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Pilot Appraisal for low-carbon technology innovation and diffusion in the Thai manufacturing sector

Working Paper

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Chapter 1: Introduction

1.1. Background, objective and scope

To enable developing countries reduce greenhouse gas emissions, and move towards a low carbon society, it is important to

- formulate policies that promote renewable energy and energy efficiency,
- create innovative financial mechanisms that accelerate the promotion of low carbon and greener technologies,
- strengthen institutions and create human resources that foster innovation and implementation of cleaner technologies, and
- facilitate transfer of technology that spur the transition to a low carbon economy

This, however, requires locally appropriate and environmentally sound low carbon technology (LCTs) projects to assist the developing countries. In this context, a study was carried out to evalaute the potential for such centers and networks to initiate, catalyze and accelerate the development, deployment and dissemination of low carbon technologies in the manufacturing sectors in Thailand. It is expected that this exercise would lead to:

- Greater awareness of the potential for utilizing existing technology and innovation related centers for development, deployment and dissemination of low carbon technologies
- Identification of key activities required to effectively engage existing centers and networks into the global effort to up-scale and speed up the development, deployment and dissemination of low carbon technologies.

1.2. Sector selection and status

The energy demand of Thailand was 65,890 ktoe in 2008, an increase of 1.56% from 2007 while the Thai economy expanded by 2.6% during the same period. The total energy consumption of Thailand in 2008 was contributed by manufacturing sector (36.7%), transportation sector (35.1%), residential sector (15.1%), commercial sector (7.5%), agricultural sector (5.2%) and construction sector (0.2%). The manufacturing sector in Thailand has the highest energy consumption, and the highest emissions (45 Mt of carbon dioxide) in 2008. Among the manufacturing sectors, the key sectors are food and beverages, non metallic (including construction materials), metallic and pulp and paper. Of the 36,249,100 people employed in the Thailand, about 5,619,200 people were employed in the manufacturing sector. For the pilot appraisal study, the two manufacturing sectors which are pulp and paper, and cement industries were selected as these they contribute to employment, export earnings and are also energy intensive

Pulp and paper sector: The total export by this sector in 2006 was 1,071,000 tons and the industry's export earnings are about Baht 15 billion. In terms of energy consumption, the pulp and paper industry uses mainly coal for power and steam generation, while integrated mills are using dissolved lignin (black liquor) as a fuel. The energy efficiency could be improved, as some mills are old and not energy efficient. The sector employs about 30-50,000 people involved in the production of and sale of pulp and paper, corrugated paper board, etc.

Cement sector: The cement sector had export earnings of more than Baht 18 billion in 2005 with a total production of nearly 79 million tons. The specific energy consumption in the cement sector varies from about 3.54 to 6.68 GJ/ton, which amounts to an estimated consumption of 3,990 ktoe, thereby contributing to emissions of 14.5 million tons of carbon dioxide. Coal, lignite and biomass are the major primary energy sources. Thailand manufactures white cement, grey cement, Portland cement, ready mix concrete, etc.

1.3. Activities and methodology for the pilot appraisal study

The report presents:

(a) Summary of status of technology use in two selected manufacturing sectors and quantities of greenhouse gas (GHG) emission
(b) Opportunities for application of low carbon technologies, practices and systems in the selected sectors and the potential reductions of GHG emissions achievable with the low carbon technologies, practices and systems identified for the selected sectors
(c) A 3-5 year plan of activities for the further development, deployment and dissemination of the identified low carbon technologies, practices and systems in the selected sectors
    a. taking into consideration the gaps in human and/or institutional capacity to undertake implementation of these activities required for the development, deployment and dissemination of the low carbon technologies, practices and systems in the selected sectors, and
    b. lessons from the pilot appraisal that should be considered when setting up Low Carbon Technology Innovation and Diffusion Centres (LCTIDCs).

The pilot appraisal study was carried out through:

- Literature review,
- Conduction of workshop for interaction with industry personnel, ministry and other institutions (NGOs)
- Data collection through survey on "Identification and implementation of low carbon technologies in each sector" and "Promotion of LCTs in each sector"
- Data analysis and report writing

The report is organized as follows:

- Chapter 2 and 3 presents the following in detail focusing on pulp and paper and the cement sector
    - Sector status
        - Trend of Global production
        - Current status of Thailand production and projections
        - Type of Industries and outputs
        - Major manufacturers in Thailand
        - Description of production process
    - Energy use
    - Specific energy consumption
        - Fuel choices
        - GHGs emissions status
    - Barriers for the promotion of low carbon technologies and the potential

- Chapter 4 presents an analysis of the Low carbon Technology Innovation and Diffusion center (LCTIDC) in terms of
    - Need, role and activities of the proposed LCTIDC in Thailand
    - Suggested time frame of activities of the Center

Chapter 2: Pulp and Paper Industry

2.1. Overview

2.1.1. Trend of global pulp and paper production

The world demand for paper and paperboard continues to grow at an average growth rate of 2.2 % per annum. The increase in demand of paper and paper board are mainly due to industrial growth, increase of media awareness and literacy rate in the developing countries such as India, China, Vietnam, Indonesia, and Thailand. It is estimated that the demand for paper and paper board will reach around 450 Mt by the year 2015. Globally, as demand for recovered paper is more, its procurement and supply is becoming more difficult. So, there will be an increase in need of hardwood fiber in the paper sector.

The global consumption of industrial round wood is mainly procured from fast-growing plantations. The area of land used for cultivation and production of round wood was 76 Mha in 2000 which is expected to increase to 88 Mha in 2015. The required incremental hardwood for consumption is expected to come from mixed tropical hardwood plus acacia and eucalyptus plantations. The main focus will shift towards countries like Brazil, Indonesia, Russia and China who will be the major producers and suppliers of the hard wood chips as well as dried pulp to the mill.

The price of recovered paper such as old news print and old corrugated container board (OCC) trends appears to increase indicating that the awareness of paper collection is rising which can be estimated to reach around 50% by 2010. Asian countries will make continuous demand for paper making fiber, whereas part of the fiber will be substituted by recovered paper in the region. The forecast is that the bulk of incremental fiber needs will be provided by recovered paper i.e. around 90 Mt by the year of 2015 (Source: Kuusisto, 2004.)

Thus, though wood pulp is still the most important paper making raw material, recovered paper continuously increases its share of the today's total global pulp requirement which is about 48%. This will drive the focus towards Asian countries whose contribution in global production is 45%. Asian countries will face challenges such as raw material shortage, increasing energy costs and pollution abatement issues. The other major challenges are supply of raw materials such as pulp, recovered paper and chemicals.

2.1.2 Status of Thailand pulp and paper sector and projections

Globally, Thailand holds the twentieth position in the pulp and paper sector and is one of the major producers of pulp, paper and paper board amongst the other developing countries in the region. Thailand has a pulp production capacity of 1.2 Mt with a utilization rate of 94% of which exports is around 0.19 Mt of pulp to other countries. The major pulp export destinations were China, South Korea, Taiwan, Indonesia and Vietnam. The change pattern in the consumption of short fibers is due to the lesser use of imported long fiber pulp from Canada, Sweden and United States of America. The estimated consumption of domestic pulp grew by 2% p.a in line with the growth of printing and writing paper industries. It is estimated that the demand of pulp required by industries would reach around 1.4 Mt in the year 2013.

Thailand has a paper and paperboard production capacity of around 4.9 Mt, whereas the actual paper and paperboard production was 4.2 Mt with a capacity utilization rate of 87%. In 2008, the consumption of paper and paperboard was 3.5 Mt, a reduction of 2% from the previous year due to the reduced consumption of specific paper grades such as newsprint paper, writing and printing paper. The actual per capita consumption of paper and paper board was 55 kg. The paper and paper boards were mainly exported to South Korea, Taiwan, and Hong Kong as well as to other South East Asian countries which are around 1.1 Mt, and marginally dropped by 5%.

In 2008, the trend shows that the increase in collection rate of recovered paper was 12% which accounts for a total volume of 2.1 Mt. Besides, the consumption of recovered paper was 3.3 Mt, an increase by 22% from the previous year. Awareness on creating friendly environment, rising cost of energy and virgin fiber prices has motivated the use of recycled pulp thus boosting the trend of recovered paper consumption. The import of recovered paper was 1.22 Mt which is higher compared to previous year by 20%. The major grades that were imported into the country were old corrugated carton (OCC), mixed waste, old newspaper respectively. The estimated recovered paper consumption is expected to grow by 3% p.a.(Source: TPPIA, 2008)

2.2. Pulp and paper industry in Thailand

The pulp and paper sector in Thailand consists of 44 mills of which six are integrated pulp and paper mill while the others are mainly recovered paper based kraft paper, tissue paper and packaging board mill. All the paper and paper board mill are spread across the country, though most of the mills are located in the central region. The total capacity to produce pulp is around 0.25 Mt. The country's major production of hard wood pulp is mainly from eucalyptus plantations with a production capacity of 1.1 Mt whereas non wood based bleached bagasse pulp plant capacity is only 0.1 Mt.

Thai paper sector is solely dependent on recovered paper because its major paper production grades are Kraft liner, tissue and container board which is almost 70%. These recovered paper based paper mill mainly consumes the purchased power, steam and fuel oil for their process use. The integrated paper mill in the country uses biomass, such as bark from wood as a fuel, which is partially used in the production of energy and steam.

2.2.1. Type of Industries

The pulp and paper industries can be categorized by the type of process and various grade of paper produced. The Thai pulp and paper industry can be classified as:

Types of Mill	**Raw material/ paper produced**
Integrated Pulp and paper mill	(wood /free fine paper)
Integrated Pulp mill	(wood /Bleached market pulp)
Non integrated Paper mill	(Writing and printing paper)
Non integrated RCF based unbleached Kraft paper mill	(Recovered corrugated waste paper)
Non integrated RCF based news print mill	(Old news print waste paper)
Non integrated RCF based tissue mill.	(Recovered office waste paper)

The country's major production is Kraft paper which accounts for 62%, and is mainly used in the packaging sector as packaging material. The next paper grade is writing and printing paper mainly used as copier paper, printing process (23%). The paper board production is 9%. The country has only one non integrated recovered fiber based news print mill which serves the media sector and accounts for 3%, while the deficit amount of paper board is imported.

2.2.2. Major pulp manufacturers

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The major pulp producers in the country are Advanced Agro Ltd and Siam Cement Group which has subsidiaries of 22 paper mill. The others are Panjapol Paper Co Ltd., Phoenix Pulp and Paper, and Environmental Pulp and Paper Co Ltd. (EPPCO). Table 2.1 presents the list of integrated pulp and paper mill in Thailand. These mills mainly use plantation hard wood as their raw material where as EPPCO mill uses bagasse only. The total capacity of pulp production is shared mainly by these six mills.

Table 2.1: Major integrated pulp and paper mills in Thailand

Name of the Company	Actual Capacity (Mt)	Raw material use /Grade produced
1.Advance Agro limited	0.560	Eucalyptus (Bleached Hardwood)
2.Phoenix Pulp and Paper	0.235	Eucalyptus, Bamboo, Acacia,(BKP)
3.Panjapol Pulp Industry	0.110	Eucalyptus (unbleached H W pulp)
4.SCG Paper	0.105	Eucalyptus, BCTMP and UBHWP
5.Siam Cellulose	0.086	Eucalyptus (Bleached Hard wood pulp)
6.Environment Pulp and Paper	0.100	Bagasse (Bleached pulp)
Total	**1.196**	

2.2.3 Grade wise pulp and paper output and utilization rates

Table 2.2 presents the overall figures on type of product output, grade produced with their respective capacity and actual production. The country's main pulp production is based on hardwood, whereas soft wood pulp is mainly imported.

Table 2.2: Production and capacity utilization of pulp and paper manufacture in Thailand (Source: FAO 2008-2013)

Total pulp capacity of Thailand	Actual production in 2008	Design capacity					Capacity utilization (%)	
		2007	2008	2009	2010	2011	Thailand	World
	1000 Air Dry MT per year							
Wood pulp for paper and paper board	1025	991	991	991	991	991	103	-
Semi- chem. pulp(non coniferous)	62	58	58	58	58	58	107	81
Un- bleached Kraft pulp	85	110	110	110	110	110	85	111
Bleached sulphate and soda (non-coniferous)	963	823	823	823	823	823	117	58
Pulp from other fiber	104	155	155	155	155	155	67	-
Bagasse pulp	59	100	100	100	100	100	59	81
Bamboo pulp	45	45	45	45	45	45	100	26
Others	0	10	10	10	10	10	42	74
	1000 Air Dry MT per year							
Market pulp	384	360	360	360	360	360	-	-
	1000 Air Dry MT per year							
Paper and paper board	4324	5173	5173	5173	5173	5173	84	-
News print	130	135	135	135	135	135	96	81
Writing and printing paper	21	1271	1271	1271	1271	1271	96	58
House hold sanitary paper	118	136	136	136	136	136	87	58
Liner board	886	1255	1255	1255	1255	1255	71	79

Fluting medium	1646	1715	1715	1715	1715	1715	96	51
Kraft wrapping paper	84	313	313	313	313	313	27	69
Recovered fiber based folding box board	239	348	348	348	348	348	69	61

Thailand's main challenge will be procurement of recovered paper for its own paper production because Asian countries excluding Japan have poor collection rate of paper when compared to developed countries (it is less by 20%). In the Asian region, the consumption of recovered paper will increase due to few new installations of non integrated type of paper mills.

