ENERGY FROM RECYCLABLE WASTE

By

MAHER BIN NAZIM

FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfilment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

MAHER BIN NAZIM

ABSTRACT

The topic chosen for the Final Year Project (FYP) is "A Case Study on Energy from Recyclable Waste". It is basically a study on the feasibility of using rice/paddy husks as a biomass energy resource to produce electricity. The objective is to investigate the chances of producing electricity using biomass energy. The project objectives and the scope of study are highlighted at the end of the chapter 1. The studies include; study on energy contents in paddy and grass, study on the availability of energy resources, study on steam power plant system, and lastly on the equipment efficiencies and energy conversion. Information/data collection and some technical procedures have being done to make this project successful. This report also contains the methodology of the study process and the work that have been done in the pass 2 semesters. Further information on the definitions and wastes is described at appendix A and B. The last part is conclusion which describes what have done and recommendations for further investigations.

ACKNOWLEDGEMENTS

Praise to Allah S.W.T, The Most Gracious, and The Most Merciful for His Guidance and Blessing for giving the strength and chances to undergo the project.

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LIST OF ABBREVIATIONS

UTP	–	Universiti Teknologi Petronas
JPM	–	Jabatan Pertanian Malaysia
kW	-	kilowatt
kWh	-	kilowatt hour
MW	-	Megawatt
GW	-	Gigawatt
HP	-	Horse Power
EMB	-	empty fruit bunches
CHP	-	Combined Heat and Power
MBI	-	Majlis Bandaraya Ipoh
HRSG	-	Heat Recovery Steam Generators
SREP	-	Small Renewable Energy Program
IC	-	internal combustion

CHAPTER 1
INTRODUCTION

Feasibility of using agricultural waste as renewable energy in Malaysia.

1.1 BACKGROUND OF STUDY

Malaysia currently has approximately 14 gigawatts (GW) of electric generation capacity, of which 86% is thermal and 14% is hydroelectric. In 2002, Malaysia generated around 67 billion kilowatt hours of electricity. The demand for electricity has increased, primarily due to the rapid rate of urbanization and industrialization. The Malaysian government expects that investment of $9.7 billion will be required in the electric utility sector through 2010. Among the various renewable energy sources, biomass conversion technologies appear to be one of the best suited for conversion to shaft power/electricity. Instead of coal, utilizing biofuel like agricultural residues (rice husk, rice straw, grass etc.) is better since it has lots of advantages and is being widely used for energy production.

The peak demand for electricity in Malaysia grew at a rate of 5.8% per annum, reaching 11,462 megawatts (MW) in 2003. To meet the growth in peak demand, the electricity generation capacity was increased from 12,645MW in 2000 to 17,015MW in 2003 as can be seen in Table 1 [3].

Table 1 : Installed Capacity, Peak Demand and Reserve Margin, 2000-2005 for Tenaga Nasional Berhad, Malaysian National Electricity Provider.

(Ref: Mid-Term Review of the 8th Malaysian Plan 2001-2005)

YEAR	ACCUMULATED INSTALLED CAPACITY (MW)	PEAK DEMAND (MW)	RESERVED MARGIN (%)
2000	12645	9712	30.2
2003	17015	11462	48.4
2005	18465	13172	40.2

The main sources of energy supply that are found in Malaysia are hydro, natural gas, crude oil, and coal.

Table 2 : Fuel Mix in Electricity Generation

(Ref: Mid-Term Review of the 8^{th} Malaysian Plan 2001-2005)

YEAR	OIL (%)	COAL (%)	GAS (%)	HYDRO (%)	OTHERS (%)	TOTAL (GWh)
2000	4.2	8.8	77	10	0	69.280
2003	2.6	16.5	73.2	7	0.7	81.488
2005	2.4	26.8	64.3	5.9	0.6	96.087

1.2 PROBLEM STATEMENT

With the awareness of humans towards the depletion of energy resources, it is time to move on to develop other methods of fulfilling our requirement of energy. Biomass is an effective alternative to alleviate this problem and is generally a valuable source in our lives.

Malaysia, well known for its agricultural sector, is one of the leading producers of paddy. Rice is a staple food in Malaysia, therefore coherent to that, large amounts of rice husks are being burdened by their producers to be dispelled. Moving towards a conscious of zero waste, rice husks is being increasingly seen as a potential source for biomass. Malaysia itself produces approximately 0.48 million tons of rice husks a year and due to vast technological developments in paddy growth, rice husks can be a valuable asset in reducing the cost and pollution in creating energy [1].

Over the years, coal has been used as a fuel to generate useful electricity. Concurrently, many other fuels, mostly un-renewable fuels from crude oil are also used. The amount of these fuels is depleting rapidly, and one of the major impacts is pollution. Its high emission of sulphur and nitrate based gases is a threat to mankind.

Because of that, alternative methods such as co-firing may be carried out. Negative impacts such as global warming, and acid rain may be avoided, and hence providing it with a bright future in becoming a popular alternative method in Malaysia and other parts of the world.

1.3 OBJECTIVES AND SCOPE OF STUDY

1.3.1 Project Objectives

The objective of this project is to investigate the potentials of waste which is in a scope of agricultural or biomass waste as a source of a new energy for electricity generation in Malaysia. This will include the energy contents, the availabilities and the conversion of energy to power.

1.3.2 Scope of Study

Recyclable wastes include wood, agricultural residues, manure and municipal waste. The author's scope of study is to study the potential of mainly paddy husks and its straws as a source to generate electricity.

CHAPTER 2
LITERATURE REVIEW

2.1 ENERGY

The word energy is defined as the amount of work a physical system is capable to perform. Energy can neither be created nor consumed or destroyed.

Energy however may be converted or transferred to different forms: The kinetic energy of high pressured moving air or steam molecules may be converted to rotational energy by the steam turbine, which in turn may be converted to electrical energy by the stem turbine generator. With each conversion of energy, part of the energy from the source is converted into heat energy.

The expression energy loss is loosely used (which is impossible by the definition above). What was meant is that part of the energy from the source cannot be used directly in the next link of the energy conversion system. This is because it is converted into heat. E.g. rotors, gearboxes or generators are never 100 per cent efficient, because of heat losses due to friction in the bearings, or friction between air molecules.

According to physicists, the amount of entropy in the universe has increased. By that, they mean that our ability to perform useful work converting energy decreases each time we let energy end up as heat which is dissipated into the universe. Useful work is called exergy by physicists.

Since the vast majority of steam turbines produce electricity, we usually measure their performance in terms of the amount of electrical energy they are able to convert from the kinetic energy of the steam. We usually measure that energy in terms of kilowatt hours (kWh) or megawatt hours MWh during a certain period of time.

Note:

Energy is not measured in kilowatts, but in kilowatt hours (kWh).

Energy Units

1 J (joule) = 1 Ws = 0.2388 cal
1 GJ (gigajoule) = 10^{9} J
1 TJ (terajoule) = 10^{12} J
1 PJ (petajoule) = 10^{15} J
1 kWh (kilowatt hour) = 3,600,000 Joule

2.2 POWER

Electrical power is usually measured in watt (W), kilowatt (kW), megawatt (MW), etc. Power is energy transfer per unit of time. Power may be measured at any point in time, whereas energy has to be measured during a certain period, e.g. a second, an hour, or a year.

Power Units

1 kW = 1.359 HP

Energy	Time	Power	
1 Joules		1 Watts	This is the average power in full sunlight falling on a 0.05167 square foot surface, directed toward the sun, and collecting 5 hours each day.
0.0002778 Watt Hours		0.001 Kilowatts	
2.77800000(Kilowatt Hours	1 Seconds	0.001341 Horsepower	
0.0009485 BTU		3.414 BTU/hr	
9.48500000(Therms		0.0002845 tons	

Figure 1 : Conversion of Energy to Power for 1 Second.[5]

Energy	Time	Power	
1 Joules		0.01667 Watts	This is the average power in full sunlight falling on a 0.0008611 square foot surface, directed toward the sun, and collecting 5 hours each day.
0.0002778 Watt Hours		0.00001667 Kilowatts	
2.77800000(Kilowatt Hours	1 Minutes	0.00002235(Horsepower	
0.0009485 BTU		0.05691 BTU/hr	
9.48500000(Therms		0.00000474(tons	

Figure 2 : Conversion of Energy to Power for 1 Minute.[5]

Energy	Time	Power	
1 Joules		0.0002778 Watts	This is the average power in full sunlight falling on a 0.00001435(square foot surface, directed toward the sun, and collecting 5 hours each day.
0.0002778 Watt Hours		2.77800000(Kilowatts	
2.77800000(Kilowatt Hours	1 Hours	3.72500000(Horsepower	
0.0009485 BTU		0.0009484 BTU/hr	
9.48500000(Therms		7.90400000(tons	

Figure 3 : Conversion of Energy to Power for 1 Hour.[5]

2.3 ENERGY FROM RECYCLABLE WASTE

All human and industrial processes produce waste. In the industrial countries the amount of municipal solid waste derived from domestic, commercial and industrial sources increases every year. Wastes that can form sources of biofuels include domestic refuse, industrial wastes, agricultural wastes, forestry residues, sewage and industrial effluents. It is highly desirable that the recovery of energy from waste should form part of an integrated approach to waste management, designed to maximize waste recycling and reclamation. Recycling prevents the emission of many greenhouse gasses and water pollutants saves energy, supplies valuable raw materials to industry, creates jobs, stimulates the development of greener technologies, conserve resources for future and reduces the need for few for new landfills and combustors (incinerators).

Most domestic waste is in solid form. Table below shows the caloric value for some municipal solid waste.

Table 3 : Municipal Solid Waste, (MSW) [14]

Category	Caloric value (MJ/kg)
Paper and cardboard	14.6
food waste	6.7
Metal	0
Glass	0
Dust and cinders	9.6
Textiles	16
Leather, Rubber	17.6 - 37
Miscellaneous	17.6

Besides municipal waste, agricultural wastes give a lot of potential in converting them into fuels. This conversion is called biomass.

2.4 THE FUEL

The target share of renewable energy is 5% of the total energy supply by the end of the Eighth Malaysia Plan. From Research biomass residues from the oil palm sector have been identified as one of the biggest potential resources of energy to meet the target. Even though statistically this resource is widely used in Malaysia for heat and power generation through combustion, it is being utilized inefficiently. A few studies show that the access power from the combine heat and power plant using palm oil biomass is viable to be connected to national grid system (Jurutera, November 2004). Currently, the total power generation capacity from oil palm residues for internal consumption is about 211MWe. However pretreatment have to be conducted before it goes into the boiler. Utilization should be improved through an efficient biomass technology.

Some of the advantages of using biomass as a source of energy are:

- Biomass is available all round the year. It is cheap, widely available, easy to transport, store, and has no environmental hazards.
- It can be obtained from plantation of land having no competitive use.
- Biomass-based power generation systems, linked to plantations on wasteland, simultaneously address the vital issues of wastelands development, environmental restoration, rural employment generation, and generation of power with no distribution losses.
- It can be combined with production of other useful products

2.4.1 Development and Commercialization of Biomass Energy

The Eighth Malaysia Plan is a period to test, demonstrate and even commercialize several initiatives arising from a number of renewable energy feasibility studies.

The launch of the Small Renewable Energy Program (SREP) on 11 May 2001 is among the steps being taken by the government to encourage and intensify the utilization of renewable energy in power generation with the target 5% of the total electricity generation by 2005. Up to November 2004 about 62 SERP projects have been approved [4]. See table below.

Table 4 : Status of SREP Projects Approved by Score As of September 2004 (Ref: Jurutera, November 2004 [4])

No.	Type	Energy Resources	Approved Application	Grid Connected Capacity (MW)	%
1	Biomass	Empty Fruit Bunches	25	165.9	52.8
		Wood Residues	1	6.6	2.1
		Rice Husk	2	12.0	3.8
		Municipal Solid Waste	1	5.0	1.6
		Mix Fuels	3	19.2	6.1
2	Landfill gas		5	10.0	3.2
3	Mini-hydro		25	95.4	30.4
4	Wind and Solar		0	0.0	0.0
	Total		62	314.1	100.0

From the table above, it shows that 25 applications that are approved are to use EFB as the fuel followed by mix fuels, 3, and rice husks 2. Rice husks have the potential in direct burning combustion system compared to EFB. EFB has bigger number of approval because of its potential in gasification process which produces the methane and ethane. It has higher potential in the extraction of energy compared to rice husks but it requires higher cost in implementing the project.

2.4.2 Fuel Considerations

Table below shows some potential biomass fuel with the energy contents that is available in Asia.

