveness of a project. Some indicators are used to compare several projects to decide which one is the best alternative.

The sizing of the cogeneration system is sometimes carried out by financial analysis in grid dependent cases where there is an option for importing electricity instead of self-generation of all the electricity. In such circumstances, the optimum size of cogeneration would correspond to a system that has the minimum annual total cost (or maximum annual net profit).

Commonly employed financial indicators for cogeneration feasibility study are the payback period (PBP), net present value (NPV), and internal rate of return (IRR).

The easiest and basic measure of the financial attractiveness of a project is the payback period (PBP). It reflects the length of time required for a project to return its investment through the net income derived or net savings realized. It is the most widely employed quantitative method for evaluating the attractiveness of a cogeneration system. The simple payback period gives an idea of the time frame necessary for the net energy cost saving (or cash benefits) to pay the total installation cost of a cogeneration system. It disregards the salvage value, and the time value of money.

The net present value (NPV) of a stream of annual cash flows is the sum of discounted values of all cash inflows and outflows over a certain time period. For a cogeneration project, initial investment costs are assumed as cash outflows and net annual energy cost savings (or net annual benefits) are cash inflows.

When cogeneration system alternatives of different capacities are being compared, the net present value is an important financial parameter. The project that has the highest net present value would be chosen as the best alternative system.

The internal rate of return (IRR) is defined as the discount rate that equates the present value of the future cash inflows of an investment to the cost of the investment itself. Actually, the IRR is the rate of return that the project earns.

To judge the suitability of a cogeneration project, comparison is made between IRR and discount rate (or required minimum rate). If IRR happens to be less than the discount rate, the project would be rejected.

In the estimation of NPV for a cogeneration project, the total investment costs are taken as cash outflows, and cash inflows are the difference between the annual total cost of cogeneration system and that of the conventional energy supplies.

Sometimes, the total discounted costs of different cogeneration alternatives are estimated instead of the NPV of a single alternative, e.g., the case of a grid independent project. All the cash outflows are considered and discounted to the present value. The option that has the least discounted costs would be selected as the best system.

Investment decisions are based on the above mentioned financial indicators which are calculated from cash flow streams. The cash flows are estimated based on a number of factors such as future costs, interest rates, fuel costs, expected investment levels, tax rates and so on. Therefore changes in these parameters affect drastically the financial indicators and investment decisions. It is necessary to analyze how the value of a financial indicator (e.g. internal rate of return) changes when one or more of the input parameters (e.g. discount rates, fuel prices, investment costs) deviate by a certain amount (or percentage) from the expected value. This is known as the sensitivity analysis.

If the system to be installed has no access to the utility grid, the financial feasibility study will lead to the best cogeneration alternative since the sizing of different alternatives would have been carried out in the technical feasibility study. Financial indicators are estimated for each cogeneration system retained after the technical feasibility study. The best cogeneration alternative that has the highest NPV (or the least total discounted cost) would be selected.

3.2.8 *Recommendations*

From the description in the preceding sections it is understood that development of cogeneration applications in India is well ahead compared to other member countries of SAARC region. The following recommendations have been made to increase pace of development of cogeneration throughout India:

- Industry Association like “Cogeneration Association of India” along with concerned Financial Institutions and other stakeholders should keep continued pursuing the Central Electricity Regulatory Commission (CERC) to guide State Electricity Regulatory Commissions (SERCs) to facilitate in adopting uniform tariff, establishing right policy framework and adequacy of regulatory measures.

- Arrangement of workshops/seminars within the state and inter-states for development of skilled manpower and management. On the job training is also impotent to develop skilled manpower for the electric utilities as well as the industrial plants and managers to handle the specific tasks of combined heat and power (CHP) production i.e cogeneration.

3.3 Pakistan

3.3.1 *Industry Structure*

Pakistan is the 15thlargest producer of sugar in the world, 5thlargest in terms of area under sugar cultivation and 60thin yield. The sugar industry is the 2ndlargest agro based industry which comprises of 89sugar mills with crushing capacity of 6 million tons per year.

Sugarcane is among the most valuable crops of Pakistan. It is a source of raw material for entire sugar industry. Production efficiency has become an important determinant for the future of this industry in Pakistan due to declining competitiveness of the domestic sugar industry because of increasing imports, and high costs of production. The Development and adoption of new production technologies can improve productive efficiency. Therefore, this industry can improve the efficiency of its operations using currently available technology. Measures of productivity, its growth and sources for the sugar industry of Pakistan play a significant role for policy development.

The sugar industry in Pakistan evolved from a relatively small base at the time of partition to its present status of importance in the agribusiness and agriculture sectors. As a cash crop, by 1988 it was second only to cotton, and it trailed only textiles in order of importance in the processing sector and by that time there were 48 sugar mills in Pakistan with the production capacity over 1.8 million tons of sugar per year. Presently 89 sugar mills are operating in Pakistan with a total production capacity of 5 millions tons per year.

The sugar is produced predominantly from sugarcane. The acreage under cane was reported as 1080,000 hectares in 2009-10 produced about 55 million tons of sugarcane. Punjab province accounted for over half of the total cane produced followed by Sindh Province.

A potential complication for consideration of the sugar industry as a source of energy for grid electricity is the fact that until recently, bagasse was used as a feed stock for both paper and chipboard manufacture. While this might confirm that some of the sugar mills are relatively efficient, as they apparently generate their own power and steam from bagasse, yet still supply bagasse as a by-product, it also suggests that there is already a market value for bagasse which electricity production will have to compete with. In reality, the bagasse sold as a by-product might be a trade off where the revenues are used to buy furnace oil as an energy replacement.

3.3.2 *Current Cogeneration Situation*

Using a conservative factor that crushing 90,000 tons of cane will provide enough bagasse to produce 1 net MW of excess power per season (net means that the sugar factory power needs have already been met) for sale to the grid. The assumption is made that new high temperature, high-pressure boilers and turbine generators will have to be procured to realize fully this potential. One potential advantage in Pakistan is that every piece of hardware excepting the steam turbines can be produced in-country, helping to stimulate the economy, while saving foreign exchange if the local boilermakers can increase the pressure and temperature ratings they can supply.

The total of 200 MW is significant in the sugar industry, when treated as an indigenous energy resource and potential supplier, can make a significant contribution in the power sector, mainly in the more rural areas where the kWh and voltage control potential can have excellent value.

3.3.3 *Cogeneration Potential*

Power generation by cogeneration at the sugar mills of Pakistan have been reviewed on the basis of the following article:

Sugar Industry: A cheap and easy source of Electricity. (A case study of District Mandi Bahauddin) by Muhammad Tahir, (M.S. Economics, Preston University, Islamabad and Dr Khalid Mughal (Faculty, Preston University, Islamabad. *drkhalid0@gmail.com).

In the said article, it has been noted that the sugar mill in District Mandi Bahauddin can easily sell the surplus electricity to public grid at cheap rates up to 6 months. The electricity produced during the winter season is particularly vital for utilities because of lack of rain and snowfall in the northern areas and water level in hydroelectric dams touch to the bottom level.

According to Alternative Energy Development Board (AEDB), Pakistan sugar industry can provide cheap and easy electricity to the common consumers on local level as well as to the industry to some extent.

The objective of this case study was to examine the alternative resources of energy (sugar industry and electricity) in Pakistan. The main objective of the studies is to bring into work the wastage (bagasse)of "The sugar industry" to generate cheaper, easy available and environmental favorable electricity and also decrease the difference between demand and supply of electricity on local level with possible available alternative means of electricity.

District Mandi Bahauddin which is 250 km away from the capital of Punjab, Lahore is a fascinating fertile land. The District contains two sugar mills. One is Shah Taj Sugar mill which lies 8 km north to Mandi Bahauddin city while other lies to south of the city 12 km away from Phalia city. The case forcheap and easiest source of electricity was studied in the two sugar mills in the District MandiBahauddin.

Total cultivated area of sugarcane in District Mandi Bahauddin comprised 78,000 acre in 2010-11which increased 9% in 2011-12 with total cultivated area reached up to 85,000 acre. The recent statistics data showed 550 tons / acre production of sugarcane. This considerable increase in the production of sugarcane is mainly because of good price rate in the market with favorable weather condition for the crop. Both these sugar mills are provided with sugarcane not only by the local farmers of the District but also a big quantity is supplied from the suburbs of District Sargodha.

Phalia Sugar Mill

The capacity to crush the sugar cane of Phalia Sugar Mill is 6000 tons per day. Bagasse and juice with ratio of 28: 72 is produced 70 tons/hour. The energy produced from sugarcane in the form of ethanol is very useful. When bagasse is burnt, it provides sufficient heat to run turbines which eventually produce electricity to run the mill. By burning all the available bagasse, a steam pressure of 24 kg/cm2 is achieved which can operate two steam turbine generators (T.G) of 2 MW and 5 MW capacity and results in generating electricity 1.45 MW and 3.7 MW respectively. In this way, 5.5 MW of electricity is produced which meet the needs of the mill itself.

Table3.7: Estimated Co-generation @ 6000 Tons per day Cane Crushing Rate

<table>
<tr><td colspan="2">Cane crushing rate</td><td colspan="2">250 Tons per hour</td></tr>
<tr><td colspan="2">Available bagasse @ 28%</td><td colspan="2">70 Tons per hour</td></tr>
<tr><td colspan="2">Process house steam required @ 45%</td><td colspan="2">112.5 Tons per hour</td></tr>
<tr><td colspan="4">Exhaust steam & Electric Generation</td></tr>
<tr><td>T.G No.</td><td colspan="2">Type</td><td>Electric Generation (MW)</td></tr>
<tr><td>T.G 1 (2MW) Steam Pressure 24kg/cm^2</td><td colspan="2">Back pressure at 1.5 kg/cm^2</td><td>1.45</td></tr>
<tr><td>T.G 2(5MW) Steam Pressure 24kg/cm^2</td><td colspan="2">Extraction at 1.5 kg/cm^2</td><td>3.15</td></tr>
<tr><td></td><td colspan="2">For Condenser</td><td>0.55</td></tr>
<tr><td></td><td colspan="2">Total</td><td>5.15</td></tr>
<tr><td colspan="4">Electricity Balance</td></tr>
<tr><td colspan="2">T.G No.</td><td colspan="2">Type</td></tr>
<tr><td colspan="2">Total Generation</td><td colspan="2">5.15 MW</td></tr>
<tr><td colspan="2">In House Consumption</td><td colspan="2">5.15 MW</td></tr>
<tr><td colspan="2">Surplus available for sale</td><td colspan="2">0 MW</td></tr>
</table>

