

The EC - ASEAN Business Facilitator

Applicability of European Technologies in ASEAN Market



February 2004

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EC-ASEAN COGEN Programme (COGEN 3)

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The objective of COGEN 3 is to promote the use of proven, clean and efficient cogeneration using biomass, coal or gas as fuel. This is achieved through partnership between ASEAN industries and European equipment suppliers.

The programme is co-ordinated in ASEAN by the Asian Institute of Technology (AIT), Bangkok, Thailand and in Europe by Carl Bro International, Sweden. COGEN 3 started its operation in January 2002 and will continue until December 2004.

Disclaimer

The views expressed in this report are those of COGEN 3 and do not represent any official view of either the European Commission or the Association of Southeast Asian Nations. All information contained in this report has been researched and compiled from sources believed to be accurate and reliable at the time of publishing.

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Abbreviations

ASEAN	Association of Southeast Asian Nations
ASTM	American Society for Testing and Materials
BFB	Bubbling Fluidised Bed
BOD	Biochemical Oxygen Demand
CHP	Combined Heat and Power
CHPC	Combined Heat, Power and Cooling
COD	Chemical Oxygen Demand
CPC	Cogeneration of Power and Cooling
EFB	Empty Fruit Bunch
EU	European Union
FFB	Fresh Fruit Bunch
HRSG	Heat Recovery Steam Generator
MSW	Municipal Solid Waste
IPP	Independent Power Producer
kWh	kilo Watt Hour
LPG	Liquid Petroleum Gas
MJ/kg	millions of Joules per kilogram
mm	Millimetre
Mwe	Mega Watt –electric
PC	Pulverised Combustion
POME	Palm Oil Effluents
RDF	Refuse Derived Fuel
SPP	Small Power Producer
USD	American Dollar - \$

FOREWORD

Being an economic co-operation project, the EC-ASEAN COGEN Programme Phase III, (COGEN 3) aims at promoting cogeneration and facilitating business between European and ASEAN companies.

Cogeneration has been used for decades in various industries such as food processing, wood, textiles, pulp and paper, chemical, petrochemical industries etc. An increasing trend is seen in the applications of cogeneration in these industries but also in industrial estates and in buildings etc to cover the heat and/or cooling requirements. These sectors have high energy requirements and represent a large market for cogeneration technology.

This report on the applicability of European Technologies in the ASEAN industry context has been compiled with the intention of providing relevant information on market potentials for European equipment suppliers of cogeneration technology in ASEAN countries. This report would be regularly updated to incorporate the most recent and relevant information available.

It is the result of teamwork between COGEN 3 experts from Carl Bro International AB, Malmoe, Sweden and from the Asian Institute of Technology (AIT), Bangkok, Thailand. I would like to particularly thank those colleagues who have contributed to the preparation of the report.

We trust that you will find this report useful and look forward to receive your comments and suggestions.

Ludovic Lacrosse
Cogen 3 Co-ordinator.

1. Introduction

Cogeneration processes benefits industries in which uninterrupted availability of electrical power and steam without any significant fluctuation in voltage and frequency is essential for supporting their day-to-day operations. Cogeneration represents a method, which brings better utilisation of scarce and increasingly expensive fossil fuels or a possibility utilising wastes produced in the industry. The utilisation of wastes as fuel sources to produce energy in the industry illustrates the major benefits of cogeneration. In this context, cogeneration is the answer to effective management of wastes and it also represents a mechanism to an economical energy resource application.

The status with regard to cogeneration in the ASEAN region and also its future potential has been discussed in this report. The baseline is the various industries, many of which are found in the agricultural sector. The existing cogeneration equipment has been discussed and the types of equipment that have potential contributing to a more efficient use of the wastes have been suggested.

The report has been organised into three sections to represent 10 industries in a systematic way. After a brief introduction of the report in the first section, each industry and the wastes produced and the possibilities of using them as fuels for cogeneration are presented. Thereafter, section 3 gives a picture of possible cogeneration equipment for the different industries.

The description of the different industries is made in general terms. By providing the examples, the intention is to illustrate the potential and broadly cover the cogeneration process possibilities in the ASEAN region.

2. ASEAN industries with cogeneration potential.

1. The Sugar Industry

Bagasse is the fibrous residue delivered after the extraction of juice from sugarcane. It has been traditionally used as fuel to produce power and steam for internal consumption in the mills. Anaerobic treatment of sugar wastewater discharge can also yield biogas as a source of energy. Figure 1 outlines the energy requirements and raw material supply in sugar mills

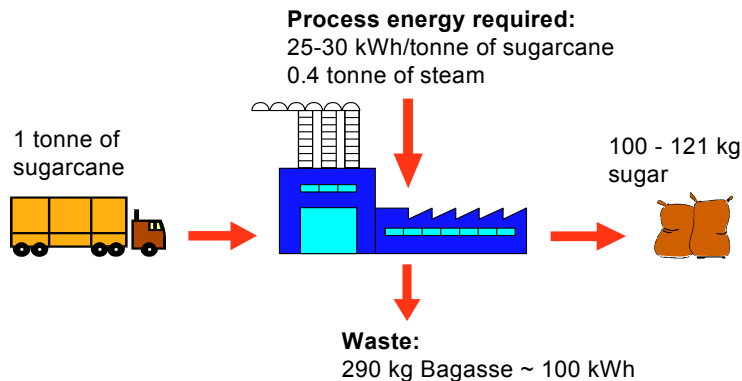


Figure 1: Energy requirement and supply in the sugar mills

Bagasse as fuel

Bagasse constitutes the cellular walls of the cane with most of the water-soluble elements, like alkali and chlorine, extracted and washed out in the process. Therefore, the remaining inorganic matter or ash will be comparatively low, 1-2 %, and at large constitute silica, aluminium and iron. For the same reason the resulting ash fusion temperatures (according to ASTM D 1857-87) will be relatively high. This is also indicated in equilibrium calculations simulating combustion, from which can be deduced that a critical share of fused ash is achieved at about 1200 °C. Vapors of alkali compounds, the most aggressive with sulphur and chlorine, which may condense on cooled tube surfaces, will be found in low concentrations.

Based on these properties it is expected that bagasse can be burned provided proper attention is paid to the fact that the moisture content normally would be around 50 %. The low ash content may restrict the use of traveling grates. However, with the fuel bed/primary zone combustion temperature being well controlled and kept below the critical ash fusion temperature level, traveling grates may still be a viable alternative. The low concentration of condensable vapors would indicate small to insignificant problems related to corrosion and deposits in the superheater section as well as in the convection parts.

Present status of equipment and technology

Cogeneration in most mills is still limited to outdated equipment using conventional steam thermal technology based on old cogeneration plants (20 to 50 years). The equipment comprise basic conventional low pressure boilers incorporating fixed grates or travelling grates with spreader stokers operating at 20-30 bar, 360 °C and less efficient back pressure turbines. More modern installations are operated at up to 40 bar steam pressure. Very few mills use extraction-condensing turbines. A sugar mill will normally operate a number of boilers connected to a common main in order to be able to meet varying process conditions. The combustion is characterized by high excess air (7 % O₂) and high flue gas temperature (250 °C). In combination with the high moisture content of the fuel, it results in a considerable flue gas loss and consequently low boiler efficiency, in the order of 75 %. Industrial plants, not having SPP (Small Power Producer) status, being operated at the lower end of the above

steam admission data span show an overall electric power efficiency of about 10 % only. This is based on the portion of the steam used for running the backpressure turbines. However most of the live steam is used for mechanical drive and (after being reduced) as process steam. The power-to-heat ratio is about 0.1-0.12. The above may reflect that bagasse has been abundant and for free. This situation is changing.

