Management of Agricultural Wastes and Residues in Thailand: Wastes to Energy Approach

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Abstract

Agriculture sector in Thailand has played a significant role in economic contribution since historical times. Among the total area of 520 million square kilometers, more than 65% is occupied by agriculture related activities. With the ever increasing market demand for agricultural products, most of the agricultural residues often end up in the municipal waste streams or in some cases, not efficiently used. Since 2001, energy demand in Thailand has been increasing at about 4% per year. A large portion of the fossil fuels is imported to meet the industrial and domestic needs, thus causing concern for energy security. In addition, utilization of fossil fuels is associated with green house gas emissions with significant environmental impacts. This paper describes an acceptable approach of utilizing agricultural waste and residues as a potential source of alternative and sustainable energy in Thailand. It also explains the energy potential of agricultural residues and animal manures that could be exploited to reduce the dependency on fossil fuels. The paper also examines the prevailing methods and technologies employed in utilizing the agricultural biomass from the major crop products and animal manures with some case studies.

1. Introduction

Being one of the world leaders in agricultural products and export, Thailand also has abundant biomass resources, especially agricultural residues. The European Commission's ASEAN COGEN Program estimated that the energy potential from four main agricultural residues, i.e. bagasse, rice husk, palm oil wastes, and wood residues, was 11.2 TWh/year or 2985 MW of power generation capacity. Other agricultural residues could also be used as potential sources of energy. Department of Energy Development and Promotion (DEDP, 1997) of Thailand conducted a test on ten main agricultural products with high residue energy potential. It was performed based on the Residue Product Ratio (RPR) and as received as calorific values. Apart from agricultural residues, animal manure which is principally composed of organic matter could also be used as a potential source of energy after successful decomposition either by aerobic or anaerobic processes.

1.1 Agriculture in Southeast Asia.

If all process-based agricultural residues alone were to be utilized, they would contribute between 25-40% of the total primary commercial energy production in various Southeast Asian countries. However, the successful utilization of these residues for electricity (and heat) production in large-scale conversion plants strongly depends on a secure fuel-supply.

1.2 Agricultural production in Thailand.

Thailand has a total area of about 51.31 million hectare, of which about 41% is under cultivation. Agriculture population accounts for 35.85 million in 1991, or 62% of the total population in the country. Agricultural active labour force is taken by 19.48 million in the same year, or approximately 67% of the total labour force. The main crop components are Rice, Sugarcane and Oil Palm in Thailand. Rice is the most important food crop grown in all regions of Thailand. Over 50% of the Thai farmland is devoted to rice, yielding about 20 million tons of paddy annually. Sugarcane is concentrated in the central region accounting for over 50% of both planted area and production.

1.3. Energy potentials of agricultural residues

Expanding agricultural production has naturally resulted in increased quantities of livestock waste, agricultural crop residues and agro-industrial by-products. Large quantities of crop residues are produced annually in Thailand, and are vastly under-utilized. Table 1 shows the details about agricultural residues for main crops in Thailand. A common agricultural residue is rice husk, which makes up 25% of rice by mass. Other plant residues include sugar cane fibre (bagasse), coconut husks and shells, palm oil fibre and groundnut shells. (*http://www.reslab.com.au*). According to the residue potential of ten main agriculture products assessment in 2001, 22 million tons out of 66 million tons were used as fuel and a small amount for other purposes. Whereas, about 44 million tons of agricultural residues, equivalent to 612.89 Pica Joule (PJ) of energy, were unused (Phongjaroon Srisovanna, 2004). Mainly attention should be given to the unused portion of agricultural residues to gain a monetary value.

Table 1.Agricultural residues from rice, sugarcane and palm oil in Thailand (2004)

(Unit: 1,000 tons per year)

Type	**Production**	**Agricultural Residues**	**CRR**	**Residues**	**Surplus Availability factor**	**Available unused Residue**
Sugar cane	70101	Bagasse Trash	0.291 0.302	20399 21171	0.207 0.986	4223 20874
Rice	26841	Rice husk Rice straw	0.230 0.447	6173 11998	0.493 0.684	3044 8207
Oil palm	4903	EFB Fiber Shells Fronds	0.250 0.147 0.049 2.604	1226 721 240 12767	0.584 0.134 0.037 1.000	716 97 9 12767
Total				74695		49936

Remarks: CRR= Crop-to-residue ratios
EFB= Empty Fruit Bunches

(Source**:** Seksan Papong, et al, 2004)

Table 2 shows the estimated energy potential of agricultural residues in 1997, 2005 and 2010. Agricultural residue potential for the years 2005 and 2010 have been projected based on historical data of harvested land and production statistics from the Center for Agricultural Information (CAI) during 1988 and 1999 (Boonrod Sajjakulnukit, et al., 2005).

Table 2. Energy potentials of agricultural residues

Product	Production (Mt)			Residue	Residue available for energy (Mt)			Energy potential (PJ)		
	1997	2005	2010		1997	2005	2010	1997	2005	2010
Sugarcane	56.39	63.61	68.58	Bagasse	14.1	15.9 0	17.15	90.65	102.15	110.14
				Top & trash	16.79	18.9	20.42	114.52	129.18	139.27
Paddy	22.33	23.73	24.66	Husk	5.14	5.46	5.67	66.01	70.15	72.86
				Straw (top)	6.83	7.26	7.54	60.29	64.08	66.56
Oil palm	2.69	4.03	5.20	Empty bunches	0.71	1.06	1.37	11.62	17.42	22.45
				Fiber	0.39	0.59	0.76	6.35	9.52	12.27
				Shell	0.08	0.12	0.16	1.40	2.10	2.71
				Frond	7.00	10.50	13.53	55.80	83.70	107.83
				Male bunches	0.63	0.94	1.21	9.31	13.96	18.00
Coconut	1.42	1.42	1.42	Husk	0.45	0.45	0.45	6.70	6.70	6.70
				Shell	0.18	0.18	0.18	2.96	2.96	2.96
				Empty bunches	0.07	0.07	0.07	0.96	0.96	0.96
				Frond	0.31	0.31	0.31	4.49	4.49	4.49
Cassava	18.08	15.85	14.59	Stalk	0.65	0.57	0.52	11.00	9.63	8.88
Maize	4.53	5.43	6.07	Corn cob	0.98	1.17	1.31	16.26	19.46	21.78
Groundnut	0.15	0.16	0.17	Shell	0.05	0.05	0.05	0.53	0.58	0.60
Cotton	0.08	0.08	0.08	Stalk	0.24	0.24	0.24	3.17	3.17	3.17
Soybean	0.36	0.36	0.36	Stalk, leaves, shell	0.73	0.73	0.73	13.20	13.20	13.20
Sorghum	0.23	0.26	0.29	Leaves & stem	0.22	0.25	0.28	3.84	4.49	4.95
Total	106.26	114.92	121.40		55.5	64.80	71.95	479.06	557.90	619.80

(Source: Boonrod Sajjakulnukit, et al, 2005)

Changes in production were estimated from historical trends of two essential parameters, namely harvested area and product yield. Other parameters, for instance, RPR ratio and residue availability factor were assumed to be constant. The estimation for years 2005 and 2010 is based on the following assumptions:

(i) During 1998 and 2000 sugarcane harvested area has been more or less constant while yield per hectare has improved at an average annual rate of 1.5%. Production of sugarcane has therefore been projected to increase at a rate of 1.5% per annum.