Shah Taj Sugar Mill

This mill stays in the top 10 of ranking of 84 sugar mills of Pakistan in its production. This process of generating energy supports ethanol units to be self-sufficient in electricity and even sell to the public grid. Currently extraction of 288 MJ of electricity is achieved from 1 ton of bagasse. The industry’s self-use is 180 MJ. In the larger view, the expansion of this process can have surplus electricity to utilities. Table3.9)

Table 3.8: Estimated Co-Generation @ 9600 Tons per day Cane Crushing rate

<table>
<tr><th colspan="2">T.G No.</th><th colspan="3">Type</th></tr>
<tr><td colspan="2">Cane crushing rate</td><td colspan="3">400 Tons per hour</td></tr>
<tr><td colspan="2">Available bagasse @ 28%</td><td colspan="3">112 Tons per hour</td></tr>
<tr><td colspan="2">Process house steam required @ 45%</td><td colspan="3">180 Tons per hour</td></tr>
<tr><td colspan="5">Exhaust Steam & Electric Generation</td></tr>
<tr><th>T.G No.</th><th>Type</th><th>Steam consumption rate (kg/kwh)</th><th>Electric Generation (MW)</th><th>Exhaust steam (Tons per hour)</th></tr>
<tr><td>T.G 1 (15MW) Steam Pressure 65kg/cm^2</td><td>Back pressure at 1.5 kg/cm^2</td><td>6.40</td><td>10.90</td><td>70.00</td></tr>
<tr><td rowspan="2">T.G 2 (15MW) Steam Pressure 65kg/cm^2</td><td>Extraction at 1.5 kg/cm^2</td><td>6.40</td><td>9.20</td><td>59.00</td></tr>
<tr><td>For Condenser</td><td>4.10</td><td>1.46</td><td>6.00</td></tr>
<tr><td rowspan="2">T.G 3 (15MW) Steam Pressure 65kg/cm^2</td><td>Extraction at 1.5 kg/cm^2</td><td>6.40</td><td>9.20</td><td>59.00</td></tr>
<tr><td>For Condenser</td><td>4.10</td><td>1.46</td><td>6.00</td></tr>
<tr><td colspan="2">Total</td><td></td><td>32.22</td><td>200.00</td></tr>
<tr><td colspan="5">Electricity Balance</td></tr>
<tr><th colspan="2">T.G No.</th><th colspan="3">Type</th></tr>
<tr><td colspan="2">Total Generation</td><td colspan="3">32.22 MW</td></tr>
<tr><td colspan="2">In House Consumption</td><td colspan="3">12.50 MW</td></tr>
<tr><td colspan="2">Surplus available for sale</td><td colspan="3">19.72 MW</td></tr>
</table>

Table3.9: Bagasse Balance

Total Bagasse available	112.00 Tons per hour
Total Bagasse required to generation 200 Tons steam @ 2.2 kg steam/kg bagasse	90.90 Tons per hour
Surplus Bagasse	21.10 Tons per hour

With the available bagasse 32.22 MW of electricity can be produced for six (6) months. During the crushing season of sugarcane for four (4) months, 19.72 MW would be available as surplus for sale and in the off-season 32.22 MW would be available for two (2) months.

Shah Taj Sugar Mill is generating 32.22 MW of electricity with the help of its 3 turbines which have 15 MW capacity of generating electricity each. Shah Taj uses its own generated electricity up to 12.5 MW and the remaining 19.72 MW electricity is available to sell for the 4 months. After crushing season, the remaining bagasse has a capacity to generate 32.22 MW. This is available to sell for the next two months to different sectors at very cheap rates which is Rs.7.33/ kWh (Table 3.10). Investment on this sort of projects is probably half of the price referred by the World Bank. A rough calculation shows that energy production from wastage burning is from 30 to 110 MW which vary with the use of technology. While higher statistics can be achieved by replacing machinery and by use of different bio energy sources.

Table 3.10: Electricity Generation cost by different sources

Source	Cost Rs./kWh
R.F.O	14.84
Coal	3.12
High Speed Diesel	18.31
Gas	3.89
Nuclear	1.12
Wind	9.12
Hydro	0.16
Sugar Industry	7.33

Source: National Electric Power Regulatory Authority (NEPRA)

The comparison between the electricity generated from various sources and the electricity generated from Sugar Industry encourages investment of capital in the Sugar Industry.

The consumption of electricity has increased considerably in the last two decades in District Mandi Bahauddin. The monthly demand of electricity in the whole district is almost 85.6 MW, while the district gets 64 MW from public grid. The shortfall reaches to 21.6 MW nearly. This shortfall is returnable with the help of Shah Taj Sugar Mill.

The case studied for electricity in District Mandi Bahauddin is valuable for the people of this District due to cheap and easiest source. The electricity available to the District by public grid has the difference of demand and supply approximately is 21 MW. The difference can be lessened or avoided with the help of the sugar industry. District Mandi Bahauddin is an excellent example in this respect. If sufficient cooperation is available, this duration of electricity production can be maximized to 8 months. This is not only a cheaper way of generating electricity but also environment friendly. The average cost of 1 kWh of electricity which is available from grid is Rupees 8.84. But in Shah Taj Sugar Mill, this rate has been decreased down by rupees 1.51**.** Similarly the average cost of 1 kWh of electricity through RFO is rupees 14.84 and High Speed Diesel is rupees 18.31, which is almost double to the cost of Shah Taj Sugar Mill. The Shah Taj Sugar Mill has capacity to generate surplus electricity for the household and industry of the District Mandi Bahauddin. The production of electricity is particularly significant in the winter term because there is low water level in dams. This process of bagasse burning is very useful because it suits the conditions which achieve maximum production at minimum air pollution when compared to coal. There is little sulphur in it and it emits little nitrous oxide as it burns at very low temperature.

The above mentioned discussion and analysis shows if possible measures are taken for the production of electricity within the country by using alternative means power crisis could be minimized to a large scale. There are 89 sugar mills in the country and most of them have the capacity to generate electricity more than their demand and requirement. Through effective measures on local level shortfall of electricity could be avoided by providing electricity to the public grids for 4 to 6 months.

From internet browsing, a paper captioned "Pakistan: Need to push for co-generation" published on 11 April 2013, it is learnt that for the last five years or more, various proposals have been explored to co-generate power and supply it to the national grid, according to Power Engineering magazine of Pakistan. There has not been much of a progress in this direction despite a severe energy crisis faced by the country. This paper explored the subject, examined the reasons of lack of success and presented some thoughts and recommendations for meaningful prospects in this respect.

Presently in Pakistan, 89 sugar plants are operating with a total sugar production capacity of 5 million tons per year. Additionally, there are 19 distilleries which process the by-product molasses into ethanol with a combined capacity of 400,000 tons. By the year 2005, most of the molasses were exported, and today molasses are not exported at all and the value-added product ethanol is exported. The same could happen in energy sector, provided both the sugar sector and the government develop and pursue viable proposals benefiting both the consumers and the producers.

The National Policy for Power Cogeneration by Sugar Industry of Pakistan stated that cogeneration potential of the sugar sector stands at 3000 MW which may be a little exaggeration. By comparison, Indian sugar sector is about 5 times larger than Pakistan's and they estimate their potential at 5000 MW of which only 1666 MW has been achieved by now. In that comparison, Pakistan potential comes out to be 1000 MW.

It should be reasonable to expect a realisable potential of 1000 MW and if coal is added as an alternative/additional fuel, this may go up to 2000 MW. The most important thing that has to be kept in view is that sugar sector has the dynamism, organisational and institutional capacity and the financial capability to undertake capital intensive ventures of this nature. All sugar mills have experience of power production, albeit for their own self use. So if a reasonable framework is developed, it is reasonable to expect that progress would come up.

3.3.4 *Institutional Facilitators*

Government has taken initiative to promote power generation through environmental friendly and cost effective means. The National Policy for Power Co-Generation by Sugar Industry (the Co-Gen Policy), is one of the major step towards achieving this aspiration. The main characteristic of Co-Gen Policy is its simplicity, which is key for attracting investment and making possible for achieving early commissioning of private power projects.

In order to facilitate prospective investors, the Private Power & Infrastructure Board has prepared "Guidelines for Processing Co-Generation Power Project Proposals". which would help sugar mills in moving forward with their projects.

3.3.5 *Government Initiatives and Legal Frameworks*

Realizing the importance of tapping the potential of sugar industry in contributing towards power generation, the Government of Pakistan has approved a National Co-Generation Policy. The National Co-Generation Policy envisages mainstreaming of co-generation electricity from our existing sugar industry in the development plans of the country. As PPIB has been assigned issuance of Letter of Support to interested sponsors, PPIB has prepared the "Guidelines for Processing Co-generation Power Project Proposals". The document presents both the'Co-Gen Policy' and the'Guidelines for investors' would help investors in developing Co-Generation projects in Pakistan.

3.3.6 *Barriers and Constraints*

The barriers confronting the development of economic cogeneration can be classified into following four main categories e.g market, institutional, regulatory and other barriers:

Market Barriers

(c) Price of electricity

Market pricing mechanisms in cogeneration are not available. Thus there is uncertainty on the market prices with which cogeneration will have to compete. Price setting by a major player could preclude cogenerators from entering the market if they envisaged selling to the grid. Public power generating entities could offer heavily discounted rates to large consumers to ensure that they retain them as consumers and keep their load base.

(d) Cost of generation technology

With the advancement in cogeneration technology that result in lower cost per unit of power produced and/or increased efficiency, the cost remains high for some applications. Future efficiency improvements can result in lower costs per KWh of electricity that is generated. It is expected that this barrier will be reduced if the market demand for cogeneration technology increases in the future. This increased demand will lead to further investments in R&D and larger, more efficient production facilities which, in turn, would lead to higher operating efficiencies and lower cost for the equipment. Government can reduce costs through tax which may affect economics of cogeneration projects.

Institutional Barriers

(e) Management involvement

The barriers can basically be divided into following three categories:

(i) long-term commitments,

(ii) competition for limited funds, and

(iii) attitudes of senior management

It is noted that the management of potential large consumers of many of the most attractive cogeneration sites with a sufficiently high steam and electricity demand will be reluctant to make the long-term commitment required to construct a cogeneration plant. This reluctance could become an issue as the electricity market opens up and the future price of electricity is unknown. The management used to compare the return/pay-back period of potential cogeneration facilities against other potential capital projects. Other projects may have higher potential returns and a faster payback period compared to the cogeneration facility.

Related to the first two barriers are attitudes of management of the most attractive potential cogeneration sites. These attitudes are based on the fact that power supply is not part of their core business. However, in cases where managers are concerned about the reliability and quality of power supply from the grid, those factors would be mitigated.

(f) Government Ownership

Most of the industrial facilities in Pakistan are owned by the government. Due to constraints on the availability of investment capital, many governments owned facilities are unable to obtain funding to improve their efficiency or energy utilization via cogeneration.