Potential for new technology

Given the state of the timeworn equipment installed and the fact that bagasse is regarded a valuable and primary fuel resource, it is suggested that cogeneration configuration of high pressure and high temperature capacity boilers is employed. The favourable fuel properties of bagasse not only allow for advanced steam admission data but also for high boiler efficiencies, which combined promise high overall efficiencies. A distinct advantage with such systems is efficient energy production using less quantity of fuel. An upgrading of steam pressure to 40 bar is and has been under way (see above), but further upgrading is possible, first of all to 60 bar, 480°C combined with extraction condensing turbines. Different modification options related to the industrial process exist. One of them constitutes development and construction of entirely new core power plants based on single high pressure boilers and turbo generator systems. Already a few sugar mills have entered upon this course. With boilers designed and operated for high boiler efficiencies overall efficiencies of about 25 % can be obtained. With the power-to-heat ratio increasing to 0.3-0.33 a surplus of electricity is created for export to the grid.

From a techno/economical point of view the steam admission data referred to will probably be close to optimum. From a true technical standpoint, fully utilizing the favorable fuel properties of bagasse, further improvement of efficiency would seem possible going for steam admission data of 120 bar, 480-500 °C. It can be questioned though, if the marginal benefit of such an expansion will pay off, considering the expense moving upwards in the pressure class and superheater material charts.

An indication of the size of the plants is given by the statistics concerning SPP plants in Thailand currently in operation. About 30 plants (a few practicing co-combustion is not included) generate in total about 550 MW, i.e. the medium sized plant will generate about 20 MW. With the fuel quantities available and a development like the one indicated above this figure could reach about 30 MW.

Core Equipment Required

- High pressure boiler (over 60 bar, 480 °C)
- Turbo-generator (extraction-condensing, back pressure and condensing turbine)
- Biogas generation plant
- Gas engine

Applicable EU Technology

- Steam thermal system (boiler + turbo-generator)
- Biogas generation system and gas engine (if biogas potential is good)

Countries with Potential for Cogeneration within the Sugar Industry

- Thailand
- Indonesia
- Philippines
- Vietnam.

2. The Palm Oil Industry

In this industry as much as 70% of the fresh fruit bunches (FFB) are turned into wastes in the form of empty fruit bunches (EFB), fibres and shells plus 600-700 kg of liquid effluent (POME) per tonne of FFB. Based on effluent standards the liquid effluent generates a pollution load of BOD 27 kg, COD 52 kg, suspended solids 13 kg plus oil and grease 8 kg/t. The solid residues are used as fuels to generate power and steam and the effluents are treated to produce biogas primarily for generation of power in gas engine gensets. Figure 2 outlines the energy requirements and raw material supply in palm oil mills.

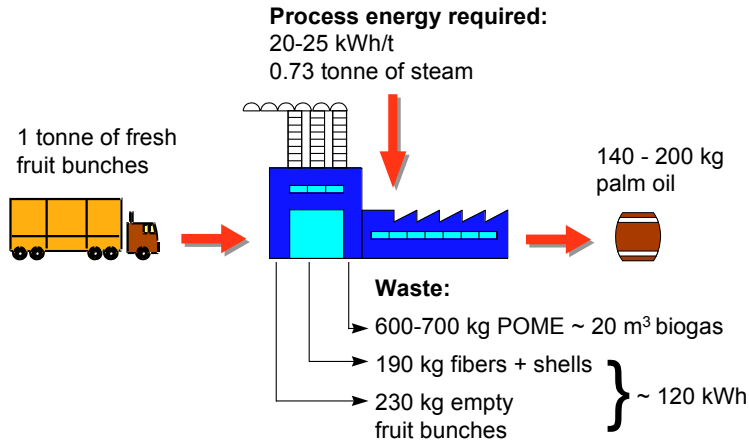


Figure 2: Energy requirement and supply in the palm oil industry

Palm oil factories have traditionally been designed to provide their own energy (process heat and electricity) by utilising diesel gensets and turbo-generators. However, more efficient energy conversion technologies that utilise the palm oil residues such as EFB, fibres and shell, which yield considerable quantities of electricity, are currently promoted in the energy markets. Thus, palm oil factories have the potential of generating large amounts of electricity using their own residues and extra power generated can be exported to the national grid.

Most palm oil mills generate combined heat and power from fibres and shells, making them energy self-sufficient. However, the use of palm oil residues could still be optimised. Most of the palm oil mills operate old cogeneration plants (20 to 50 years), using low pressure boilers at 20 to 30 bar and less efficient back pressure turbines.

Palm oil residues as fuel

Palm oil solid residues comprise shell, fibre and empty bunches (EFB). Proximate analyses indicate ash contents of about 4 %. The moisture content is in the 10 - 15 % interval for shells and about 40 % for fibre and EFB. As indicated from their handling properties and how these residues are used today, they represent from good over reasonable to difficult fuels in the same order. Considering shell and fibre the difference has resulted in that shell can be sold as a prime fuel, whilst fibre is kept and used in the industry. However, based on chemical analysis and fuel ash properties per se, combustion properties overall disregarded, the above ranking should be shifted. Like bagasse, shell and fibre develop critical shares of fused ash at about 1200 °C. In the actual applications palm shell will probably show a “more” critical behavior due to a considerably higher share of fused ash preceded by a distinct increase at this temperature. This would indicate that problems could occur on grates should not proper precautions be taken. Problems related to deposits and corrosion further downstream in the furnace and in the convection pass cannot be ignored with either fuel, though it's not of immediate concern.

EFB on the other hand is known to give rise to deposits and corrosion problems. The concentration of vapors in the flue gas capable of condensing on cold boiler surfaces will be high due to very high contents of alkali, especially potassium, and chlorine. The latter corresponds to levels seen in Refuse Derived Fuel (RDF) or, considering the moisture content of 35-40 %, even Municipal Solid Waste (MSW). The content of fused ash will also be high. Already at about 700 °C the ash starts to melt and at about 950 °C the share of fused ash will reach a critical level and then again increase sharply beyond approx 1030 °C. This is due to high concentrations of different low melting silica alkali (potassium) compounds. It is obvious that EFB will require great attention and a particular boiler design – a concept similar to what is required when burning MSW is probably necessary.

Present status of equipment and technology

Heat and power demand in the palm oil industry is generally met operating low-pressure horizontal fixed grate three pass boilers of simple design at 20-25 bar, saturated steam (220° C) or maximum 250-300° C, with backpressure turbines. The industry is essentially energy self-sufficient using fibers and shells, however if possible, production is kept up with fibers only to be able sell the shells, since they are in demand as a premium biomass fuel. Hitherto no doubt, steam demand has been given priority over electricity production and certainly, producing electricity for export to the grid has come further down the list. This situation seems to stem from the fact that there is no condensate return from the sterilizers - this unrecovered steam represents about 60 % of the steam demand of the process – and therefore investment in water treatment for more advanced turbine operation has not paid off. The softened only, i.e. not demineralized, water does not allow for advanced steam data.

Burning fibre requires that slag deposits, which can grow to a thickness of up to 1 meter in the furnace, must be removed every third to fourth week. The second and third passes of the boiler does not have this kind of problem. The deposits are normally loose and friable and can easily be removed by soot blowing, many boilers are equipped with e.g. sonic systems. The boilers are operated with high excess air (7+ % O₂) and flue gas temperature (300+ °C), which combined with the relatively high fiber moisture content of 35-40 % results in boiler efficiencies of about 75 % only. The overall electric power efficiency of these plants, based on the portion of steam used for running the backpressure turbines, will be about 5 %. The power-to-heat ratio is in the range of 0,05-0,06.