(ii) Paddy harvested area has been almost constant at about 9.92 million hectares since 1989 when the production increased from about 21.3 Mt in 1989 to 23.6 Mt in 1998 due to increase in product yield from 2.15 to 2.38 t ha^{-1}. An average annual increase rate of 0.7% has been used to predict the paddy production of the year 2010. This projected rate was a little lower than the targeted increase of paddy production specified in the 8th National Economic and Social Development Plan which targeted 1-2% increase in paddy production through increased yield while maintaining about the same planted area.

(iii) Both harvested area and product yield of palm oil increased at annual rates of 4.8% and 5.2%, respectively, during 1988-2000. Since the product yield of about 15.63 t ha^{-1} yr^{-1} in Thailand is relatively low, increase in future production is more likely to be from the improvement of product yield than increase of harvested area. Future production has therefore been predicted by using a productivity increase rate of 5.2% per annum.

(iv) Harvested area of cassava decreased at an average annual rate of 2.6% while product yield increased with an average annual rate of 1.0% during 1988 and 2000. Future production has been projected to decrease at a net rate of 1.6% per year.

(v) Harvested area of maize decreased from 1.79 to 1.22 million hectare during 1989-1994. It has been more or less constant since then while product yield has improved at an average rate of 2.27% per year. This rate has been used to predict maize production for the year 2010.

(vi) For other products such as coconut, cotton and soybean, there was no significant change in harvested area and product yield during 1989-2000. Although for groundnut and sorghum there was no change in harvested area, production yield did increase at average annual rates of 0.93% and 2.0%, respectively.

1.5 Prevailing usage of Agricultural residues

1.5.1 Paddy residues

The normal harvesting practice of paddy in Thailand leaves huge quantities of rice straw which contains the top portion of the rice stem with three to five leaves. Rice husks are generated in rice mills all over Thailand, at varying quantities depending on the milling input capacities.

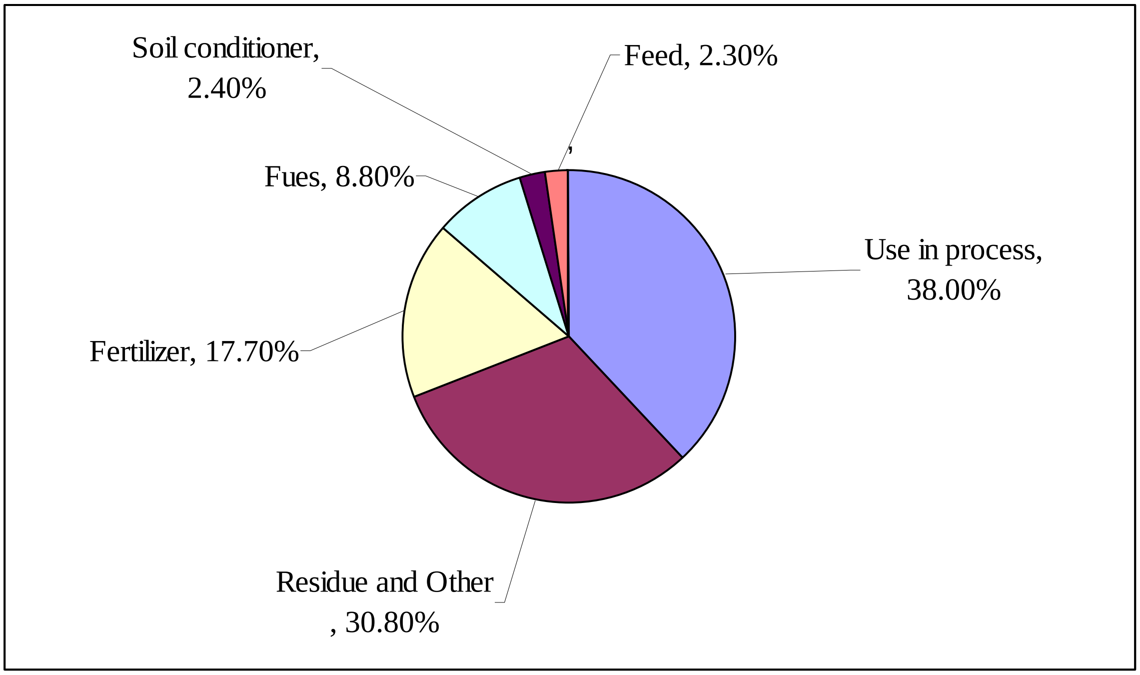
Rice straw is principally used as a raw material for fibre in the paper industry. It is also used as animal feed. To some extent, it is used as field cover to retain soil moisture, as protection from heat, for weed control and to provide humus to the soil. Most of the rice straw, however, is burnt in the fields and the ash is used as organic fertilizer by the farmers. Buangsuwon (1990) reports that 50% of straw produced in Thailand is used as animal feed, 30% for the paper industry (as raw material), 10% for other uses, 10% as field wastes, and 0% for energy use.

Paddy husk is used as an energy source through direct combustion in large rice mills or as fuel in the production of charcoal from wood logs. Koopmans and Koopejan (1997) cite that about 50-70% of the husk is used by the rice mills themselves. Apparently, the remaining 30-50 % is not used. According to USAID (1990), only about 30 to 50% of the husk generated is used for energy purpose. Intarapravich, et al, (1995) also reports that 87% of the total rice husk is used for industry consumption and the remaining 13% is discarded as waste (*http://www.eppo.go.th/encon/encon-Chap2.doc*).

Also Thipwimon Chungsangunsit, et al, (2004) describe that rice husk can be used for Cement industry to add silica in the product itself because rice husk content high silica. These ways are not enough to significantly reduce rice husk disposal problem. Another way that has been proposed is using the husk for energy purpose. Rice husk can be used as solid fuel by combustion process. Many countries including Thailand use rice husk to produce electricity.

Other uses of the rice husk are: filler in the brick industry, domestic fuel for cooking and occasionally as a bedding material for animals. The various uses of rice husk are indicated in figure 1.

Figure.1 Percentage of the rice husk consumption



(Source: Seksan Papong, et al, 2004)

1.5.2 Sugarcane residues

Sugar cane residues are basically of two types: the cane residues made up of leaves, tops of cane plants (also known as cane trash) that remain in the field after the harvest and bagasse which is the fibrous residue after the extraction of the juice from the sugarcane in the mills. The precise amount of biomass available from cane residues (on field) varies with plant varieties, climate and soil conditions, etc.

The current practice of utilizing sugarcane residues in Thailand are as follows:
Cane residues (mainly tops and leaves) are left in the field. These residues serve as soil enrichments thus improving the physical, chemical and biological properties of soil.
Molasses is mainly used for ethyl alcohol (ethanol) production.
Bagasse is mainly used for cogeneration and for paper and particle board production.

1.6 Energy potential of animal manure

During the Seventh National Economic and Social Development Plan (1992-1996), livestock expansion was set at an average of 5.6% per annum. After the end of the seventh plan, livestock business has grown at a much slower rate, 2.5-3.0% per annum on average, due to reduction of total agricultural land and changes in international livestock market conditions. In 1997 about 3.2 million people used a total area of 1.5 million hectares for livestock production.