(g) Lack of Information

Although not a new technology, there is generally a lack of information, understanding and confidence in cogeneration technologies both by potential users as well as investors. This barrier results in the need by both potential customers and investors to spend time and cost to qualify themselves about this technology.

Information costs may be one of the most important institutional barriers and lack of information, understanding and confidence are effectively relate to information costs.

(h) *Transmission Access*

The design of any cogeneration installation is very specific to the characteristics of the site: the size of the electricity load, the size of the heat load, and the time patterns of their usage (the load durations). In many cases, a cogeneration facility which can meet the heat load efficiently will produce more electricity than the steam host requires. For the cogeneration application to maximize value, and perhaps even to be economic, it requires access to the electricity market for the surplus power. Access to the market will be provided in the coming competitive environment. However, there remains uncertainty as to the rules and regulations that will apply to such access.

Regulatory Barriers

Some of the regulatory issues concern fulfilling of technical requirements, licensing arrangements, ability to "wheel" (i.e. allowing cogenerators to sell electricity and heat directly to energy consumers, not through utilities), etc. While the principle of authorization sounds reasonable, procedures can be bureaucratic, complex and time consuming, thus perceived as a disincentive for potential cogenerators with little experience in the power sector.

As a relatively low emission technology, it will be important to ensure that potential cogeneration projects are reviewed efficiently and promptly:

The environmental authorities should set procedures for three categories of projects:

(i) those that require an individual environmental assessment;

(ii) those that would require a screening process; and

(iii) those that would not require approval under the existing environmental regulations

In order to make cogeneration attractive to potential investors, the fiscal incentives should be extended to the potential investors and where possible improved.

Other Barriers

Other barriers include the lack of skilled manpower and management. In most cases, both the electric utilities as well as the industrial plants lack skilled manpower and managers to handle the specific task of heat and power production.

3.3.7 *Cost Benefit Analysis*

A case study for "Cheap and easy source of electricity in a district under Punjab narrated above under cogeneration potential (section 3.3.3) that the electricity available to the District from public grid has the difference of demand and supply approximately 21 MW. The difference has been abolished with the help of sugar industry. This is not only a cheaper way of generating electricity but also environment friendly. The average cost of 1 kWh of electricity was available from grid at Rupees 8.84. But due to sugar mill, this rate has been decreased down to Rupees 1.51**.** Similarly the average cost of 1 kWh of electricity through Furness Oil was Rupees 14.84 and High Speed Diesel was Rupees 18.31 which is almost double to the cost of sugar mill.

The use of cogeneration has large environmental benefits in terms of reduced usage of fossil fuels. As an example, if one assumes that the full cogeneration potential potential of 1000 MW is utilised in Pakistan, then comparing it with a 1000 MW coal fired power station operating on Thar coal (calorific value of 2960 kCal/kg), the savings in coal used is 6 million tonnes per annum and this translates to a reduction of carbon dioxide emissions of 5 million tonnes per annum.

The above mentioned analysis shows if possible measures are taken for the production of electricity from sugar mills within the country by using alternative means, power crisis could be minimized to a large scale. There are more than 89 sugar mills in the country and most of them have the capacity to generate electricity more than their demand and requirement. From the above discussion conclusion could be drawn that sugar mills are in a win-win position to generate electricity and sell it to the national grid.

3.3.8 *Recommendations*

From the above narrations on sugar sector of Pakistan it is understood that Sugar mills remain idle during off-season and produce no energy and as such to run the mill throughout the year as a cogeneration system, following steps could be taken:

- Must find outa secondary fuel such as coal, etc. As storing of bagasse is uneconomic, the co-generation project will be based on bagasse during the cane-crushing season i.e. November to February as main fuel andduring the non-crushing season i.e. from March to October on imported or local coal, as the main fuel. This enables bagasse cogeneration plants to operate beyond the crushing season for up to 300-330 days/year.

- The concerned entities responsible for the development of sugar sector may establish a co-ordinating committee with a view to:

  - emphasis on use of cogeneration
  - promoting cogeneration technology
  - keep constant liaisons with regulatory authorities to have the opportunities of Co-Gen Policy towards the growth of cogeneration
  - organize training workshop/seminars for exchanging experiences and information among other potential industries and SAARC member states.

3.4 Sri Lanka

This section has been prepared on the basis of Technology factsheet on Cogeneration with Biomass-extracted from TNA Report: Mitigation for Sri Lanka and the Sunday Times (11 December 2011).

3.4.1 *Industry Structure*

Sri Lanka's sugar producing sector has now been reduced to a crises-ridden industry owing to neglect and absence of a coherent government policy covering the interest of all the stakeholders - growers of sugarcane and the consumers.

Ad hoc privatization of the local sugar industry in the 1990s and then again in early 2002, without a regulatory power- structure in the hands of the government, has lead to its rapid decline. The declining trend in the industry has further been aggravated by short-term profiteering and politics, creating a strong negative effect on the industry and on the research effort, he added.

The national policy on the Sri Lanka sugar sector development was approved by the cabinet of ministers in 2005 which recognizes that domestic sugar industry has the potential to produce at least 50% of the domestic requirement of sugar and other value added products of sugarcane within the next nine years. Under the said policy, the Moneragala and Bibile-Medagama region were recognized as among the key potential areas for sugar development. It recognizes the lead role the private sector has to play as investors and project promoters with minimal financial burden to the government.

The land use plan issued by the Survey Department had clearly identified the lands suitable for sugar cultivation in Moneragala, Ampara, Kantale and Trincomalee districts. Under this over 90,000 ha should be cultivated with sugarcane to produce 40 % of the country's sugar requirements. But the government had failed to give due assistance to improve the industry in the North which has a great potential. Similarly the Uva-Wellassa area sugarcane cultivation was also not materialized. In 1992 Hingurana and Kantale factories were sold to two Colombo sugar traders at a very low price. This was the actual turning point of the sugar industry in Sri Lanka. Unrest among the factory workers and sugar cultivators slowed down the functioning of the factories under the private management.

Sri Lanka has four sugar mills - Kantale, Hingurana, Pelwatte and Sevanagala. Kantale and Hingurana were fully government-owned mills. Up to their closure they were never headed by professionals except for short stints. After they declined, Kantale and Hingurana were privatized and subsequently closed down due to poor privatization processes in the 1990s. The other two are functional producing about 45,000 Mt of sugar last year.

Kantale and Hingurana, two of the four factories producing sugar had to be closed down and the remaining two factories (Pelwatte and Sevanagala) are facing a crisis situation due to the government's action to take over it under the Revival of Underperforming Enterprises and Underutilized Assets Act. It will affect the sugarcane cultivations in Pelwatte and Sevanagala that will result in a further decline in the sugar production next year.

Emphasizing the need to operate these sugar factories efficiently in a productive manner, the need of the hour is to strengthen the private sector management with government's regulatory control, but not ad hoc changes in management. An example is cited that Pelwatte sugar under the present management has been able to increase the crushing capacity from 230,000 Mt of sugar cane to 330,000 Mt and produce 30,000 Mt of sugar within a period of around six months. There was a plan to cultivate high quality treated seedcane in 6,000 more ha in Pelwatte to further increase production.

Although the potential for expansion of the industry exists, as Sri Lanka imports over half a million tonnes of sugar per annum, the government is yet to create conditions favourable for its development by enacting a Sri Lanka Sugar Act to regulate the stakeholders, viz - the farmer, miller and government activities, The government should accord high priority to revitalize the sugarcane industry, considering the huge sum of around Rs. 41 billion spent on sugar imports annually. There is a substantial ready market locally for sugar if matching mill capacities are available. Only 10 – 12% of sugar consumption in the country is produced by Pelwatte and Sevanagala. The rest is imported at a huge cost of foreign exchange to the country.

Sugar prices in the past were dominated by the subsidized sugar produced in the European Union which exported sugar below the cost of production due to their favourable government policies. However since the World Trade Organization (WTO) came into being after successive rounds of negotiations these subsidies have been dispensed with and the era of cheap subsidized sugar is over. Furthermore the largest producer in the world market, Brazil has increasingly begun to convert its sugarcane to Ethanol as a motor fuel. This has lead to the world price of sugar rising by more than 100% during the last few years and this trend is likely to continue in the foreseeable future. This means that Sri Lanka is now exposed to the upward movement of world sugar prices.

3.4.2 *Current Cogeneration Situation*

Many industries in Sri Lanka generate steam at a pressure of about 5 to 10 bar for process heat applications. The steam outputs from these boilers vary from about 1 ton per hour to over 10 tons per hour. While some of these boilers operate only for 8 hours per day, many boilers operate continuously for 24 hours per day. As the cost of biomass fuel is less than half the cost of petroleum fuels, many of these boilers use biomass fuels.

In Sri Lanka, the Sri Lanka Sustainable Energy Authority and the Ceylon Electricity Board (CEB) have formulated a scheme, where any renewable energy based electricity generation, including biomass, could be sold to the CEB at the price specified in the Standardized Power Purchase Agreement (SPPA). For biomass based electricity generation, the present price applicable is Rs. 20.70 per kWh. This may be compared to the price charged from industries for electricity consumption is around Rs. 14 per kWh. Hence by selling this electricity to the CEB, the factory would make financial gain.

Moreover, under the SPPA, CEB is obliged to purchase all the electricity generated by the producer. There are no penalties imposed for variations in the rate of output of electrical power (provided it conforms to the required voltage and frequency and other specifications).

By introducing this technology, the industries presently generating process steam could obtain additional revenue by the sale of electricity to the CEB. The additional fuel cost incurred for the generation of electricity will be very small compared to the price paid by the CEB for the electricity.

3.4.3 *Cogeneration Potential*

There are three installations in Sri Lanka where this technology is practiced. Two of these are very old and were compelled to adopt this technology as in these specific locations at the time these industries were established, the national electricity grid was not available in these locations. Moreover, these industries are both sugar factories using bagasse generated in the factory itself as the fuel in their boilers. This being the practice all over the world, it was natural for these two factories to adopt cogeneration. The third is an activated carbon plant using very low pressure (1bar) steam for their process. The factory used a steam boiler capable of delivering 10 bar saturated steam. Hence, the engineers at this factory decided to retrofit a supper heater and a back pressure turbine-alternator and generate some quantity of electricity. The cost of retrofit was recovered in a short period.

3.4.4 *Institutional Facilitators*

The Sri Lanka Sustainable Energy Authority and the Ceylon Electricity Board (CEB) is providing institutional facilitation by formulating a scheme, where any renewable energy based electricity generation, including biomass, could be sold to the CEB at the price specified in the Standardized Power Purchase Agreement (SPPA).