Table 5 : Arising Residues and Energy Content of Major Residues (Courtesy of Bhattacharya 1985 [10])

Residue	Arising ('000 tonnes)	Yield (t/ha)	Energy content ($\times 10^{15}$J)
Cassava stalks	7 115.20	5.76	39.84
Coconut husks	355.08	0.91	4.62
Coconut shells	161.40	0.41	2.91
Cotton stalks	244.00	2.13	1.37
Groundnut stalks	363.25	2.98	2.03
Maize stalks	6 004.60	3.58	33.62
Mungbean stalks	703.25	1.45	3.94
Rice straw	**25 318.50**	**2.63**	**212.66**
Rice husks	**4 219.75**	0.44	**58.23**
Sorghum stalks	827.05	3.37	4.63
Soybean stalks	340.20	2.73	1.90
Bagasse	5 857.68	10.04	82.00
Sawdust and shavings			0.77
Total			448.52

Table 6 : Average heat energy content of fuels [7]

Fuel	Energy	
	GJ /ton	GJ /m^3
Wood (green, 60% moisture)	6.00	7.00
Wood (air dried, 20% moisture)	15.00	9.00
Wood (oven-dried, 0% moisture)	18.00	9.00
Charcoal	30.00	*
Grass (fresh-cut)	4.00	3.00
Straw (as harvested, baled)	15.00	1.50
Domestic refuse (as collected)	9.00	1.50
Oil (petroleum)	42.00	34.00
Coal	28.00	50.00
Natural gas (at supply pressure)	55.00	0.04

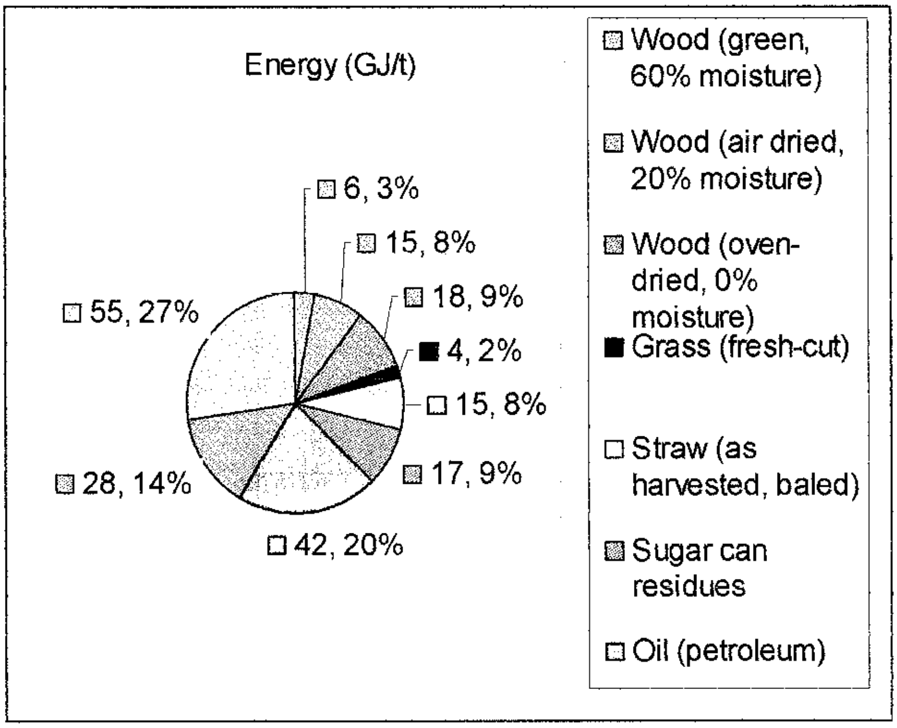


Figure 4 : Energy content (GJ/t) for each waste (fuel)

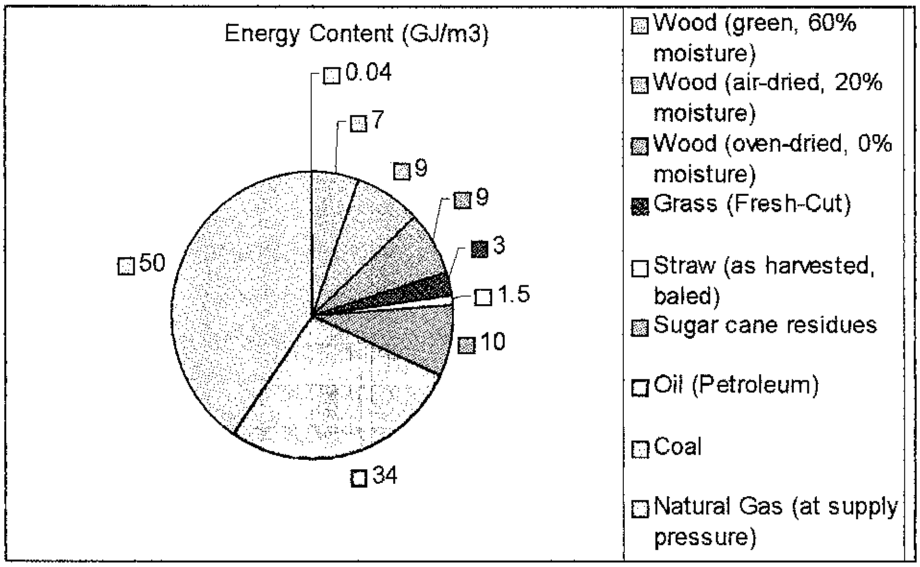


Figure 5 : Energy content (GJ/m^3) for each waste (fuel)

2.4.3 Malaysia's Paddy Production

Area (hectares)	1999/2000	2000/2001	2001/2002	2002/2003
Malaysia	441,104	420.021	423,198	422,101
Peninsular Malaysia	270,864	257,938	263,122	262,141
Granary area	197,036	184,154	189,754	191,797
Sabah	39,713	37,634	33,042	32,565
Sarawak	130,527	124,449	127,034	127,395

Average yield (kg/ha)	1999/2000	2000/2001	2001/2002	2002/2003
Malaysia	2,720	2,786	2,952	3,168
Peninsular Malaysia	3,486	3,531	3,560	3,858
Granary area	3,692	3,786	3,732	4,114
Sabah	3,013	3,188	3,148	3,246
Sarawak	1,043	1,121	1,639	1,728

(Courtesy of Malaysia Agricultural department)

2.4.4 Malaysia's Paddy Husks and Straws Production

Malaysia's Rice Straw Production

Total planted/year	=	647,750 acre (262,141 ha)
Total Straw Production	=	1,425,050 tons
Total rice (paddy)	=	1,011,000 tons
Available paddy husk (20% of paddy produced)	=	202,000 tons
Average straw production per acre	=	2.2 tons

Approximate bale specifications

Small 3-string	= 15-18 inches x 22inches x ± 45 inches	=	80-95 pounds
Small 2-string	= 16 inches x 18inches x ± 45 inches	=	55-65 pounds
Large	= 3ft x 4ft x 8ft	=	950-1000 pounds
Jumbo	= 4ft x 4ft x 8ft	=	1200-1250 pounds

(Courtesy of Malaysia Agricultural department)

2.5 POWER PLANT

Electric power plants have a number of components in common and are an interesting study in the various forms and changes of energy necessary to produce electricity.

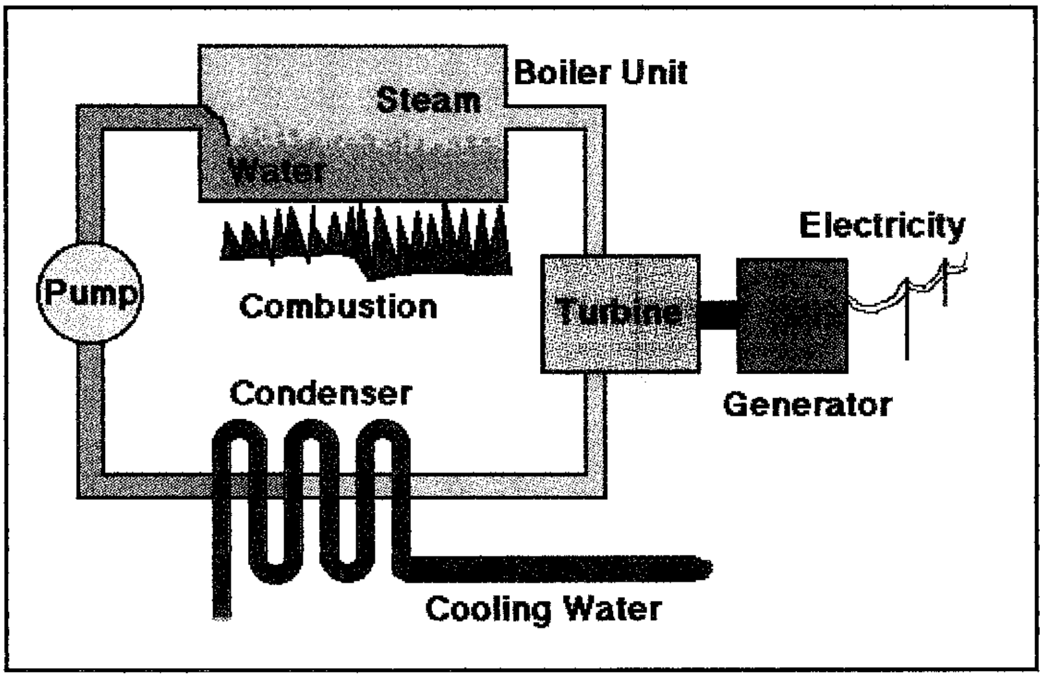


Figure 6 : Example Of A Schematic Power Generating Plant

2.5.1 Plant Specifications

Boiler unit

Almost all of power plants operate by heating water in a boiler unit into super heated steam at very high pressures. The source of heat from combustion reactions may vary in fossil fuel plants from the source of fuels such as coal, oil, or natural gas. Biomass or waste plant parts may also be used as a source of fuel. In some areas solid waste incinerators are also used as a source of heat. All of these sources of fuels result in varying amounts of air pollution, as well as carbon dioxide (a gas implicated in global warming problems).

Turbine-generator

The super heated steam is used to spin the blades of a turbine, which in turn is used in the generator to turn a coil of wires within a circular arrangement of magnets. The rotating coil of wire in the magnets results in the generation of electricity.

Cooling water

After the steam travels through the turbine, it must be cooled and condensed back into liquid water to start the cycle over again. Cooling water can be obtained from a nearby river or lake. The water is returned to the body of water 10 -20 degrees higher in temperature than the intake water. Alternate method is to use a very tall cooling tower, where the evaporation of water falling through the tower provides the cooling effect

2.5.2 Introduction to Power Plant

According to the Webster's International Encyclopedia (1996), an electric power plant creates mechanical energy that is converted via a generator into electricity. The production of electricity may be used for industrial, residential and rural use. Besides that, according to Perry and Green, 1997, it states that these plant units, which are mainly stationary plants, convert energy from various methods which includes falling water, fossil fuel, solar, wind, and biomass.

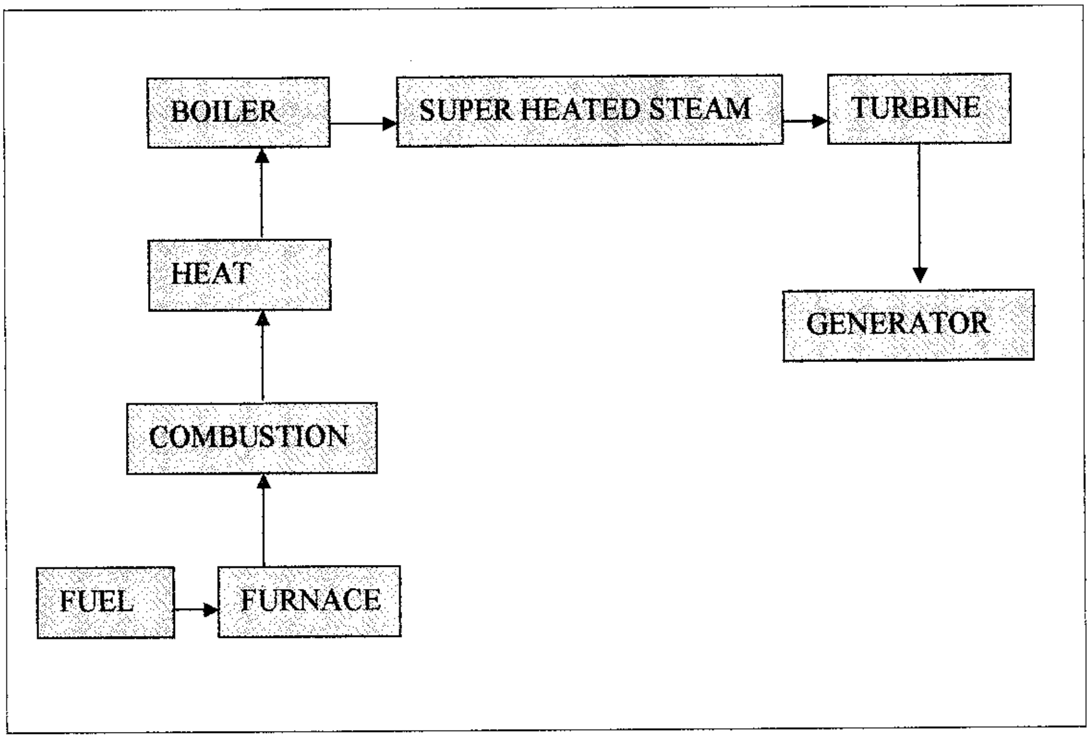


Figure 7 : Process conversion of heat to electrical energy

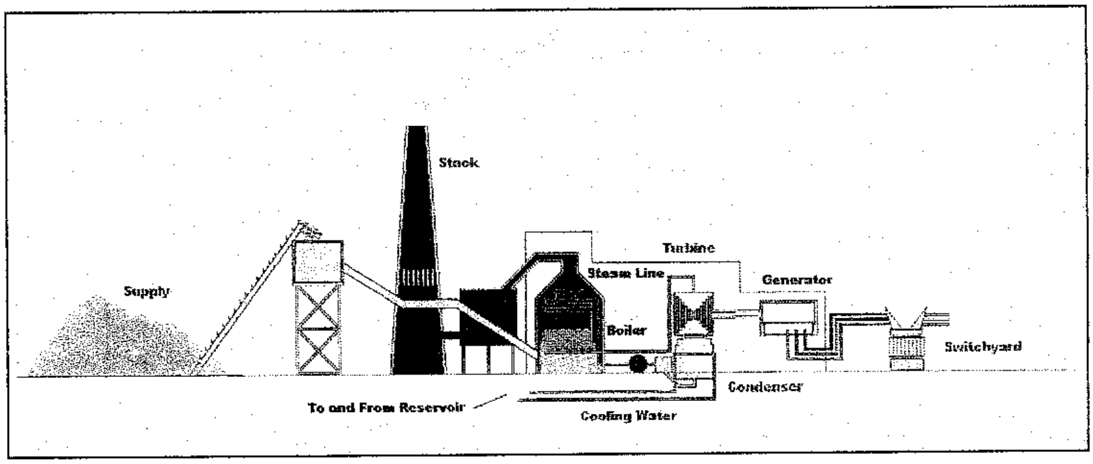


Figure 8 : Example of the biomass fired power plant.

2.5.3 Types of Power Plant

Combine cycle power plant

The combined-cycle unit combines the Rankine (steam turbine) and Brayton (gas turbine) thermodynamic cycles by using heat recovery boilers to capture the energy in the gas turbine exhaust gases for steam production to supply a steam turbine as shown in the figure "Combined-Cycle Cogeneration Unit". Process steam can be also provided for industrial purposes [6].