EFB is not known to have been used successfully as a single fuel so far. Some mills, mainly in Malaysia and Thailand, are testing co-combustion of EFB and fibre on a more or less regular basis. It seems as if this is practiced using the existing boilers or new units of the same type designed for fibre only. Deposit problems have been reported in one case requiring redesign of the tube bank interspacing. In other cases it is reported, that boilers being tested with a “high” share of EFB in the fuel mix have had to be cleansed from clinker and slag at an increased frequency, from every second to third week. This has not discouraged other palm oil millers in the ASEAN region. During 2003 two boilers firing EFB solely have been commissioned and at least one more will be so during 2004. It is not known in detail what type of boiler technology is being used in these cases.

Potential for new technology

Self-sufficiency in the palm oil industry is achieved by using simple technology and a “straight-forward” cogeneration system set up based upon the demands of the industry core process. With regard to steam it can be characterized as a once through process. The ultimate solution from efficiency point of view would be to apply and construct a fully integrated plant, i.e. closing the steam/condensate cycle such that all condensate is recirculated and reused. A prerequisite is that the sterilizer condensate return shows a quality making extensive water treatment unnecessary. If it appears that more treatment of the sterilizer condensate return would be required than of the raw water supply it may not be practical to recover this steam. If on the other hand the steam/condensate system can be closed (circulating water to fulfill conventional quality criteria regarding hardness and silica concentration) a cogeneration plant with high efficiency can be designed and constructed. Based on an increased use of fuel

jacking up the total steam capability and utilizing this for surplus electricity production, an overall efficiency of about 18-20 % can be achieved. The power-to-heat ratio improves to 0.35-0.40. These figures are based on steam admission data of 40 bar, 400 °C and boiler efficiencies of about 87 %. The latter requires that combustion be far better controlled than in the current units. The steam admission data are about the maximum possible considering the fuel and fuel ash properties.

The boiler and combustion equipment for fibre may be based on vibrating or slightly sloped reciprocating grates provided that combustion temperature is controlled preventing sinters be formed on the grate. The feeding system can probably be based on today's solutions with spreader-like devices injecting the fibers into the boiler by means of directed air.

For EFB a concept or systems designs similar to what is required when burning MSW, i.e. a class of fuels with high moisture contents, low ash fusion temperatures and corrosive ash properties, has been discussed as a solution. Important design elements is a moving grate tilting the fuel to complete the burnout and prevent large scale sinter formation and a boiler pass without tube bundles preceding the convection pass(es) and the superheater section where the flue gas temperature is reduced principally by radiation to about 600 °C. The concept has been introduced to minimize superheater corrosion. Further reduction of this risk is achieved by the use of advanced materials and moderate steam admission data, normally limited to 40-60 bar, 400-420 °C in the MSW applications.

A medium to large size plant will process about 1000 tonne FFB/day (45 tonne/h) in one production line. For each tonne of FFB about 190 kg of fibre and shell is generated according to figure 2. These are the wastes that are used today. This will qualify for about 25 MW supplied fuel, in today's plants turned into 1.5 MW electric (based on the portion of steam that is used for running the back pressure turbine). In updated plants the power production will be about 5 MW electric. If the additional 230 kg of EFB were to be used the potential in the same sized industry is about 11 MW electric.

Core Equipment Required

- High pressure boiler for cogeneration plant 40-60 bar, 400-420 °C fibre and EFB alike.
- Steam turbogenerators (extraction-condensing or back pressure condensing)
- Biogas generation plant
- Gas engine
- Fuel handling system.

Applicable EU Technology:

- Steam thermal system (boiler + turbo-generator), typically 1 – 20 MWe
- Biogas generation system and gas engine (if biogas potential is good)

Countries with Potential for Cogeneration within the Palm Oil Industry

- Malaysia
- Indonesia
- Thailand
- Cambodia.

3. The Rice Industry

De-husking of paddy produces a large amount of rice-husk as solid residue. This rice-husk can be used as a fuel source for power generation by cogeneration. A typical rice-husk process consists of cleaning, hulling, milling and polishing. The milling of rice removes the bran from the husk and comprises two distinctive methods yielding white rice or par-boiled rice.

Energy consumption patterns in rice mills vary, depending on whether the mill is a par-boiled rice mill or white rice mill. The former consumes more energy than the latter due to the energy requirements for milling as well as for parboiling. Simple milling may require 30 kWh/tonne of paddy, while milling of par-boiled rice requires up to about 60 kWh/tonne of paddy. Par-boiled rice processing requires an additional process of steaming prior to milling the rice husk. Figure 3 outlines the energy requirement and raw material supply in rice mills.

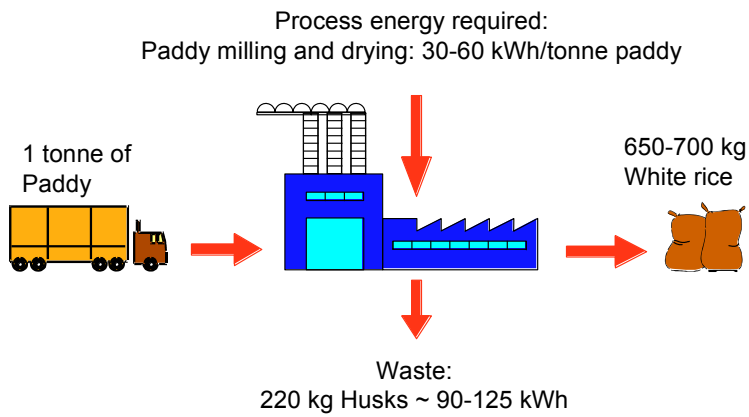


Figure 3: Energy requirement and supply in the rice industry

In contrast to the sugar and palm oil mills, the rice mills in the ASEAN countries have very few installations of cogeneration systems. As rice is a staple food and also the fact that rice is a widely exported agricultural commodity in this region, cogeneration systems with configuration of medium pressure boilers (over 30 bar, 360 °C) and efficient extraction condensing turbines seem to meet the challenges posed by rice husk disposal. The sale of ash produced during the combustion of rice-husk can yield revenues of up to 100 USD/ton for prime quality amorphous silica ash furthering the promotion of such systems.

Rice husk as fuel

Rice husk has a calorific value of around 12 MJ/kg, which is low, considering its origin as a biomass residue and low moisture content of 10-12 %. The reason is the high ash content of approximately 20 %. This ash is to 90-95 % made up of silica oxide, a fact that positively conduces to favourable ash properties. The critical share of fused ash is reached only beyond 1500 °C, which means that rice husk can be fired in most types of equipment without problems related to clinker formation and slagging.

However, there is one aspect worthwhile addressing. It relates to combustion of loose rice husk based on technology that now seems to have reached a state of standard, i.e. spreader stoker combustion. The combined effect of the comparatively slow burning rate using this technique and the thermo-chemical properties of the husk reduce the reactivity of the remaining char. To offset this property and e.g. meet the burnout standards related to requirements on unburnt carbon of the ash to be able turn it into a salable product, the suppliers prescribe operation at high air excess levels. Some suppliers using this technique have also focused on extended retention time.

Present status of equipment and technology

The potential for European technology primarily is in projects of reasonable size and/or where efficiency comes high on the list. This is not to say that other sized projects should be considered insignificant or irrelevant. Below follows a short recapitulation of the various plant schemes that can be found in the rice industry in ASEAN region today.

There are plants still being commissioned based on very unsophisticated combustion/boiler technology for generation of 10 bar saturated steam feeding steam engines for mechanical drive of the mills. The overall efficiency is on the order of 5 %. This used to be the standard technology before (simple) gasification technology came into the picture. Both gasifiers and engines (standardized 250 kW engines), for the most part of Chinese make, operate in the efficiency range of 10-12 % overall.