Major animals were cattle, buffalo, swine and chicken. The total number of animals raised in 1997, spread over six different types, was more than 200 million heads as shown in Table 3. It is estimated that about 3.2 Mt of dry matter of animal manure produced in 1997 could be recovered. This amount of manure could be used to produce 620 million N m^3 of biogas, which is equivalent to about 13 PJ. Although cattle manure has the highest share of the total energy potential of the animal manure, the ongoing biogas promotion program emphasizes pig farms. During the last decade the structure of pig farms in Thailand has changed markedly. In the past almost all pig farms were small with only a few animals. Today, more than 50% of the annual production, of almost 10 million pigs, is from large modern farms. We assume that the energy potential of animal manure will remain as 13 PJ in years 2005 and 20l0

Table 3. Energy potential of animal manure (1997)

Animal	Number	Fresh waste	Recoverable	Dry matter	Volatile	Recoverable	Biogas yield	Amount of	Energy
	(head)	(kg $head^{-1}$ d^{-1})	fraction[a]	(DM)[b]	solids[b]	DM	(m^3 kg^{-1} VS)	biogas	**PJ**
				(%)	(%)	(kt DM yr^{-1})		(Mm^3 yr^{-1})	
Cattle									
Beef	5,291,936	5.00	0.50	17.44	13.37	842.16	0.307	198.21	4.162
Dairy	302,872	15.00	0.80	17.44	13.37	231.36	0.307	54.45	1.143
Buffalo	2,293,938	8.00	0.50	17.77	13.64	595.14	0.286	130.62	2.744
Swine									
Sow	397,460	2.00	0.80	35.22	24.84	81.75	0.217	12.51	0.263
Boar	91,391	2.00	0.80	35.22	24.84	18.80	0.217	2.88	0.060
Piglet	3,197,358	0.50	0.80	35.22	24.84	164.41	0.217	25.16	0.528
Fattening	5,587,565	1.20	0.80	35.22	24.84	689.57	0.217	105.54	2.216
Native	325,266	1.20	0.80	35.22	24.84	40.14	0.217	6.14	0.129
Chicken	164,607,487	0.03	0.80	33.99	22.34	490.19	0.242	77.87	1.637
Duck	21,829,780	0.03	0.40	26.82	17.44	25.64	0.310	5.16	0.109
Elephant	3500	40.00	0.50	26.64	21.61	6.81	0.241	1.33	0.028
Total						3185.97		619.87	13.020

Remarks : a = Estimated from field investigation by DEDP; b= Results from DEDP tests.

(Source: Boonrod Sajjakulnukit, et al, 2005)

1.7 Prevailing usage of Animal Manure

Animal wastes contain a high proportion of biomass and their utilization and recycling is important for economic and environmental aspects. Anaerobic digestion has been one of the most widely used processes for treating these wastes since it produces biogas as an alternative energy source.

Potential of Biomass Energy Resources using residues

Biomass is the most important source of energy and it can be defined as, organic matter available on a renewable basis. Biomass includes agricultural crops and its residues, forest and mill residues, wood and wood wastes, animal wastes, livestock operation residues, aquatic plants, fast growing trees and plants and municipal and industrial wastes. Rice, sugarcane, oil palm and wood wastes are the four major sources of biomass in Thailand. At present, agro-industry is an important source of the biomass due to a large scale production and expedience collection of biomass from facilities such as rice mills, sugar mills and oil palm mills (Seksan Papong, et al, 2004).

Apart from biomass there are other different sources of energy which take priority in generation. The different sources and the energy consumed from these are presented in Table 4.

Table.4. Energy Consumption by Sources (Thailand)

(Unit: ktoe)

Source	1998	1999	2000	2001	2002
Coal & Lignite	3,237	3,876	3,627	4,377	4,884
Petroleum Products	3,853	3,971	4,136	3,988	4,235
Natural Gas	877	1,112	1,374	1,556	1,745
Electricity	2,565	3,012	3,346	3,494	3,808
Biomass	3,222	3,517	3,725	3,507	4,007
Total	13,754	15,488	16,208	16,922	18,679

Remark: ktoe=kilo-ton-oil-equivalent

(Source**:** Natthaporn Suwannakhanthi, 2004)

In Thailand, biomass is used to generate/ produce electricity, heat and liquid fuels that have substantially lower environmental impacts than traditional fossil fuels. Industries that rely on biomass as energy source are brick production, tobacco, lime production and fish mill production.

Table 5. Biomass energy consumption in Thailand during 1998-2003

(Unit: toe)

Source	1998	1999	2000	2001	2002	2003
Fuel Wood	3,188	3,279	3,258	3,265	3,342	3,493
Charcoal	3,188	2,218	2,277	2,286	2,307	2,357
Paddy Husk	778	733	828	903	896	996
Bagasse	1,665	2,092	2,236	1,989	2,498	2,905
Total	7,885	8,322	8,599	8,443	9,043	9,751

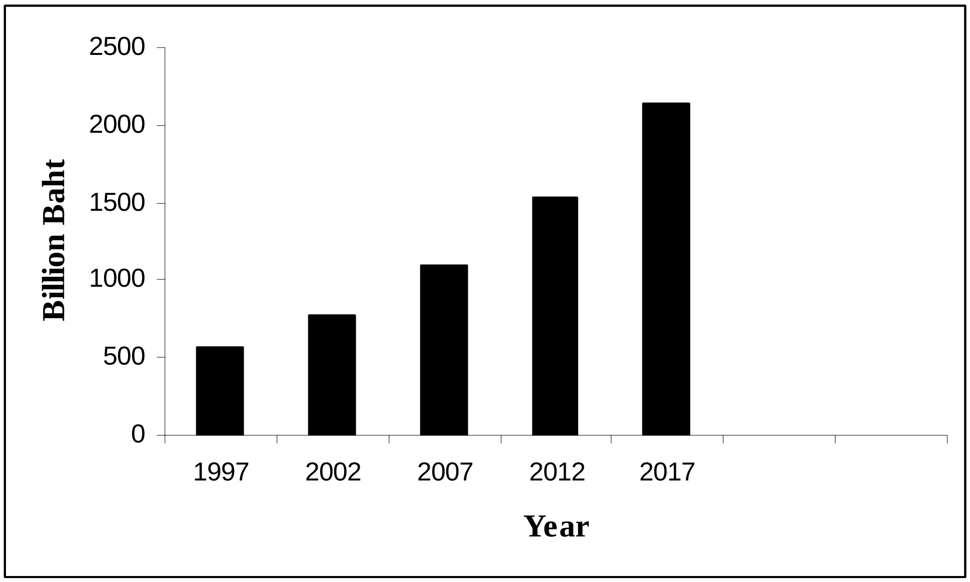
(Source: Seksan Papong, et al, 2004)

Table 5 clearly indicates that energy production from paddy husk and bagasse has increased significantly since 1998.

2. Potential of Biomass for Energy supply in Thailand.

In the past several years, energy demand in Thailand has increased rapidly as results of the economic development and population growth. With high energy demands in industrial, transport, commercial and residential sectors, Figure 2 predicts the national energy cost to soar up to almost two folds from now should Thailand move forward with the same pace for another one decade.