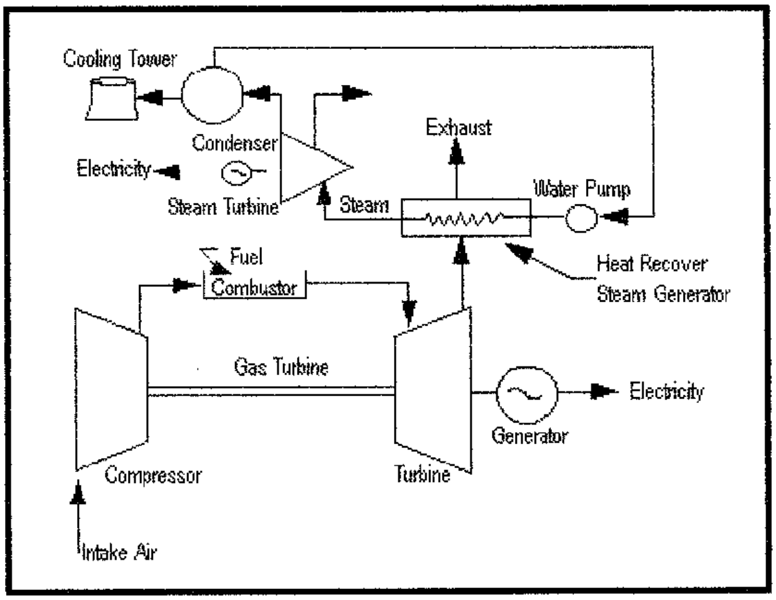


Figure 9 : Schematic Diagram Example of Combine Cycle Power Plant (courtesy of cogeneration.net [6])

Fossil fuel-fired (central) power plants use either steam or combustion turbines to provide the mechanical power to electrical generators. Pressurized high temperature steam or gas expands through various stages of a turbine, transferring energy to the rotating turbine blades. The turbine is mechanically coupled to a generator, which produces electricity.

Steam Turbine Power Plants:

Steam turbine power plants operate on a Rankine cycle. The steam is created by a boiler, where pure water passes through a series of tubes to capture heat from the firebox and then boils under high pressure to become superheated steam. The heat in the firebox is normally provided by burning fossil fuel (e.g. coal, fuel oil or natural gas). However, the heat can also be provided by biomass, solar energy or nuclear fuel. The superheated steam leaving the boiler then enters the steam turbine throttle, where it powers the turbine and the connected generator to produce electricity. After the steam expands through the turbine, it exits at the back end of the turbine, where it is cooled and condensed back to water in the surface condenser. This condensate is then returned to the boiler through high-pressure feed pumps for reuse. Heat from the condensing steam is normally rejected from the condenser to a body of water, such as a river or a cooling tower.

Steam turbine plants generally have a history of achieving up to 95% availability and can operate for more than a year between shutdowns for maintenance and inspections[6]. Their unplanned or forced outage rates are typically less than 2% or less than one week per year.

Modern large steam turbine plants (over 500 MW) have efficiencies approaching 40-45%.

Combustion (Gas) Turbines:

Combustion turbine plants operate on the Brayton cycle. They use a compressor to compress the inlet air upstream of a combustion chamber. Then the fuel is introduced and ignited to produce a high temperature, high-pressure gas that enters and expands through the turbine section. The turbine section powers both the generator and compressor. Combustion turbines are also able to burn a wide range of liquid and gaseous fuels from crude oil to natural gas.

The combustion turbine's energy conversion typically ranges between 25% to 35% efficiency as a simple cycle. The simple cycle efficiency can be increased by installing a recuperator or waste heat boiler onto the turbine's exhaust. A recuperator captures waste heat in the turbine exhaust stream to preheat the compressor discharge air before it enters the combustion chamber. A waste heat boiler generates steam by capturing heat form the turbine exhaust. These boilers are known as heat recovery steam generators (HRSG). Steam can be provided for heating or industrial processes, which is called cogeneration. Power can also be generated by the high-pressure steam from these boilers with steam turbines, which is called a combined cycle (steam and combustion turbine operation). Recuperators and HRSGs can increase the combustion turbine's overall energy cycle efficiency up to 80%.

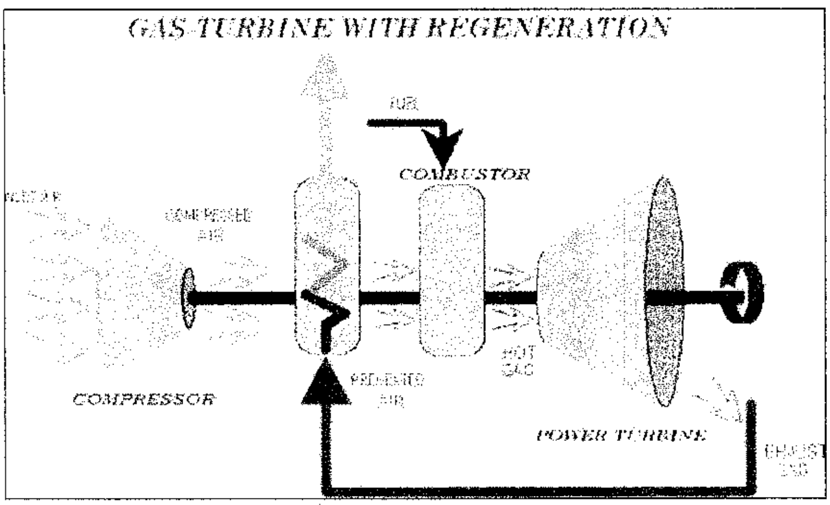


Figure 10 : Schematic Diagram Example of Combustion Gas Turbine. (courtesy of cogeneration.net [6])

Combustion (natural gas) turbine development increased in the 1930's as a means of jet aircraft propulsion. In the early 1980's, the efficiency and reliability of gas turbines had progressed sufficiently to be widely adopted for stationary power applications. Gas turbines range in size from 30 kW (micro-turbines) to 250 MW (industrial frames). Industrial gas turbines have efficiencies approaching 40% and 60% for simple and combined cycles respectively [6].

2.5.4 Coal Power Plants

The coal power plant utilizes coal as fuel in producing electricity. A general description of coal power plant consists of:

1. Burner - Feeds coal to the combustion chamber for combustion
2. Boiler - Utilizes the heat of coal combustion to convert feed water to high temperature and pressure steam
3. Steam lines - consists of properly sized pipes to feed the steam produced to the turbine
4. Turbine - converts steam pressure to rotational mechanical work
5. Generator- converts mechanical work to electricity

<u>Generating Unit Size</u>

There are a few factors, which can influence the size and capacity of a power plant. These factors include:

1. Type of unit
2. Duty required

The types of units as stated by Parker (1993) are such as:

1. Base load – as large as 1200MW or more
2. Intermediate duty generators – 200 – 600 MW
3. Peak-load – 10 – 100 MW

In Malaysia, the type of unit of a coal fired power plant ranges from intermediate duty generators to base load units as can be seen from the table 7.

Table 7 : List of Coal Fired Power Plants in Malaysia (Existing and Planned Coal-Fired Power Plant, 2004)

Plant	Capacity	Coal Utilization
TNB Kapar Ph.2	600 MW	1.5 mtpa
TNB Kapar Ph.3	1000 MW	2.5 mpta
TNB Janamanjung	2100 MW	6.0 mtpa
SKS-IPP	2100 MW	5.7 mtpa
Jimah-IPP	1400 MW	3.5 mtpa
Total	7200 MW	19.2 mtpa

The table above lists the coal fired power plants available in Malaysia. From there, it can be seen that the total amount of electrical energy supplied is 7200 MW with coal utilization of 19.2 million tons of coal per year.

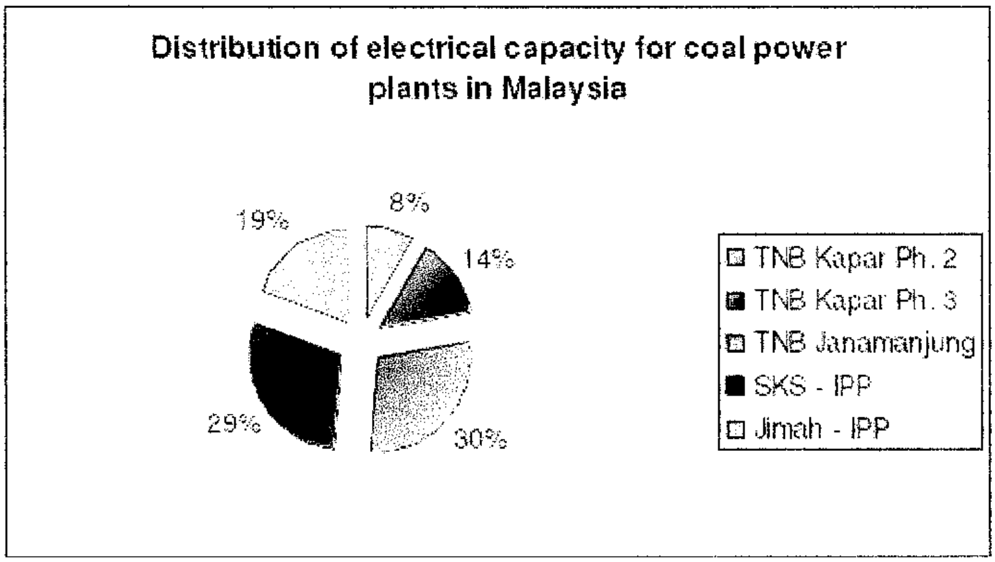


Figure 11 : Distribution of Electrical Capacity for Coal Power Plants in Malaysia

2.5.5 Steam Power Plant Basic Design and Principle of Operation

The basic design of the steam power plant is shown schematically below:

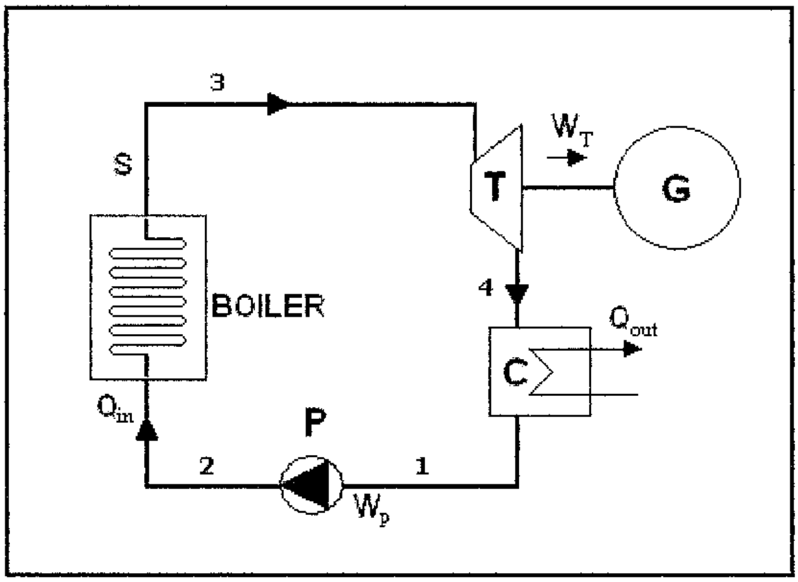


Figure 12 : Principle schematic diagram of a steam power plant; **S** superheater, **T** turbine, **G** generator, **C** condenser, **P** feed pump

It comprises the following major components:

- boiler (steam generator)
- superheater
- steam turbine with electric generator
- condenser
- feed pump

(Refer to Figure 12 and 13)

In the boiler, the working fluid (water) is first heated from its initial temperature (state 2) to the saturation temperature and dry saturated steam (state 3) is formed. In the superheater, this steam is superheated to live steam temperature. The entire process 1, 2, 3 and 4 in the boiler and superheater takes place with heat addition at a constant pressure p_1. In the steam turbine, T the superheated live steam expands adiabatically, i.e. without heat exchange with the surroundings from state 3 to state 4, thereby the pressure drops from p_1 to p_2. The steam output from the turbine will the passes from turbine to the condenser C where it is condensed at constant pressure p2 as a result of heat removal to the cooling water. The condensate (state 1) is saturated liquid (water) at pressure p2. The feed pump P raises the pressure from p_2 to p_1 and pumps the feedwater (state 2) to the boiler.

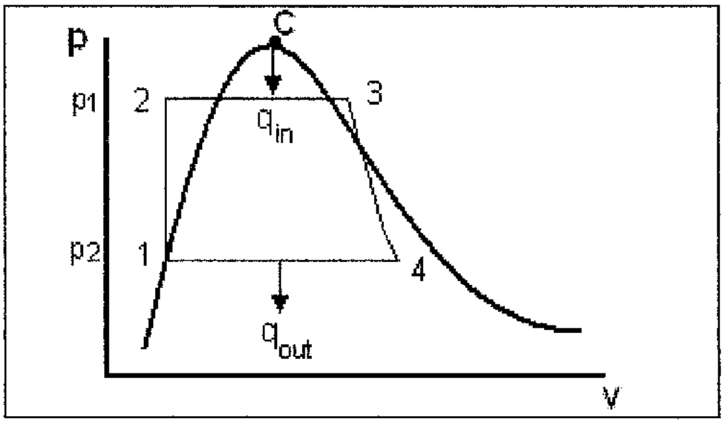
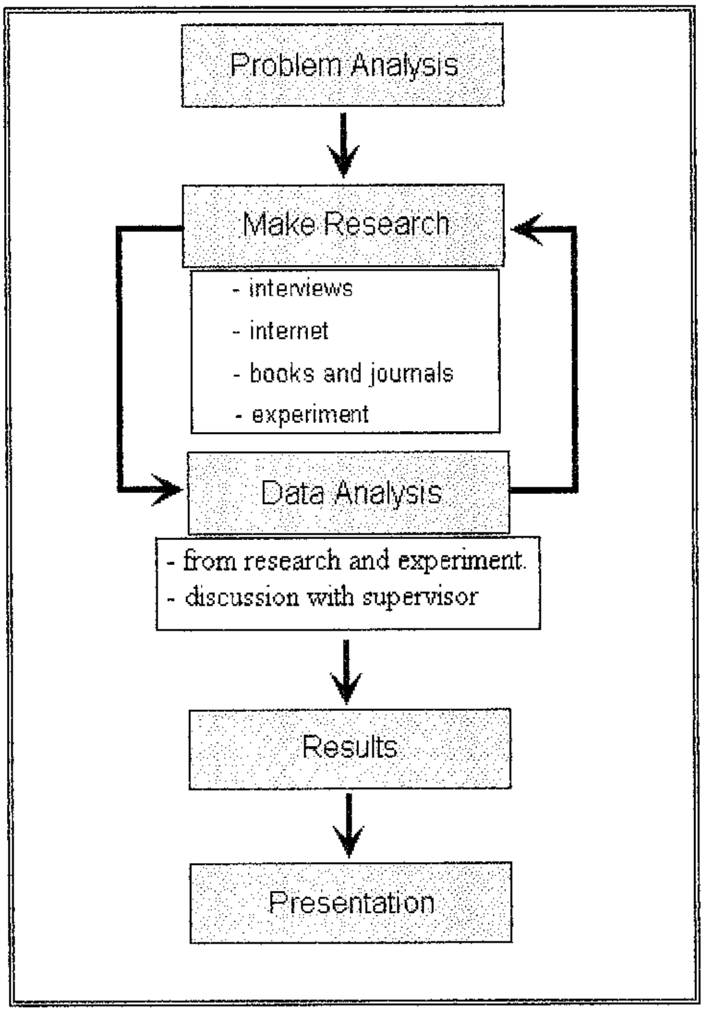