2.3 Energy consumption in the pulp and paper mill

Pulp and paper production is highly energy intensive with 75-85% of the energy being used for process heat and the remaining for electrical power (15-25%). These two energy requirements qualifies for the use of co-generation (low pressure steam for process heat and high pressure steam for electricity generation). The total final energy used in Asian countries generated of their internal sources comprises only 30- 45% when compared to 60-70% in developed countries (Mohanty, 1997). Chinese rural paper mills use about 23 GJ/t of primary energy. Average primary energy use for paper and paperboard making in China, including pulping, is 45 GJ/t.

Table 2.3 shows the grade wise total energy and types of fuel consumed by pulp and paper industries of Thailand is 2,058 ktoe in which power accounts for 401 ktoe and heat energy of 1,657 ktoe in the year 2006.

Table 2.3: Comparison of fuel distribution for different grades of paper (Source: TPPIA,2006)

Different grade	Type of fuel						
	Coal %	**Bunker oil %**	**Diesel %**	**Bark %**	**Saw dust%**	**LPG %**	**Black Liquor %**
Bleached pulp	29.44	6.80	0.02	0.0031	0.94	-	62.79
Kraft paper	72.08	20.90	0.04	6.07	0.90	-	-
Duplex board	69.73	22.65	-	-	7.63	-	-
Writing paper	40.71	16.88	-	34.06	8.35	-	-
Newsprint	-	100	-	-	-	-	-
Tissue paper	6.31	73.07	-	-	-	20.6	-
Packaging board	-	100	-	-	-	-	-

The energy consumption of various processes in the pulp and paper mill are presented in the Appendix A.

2.4.1 Energy use in kraft and fine paper mill

Chemical pulping plants are energy-intensive installations that consume high amounts of energy but at the same time produces steam and electrical power on site. Furthermore, secondary energy from different process steps can be recovered as warm and hot water (40-80^{o}C). A large modern chemical pulp mill is self-sufficient in energy terms, using only biomass and delivering surplus electricity to the grid. Such a mill typically has a steam consumption of 10.4 GJ/ADMT (Air dry ton pulp) and excess of electricity production of 2 GJ/ADMT. The electricity use for stock preparation depends on the paper type and may vary from 600-1200 kWh/t.

Despite rising energy prices, energy consumption in the paper industry has increased over time. This is mainly due to declining rates of capacity utilization in running plants, increases in the production of specialty papers, shortages of paper, coal, inadequate and unsuitable supply of raw materials. Table 2.4 shows energy consumption of different types of pulp and Paper mill.

Table 2.4: Comparison of electricity/heat consumption by different types of paper mills (Source: DEDE, 2007).

Type of paper mill	European mill		Thailand paper mill	
	Electricity [kWh/t]	Thermal (GJ/t)	Electricity [kWh/t]	Thermal (GJ/t)
Newsprint	500-650	4-6.5	850	4.6
Uncoated Wood free	500-650	5.0-7.1	625	6.7
Kraft paper	550	6-6.5	640	5.8
Tissue and specialty paper	500-3000	7.5-12.0	1820	9.3
Box board	550	5.8	780	6.9
Note: All the data are calculated by actual consumption of energy or heat / actual production for the month. The data consists for group of paper factory (52 Nos.) in Thailand. The data for EU is from European commission 2001.				

2.4.2 GHG emissions from pulp and paper mill

Among the pollution problems associated with pulp and paper industry are consumption of wood, oil for production of energy and steam, which is used in drying process. To make one ton of paper about 2.5t of wood raw materials is required. The dry bark from wood and lignin in black liquor are used as solid fuels/ liquid fuels. These fuels prodcue mainly air pollution as well as particulate matter. The gases from the recovery boiler, lime kilns and auxiliary boiler are generally identified as CO, CO_2 and NO_x. The release of sulfur as a pollutant is very small in quantity which depends on the recovery efficiency to collect salt cake in the recovery boiler and sulfur oxides are absorbed in the lime kiln process.

The green house gas (GHG) emissions can be classified into direct emission and indirect emissions where direct emissions are “emissions from combustion of fossil fuel in boiler, combined heat power plant and infra red dryer equipment” whereas indirect emissions is termed as “purchased electricity on heat from external source”. The GHG emission by Thailand’s manufacturing industries as equivalent of CO_2 emissions is around 214 Mt, of which the pulp and paper industries emit about 20.5 Mt. The direct emission of Thai pulp and paper industries excluding bio mass component is around 980 kg of CO_2 eq/t of product, whereas indirect emission is 180 kg of CO_2 eq/t of product (Source : Kuenen. and Bosch, 2009).

The Thai kraft pulp mill releases total carbon emission from stages of harvesting to paper production is equivalent to 2.9 Mt of CO_2 eq/yr. The major source of carbon emissions from a kraft fine paper mill are mainly from biomass combustion, lime kiln operations is around 65% and 30%. The second source of carbon emission is mainly from bunker oil use, recovery boiler, bleaching line and waste water plant. Table 2.5 presents the process wise GHG emissions of Kraft pulp mill.

Table 2.5: Process wise GHG emissions from Kraft pulp mill (Source: Warit jawjit,2006).

Process	CO_2 (1000 t) CO_2 eq/yr	CH_4 (1000 t) CO_2 eq/yr	NO_x (1000 t) CO_2 eq/yr	Total (1000 t) CO_2 eq/yr
Bio mass combustion	1898	10.87	21.40	1930
Lime kiln operation	867.10	0	0	867.1
Bunker oil use	70.92	38	170	71.13
Recovery boiler operation	3.67	0	0	3.67
Waste water	6.06	1.39	1.38	8.83
Sub Total	**2845.75**	**50.26**	**192.78**	**2880.73**

The typical integrated fine pulp and paper mill with best available technologies (BAT) production process emits 3kg of CO_2 equivalent per kilogram of paper produced. A comparison of GHG emissions for Thai non-integrated mills and integrated mechanical pulp and paper mills are shown in Table 2.6.

Table 2.6: Average GHG emissions from different types of pulp and paper mills

Parameters	News print mill	Integrated kraft and fine mill	Integrated fine mill	Non integrated Kraft paper mill
CO_2 Direct ton/ton	0.35	0.83	0.96	NA
CO_2 Indirect t /t	0.46	0.1	0.27	NA
Power MWh/t	0.86	0.95	0.77	0.47
Heat GJ/t	4.5	14.4	13.2	6.0
Land fill				
Hazardous waste kg/t	0.01	0.4	0.35	0.01
Non Hazardous waste kg /t	200	250	210	200
Air Emission				
NO_x g/t	1280	1361	800	1754
SO_x g/ t	2580	1600	1100	2730
PM g/t	500	700	210	600
Note: The above mentioned data are populated from Thai Paper mill (SCG, Norkge skog) sustainability report 2008.				

The wastewater flow is based on the assumption that cooling water and other clean water are discharged separately. The parameters that are measured for control of emission to water are treated water flow, chemical oxygen demand (COD), biological oxygen demand (BOD), total dissolved solids (TDS) and total nitrogen and phosphorus. These values refer to integrated mills i.e. recovered paper processing and paper making is carried out at the same site. For bleached, recycled paper and unbleached Kraft pulp mills the BAT emission levels to water that are associated are shown in Table 2.7.

Table 2.7: Emissions to water from different pulp and paper mills with BAT standards

BAT standards				Emissions to water		
Parameters	**Bleached pulp**	**Unbleached pulp**	**Integrated Mechanical mill**	**Bleached pulp**	**Unbleached pulp**	**Integrated Mechanical mill**
Flow m^3/t	30 - 50	15 - 25	15-20	**22-25**	**14**	**8**
COD kg/t	8-23	5-10	10-20	**7-10**	**3.5**	**11**
BOD kg/t	0.3-1.5	0.2-0.7	0.5-1.0	**0.2-0.6**	**0.3**	**1**
TSS kg/t	0.6-1.5	0.3-1.0	0.5-1.0	**0.6-1.0**	**0.54**	**1**
AOX kg/t	< 0.25	-	-	**0.05**	**-**	**-**

The technical potential to reduce energy use in the paper industry can be around 30% or more have been identified in various countries, with cost-effective potentials of at least 15 to 20%. The potential and opportunities to reduce carbon emission from Thai pulp and paper sector from current level is about 10-15%. However, the use of best available technologies will save energy in the pulp and paper industries and the most promising energy savings technologies are black-liquor gasification, Bio refining, Ligno boost technology and advanced drying technologies which are listed in Table 2.8. The GHG equivalent emissions that can be reduced are approximately 2 Mt/yr.

2.5 Barriers in adapting best available technologies

The barriers to adapt available or new technologies were identified by arranging a consultative stake holder meeting, distribution of survey questionnaire and feedback from pulp and paper sector. The participants were mainly from the Ministry of industry, equipment supplier, energy consultants, and operational managers from pulp and paper mills. The feedback regarding barriers in adapting available technologies is elaborated below.

2.5.1 Investment in technology

The pulp and paper mill is highly capital intensive and fully utilized plants life cycle period is around 20-25 years. Most pulp and paper mill management avoid large investments as the return on investment (ROI) is not very much attractive (less than 10%). The important aspects considered for investment are direct contribution to process or product improvement and projects with short payback time. There is lack of motivation for investing in the improvement projects which needs additional or new technology or equipments.

2.5.2 Technology Transfer

Historically, developed countries have the best available technologies that reduce energy, and carbon emissions in the manufacturing process. The actual hindrance for new investment projects are that the scope of work is not defined properly, cost of technology transfer is very high, and the real and perceived risks regarding new technologies. There is no methodology to evaluate the performance of the technologies that can be adapted and there is uncertainty and skepticism regarding the cost and performance of the technologies used for improving the operation. This is due to lack of end user awareness and knowledge on the adapted technologies. There is no technology information that can help to identify technologies that can be adapted as shown in Figure 2.1.

2.5.3 Know-How of Technologies

The state of art technologies needs strict control or supervision on their operations. This also depends on qualification of the operating personnel and individual capacity of personnel. Lack of understanding and knowledge about equipment makes it more difficult to adapt new technologies. There is no basic know how or training on the process of adaptable new technologies in the mill. Installation of new equipment with existing set-up without know-how or training leads to operational problems.

2.5.4 Training needs

Generally, the training needs in the pulp and paper sector can be categorized in three levels - basic training at operational level, advanced problem solving training methods for middle level managers and business plan approach for the top level managers of the mill.

Training is usually in-house or on the job training which are not properly focused. In addition, there is no emphasis on training module that will upgrade the basic skills of personnel and access to technical knowledge. The biggest gap in the training needs of operating and middle level personnel are no cross functional internship or exchange programme locally or internationally to learn the trade work or computer based training or hands on work in the mill. There is no specific workshop or seminars that addresses the specific needs of interested pulp and paper group of people who want to enhance/upgrade their knowledge.

2.5.5 Mill down time

In any successful pulp and paper mill operation, one important factor where management focuses is on downtime and break down only. Usually, the main aim is to keep running the machines to avoid downtime and loss of production. This leads to inefficient operation and the desired production or output cannot be achieved. Because of this, paper machine faces frequent break down of equipment, unscheduled machine stoppages and no proper capacity utilization of mill. Due to inefficient process, there is an increase in the energy cost of product in turn resulting in higher cost of production.

2.5.6 Retrofit process with the existing mill equipment

Smaller plant capacities cannot afford to retrofit technologies with their existing plant size because the cost of equipment can be quite higher which directly affects existing product price. However, bigger capacity plants can afford to adapt new retrofit technologies because their payback time is less and it does not affect the product price too much. The entire mill should identify the process difficulties and what kind of retrofit technologies that can be adapted to de-bottleneck their process constraint in order to sustain continuous smooth operations.

In conclusion, the four major issues that hinders adaptation of new technologies in the process are investment, know–how of technologies, available adaptable retrofit technologies and training needs. The LCTIDC should support and work on Research and Development programmes, creating suitable training modules, providing services in analyzing life cycle assessment of their product and consultancy services such as process and energy audits in their mill.

2.6 Issues on promotion of LCTs in the pulp and paper sector

The workshop titled “Low carbon technology innovation and diffusion in Thai manufacturing sectors” was organized on 28 January 2010 at Bangkok, Thailand with participants from the pulp and paper industry, NGOs, and international organizations. The issues emphasized by the participants during the deliberation of promotion of LCTs in the pulp and paper sector are summarized below.

Research and Development:

- Large companies R&D department focuses on long term plan of 5-10 years considering both feasibility and technical analysis. It was observed that it is not only information of technology that is not available and easy to access, but the implementation of the project and/or project design is also not available.

- Participants observed that energy efficient technologies are expensive, and therefore, the development of local technology should be considered. The participants were informed that demonstration of LCTs projects and information sharing with other plants within the company group is the general working style of SCG group.

- It was also noted that the high cost of energy efficient technology is because of technology patent. Cross industrial sharing of information would be necessary for LCTs promotion. For example, the best practices in the petro chemical sector could be adapted and adopted in other industries as well.

Business incubation:

- It was observed that there is no institution that provides specific training for specific requirements of each industry. Therefore, there is a need to link between R&D institutes and industries. Both the best and failures of LCTs projects in each industry need to be analysed and studied. Some academic institutions have only limited project experiences and they are not keen to address the needs of industries.

- The participants felt that there are no business incubation centers in Thailand.

Capacity building needs:

- Participants noted that operator level training needs to be conducted. Simulation program of training can be used for pulp training but it is not suitable for paper training.

- Another training topic was on best available techniques.

- One participant was concerned on how to show and share the best available technique and other issues. He also highlighted that persons at different level of management should be trained in different perspectives.