The true interest for upgraded technology with efficient Rankine cycles is found among larger mill sizes than the small to medium sized mills operating e.g. gasifiers, and in Thailand for example also among those that can acquire SPP status. Installed power in the larger industrial plants and SPP plants cover a range from about 5 to 20 MW. Many units from the lower end to about 10 MW are based on spreader stokers and traveling grates with steam conditions typically 40 bar, 400 °C. As indicated above the overall efficiencies are limited to below 20 %, part of which can be attributed to low boiler (combustion) efficiencies in the range 84-85 %. This is due to high excess air plus high flue gas temperatures.

Some units in the upper end of the size interval are operating at higher efficiencies based on more advanced steam data. Reference can here also be made to plants that are still in the tendering phase (Feb 2004), in some of which European suppliers offer alternative technologies like bubbling fluidised bed (BFB) and pulverized combustion (PC) at live steam data of 60 bar, 450 °C. Based on those schemes one can expect overall net efficiencies of 24-27 % and boiler (combustion) efficiencies of 88-92 % depending on technology.

Potential for new technology

With the above-mentioned projects the focus towards more advanced technology and improved efficiency has begun. This concerns mainly power only production. Though the need for cogeneration using efficient extraction condensing turbines is limited to parboil units, there is some potential related to industrial parks. In order to further increase power export to the grids even higher live steam admission data, 100-120 bar and 480-500 °C should be possible, taking full technical advantage of the favourable properties of rice husk.

One aspect that has to be addressed concerning alternative combustion techniques is the significance of meeting the requirements with regard to burnout of the ash, i.e. less than 5 % unburnt carbon in ash, to be able sell it to steelworks. The revenue potential from sale of ash meeting these requirements is up to 100 USD/ton for prime quality amorphous silica ash. With 20 % ash this represents 100 % of the value of the fuel prized at 20 USD/ton. This needs to be addressed and included in the calculations with regard to alternatives. With BFB, which can be operated at higher boiler efficiency due to less excess air still meeting the unburnt carbon in ash requirement (more efficient combustion in the fluid bed), this advantage, i.e. using less fuel for a given output, has to balance the fact that the (amorphous) silica ash cannot be sold due to dilution and contamination with spent bed sand. With regard to pulverized combustion (PC), which also can be operated at higher efficiency for the same reason (though improved burnout in this case can be attributed to reduced size and increased reactivity of the char), the use of less fuel for a given output has to balance the investment in pulverizing equipment.

In small-scale applications, in this context represented by e.g. a medium sized rice mill with a capacity of 150 tonne paddy/day the power demand will be up to 200 kW with an installed capacity of about 300 kW. Based on a husk generation of some 30 tonne/day the power production will be 600-700 kW in a steam thermal process based on an oven/boiler concept operating at up to approx 23 bar, 300-400 °C. The overall efficiency, in the order of 15 %, is

about 50 % higher than that of the present gasifier/engine technology. The separate oven and boiler concept, where the boiler is of the fire tube type having a maximum operating pressure of approx 23 bar, is, as it seems, the only concept that currently have a chance to be competitive. In a somewhat longer term the competitiveness with the combustion/steam turbine concept vis-à-vis the current gasification technology is likely to improve due to definitive advantages concerning environmental issues – gasifiers give rise to substantial water pollution and generate toxic solid wastes.

Core Equipment Required

- High pressure boiler for cogeneration plant above 10 MWe (60 bar, 450 °C up to 100-120 bar, 480-500 °C)
- Medium pressure boiler for cogeneration plant less than 10 MWe (40 bar, 400 °C)
- Low pressure oven/boiler for cogeneration plant less than 2 MWe (25 bar, 300-400 °C)
- Fuel handling system
- Extraction-condensing steam turbine
- Condensing steam turbine
- Generator

Applicable EU Technology

- Steam thermal system (boiler or oven/boiler + turbo-generator) 2 – 20 MW electricity

Countries with Potential for Cogeneration within the Rice Industry

- Thailand
- Vietnam
- Philippines
- Malaysia
- Cambodia.

4. The Wood Industry

Within the scope of this report wood industry is restricted to saw mills and plywood mills. These industries generate large amounts of waste, up to 50% of the raw material, which constitute bark, chips, shavings, off-cuts and sawdust, etc. Of this only about 10 % is used by the mills as fuel in drying processes and to a lesser extent for turbine operation. In general, following the technical standard and type of production, the demand of energy in the mills varies widely. In general it is conceived that mills can meet both their electrical as well as thermal energy demand by using the waste. Cogeneration schemes are of particular interest in isolated regions, which lack any connections to the national grid.

The Sawmills

Sawmills are classified as softwood sawmills and hardwood sawmills. Most softwood sawmills dry the wood products before selling them. The drying is carried out, in the kilns fuelled usually by the mill residues. The hardwood saw mills usually sell their products green, i.e. without drying, however the secondary manufacturers, e.g. furniture industry, buy the mill residues along with the wood to fire their kilns for drying purposes. Figure 4.1 outlines energy requirement with regard to electricity plus steam and raw material supply in sawmills.

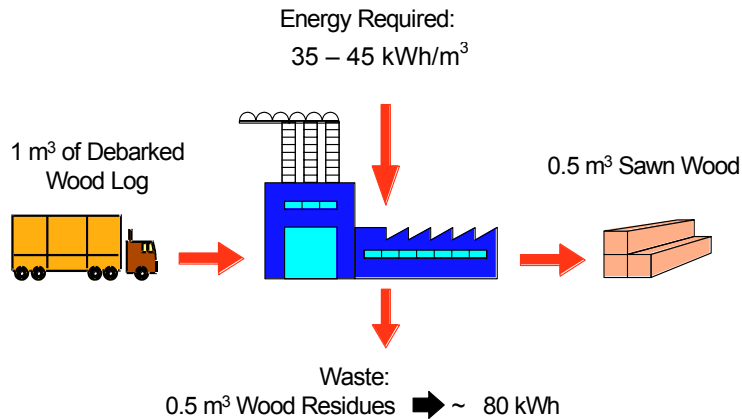


Figure 4.1: Energy requirement and supply at the saw mills

The Plywood Mills

Plywood is manufactured based on veneer sheets, which are glued together in multiple layers. The veneer itself is a thin (0.3 mm to 6.0 mm) sheet of debarked wood sliced very finely. About 50% of the raw material is turned into residue, which does not imply that all of this is available as fuel source for cogeneration. Plywood mill residues are used as raw material in the pulp and paper industry but also as fuel in boilers and drying kilns. Figure 4.2 outlines energy requirement with regard to electricity plus steam and raw material supply in ply mills.