3.4.5 *Government Initiatives and Legal Frameworks*

The following situations prevailing in Sri Lanka make this technology applicable here:

- Government Policy to generate at least 10% of the electricity through Non Conventional Renewable Energy sources by the year 2015 and 20% by the year 2020.
- An attractive power purchase tariff for biomass based electricity well above the selling price of electricity for the industrial sector.
- A suitable multipurpose tree (Gliricidia sepium) has been identified as a suitable tree for the production of sustainable biomass fuel. This tree has been declared as a plantation crop.

Biomass fuel is the most dominating fuel (nearly 80%) for the generation of heat in the industrial sector. The primary reason for this preference by the industries of this fuel compared with petroleum fuels is the low cost of this fuel. Many industries already use biomass fuel fired steamboilers to generate industrial process heat. Introduction of cogeneration technology amounts to an extension of the existing system.

The high cost of labor, electricity and petroleum fuels are compelling industrialists to lookout for all possible means of increasing revenue and reduction in expenses to make these industries viable.

3.4.6 *Barriers and Constraints*

At present, the Sri Lanka Sustainable Energy Authority and the Ceylon Electricity Board (CEB) are sponsoring renewable energy based electricity generation. A very attractive price at over Rs 20.70 per kWh has been offered for electricity production for cogeneration companies.

There are three installations in Sri Lanka where this technology is practiced. Two of these are very old and the third onehas been retrofittedto cogenerate electricity.

3.4.7 *Cost Benefit Analysis*

Cogeneration has been practiced in many parts of the world for many decades. In Sri Lanka this principle has been practiced to a very limited extent. Presently there are three installations in Sri Lanka where this principle is practiced. All these three use biomass as the fuel.

There is doubt about the technical feasibility of using this technology in Sri Lanka. Practical and economical aspects of this technology need demonstration in an industrial environment. The economic aspects has become a reality with the introduction of government policy on generation of electricity and the introduction of an attractive Standardized Power Purchase Tariff for biomass based electricity generation.

The implementation of this technology in the industrial sector would enable these industries to earn an additional income by generating electricity as byproduct and selling it to CEB at an enhanced price provided through the SPP tariff.

3.4.8 *Recommendations*

From the above narration on the development of cogeneration in SriLanka it is recommended that the potential entities should be close contact with the SriLanka Sustainable Energy Authority (SSEA) and the Ceylon Electricity Board (CEB).

4 PART C: PULP AND PAPER INDUSTRY

4.1 Bangladesh

4.1.1 *Industry Structure*

Bangladesh Chemical Industries Corporation (BCIC) which is responsible for Pulp & Paper industries in the country had played an important role in this sector in Bangladesh. BCIC now operates the Karnaphuli Paper Mills Limited (KPML) producing quality paper as well as packaging paper with yearly capacity of 30,000 MT and it was commissioned in 1953. Other mills under BCIC now closed include: KNM, SPPM and NBPM. The Khulna Newsprint Mill (KNM), only newsprint producing plant began production in 1959 with an annual capacity of 50,000 MT. The North Bengal Paper Mill (NBPM) was commissioned in 1973 with the capacity of 15,000 MT and it produced writing and printing paper using bagasse. The Sylhet Pulp & Paper Mill (SPPM), the only pulp producing plant began production in 1975 with an annual production capacity of 20,000 MT. The Magura Paper Mills producing packaging paper around 15000 MT per year is a joint venture with BCIC. BCIC used to produce around 90% of the total paper used in Bangladesh 25 years ago. BCIC/KPM is today producing less than 5 % of the total paper used in Bangladesh.

The private sector has taken over the paper sector in the country. The private sector paper mills includes: T.K. group (paper, board and tissue mill), Basundhara group (paper, tissue, and newsprint), Creative paper mill, Capital paper mill, Hakkani paper mill, Hossain pulp & paper mills, etc. Although, the private sector plays the major role in paper & paper board production, KPML still is producing yearly 20,000-25,000 MT of different types of paper including specialty paper.

The per capita paper and board consumption in Bangladesh is about **3.5~4kg** and that in advanced countries is more the 300 kg and the world average is around 50 kg while the Asia average is around 30 kg. The per capita paper consumption as well as total paper consumption are increasing all over the developing countries and, also, in Bangladesh. It will increase further in future.

4.1.2 *Current Cogeneration Situation*

Cogeneration is already used in Bangladesh in several industries including pulp and paper industries. However, most of the existing equipment used to produce steam and power is, on average, quite old and well past its economic life. In order to continue reliable, efficient and safe operation, much of the cogeneration equipment will have to be replaced/refurbished in the near future.

The pulp and paper industry has about 35 MW being generated from cogeneration and this is expected to increase by another 8 MW in the near future.

4.1.3 *Cogeneration Potential*

A study conducted by the Center for Energy Studies (CES) & Mechanical Engineering Department of Bangladesh of Engineering and Technology (BUET), Dhaka in Association with Energy Monitoring and Conversation Centre (EMCC), Bangladesh and UN-ESCAP, Bangkok estimated that the potential for new cogeneration in Bangladesh is to be close to 1,000 MW out of which paper & pulp industries' share is more than 50 MW. Additional electric power produced in cogeneration facilities could be used by the electrical grid to supply other consumers whose requirements are not being met.

4.1.4 *Institutional Facilitators*

However, this matter could be addressed by Bangladesh Chemical Industries Corporation (BCIC) through Bangladesh University of Engineering and Technology (BUET) for looking into the potential for cogeneration in the pulp and paper sector.

4.1.5 *Government Initiatives and Legal Frameworks*

The government is giving special attention to alleviate the power crisis of the country by establishing some new power stations. But the installation of a new power station requires huge investment and continuous fuel supply, both of them have severe scarcity in our country. Also, it would take a long time to install a power plant. Therefore, the government is looking for alternative options that might lessen the electricity crisis through Co-generation process in paper and pulp industries.

4.1.6 *Barriers and Constraints*

The barriers confronting the development of economic cogeneration projects can be classified into four main categories, market, institutional, regulatory and other barriers.

Examples in each category are outlined below.

- An industrial/commercial installation that requires electricity and steam/heat but currently does not use cogeneration.
- An industrial/commercial installation that requires electricity and steam/heat but currently only uses cogeneration to produce part of its internal requirements for these commodities.
- An industrial/commercial installation that uses cogeneration to produce some or all of its requirements for electricity and steam/heat but does so using equipment that has reached the end of its life and needs to be replaced.
- An industrial/commercial installation that would like to sell excess electricity and steam/heat produced via its cogeneration facilities in order to achieve sufficient return on its investment.

In most paper and pulp mills, there is a lack of sound technical management to maintain high-pressure boilers. The existing low-pressure boiler is itself not being maintained satisfactorily in most cases with the result that there are interruptions in the paper and pulp manufacturing process. In any event, paper being still a highly regulated industry, the management is occupied with raw materials, and the financial and administrative problems of producing and selling, and very few have the time to take up the additional responsibility of electricity cogeneration.

In Bangladesh, while there are many paper industries, there are very few wood pulp production industries, namelySylhet Pulp and PaperMillandothers are likely to be using imported wood pulp from different countries such as Canada, New Zealand, Sweden etc. The cogeneration potential mainly resides with the wood pulping process and therefore in the wood pulp manufacturing countries. Since Bangladesh does not have many wood pulp manufacturers[15], there is low potential for cogeneration from the pulp and paper industries.

4.1.7 *Cost Benefit Analysis*

Above mentioned study (4.1.3) also provided an estimate of the economic potential of cogeneration activities in Bangladesh and identifying the role of the private sector participation in the development of this potential.

At the outset of the study, it was determined that in order for the private sector to be interested in participating in cogeneration, the project's size would have to be in order of magnitude that would not require too much capital outlay and at the same time have the potential to earn a reasonable rate of return on the investment.

From the study it has been noted that many of the potential projects would fall in the range of 5 MW or less. Considering capital requirements, potential revenues and the type of projects available, it was decided to focus on cogeneration projects with sizes ranging from 1 to 20 MW.

4.1.8 *Recommendations*

Energy Ministry with the concerned entities responsible for the development of pulp and paper sector may establish a co-ordinating committee with a view to:

- emphasis on use of cogeneration
- promoting cogeneration technology
- time to time discussion with regulatory authorities with policy, tariff, etc. for favour the growth of cogeneration
- organize training workshop/seminars for exchanging experiences and information other potential industries and SAARC member states.

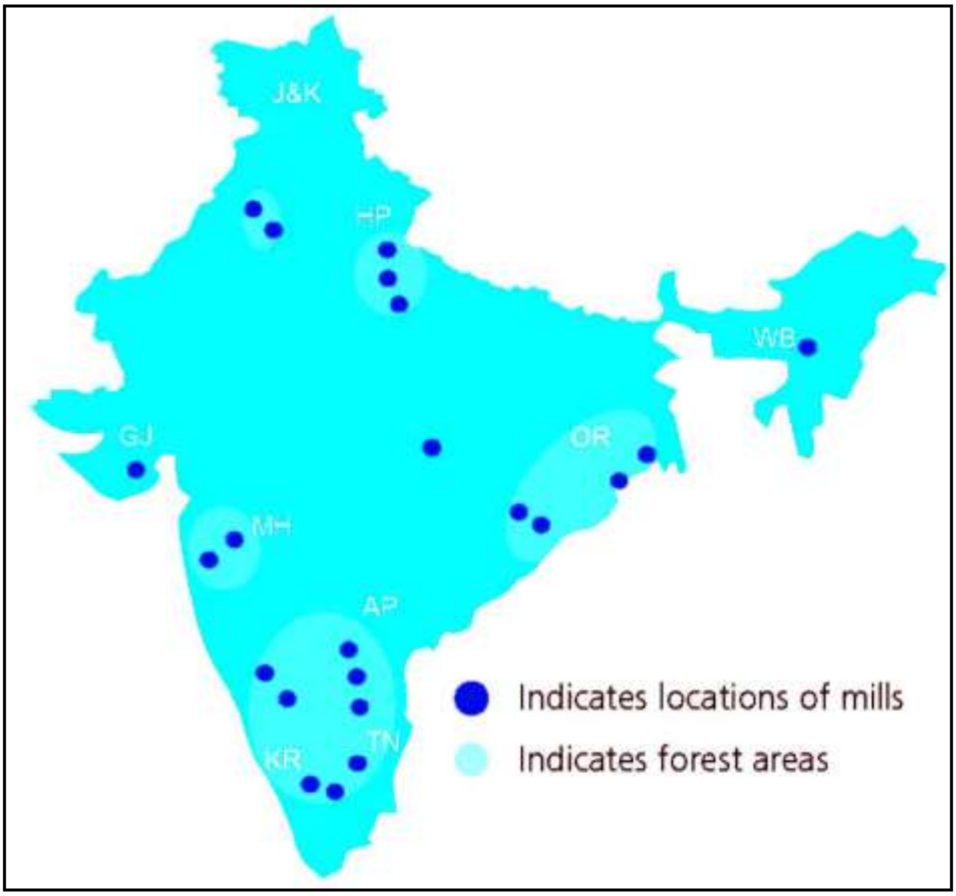
[15] and this is logical, given the scarcity of land in Bangladesh for commercial tree plantations (compared to such as New Zealand and Canada)

4.2 India

The Indian Paper Industry accounts for about 1.6% of the world's production of paper and paperboard. The estimated turnover of the industry is USD 7 billion approximately and its contribution to the exchequer is around Rs. 3000 crore (USD 0.6 billion). The industry provides employment to more than 0.37 million people directly and 1.3 million people indirectly.