Figure 2 Forecast of national energy consumption in the future



Assumption: Energy Elasticity = 1.4:1 and Est. GDP Growth rate =5% per year
(Source: *http://www.eppo.go.th*)

With the agricultural output (as in 2004, 27 Mt of rice, 70 Mt of sugarcane and 5 Mt of Oil palm) and with the same CRR, it would be not difficult for Thailand to meet its soaring energy demand should energy from biomass resource be considered as top priority from the ongoing research and developments. According to statistical data, the major crops harvested in Thailand are rice and sugarcane and it leaves behind almost 20-50% of agricultural residue (rice husk and sugarcane bagasse) depending on the method of harvesting.

With respect to the growing energy demand, availability of biomass residues and with the touch of modern technology and concept, Thailand could boldly move forward in investing/ focusing on how to effectively utilize (the existing biomass resources) and channel those which are wasted (often in the dumpsites) to energy production. In areas where biomass are extensively used, energy efficiency enhancements of output from the biomass could be taken up (especially in rural households and small and medium scale industries) by simply improving the current technology and auditing the prevailing equipments.

2.1. Biomass energy production from rice husk in Thailand.

Rice husk is traditionally used as an energy source through direct combustion in the large rice mills, or as fuel in the production of charcoal from wood. In the recent years technology has developed so that about 1 MW of electricity could be generated using about 10,000 tons of rice husk. Many countries, including Thailand have started using rice husk to generate electricity. A case study of rice husk usage in power generation at Roi Et Green Power Plant in Thailand has been conducted by Thipwimon Chungsangunsit, et al, (2004).

2.1.1 Rice husk usage in Roi Et Green Power Plant, Thailand (a case study).

The Northeastern region around Roi Et province of Thailand is particularly important as one of the major rice growing belts. A pilot plant of capacity 9.8 MW using rice husk is located in this area. The project, established in July 2000 is a partnership between EGCO Green Co. Ltd (95%) and Sommai Rice Mill (5%). The plant uses energy equivalent of 1 MW and the excess electricity generated equivalent to 8.8 MW is sold. The expected life time of the plant is 35-40 years.

Table 6 shows the rice husk analysis conducted by Thipwimon Chungsangunsit, et al, (2004).

Table 6 Characteristics of rice husk

Parameter	Unit	Result	Basis
Total moisture	%	11.94	as received
Ash content	%	14.22	dry
Low Heating Value (LHV)	kJ/kg	13158.7	as received
High Heating Value (HHV)	kJ/kg	15217.2	dry
Volatile matter	%	59.87	dry
Fixed carbon	%	18.56	dry

(Source: Thipwimon Chungsangunsit, et al, 2004)

2.1.2 Process description in the power plant.

The process at the power plant starts at treating the water from Shi River to remove particulates and ions so as to protect erosion of the boiler. The treated water is passed through a filter tank and demineralization tank to remove any ions present in it using an ion-exchange resin. After this, the water is heated in an economizer which uses the waste heat from the flue gas released after steam production in the boiler. The preheated water is then sent to the boiler. Rice husk, the fuel source for boiler is ignited by burning paper during startup. Steam produced at about 300°C, is further heated by a super-heater to raise its temperature to 400°C so as produce a high energy steam. This superheated steam is then used in a steam turbine to generate electricity. The exhaust steam is then condensed to water by the cooling tower.

2.2 Biomass energy production from sugarcane bagasse in Thailand.

Large amount of sugarcane Biomass is produced in Thailand each year. Sugarcane plant is one of the most efficient converters of solar energy into biomass. Apart from being used to produce sugar and molasses, sugarcane grows faster and produces more biomass than most energy crops. In case of availability sugarcane biomass can be divided into two main forms: sugarcane trash and bagasse.

Today, in most sugar mills the electricity generation capacity is designed to cover the requirement of the mill only. Generation is often restricted to the milling period, which varies between six and ten months, though could continue during the off-seasons. The efficiency of electricity generation in many sugar mills is poor due to low steam and temperature. Table 7 presents the main characteristics of bagasse used for to biomass based electricity generation.

Table 7 Main characteristics of bagasse.

Parameter	**Unit**	**Result**
Moisture Content. As received	%	52% (48-55%)
Moisture Content. air dry	%	n.a.
Low Heating value (LHV) As received	GJ/tone	7.4* (7.4-9.5)
Low Heating value(LHV) air dry	GJ/tone	n.a.
Bulk density. Loose / baled	kg/m^3	85 / 150
Seasonal Availability	n.a	Dec.-April

Remarks: n.a = not available

(Source: Martin Junginger, et al, 2000)

Sugar factories are one of the major industries which produce electricity as small power producers during the sugarcane season. An average sugarcane factory in Thailand has a capacity to process between 15,000 and 30,000 tones of sugarcane per day, and has an electricity generating capacity between 12-30 MW of which all or the major part is required for the milling process. As on March 2000, 14 of the 46 sugar factories in Thailand deliver about 3-8 MW electricity to the grid during the season. (Martin Junginger, 2000)

2.2.1 Dan Chang Bio Energy scheme, bagasse-fired cogeneration project (a case study).

The following case study is on a project being implemented in Thailand under the Full Scale Demonstration Project scheme of COGEN. (EC-ASEAN COGEN, 2004). Although most of the sugar industries in Thailand already have cogeneration plants, the technologies used in these systems are old and inefficient. With the present efficiency, it requires up to 9 kg of bagasse to produce 1 kWh of electricity. These boilers have been designed deliberately with low efficiency to burn large quantities of bagasse while producing the amount of steam and/or power needed by the mill. However, recent developments such as alternative uses of bagasse and the possibility of selling electricity to the grid have shown that bagasse can actually be a valuable resource which should be managed efficiently.

2.2.2. Project description

Dan Chang Bio Energy (DC), a special purpose company established by Mitr Phol Sugar Corporation Ltd. (MP), recently decided to implement a cogeneration project in their sugar mill at Dan Chang, Thailand. The objective of the project is to generate steam and electricity to cover the needs of the sugar mill and to sell the excess electricity to the national grid. The fuel sources are mainly bagasse and cane leaves. A summary of the project is presented in Table 8.

Table 8. Summary of the project information.

Owner/Developer	Mitr Phol Sugar Corp. Ltd.
Industry	Sugar
Location	Dan Chang, Thailand
Existing equipment	Mitr Phol has an existing cogeneration plant (consisting of several old boilers and turbines), which covers the steam and power requirements of the sugar mill. The old system is able to export excess electricity of about 3 - 5 MW to EGAT during the milling operations.
New scheme	Existing boilers and turbines will be replaced with two efficient high pressure boilers (2 x 120 tph, 68 bar, 510 °C) and one efficient extraction condensing turbine of about 41 MW.

Source: (EC-ASEAN COGEN, 2004)

3. Discussions

Advantages of energy generation from biomass are comparable and significant. Combustion of biomass emits CO_2. Carbon sequestered in the biomass is always a part of the global carbon cycle and hence does not contribute to global warming. Moreover, the use of agricultural residues as biomass for electricity generation is additional to the usual scenario which focuses more on other means of disposal without utilizing the energy content. The fact that these agricultural residues contain very low sulphur, of the order of 0.4%, makes it clear that the SO_2 emissions are also less compared to conventional fossil fuels such as coal and oil. Closed chambers and controlled conditions ensure that the combustion is complete, thus eliminating emissions of CO. Ability of biomass to avoid all possible emissions associated with burning of conventional fuels makes it a clean source of energy. The mere fact that they generate clean energy makes them qualify as Clean Development Mechanism (CDM) projects thereby generating additional revenue through sale of emission reductions.