Figure 13 : Rankine cycle on pressure, p and volume, v

CHAPTER 3
METHODOLOGY/PROJECT WORK

3.1 METHODOLOGY

The methodology used is very important in order to complete this project. The methodologies that have been identified are as follows:



3.2 PROJECT WORK

3.2.1 Grass Cutting

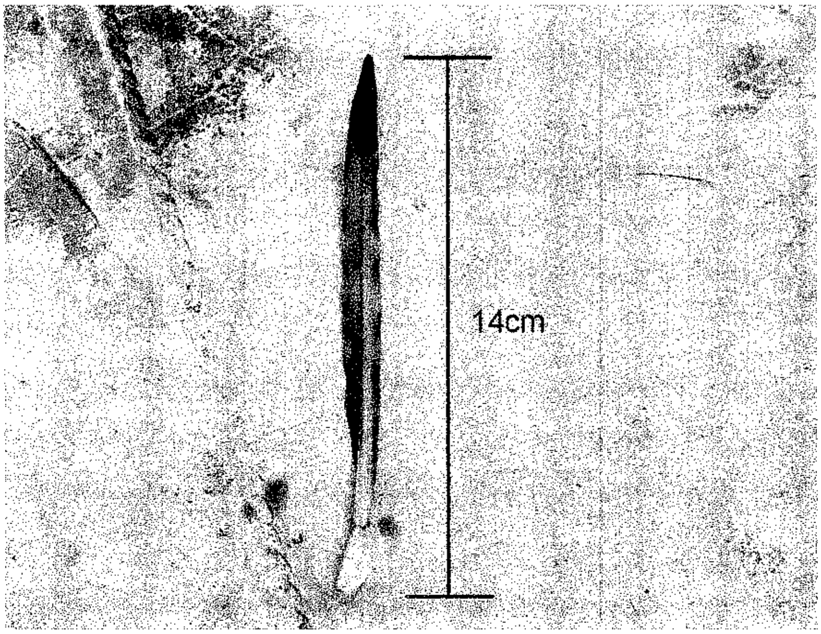


Figure 14 :Grass length in two weeks

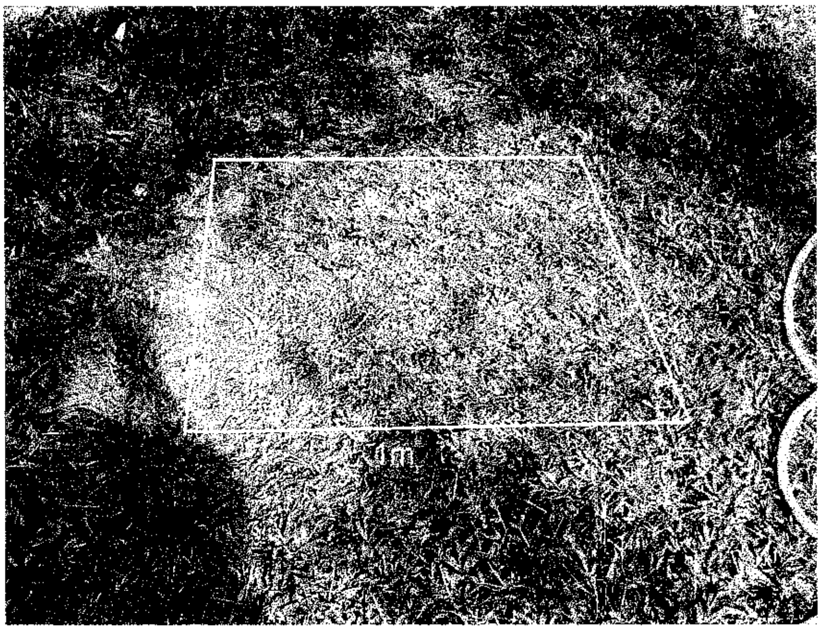


Figure 15 : Grass Area; 1 m^2 of grass was cut.

Figure 16 : The amount of grass collected from1m2 grass area.

3.2.2 Study on Chemical Properties of Grass

Table 8 : Grass (fuel) properties [16]

COMBUSTION ASH	4.5-5.8 %
ASH FUSION TEMPERATURE	1016 °C
SULFUR CONTENT	0.12 %
ENERGY CONTENT	4GJ/T
ENERGY CONTENT	$3GJ/M^3$
HOLLOCELLULOSE	54-67 %
ETHANOL RECOVERY	280L/KG

3.2.3 Study on Paddy/Rice Husks

Availability of Rice Husks/Hulls

The availability of rice hulls varies from country to country and from location to location. Rice hull availability depends on the type and size of the rice mills, and their locations. Larger rice mills that are located in or close to urban areas will have more disposal problems with hulls compared to smaller village-type rice mills located in rural areas. In addition, some rice mills operate only a few months out of the year, whereas others operate throughout the year. Finally, restrictions on open-pile burning affect the availability of hulls as well.

In most rice mills, rice hulls are separated from husked rice through aspiration, as rice hulls are lighter in weight than husked rice. In some rice mills, hulls are ground prior to piling or storage. Grinding makes it easier to transport hulls in suspended air, reduces space needed for storage, and reduces transportation costs.

Rice husk/hull as Animal feed

Rice hull has traditionally been used as an ingredient in ruminant and poultry feeds. Currently, commercial feeds may contain up to 5% to 10% of ground rice hulls. Feeding ground rice hulls directly as roughage to cattle, hogs, and horses is a common practice in many countries, although rice hulls have low digestibility and nutritive value. Of all cereal by-products, the rice hull has the lowest percentage of total digestible nutrients (less than10%). Like rice straw, adding a source of nitrogen can enhance rice hulls as a feed source. Rice-mill feed is a mixture of rice hulls and other rice milling byproducts and is an acceptable component of animal feeds. Constraints for rice hull use as feed are low digestibility, its peculiar size, low bulk density, high ash/silica content and abrasive characteristics.

Rice hull as fertilizer

Rice yields can be improved over and above yields obtained with regular use of fertilizer by addition of rice husk ash. Rice hull can also serve as a moisture retention helper or as a weed growth inhibitor in a soil. When rice hull is burned, the remaining ash can serve as a mix for fertilizer as was done traditionally in China, and is currently practiced in Bangladesh, Vietnam and other countries where rice hull is used as a domestic fuel. Finely ground rice hulls are also used as component in commercial mixed fertilizers. The rice hull prevents caking of other fertilizer components. In Japan, farmers have been using carbonized (partially burnt) rice hulls as soil conditioner for a long time.

Fuel: Rice hull combustion

Rice husks are a much more economic material for direct combustion compared to rice straw. Husks do not contain the same levels of potassium or chlorine; therefore they do not require leaching before use. Husks are generated at a central location at the rice mill and can be easily transported. Husks also produce higher purity ash that can be used in iron furnaces and cement. Approximately 30% of the husk ends up as ash which presently has a retail value of $200 per ton. In the USA, the cost of installing an electrical power plant, which uses rice husks, is approximately $1 million per MW of electric power capacity. Such a power plant will require 1.5-2.0 tons of husk for each MW hour of electricity produced. Production costs are 2-3 cents per kWh and the power plant will consume about 10% of the power produced for its own needs. In California, rice hull is used as a fuel for electricity generation in medium sized (25 - 50 MWe) combustion facilities.

In the modern rice milling industry, rice hulls are used as fuel source for grain drying and parboiling. In Thailand, rice is dried in high-temperature fluidized bed dryers, and drying heat is provided by cyclonic rice hull furnaces. In Arkansas, about 30% of rice produced is parboiled, and heat for process steam and rotary grain dryers is produced from rice hulls. In Bangladesh, rice hulls are the preferred fuel for parboiling, and rice hulls are widely used for grain drying in the larger rice mills in Northern India.

At the domestic level, rice hull can be briquetted to improve combustion characteristics and ease of handling. Extruder technology for rice hulls that originated in Korea and is now common in rural Bangladesh.

Fuel: Rice hull gasification

The gasification of rice hulls to produce a combustible gas can have several objectives: direct combustion in boilers or furnaces, combustion in Internal Combustion (IC) engines, or production of cooking gas. Gas produced in gasifiers (commonly referred to as "producer gas") for use in boilers and furnaces is a technically and economically proven technology, and provides a more efficient type of energy conversion than direct combustion of rice hull. Technologies for combustion in IC engines were developed in a number of countries (China, Italy, Thailand, India, U.S.A.), and this is technically feasible for both diesel and gasoline-fueled engines. Large Italian rice mills have traditionally gasified their rice husks and used the gas to drive power units for milling. However, considering the volume of production of rice hull in the world and the wide use of IC engines, use of this technology is not widespread. A limited number of small-scale rice hull gasifiers (5 - 20 kW) are in use in Northern-India for generation of electricity and irrigation water pumping.

Industrial use of Rice hull and Rice hull ash

The high silica content of rice hull ash, made it very usable as industrial commodity in the steel industry. It is used as an insulator during steel manufacturing, to prevent rapid cooling of steel and ensure uniform solidification. Prices for rice hull ash on the world market are approximately $200 per ton of ash (equivalent to $ 40 per ton of rice hulls, or $ 8 per ton of rough rice). Using rice hull ash in the cement industry is currently considered as well. Other reported industrial uses of rice hull include use of rice hulls in ceramic bricks, refractory, furfural, abrasives, and sodium silicate.

Rice husks may be used as energy sources in a number of forms:

• In their raw form, they are burnt to provide energy for the cooking of slow cooking foods. In this form, they are also used by charcoal makers in India to provide energy during the firing of the kiln;

• Rice husks may be made to undergo either physical or chemical transformation to produce a higher energy product which may be burnt directly or they may be burnt indirectly;

• Rice husks have a bulky structure, dry in texture, and have low moisture content. These characteristics affect the fuel properties of rice husks. The common physical conversions of rice husks are densification, briquetting and gasification.

Densification may involve the process of increasing the material density so that a bigger mass may occupy the same volume as the original mass. Briquetting of the husks can be done using presses to form cubes of high density husks. Balling, pelleting, cubing, tabletting and roll compaction are also possible transformations.

Table 9 : Properties contained in Paddy husks [7]

PROPERTIES	MASS	DRY
CARBON (%)	34.61	38.43
HYDROGEN (%)	3.79	2.97
NITROGEN (%)	0.44	0.49
OXYGEN (%)	41.58	36.36
SULPHUR (%)	0.06	0.07
VOLATILE MATTER (%)	55.54	61.68
FIXED CARBON (%)	14.99	16.65
ASH (%)	19.52	21.68
HUMIDITY (%)	9.95	0.00
CALORIC VALUE (kJ/kg)	**13800**	**15324**

Table 10 : Paddy Emission Mitigation Potential [15]

CO_2 emission reduction potential	Ton/year	14762.30
CH_4 emission reduction potential	Ton/year	74.93
N_2O emission reduction potential	Ton/year	0.16
CHG emission reduction potential	Ton of CO_2 eq/year	16382.30
CO emission reduction potential	Ton/year	1441.57
NMVOC emission reduction potential	Ton/year	1.00
NO_X emission reduction potential	Ton/year	81.26
SO_X emission reduction potential	Ton/year	54.56

3.2.4 Conversion of Biomass to another form of Energy

1. <u>Direct combustion of biomass</u>

Combustion is the best-known and probably the most efficient form of converting solid biomass to steam or electricity.

2. <u>Biomass gasification</u>

Gasification is a process that uses heat, pressure, and steam to convert materials directly into a gas composed primarily of carbon monoxide and hydrogen. Gasification technologies differ in many aspects but rely on four key engineering factors:

- Gasification reactor atmosphere (level of oxygen or air content).
- Reactor design.
- Internal and external heating.
- Operating temperature.

Typical raw materials used in gasification are coal, petroleum-based materials, and organic materials. The feedstock is prepared and fed, in either dry or slurried form, into a sealed reactor chamber called a gasifier. The feedstock is subjected to high heat, pressure, and either an oxygen-rich or oxygen-starved environment within the gasifier. Most commercial gasification technologies do not use oxygen. All require an energy source to generate heat and begin processing.[8]

There are three primary products from gasification:

- Hydrocarbon gases (also called syngas).
- Hydrocarbon liquids (oils).
- Char (carbon black and ash).

Syngas is primarily carbon monoxide and hydrogen (more than 85 percent by volume) and smaller quantities of carbon dioxide and methane. Syngas can be used as a fuel to generate electricity or steam, or as a basic chemical building block for a multitude of uses. When mixed with air, syngas can be used in gasoline or diesel engines with few modifications to the engine.

3. Biomass pyrolysis.

In addition to gas, liquid fuels can be produced from biomass through a process called pyrolysis. Pyrolysis occurs when biomass is heated in the absence of oxygen. The biomass then turns into a liquid called pyrolysis oil, which can be burned like petroleum to generate electricity.

4. Biomass anaerobic digestion (biogas)

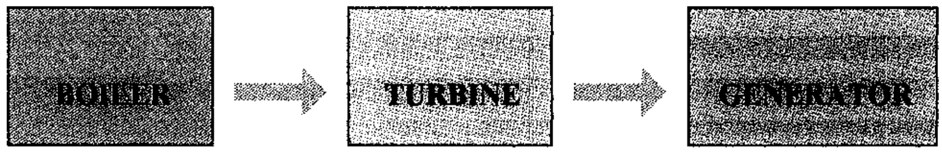
Anaerobic digestion is the bacterial breakdown of organic materials in the absence of oxygen. This biological process produces a gas, sometimes called biogas, principally composed of methane and carbon dioxide. This gas is produced from feedstocks such as sewage sludge, livestock manure, and wet organic materials.

The anaerobic digestion process occurs in three steps:

- Decomposition of plant or animal matter by bacteria into molecules such as sugar.
- Conversion of decomposed matter to organic acids.
- Organic acid conversion to methane gas.

Anaerobic processes can occur naturally or in a controlled environment such as a biogas plant. In controlled environments, organic materials such as sewage sludge and other relatively wet organic materials, along with various types of bacteria, are put in an airtight container called a digester where the process occurs. Depending on the waste feedstock and the system design, biogas is typically 55 to 75 percent pure methane.