Since India is a vast market, it is important to understand locations that are conducive to achieving the leading possible return on investment. Two factors are dominant in determining the location of paper mills: the fact that small players in the Indian market provide acquisition opportunity and the proximity to raw materials. It is advantageous to stay close to raw material availability due to inefficient distribution and prohibitive cost of transportation. The following Indian map identifies the location of paper mills across the country.

Figure 4.1: Indian Map Identified the Location of Paper Mills



India's dense forest cover is in the northern states of Jammu & Kashmir (J&K), Himachal Pradesh (HP) and Uttaranchal (UA), the northeastern states (NE), the eastern states of West Bengal (WB) and Orissa (OR), and the western coastal state of Kerala (KR).The existing paper mills are in states close to the raw material. The largest paper producers in India, own mills in Andhra Pradesh (AP), Maharashtra (MH), Tamil Nadu (TN), and West Bengal (WB).

States like Andhra Pradesh (AP), Karnataka (KA), Maharashtra (MH), and Gujarat (GJ) offer reasonable proximity to raw material. Additionally, these states' laws are conducive to both foreign and domestic investments.[16]

4.2.1 *Industry Structure*

The paper industry in India is more than a century old. At present there are over 850 paper mills manufacturing a wide variety of items required by the consumers.

Most of the paper mills are in existence for a long time and hence present technologies fall in a wide spectrum ranging from oldest to the most modern. The mills use a variety of raw material viz. wood, bamboo, recycled fibre, bagasse, wheat straw, rice husk, etc.; approximately 35% are based on chemical pulp, 44% on recycled fibre and 21% on agro-residues. The geographical spread of the industry as well as market is mainly responsible for regional balance of production and consumption.

The operating capacity of the industry currently stands at 12.75 million tons. Demand of paper has been hovering around 8% for some time. So far, the growth in paper industry has mirrored the growth in GDP. India is the fastest growing market for paper globally and it presents an exciting scenario; paper consumption is poised for a big leap forward in line with the economic growth and is estimated to touch 13.95 million tons by 2015-16. The futuristic view is that growth in paper consumption would be in multiples of GDP and hence an increase in consumption by one kg per capita would lead to an increase in demand of 1 million tons.[17]

These paper mills are manufacturing industrial grades, cultural grades and other specialty papers. The paper industry in India could be classified into 3 categories according to the raw material consumed.

a) Wood based
b) Agro based &
c) Waste paper based

While the numbers of wood based mills are around 14 and balance 836 mills are based on non-conventional raw materials (agro residues and recycled fibre - waste paper)

The Govt. of India has relaxed the rules and regulations and also de-licensed the paper industry to encourage investment into this sector and joint venture is allowed and some of the joint ventures have also started in India. The paper industry in India is looking for state-of-art technologies to reduce its production cost and to upgrade the technology to meet the international standards.

The Indian paper industry is among the top 12 global players today, with an output of more than 13.5 million tons annual with an estimated turnover of Rs. 35000 crore.

[16]http://www.itcportal.com/about-itc/newsroom/press-reports/PressReport.aspx?id=1053&type= C&news=enough-untapped-opportunity-in-India

[17] http://ipma.co.in/paper_industry_overview.asp

Paper industry in India is moving up with a strong demand push and is in expansion mode to meet theprojected demand of 20 million tons by 2020. Thus paper industry in India is on the growth trajectory and is expected to touch 8.5% GDP in the coming years. Therefore, the growth of Industry will out span the present growth rate of 6.5%.

4.2.2 *Current Cogeneration Situation*

India continues to face serious power shortages in spite of an installed capacity closeto90,000 MW, mainly due to the lack of funds for new installations as well as poor operation of the power industry managed by the public sector. As a result, the country faces shortages of more than 18 per cent in peak demand and over 9 per cent in electricity requirements.

Realizing the important role that the private sector can play in power development, government has recently opened the power sector to the private sector. In addition, government is also encouraging other low-cost or more efficient alternatives, such as the use of non-conventional energies and cogeneration in industry.

Cogeneration is widely used in paper mills around the world. Steam generated is used at different pressures and temperatures for cooking of chips in digesters in the pulping process and for drying of paper in paper machines. In addition, some amount of steam is used for concentration of black liquor in multiple effect evaporators.

A small paper mill in India with an installed capacity to produce 60 tons of writing, printing and duplex quality paper per day, uses agro-industrial residue based cogeneration to meet all the process energy requirements. Waste paper is mainly used as the raw material and a small quantity of pulp is produced from bagasse, the residue from the cane sugar mills.

4.2.3 *Cogeneration Potential*

A report prepared by the Ministry of Power reveals that considering the various in-house generating facilities adopted by Indian industries, the installed capacity in industry alone is around 12,000 MW, without taking into account units of less than 1 MW capacity. Though some of the industries have already adopted cogeneration plants, additional cogeneration potential in selected industrial sub-sectors is estimated to be 6,530 MW. The actual installed capacity is still very low, and aside from the sugar industry, cogeneration has not been pursued seriously due to various reasons.

A recent national survey estimates the overall industrial cogeneration potential to be around 15,000 MW, with the sugar mills alone accounting for one-third of the total, followed by distilleries, fertilizer plants, rice mills, textile industries and pulp and paper mills, and others. Considering another report, share of Pulp and Paper mills out of the total cogeneration potential in Indian industry, has been assumed at 5% i.e. 750 MW.

4.2.4 *Institutional Facilitators*

Some progresses in cogeneration have been made through proactive role of the Ministry of Non-conventional Energy Sources (MNES) and the Indian Renewable Energy Development Agency (IREDA). They have extended financial assistance such as subsidies, low-cost loans and technical assistance. In order to launch demonstration projects, MNES provides capital subsidy of Rs 20 million/MW of surplus power (comprising Rs 7 million/MW as subsidy and balance as soft loan) to cooperatives and public sector sugar mills, and Rs 7 million/MW of subsidy (maximum of Rs 60 million per project) to other sugar mills. 5 In addition, there is an interest subsidy of Rs 1.5 million/MW for projects with 1-4 MW of surplus power generating capacity, and Rs 3.5 million/MW for those with more than 4 MW surplus capacity. IREDA provides up to 75 per cent of the financing of the project at lower than market interest rates, and allows for a repayment period of 10 years, allowing for a moratorium period before the cogenerator is actually required to start repaying the loan.

4.2.5 *Government Initiatives and Legal Frameworks*

Acknowledging the fact that cogeneration plants are more efficient, have low gestation period, and can effectively create additional power generating capacity, government has issued guidelines related to clearance of projects and fixing of tariff for export of electricity by cogenerators.

Industries will be allowed to develop cogeneration facilities without necessarily going through competitive bidding process. If the cogeneration plant is a topping-cycle, it must supply at least 5 MW to the grid for not less than 250 days in a year in order to assure grid stability and adequate planning of the power system. Depending on the type of fuel used, the plant should meet certain efficiency criteria to be eligible as a cogeneration facility. If the cogeneration facility is a bottoming cycle, the total useful power output should not be less than 50 per cent of the total heat input through supplementary firing.

The schedule for power supply to the grid should be mutually worked out between the SEB and the cogenerator, keeping in mind that the surplus power may vary during the day and with season. While negotiating tariff, the basic consideration should be to share the benefits of higher efficiency. Industry will be assured of power supply, possibly at a lower tariff than that charged by the utility due to cross subsidization.

Lately, the Ministry of Power has been involved in simplifying procedures by persuading SEBs to allow third-party sale of electricity, buy-back surplus power at higher rates (close to Rs 2.25 per kWh in most instances), and offer clear and transparent wheeling and banking policies. SEBs are now more receptive to the idea of captive power generation and are encouraging proposals for cogeneration facilities. Some state governments are also providing incentives for cogeneration, such as capital cost subsidies and exemption from generation taxes.

4.2.6 *Barriers and Constraints*

The main drawback in cogeneration development has been the lack of clear policies and regulations. The State Electricity Boards (SEBs) have not been supportive of the idea of captive power plants; cogeneration being regarded as a subset of the captive segment, was also neglected and never fully promoted. SEBs consider the power from industry to be too small and its cost to be generally higher than the prevailing tariff. As industries are charged a higher tariff, utilities are afraid to lose good customers.

Many industries are not aware of the benefits of cogeneration in terms of cost savings, the low level of incremental investment needed, and the existence of a number of financing options. They are concerned about the problem of space, shut down and investment necessary for setting up cogeneration facilities. They are not sure about the long-term availability of fuel for operating the cogeneration plant. In case there is excess electricity available for export to the grid, industries are not sure whether the SEBs can pay as most of them are facing acute financial constraints

4.2.7 *Cost Benefit Analysis*

The main arguments for cogeneration in India have centered on two compelling issues: cogeneration is a relatively inexpensive means to augment conventional power supplies and energy conservation via cogeneration can reduce costs, and possibly increase profits, while reducing or avoiding the pollution attendant with fossil fuel utilization. The need for electrical power in India clearly justifies industrial cogeneration where technically and economically feasible.

A wide range of considerations must be taken into account in deciding whether to invest in an industrial cogeneration system. These include both internal and exogenous economic factors, fuel cost and availability, ownership and financing, tax incentives, utility capacity expansion plans and rates for purchases of cogenerated power, and a variety of perceived risks in such an investment.

Prior to undertaking any economic analysis to assist the commercial benefit of a cogeneration project, technical parameters which are summarized below:

a) Heat-to-power ratio;
b) Quality of thermal energy needed;
c) Electrical and thermal energy demand patterns;
d) Fuel availability;
e) Required system reliability;
f) Local environmental regulations;
g) Dependency on the local power grid;
h) Option for exporting excess electricity to the grid or a third party, etc.