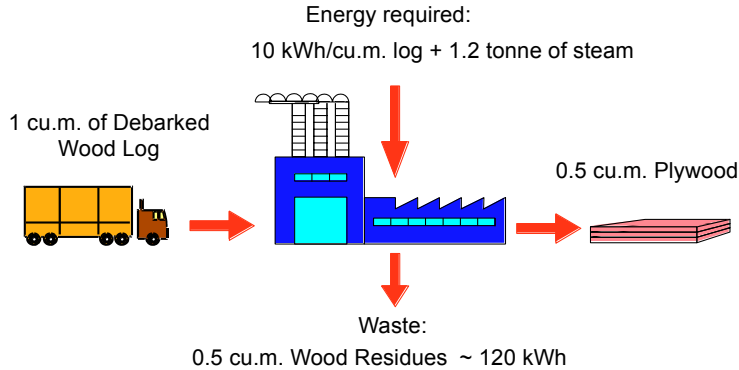


Figure 4.2: Energy requirement and supply at the plywood mills

Wood as fuel

Wood fuel is normally considered easy to burn. However a distinction has to be made between bark and white (barked) wood. Bark normally has higher ash content with a lower ash fusion temperature compared to ash from white wood. In some parts of the ASEAN region wood may be synonymous with parawood, which, contrary to other wood species, as a fuel needs some consideration with regard to choice of technology and operation. While fuels based on hardwood for the most part can be categorized as “easy-to-burn fuels, parawood reaches a critical temperature related to fused ash already at approximately 900 °C. The proportion of fused to solid ash stays relatively constant or even drops in some temperature intervals. Still, good combustion control is called for and the technology applied should favor the fuel be burned in a comparatively thin bed/layer to prevent ash from melting in high temperature zones. As far as condensable vapors is concerned there is a potential for deposits formed in the convection parts of a boiler. These will probably be friable, more like dust, and easy to remove. This is based on the probability that the high concentration of calcium and magnesium compounds will offset that of potassium. The contents of both chlorine and sulphur are low.

Present status of equipment and technology

In general the current technology for combustion and heat recovery within the industry is very basic and for the most part based on generation of saturated steam at low pressure for drying purposes. Very few power/cogeneration plants with backpressure or extraction condensing turbines have been implemented. The plants may comprise refractory lined ovens connected to 3-pass fire tube boilers. Sometimes the ovens have water tubes arranged along the inner walls and in the ceiling.

Some saw mills burn sawdust in BFB boilers of simple/unsophisticated design. To overcome problems with high moisture content of the sawdust during the rainy season some plants can arrange for co-combustion with coal.

Potential for new technology

Within this industry there is a good potential for up-to-date Rankine cycles incorporating modern and efficient boilers and extraction condensing turbines. A division could be considered such that reasonably sized mills are limited to medium pressure boilers operating at 25-40 bar, 400 °C, whilst even larger mills ought to be able to invest in systems with further enhanced steam admission data, preferably to 40-60 bar, 440-460 °C. The final choice of steam admission data, particularly steam temperature, fitting the last group, will have to be decided upon the type of wood being fired. Irrespective of size the plant configuration should

be adapted to a situation making best use of the waste for combined heat and power production where surplus electric power is exported to the grid.

Boiler concepts based on vibrating grates, sloped reciprocating grates or underfeed grates may very well, with regard to smaller units, incorporate separate ovens followed by fire tube boilers up to 25 bar pressure level, while higher pressure require water tube boilers. Larger units from some defined size and upwards, for BFB's from 5 MWe and up, will normally constitute fully integrated solutions. For wood waste fuels with low to moderate ash content travelling grates are not fully accepted due to the fact they rely on an ash layer for protection of the grate.

Fluidised bed combustion, preferably BFB, with operating temperatures of 800-850 °C would seem an appropriate technique for para wood based on the low ash fusion temperature. This would however require frequent change of bed material. The high concentrations of calcium and potassium in the ash together with the silica of the (sand) bed will otherwise result in formation of low melting compounds (eutectics), which may cause bed sintering.

For saw mills requiring from some hundred kilowatts to around 1 MW the combination of gasification and gas engine ought to be a viable alternative compared to steam thermal systems. Though European suppliers will have difficulties to compete with the small scale gasification technology for wood, which has been developed in e.g. India, they will be able to compete with regard to gas engines in those applications. The electric power efficiency in the wood gasification systems are in the order of 25-30 %. This is more than double the efficiency that can be achieved with steam thermal systems of this size. The basis is gasification and gas engine efficiencies of 80-85 % and 30-35 % respectively. The exhaust heat can be retrieved either as thermal energy in the form of low pressure steam in a heat recovery steam generator (HRSG) for process purposes or be directly used in a hot gas dryer for drying of cut wood (chips) to the gasifier.

Core Equipment Required

- High pressure boiler for cogeneration plant above 10 MWe (over 40-60 bar, 440-460°C)
- Medium pressure boiler for cogeneration plant less than 10 MWe (over 25-40 bar, 400°C)
- Fuel handling system
- Extraction-condensing steam turbine
- Condensing steam turbine
- Generator

Applicable EU Technology

- Steam turbine system (boiler + turbo-generator) typically > 1 MWe

Countries with Potential for Cogeneration within the Wood Industry

- Indonesia
- Malaysia
- Thailand
- Vietnam
- Philippines (Mindanao Region)

5. The Pulp and Paper Industry

Pulp and paper mills around the world use cogeneration to generate steam at different pressures and temperatures. Steam is required for multiple purposes ranging from thermal treatment (cooking) of chips in the digesters over concentration of black liquor (spent pulping liquor) in multiple effect evaporators to drying of paper in paper machines. All black liquor and most mill residues, generated in the pulp and paper processing, are used at the mill sites to fuel the cogeneration systems providing steam and electricity for on-site use. Below a division has been made in the pulping and papermaking processes.

The Pulping Process

Pulping is the chemical process by which the cellulose and hemi cellulose fibres preferably in wood, but other fibrous materials can be used, are separated from lignin and treated to produce pulp. The wood or non-wood raw materials can be transformed into pulp slurry by either the chemical process indicated or by a mechanical process. The chemical process is based on cooking wood (chips) in digesters whereby black liquor is generated as a by-product. It contains dissolved lignin and inorganic cooking chemicals from the pulping operation. Today, black liquor is processed in chemical recovery boilers to regenerate the chemicals and recover the energy as steam and electric power. The mechanical pulping process by which the wood is ground in mill grinders requires a lot of electricity, making the selection of the right kind of fuels for producing electricity, if done in the industry at all, an imperative to cost-effective and environmentally safe production. Normally electricity for the mechanical pulping process is supplied from the power grid. Water and energy consumption in the pulping processes is higher than in the actual paper making process. Figure 5.1 outlines the energy requirement with regard to electricity plus steam and raw material supply in the pulp process.

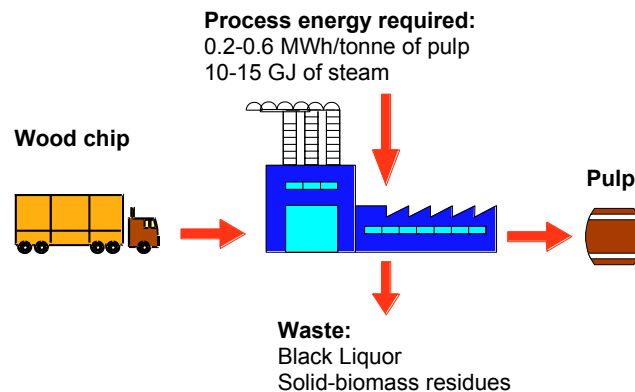


Figure 5.1: Energy requirement and supply in the pulp processing

The Papermaking Process

Paper production involves preparing the stock from pulp, forming a sheet, dewatering and drying, and sometimes coating the paper. All paper machines have three basic sections: the wet, the press, and the drying section respectively. Figure 5.2 outlines the energy requirement with regard to electricity plus steam and raw material supply in papermaking.