Difficulty in assessment of resources, inconsistent production, inappropriate properties such as low bulk density and high moisture content, problems of collection, transportation and storage, and availability and reliability concerns are the major limitations of utilizing biomass as an alternative energy source. Most of these limitations could be overcome by appropriate planning and implementation.

In addition, Institutional barriers, Policy barriers, Technical barriers and Information barriers could be crossed by making key policy decisions, encouraging research and development on biomass energy sources and disseminating the information among potential investors.

The fact that agricultural residues are available in abundant quantities in rural areas improves the viability of these projects in those areas. Cost of transporting the biomass reduces and hence increases the profit. Development of biomass power projects in rural areas helps in decentralizing the energy source. This also contributes to the local economy by way of employment and other benefits.

4. Conclusion

Biomass power is a major contribution to domestic energy needs and provides substantial environmental benefits. Various technologies are available both at the national and international level for the effective utilization of biomass. These technologies should be used in the right way to utilize the available energy potential. While there are several constraints to be overcome, it could be clearly seen that there are enormous opportunities to promote the utilization of biomass and improve the efficiency. International experience shows that biomass serves as a promising option of renewable energy. These experiences coupled with the available potential should be used to take the nation forward towards a clean and secure energy source.

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Management of Agricultural Wastes and Residues in Thailand: Wastes to Energy Approach

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Agriculture

ASEAN & Asia Pacific region

- Landscape is richly endowed with natural resources
- Agriculture was the primary source of income
- Humid tropical climate ensure that the constraints to agricultural development have historically been more economic and institutional than environment
- Agriculture is the primary producing sector of the developing countries of the Asian and Pacific region.

Agriculture

ASEAN & Asia Pacific region

- Viet Nam, Pakistan, Thailand and India are the major food grain exporters of the region
- In 1998, Thailand (27), India (11), Pakistan (6.5) and Viet Nam (6) recorded a total of 50.53 % of total world rice exports.
- ASEAN region’s exports of rice and sugar played important roles in the global market.

Agriculture

Thailand

- GDP: US$ 143,303 million (2003) at current market prices

- *Agriculture:* 9%
  Industry (including Agro based industry): 44.3%
  Services: 46.7%

- Food industry is a major industry of Thailand. It is an important export industry; it creates food security for the country, and it also provides income for the agriculture sector.

- In 2000, the value of the country 's food exports was 401,032 million baht, increased by 13 % compared with 377,968 million baht in 1999

Agriculture

Thailand

- Main crop component of Thailand are Rice, Sugarcane and Palm oil
- Rainfall is the most important water source for agriculture as about 80 % of agriculture area are under rained condition
- Thailand has the total area of about 51.31 million hectare, of which about 41 % is engaged in agriculture

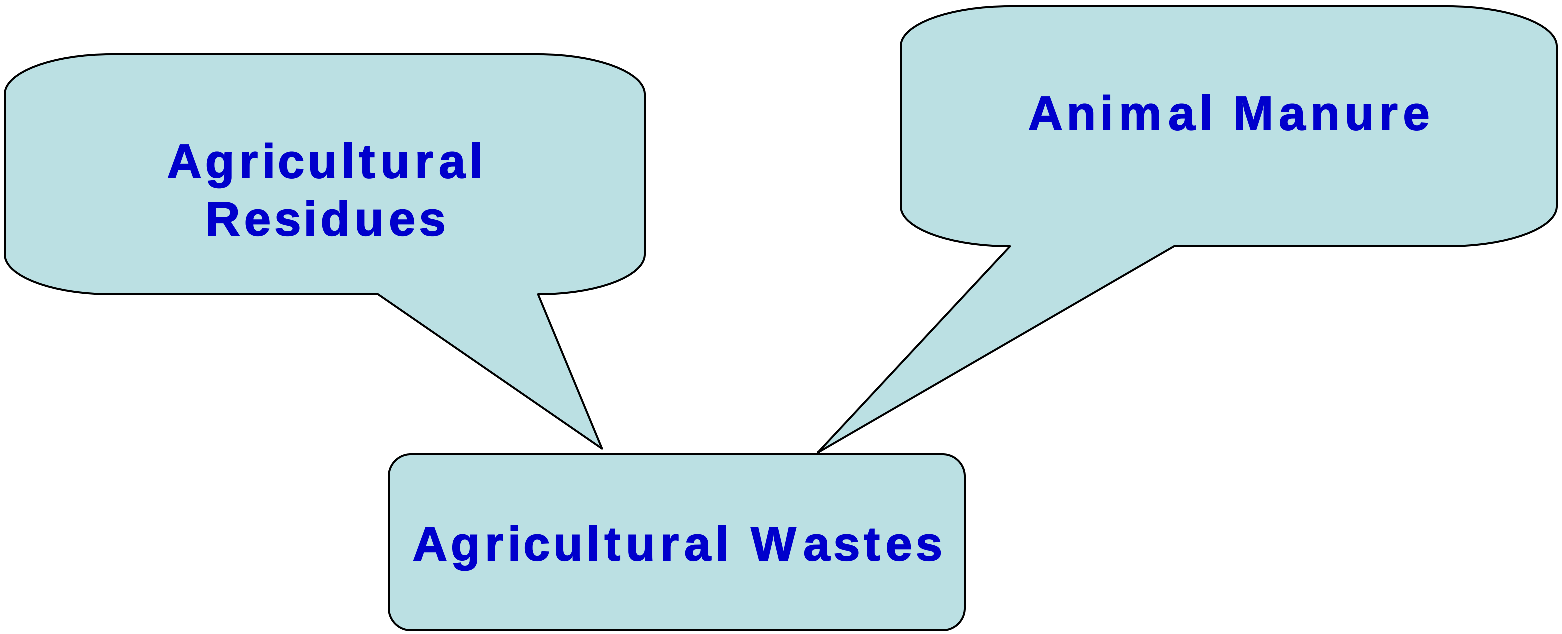
Agriculture

Thailand

- Rice is the most important food crop grown in all regions of Thailand
- Over 50 % of the Thai farmland is devoted to rice, yielding about 20 million tons of paddy annually
- Oil palm is widely grown in the south of Thailand, with current total planted area of 0.8 million rai and annual fresh fruit bunch production of 1.5 million tons

Agricultural Wastes/ Residues

Definition: ? ‘or’ what does it mean from Asian context?



Expanding agricultural production has naturally resulted in increased quantities of livestock waste, agricultural crop residues and agro-industrial by-products.

I. Agricultural Residues

- Large quantities of crop residues are produced annually in Thailand,

  and are vastly underutilized
- A common agricultural residue is rice husk, which makes up 25 % of rice by mass
- Only 22 million tons (in 2001) were used as fuel and small amount for other purposes out of 66 million tons .
- Whereas about 44 million tons of agricultural residues were unused and equivalent to 612.89 PJ (Pica Joule)

I. Agricultural Residues

Paddy residues

- Rice husk is the outer cover of rice that accounts for about 20 % by weights of the rice
- Rice husks are generated in rice mills all over the Thailand, at varying quantities depending on the milling input capacities.
- Normal harvesting practice of paddy in Thailand leaves huge quantities of rice straw which contains the top portion of the rice stem with three to five leaves.