Cogeneration may be considered economical only if the different forms of energy produced have a higher value than the investment and operating costs incurred on the cogeneration facility. In some cases, the revenue generated from the sale of excess electricity and heat or the cost of availing stand-by connection must be included. More difficult to quantify are the indirect benefits that may accrue from the project, such as avoidance of economic losses associated with the disruption in grid power, and improvement in productivity and product quality.

4.2.8 *Recommendations*

From the description in the preceding sections it is understood that development of cogeneration applications in India is well ahead compared to other member countries of SAARC region, yet the following recommendations have been made to increase pace of development of cogeneration throughout India:

- Industry association like "cogeneration association of india" along with concerned financial institutions and other stakeholders should keep pursuing the Central Electricity Regulatory Commission (CERC) to guide State Electricity Regulatory Commissions (SERCs) to facilitate in adopting uniform tariff, establishing right policy framework and adequacy of regulatory measures.

- Arrangement of workshops/seminars within the state and inter-states for development of skilled manpower and management. On the job training is also impotent to develop skilled manpower for the electric utilities as well as the industrial plants and managers to handle the specific tasks of combined heat and power (CHP) production i.e cogeneration.

4.3 Pakistan

4.3.1 *Industry Structure*

After the independence of Pakistan in 1947, Pakistan Industrial Development Corporation (PIDC) was set up for the establishment of different industries including paper mill in public sector. In 1953, PIDC established the first paper mill at Chandargona in East Pakistan (now Bangladesh), followed by a high grade paper mills -Adamjee Paper & Board Mills at Nowshera in North-West Frontier Province (NWFP) of Pakistan and a newsprint mill at Khulna in East Pakistan (Bangladesh) in 1959. Later on Adamjee Paper and Board closed down its operation. With the separation of East Pakistan in 1971, a serious shortage of writing/printing paper and newsprint was created in West Pakistan, as the supplies of these papers were completely cut off from Bangladesh.

Now, this industry has different units across the country producing various grades of papers, using local and imported raw materials. Unfortunately, due to poor planning in 1980's and 1990's, many of the units are lying closed from that time. At present, in Pakistan there are about 100 units in the organized and unorganized sectors. These units produce writing and printing paper, wrapping and packing paper, white duplex coated, un-coated board, chip board and other board.

Figure 4.2: Paper Manufacturing in Pakistan

Paper Industry of Pakistan is not among the prime industries of the country and is in developing stage. At present there are 100 units of paper mills with 900,000 tons capacity are running in Pakistan out of which more than 70% are located in Punjab province, 20 % are in Sindh province and 10% are in Khyber Pakhtunkhwa province.

Neutral sulfite semi-chemical pulping process (NSSC) is one of the most common pulping methods in Pakistan and wheat straw is used as a raw material. The pulping liquor used in NSSC process is a solution of sodium sulfite containing sodium bicarbonate or sodium hydroxide as a buffer to keep the PH around 7. The NSSC process consist of four steps (a) steaming of raw material for 30 min at atmospheric pressure, (b) addition of pulping chemical and application of 100 psi pressure at a temperature of 120-125 centigrade for 60 min, (c) third step is the removal of excess liquor not absorbed by the raw material, (d) lastly digestion at 140-160 centigrade for 1-6 h. The yield of this process is 65-90% depending upon raw material, buffering agent and cooking time.

Pakistan is also one of the few countries in the world where agricultural waste and neutral sodium sulfite cooking process is also used to produce paper and paperboard grades. The fiber is given a combination of treatments with alkali and chlorine. Such methods were used for bleaching as early as 1787, and it is claimed that straw pulp was so made in 1830.

The basic raw material sources for manufacturing of paper and paper board are broadly classified into three group as under:

Wood based material

Among the wood based raw materials, coniferous pine is in short supply in Pakistan. The soft wood forests in the country exist in extreme northern hills of North West Frontier province and Azad Kashmir which are mostly inaccessible due to lack of suitable communication facilities. As we know that forest plantations are the major assets of the pulp and paper industry. Unfortunately, forests in Pakistan cover constitute only 4.8 % [1] of total land against the international benchmark of 25 %.

Figure 4.3: Eucalyptus trees in Pakistan- Source of Raw material Paper Pulp

Eucalyptus in Pakistan is among the non-coniferous species, are produced mostly on irrigated land. The eucalyptus trees plantations are not yet sufficient to meet pulping requirements of the paper industry. Also it’s a fact that the specie of eucalyptus grown in Pakistan consumes lot of underground water. So its growth is restricted due to this fact.

Agricultural wastes

Among the agro-based wastes the following are being extensive used:

Straws

Straws are by-products of cereal crops, the major being wheat and rice. Paper and paper board industry is presently the main user of the marketed supplies of wheat straw. Adequate quantities of wheat straw are available for the industry. Rice straw is generally used as packing material for glass and ceramic products. Its use in paper making is limited as it contains silica and gives some process problems.

Figure 4.4 : Wheat Straw used in enrichment in Pakistan.

Bagasse

It is a well-established raw material for making almost all grades of paper, from fine quality paper to board.

Grasses

There is a wide range of grasses grown in Pakistan which can be used for making pulp and paper. Kahi grass grows wild along the river banks, some quantity are already being use by paper mills. Other grasses available in Pakistan are Bhabbar, Gauj Gumaz,

Rhodes grass, chorkha, pawpi, chari and dhawar. The main problems for using grasses relate to their collection and procurement.

Waste Paper

There are two main sources of collection of waste paper. One is waste paper collected at offices and factories such as government offices, business concerns, banks, newspapers and publishing companies, printing and book binding concerns etc. the other source is waste paper purchased by trash dealers from private persons at their homes. It is estimated that adequate quantities of waste paper are available for use in paper board industry. It is also being imported for the paper industry.

4.3.2 *Current Cogeneration Situation*

Cogeneration is already in process but due to unavailability of information and limited data to provide current situation.

The Cogeneration data in Paper industry of the country was limited to calculate accurate estimates in this regard. Currently there are two mills, which have cogeneration plants installed, these are, Century Paper and Board Mills with an installed capacity of 30 MW and Packages Ltd. with an installed capacity of 50 MW but normally operates at lower capacity between 20 to 30 M.Ths. total installed capacity of cogeneration in Paper industry in Pakistan is 80 MW, whereas the available generating capacity is around 50 MW. Pulp industry can offer more cogeneration potential but there is no pulp industry available in Pakistan.

4.3.3 *Cogeneration Potential*

Based on the information provided by All Pakistan Paper Mills Association (reference item 38 of Annex A) and individual mills, it is estimated that total potential available in the country ranges between 200 MW to 300 MW provided majority of paper mills adopt cogeneration technology.

4.3.4 *Institutional Facilitators*

Government has taken initiative to promote power generation through environmental friendly and cost effective means. The National Policy for Power Co-Generation (the Co-Gen Policy) provides key role for attracting investment and making possible for achieving early commissioning of private power projects.

In order to facilitate prospective investors, the Private Power & Infrastructure Board (PPIB) has prepared "Guidelines for Processing Co-Generation Power Project Proposals", which would help paper mills in moving forward with co-generation applications.

4.3.5 *Government Initiatives and Legal Frameworks*

Realizing the importance of tapping the potential of cogeneration in contributing towards power generation, the Government of Pakistan has approved a National Co-Generation Policy. The National Co-Generation Policy envisages mainstreaming of co-generation electricity from existing paper industry in the development plans of the country. As Private Power & Infrastructure Board (PPIB) has been assigned for issuing of Letter of Support to interested sponsors, PPIB has prepared the "Guidelines for Processing Co-generation Power Project Proposals". This brochure presenting both the 'Co-Gen Policy' and the 'Guidelines for investors' would surely help investors in developing cogeneration projects in Pakistan.

4.3.6 *Barriers and Constraints*

The barriers confronting to the use of energy efficient in industries, the most important points arelack of awareness about cogeneration and shortage of financial resources. There are also lack of sound technical management and maintenance of equipment. In any event, paper being still a highly regulated industry, the management is occupied with raw materials and the financial and administrative problems of producing and selling, and very few have the time to take up the additional responsibility of electricity cogeneration.

4.3.7 *Cost Benefit Analysis*

If possible measures are taken by using alternative means for the production of electricity from paper mills within the country power crisis could be minimized to a large scale. There are more than 100 units of paper mills in the country and most of them have the capacity to cogenerate electricity more than their demand and requirement.

4.3.8 *Recommendations*

The concerned entities responsible for the development of paper industries may establish a Co-ordinating Committee with a view to:

- emphasis on use of cogeneration
- promoting cogeneration technology
- keep constant liaisons with regulatory authorities to have the opportunities of Co-Gen Policy towards the growth of cogeneration
- organize training workshop/seminars for exchanging experiences and information among other potential industries within the country and others within SAARC region.

4.4 Sri Lanka

This section has been prepared on the basis of Technology Factsheet on Cogeneration with Biomass-extracted from TNA Report: Mitigation for Sri Lanka and correspondence with the Sri-Lanka Sustainable Energy Authority (SSEA).

4.4.1 *Industry Structure*

The development of paper industry in Sri Lanka was closely linked with the industrial policies adopted by successive Governments in the country. The first paper mill which was semi-mechanized was established during the Second World War period. This did not function properly and was closed down with in a couple of years. The first modern paper mill was established in 1956 at Valachchanai, and this was followed by over twenty years later by the second one, the Embilipitiya factory.

Both the paper mills in Sri Lanka are Government owned enterprise and are managed by the publicly owned National Paper Corporation. However, at present these paper mills are not operating in full scale.

4.4.2 *Current Cogeneration Situation*

The Sri Lanka Sustainable Energy Authority and the Ceylon Electricity Board (CEB) have formulated a scheme, where any renewable energy based electricity generation, including biomass, could be sold to the CEB at the price specified in the Standardized Power Purchase Agreement (SPPA). This may be compared to the price charged from industries for electricity consumption is around Rs. 14 per kWh. Hence by selling this electricity to the CEB, the factory would make financial gain.

Moreover, under the SPPA, CEB is obliged to purchase all the electricity generated by the producer. There are no penalties imposed for variations in the rate of output of electrical power (provided it conforms to the required voltage and frequency and other specifications).

By introducing this technology, the industries presently generating process steam could obtain additional revenue by the sale of electricity to the CEB. The additional fuel cost incurred for the generation of electricity will be very small compared to the price paid by the CEB for the electricity.

4.4.3 *Cogeneration Potential*

Information was not readily available.

4.4.4 *Institutional Facilitators*

The Sri Lanka Sustainable Energy Authority (SSEA) and the Ceylon Electricity Board (CEB) is providing institutional facilitation by formulating a scheme, where any renewable energy based electricity generation, including biomass, could be sold to the CEB at the price specified in the Standardized Power Purchase Agreement (SPPA).