- It was suggested that field visit as part of training would be important.

Financial mechanisms:

- Reducing tax for LCTs is the one option to promote LCTs.

- High CDM validation and verification cost ~ 8-10 Million Baht (include monitoring equipments) is the main barrier for small scale of CO_2 reduction project.

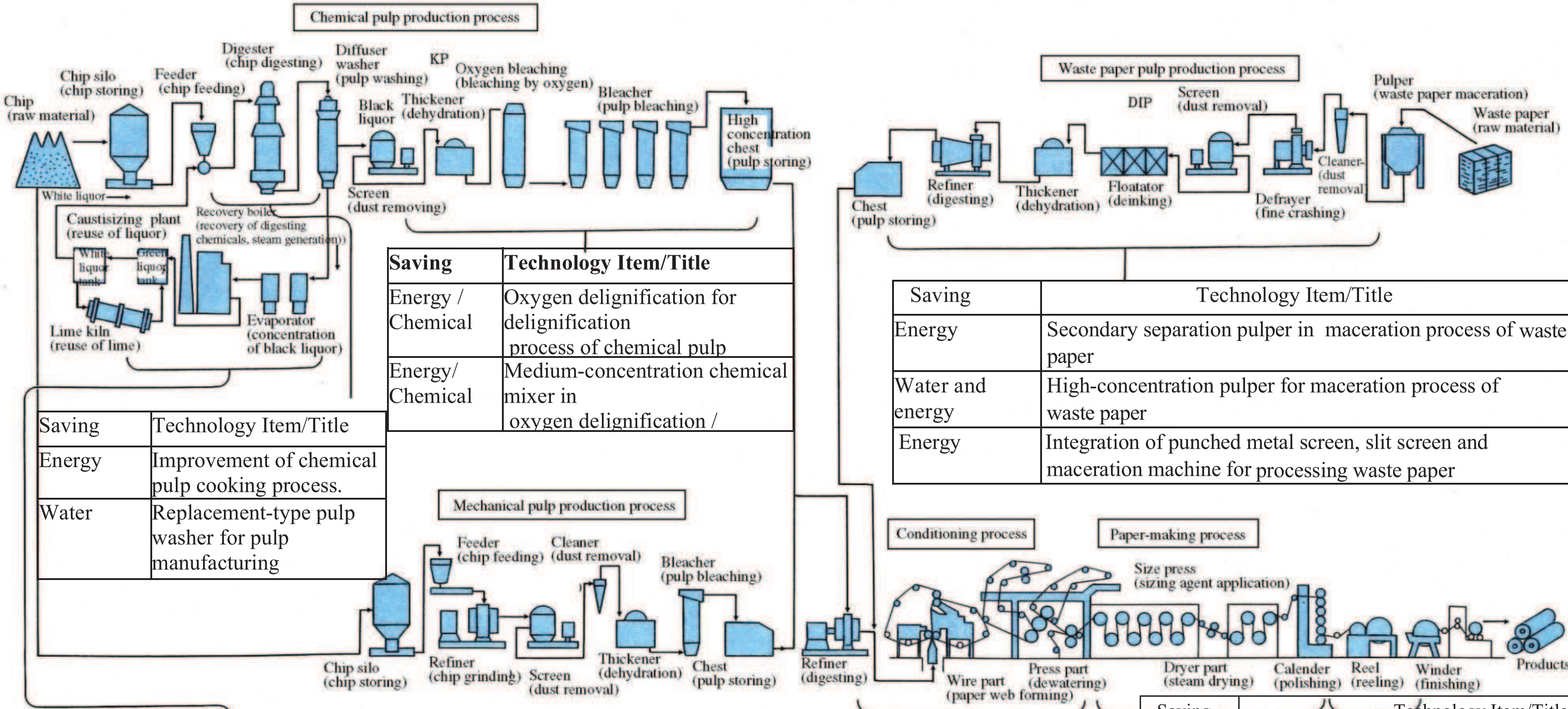
- A participant observed that carbon tax will be difficult to implement in Thailand

- Participants were informed that The Ministry of Industry has developed the PoA program for small scale CDM and the BOI tax incentive was launched.

- DEDE also has soft loan for project the has payback period < 7 years and investment of up to 50 Million Baht

***Policies and regulatory measures*:**
On the issue of policies and regulatory measures to promote LCTs in Thailand, it was suggested that the new policy to promote as voluntary and motivation is better than command and control option. Participants felt that Polluters Pay Principle (PPP) is difficult to apply in Thailand.

Figure 2.1: Pulp & Paper: Production Process and Energy Saving Technologies (Source: ECCJ)



Saving	Technology Item/Title
Energy / Chemical	Oxygen delignification for delignification process of chemical pulp
Energy/ Chemical	Medium-concentration chemical mixer in oxygen delignification /

Saving	Technology Item/Title
Energy	Secondary separation pulper in maceration process of waste paper
Water and energy	High-concentration pulper for maceration process of waste paper
Energy	Integration of punched metal screen, slit screen and maceration machine for processing waste paper

Saving	Technology Item/Title
Energy	Improvement of chemical pulp cooking process.
Water	Replacement-type pulp washer for pulp manufacturing

Saving	Technology Item/Title
Emission	High-temperature odorless Heat Recovery Boiler
Energy / Heat	Plate-type multi-effect liquid-film evaporator for condensing black liquor of chemical pulp
Saving.	Technology Item/Title
Energy	Sludge incinerator
Energy	Re-powering system and gas turbine waste heat

Saving	Technology Item/Title
Energy	High-concentration size press
Energy	High efficiency dehydrator for dryer of paper-making
Energy	High-temperature soft calender for paper making
Energy	Heat recovery from thermo-mechanical pulp (TMP) in mechanical pulp manufacturing process
Energy	Energy efficient production process of thermo-mechanical pulp (TMP)

Saving	Technology Item/Title
Energy	Dryer with dryer bars installed inside for paper-making
Energy	Installation of steam-recompression heat pump on paper-making dryer
Energy	Improvement of dryer part hood to closed type
Energy	Energy saving of vacuum pump for paper-making machine
Energy	IR to gas fired system.
Energy	Soft nip super calender.

Table 2.8: List of Energy saving options and equipment availability in pulp and paper mills

Section: Stock and paper mill.			Primary energy saving (GJ/t product)	CO_2 emission reduction (t CO_2 eq /t product)	Thai P&P status	Barrier to adapt			Reduction of Emission		
No.	Process /Unit	Energy efficient Equip./process /technology				Technology	Investment	Know how	Energy	Water	Air
1	Slushing	New Hybrid rotor	0.01	0.008	adapted	-	yes	-	yes	-	-
2	Screening	New Hybrid screen rotor	0.01	0.008	Partially	-	yes	-	yes	-	-
3	Refining/deinking	Enzymatic Process	0.2	0.13	Not adapted	-	yes	Yes	yes	-	-
4	Forming and draining	Hybrid foils	0.3	0.2	partially adapted	-	yes	Yes	yes	-	-
5	Pressing	Extended Nip press	0.8	8900 TPY [C]	Not adapted	yes	yes	Yes	yes	yes	Yes
6	Drying	Hood Heat recovery system	1.5	0.9	Partially	yes	yes	Yes	yes	yes	Yes
		Internal heat pump	2.5	2.0	Partially	yes	yes	Yes	yes	yes	Yes
		Impulse drying	0.45-0.9	0.5	Partially	yes	yes	Yes	yes	yes	Yes
7	Size press and Post dryer section	Increase in Size press solids/Power dry	Reduction of Steam consumption by 50% in the post dryer section of paper machine		Not adapted	yes	yes	Yes	yes	-	-
8	Coating and dryer	Power dry/ bio polymer use	1.9 GJ/Ton	12000 TPY	Not adapted	yes	yes	yes	-	-	-
9	Hydro power generator barrel	use of barrel in the waste water stream	NA	NA	Not adapted	Yes	Yes	yes	-	-	-

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Section: Pulp mill and recovery island			Primary energy saving (GJ/t)	CO_2 emission reduction kg CO_2/t	Thai P&P status	Barrier to adapt			Reduction of Emission		
No	Process /Unit	Energy efficient Equip./process /technology				Techno logy	Invest ment	Know how	Ener gy	Wate r	Air
1	Extended modified cooking	Impregnate wood chips with black liquor	Extra steam generation by 1 %		partially adapted	-	-	Yes	yes	yes	-
2	Use of poly-sulphide and Anthraquinone	Use of additives in the process	Extra yield of pulp by 2 -5 %		Not adapted	-	-	Yes	yes	yes	Yes
3	Improvements of refiners plates/heat recovery	Hybrid new plates	0.36GJ/Ton	6600 TPY	partially adapted	yes	yes	-	yes	-	Yes
4	Increased system closure combined with Kidneys	use of ultra-filtration/filters	Reduction of water consumption by 10- 15% in the paper machine		partially adapted	yes	yes	yes	yes	yes	-
6	Oxygen delignification	one or two stage	0.25GJ/t	0.33t /t of product	partially adapted	yes	yes	Yes	yes	yes	Yes
7	Efficient washing and process control	Diffuser washing	0.005GJ/t	2500 TPY	partially adapted	yes	Yes	yes	yes	yes	-
8	Stripping and re-use of condensates	Stripper in Evaporator	-	-	Not adapted	yes	Yes	yes	yes	yes	Yes
9	Increase of DS of black liquor	concentrator/gasification	0.5-.8 EJ /yr	30- 75 Mt/year [a]	Not adapted	yes	Yes	yes	yes	yes	Yes
10	Incineration of odorous gases in the R.boiler	yes	-	0.33 t /t of solids	Not adapted	yes	Yes	yes	yes	yes	Yes
11	Partly closure of the bleach plant	Use of Pressure Filter	-	Reduction in BOD /COD	partially adapted	yes	Yes	yes	-	yes	Yes
12	Biological wastewater treatment	yes	3GJ/t of COD	18000TPY [b]	Not adapted	yes	Yes	yes	yes	yes	yes
13	Installation of scrubbers on RB	Use of strong liquor in scrubber	-	Reduction in SOx/ NOx	partially adapted	yes	Yes	yes	-	yes	Yes
14	Use of solid lignin pellet as a fuel in lime kiln	Retrofit Ligno boost process	Equivalent of 20,000 cu.mt oil	66000 TPY [D]	partially adapted	yes	Yes	yes	-	yes	-

References:

BERF manual. Retrieved November 19, 2009, from http://eippcb.jrc.es/

Chapter :6.,Pulp and paper process flow sheets. Retrieved January 25, 2010, from http://www.energymanagertraining.com/ECDirectory_NEDO/14-Chapter3-Section6-Pulp%20&%20Paper%20Industry-Page243-271.pdf.

Chapter :1, Report on pulp and paper industry, published by Thai association of pulp and paper,2006.

FAO report, 2009. Retrieved November 22, 2009, from www.foris.fao.org/meetings/download/_2009/...on.../**thailand**_2.pdf

FAO 2008-2013. Survey report on Pulp and Paper capacities. Retrieved November 22, 2009, from www.foris.fao.org/meetings/download/_2009/...on.../**thailand**_2.pdf

IPPC, Dec.2001,"Reference document on Best available techniques in pulp and paper Industry".

Jawjit,W, 2006.An Environmental Systems Analysis of the Kraft Pulp Industry in Thailand. http://library.wur.nl/wda/dissertations/dis4081.pdf (ISBN 90-8504-510-X)

Kuenen.J.,Bosch.P, November 2009. GHG efficiency of Industries. Retrieved November25, 2009 from http://ec.europa.eu/environment/climat/emission/pdf/bm/bmsh_6_11_09_tno_ghg_efficiency.pdf

Kuusisto, I., 2004. Trends and Developments in the Chinese Pulp and Paper Industry: *International Forum on Investment and Finance in China's Forestry Sector.* Retrieved November 22,2009, from http://www.forest- trends.org/~foresttr/documents/files/doc_1149.pdf

Mohanty, B., 1997. Technology, Energy Efficiency and Environmental Externalities in the Pulp and Paper Industry. *Asian Institute of Technology*,1997, ISBN 974 – 8256 –72 –3.

SEPA-Report 4712-4, 1997,Energy conservation in the pulp and paper industry, Jaakko Pöyry Consulting AB. 1997

Warisara,2007. Report on Energy index of pulp and paper Industry from DEDE, Thailand

World Energy Council, 1995: "Energy Efficiency Improvement Utilizing High Technology: An Assessment of Energy Use in Industry and Buildings", prepared by: Marc D. Levine, Lynn Price, Nathan Martin and Ernst Worrell, London: World Energy Council.

Chapter 3: Cement Industry

3.1 Overview

3.1.1 Status of world cement industry

Cement is a basic ingredient for the construction industry. It is made of limestone and clay. Cement production is a continuous process and is highly energy intensive as the temperature in rotating kiln is in excess of 1400^0C. The cost of the cement production is comprised of 29 % energy, 27 % raw materials, 32 % labor and 12 % depreciation (Lasserre, 2007).

The global cement production increased from 594 Mt in 1970 to 2,284 Mt in 2005. The major growth was in developing countries, especially China with production of 1,064 Mt or 47% of the world production (Figure 3.1) (Taylor et al., 2006). It is estimated that in 2010, the expected demand will be 2,836 Mt worldwide.