3.2.5 Calculating the Output Load



$\eta_{BOILER} = 50\%$ $\eta_{TURBINE} = 45\%$ $\eta_{GENERATOR} = 76\%$

$\eta_{TOTAL} = 17.1\%$

$$\boxed{P_{OUT} / P_{IN} = \eta}$$

$$\boxed{P_{OUT} = \eta \times P_{IN}}$$

For power generation, we have to consider the efficiency of three elements of the plant which are the boiler, the steam turbine and the generator. Knowing the input energy;

- Rice husks =13800kJ/kg for mass and 15324kJ/kg for dry
- Grass = 4MJ/kg.

From the energy conversion table,

$$\boxed{1\ J = 1\ W/s}$$

$$\boxed{1\ kWh = 3{,}600\ kJ}$$

From the normal efficiencies of the three vital components/equipments of the plant, we can find the output power. From the author's research on the internet, normal efficiency for boiler = 50% - 88%, steam turbine = 45 - 98% and generator = 45 - 90%.

<u>Boiler Efficiencies</u>

If we look at table 7 below, the efficiency for automatically stoked boiler to get power up to 10kW is 76%.

Table 11 : Boiler Efficiency[2]

furnace	**boiler efficiency**
hand stoked	
up to 10 kW	73 %
>10 to 200 kW	(65.3 + 7.7 log Pn) %
>200 kW	83 %
automatically stoked	
up to 10 kW	76 %
>10 to 200 kW	(68.3 + 7.7 log Pn) %
>200 kW	86 %

From a page (shown below) which was taken from the internet [5], the normal total efficiency for fossil fuel to get electricity is about 33%.

> **Efficiency**
>
> Always remember that, in every energy conversion, some of it goes where you want it, and some goes elsewhere (usually heat). The ratio of what you want to the amount that you start with is called *efficiency*. Here are some typical efficiencies encountered in everyday processes:
>
> - burning fossil fuel to get useable heat - about 85% (running a gas-fired water heater, or making steam to power a turbine...some heat goes up the smokestack).
> - burning fossil fuel to get electricity - about 33%
> - sunlight to electricity in a PV cell - about 10%
> - putting electrical energy into a battery (charging it) and pulling it back out: about 90%
> - converting electrical energy into mechanical energy with an electric motor about 85%

Steam turbine Efficiencies

The combustion turbine drives an electric generator. Hot air from the combustion turbine is channeled back to the gasifier or the air separation unit, while exhaust heat from the combustion turbine is recovered and used to boil water, creating steam for a steam turbine-generator.

The use of these two types of turbines - a combustion turbine and a steam turbine - in combination, known as a "combined cycle," is one reason why gasification-based power systems can achieve unprecedented power generation efficiencies. Currently, gasification-based systems can operate at around 45% efficiencies; in the future, these systems may be able to achieve efficiencies approaching 60%. (A conventional coal-based boiler plant, by contrast, employs only a steam turbine-generator and is typically limited to 33-40% efficiencies.)

Higher efficiencies mean that less fuel is used to generate the rated power, resulting in better economics (which can mean lower costs to ratepayers) and the formation of fewer greenhouse gases (a 60%-efficient gasification power plant can cut the formation of carbon dioxide by 40% compared to a typical coal combustion plant).

From the information obtained, the efficiency from each equipment can be summaries as below.

$$\eta_{BOILER} = 50\%,\ \eta_{TURBINE} = 45\%,\ \eta_{GENERATOR} = 76\%$$

Table 12 : Energy Conversion for Rice Husks(mass), 13800kJ/kg=3.833 kWh

Energy	Time	Power	
13800000 Joules		3833 Watts	This is the average power in full sunlight falling on a 198.1 square foot surface, directed toward the sun, and collecting 5 hours each day.
3833 Watt Hours		3.833 Kilowatts	
3.833 Kilowatt Hours	1 Hours	5.141 Horsepower	
13090 BTU		13090 BTU/hr	
0.1309 Therms		1.091 tons	

$$P_{OUT} = \eta_{BOILER} \times \eta_{TURBINE} \times \eta_{GENERATOR} \times P_{IN}$$

$$P_{OUT} = 0.50 \times 0.45 \times 0.76 \times 3.833\text{kWh}$$

$$P_{OUT} = 0.6554\text{kWh}$$

Table 13 : Energy Conversion for Rice Husks(dry),15324kJ/kg = 4.257kWh

Energy	Time	Power	
15320000 Joules	1 Hours	4257 Watts	This is the average power in full sunlight falling on a 219.9 square foot surface, directed toward the sun, and collecting 5 hours each day.
4257 Watt Hours		4.257 Kilowatts	
4.257 Kilowatt Hours		5.708 Horsepower	
14530 BTU		14530 BTU/hr	
0.1453 Therms		1.211 tons	

$$P_{OUT} = \eta_{BOILER} \times \eta_{TURBINE} \times \eta_{GENERATOR} \times P_{IN}$$

$$P_{OUT} = 0.50 \times 0.45 \times 0.76 \times 4.257\text{kWh}$$

$$P_{OUT} = 0.7279 \text{ kWh}$$

Table 14 : Energy Conversion for Rice Straw, 8400kJ/kg=2.333 kWh

Energy	Time	Power	
8400000 Joules	1 Hours	2333 Watts	This is the average power in full sunlight falling on a 120.6 square foot surface, directed toward the sun, and collecting 5 hours each day.
2333 Watt Hours		2.333 Kilowatts	
2.333 Kilowatt Hours		3.129 Horsepower	
7967 BTU		7967 BTU/hr	
0.07967 Therms		0.6639 tons	

$$P_{OUT} = \eta_{BOILER} \times \eta_{TURBINE} \times \eta_{GENERATOR} \times P_{IN}$$

$$P_{OUT} = 0.50 \times 0.45 \times 0.76 \times 2.333\text{kWh}$$

$$P_{OUT} = 0.3989\text{kWh} \sim 0.4\text{kWh}$$

Table 15 : Energy Conversion for grass, 4000kJ/kg=1.111kWh

Energy	Time	Power	
4000000 Joules		1111 Watts	This is the average power in full sunlight falling on a 57.41 square foot surface, directed toward the sun, and collecting 5 hours each day.
1111 Watt Hours		1.111 Kilowatts	
1.111 Kilowatt Hours	1 Hours	1.49 Horsepower	
3794 BTU		3794 BTU/hr	
0.03794 Therms		0.3161 tons	

$$P_{OUT} = \eta_{BOILER} \times \eta_{TURBINE} \times \eta_{GENERATOR} \times P_{IN}$$

$$P_{OUT} = 0.50 \times 0.45 \times 0.76 \times 1.111\text{kWh}$$

$$P_{OUT} = 0.19\text{kWh}$$

From the research done, the total energy in biomass to be converted to electricity is in at the range of 33 -37% efficiency.

<u>For Rice Husks (mass), 13800kJ/kg = 3.833kWh</u>

$$P_{OUT} = \eta_{PLANT} \times P_{IN}$$

$$P_{OUT} = 0.33 \times 3.833\text{kWh}$$

$$P_{OUT} = \underline{1.264\text{ kWh}}$$

<u>For Rice Husks (dry), 15324kJ/kg = 4.257kWh</u>

$$P_{OUT} = \eta_{PLANT} \times P_{IN}$$

$$P_{OUT} = 0.33 \times 4.257\text{kWh}$$

$$P_{OUT} = \underline{1.405\text{ kWh}}$$

For Rice Straw, 8400kJ/kg = 2.333kWh

$$P_{OUT} = \eta_{PLANT} \times P_{IN}$$

$$P_{OUT} = 0.33 \times 2.333\text{kWh}$$

$$P_{OUT} = \underline{0.77 \text{ kWh}}$$

For grass, 4000kJ/kg = 1.111kWh

$$P_{OUT} = \eta_{PLANT} \times P_{IN}$$

$$P_{OUT} = 0.33 \times 1.111 \text{ kWh}$$

$$P_{OUT} = \underline{0.36663 \text{ kWh}}$$

3.2.6 Calculating the Feed/Fuel required for a Certain Load.

Case 1: Rice husks Requirement to get a load of 50kW.

From table 5, it is clear that energy content for 1kg of rice husks is 13800kJ. So, knowing the load required is 50kW for 1 hour and 1200kWh per day, the total efficiency is 17.1 %, the input load can be calculated where:

$$\boxed{P_{out}/P_{in} = \eta_{total}}$$

$$\boxed{P_{in} = P_{out}/\ \eta_{total}}$$

E_{in} = 1200kWh/0.171 = 7017.54kWh.

Knowing that 1kWh = 3600kJ,

So, the energy input, $E_{in}(3600)$ = 7017.54(3600) = 25263157.89kJ.

1kg of husks = 13800kJ

Mass = Ein/(13800kJ/kg) = 1830.66kg ~ 1.8 ton

Mass for an hour = 75 kg.

Malaysian Rice Straw and Rice husks production (2002/2003)(In Peninsular Only)

- Total planted/year = 647,750 acre (262,141ha)
- Total straw production = 1,425,050 ton
- Total rice production = 1011000 ton
- Total husks (20% of total rice)= 202000 ton

Calculation on the load that can be achieved if all annual paddy/rice husks are used

1 year = 202,000 ton

1 month = 16833.333 ton

1 day = 561.111 ton = 561111.111 kg

1 kg of rice husks = 138000 kJ.

So total energy = 7,743,333,318kJ

1kWh = 3600kJ

So, total input load, P_{in} = 2,150,925.922kWh

$$P_{out}/P_{in} = \eta_{total}$$

$$P_{out} = P_{in}\,\eta_{total}$$

$P_{out} = 0.171(P_{in})$

= 367,808.33 kWh

= 367.808MWh per day

= 15.3 MW

3.2.7 Plant Studies

The process of a steam power plant is presented in the literature review section. Below are the details on steam generator and followed with flue gas treatment processes. In this section, it discusses on the heating surfaces of pipes and the cleaning of the fumes or flue gas treatment.

Design of Steam Generator Heating Surfaces

The heating surfaces of a steam generator are divided into the radiation and convection surfaces. Thus, the evaporator and the radiation superheater make up the radiation part of steam generator. The heating surface of evaporator is arranged on the furnace walls. The radiation superheater is suspended in the upper part of furnace. The convection part consists of convection superheater, steam reheater, feed water preheater and air preheater. As a rule, these heating surfaces are installed in the second flue gas pass of the steam generator.

Typical construction of heating surfaces of the steam generator, i.e of evaporator, superheater, feedwater preheater (economizer) and air preheter are schematically shown in Figure 18 below.

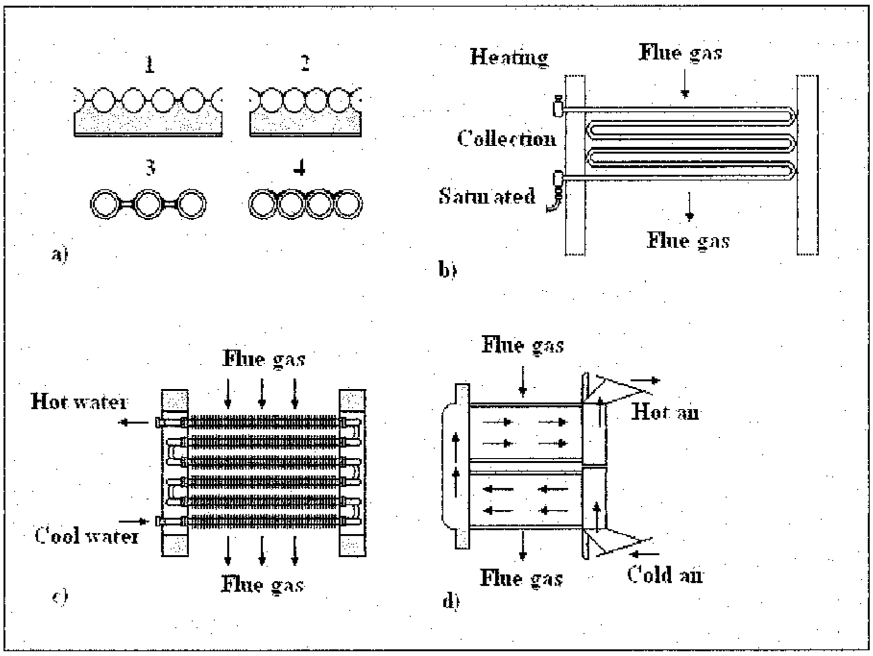


Figure 17 : Typical construction variants of heating surfaces.

Figure 17 shows:

- Evaporator constructions: 1. Membrane wall construction, 2. Tube wall, 3. Tubes with welded ribs, 4. Welded tubes;
- Superheater;
- Feedwater preheater
- Air preheater

Design of Particulate Solid Removal

1. Mass Force Dust Collectors

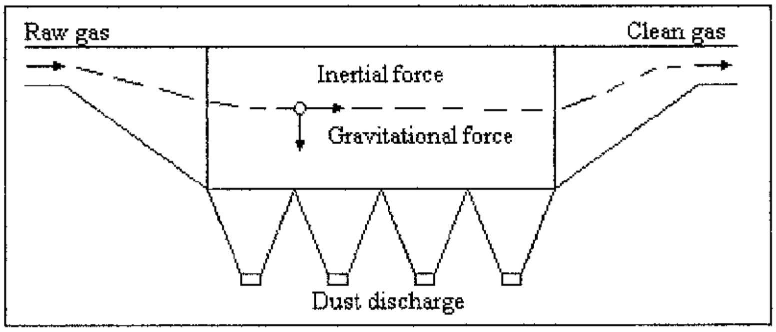


Figure 18 : Schematic diagram of a mass force dust collectors

Raw flue gas with solid particles will go in the mass force dust discharger by an inertial force. At the same time, gravitational force get into action which removes the flying ashes from the flue gas and particularly, will result with the output of cleaner gas.

2. Cyclones

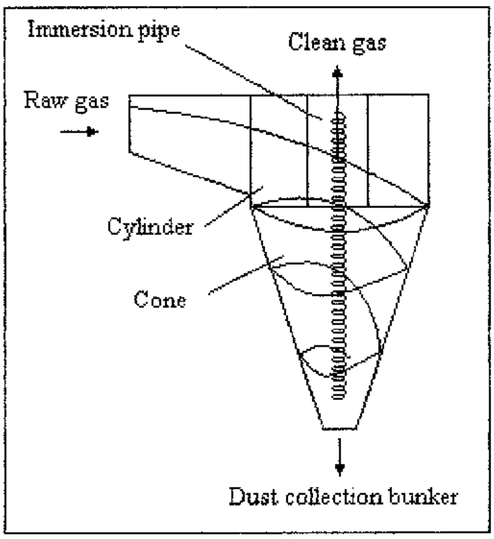


Figure 19 : Cyclone Schematic Diagram.