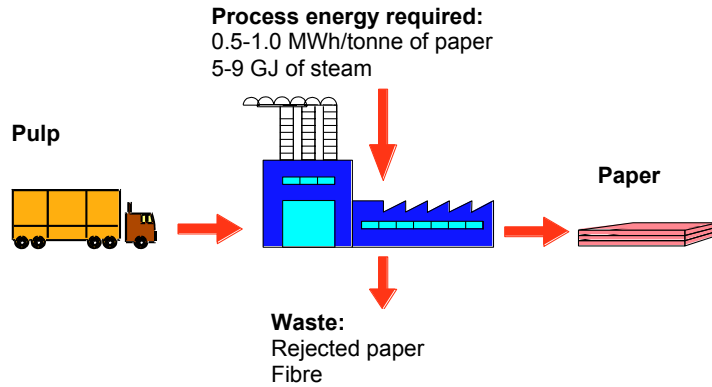


Figure 5.2: Energy requirement and supply in the papermaking process

Fuel Options

- Biomass (black liquor and wood wastes)
- Coal
- Fuel oil
- Natural gas.

Core Equipment Required

- High pressure Boilers (Power and/or recovery boilers)
- Extraction condensing turbine
- Back pressure turbine
- Generator
- Fuel handling system.

Applicable EU Technology

- Steam turbine system (Boiler + turbo-generator)
- Gas turbine system (Gas turbine + HRSG)
- Typically 10 – 50 MW electricity.

Countries with Potential for Cogeneration within the Pulp and Paper Industry

- Indonesia
- Malaysia
- Thailand
- Vietnam

6. The Cement Industry

The cement sector is an energy-intensive industry. It is estimated that the cost of energy consumed represents 20-30% of total cement production costs. The cement production process requires two types of energy: electricity and thermal energy. In most cement industries, electricity is supplied from the power grid, and burning coal, fuel oil or natural gas provides for thermal energy.

The specific energy consumption varies from factory to factory, depending on the type of the technological process employed (wet, semi-wet, dry or semi-dry process). The average energy consumption at the cement plants around the world is presented in Table 6.1. Many cement industries in ASEAN countries, often use old obsolete equipment and operate with much less recirculation of chemicals and energy, leading to a much higher consumption of fuel, raw material and electricity than their industrialised countries' counterparts.

Table 6.1: Specific Energy Consumption in Cement Factories

Process	Thermal energy (GJ/ton clinker)	Electricity (kWh/ton cement)
Wet process	5.02 – 5.43	70 – 125
Semi-wet process	3.15 – 3.86	70 – 125
Dry process	2.88 – 3.40	110 – 125
Semi-dry process	3.10 – 3.50	110 – 125

Figure 6.1 outlines the energy requirement with regard to electricity plus steam and raw material supply in the cement industry.

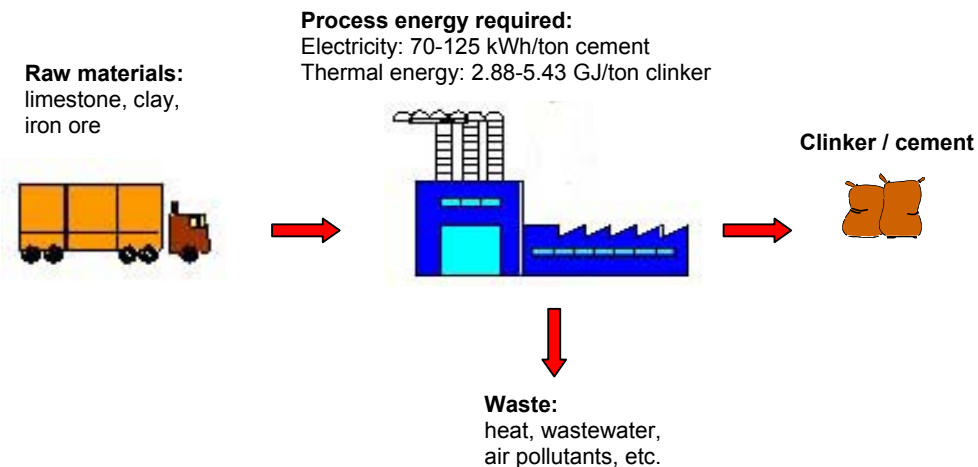


Figure 6.1: Energy requirement and supply in the cement industry (Wet Process)

Fuel Options

- Coal
- Fuel oil
- Natural gas.

These fuels represent the primary fuels. The consumption of them can be reduced by increased recycling/reuse of waste heat, which is available in the form of:

- Preheater /calcinator exhaust gas (280 – 600 °C)

- Clinker cooler exhaust gas (150 – 400 °C)
- Kiln exhaust gas (700 – 1,200 °C)
- Hot air from clinker cooler (700 – 900 °C)

The figure 6.2 is a schematic of the sub-processes making up the overall cement process. The main flows including waste heat streams have been indicated.

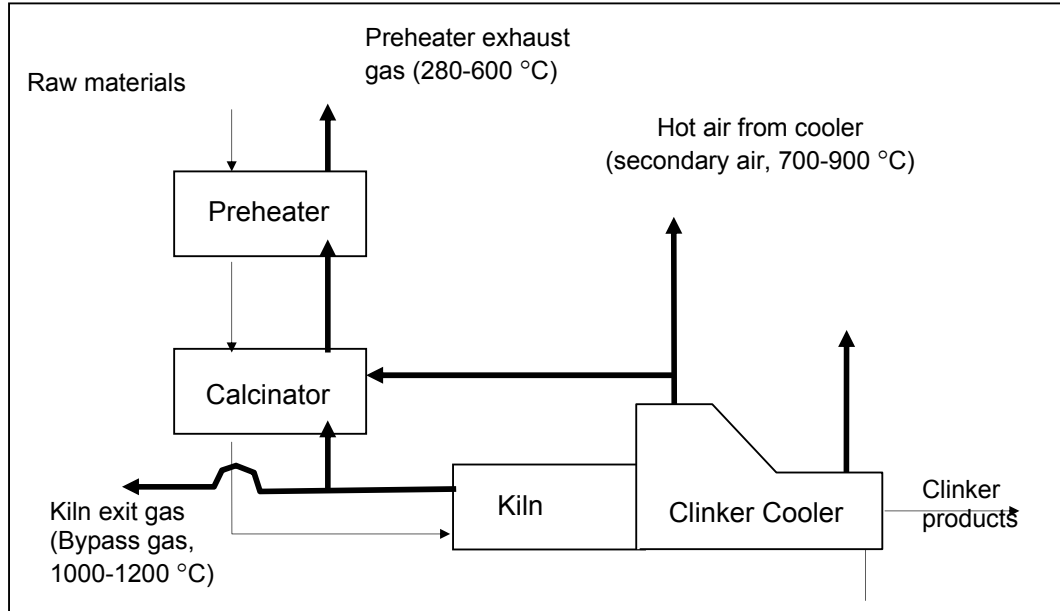


Figure 6.2: Availability of waste heat at different temperature levels

The high temperature waste heat can be reused in the cement production process. The kiln exhaust gas is primarily utilised for pre-drying and preheating the raw materials before their introduction into the kiln. The hot air from clinker cooler is used to preheat combustion air and also to dry and preheat the raw materials.

Promoting cogeneration to utilise waste heat resulting from high temperature sintering processes is an attractive proposition, although this is a fairly new phenomenon in the cement industry particularly in ASEAN countries. Cogeneration from this waste heat has to compete with the purpose of drying the raw materials inside a cement industry. Depending on the temperatures of the exhaust gas, the steam Rankine cycle or even the organic Rankine cycle, though the latter probably is disqualified due to a prohibitive price tag, best qualifies for power generation process. In some cases, the supplementary fuel firing can be used in heat recovery steam generator (HRSG) in order to increase the efficiency of waste heat utilisation.