I. Agricultural Residues

Agricultural residues from rice, sugarcane and oil palm in 2004 in Thailand

(Unit: 1000 tons per year)

Type	Production	Agricultural residues	CRR	Residues	Surplus Availability factor	Available Unused residue
Sugarcane	70,101	Bagasse	0.291	20399	0.207	4223
		Trash	0.302	21171	0.986	20874
Rice	26,841	Rice husk	0.230	6173	0.493	3044
		Rice straw	0.447	11998	0.684	8207
Oil Palm	4,903	EFB	0.250	1226	0.584	716
		Fiber	0.147	721	0.134	97
		Shells	0.049	240	0.037	9
		Fronds	2.604	12767	1.000	12767
Total				**74695**		**49936**

Remarks: CRR=Crop-to-residue ratios; EFB= Empty Fruit Bunches

I. Agricultural Residues

Existing usage of paddy residues (Thailand)

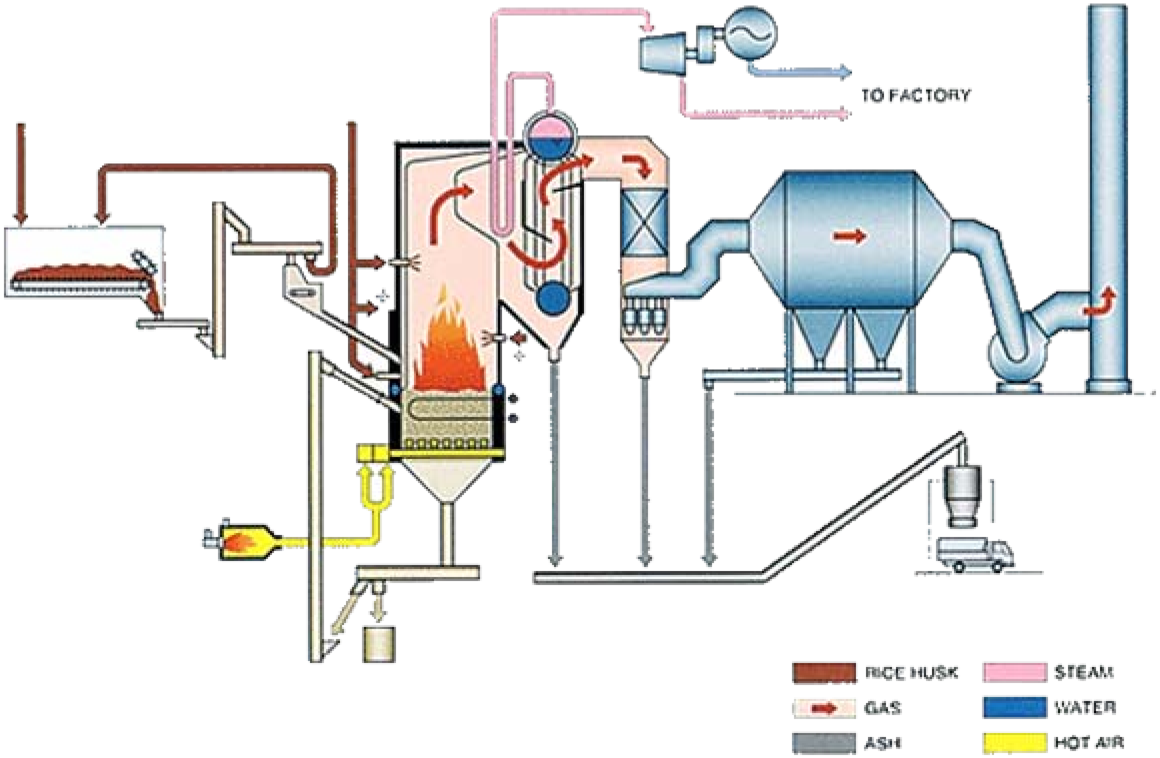
- Rice straw is principally used as an industrial raw material for fibre in the paper industry. It is also used as an animal feed.
- Paddy husk is used as an energy source through direct combustion in large rice mills or as fuel in the production of charcoal from wood logs
- Many countries including Thailand use rice husk to produce electricity
- Other uses of the rice husk are: as filler in the brick industry for cement industry, as domestic fuel for cooking, and occasionally, as a bedding material for animals.

I. Agricultural Residues

Rice Husk, Thailand

I. Agricultural Residues

Rice husk firing Boiler, Thailand



Source: TAKUMA

I. Agricultural Residues

Sugarcane waste, Bagasse, Thailand

I. Agricultural Residues

Bagasse firing Boiler, Thailand

A bagasse firing boiler in a sugar factory of Thailand (300t/h 2units).

Source: TAKUMA

I. Agricultural Residues

Palm Oil Production, Thailand

I. Agricultural Residues

Palm Oil Production, Thailand

I. Agricultural Residues

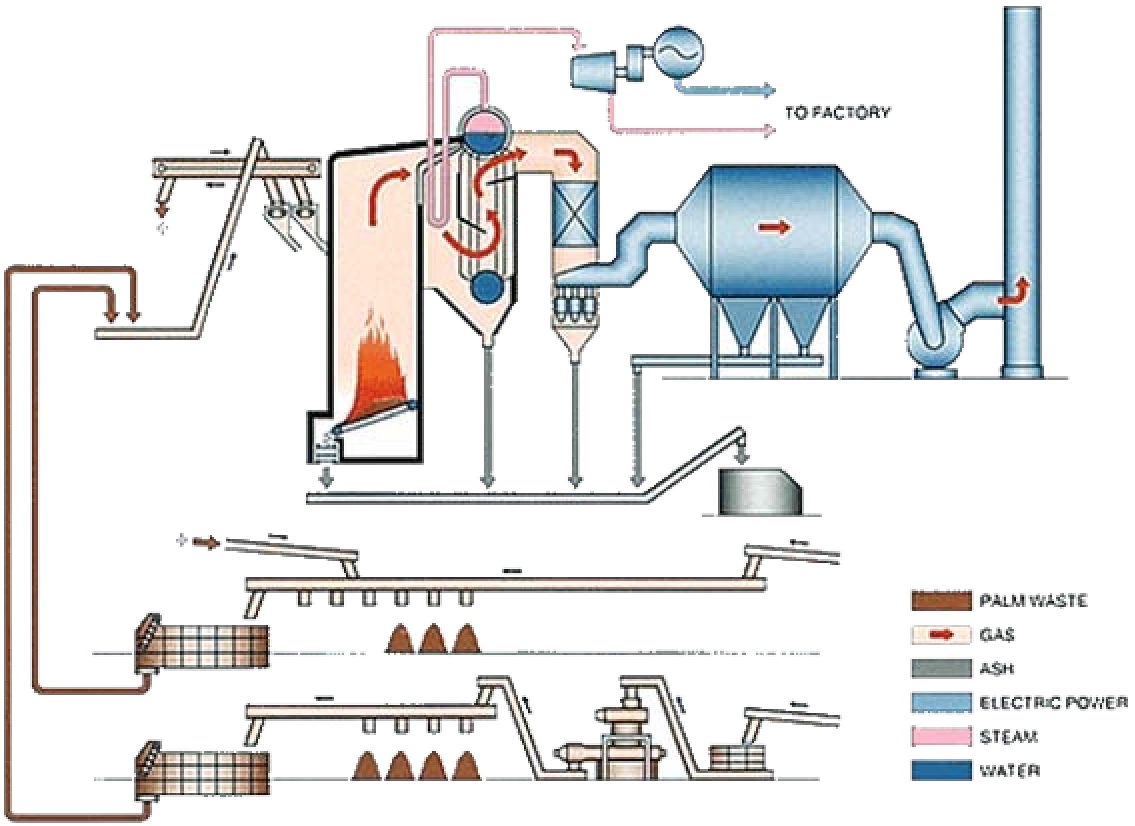
Palm Oil Production, Thailand

I. Agricultural Residues

Palm Oil waste, Thailand

I. Agricultural Residues

Palm Oil waste firing Boiler, Thailand



Source: TAKUMA

I. Agricultural Residues

Existing usage of sugarcane residues (Thailand)