Centrifugal force collectors or cyclones operate on the basis of great difference in the densities of gas and solid particles and they are suitable for removal of coarse particles.

Below is an example of a raw flue gas treatment in an industry

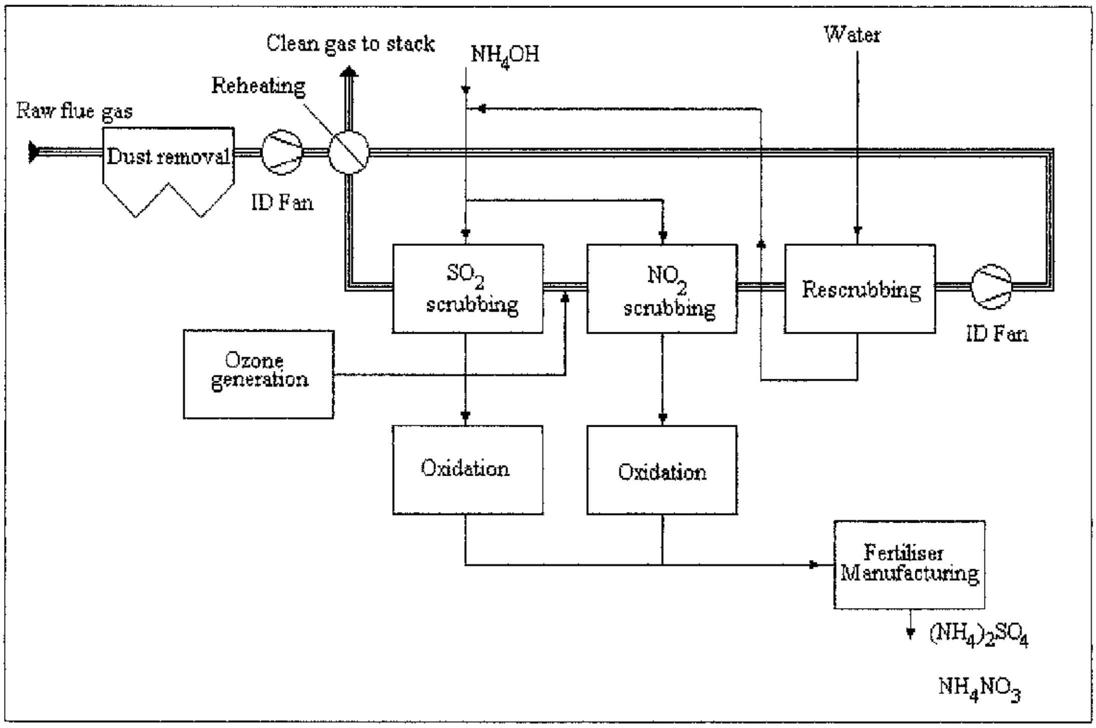


Figure 20 : Flow diagram of plant for simultaneous removal of sulphur and nitrogen oxides from flue gas

CHAPTER 4
RESULTS AND DISCUSSION

4.1 GRASS POTENTIAL AS ENERGY USAGE IN MALAYSIA

"It takes 70 days to grow a crop of grass for pellets, but it takes 70 million years to make fossil fuels."

Results from Grass Cutting

The mass of grass for $1m^2$ area = 210g
The mass of grass for 2 x 1 m^2 area = 415g

So, practically in 2 weeks after first cutting, the mass of fresh cut grass for $1m^2$ is 200g @ 0.2kg.
For 1kg of grass, the area of grass required is $5m^2$.

For a particular terrace housing area where each houses has a grass area of:

Front: 2 x $4m^2 = 8m^2$
Back area: 4 x $2m^2 = 8m^2$

Total area for one house: $16m^2$
Number of houses for one housing area: 300 units
Therefore total grass area: $300x16m^2 = 4800m^2$
Total weight of grass: 4800m2 x 0.2kg
= 960kg ~ 1 ton

For one housing area can produce 1 ton of residence grass. In a state in Malaysia, there are many housing areas not yet include road sides and fields which means the production of this kind of waste is quite large. Grass, when palletized, has considerable potential to displace oil, natural gas, and electricity used for heating fuel. This development can significantly reduce greenhouse gases and heating costs and sustainably assist the development of rural communities. A type of grass like switchgrass can be plant in hectares. Fast growing warm season perennial grasses have been identified as ideal candidates for biomass fuel production due to their high net energy yield per hectare and low cost of production.

From the results, further studies have to be made on the total weight of waste grass from a city or state. In Ipoh, Perak, alone there are about 9.66% plant wastes collected by Majlis Bandar Ipoh, MBI in the year 2004 with the mass equals to 16 million tones. The percentage is with respect to the total wastes collected by MBI which comprises off trade waste, market waste, domestic waste, industrial waste and plant waste itself.

4.2 CALCULATIONS ON ENERGY TO POWER CONVERSION

From calculation in section 3.2.5, the results for plant efficiency = 17.1% are like below:

Table 16 : the power output that can be obtained from a total efficiency of 17.1%

Fuel	Power output
Rice husks (mass)	0.6554kWh
Rice husks (dry)	0.7279kWh
Rice straw	0.4Wh
Grass	0.19kWh

The results for plant efficiency = 33% are like below:

Table 17 : the power output that can be obtained from a total efficiency of 33%

Fuel	Power output
Rice husks (mass)	1.264 kWh
Rice husks (dry)	1.405 kWh
Rice straw	0.77 kWh
Grass	0.36663 kWh

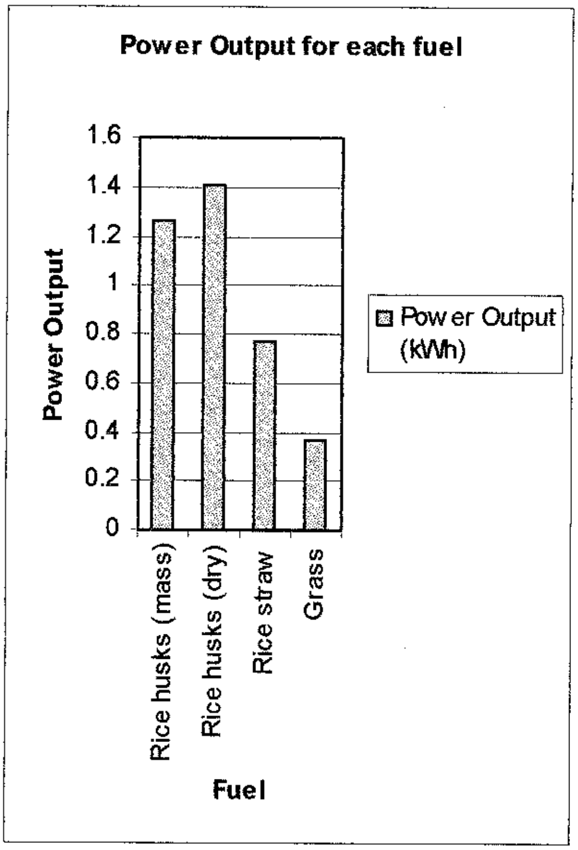


Figure 21 : power output that can be obtained from a total efficiency of 33%

From the results obtained, the efficiency of the plant can be estimated to be around 40% below. The output power which was calculated shows that the maximum power is 1.2kW. This is produced by a kilogram of mass rice husks. If 1 ton, the energy content will be 13800MJ and the power will be 3833kW. Using Power efficiency to be 33%, the output power is 1264.89kW or 1.265MW.

Table 18 :Calculation on the output load to compare it with oven dried wood and charcoal.(with 33% efficiency)

Fuel	Energy		Input load	Output load
	GJ /ton	kJ/kg	kW	kW
Wood (green, 60% moisture)	6.00	6000	1.667	0.55
Wood (air dried, 20% moisture)	15.00	15000	4.167	1.375
Wood (oven-dried, 0% moisture)	18.00	18000	5.000	1.65
Charcoal	30.00	30000	8.333	2.75
Grass (fresh-cut)	4.00	4000	1.111	0.36663

4.3 RESULTS FOR TOTAL MASS REQUIRED TO GENERATE POWER

WASTE FROM BIOMASS(Rice Husks)
Fuel heating energy: 13800kJ/kg

Small Scale (500 - 5kW)

Load		Input load		Mass			
(kW)	(p/day)kWh	(kWh)	(kJ)	(kg/day)	(kg/hr)	(ton/day)	(ton/hr)
0.5	12	70.1754386	252631.6789	18.30663616	0.762776506	0.018306636	0.000762777
0.75	18	105.2631579	378947.3684	27.45995423	1.14416476	0.027459954	0.001144165
1	24	140.3508772	505263.1579	36.61327231	1.525553013	0.036613272	0.001525553
5	120	701.754386	2526315.789	183.0663616	7.627765065	0.183066362	0.007627765

Medium Scale (5kW - 75kW)

Load		Input load		Mass			
(kW)	(p/day)kWh	(kWh)	(kJ)	(kg/day)	(kg/hr)	(ton/day)	(ton/hr)
5	120	701.754386	2526315.789	183.0663616	7.627765065	0.183066362	0.007627765
10	240	1403.508772	5052631.579	366.1327231	15.25553013	0.366132723	0.01525553
50	1200	7017.54386	25263157.89	1830.663616	76.27765065	1.830663616	0.076277651
75	1800	10526.31579	37894736.84	2745.995423	114.416476	2.745995423	0.114416476

Large Scale (75kW - 4MW)

Load		Input load		Mass			
(kW)	(p/day)kWh	(kWh)	(kJ)	(kg/day)	(kg/hr)	(ton/day)	(ton/hr)
75	1800	5847.953216	21052631.58	1525.553013	63.56470887	1.525553013	0.063564709
100	2400	7797.270956	28070175.44	2034.070684	84.75294516	2.034070684	0.084752945
500	12000	38986.35478	140350877.2	10170.35342	423.7647258	10.17035342	0.423764726
1000	24000	77972.70955	280701754.4	20340.70684	847.5294516	20.34070684	0.847529452
4000	96000	311890.8382	1122807018	81362.82736	3390.117807	81.36282736	3.390117807

Total mass of rice husks required for required load

WASTE FROM BIOMASS(Rice Straw)
Fuel heating energy: 8400kJ/kg

Small Scale (500 - 5kW)

Load		Input load		Mass			
(kW)	(p/day)kWh	(kWh)	(kJ)	(kg/day)	(kg/hr)	(ton/day)	(ton/hr)
0.5	12	70.1754386	252631.5789	30.07518797	1.253132832	0.030075188	0.001253133
0.75	18	105.2631579	378947.3684	45.11278195	1.879699248	0.045112782	0.001879699
1	24	140.3508772	505263.1579	60.15037594	2.506265664	0.060150376	0.002506266
5	120	701.754386	2526315.789	300.7518797	12.53132832	0.30075188	0.012531328

Medium Scale (5kW - 75kW)

Load		Input load		Mass			
(kW)	(p/day)kWh	(kWh)	(kJ)	(kg/day)	(kg/hr)	(ton/day)	(ton/hr)
5	120	701.754386	2526315.789	300.7518797	12.53132832	0.30075188	0.012531328
10	240	1403.508772	5052631.579	601.5037594	25.06265664	0.601503759	0.025062657
50	1200	7017.54386	25263157.89	3007.518797	125.3132832	3.007518797	0.125313283
75	1800	10526.31579	37894736.84	4511.278195	187.9699248	4.511278195	0.187969925

Large Scale (75kW - 4MW)

Load		Input load		Mass			
(kW)	(p/day)kWh	(kWh)	(kJ)	(kg/day)	(kg/hr)	(ton/day)	(ton/hr)
75	1800	10526.31579	37894736.84	4511.278195	187.9699248	4.511278195	0.187969925
100	2400	14035.08772	50526315.79	6015.037594	250.6265664	6.015037594	0.250626566
500	12000	70175.4386	252631578.9	30075.18797	1253.132832	30.07518797	1.253132832
1000	24000	140350.8772	505263157.9	60150.37594	2506.265664	60.15037594	2.506265664
4000	96000	561403.5088	2021052632	240601.5038	10025.06266	240.6015038	10.02506266

Total mass of rice straw required for required load

WASTE FROM BIOMASS(Grass) Fuel heating energy: 4000kJ/kg							
Small Scale (500 - 5kW)							
Load		Input load		Mass			
(kW)	(p/day)kWh	(kWh)	(kJ)	(kg/day)	(kg/hr)	(ton/day)	(ton/hr)
0.5	12	70.1754386	252631.5789	63.15789474	2.631578947	0.063157895	0.002631579
0.75	18	105.2631579	378947.3684	94.73684211	3.947368421	0.094736842	0.003947368
1	24	140.3508772	505263.1579	126.3157895	5.263157895	0.126315789	0.005263158
5	120	701.754386	2526315.789	631.5789474	26.31578947	0.631578947	0.026315789
Medium Scale (5kW - 75kW)							
Load		Input load		Mass			
(kW)	(p/day)kWh	(kWh)	(kJ)	(kg/day)	(kg/hr)	(ton/day)	(ton/hr)
5	120	701.754386	2526315.789	631.5789474	26.31578947	0.631578947	0.026315789
10	240	1403.508772	5052631.579	1263.157895	52.63157895	1.263157895	0.052631579
50	1200	7017.54386	25263157.89	6315.789474	263.1578947	6.315789474	0.263157895
75	1800	10526.31579	37894736.84	9473.684211	394.7368421	9.473684211	0.394736842
Large Scale (75kW - 4MW)							
Load		Input load		Mass			
(kW)	(p/day)kWh	(kWh)	(kJ)	(kg/day)	(kg/hr)	(ton/day)	(ton/hr)
75	1800	10526.31579	37894736.84	9473.684211	394.7368421	9.473684211	0.394736842
100	2400	14035.08772	50526315.79	12631.57895	526.3157895	12.63157895	0.526315789
500	12000	70175.4386	252631578.9	63157.89474	2631.578947	63.15789474	2.631578947
1000	24000	140350.8772	505263157.9	126315.7895	5263.157895	126.3157895	5.263157895
4000	96000	561403.5088	2021052632	505263.1579	21052.63158	505.2631579	21.05263158