4.4.5 *Government Initiatives and Legal Frameworks*

The following situations prevailing in Sri Lanka which make this cogeneration technology applicable:

- The Government has introduced a electricity feed-in system to the national grid, under very good terms and an attractive feed-in tariff.
- For biomass based electricity generation, the present price applicable is Rs. 20.70 per kWh, well above the industrial rate.
- Government has a policy to generate at least 10% of the electricity through non-conventional renewable energy sources by the year 2015 and 20% by the year 2020.
- An attractive power purchase tariff for biomass based electricity well above the selling price of electricity for the industrial sector.
- A suitable multipurpose tree (Gliricidia sepium) has been identified as a suitable tree for the production of sustainable biomass fuel. This tree has been declared as a plantation crop.

Biomass fuel is the most dominating fuel (nearly 80%) for the generation of heat in the industrial sector. The primary reason for this preference by the industries of this fuel compared with petroleum fuels is the low cost of this fuel. Many industries already use biomass fuel fired steam boilers to generate industrial process heat. Introduction of cogeneration technology amounts to an extension of the existing system.

4.4.6 *Barriers and Constraints*

At present, the Sri Lanka Sustainable Energy Authority and the Ceylon Electricity Board (CEB) are sponsoring renewable energy based electricity generation. A very attractive price at over Rs 20.70 per kWh has been offered for electricity production for cogeneration companies.

The main need for cogeneration in the pulp and paper industry is the existence of pulping industry within the country but in Sri Lanka there are only 2 (two) paper mills in operation which are not operating in full scale at present.

4.4.7 *Cost Benefit Analysis*

In Sri Lanka this principle has been practiced to a very limited extent. Presently there are three installations in Sri Lanka where this principle is practiced. All these three use biomass as the fuel.

There is doubt about the technical feasibility of using this technology in Sri Lanka. Practical and economical aspects of this technology need demonstration in an industrial environment. The economical aspects has become a reality with the introduction of government policy on generation of electricity and the introduction of an attractive Standardized Power Purchase Tariff for biomass based electricity generation.

4.4.8 *Recommendations*

From the above narration on the development of cogeneration in Sri Lanka, it is recommended that the potential entities should be in close contact with the Sri Lanka Sustainable Energy Authority (SSEA) and the Ceylon Electricity Board (CEB).

Moreover, they may establish a co-ordinating committee to organize training workshop/seminars for increasing awareness about cogeneration, exchanging experiences and information among other potential industries of other countries within SAARC region.

5 PART D: SUMMARY AND RECOMMENDATIONS

5.1 Summary of Cogeneration Situation and Potential

A Summary Matrix showing cogeneration situation and potential has been prepared and appended in the table below:

Table 5.1: Summary of Cogeneration Situation and Potential

Country	Cogeneration Situation	Cogeneration Potential
Bangladesh	Sugar Industry All sugar mills have cogeneration facilities but these mills are only operating during the cane harvesting/crushing season i.e 150 days per year. If they can be operated after upgrading the power generation equipment and plant, more power could be generated which can alleviate the power shortage in the country.	Potential of cogeneration in the sugar sector concluded that with the available bagasse, power generation could be achieved in excess of **100 MW** for all the sugar mills. This may be achieved with an average installation of 10 MW at individual sugar mills. Most sugar factories have low-pressure (15 bar) boilers. By installing high-pressure boilers, these can produce more power efficiently. The choice of boiler pressure of 64 kg/cm2 and above appears inevitable for mills intending to sell power to the national grid. Typically, a well-designed 2,500 tons crushed/day plant can sell 10 MW of power to national grid.
	Paper Industry The pulp and paper industry has about 35 MW, being generated from cogeneration and this is expected to increase by another 8 MW in the near future.	The potential for new cogeneration in Bangladesh in paper & pulp industries' is more than **50 MW**.
India	Sugar Industry Industrial cogeneration has been the subject of considerable interest and inquiry in India for over a decade. Depending on the technology deployed, and the corresponding efficiency, about 75-90% of the	The potential of 3,500 MW can be easily increased to over **5,000 MW** by employing equipment and systems for reduction of steam and power usage in sugar processes (from present 50-52% steam on cane and 22 units of electricity per ton of cane crushed

Country	Cogeneration Situation	Cogeneration Potential
	bagasse available at Indian mills is used to produce internal steam and electricity; the balance is considered surplus and is either discarded or used for other purposes. The availability of surplus bagasse, or other fuels, is a major issue when considering year-round cogeneration with power export to the grid. <u>Paper Industry</u> Paper mills in India use agro-industrial residue based cogeneration to meet all the process energy requirement.	to 42-45% steam on cane and 16 units of electricity per ton of cane crushed), as well as for the manufacture of by-products. A recent national survey estimates the overall industrial cogeneration potential to be around 15,000 MW, with the sugar mills alone accounting for one-third of the total, followed by other industries including pulp and paper mills (assumed to be 5% which is around **750 MW**).
Pakistan	<u>Sugar Industry</u> A conservative factor is being assumed that crushing of 90,000 tons of sugar cane provide enough bagasse to produce 1 MW net of excess power per season (net means that the sugar factory power needs have already been met) for sale to the grid. As per assumption, 9 MW of power could be supplied to the grid during the crushing season and 11 MW during the off season from the crushing of 720,000 tons of sugar cane.	The potential from all operating 89 sugar mills has been estimated around **1000 MW** and if coal is added as alternate/additional fuel, this may go up to 2000 MW. If the entire potential of 1000 MW on bagasse is utilized, it can avoid a potential 1000 MW power station operating of coal, supplied from (say) the Thar coal fields. In such a case, CO_2 emission reductions of about 5 million tons per year can be achieved.
	<u>Paper Industry</u> Relevant information was not available on current situation. There are two paper mills where total installed capacity of cogeneration is 80 MW, whereas the available capacity is around 50 MW.	Significant information was not available on facts and figures of potential. It is estimated that total cogeneration potential available in Pakistan is ranging between 200 MW to 300 MW, provided majority of paper mills adopt cogeneration technology.
Sri Lanka	Significant information was not available for both sugar and paper industries.	

5.2 Recommendations and Way Forward

5.2.1 *Recommendations*

The potential for cogeneration is attractive in industries such as sugar, pulp & paper as well as other agro based and chemical industries. Cogeneration could be considered as an important issue in the national energy conservation and efficiency of each of the SAARC Member States.

In spite of the significant techno-economic potential for cogeneration applications in the SAARC region (except India), it has not been widely adopted due to several reasons. The foremost among them is the lack of awareness at all levels about the technological alternatives, economic merits, environmental benefits and business opportunities related to the application of cogeneration as an efficient energy use option. No systematic study has been undertaken so far to assess cogeneration potential by taking into account important factors such as energy demand patterns, plant size, power-to-heat ratio, availability fuel etc. There is practically no interaction between the energy suppliers and the energy users to explore the cogeneration option though necessary steps are being taken in this region about encouraging private investment in the power sector.

From the study carried out and descriptions provided in the preceding sections on different contents, the following recommendations are made for overall development of cogeneration applications in the SAARC region:

Recommendation No. 1: Development of Regulatory Framework

The regulatory framework hurdles (institutional structure, policy and planning, energy pricing and tariff, investment and financing etc.) in this sector may be reviewed and improved by the individual member states for increasing the role of cogeneration in the country. Regulatory measures are needed for the sale of excess electricity to the grid or third party, and back-up power supply from the grid.

In order to assist in the process, there needs to be a standard framework for cogeneration for the SAARC member states. In this respect, SEC may take up and develop the following documentation:

a. Guidelines for good practices in cogeneration
b. Manual for developing a cogeneration project
c. Model contract documents between (a) cogenerator and host, and (b) cogenerators and electricity utility
d. Standard financial model for cogeneration projects.

Recommendation No. 2: Participation of State Energy Suppliers

State energy suppliers (electricity and gas companies) may play a greater role in the propagation of cogeneration by establishing partnership with potential cogenerators, public or private, in making investment, guaranteeing operation and maintenance, and sharing costs and benefits in the process.

Recommendation No. 3: Financing

Concessional financing windows for cogeneration projects need to be established. Such financing may include third-party participation, leasing, soft loan, bilateral and international funds targeted towards global environmental protection (e.g. clean development mechanism, joint implementation, special environmental Yen loan, Global Environmental Fund etc.).

Recommendation No. 4: Institutional Structure

National committees or focal points may be established under the concerned Energy Ministry of each member states with a view to put emphasis on use of cogeneration, promoting cogeneration technology, etc. along with dissemination of information regarding implementation of cogeneration applications.

Recommendation No. 5: Cogeneration Facilitator

Co-ordination among the users, suppliers, financiers, developers, etc., is very important and there is a need to have a facilitator or an intermediary agency. Cogeneration promotion activities should be combined with energy conservation and energy efficiency activities.

SAARC Energy Centre (SEC) may take the responsibility of 'Facilitator' towards promotion of cogeneration within SAARC region, by arranging seminar/workshop for awareness about opportunities and potential of each country to others[18]. They may come up with the assistance of India (as they are experienced in this region) for bilateral and international support for setting up cogeneration demonstration projects using modern technologies in various sectors of activities in order to achieve rational use of energy within the country and the region.