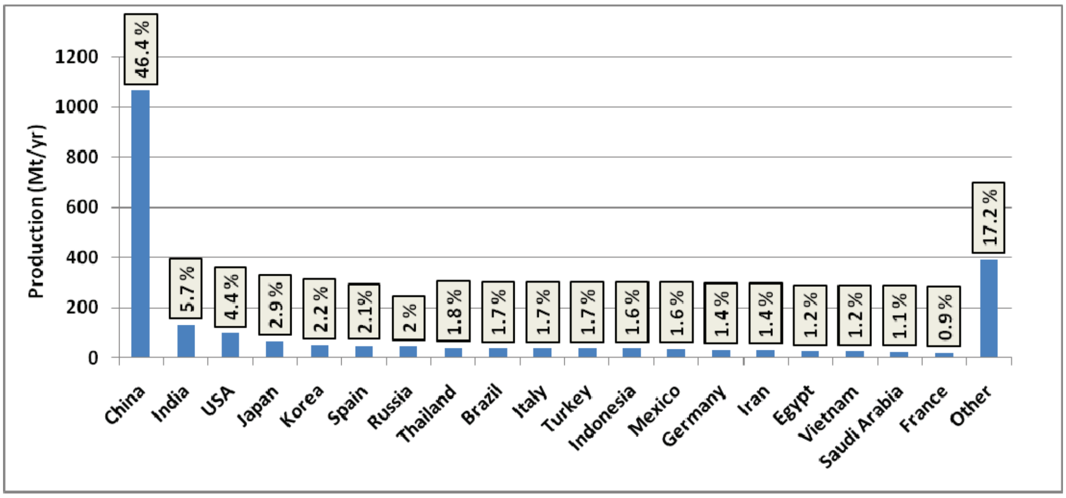

Figure 3.1: Global cement production in 2005 (Source: Taylor et al., 2006)

3.1.2 Status of Thai cement industry

There are 8 cement companies with satellite companies across the country with 14 plants and 31 kilns. The clinker production capacity was 46.82 Mt in 2007 whereas the cement production capacity was 56.3 Mt (TCMA, 2009). The overall scale of cement industry in Thailand is presented in Table 3.1.

The Thai cement industry's production capacity in 2008 was of 56.3 Mt, while demand was 24 Mt, a decline of 6% from the previous year due to political turmoil and economic slowdown. For the export market, despite demand drop in the U.S., other export markets witnessed moderate growth, resulting in a 2% rise in the global market.

Table 3.1: Demand, Supply and Export of Cement in Thailand, 2000-2008

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Production (Mt)	24.03	25.54	29.10	28.83	30.00	32.46	33.42	29.98	28.24
Domestic demand (Mt)	17.78	18.34	22.18	23.45	25.45	26.57	26.57	24.92	23.92
Per capita consumption (kg/person)	285	294	325	372	411	426	423	359	406
Domestic demand growth (%)	-4.05	3.15	20.94	5.73	8.53	4.40	0.00	-6.21	-4.01
Clinker export (Mt)	8.11	9.45	9.67	6.78	6.69	7.94	7.85	13.18	11.26
Cement export (Mt)	6.25	7.20	6.92	5.38	4.55	5.89	6.85	5.06	4.32

(Source: TCMA, 2009)

The main cement manufacturing companies in Thailand are:
1. Siam Cement Group Co.,Ltd. (SCG)
2. Siam City Cement Public Co.,Ltd. (SCC)
3. TPI Polene Public Co.,Ltd.
4. Asia Cement Public Co.,Ltd.
5. Jalaprathan Cement Public Co.,Ltd.
6. Thai Pride Cement Co.,Ltd.
7. Cemex (Thailand) Co.,Ltd.
8. Samukkee Cement Ltd.

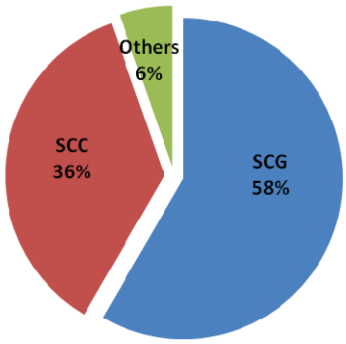

Figure 3.2: Major cement manufacturers in Thailand

SCG Co., Ltd. has been in the leading position in the Thai industry and is one of the largest cement exporters in the world. SCG had total sales of nearly 50 billion Baht[1] in 2008, an increase by 13% from the previous year. SCG contributes to 58% of Thailand total cement production (SCG annual report, 2005), while Siam City Cement (SCC) contributes to 36.2 % (SCC annual report, 2005).

[1] 1US$≈ 34 Baht

3.2 Cement manufacturing process

Cement manufacturing consists of raw material extraction and preparation, blending and prehomogenization, preheating and precalcining, clinker production in the rotary kiln, cooling, cement grinding, packaging and transportation of the cement. The detailed description of each sub process is given in Appendix (B). Generally, the first step in the cement manufacturing process is to obtain the raw material feedstock. At the quarry, the raw materials of limestone, clay and sand are reduced by primary and secondary crushers. When the raw feedstock arrives at the cement plant, the materials are proportioned to specific chemical composition. The material is ground into powder against a crush or grinder.

After grinding, the material is fed into a rotating kiln and in most cases passing first through a pre-heater and pre-calciner, before being heated in the kiln to around 1400°C. The kiln is a horizontally sloped steel cylinder, lined with firebrick, turning from about one to three revolutions per minute. From the pre-heater or pre-calciner the raw material enters the kiln. The intense heat triggers the chemical and physical changes that transform the raw feedstock into cement clinker. The clinker is then ground with the appropriate additives or clinker substitutes to form cement and is ready for storage or packaging. The overall process is shown in the Figure 3.3.

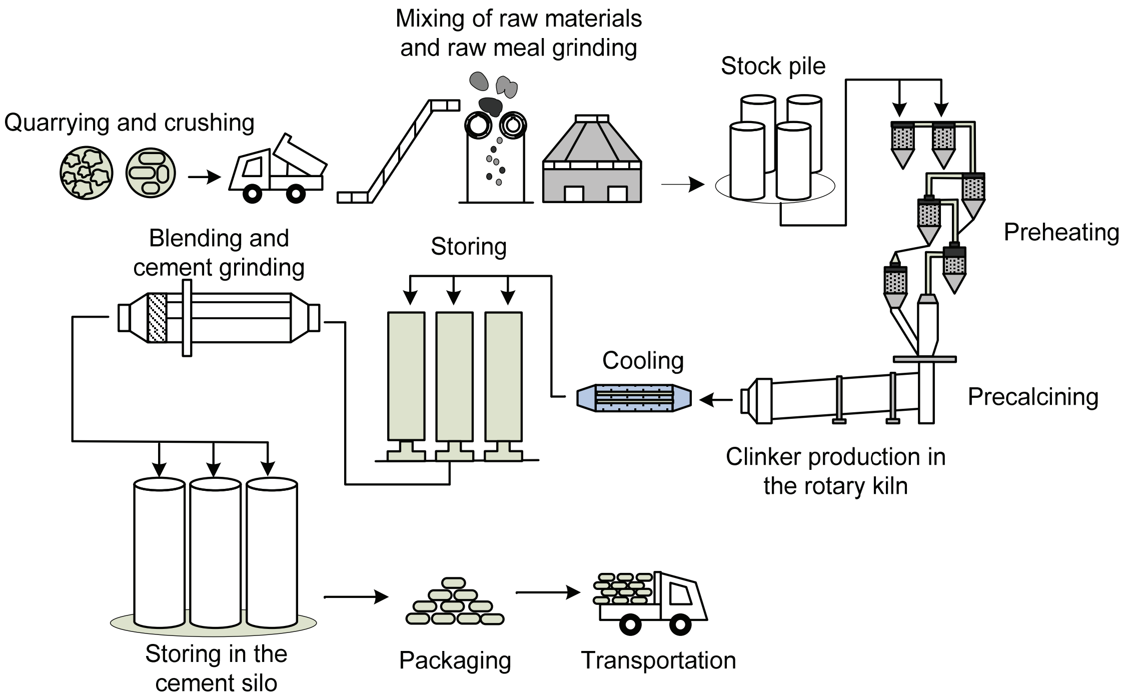

Figure 3.3: Cement production process

3.3 Energy consumption in the cement production process

The energy cost accounts for 20-30% of total cost in Portland cement production. 90 % or more fuel is consumed for clinker burning. About 40% of electric power is consumed for finish grinding, and about 30% is consumed for the raw material processing and the clinker burning process. The fuels used in cement manufacturing process are coal, natural gas or oil for thermal energy and electricity for mechanical power.

Table 3.2: Specific energy consumption in cement manufacturing process

Production Process	Energy Consumption Index			
	Electricity (kWh/t)		Primary Energy (GJ/t)	
	Global	BAT	Global	BAT
Raw materials preparation • Limestone, Chalk, Clay	25-35	22	0.09-0.13	0.08
Clinker making				
Wet process			5.0-6.7	-
Semi-dry process			3.3-4.5	
Dry process		21.4	2.9-4.6	2.85
• Long dry process			4.4	
• 1 stage cyclone pre-heater			4.0	-
• 2 stage cyclone pre-heater			3.6	
• 4 stage cyclone pre-heater			3.1	
• 4 stage pre-heater + pre-calciner			2.9	
• 5 stage pre-heater + pre-calciner			2.9-3.0	-
• 6 stage pre-heater+ pre-calciner			2.75-2.85	-
Finish grinding				
• With blast furnace slags	50-70	-	-	-
• Modern mill	32-37	-	-	25-30
Auxiliaries	9.5	-	-	-
• Conveyor belts	1-2	-	-	-

*BAT - Best Available Technology
(Sources: Worrell et al., 2000, OECD/IEA, 2007, Lu et al., 2009, and Worrell et al., 2007)

Energy consumption for Raw materials preparation
More than 1.5 t of raw materials are required to produce one ton of Portland cement. Raw material preparation is an electricity-intensive production step requiring generally about 25-35 kWh/t cement although it could require as little as 22 kWh/t (Worrell et al., 2000). Integrated vertical roller mill system has electricity consumption of 22 kWh/t cement for dry process kilns (Worrell et al., 2007).

Energy consumption for Clinker production
Clinker production is the most energy-intensive stage in cement production. In a wet process, the fuel use in a wet kiln varies between 5.0 and 6.7 GJ/t cement. In a dry process, the typical fuel consumption of a dry kiln with 4 or 5 stage preheating can vary between 2.9 and 3.0 GJ/t cement. A six stage preheater kiln can theoretically use as low as 2.75-2.85 GJ/t cement. The most efficient pre-heater, pre-calciner kilns consumes approximately 2.85 GJ/t cement. The best practice for clinker making mechanical requirements is estimated to be 21.4 kWh/t cement, while fuel use has been reported as low as 2.7 GJ/t cement.

Energy consumption for Finish grinding

Electricity use for raw meal and finish grinding depends strongly on the hardness of the material (limestone, clinker, pozzolana extenders), the desired fineness of the cement and the amount of additives. Blast furnace slags are harder to grind and hence use between 50-70 kWh/t cement (Worrell et al., 2000). Traditionally, ball mills are used in finish grinding, while many plants use vertical roller mills. Modern state-of-the-art concepts utilize a high-pressure roller mill and are claimed to use 20-50% less energy than a ball mill. Modern ball mills may consume between 32 and 37 kWh/t cement.

Energy consumption for Auxiliaries

Additional power is consumed for conveyor belts and packing of cement. The total consumption for these purposes is generally low and not more than 5% of total power and is estimated at roughly 9.5 kWh/t cement. The power use for conveyor belts is estimated at 1-2 kWh/t cement.

Table 3.3: Specific energy consumption of best available technologies

Product	Production Process	Electricity (kWh/t cement)	Primary Energy -fuel (GJ/t cement)
Portland cement with 5% additives	Raw materials preparation	22	-
	Solid fuels preparation	1.8	-
	Clinker making	21.4	2.71
	**Additives preparation	55	0.75
	Finish grinding	25-31	-
Fly ash cement with 25% additives	Raw materials preparation	17.3	-
	Solid fuels preparation	1.8	-
	Clinker making	16.9	2.1
	Additives preparation	11	-
	Finish grinding	31-38	-
Blast furnace cement with 65% blast furnace slag	Raw materials preparation	21.9	-
	Solid fuels preparation	1.8	-
	Clinker making	7.9	1
	Additives preparation	33	0.45
	Finish grinding	58-72	-

** The unit used is per ton of cement but for additives is per ton of additives only in Portland cement.
(Source:Worrell et al., 2007)

Table 3.3 refers to the specific energy consumption for different cement types using best available technology. In addition to clinker, some plants use additives in the final cement product. The difference lies between blending and grinding Portland cement (5% additives) and other types of cement (up to 65% additives). This reduces the most energy intensive stage of production (clinker making), as well as the carbonation process which produces additional CO_2 as a product of the reaction. However, additional electricity is required to blend and grind the additives, while additional fuel is required to dry some additives like blast furnace and other slags. Portland cement requires about 25-31 kWh/t for cement grinding, while fly ash cement (with 25% fly ash) requires 31-38 kWh/t cement and blast furnace slag cement (with 65% slag) requires 58-72 kWh/t cement. However, in terms of primary energy consumption is the highest in Portland cement and the lowest in blast furnace cement with 65% blast furnace slag.

3.3.1 Thermal energy consumption in clinker production

Figure 3.4 gives the worldwide average thermal energy consumption per ton of clinker for the different kiln types.