- Cane residues, mainly tops and leaves can be used as soil amendments which can improve the physical, chemical and biological soil properties

- Bagasse is mainly used for power cogeneration producing electricity and for paper and particle board production

- Molasses are mainly used for ethyl alcohol (ethanol) production which can be further utilized for the distillation industry

II. Animal manure

Livestock farms

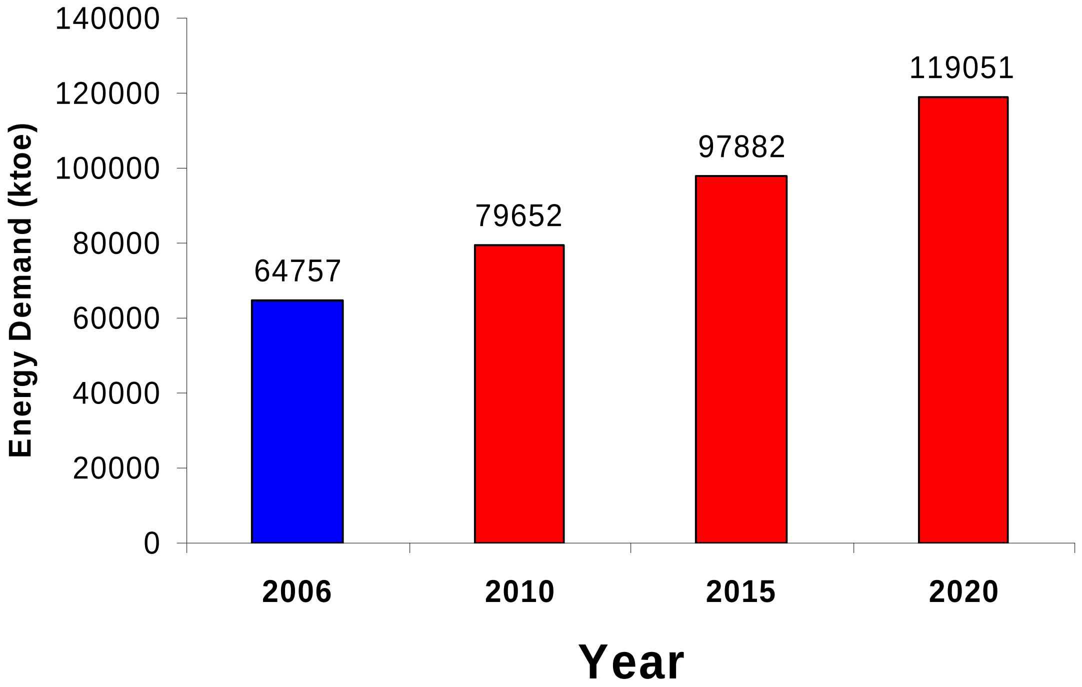
- Fast growing pig and poultry production around big urban centers in Thailand is posing an increasing threat to the environment
- Livestock production is largely concentrated on specialized farms with little or no land to use the animal excreta
- Most common sources are manures from pigs, chickens and cattle (in feed lots) because these animals are reared in confined areas generating a large amount of waste in a small area

Farm wastes in Thailand

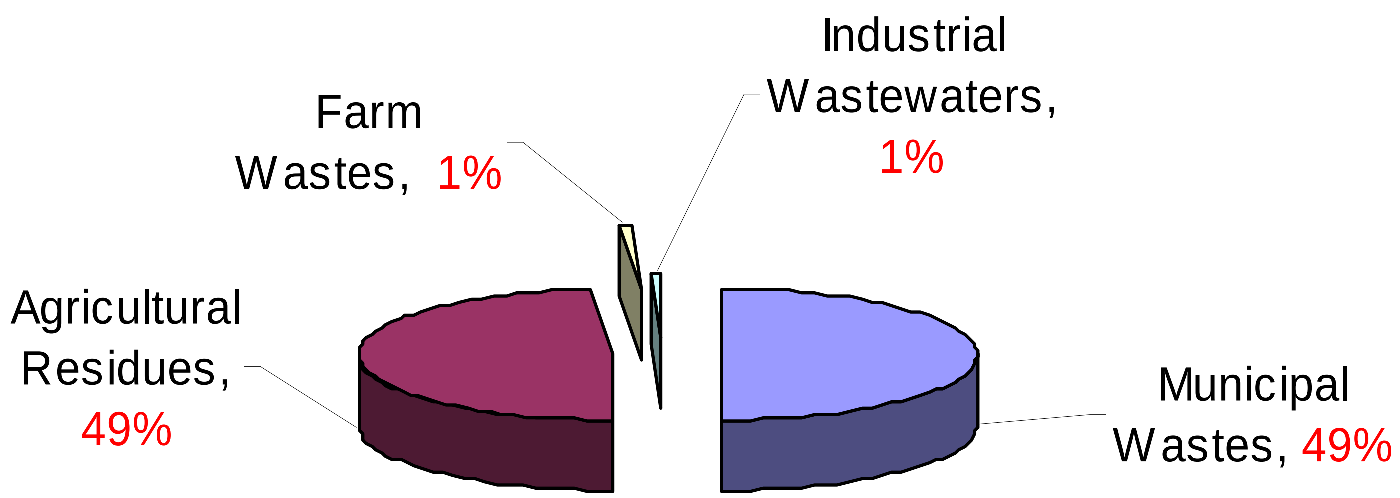
Type	Number (Heads) X10^6	Manure (kg/head/d)	Collectible ratio	Biogas (m^3/kg vol solids)	Biogas (10^6. m^3/yr)	Potential Energy (TJ/yr)
Cattle	4.9	5	0.5	0.307	183.55	3855
Dairy Cow	0.3	15	0.8	0.307	55.36	1163
Buffalo	0.2	8	0.5	0.286	96.95	2036
Swine-F	0.8	2	0.8	0.217	24.90	523
Swine-M	0.8	2	0.8	0.217	24.90	80
Swine Piglet	2.1	0.5	0.8	0.217	24.90	351
Swine Khun	4.4	1.2	0.8	0.217	24.90	1745
Swine Native	0.3	1.2	0.8	0.217	24.90	129
Chicken	172.2	0.03	0.8	0.242	6.14	1713
Duck	27.9	0.03	0.4	0.31	6.60	139
Elephant	0.002	40	0.5	0.241	0.83	17