Core Equipment Required

- Heat recovery steam generator (with or without supplementary fuel firing)
- Organic vapour boiler
- Steam turbine
- Steam engine
- Organic vapour expander
- Generator

Applicable EU Technology

- Steam turbine or Steam engine systems (HRSG + steam turbo- or engine with generator)
- Organic Rankine bottoming cycle (Organic vapour boiler + turbo-generator)

Countries with Potential for Cogeneration within the Cement Industry

- Thailand
- Vietnam
- Indonesia
- Philippines
- Malaysian
- Cambodia.

7. The Petrochemical Industry

In the petrochemical industry, the major processes can be categorised into refinery process and petrochemical process. The crude oils are the primary raw materials during the refinery process while the raw material for petrochemical process is natural gas.

In a petrochemical complex, there are three main processes:

1. The Upstream process is the first step of the petrochemical process and is carried out normally in the gas separation plant. The activity is to separate the natural gas to produce 2 main products, ethane and propane also producing by-products in form of propane & butane (LPG) and methane (fuel gas).
2. An Intermediate process converts the products of the upstream process, ethane and propane to ethylene and propylene.
3. In the Downstream process ethylene and propylene are used as raw materials and are converted to other products as per the industry requirements.

Most petrochemical companies in the ASEAN region are involved in the production of plastic monomers and other downstream products. Given the nature of the processing involved, the amount of heat and electrical energy consumption in each facility is relatively large. A constant and reliable electricity supply is required in all of these processes.

To determine the appropriate cogeneration technologies to be implemented for petrochemical plants, the power to steam ratio should be established first. It has been observed that most plants can only use the topping cycle cogeneration in their plants. Figure 7 outlines the energy requirement with regard to electricity plus steam and raw material supply in the petrochemical industry.

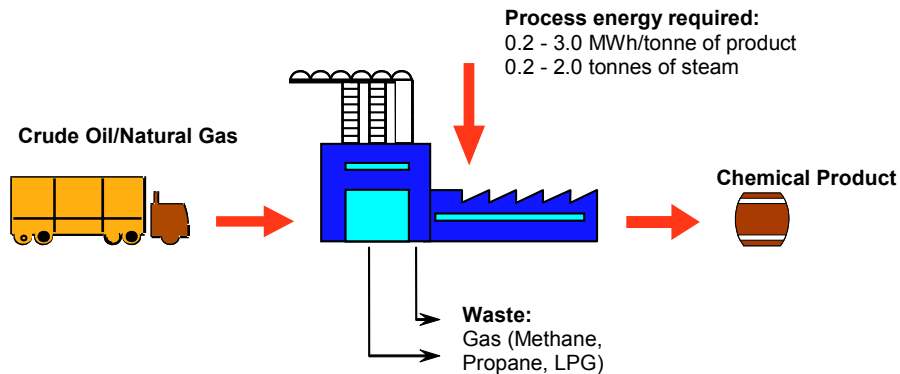


Figure 7: Energy requirement and supply in the petrochemical processing industry

Fuel Options

- Crude oil
- Fuel oil
- Natural gas

Core Equipment Required

- High pressure boiler
- Extraction condensing turbine
- Back pressure turbine
- Generator
- Gas turbine
- Gas engine
- Heat recovery steam generator (HRSG)
- Fuel handling systems

Applicable EU Technology

- Steam turbine system (Boiler + turbo-generator)
- Gas engine system (Gas engine + HRSG)
- Gas turbine system (Gas turbine + HRSG)

Countries with Potential for Cogeneration in Petrochemicals Industry

- Indonesia
- Thailand
- Singapore
- Malaysia.

8. The Food Industry

The food industry sector includes all food-related manufacturing industries. Energy is consumed during multi-process stages in distinctive equipment like gas-fired ovens, dryers, steam boilers, electrical motors, refrigeration equipment, ventilation and air-conditioning systems. The energy requirements in food industries can be understood either in terms of the total energy consumption or the energy intensity. The high energy consumption food industries are wet corn milling, meat packing, beet sugar, malt beverages, soybean oil milling, canned fruit, vegetable, bread and cake, fluid milk, food preparations and cane sugar refining. Within this group, they can be further classified as energy-intensive or energy-extensive. Agriculture processing, packaging, transportation, storage, merchandising and preparation of food are typically of more energy intensive operations.

The processing of food products includes processing/ manufacturing end products, food preservation processes, packaging and storage. The limited shelf life of the raw materials and finished products makes it imperative to have energy-intensive strict temperature control during the entire sequences of food production, packaging and storage. Storing and preserving operations require freezing and drying of raw materials and finished goods. Drying uses fossil fuels. Older industries still use less efficient obsolete equipment leading to higher energy consumption.

The estimated energy consumption during various food processing is as described below:

- The process of heating uses approximately 29% of total energy in the food industry
- The process of cooling and refrigeration demands about 16% of total energy inputs.
- The non-processes, including facility heating, ventilation, refrigeration, lighting, facility support, onsite transportation, and conventional electricity generation utilizes 8 % of the total energy requirements.

Newer systems are designed with recirculation dampers and thermal energy recovery equipment to cut energy consumption up to 40%.

Types of Energy Sources Used in the Food Industry

Natural gas, fuel oil including, biogas produced from process residues, coke and coal form the fleet of energy supplies in the food industry. Cogeneration is said to have a wide scope when the process residues/wastes are utilised as renewable energy resources for fuelling cogeneration systems. These resources can be utilised for heat (hot water/steam) production, which leads to that heat extraction for heating purposes can be lessened. In turn the power-to-heat ratio can be increased. Figure 8 outlines the principal flow of material and energy in a generic food industry.

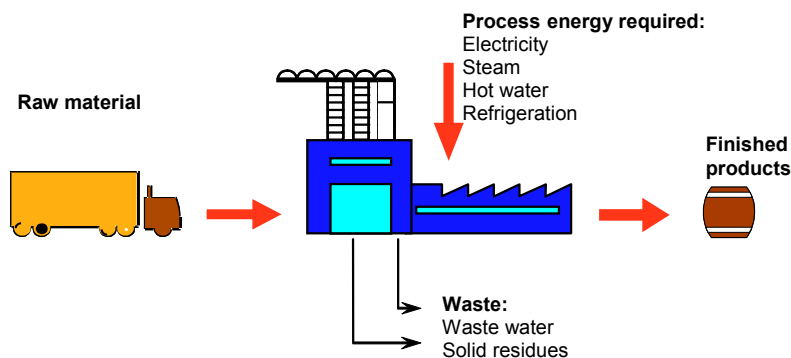


Figure 8: Energy requirement and supply in the food processing industry

Cogeneration in food the industry

The use of cogeneration in the food industry has generally been confined to the processing of bulk commodities where highly energy-intensive operations are required, such in the beet sugar processing, corn (wet milling) and cane sugar processing and refining industries.

Core Equipment Required

- Steam boiler
- Steam turbine
- Generator
- Steam engine
- Gas turbine
- Gas engine
- Heat recovery steam generator (HRSG)
- Heat exchanger
- Air compressors
- Chillers and pumps
- Cooling tower fans and pumps
- Electricity demand management system and Anaerobic biogas systems

Applicable EU Technology

- Steam turbine or steam engine systems (Boiler + turbo or engine with generator)
- Gas turbine or Gas engine systems
 - Cogeneration of heat and power
 - Trigeneration of heat, power and refrigeration

Countries with Potential for Cogeneration within the Food Industry

- Indonesia
- Malaysia
- Thailand
- Singapore
- Vietnam

9. The Textile Industry

The manufacturing stages of textile products are elaborate and time consuming. There is a large amount of energy in the form of electricity and steam required while processing the materials in the textile industry. Based on the raw material used, the textile industry can be classified into:

1- Wovens

- *Raw materials* can be natural fibres like cotton, silk to synthetic fibres like polyester, acrylic fibres and etc.
- *Process*: Spinning to get yarns, starching/sizing of yarns before mounting to looms for weaving, weaving or knitting, fabric scouring, bleaching, dyeing and finishing of fabrics. Except for the actual spinning and weaving operations, all other processes need large amount of steam

The Temperature requirements:

Table 9.1: Specific Temperature Requirements in the Textiles Industries.