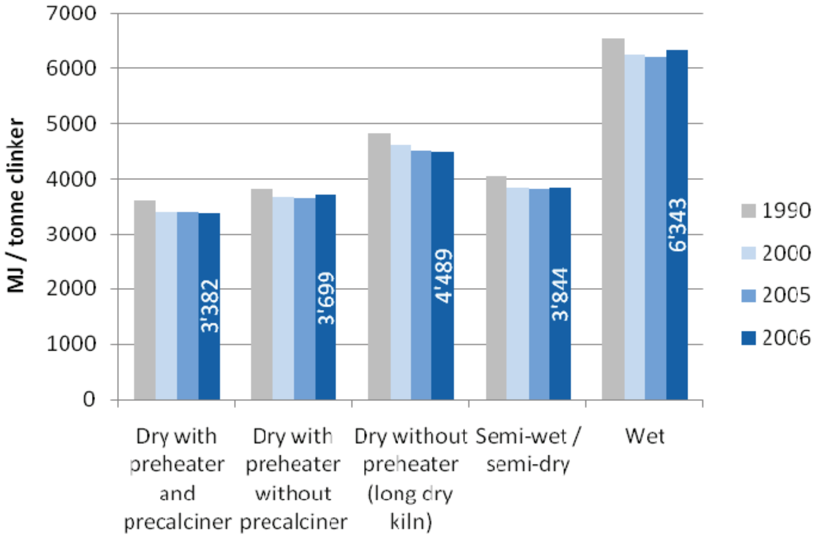

Figure 3.4: Influence of kiln technology on thermal efficiency (Source: WBCSD CSI, 2006**)**

The best energy efficiency – 3,380 MJ/t of clinker – is achieved with preheater kilns with precalciner (PH-PC), followed by preheater kilns without precalciner (PH), which are on average ~9% less efficient. The variation of performance within each technology is around 5%. Modern PH-PC kilns have a higher production capacity than older installations, which also contributes to higher energy efficiency across the board. Long dry kilns without preheater towers consume around 33% more thermal energy and the old wet kilns consume up to 85% more energy than in PH-PC kilns. There are very wide range of technologies available, and savings on a per unit basis range from 0.2-3.5 GJ/t clinker.

Current state of the art for cement production technology is the dry manufacturing process with preheater and precalciner technology (WBCSD, 2006). The kilns using raw material with low moisture content consumes the lowest energy (3.1 GJ/t clinker or 2.9 GJ/t cement). Kilns with wet process have the highest energy consumption (6.0 GJ/t clinker or 5.7 GJ/t cement). Globally, the average energy consumption is 3.7 GJ/t clinker or 3.5 GJ/t cement.

3.3.2 Electricity consumption in cement production

The global average electric energy consumption for cement production (Table 3.4) is 111 kWh/t cement while the energy consumption of 10^{th} percentile mills (most efficient mills) is 89 kWh/t cement while that of 90^{th} percentile mills is 130 kWh/t cement.

Table 3.4: Global average electrical energy consumption for cement production

Electric energy consumption for cement manufacture	kWh/t cement
10^{th} percentile mills	89
90^{th} percentile mills	130
Global weighted average	111

3.3.3 Energy consumption in Thailand cement industry

The energy consumption in manufacturing sector in 2008 was 24,195 ktoe and accounted for 36.7 % of the final energy consumption, 2.8 % increase from previous year, 2007. The major energy consumed was coal, with a share of 32.0% of the energy consumption in this sector followed by renewable energy, electricity, petroleum products, and natural gas which had shares of 26.3%, 19.8%, 11.6% and 10.3% respectively.

In 2005, the Thai cement industry consumed 3,990 ktoe or about 17.6% of total energy consumed by industrial sector of Thailand. The specific energy consumption of cement industry was 4.04 GJ/t of cement (DEDE 2007).

As shown in the Figure 3.5, coal with a share of 53 % is primarily used as a solid fuel and is the main thermal source for the Thai cement industry. Moreover, alternative fuels such as industrial waste, biomass, and cracker bottom represents 10%, 7% and 2% respectively.

Table 3.5: Specific energy consumption in the Thai cement industry (Source: DEDE, 2007)

Process	SEC primary (GJ/t cement)
Raw meal grinding	0.17-0.49
Clinker kiln	3.02-5.89
Finish grinding	0.18-0.41
Overall cement production process	3.54-6.68
Average SEC in 2005	4.04

3.4 GHGs emission from cement manufacturing

3.4.1 Carbon dioxide emissions from world cement industries

CO_2 emission from cement production currently represents about 5% of the world's anthropogenic global CO_2 emissions (WBCSD CSI, 2006). The calcination process in cement production accounts for about half of the total carbon dioxide emissions from the cement industry (Hasanbeigi et al, 2010). Moreover, the total world carbon dioxide emission in gross or net term is shown in Figure 3.6. It clearly can be seen both gross and net CO_2 emission has increased during 1990 to 2006.

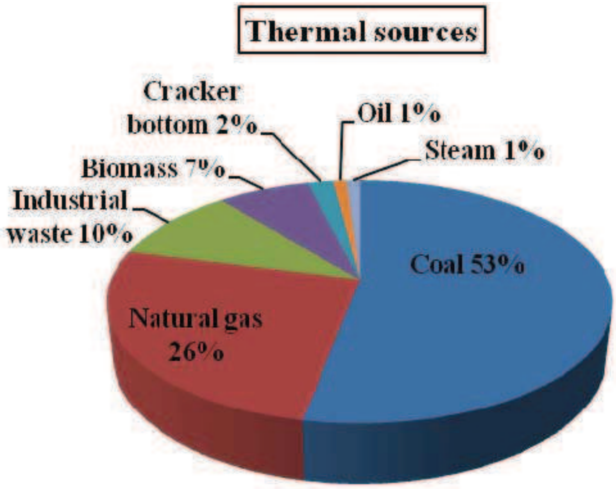

Figure 3.5: Fuel choices in Thailand cement industry (Source: SCG, 2008)

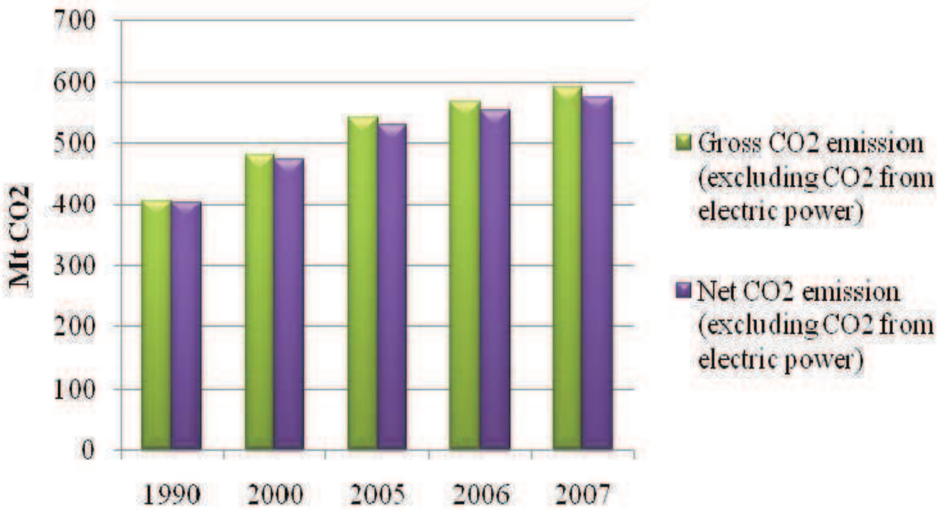

Figure 3.6: World CO_2 emission from cement industries (WBCSD CSI 2006)

**Net CO2 emissions: gross CO2 emissions minus emissions from alternative fossil fuels

**Net CO2 emissions is about 4% less than Gross CO2 emissions

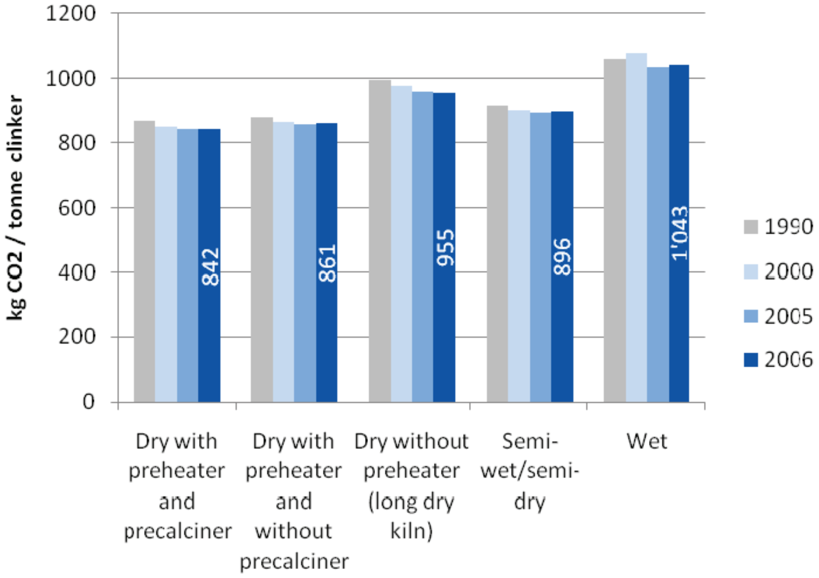

Figure 3.7: World CO_2 emissions depending on kiln type

The global gross CO_2 emissions per ton of clinker for the different kiln types are shown in Figure 3.7. The amount of CO_2 emission in each kiln type in 2006 shows a reduction compared to that in 1990. However, in terms of kiln types comparison, the least CO_2 emissions can be achieved with preheater kilns with precalciner (PH-PC), followed by preheater kilns without precalciner (PH). The kilns with highest emissions are wet kiln technology with ~24 % more emissions than PH-PC and the long dry kilns without preheater with ~13 % more than PH-PC. The spread in CO_2 intensity between kiln technologies is ~25% between the average wet and average preheater - precalciner kiln, compared to ~85% spread in thermal efficiency.

3.4.2 GHG emissions from Thailand cement industries

According to the Carbon Dioxide Information Analysis Center (2005), the CO_2 emissions from cement manufacturing in Thailand accounts for 12.7 Mt in the year 2000. The calculated carbon dioxide emission from Thai cement industry was about 20.6 million tons of CO_2 in 2005 (Hasanbeigi et al, 2010). Moreover, the total GHG emissions from Thai cement industry can be seen from the Figure 3.8.

3.5 Low carbon technologies with potential for energy saving and CO_2 reduction in Thailand cement industry

Hasanbeigi et al. (2010) and Worrell et al. (2000 & 2008) have identified about 47 energy-efficiency technologies and measures which are applicable in Thai cement industries for CO_2 emission reduction. CO_2 reduction potential of some technologies and measures which have higher reduction potential are given in Table 3.6. The detailed description of each technology is discussed in the Appendix B.

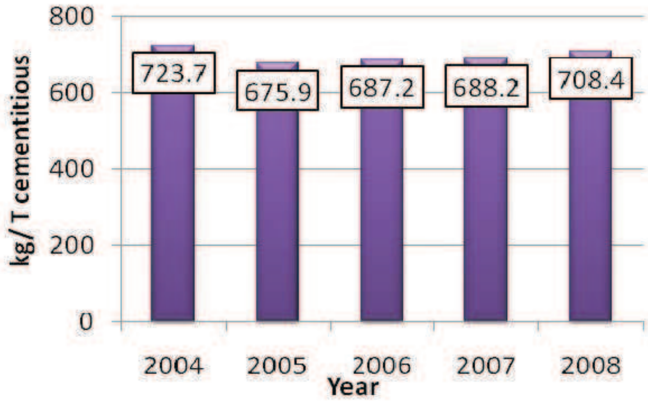

Figure 3.8: Total GHG emissions from Thailand cement production (Source: SCG, 2008)

Table 3.6: Summary of technologies and measures with highest CO_2 reduction potential in Thai Cement Plants

No	Technology/measure	CO_2 reduction (kg CO_2/t cement)
A	*Raw materials*	
	Efficient transport system	1.3
	Raw meal blending	1.11
	High efficiency roller mill	4.24
	High efficiency classifiers	2.12
B	*Clinker making*	
	Energy management and process control systems	16.05
	Combustion system improvement	24.13
	Kiln shell heat loss reduction	20.91
	Optimize heat recovery/ upgrade clinker cooler	8.01
	Convert to reciprocating grate cooler	20.46
	Low temp. waste heat recovery power generation	12.83
	High temperature heat recovery for power generation	9.25
	Upgrading of a preheater kiln to a preheater/ precalciner	34.59
	Conversion of long dry kiln to preheater/ precalciner	112.61
	Adjustable speed drive for kiln fan	2.57
	Upgrading the preheater from 5 stages to 6 stages	8.44
	Older dry kiln upgrade to multi-stage preheater kiln	72.39
	Modifying clinker cooler (mechanical flow regulator)	6.837
C	*Finish grinding*	
	Replacing a ball mill with vertical roller mill	8.82

	High pressure roller press as pre-grinding to ball mill	8.30
D	*General measures*	
	Preventative maintenance	5.28

(Source: Hasanbeigi et al. (2010)

3.6 Carbon dioxide reduction potential in Thai cement industry

Ruth et al. (2000) have estimated the carbon reduction potential per ton of cement produced in Thailand by using a process wise benchmarking. The detail of the study with different options is given in Table 3.7. Among the three options, the production capacity of the cement plant and bench marking adopted are the same. However, large differences can be observed in performance of the plant. Firstly, the comparison can be made between option I and II. Option I uses the data from an efficient plant in Thailand and the Option II used the most efficient values from a range of best available technologies where the final clinker to cement ratio (0.95) is the same in both cases. Thus, Option II using the best available technologies can reduce more carbon than Option I.