Total mass of grass required for required load

WASTE FROM BIOMASS(Oven-dried Wood) Fuel heating energy: 18000kJ/kg							
Small Scale (500 - 5kW)							
Load		Input load		Mass			
(kW)	(p/day)kWh	(kWh)	(kJ)	(kg/day)	(kg/hr)	(ton/day)	(ton/hr)
0.5	12	70.1754386	252631.5789	14.03508772	0.584795322	0.014035088	0.000584795
0.75	18	105.2631579	378947.3684	21.05263158	0.877192982	0.021052632	0.000877193
1	24	140.3508772	505263.1579	28.07017544	1.169590643	0.028070175	0.001169591
5	120	701.754386	2526315.789	140.3508772	5.847953216	0.140350877	0.005847953
Medium Scale (5kW - 75kW)							
Load		Input load		Mass			
(kW)	(p/day)kWh	(kWh)	(kJ)	(kg/day)	(kg/hr)	(ton/day)	(ton/hr)
5	120	701.754386	2526315.789	140.3508772	5.847953216	0.140350877	0.005847953
10	240	1403.508772	5052631.579	280.7017544	11.69590643	0.280701754	0.011695906
50	1200	7017.54386	25263157.89	1403.508772	58.47953216	1.403508772	0.058479532
75	1800	10526.31579	37894736.84	2105.263158	87.71929825	2.105263158	0.087719298
Large Scale (75kW - 4MW)							
Load		Input load		Mass			
(kW)	(p/day)kWh	(kWh)	(kJ)	(kg/day)	(kg/hr)	(ton/day)	(ton/hr)
75	1800	10526.31579	37894736.84	2105.263158	87.71929825	2.105263158	0.087719298
100	2400	14035.08772	50526315.79	2807.017544	116.9590643	2.807017544	0.116959064
500	12000	70175.4386	252631578.9	14035.08772	584.7953216	14.03508772	0.584795322
1000	24000	140350.8772	505263157.9	28070.17544	1169.590643	28.07017544	1.169590643
4000	96000	561403.5088	2021052632	112280.7018	4678.362573	112.2807018	4.678362573

Total mass of oven-dried wood required for required load

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Biomass is an important energy source. Its main application is not only in the traditional domestic sector and small scale industries but also in modern systems for cogeneration and power generation. Even though oil palm residues have huge potential in power generation but rice husks and its straws also have the potential. Palm oil has more potential in gasification process which produces better fuel. A new plant has to be build for this purpose. Unlike rice husks, they can replace or used in co-firing in a coal power plant.

Co-firing biomass with coal offers several environmental benefits. One of the benefits includes reducing the emission of CO2. The emission of CO2 for the combustion of biomass is equivalent to the amount of CO2 absorbed during its growing cycle. Therefore, the net CO2 released is approximately zero and by mass, this will show a reduction of CO2 emissions when biomass is co-fired with coal (Lacrosse and Mathias, 2004).

Besides that, co-firing also possesses an effect to reduce the amount of NOx released. According to Planet Power (2004), the NO_X level will be reduced because of lower flame temperatures as a result of combustion with high moisture content biomass. However, the emissions are highly dependant on the boiler operating conditions and design. In addition, renewable energy or biomass which was used results in reducing landfill material and alleviating the burden of waste disposal.

Rice husks and other agriculture residues have a lot of potential in Malaysia. The amount of husks produced in Malaysia is more that required and it is wasteful if not being used. With the abundance of rice husks in Malaysia and burden by farmers to dispose them, rice husks may eventually become a valuable asset for the country.

From the calculations being made, the power generation capacity for rice husks is 15.3MW which is big enough that can cover electricity demand 15 years growth.

5.2 RECOMMENDATIONS

This case study focused more on the feasibility of rice husks, rice straw, and grass. The calculation is to each component. Further studies have to be made on the feasibility of combining all components so that maximum energy from waste is used. There are possibilities that the power generated will be much higher.

The proposals for further studies for this dissertation include:

1. To study more in detail of the process of energy conversion in power plants. More details needed to be study which includes the flame temperature, the piping arrangements and the calculation on the efficiencies of the boiler, steam turbine and the generator.
2. To develop or design a biomass power plant which uses rice husks as fuel.
3. To study the feasibility of co-firing of rice husks for electrical generation in Malaysia.

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APPENDICES

APPENDIX A

SOURCES AND TYPES OF WASTE

Source	Typical waste generators	Types of solid wastes
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes.).
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants.	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes.
Commercial	Stores, hotels, restaurants, markets, office buildings, etc.	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes.
Institutional	Schools, hospitals, prisons, government centers.	Same as commercial.
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, etc.
Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants.	Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas; sludge.
Process (manufacturing, etc.)	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing.	Industrial process wastes, scrap materials, off-specification products, slay, tailings.
Agriculture	Crops, orchards, vineyards, dairies, feedlots, farms.	Spoiled food wastes, agricultural wastes, hazardous wastes (e.g., pesticides).

APPENDIX B
ENERGY DEFINITIONS

One considering issues regarding energy, definitions of terminology are often a must.

Energy Definitions

- **Alcohol Fuels**: Alcohol can be blended with gasoline for use as transportation fuel. It may be produced from a wide variety of organic feedstock. The common alcohol fuels are methanol and ethanol. Methanol may be produced from coal, natural gas, wood and organic waste. Ethanol is commonly made from agricultural plants, primarily corn, containing sugar.

- **Alternating Current** (AC): An electric current that reverses its direction at regularly recurring intervals, usually 50 or 60 times per second.

- **Amorphous Silicon**: An alloy of silica and hydrogen, with a disordered, noncrystalline internal atomic arrangement, that can be deposited in thin-layers (a few micrometers in thickness) by a number of deposition methods to produce thin-film photovoltaic cells on glass, metal, or plastic substrates.

- **Availability Factor**: A percentage representing the number of hours a generating unit is available to produce power (regardless of the amount of power) in a given period, compared to the number of hours in the period.

- **Biomass**: Organic nonfossil material of biological origin constituting a renewable energy source.

- **Bioenergy**: Useful, renewable energy produced from organic matter, which may either be used directly as a fuel or processed into liquids and gases.

- **Biofuels:** Liquid fuels and blending components produced from biomass (plant) feedstocks, used primarily for transportation.

- **Biomass gas** (Biogas): A medium Btu gas containing methane and carbon dioxide, resulting from the action of microorganisms on organic materials such as a landfill.
- **Black Liquor** (Pulping Liquor): The alkaline spent liquor removed from the digesters in the process of chemically pulping wood. After evaporation, the liquor is burned as a fuel in a recovery furnace that permits the recovery of certain basic chemicals.

- **Capacity Factor**: The ratio of the electrical energy produced by a generating unit for the period of time considered to the electrical energy that could have been produced at continuous full-power operation during the same period.

- **Capacity, Gross**: The full-load continuous rating of a generator, prime mover, or other electric equipment under specified conditions as designated by the manufacturer. It is usually indicated on a nameplate attached to the equipment.

- **Capital Cost**: The cost of field development and plant construction and the equipment required for the generation of electricity.

- **Cast Silicon**: Crystalline silicon obtained by pouring pure molten silicon into a vertical mold and adjusting the temperature gradient along the mold volume during cooling to obtain slow, vertically-advancing crystallization of the silicon. The polycrystalline ingot thus formed is composed of large, relatively parallel, interlocking crystals. The cast ingots are sawed into wafers for further fabrication into photovoltaic cells. Cast-silicon wafers and ribbon-silicon sheets fabricated into cells are usually referred to as polycrystalline photovoltaic cells.

- **Cogeneration**: see combined heat and power.

- **Combined Cycle**: An electric generating technology in which electricity is produced from otherwise lost waste heat exiting from one or more gas (combustion) turbines. The exiting heat is routed to a conventional boiler or to a heat recovery steam generator for utilization by a steam turbine in the production of electricity. Such designs increase the efficiency of the electric generating unit.

- **Combined Heat and Power** (CHP) Plant: A plant designed to produce both heat and electricity from a single heat source. Note: This term is being used in place of the term "cogenerator" that was used by EIA in the past. CHP better describes the facilities because some of the plants included do not produce heat and power in a sequential fashion and, as a result, do not meet the legal definition of cogeneration specified in the Public Utility Regulatory Policies Act (PURPA).
- **Commercial Sector**: An energy-consuming sector that consists of service-providing facilities and equipment of: businesses; Federal, State, and local governments; and other private and public organizations, such as religious, social, or fraternal groups. The commercial sector includes institutional living quarters. It also includes sewage treatment facilities. Common uses of energy associated with this sector include space heating, water heating, air conditioning, lighting, refrigeration, cooking, and running a wide variety of other equipment. Note: This sector includes generators that produce electricity and/or useful thermal output primarily to support the activities of the above-mentioned commercial establishments.

- **Concentrator**: A reflective or refractive device that focuses incident insolation onto an area smaller than the reflective or refractive surface, resulting in increased insolation at the point of focus.

- **Conventional hydroelectric (hydropower) plant**: A plant in which all of the power is produced from natural streamflow as regulated by available storage.

- **Digester Gas**: Biogass that is produced using a digester which is an airtight vessel or enclosure in which bacteria decomposes biomass in water to produce biogas.

- **Direct Current** (DC): An electric current that flows in a constant direction. The magnitude of the current does not vary or has a slight variation.

- **Distributed Generation** (Distributed Energy Resources): Refers to electricity provided by small, modular power generators (typically ranging in capacity from a few kilowatts to 50 megawatts) located at or near customer demand.

- **Electric power sector**: An energy-consuming sector that consists of electricity only and combined heat and power(CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public--i.e., North American Industry Classification System 22 plants.

- **Electric Utility**: A corporation, person, agency, authority, or other legal entity or instrumentality aligned with distribution facilities for delivery of electric energy for use primarily by the public. Included are investor-owned electric utilities, municipal and State utilities, Federal electric utilities, and rural electric cooperatives. A few entities that are tariff based and corporately aligned with companies that own distribution facilities are also included.
- **Electric Utility Restructuring**: The introduction of competition into at least the generation phase of electricity production, with a corresponding decrease in regulatory control.

- **Emissions**: Anthropogenic releases of gases to the atmosphere. In the context of global climate change, they consist of radiatively important greenhouse gases (e.g., the release of carbon dioxide during fuel combustion).

- **Energy Crops**: Crops grown specifically for their fuel value. These include food crops such as corn and sugarcane, and nonfood crops such as poplar trees and switchgrass. Currently, two energy crops are under development: short -

rotation woody crops, which are fast - growing hardwood trees harvested in five to eight years, and herbaceous energy crops, such as perennial grasses, which are harvested annually after taking two to three years to reach full productivity.

- **Ethanol** (also known as Ethyl Alcohol or Grain Alcohol, CH_3-CH_2OH): A clear, colorless flammable oxygenated hydrocarbon with a boiling point of 173.5 degrees Fahrenheit in the anhydrous state. However it readily forms a binary azetrope with water, with a boiling point of 172.67 degrees Fahrenheit at a composition of 95.57 percent by weight ethanol. It is used in the United States as a gasoline octane enhancer and oxygenate (maximum 10 percent concentration). Ethanol can be used in higher concentrations (E85) in vehicles designed for its use. Ethanol is typically produced chemically from ethylene, or biologically from fermentation of various sugars from carbohydrates found in agricultural crops and cellulosic residues from crops or wood. The lower heating value, equal to 76,000 Btu per gallon, is assumed for estimates in this report.

- **Evacuated Tube**: In a solar thermal collector, an absorber tube, which is contained in an evacuated glass cylinder, through which collector fluids flows.

- **Flat Plate Pumped**: A medium-temperature solar thermal collector that typically consists of a metal frame, glazing, absorbers (usually metal), and insulation and that uses a pump liquid as the heat-transfer medium: predominant use is in water heating applications.

- **Fuel Cells**: One or more cells capable of generating an electrical current by converting the chemical energy of a fuel directly into electrical energy. Fuel cells differ from conventional electrical cells in that the active materials such as fuel and oxygen are not contained within the cell but are supplied from outside.
- **Fuelwood**: Wood and wood products, possibly including coppices, scrubs, branches, etc., bought or gathered, and used by direct combustion.

- **Generation** (Electricity): The process of producing electric energy from other forms of energy; also, the amount of electric energy produced, expressed in watthours (Wh).

- **Gross Generation**: The total amount of electric energy produced by the generating units at a generating station or stations, measured at the generator terminals.

- **Net Generation**: Gross generation less the electric energy consumed at the generating station for station's use.

- **Geothermal Energy**: As used at electric power plants, hot water or steam extracted from geothermal reservoirs in the Earth's crust that is supplied to steam turbines at electric power plants that drive generators to produce electricity.

- **Geothermal Plant**: A plant in which a turbine is driven either from hot water or by natural steam that derives its energy from heat found in rocks or fluids at various depths beneath the surface of the earth. The fluids are extracted by drilling and/or pumping.

- **Giga**: One billion.

- **Green Pricing/Marketing**: In the case of renewable electricity, green pricing represents a market solution to the various problems associated with regulatory valuation of the nonmarket benefits of renewables. Green pricing programs allow electricity customers to express their willingness to pay for renewable energy development through direct payments on their monthly utility bills.

- **Grid**: The layout of an electrical distribution system.

- **Hardwoods**: Usually broad-leaved and deciduous trees.

- **Heat Pump**: A year-round heating and air-conditioning system employing a refrigeration cycle. In a refrigeration cycle, a refrigerant is compressed (as a liquid) and expanded (as a vapor) to absorb and reject heat. The heat pump transfers heat to a space to be heated during the winter period and by reversing the operation extracts (absorbs) heat from the same space to be cooled during the summer period. The refrigerant within the heat pump in the heating mode absorbs the heat to be supplied to the space to be heated from an outside medium (air, ground or ground water) and in the cooling mode absorbs heat from the space to be cooled to be rejected to the outside medium.

- **Heat Pump (Air Source):** An air-source heat pump is the most common type of heat pump. The heat pump absorbs heat from the outside air and transfers the heat to the space to be heated in the heating mode. In the cooling mode the heat pump absorbs heat from the space to be cooled and rejects the heat to the outside air. In the heating mode when the outside air approaches 32o F or less, air-source heat pumps loose efficiency and generally require a back-up (resistance) heating system.

- **Heat Pump (Geothermal):** A heat pump in which the refrigerant exchanges heat (in a heat exchanger) with a fluid circulating through an earth connection medium (ground or ground water). The fluid is contained in a variety of loop (pipe) configurations depending on the temperature of the ground and the ground area available. Loops may be installed horizontally or vertically in the ground or submersed in a body of water.