Process	Typical Temperature Requirements
Desizing	90 ⁰ C to 120 ⁰ C- depending on the fabric material and chemical used for sizing.
Scouring and Bleaching	55 ⁰ C to 60 ⁰ C
Dyeing	120 ⁰ C to 130 ⁰ C
Printing	160 ⁰ C to 190 ⁰ C
Temperature Setting	200 ⁰ C to 240 ⁰ C
Mechanical Finishing	80 ⁰ C to 120 ⁰ C
Drying	Natural fibre fabric – 40 ⁰ C to 60 ⁰ C Synthetic fibre fabric – typically 20 ⁰ C to 30 ⁰ C below the melting point of the fibre.

2- Non-Wovens

- *Raw materials* are usually synthetic staple fibres.
- *Process*: The fibres cut to a specific length called as staple fibres are bonded at high temperature to get continuous sheets of material and these sheets are further temperature-set to get the desired properties and finishing. End-use of non-wovens dictates such kind of temperature finishing.

Temperature around 400⁰ C to 550⁰ C is required for the high temperature bonding of fibres process.

3- Industrials Fabrics

- *Raw materials* consists of high strength and high tensile materials like nylon (used in tyre- threads), polyesters and Kevlar
- *Process*: The raw materials are set at high temperatures for optimising the desired level of strength and agility due to the end use nature of the products.

Temperature requirement varies depending on the raw material used and the specific property desired from the product depending on its end use. Since most of the time, synthetic raw materials like nylon, polyester, Kevlar and carbon material, typically the temperature requirement is very high.

From this classification, it can be concluded that the textile industry is an energy intensive industry and the cogeneration option is well suited for serving the purposes of providing the high demand steam as well as electricity. Figure 9 outlines the principal flow of material and energy in a generic textile industry.

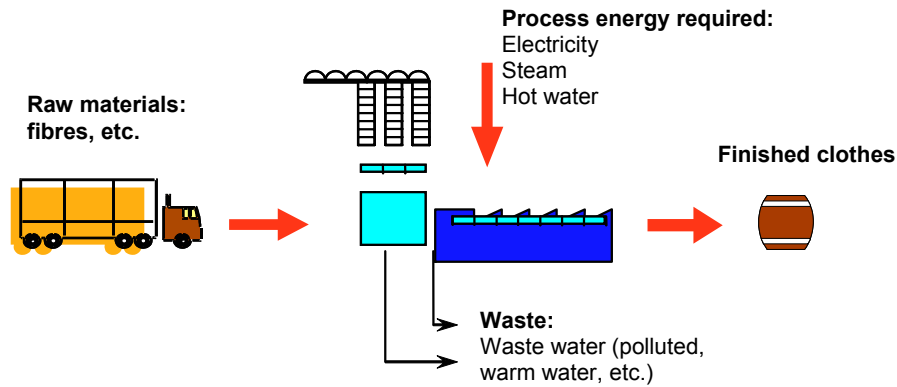


Figure 9: Energy requirement and supply in the textile industry

Fuel options:

- Natural gas
- coal
- Heavy fuel oil.

Core Equipment Required

- Boiler
- Steam turbine (back pressure, extracting-condensing)
- Steam engine
- Gas turbine
- Gas / diesel engine
- Heat recovery steam generator (HRSG)
- Fuel handling system

Applicable EU Technology

- Typically 1 – 20 MW
- Steam turbine cogeneration
- Gas turbine cogeneration
- Gas / diesel engine cogeneration
- Combined cycle cogeneration (>30 MW)

Countries with Potential for Cogeneration within the Textile Industry

- Indonesia
- Thailand
- Malaysia
- Vietnam

10. Cogeneration for Buildings

Commercial buildings typically use three types of energy: thermal energy (usually in form of hot water), cooling, and electricity. Within ASEAN countries, hot water and cooling are produced by using resistance water heaters and electric air-conditioners respectively.

Due to the potential benefits, cogeneration and trigeneration are starting to be promoted within the ASEAN countries. Besides these limited promotions, the popularity of cogeneration installations are expected to be at a low.

At present, there are three cogeneration systems, which can be used for commercial buildings:

1. Cogeneration of heat and power (CHP) - Internal combustion engines or gas turbines normally using gas or diesel oil as fuel to produce electricity. The rejected heat from both the water cooling jackets and the stack will be recovered by heat exchanger(s) to generate the thermal energy.
2. Cogeneration of power and cooling (CPC) - In this system, the rejected heat from engines or turbines will be recovered to produce thermal energy (steam/superheated water). The produced thermal energy is the heat source for the absorption chiller(s) to generate cold water in cooling applications.
3. Trigeneration of heat, power and cooling (CHPC) - In this system, besides the cooling produced by absorption chiller(s), the produced thermal energy (steam/superheated water) will be used to generate hot water by using a heat exchanger.

Figure 10 outlines the principal flow of resources and energy in a generic building.

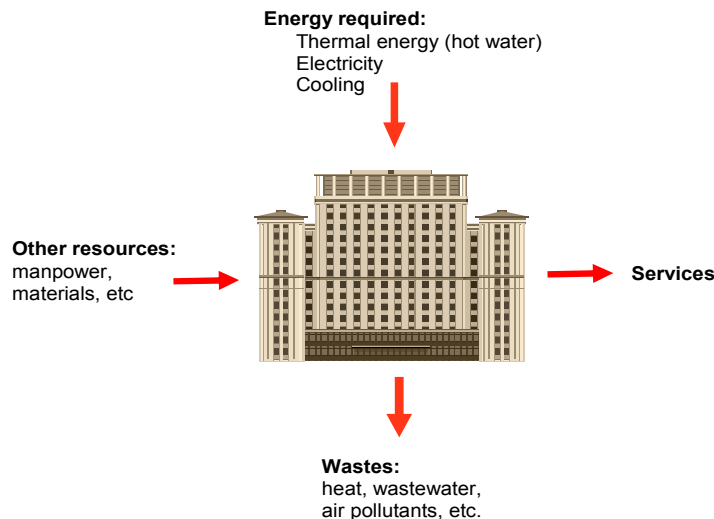


Figure 10: Energy requirement and supply in the buildings

Core Equipment Required

- Gas engine
- Gas turbine
- Micro turbine
- Heat recovery steam generator (HRSG)
- Absorption chiller (absorption refrigerator, absorption air-conditioner)

Applicable EU Technology

- Gas engine and gas turbine systems for
 - Cogeneration of heat and power (CHP)
 - Cogeneration of power and cooling (CPC)
 - Trigeneration of heat, power and cooling (CHPC)

3. Possible Cogeneration Equipment for the Different Industrial Sectors

Industry	Steam boiler			Prime mover				Others			
	Biomass-fired	Coal-fired	Gas-fired	Steam turbine	Steam engine	Gas turbine	Gas engine	HRSG	Heat exchanger	Absorption Chiller	Biogas Generation System
Sugar	•			•	•		•				•
Palm oil	•			•	•		•				•
Rice	•			•	•						
Wood	•			•	•						
Pulp & Paper	•	•	•	•		•		•			
Cement				•				•			
Chemicals & Petrochemicals		•	•	•		•	•	•			
Food		•	•	•	•	•	•	•	•	•	•
Textiles		•	•	•	•	•	•	•	•		
Commercial Enterprise						•	•	•	•	•	

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