In the case of Option III, the final clinker to cement ratio was reduced (0.65) where as it is 0.95 in the case of Option I. Option III refers that the plant is running with normal efficient technology similar to that of Option I. However, clinker substitution and reduction the clinker content in cement can make a large difference as it can reduce the carbon up to 69.7 kg C/t cement. Based on the carbon reduction potential estimated by Ruth et al. (2000) and the Thailand cement production in 2008, the estimated CO_2 reduction potential for Thailand in 2008 for Option I, II and III are 0.3 Mt CO_2, 1.1 Mt CO_2 and 7.2 Mt CO_2 respectively.

Table 3.7: Scenarios for Option I, II and III

Scenarios	Option I	Option II	Option III
Production	• 3.4 Mt raw material • 2.0 Mt clinker • 2.1 Mt cement		
Benchmarks	• 20 kWh/t raw material • 3200 MJ/t clinker • 36 kWh/t cement • 0.95 t clinker/t cement		
Performance	• 21 kWh/t raw material • 2977 MJ/t clinker • 42 kWh/t cement • 0.95 t clinker/t cement	• 10 kWh/t raw material • 2900 MJ/t clinker • 25 kWh/t cement • 0.95 t clinker/t cement	• 20 kWh/t raw material • 3200 MJ/t clinker • 36 kWh/t cement • 0.65 t clinker/t cement
Carbon reduction potential	3.2 kg C/t cement	10.4 kg C/t cement	69.7 kg C/t cement

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Estimated CO_2 reduction potential	11.73 kg CO_2/t cement	38.1 kg CO_2/t cement	255.6 kg CO_2/t cement
Estimated total CO_2 reduction potential in 2008	0.3 Mt CO_2	1.1 Mt CO_2	7.2 Mt CO_2

Table 3.8: Estimation of CO_2 reduction potential in Thai cement industry (Hasanbeigi et al., 2010)

No.	Technology/measure	No of measures	**CO_2 reduction potential**	
			kg CO_2/t cement (Hasanbeigi et al., 2010)	**kt CO_2/ yr (Estimation for Thailand)**
1	Fuel preparation	2	0.18	5.1
2	Raw materials	9	11.61	327.9
3	Clinker making	23	351.98	9939.9
4	Finish grinding	6	22.99	649.2
5	General measures	3	9.95	281.0
Total			**396.7**	**11203.1**

Using the study results of Hasanbeigi et al.,2010, the potential of total CO_2 reduction in Thai cement industry for 2008 was estimated to be (as shown in Table 3.8) 11.2 Mt, whereas it was 0.3 Mt CO_2 for Option I, 1.1 Mt CO_2 for Option II and 7.2 Mt CO_2 for Option III based on the study of Ruth et al. (2000). Accordingly, the CO_2 reduction potential in Thai cement industry is estimated to be varies from 0.3 - 11.2 Mt for year 2008.

3.7 Barriers to adapting best available technologies

The existence of barriers is largely due to the inadequacy of information and decision support tools used to quantify and qualify the merits of ESTs and related investments. The challenge is even greater in the context of developing countries, given the complexity of factors that influence and determine investment decisions.

Information

While removing information barriers is a major factor for transfer and widespread of LCTs, there is no system of collection and distribution of information about environmentally sound technologies. At present, information needs include the learning of both access and utilization ways of technological information provided by international centers, as well as creation of developed informational systems and their connection to both regional and international networks through specialized bodies and information private firms. It is necessary to develop activities for raising public awareness on climate change issues, energy efficiency, enhancing utilization of renewable sources of energy as well.

Human capacity
The transfer of LCTs demands a wide range of high-skilled technical, business, and management experts. Besides this, the experts should have high competence regarding local circumstances of economic and environmental conditions, be able to ensure evaluation of local technological needs, know the opportunities and specifications of technology transfer process, promote necessary information exchange between local enterprises and international partners.

3.8 Issues on promotion of LCTs in the cement sector

A workshop titled "Low carbon technology innovation and diffusion in Thai manufacturing sectors" was organised on 28 January 2010 at Bangkok, Thailand with participants from cement industry, NGOs, and international organizations. The issues emphasized by the participants during the deliberation of promotion of LCTs in the cement sector are summarized below.

Research and Development:

- One area of research needs that was suggested was the need for more research and development activities related to carbon capture and storage and usage of alternative energy sources in the cement industry. This would directly address the current major issue of global climate change and fossil fuel use.
- Participants also emphasized the need to access the research and development publications related to the cement sector to keep in touch with latest research trend.

Business incubation:

- Participants suggested that networking with TBCSD (Thailand Business Council for Sustainable Development) would help in the technological transfer in the cement sector.

Capacity building needs:

- Specific trainings related to new LCTs, best practices, bench marking etc. should be formulated and conducted by the envisaged low carbon technology innovation and diffusion centre.
- Access to information related to LCTs and networking of organizations working on LCTs and sustainable development, such as, World Business Council on Sustainable Development, were also identified as important factors to promote the deployment of LCTs in the cement sector.

Financial mechanisms:

- Promotion or diffusion of LCTs could be accelerated by introducing funding opportunities/financing mechanisms similar to CDM but specifically for the industrial sectors.
- Cement industry is the only business which can handle or solve the problems of infectious wastes and sewage sludge going to the landfill. Therefore, the government should support financially and encourage the industries more on this issue.

Policies and regulatory measures:

- The absence of suitable policy and regulatory measures was identified as the major obstacle for the promotion of LCTs.
- Policy and regulatory measures related to promotion of usage of alternative energy sources in the cement industry, for example, providing incentives to use alternative energy sources, and support to collection and transportation of MSW, sludge etc., should be considered urgently.

References

Carbon Dioxide Information Analysis Center (2005), Carbon Dioxide Emissions from Fossil-Fuel Consumption and Cement Manufacture.

DEDE, 2007. Department of Alternative Energy Development and Efficiency, Thailand.

DEDE, 2008. Department of Alternate Energy Development and Efficiency, Thailand Energy Situation, 2008

Dolores, R. and M.F. Moran. 2001. Maintenance and Production Improvements with ASDs Proc.2001 IEEE-IAS/PCA Cement Industry Technical Conference: 85-97.

Galitsky et al., 2008. Guidebook for Using the Tool BEST Cement: Benchmarking and Energy Savings Tool for the Cement Industry. Lawrence Berkeley National Laboratory

Hasanbeigi, A., Menke, C., and Therdyothin, A., 2010. The use of conservation supply curves in energy policy and economic analysis: The case study of Thai cements industry. *Energy Policy*, 38(1), 392-405.

Japanese Cement Association, JCA (2006), *Cement Industry's Status and Activities for GHG Emissions Reduction in Japan,* presentation to the IEA-WBCSD Workshop "Energy Efficiency and CO2 Emission Reduction Potentials and Policies in the Cement Industry", IEA, Paris, 4-5 September 2006

Lang, Theodor A., 1994. Energy Savings Potential in the Cement Industry and Special Activities of the 'Holderbank' Group, in *Industrial Energy Efficiency: Policies and Programmes Conference Proceedings* (May 26-27, 1994). Paris: International Energy Agency and U.S. Department of Energy.

Lasserre, P., 2007. The Global Cement Industry: *Global Strategic Management Mini Cases Series.* Retrieved November 29, 2009, from http://www.philippelasserre.net/contenu/Download/Global_Cement_industry.pdf

Lu et al., 2009. Evaluation of Life-Cycle Assessment Studies of Chinese Cement Production: Challenges and Opportunities. Proceedings of the 2009 ACEEE Summer Study on Energy Efficiency in Industry. Lawrence Berkeley National Laboratory.

Martin, N., E. Worrell, and L. Price. 1999. Energy Efficiency and Carbon Dioxide Emissions Reduction Opportunities in the U.S. Cement Industry. Lawrence Berkeley National Laboratory, Berkeley, CA. September. (LBNL-44182).

OECD/IEA, 2007. Tracking Industrial Energy Efficiency and CO2 Emissions.

Ruth M, Worrel, E, and Price, L. 2000. Evaluating Clean Development Mechanism Projects in the Cement Industry Using a Process-Step Benchmarking Approach. Ernest Orlando Lawrence Berkeley National Laboratory, LBNL-45346.

SCG annual report, 2005. Retrieved January 2010, from http://www.siamcement.com/en/04investor_governance/07_annual_report_sustainability_report.html

SCC annual report, 2005. Retrieved January 2010, from http://www.siamcitycement.com/about/investor/yearly_report.aspx?lang=en

Taylor, M., Tam, C., and Gielen, D., 2006. Energy efficiency and CO_2 emission from the global cement industry: *Paper prepared for the IEA-WBCSD workshop*. Retrieved November 29, 2009, from
http://www.iea.org/work/2006/cement/taylor_background.pdf

TCMA, 2009; (Thailand Cement Manufacturing Association). Thailand cement industry, report published by TCMA. Retrieved November 29, 2009, from http://www.thaicma.or.th/Scale%20of%20Industry%20Dec.htm

Venkateswaran, S.R. and H.E. Lowitt. 1988. The U.S. Cement Industry, An Energy Perspective, U.S. Department of Energy, Washington D.C., USA.

WBCSD CSI, 2006. World business council for sustainable development (WBCSD), Cement sustainability initiatives, Getting the number (GNR) report 2006.

Worrell et al., 2000. Energy Efficiency Improvement and Cost Saving Opportunities for Cement Making An ENERGY STAR® Guide for Energy and Plant Managers

Worrell et al., 2007. World Best Practice Energy Intensity Values for Selected Industrial Sectors. Ernest Orlando Lawrence Berkeley National Laboratory, LBNL-62806.

Worrell, E., Galitsky, C., and Price., L., 2008. Energy Efficiency Improvement Opportunities for Cement Industry. Environmental Energy Technology Division, Ernest Orlando Lawrence Barkeley National Laboratory, January 2008. LBNL-72E.

Chapter 4: Low carbon technology innovation and diffusion center

4.1 Need for the establishment of Low Carbon Technology Innovation and Diffusion Centres

To ensure a smooth transition to a low-carbon world, developing countries also need to participate fully. To enable developing countries reduce their greenhouse gas emissions, and move towards a low carbon society, policies and measures that:

- promote renewable energy and energy efficiency,
- create innovative financing mechanisms to accelerate the adoption of low carbon and greener technologies,
- strengthen institutions and create human resources that foster innovation and implementation of cleaner technologies, and
- facilitate transfer of technology that spur the transition to a low carbon economy.

need to be put in place. However, promotion of low carbon technologies is possible only when the barriers are eliminated. Some of the interventions needed for the promotion of LCTs include (Carbon Trust, 2008):

- Applied research and development, promoting new technologies and energy efficiency initiatives
- Business incubation and enterprise creation activities, especially by providing funding for development of innovative LCTs and measures
- Capacity building and skills development, and
- National policy recommendations to promote low carbon society

To eliminate the barriers in LCT promotion, the two major stakeholders, namely the industry and the research institution needs to address a number of issues listed below:

Industry

- Access to efficient LCTs
- Technology transfer know-how and operational knowledge of know -how
- Adaptation and technological capacity development
- Retrofitting with existing set-up
- Payback period of investment

Research Institutions

- No proper interaction between industry and institution
- R&D facilities are not fully utilized
- Current work are not suited to the needs of industries
- R&D works are mainly product development rather than process or equipment development
- Lack of funding for research and lack of equipment

They should work in tandem to address the above issues that will lead to good working relationships and thus promote technology transfer and lead to improved energy efficiency and thus reducing carbon emissions through the use of best technologies that suit the industry. This, however, requires an assessment of the national situation, local markets and institutions. The establishment/promotion of Low Carbon Technology Innovation and Diffusion Centres

(LCTIDCs) in developing countries would thus accelerate the development and deployment of low carbon technologies and for developing appropriate policies. This would also help to develop institutional and human capacities to accelerate the wider adoption of LCTs. The centres could play an important catalytical role in the deployment and diffusion of LCTs by addressing the interventions specific to the national context.

Similar centres/institutions cater to only one or two major activities which are often restricted to dissemination and training. Furthermore, involvement of industries in such centres tends to be weak resulting in divergence of outputs of the centre and the needs of the industries. There is no business incubation centre, which can help identify and nurture LCTs. Where there are linkages, the research institutions linkage with industries is only for specific project related activities.

The twin challenges of global climate change and energy security can only be solved by rapid development and diffusion of low carbon technologies, both for energy supply and energy efficiency. Thus, the focus of LCTID center will be mainly to address the barriers and gaps that have to be conceptualized by developing/promoting practical LCTs at national level. The functions of LCTID center will be to promote research and development activities that can address needs of manufacturing sector by creating direct linkage between research institution and industries. In addition, the centre should also develop training modules to promote more awareness on adaptable best available technologies.

The perspectives of the different stakeholders regarding promotion of LCTs in the manufacturing sector are:

- The concerns of the **industry** are on the access to LCTs, development and deployment of new knowledge, investment and human capacity to introduce LCTs.
- **Investors** do not see viable new projects and hence the support for (new) investment is low.
- Though **government** policies favour promoting renewable and energy efficiency, there is a perception that there is less priority towards LCTs, and a lack of interest on the verification of improvements obtained through introduction of LCT's in the industry.
- **Equipment suppliers** feel that the market for LCTs is weak, which could be due to lack of communication and vision on the part of the industry.
- The linkage between **research institutions** and industry sector is weak, leading to less funding to develop and deploy LCTs, along with lack of appropriate R & D. **NGOs** and related groups are perceived to have a narrow focus only on emission mitigation.