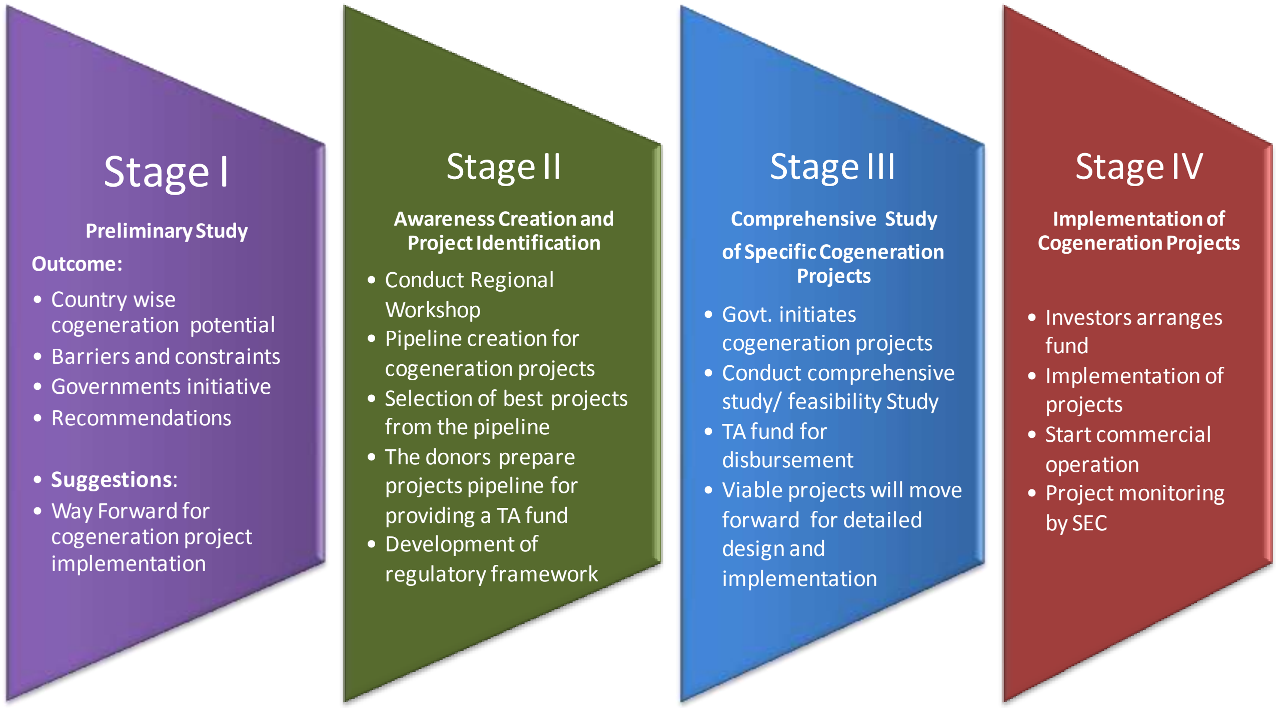
5.2.2 *Way Forward*

It has been observed that cogeneration can meet both power and heat needed for an individual plant with advantages of significant cost savings. In environmental context, it's crucial role would be to reduce emissions of pollutants due to efficient fuel consumption.

Considering its immense environmental and economic benefits, cogeneration needs to be implemented at individual plant basis. In this regard, a stage-wise cogeneration implementation strategy is depicted below, followed by a brief description of each stage.

[18] Stage II in the sec.5.2.2 Way Forward

Figure 5.1: Flow Chart of Cogeneration Implementation Strategy



SEC may facilitate in implementing the above stages i.e. awareness creation by arranging regional workshop, comprehensive study on specific cogeneration project and oversee its implementation.

Stage I: Preliminary Study

The preliminary study of implementation of cogeneration at individual plant level revealed the following outcome:

- Country-wise Cogeneration Potential
- Barriers & Constraints
- Government Initiatives
- Recommendations

The study suggests some effective steps (from Stage II to Stage IV) as the way forward to implement country wise cogeneration projects by mitigating their barriers and constraints.

This stage has been completedwith the completion of this study.

Stage II: Awareness Creation and Project Identification

The SEC will arrange workshop in each SAARC country for awareness creation. Initially the workshop may be arranged in Bangladesh, India, Pakistan and Sri Lanka and rest others later on. The workshop will be attended by the participants from the relevant ministries and executing agencies, donors, and potential Investors.

Before the workshop, the executing agencies will prepare a list of potential cogeneration projects with concept papers to the relevant ministries. Ministries will shorlist and prepare detailed concept papers of the project taking professional assistance from the consultant, may be 10 projects will be selected for discussions in the workshop. SEC may assist in engaging such consultant. After deliberation and interactive discussion of participants in the workshop, priority of implementation will be fixed up in terms of economic benefit and donors acceptance of the project.

It is recommended for SEC to be most active in this stage and assist the member states in the development of Regulatory Framework (Recommendation No. 1) .

Stage III: Comprehensive Study of Specific Cogeneration Projects

The Govt. or the relevant executing agency will initiate cogeneration projects under relevant ministry/ authoruity. Donors will provide Technical Assistance (TA) fund for projectwise comprehensive study. Consultants will be appointed to carry out comprehensive study for each project. The outcome of the study will be to find out the viability of the project to move towards implementation for the country's economic benefit.

Once the viable projects are identified, the executing agency will move forward for detailed design and implementation of the cogeneration project.

It is recommended for SEC to be involved up to the point where decision is made by the host agency to carry out a feasibility study for a sepecific cogeneration project. In this respect, SEC may work with suitable donors and facilitate the mobilisation of TA funds for the feasibility studies.

Stage IV: Implementation of Cogeneration Projects

The projects will be ready for physical implementation. The investors will arrange fund by means of equity, loan from commercial financial institutions, and incentives from donor agencies. After management of fund, the investor will start construction and implementation of the projects. The project will start commercial operation within a stipulated time period as per the schedule designed for the project.

It is recommended for SEC to overview project implementation and use successes for identifying more projects for Stage II.

5.3 Conclusions

The development of cogeneration is basically a policy issue. Therefore, the first prerequisite is an ideal policy framework, as has been demonstrated by some countries which have made considerable progress in the development of cogeneration, such as Japan, Republic of Korea and Thailand in Asia, and the Netherlands and Denmark in Western Europe. As such, planning and decision making regarding capacity expansion involving national authorities, electricity producers and distributors as well as potential developers of alternative energy sources including cogeneration needs establishment of right policy framework. Fair and transparent criteria such as cost effectiveness and environmental benefits will help to create a more competitive and convivial atmosphere for investment. Certain principles need to be upheld by the policy makers to assure private sector participation in energy generation and cogeneration, so that the capital requirements for power system expansion can be met.

There should be certain regulations that clearly define the cogeneration system by specifying the fuel to be used, energy efficiency, minimum or maximum ratio of heat to power, etc. **Regulations should allow the purchase and sale of power between cogenerators and electric utilities.** The obligations and rights of cogenerators and electricity utilities must be clearly defined as well as the interaction between them. A sound investment climate should be created in order to attract foreign investment into the field of cogeneration.

Development of a positive regulatory framework regarding the role of the electricity industry will provide the right signal to the potential cogenerator. This should include purchase and sale of electricity, back-up facilities and wheeling of electricity to third parties. There should be arrangement for the grid to buy back electricity from a cogenerator.

It is important to set ambitious but realistic targets for cogeneration development with clear commitment. If insufficient action is being taken, pressure may be applied by the organizations which are responsible for promoting cogeneration. SEC may facilitate regular interactions among the responsible organizations of SAARC Member States for promotion and implementation of Cogeneration.

Annex A: List of Reference Documents

1. Barbara Haya et al, Barriers to sugar mill cogeneration in India: Insights into the structure of post-2012 climate financing instruments, Climate and Development, 1 (2009) 66-81, Earthscan.
2. Industrial, Commercial, and Rural Cogeneration Opportunities (Chapter 5), Industrial and Commercial Cogeneration.
3. Johannes Alexeew and Ahmad Khalid, Co-generation and Energy Efficiency in the Sugar Mill and Rice Husk Sector, GIZ Regional Energy Efficiency Programme (REEP), 10-16 February, 2013, New Delhi.
4. Harsh Malhotra, Co-generation & Combined Heat and Power (CHP).
5. Na Raghu, Cogeneration Opportunities in Process Industries, Chemical Engineering word. (70-72)April 2010, India.
6. International Sugar Organization, Cogeneration-Opportunities in the World Sugar Industries, (April 2009), MECAS (09)05.
7. Cogeneration: A Successful Response to the Energy Crisis
   Volume 9, Issue 3, 1980 Article 1 for Fordham Urban Law Journal
8. Overview of Cogeneration and Its Status in Asia, UNESCAP, 1988
9. Winrock International, Advancing Cogeneration in the Indian Sugar Industry, USAID, India, May 1993
10. Dr M Eusuf, Presentation on ADB PREG Activities & Beyond, Bangladesh Centre for Advanced Studies, (BCAS) 8-9 April 2008, Dhaka
11. Guidebook on cogeneration as means of pollution control and energy efficiency in Asia, UNESCAP & BUET Bangladesh (2000).
12. Industrial and Commercial Cogeneration (February 1983).
13. M A Rashid Sarkar, Presentation on Energy efficiency gains in industrial establishments, BUET Bangladesh
14. Harshad P Pandya, Cogeneration-Combined Heat & Power, India
15. Almoiz,Bagasse Cogeneration Project, Pakistan, 15, March, 2008.
16. Capacity Utilization of Sugar Mills in SAARC Countries, ICMA Pakistan, December 2012
17. Avant Garde, Energy Audit in Sugar Industry.
18. Sugar Industry of Pakistan Potential for Grid Power Supply, IRG, Pakistan, September 1990
19. PBIT-Moazzam Husain, Power Generation from Sugar Mills, Pakistan 8 December 2010.

20. Co-Generation in Sugar Mills of Bangladesh Sugar and Food Industries, Corporation (BSFIC): A Feasibility Study, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh, 2009.
21. Leif Mortensen, Presentation on what is cogeneration and why Cogeneration? Malaysian Cogeneration, 6-7 July 2004
22. Mohan Kashyap, Cogeneration Opportunities in Process Industry, India, 2012
23. Hilal-Raza, Presentation on SAARC Initiative on Regional Cooperation in Energy Sector, India,11 December 2012
24. Reggie Davidrajuh, Design of Optimal Power Cogeneration for North-east Sri Lanka based on Stand-alone Renewable Energy Systems, Country paper Sri Lanka, Sri Lanka
25. Pak-Tenth Five Year Plan Version VII Final, Planning Commission, Pakistan, 31 May 2010
26. Clean Development Mechanism Project Opportunities in Bangladesh, BUET-BD, October 2002
27. Sector wise Industrial Guidelines Pulp & Paper, Bangladesh, 1997
28. National Policy for Power Cogeneration by Sugar Industry and Guidelines for Investors January 2008, Pakistan
29. Muhammad Tahir & Dr Khalid Mughal, Sugar Industry: A cheap and easy source of Electricity, Universal Journal of Management and Social Sciences, (Vol.2 No 4, April 2012.)
30. Pakistan: Need to push for co-generation, 11 April 2013.
31. Dr.C.S. Weeraratna, Declining Sugar Sector, 23 July 2012, Sri Lanka.
32. Bandula Sirimanna, Sri Lanka’s Sugar Industry in Crisis, Sri Lanka..
33. Viability of Biomass-fuelled Cogeneration Plants in Paper Mills
34. Pulp and paper industry in Pakistan, 2012
35. AEDB, Framework for Power Cogeneration 2013 Bagasse and Biomass Pakistan, 2013
36. Profile of Century Paper & Board Mills Limited, Pakistan
37. Zafar Bhutta, Co-generation Power Projects: Sugar Mills Reject NEPRA Tariff, 14 August 2008
38. Paper Industry of Pakistan [(i). Report on Paper and Board Industry of Pakistan by S. Shabbir & S. Mahmood, Aug, 2010,&(ii). Pakistan Trade Liberalization; Sectoral Study on Paper and Paperboard Industry”, published by Pakistan Institute of Trade and Development, 2012]