- **Heat Pump (efficiency):** The efficiency of a heat pump, that is, the electrical energy to operate it, is directly related to temperatures between which it operates. Geothermal heat pumps are more efficient than conventional heat pumps or air conditioners that use the outdoor air since the ground or ground water a few feet below the earth's surface remains relatively constant throughout the year. It is more efficient in the winter to draw heat from the relatively warm ground than from the atmosphere where the air temperature is much colder, and in summer transfer waste heat to the relatively cool ground than to hotter air. Geothermal heat pumps are generally more expensive ($2,000 $5,000) to install than outside air heat pumps. However, depending on the location geothermal heat pumps can reduce energy consumption (operating cost) and correspondingly, emissions by more than 20 percent compared to high efficiency outside air heat pumps. Geothermal heat pumps also use the waste heat from air-conditioning to provide free hot water heating in the summer.

- **High-Temperature Collector**: A solar thermal collector designed to operate at a temperature of 180 degrees Fahrenheit or higher.

- **Incentives**: Subsidies and other Government actions where the Governments's financial assistance is indirect.

- **Independent Power Producer** (IPP): A corporation, person, agency, authority, or other legal entity or instrumentality that owns or operates facilities for the generation of electricity for use primarily by the public, and that is not an electric utility.

- **Internal Collector Storage** (ICS): A solar thermal collector in which incident solar radiation is absorbed by the storage medium.

- **Industrial Sector**: An energy-consuming sector that consists of all facilities and equipment used for producing, processing, or assembling goods. The industrial sector encompasses the following types of activity: manufacturing (NAICS codes 31-33); agriculture, forestry, and fisheries (NAICS code 11); mining, including oil and gas extraction (NAICS code 21); natural gas transmission (NAICS code 2212); and construction (NAICS code 23). Overall energy use in this sector is largely for process heat and cooling and powering machinery, with lesser amounts used for facility heating, air conditioning, and lighting. Fossil fuels are also used as raw material inputs to manufactured products. Note: This sector includes generators that produce electricity and/or useful thermal output primarily to support the above-mentioned industrial activities.

- **Kilowatt** (kW): One thousand watts of electricity (See Watt).

- **Kilowatthour** (kWh): One thousand watthours.

- **Landfill Gas**: Gas that is generated by decomposition of organic material at landfill disposal sites. Landfill gas is approximately 50 percent methane.

- **Levelized Cost**: The present value of the total cost of building and operating a generating plant over its economic life, converted to equal annual payments. Costs are levelized in real dollars (i.e., adjusted to remove the impact of inflation).

- **Liquid Collector**: A medium-temperature solar thermal collector, employed predominantly in water heating, which uses pumped liquid as the heat-transfer medium.

- **Low-Temperature Collectors**: Metallic or nonmetallic solar thermal collectors that generally operate at temperatures below 110 degrees Fahrenheit and use pumped liquid or air as the heat transfer medium. They usually contain no glazing and no insulation, and they are often made of plastic or rubber, although some are made of metal.
- **Marginal Cost**: The change in cost associated with a unit change in quantity supplied or produced.

- **Medium-Temperature Collectors**: Solar thermal col-lectors designed to operate in the temperature range of 140 degrees to 180 degrees Fahrenheit, but that can also operate at a temperature as low as 110 degrees Fahrenheit. The collector typically consists of a metal frame, metal absorption panels with integral flow channels (attached tubing for liquid collectors or integral ducting for air collectors), and glazing and insulation on the sides and back.

- **Megawatt** (MW): One million watts of electricity (See Watt).

- **Methane**: A colorless, flammable, odorless hydrocarbon gas (CH4) which is the major component of natural gas. It is also an important source of hydrogen in various industrial processes. Methane is a greenhouse gas.

- **MTBE**: Methyl Tertiary Butyl Ether is a fuel oxygenate produced by reacting methanol with isobutylene.

- **MSW (Municipal Solid Waste):** Residential solid waste and some nonhazardous commercial, institutional, and industrial wastes.

- **Net Metering**: Arrangement that permits a facility (using a meter that reads inflows and outflows of electricity) to sell any excess power it generates over its load requirement back to the electrical grid to offset consumption.

- **Net Photovoltaic Cell Shipment:** The difference between photovoltaic cell shipments and photovoltaic cell purchases.

- **Net Photovoltaic Module Shipment:** The difference between photovoltaic module shipments and photovoltaic module purchases.

- **Net summer capacity:** The maximum output, commonly expressed in megawatts (MW), that generating equipment can supply to system load, as demonstrated by a multi-hour test, at the time of summer peak demand (period of May 1 through October 31). This output reflects a reduction in capacity due to electricity use for station service or auxiliaries.

- **Nonutility Generation:** Electric generation by nonutility power producers to supply electric power for industrial, commercial, and military operations, or sales to electric utilities. See Nonutility Power Producer.

- **Nonutility Power Producer**: A corporation, person, agency, authority, or other legal entity or instrumentality that owns electric generating capacity and is not an electric utility. Nonutility power producers include qualifying cogenerators, qualifying small power producers, and other nonutility generators (including independent power producers) without a designated, franchised service area that do not file forms listed in the Code of Federal Regulations, Title 18, Part 141.

- **Operation and Maintenance (O&M) Cost**: Operating expenses are associated with operating a facility (i.e., supervising and engineering expenses). Maintenance expenses are that portion of expenses consisting of labor, materials, and other direct and indirect expenses incurred for preserving the operating efficiency or physical condition of utility plants that are used for power production, transmission, and distribution of energy.

- **Other Biomass**: This category of biomass energy includes: agricultural byproducts/crops (agricultural byproducts, straw); other biomass gas (digester gas, methane); other biomass liquids (fish oil, liquid acetonitrite, waste, tall oil, waste alcohol); other biomass solids (medical waste, solid byproducts; sludge waste and tires.

- **Paper Pellets**: paper compressed and bound into uniform diameter pellets to be burned in a heating stove.

- **Parabolic Dish**: A high-temperature (above 180 degrees Fahrenheit) solar thermal concentrator, generally bowl-shaped, with two-axis tracking.

- **Parabolic Trough**: A high-temperature (above 180 degrees Fahrenheit) solar thermal concentrator with the capacity for tracking the sun using one axis of rotation.

- **Passive Solar**: A system in which solar energy alone is used for the transfer of thermal energy. Pumps, blowers, or other heat transfer devices that use energy other than solar are not used.

- **Peak Watt**: A manufacturer's unit indicating the amount of power a photovoltaic cell or module will produce at standard test conditions (normally 1,000 watts per square meter and 25 degrees Celsius).

- **Peat**: Peat consists of partially decomposed plant debris. It is considered an early stage in the development of coal. Peat is distinguished from lignite by the presence of free cellulose and a high moisture content (exceeding 70 percent). The heat content of air-dried peat (about 50 percent moisture) is about 9 million Btu per ton. Most U.S. peat is used as a soil conditioner. The first U.S. electric power plant fueled by peat began operation in Maine in 1990.

- **Photovoltaic (PV) Cell**: An electronic device consisting of layers of semiconductor materials fabricated to form a junction (adjacent layers of materials with different electronic characteristics) and electrical contacts and being capable of converting incident light directly into electricity (direct current).

- **Photovoltaic (PV) Module:** An integrated assembly of interconnected photovoltaic cells designed to deliver a selected level of working voltage and current at its output terminals, packaged for protection against environment degradation, and suited for incorporation in photovoltaic power systems.

- **Process Heating**: The direct process end use in which energy is used to raise the temperature of substances involved in the manufacturing process.

- **Production Tax Credit (PTC):** an inflation - adjusted 1.5 cents per kilowatthour payment for electricity produced using qualifying renewable energy sources.

- **Public Utility Regulatory Policies Act of 1978 (PURPA):** One part of the National Energy Act, PURPA contains measures designed to encourage the conservation of energy, more efficient use of resources, and equitable rates. Principal among these were suggested retail rate reforms and new incentives for production of electricity by cogenerators and users of renewable resources.

- **Pumped-storage hydroelectric plant**: A plant that usually generates electric energy during peak load periods by using water previously pumped into an elevated storage reservoir during off-peak periods when excess generating capacity is available to do so. When additional generating capacity is needed, the water can be released from the reservoir through a conduit to turbine generators located in a power plant at a lower level.

- **Quadrillion Btu**: Equivalent to 10 to the 15th power Btu.
- **Qualifying Facility (QF):** A cogeneration or small power production facility that meets certain ownership, operating, and efficiency criteria established by the Federal Energy Regulatory Commission (FERC) pursuant to the Public Utility Regulatory Policies Act of 1978 (PURPA). (See the Code of Federal Regulations, Title 18, Part 292.)

- **Renewable Energy Resources:** Energy resources that are naturally replenishing but flow-limited. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Renewable energy resources include: biomass, hydro, geothermal, solar, wind, ocean thermal, wave action, and tidal action.

- **Renewable Portfolio Standard** (RPS): a mandate requiring that renewable energy provide a certain percentage of total energy generation or consumption.

- **Residential Sector:** An energy-consuming sector that consists of living quarters for private households. Common uses of energy associated with this sector include space heating, water heating, air conditioning, lighting, refrigeration, cooking, and running a variety of other appliances. The residential sector excludes institutional living quarters.

- **Ribbon Silicon:** Single-crystal silicon derived by means of fabricating processes that produce sheets or ribbons of single-crystal silicon. These processes include edge-defined film-fed growth, dendritic web growth, and ribbon-to-ribbon growth.

- **Roundwood:** Wood cut specifically for use as a fuel.

- **Silicon:** A semiconductor material made from silica, purified for photovoltaic applications.

- **Single Crystal Silicon** (Czochralski): An extremely pure form of crystalline silicon produced by the Czochralski method of dipping a single crystal seed into a pool of molten silicon under high vacuum conditions and slowly withdrawing a solidifying single crystal boule rod of silicon. The boule is sawed into thin wafers and fabricated into single-crystal photovoltaic cells.

- **Sludge**: A dense, slushy, liquid-to-semifluid product that accumulates as an end result of an industrial or technological process designed to purify a substance. Industrial sludges are produced from the processing of energy-related raw materials, chemical products, water, mined ores, sewerage, and other natural and man-made products. Sludges can also form from natural processes, such as the run off produced by rain fall, and accumulate on the bottom of bogs, streams, lakes, and tidelands.

- **Solar Energy:** The radiant energy of the sun, which can be converted into other forms of energy, such as heat or electricity.

- **Solar Thermal Collector:** A device designed to receive solar radiation and convert it into thermal energy. Normally, a solar thermal collector includes a frame, glazing, and an absorber, together with the appropriate insulation. The heat collected by the solar thermal collector may be used immediately or stored for later use.

- **Solar Thermal Collector, Special:** An evacuated tube collector or a concentrating (focusing) collector. Special collectors operate in the temperature (low concentration for pool heating) to several hundred degrees Fahrenheit (high concentration for air conditioning and specialized industrial processes).

- **Spent liquor:** The liquid residue left after an industrial process; can be a component of waste materials used as fuel.

- **Spent Sulfite Liquor**: end product of pulp and paper manufacturing processes that contains lignins and has a high moisture content; often re-used in recovery boilers. Similar to black liquor.

- **Subsidy:** Financial assistance granted by the Government to firms and individuals.

- **System Benefits Charge (SBC):** A non-bypassable fee on transmission interconnection; funds are allocated among public purposes, including the development and demonstration of renewable energy technologies.

- **Tall oil**: The oily mixture of rosin acids, fatty acids, and other materials obtained by acid treatment of the alkaline liquors from the digesting (pulping) of pine wood.

- **Thermosiphon System:** A solar collector system for water heating in which circulation of the collection fluid through the storage loop is provided solely by the temperature and density difference between the hot and cold fluids.

- **Thin-Film Silicon:** a technology in which amorphous or polycrystalline material is used to make photovoltaic (PV) cells.
- **Transmission System (Electric):** An interconnected group of electric transmission lines and associated equipment for moving or transferring electric energy in bulk between points of supply and points at which it is transformed for delivery over the distribution system lines to consumers, or is delivered to other electric systems.

- **Transportation Sector:** An energy-consuming sector that consists of all vehicles whose primary purpose is transporting people and/or goods from one physical location to another. Included are automobiles; trucks; buses; motorcycles; trains, subways, and other rail vehicles; aircraft; and ships, barges, and other waterborne vehicles. Vehicles whose primary purpose is not transportation (e.g., construction cranes and bulldozers, farming vehicles, and warehouse tractors and forklifts) are classified in the sector of their primary use.

- **Turbine:** A machine for generating rotary mechanical power from the energy of a stream of fluid (such as water, steam, or hot gas). Turbines convert the kinetic energy of fluids to mechanical energy through the principles of impulse and reaction, or a mixture of the two.

- **Useful Thermal Output:** The thermal energy made available for use in any industrial or commercial process or used in any heating or cooling application, i.e., total thermal energy made available for processes and applications other than electrical generation.

- **Watt (Electric):** The electrical unit of power. The rate of energy transfer equivalent to 1 ampere of electric current flowing under a pressure of 1 volt at unity power factor.

- **Watt (Thermal):** A unit of power in the metric system, expressed in terms of energy per second, equal to the work done at a rate of 1 joule per second.

- **Watthour (Wh):** The electrical energy unit of measure equal to 1 watt of power supplied to, or taken from, an electric circuit steadily for 1 hour.

- **Wind energy:** Energy present in wind motion that can be converted to mechanical energy for driving pumps, mills, and electric power generators. Wind pushes against sails, vanes, or blades radiating from a central rotating shaft.

- **Wind power plant**: A group of wind turbines interconnected to a common utility system through a system of transformers, distribution lines, and (usually) one substation. Operation, control, and maintenance functions are often centralized through a network of computerized monitoring systems, supplemented by visual inspection. This is a term commonly used in the United States. In Europe, it is called a generating station.

- **Wood/Wood Waste:** This category of biomass energy includes: black liquor; wood/wood waste liquids (red liquor, sludge wood, spent sulfite liquor); wood/wood waste solids (peat, paper pellets, railroad ties, utility poles, wood/wood waste).

- **Wood energy:** Wood and wood products used as fuel, including round wood (cord wood), limb wood, wood chips, bark, sawdust, forest residues, charcoal, pulp waste, and spent pulping liquor.

- **Wood pellets**: Sawdust compressed into uniform diameter pellets to be burned in a heating stove.

APPENDIX C

PADDY/RICE HUSKS EXTRACTIONS