Therefore, a forum/entity (i.e. LCTIDC) which can bring these different perspectives towards the common goal of promoting LCTs in the manufacturing sector is required.

The energy consumption in the industrial sector of Thailand will still have a major share in 2030 and the corresponding emissions from this sector will also be significant. It is therefore, imperative that LCTIDC are established to help the manufacturing sector promote low carbon technologies and processes.

4.2 Role for AIT as a Regional Center for Innovation and Diffusion of Low Carbon Technologies

For more than two decades, Asian Institute of Technology (AIT- www.ait.asia) has been involved in education, training, research and dissemination of low carbon green technologies and environmental protection for various industrial sector. These are carried out by the Energy, and Environmental Engineering and Management fields of study (School of Environment, Resources and Development), and Industrial Systems and Engineering (School of Engineering and Technology) fields of study, while Management of Technology is an area of specialization in the School of Management.

AIT is well suited to be a center for innovation and diffusion of low carbon technologies in Thailand and in South East Asia because of its strength in applied research and development carried out through sponsored projects and student research, including analyses and publication of research results. As a leading regional post graduate educational institution, AIT aims to build capacity and skills through formal programmes and as well as focused training programmes, conferences, workshops and seminars.

In terms of education and training, AIT in collaboration with UNEP initiated the Certificate/Masters program in Cleaner Production in 2000. Besides, AIT faculty members are involved as resource persons in training programs/workshops/seminars organised by various organizations/institutions. AIT faculty members also assisted National Cleaner Production Centres in Vietnam and Sri Lanka in developing national Cleaner Production curriculum in these countries, with the support of UNIDO.

The Regional Energy Resources Information Center (RERIC) (www.serd.ait.ac.th/enreric) housed in the Energy field of study is the outreach arm to disseminate energy research, and to promote renewable energy, energy efficiency and related areas.

AIT has also strong links with the industrial sector in Thailand as well as the Federation of Thai Industries. AIT has its focused center "Sustainable Development in the context of Climate Change" which is directly relevant to the proposed center. Plans are also under way to foster entrepreneurship and create a business incubation center at AIT. Low carbon technologies in the current context of climate mitigation initiatives would be an important area in this regard.

AIT has been involved in research activities promoting energy efficient and environmentally sound technologies in large scale industrial sectors such as Cement, Iron and Steel, and Pulp and Paper, as well as in small and medium scale industries, and the results of the studies have been presented in conferences, workshops, journals and books.

4.3 Role and activities of the proposed LCTID Centre (perspectives from stakeholders)

The concept of LCTs center depends on each country and some specific criteria, such as, the center in Vietnam which was funded by UNIDO earlier but now transferred to the Vietnamese government, and the industrial firms have to pay fees to this center for services. The offices in Laos and Cambodia have different management system, and all operating costs are funded by UNIDO. The proposed LCTs center in Thailand is not only for innovation and technology information transfer from developed countries to the Thai industry, but it is the source of information of the best practices of Thai industry as well. It can be a node for exchange and sharing.

A workshop titled "Low carbon technology innovation and diffusion in Thai manufacturing sectors" was organised on 28 January 2010 at Bangkok, Thailand with participants from cement and pulp and paper industries, ministries, NGOs, and international organizations. The issues emphasized by the participants during the deliberation of promotion of a center focused on promoting LCTs are summarized below.

One issue regarding who would take the responsibility of the proposed Center was also raised, and it was noted that existing centers have limitation of information that is available only to their members. As the result, there is a limitation for networking and sharing information. It was suggested that the proposed center could liaise with The Federation of Thai Industries to coordinate with other industries. The participants were informed that the Ministry of Industry is currently working with GTZ in the steel, food, glass, and non-ferrous sector. In addition, LCTIDC should closely cooperate with the Ministry of Industry.

It was suggested that LCT Center should function and provide details such as technology packages catering to the needs of each industry, such as, techno-economic analysis and information regarding specific LCTs. Participants also noted that LCT Center should provide best practice available techniques. It should be easy to access and cross linked with other industries for sharing information.

The participants observed that at present there are some specific institutions related to promotion of cleaner production and technology transfer, but they have very broad mandate and goals. In this context, the proposed center that will be focused on promoting low carbon technologies has a clear mandate and therefore could work at greater depth on this focus area in order to promote sustainable development – considering social, economic and environmental issues.

Successful technology transfer warrants a number of issues.

- First, the information about the low carbon emission technologies may be available at different sources, but which one of them is most suitable for the specific context and objectives of the transferee? This relates to the question of having a right balance of criteria, acceptable to both the government and the private entrepreneurs, for assessing the appropriateness of the technology.
- Second, once the most suitable technology is determined, the question comes - to what extent the technology should be transferred? Simply buy and use, or to also acquire the capability to modify/develop by the transferee in the long run?
- Third, what is (are) the mechanism(s) of technology transfer one should choose for efficient and effective transfer of the desired technology?
- Fourth, what is the right price of the technology? The competitiveness of the products would depend mainly on three factors: price, quality, and carbon emission. The transferee need to determine what is the optimal price to be paid for the technology.

- Fifth, the issue of diffusion of LCT technologies in the specific industries. That means LCTs will gradually substitute the existing technologies already deployed by different firms. Policy and decision makers would be in a better position in formulating policy incentives if they have a clear idea of the possible rate of substitution of the existing technologies by the LCTs.

The proposed center can carry out both capacity development and policy support work on the above issues, along with others, for its effective contribution for the purpose. It will also ensure that it has its uniqueness and complements the works of other associations/groups. Though the proposed center would be mainly for promoting low carbon technologies, it could also provide the services such as emission audit, business incubation, policy briefs and the innovation of new technologies to the industry depending on their requirements. The center should be self sustainable in the long term and that the participation by all stakeholders will play a great role for the sustainability of the center.

The low carbon technology innovation and diffusion centre can carry out many functions to promote LCT in manufacturing sectors, namely,

- Understanding sector wise process technologies.
- Assessing the needs of the technologies in the industrial sector.
- Identifying LCT improvement project that can be adapted.
- Assisting in the prioritization of LCT projects
- Evaluation of LCT projects and investment opportunities.
- Analysis of technology transfer options.
- Creating fact sheets on LCTs – technology and financial details.

Moreover, the focus of the center could be extended on technology transfer components such as scope of technology transfer between parties, standardization of technology transfer cost factor and product price, evaluation of technological project with cross reference, while working closely with equipment manufacturer or suppliers and other regional centre. The other area of work is creating awareness on low technology product and arranging programme on success stories and difficulties during project implementation phase.

The centre should focus on the supporting services such as taking consultancy works like bench marking, audit work and life cycle analysis etc. The center publication services like articles, weekly/monthly magazine, conducting workshops and seminars, inviting suppliers and entrepreneurs for participation and generation of reports can be disseminated for use. The sharing of success project information from other regional centre will also help to promote LCT. The centre can also evaluate and produce a common cross industry technological bench marking data sheet that will give options of adaptable low carbon technologies.

4.4 Recommended approach and activities for LCTID Center establishment

Suitably set-up LCTID centers could be well placed to work in the way that bridge the gap between the different bodies, satisfy and assist the need of industries, and finally save our globe in terms of carbon reduction. The details of the proposed LCTIDC in Thailand is presented below:

LCTIDC MISSION

The overarching mission of the LCTIDC would be to provide services to the manufacturing sector to ensure development and deployment of low carbon technologies. For its operation, and success, it should involve industry and other stakeholders, and should be self sustaining in the medium to long term. The geographical coverage of the center would be Thailand and the ASEAN countries.

STAKEHOLDERS

The LCTIDC should involve the following stakeholders as partners in its activities: Manufacturing industries, Equipment manufacturers/ suppliers, Funding organisations, Government/regulating bodies, Investors/companies, Trade Associations, Research and Development Institutions, NGOs/Environment Associations, Mass media/Communications, and Consultants/Others.

GOVERNING COUNCIL

The Governing Council (apex body of the Center) of the LCTIDC should have members from the following stakeholders: Representatives from the manufacturing industries, Equipment manufacturers/ suppliers, Funding organisations, Government/regulating bodies, Investors/companies, Trade Associations, Research and Development Institutions, NGOs/Environment Associations, and Mass media/Communications.

The members of the governing council would hold their positions for a period of 3 years, which can be renewed. The governing council appoints the CEO in consultation with the host institution.

CORE AREAS

The activities of the LCTIDC would be broadly in the following four core areas:

Research and Development: The Center's R& D will be related to technology needs assessment, applied research on LCTs and alternative energy, research on policy issues, studies on innovative financial mechanisms, as well as studies specifically catering to the needs of the industry.

Business incubation: The Centre would act as an incubator for introduction of new technology innovation, and conduct studies focusing on financial, environmental and technical viability of cleaner technologies.

Networking and dissemination: The Centre would network with research institutions, business councils, technology suppliers to promote technology transfer and disseminate information, research results and related publications.

Capacity building: The Centre will conduct specific trainings related to new LCTs, generate new knowledge on best practices, and assist in bench marking of processes and energy use.

SUGGESTED ACTIVITIES

- ***Applied research and development:*** by providing grants, funding for the research activities based on the sector's needs. Thus, new ideas and best technologies from the research can be developed and applied to the point of potential commercial relevance in each sector.

- ***Technology and knowledge transfer:*** by designing and funding projects to transfer best technologies from developed countries to the developing countries, by conducting the field trials to reduce technology risks and cost risks, and finally dissemination of the knowledge on that technology to industries by conducting technical and operational training, and workshops.

- ***Business incubation and consultancy:*** by providing strategic business development, ideas, and suggestions to start up the industry to increase on the uptake and the deployment of the low carbon technologies on energy efficiency and carbon reduction agenda.

- ***National regulating bodies and stake holders:*** using the data and performance of " applied research and development, and technology and knowledge transfer", the following details can be developed
    - Bench marking and standards for each industry
    - Regulations and policies for energy efficiency and carbon reduction
    - Incentives for the deployment of LCTs by means of investment, funding, tax reduction, the share of investment cost between two parties (industry & government) etc.
    - Interactions between industries and other research institutions to assist the obstacles that industries are facing in terms of technological, operational knowledge and retrofitting of the existing set-up.
    - Increase public awareness on the adaption of LCT in industries.

A FIVE YEAR TIME LINE OF ACTIVITIES AND OUTPUTS

Up to Year 1 (Setting up):

The LCTIDC would have clearly defined objectives, mission, vision and goals. Organisation profile would include its Director (or CEO) assisted by senior managers – operations and finance - with performance indicators, and assisted by researchers and staff. The director would report to a governing council which will include members from industry, government, academia, donors and others.

A detailed five year business and management plan with specific activities related to the above mentioned four core areas will be developed for implementation.

Outputs:

The outputs by the end of year 1 would be:

- Mission, vision and objectives of the center is defined and agreed by the stakeholders.
- Organisational profile agreed, governing council and most of the staff in place
- Key performance indicators of the center and its staff defined
- Development of a detailed five year plan and its approval by the council for implementation (this would be in terms of R and D, focused sectors, specific research activities (barrier study, policy issues, etc), type of dissemination methodologies, business incubation center development, training unit, etc)
- Funding for the operation of the center assured
- Specific activities for the year 1 carried out and reported

Year 2 – 4 (consolidation):

The activities will be carried out in line with the approved business plan.

Research, development and deployment of LCTs could be in focused sectors and across sectors (steam generation systems, compressed air and air handling systems, pumps and motor drives, and lighting).

Other major activities would be on technology needs assessment, assessment of GHG reduction potential, barrier identification to the deployment of the identified LCTs and measures to address the barriers, technology transfer issues, analysis of policies and financial mechanisms, conduction of energy audits and consultancy services.

The business incubation unit would cater to the specific needs of the industries.

The capacity and skills development unit would conduct training programs, lectures, seminars and short courses.

The media (networking) unit would be responsible for publishing reports, newsletters, policy briefs, annual reports, organizing meetings/workshops and managing the web site, as well as liaising with all stakeholders.

Outputs:

The outputs during each of the three years would be according to the business plan proposed (and approved). Yearly performance report will have to be prepared and submitted. The performance of the Center would be monitored and evaluated by considering:

- Specific advises provided to the manufacturing industries in terms of reports
- Reports on technology needs assessment of the different industrial sectors, techno-economic analysis of LCTs, etc
- The number of technologies transferred to the manufacturing sector
- The number of business incubations proposed and implemented

- Specific research outputs prepared and delivered to the industries
- Number of training modules developed and training programmes conducted
- Impact of dissemination of LCTs
- Quantification of GHG mitigation due to the inputs/suggestions
- Amount of funding obtained from sources other than donors
- Analysis of Key Performance Indicators of the staff and the center

Year 5 – (Sustainability):

It is expected that by providing services to the industries, the center would be able to develop and expand its business plan during the second phase. Along with its core activities, the center could also initiate new ventures/initiatives, which could be related to additional portfolios, new services, and geographical extension.

Outputs:

The outputs during year 5 would be according to the business plan proposed (and approved). At the end of this year, a second phase of the activities of the center can be initiated based on the lessons learned during the past 5 years. One of the core objectives during this phase would be self sustaining nature of activities to be carried out by the center.

BUDGET AND FINANCING

The center would need financing during the initial four years through grant support. The support for the initial years would be to set up, personnel, operations, research and dissemination. This would thereafter reduce over the years, as the center should be able to generate income through its services, and be self sustaining. The grant funding could reduce to 70% during the fifth year, and further reduce later.