The Need for an alternate source of energy…Biomass

- Energy demand in Thailand has increased rapidly as results of the economic expansion and population growth



Potential of Biomass Energy resources



- With respect to the growing energy demand, availability of biomass residues and with the touch of modern technology and concept,
- Thailand could boldly move forward in focusing on how to effectively utilize existing biomass resources for energy production

Biomass energy consumption in Thailand (1998-2003)

(Unit : toe)

Source	1998	1999	2000	2001	2002	2003
Fuel wood	3188	3279	3258	3265	3342	3493
Charcoal	3188	2218	2277	2286	2307	2357
Paddy Husk	778	733	828	903	896	996
Bagasse	1665	2092	2236	1989	2498	2905
Total	7885	8322	8599	8443	9043	9751

Remark: toe = ton-oil-equivalent

Potential of Biomass Energy resources; Animal manures/ residues

Energy potential of animal manure, 1997

Animal	Number (head)	Fresh waste (kg head^{-1} d^{-1})	Recoverable fraction[a]	Dry matter (DM)[b] (%)	Volatile solids[b] (%)	Recoverable DM (kt DM yr^{-1})	Biogas yield (m^3 kg^{-1} VS)	Amount of biogas (Mm^3 yr^{-1})	Energy **PJ**
Cattle									
Beef	5,291,936	5.00	0.50	17.44	13.37	842.16	0.307	198.21	4.162
Dairy	302,872	15.00	0.80	17.44	13.37	231.36	0.307	54.45	1.143
Buffalo	2,293,938	8.00	0.50	17.77	13.64	595.14	0.286	130.62	2.744
Swine									
Sow	397,460	2.00	0.80	35.22	24.84	81.75	0.217	12.51	0.263
Boar	91,391	2.00	0.80	35.22	24.84	18.80	0.217	2.88	0.060
Piglet	3,197,358	0.50	0.80	35.22	24.84	164.41	0.217	25.16	0.528
Fattening	5,587,565	1.20	0.80	35.22	24.84	689.57	0.217	105.54	2.216
Native	325,266	1.20	0.80	35.22	24.84	40.14	0.217	6.14	0.129
Chicken	164,607,487	0.03	0.80	33.99	22.34	490.19	0.242	77.87	1.637
Duck	21,829,780	0.03	0.40	26.82	17.44	25.64	0.310	5.16	0.109
Elephant	3500	40.00	0.50	26.64	21.61	6.81	0.241	1.33	0.028
Total						3185.97		619.87	13.020

Utilization of Sugarcane Bagasse, Thailand

In Thailand, 45% of cane residue is burned;

In 2004/05;
Total production decreased; 47.8 MT (Million tons)
Residue; 15.1 MT bagasse

7.2 MT (used for steam boilers, paper and particle board)
7.9 MT used foe electricity

One ton of cane is delivered into the mill, its product proportion can be achieved as;

– Sugar	105 -120 kg
– Water	500 -510 kg
– Bagasse (50-52% H_2O)	270 -290 kg
– Filter cake	28 – 40 kg
– Molasses	50 -60 kg

Source: ET4Thai

Prevailing Biomass energy production from rice husk

- Direct combustion in the large rice mills to generate heat.
- Roi Et Green Power Plant, located in Northeast region in Thailand.
- Pilot plant project of capacity 9.8 MW using rice husk.
- Plant itself uses 1 MW and the excess electricity demand after production, 8.8 MW, is sold.
- Steam produced at about 300°C, is further heated by a super-heater to raise its temperature to 400°C so as produce a high energy steam.
- Superheated steam is then used in a steam turbine to generate electricity.

Case studies (a) -Thailand

Roi Et Green Power Plant (Process)

Water from Shi River → **Water Treatment** → Water is heated in the economizer → **Boiler**

Heat (using waste energy *)

Heat (by burning rice husk)

Steam,300°C

Super heated Steam,400°C

Super heater → **Turbine** → **Generate electricity**

*Remark : *=Waste energy from the hot flue gas released after steam production in the boiler*

Case studies (b) –
Clean Thai Biogas Plant

Type: Biogas plant at cassava Processing facility

Size: 550 tons per day of cassava starch

Objective: To convert waste into methane to reduce heavy fuel oil and electricity consumption

Scale: Rural

Duration: 2001- 2002

Funding: Total US$ 1,850,000

Source: E+Co, www.energyhouse.com

Clean Thai Biogas Plant,

Operation:

Wastewater from cassava processing used for methane generation by anaerobic digestion.

Prior to this project:

Plant pays US$ 2,300,000 in electricity & US$ 2,200,000 for heavy oil

Performance:

Methane collection powered by four gas boilers

Methane generation from the anaerobic digester replaced 100% of its heavy oil needed & 75% of its electricity consumptions.

Source: E+Co, www.energyhouse.com

Biomass energy production from sugarcane bagasse

- Being one of the most efficient converters of solar energy into biomass
- As to March 2000, 14 of the 46 sugar factories in Thailand deliver electricity to the grid during the sugarcane crushing season, on average between 3-8 MW
- Today, the electricity generation capacity in most sugar mills is designed to cover the requirement of the mill only
- Sugar factories are one of the major industries which produce electricity as small power producers during the sugarcane season.

Dan Chang Bio Energy scheme, Thailand

Owner/Developer	Mitr Phol Sugar crop. Ltd.
Industry	Sugar
Location	Dan Chang, Thailand
Existing equipment	Mitr Phol has an existing cogeneration Plant (consisting of several old boilers and turbines, which covers the steam and power requirement of the sugar mill. Old system is able to export from 3 MW to 5 MW, excess electricity to EGAT during the milling operations.
New scheme	Several existing boilers and turbines will be replaced with two efficient high pressure boilers (2 x 120 tph, 68 bar, 510 °C) and one efficient extraction condensing turbine (41 MW gross)

Biomass energy production; Animal manure

- In the past, recovered and sold as a fertilizer or spread onto agricultural land
- Waste management concept and tighter environmental controls limits such acts and provides further incentives for waste-to-energy conversion.

- Several biogas projects have been supported by the ENCON Fund, such as the biogas from animal manure for power generation in livestock farms
- Local biogas generation technologies are already available for the anaerobic treatment of animal wastes, which result in the production of 30-40 % of the farms electricity requirements.

Biomass Conversion Technology from animal manure

- A common method of converting these waste materials is via anaerobic digestion
- Animal manure, mixed with water, which is stirred and warmed inside an air-tight container, known as a digester
- Digesters range in size from around 1m^3 for a small household unit to as large as 2000m^3 for a large commercial installation
- Product from anaerobic digestion is a 'biogas' that can be used as a fuel for internal combustion engines, to generate electricity from small gas turbines, burnt directly for cooking, or for space and water heating

Anaerobic Digester

Anaerobic Digester in Siripoon Farm, Thailand

Conclusion

- Biomass power is a major contribution to domestic energy needs and provides substantial environmental benefits.
- Technologies available both at the national and international level for the effective utilization of biomass should be used.
- There are enormous opportunities to promote the utilization of biomass and improve the efficiency.
- Biomass (Agricultural residues) serves as a promising option of renewable energy.
- Move forward towards a clean and secure energy source.

Thank you