VENUE FOR THE CENTER

The launching of a center that focuses on low carbon technology promotion through innovation and diffusion would be a timely and an important milestone to the industrial sector in Thailand, and one that can help increase energy efficiency, promote renewable energy, introduce good energy management practices leading to reducing greenhouse gas emissions. Hosting such a center at the Asian Institute of Technology (AIT) would be appropriate for the reasons described in Section 4.2. Furthermore, this would also help students and researchers from Asia and beyond to participate in cutting edge development and deployment of LCTs, and to closely collaborate with the industrial sector of Thailand and other Asean countries.

Appendix A (Pulp and Paper Sector)

A.1 Description of pulping and paper making

The pulp and paper industry converts fibrous raw materials into pulp, paper and paperboard. In the first step, raw materials are processed into pulp and in the second step, paper and paper products are produced out of this pulp. Different plant categories exist depending on whether they only produce pulp (pulp mills) for further processing or only paper out of purchased pulp and/or recycled waste paper (paper mills). The third category, the integrated pulp and paper mills, combines the two processes and is most common in the paper industry. The five principal steps in pulp and paper production are wood preparation, pulping, bleaching, chemical recovery, and paper making. The following step by step description is as per the World Energy Council, 1995 (source: World Energy Council, 1995).

A) Wood Preparation

Wood preparation involves breaking wood down into small pieces suitable for subsequent pulping operations. The wood preparation processes include debarking and chipping. This process requires little energy.

B) Pulping

Wood is ground and pulped to separate the fibers from each other and to suspend the fibers in water. Pulping breaks apart the wood fibers and cleans them of unwanted residues. The ratio of wood to other materials used for pulp depends on the resources available. Non wood pulping mill uses soda process while newsprint mills use mechanical, chemical, chemi-mechanical and chemical thermo- mechanical (CTMP) processes (Mohanty, 1997).

C) Bleaching.

Bleaching process whitens cooked pulps for the manufacture of writing, printing, and decorative papers. This process alters or removes the lignin attached to the wood fiber.

D) Chemical Recovery

Chemical recovery regenerates the spent chemicals used in Kraft chemical pulping. Chemical pulping produces a waste stream of inorganic chemicals and wood residues known as black liquor. The black liquor is concentrated in evaporators and then incinerated in recovery furnaces, many of which are connected to steam turbine co- generation systems. The chemicals are separated as smelt which is then treated in with lime to produce sodium hydroxide. Sodium sulfide is also recovered.

E) Paper making

Paper making consists of stock preparation, refining, mixing, forming, pressing and drying of paper; stock preparation and drying are the most energy intensive processes. During preparation, the pulp is made more flexible through beating, a mechanical pounding and squeezing process. Pigments, dyes, filler materials, and sizing materials are added at this stage.

f) Effluent treatment and solid waste management

The treatment plant consists of three stage clarifier with activated sludge process and aeration pond for the waste water which is treated before sending out for irrigation purpose. The other main focus area is the landfill of the solid waste which is generated in the process. There are strict regulations laid down to avoid soil contamination. Many mills are approaching and implementing the concepts of zero landfill.

A.2 Low carbon technologies to reduce CO_2 emissions

Technology could play an important role in increasing energy efficiency and reducing CO_2 emissions in the pulp and paper industry. Current pulp and paper facilities in Thailand is nearing the end of their operating life and will need to be replaced over the next 10-15 years. This presents an excellent opportunity for new technology deployment to have an impact on energy savings in the sector in the medium term. The following energy efficient technologies can be adopted by Thai pulp and paper mill are

A) Increase in evaporator stages

Various industries produce low-grade fuels as a by-product, and in the paper industry, chemical pulping produces black liquor. In standard kraft pulp mills that use the sulphate process, the spent liquor produced from de-lignifying wood chips is normally burned in a large recovery boiler. Because of the high water content of black liquor (it is usually burned at a solids content of 65% to 75%), the efficiency of existing recovery boilers is limited. Electricity production is also limited, because the recovery boilers produce steam at low pressures for safety reasons. An increase in the dry-solids content of the black liquor from 65 - 70% to 80 - 85% changes the material and energy balances and the burning conditions in the recovery boiler. By increasing the dry-solids content to e.g. over 80% an increase in production or extended delignification with more efficient recovery of the black liquor can be possible in a mill. This helps in recovery boiler capacity De-bottleneck by adding another extra capacity of power generation by 11-14%.

Principle: The aim of enhanced evaporation is to achieve as high content of dry solids (DS) as possible as in the strong black liquor. After a conventional evaporation the DS content in the strong black liquor is about 65 %. By installing a super concentrator, DS content up to 80 % can be achieved. However, the achievable DS-content depends on the wood species. A target for optimal dry solid content of thick liquor in a balanced mill could be 72-73% after evaporation but measured before the recovery boiler mixer. A super concentrator can be implemented as a separate phase also to existing evaporation plants. However, the maximum DS content is limited by the increase of the viscosity and scaling tendency of the strong black liquor. This depends on the wood species and temperature. In practice, with eucalyptus and some other hardwood species it is difficult to achieve higher than 70 % DS content.

Economics: In existing mills the cost of improved evaporation and concentration of strong black liquor is tied to the target concentration. At existing mills with 1500 ADMT/day kraft pulp production the investment costs for increase in black liquor concentration from 63 % upward are as follows:

1) Concentration from 63 % to 70 %, 1.7-2.0 Million Euro
2) Concentration from 63 % to 75 %, 3.5-4.0 Million Euro
3) Concentration from 63 % to 80 %, 8.0-9.0 Million Euro

The operating costs of the improvements are not significant because of the increase in energy economy (this being 1-7 %) and gain in recovery boiler capacity. Another case by case achievable result is the increase of the capacity of the recovery boiler (4-7 %).

B) Black-liquor Gasification

Description: Gasification offers opportunities to increase the efficiency of using black liquor. In gasification, hydrocarbons react to synthesis gas, a mixture mainly of carbon monoxide and hydrogen. The synthesis gas can be used in gas-turbine power generation or as a chemical feedstock. This technology, called black liquor gasification-combined cycle (BLGCC), allows the efficient use not only of black liquor, but also of other biomass fuels such as bark and wood chips. Alternatively, the synthesis gas can be used as a feedstock to produce chemicals, in effect, turning the paper mill into a "bio-refinery." In Europe, policies aimed at increasing the share of Bio-fuels in transportation have sparked interest in using black liquor gasifiers to produce Di-methyl ether (DME) as a replacement for diesel fuel. It might be interesting for some mills where the recovery boiler is the bottleneck in the production and an increase of the chemical recovery capacity would solve these limitations as Figure A.1.

Energy Saving: A practical pulp plant will be able to produce and then sell excess electricity on the order of 220 to 335 kWh/t of pulp. The steam efficiency remained the same, 3 EJ of black liquor per year would yield an additional 300 PJ of electricity annually. The savings in terms of primary energy would be in the range of 0.5 to 0.8 EJ. The CO_2-savings potential for a 1500 TPD plant is in the range of 30 to 75 Mt/yr. The potential of producing is 1700 kWh/ADMT as compared with the present level of 800 kWh/ADMT. Thus the potential increase in the energy corresponds to 900 kWh/ADMT. At the same time the heat generation would be reduced by about 4 GJ/ADMT, which is more than a typical surplus in a modern kraft mill.

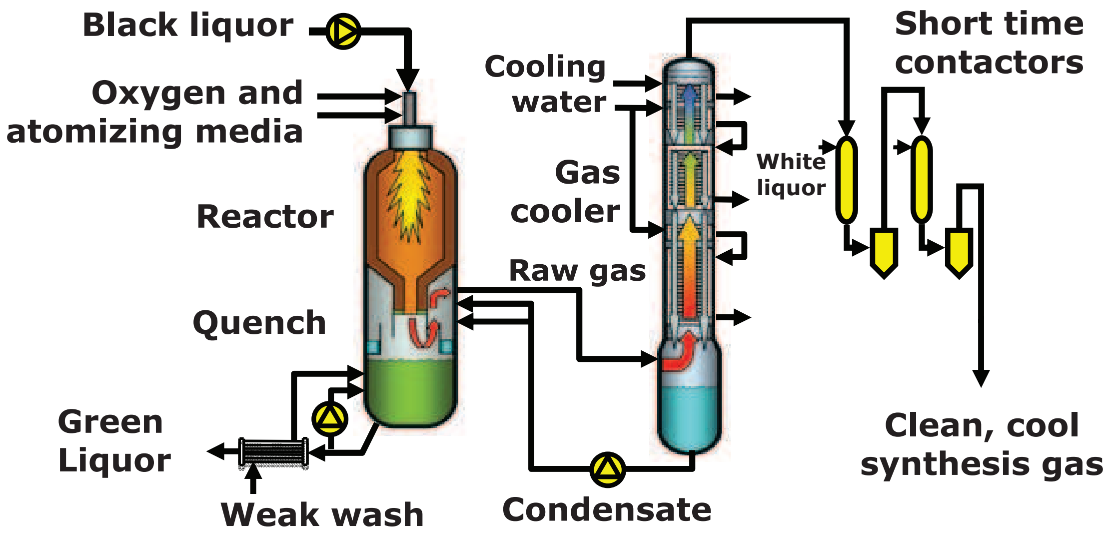

Figure A.1: Flow diagram of Black liquor gasification process (Source: Chemrec AB)

Economics: Investment is around 8- 10 Million Euro and pay back is within 1-3 year. In a situation with a surplus of steam, this appears as an interesting option for an increased power production for export and internal use.

C) Retrofit Lingo Boost technology

Description: The new technology which uses 40% solids black liquor which will use CO_2 to reduce the pH of the black liquor to precipitate lignin form the semi solids which will be again washed with dilute H_2SO_4 liquid to get a final good quality Lignin with a dry content of 65% . This can be incorporated as a separate line which can produce lignin pellets that can be used a fuel in existing coal fired boiler or fuel for Lime kiln. This is very promising technology that helps to increase the capacity of Evaporator and recovery boiler also. In the world there are very few installations and they are operating it with higher power efficiency. The heat energy after lignin separation from the weak black liquor is around 22 MJ/kg which is almost twice than that of concentrated solids fired in recovery boiler as in Figure A.2.

Energy/Economics saving: This precipitated lignin is a absolute replacement for the annual oil consumption in kraft mill of 20,000 m^3. The equivalent carbon emission can be cut down by 66,000 t/yr. Generally, the investment would be around 8-10 million Euro where as payback time depends on the investment and it varies between 1.5 to 4 years.

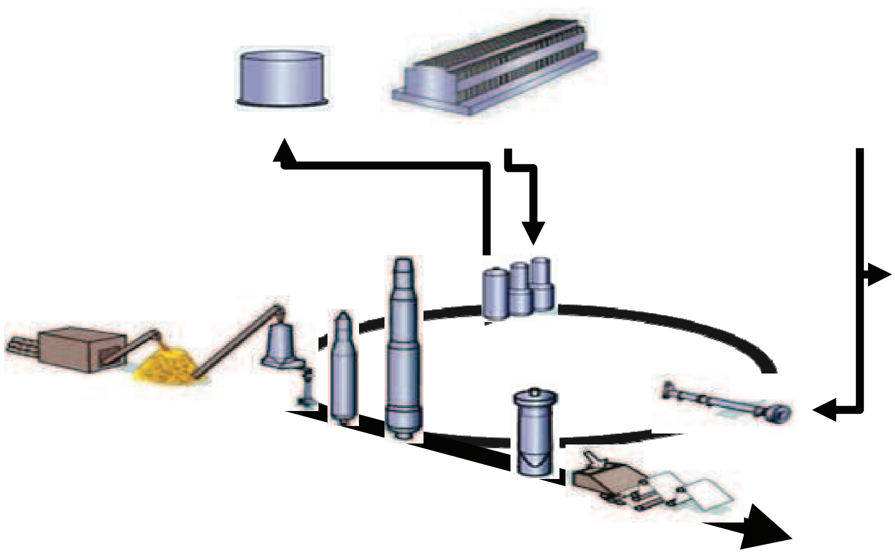

Figure A.2: Retrofit Ligno boost technology (Source: Metso 2009)

D) Conversion of Electric Infra Red (IR) drying to Gas fired system

Description: In the paper mill, coating operation Infra ray dryer is used to quickly immobilize wet coating in the paper. The IR dryer used direct electricity for this operation. Due to its long impingement drying phase it is easy to operate. This new technology power dry has higher evaporation capacity and 50% lesser energy consumption. Installation in the coating machine will lead to reduction in power consumption which is use for IR drying in coating machine. There is no maintenance cost due to non consumable and spare parts and energy cost is added. Secondly, the capacity f Dryer nozzle by upgrading to the newer version which adds 25% increase in drying rate by which steam consumption is reduced. Trend is shifting from IR drying and towards Power dry for its higher evaporation rate.

Energy saving : The change of process installation to opti-dry in the existing process, use of steam will be reduced from 3.0 GJ/t to 1.1 GJ /t ,when gas will be used as heating medium and Excess electricity can be used in the process.

Emissions : There is a potential to save CO_2 emission with combination use of turn dry and power dry by 50% i.e from 25000 - 12000 t/yr.

E) Secondary Heat recovery system

Description: In the first heat exchanger of the heat recovery system heat is recovered to incoming supply air. The next heat exchanger is for the heating of incoming fresh water. In some cases heat is also recovered to wire pit water to compensate for the heat losses in the west end. The last heat exchanger is for circulation water as presented in Figure A.3 and Table A.1. The circulation water is used to heat the incoming ventilation air. The supply air and shower water are heated to their final temperatures to 90 - 95°C and 45 -60 °C respectively.

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