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GUIDELINE

Evaluation of Industrial Energy Efficiency Project for Financial Institutes

INDUSTRIAL ENERGY EFFICIENCY PROJECT

Ministry of Industry

Department of Alternative Energy Development and Efficiency
MINISTRY OF ENERGY

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Chapter 1
Thailand's Energy Situation

1.1 Introduction

The need for importing petroleum significantly increases to 45% of the total energy consumption in Thailand. The amount accounts for over 55% if including natural gas, coal mining and electricity imports from neighboring countries. Heavy reliance on energy imports has been a serious concern over national security amid highly unstable fuel cost, falling short of energy resource in the global community and political conflicts in oil-producing countries. The record-high oil price of US$ 147 in 2008 much affected the world economy and has become a wake-up call for Thailand to come up with a well-planned macroeconomic development including energy consumption strategy.

1.2 Energy situation in 2013

1.2.1 Domestic consumption, production and primary commercial consumption

Commercial energy imports including crude oil, natural gas, condensate, petroleum products, coal-fired power and hydropower in 2013 accounted for two million barrels of oil equivalent (BOE). The amount grew up by 1.2% compared to the previous year.

- Natural gas shared the highest proportion of energy consumption accounted for 917,015 BOE per day (46% of the total energy consumption). The percentage increased by 3.2% compared to Year 2012.
- Crude oil consumption came second at 727,559 BOE per day (36% of the total energy consumption). The percentage increased by 2.6% compared to Year 2012.
- Coal and lignite power accounted for 313,320 BOE per day (16% of the total consumption), reduced by 4.4% compared to Year 2012.

- Hydropower and electricity imports stood at 46,635 BOE (2% of the total amount), reduced by 15.7% compared to Year 2012.

1.2.2 Energy consumption value

In 2013, the energy consumption value accounted for 2.13 trillion Baht. The expenditure increased by 0.9% compared to Year 2012. The following is the summarized details.

• Petroleum product	THB	1.327636	trillion
• Electricity	THB	541.974	billion
• Natural gas	THB	121.147	billion
• Coal/lignite power	THB	25.315	billion
• Renewable energy	THB	118.469	billion

1.2.3 Energy import value

Energy import cost the country 1.42 trillion Baht in 2013, reduced by 2% in the previous year. The following is the summarized details.

• Crude oil	THB	1.073	trillion
• Natural gas and liquid natural gas (LNG)	THB	146.944	billion
• Petroleum products	THB	134.306	billion
• Coal	THB	39.733	billion
• Electricity	THB	20.168	billion

1.2.4 Energy export value

Thailand could export energy valued at 357.896 billion Baht in 2013, reduced by 10.8% in the previous year.

• Petroleum product	THB	322.621	million
• Crude oil	THB	30.927	billion
• Electricity	THB	4.348	billion

1.2.5 Renewable energy development

The domestic consumption of renewable energy in 2013 was at 10.9%, compared to 9.9% in 2012. Biomass shared the highest proportion of the total renewable energy production. Ethanol production increased twice as much of the country's biomass capacity as in 2012.

Table 1.1 Proportion of renewable energy production

Type	Unit	2012	2013
1. Electricity Production			
- Wind energy	Megawatt	110.93	222.71
- Solar power	Megawatt	250.68	635.48
- Small-scale hydropower	Megawatt	96.03	104.77
- Biomass	Megawatt	1,956.85	2,230.05
- Biogas	Megawatt	172.85	262.73
- Biogas (Napier grass)	Megawatt	-	-
- Waste to energy	Megawatt	42.72	47.48
- Renewable energy	Megawatt	0.3	0.3
Total amount of renewable energy for electricity production	Megawatt	2,633.06	3,503.52
	ktoe	1,138.00	1,313.00
2. Heat energy			
- Solar power	ktoe	3.60	4.50
- Biomass	ktoe	4,346	4,769
- Biogas	ktoe	458	477
- Waste to energy	Ktoe	78.20	85
Total amount of heat energy for electricity production	Ktoe	4,885.80	5,335.50
3. Biofuel			
- Ethanol	Million liters/ day	1.29	2.53
- Biodiesel	Million liters/ Day	2.54	2.78
- Renewable fuel applied to diesel	Renewable fuel for diesel	-	-
- Compressed biogas (CBG)	Ton	-	-
Total renewable energy for biomass production	Million liters/ Day	3.83	5.31
	Ktoe	1,270	1,563

Type	Unit	2012	2013
Total domestic consumption of renewable energy	Ktoe	7,294	8,211
Final energy consumption	Ktoe	73,316	75,214
Proportion of renewable energy per final energy consumption within the country		9.9%	10.9%

Source: Energy Policy and Planning Office, Ministry of Energy, Thailand

1.2.6. Electricity Consumption

- Electricity production capacity of 33,681 Megawatt increased from the previous year by 3.32%. Major electricity providers are:
  - Electricity Generating Authority of Thailand (EGAT) 45%
  - Independent power producer (IPP) 38%
  - Small power producer (SPP) 10%
  - Electricity import 7%

- Electric power consumption accounted for 165.560 billion units, increasing by 2.3%. The amount of electric power consumption can be categorized below.
  - Industrial sector (46%)
  - Household (23%)
  - Business sector (23%)
  - Agricultural sector and others (8%)

1.3 Availability of energy saving measure/mechanism

Mechanism and measure available for promoting energy saving in Thailand can be summarized as follows:

Mechanism 1: Energy-saving measure by the Board of Investment of Thailand (BOI)

The Board of Investment of Thailand has implemented a measure aimed at increasing production efficiency and encouraging entrepreneurs already receiving investment support from BOI and those who has not yet listed under BOI support to afford investment in effective energy-saving machinery, renewable energy aimed at lowering environmental impact, innovative research and development for overall manufacturing efficiency. The following three measures can be applied to this mechanism.

1. Investment support on renewable energy use. Entrepreneurs interested in the program can submit their investment plans on energy-saving machinery and renewable energy use for lowering environmental impact following the BOI requirements

2. Investment support on increasing efficiency of machinery. Any entrepreneur interested in the program needs to submit an investment plan in accordance to BOI requirements for example adopting an automatic system for use with its production line.

3. Investment support on research and development (R&D) and engineering design. Any entrepreneur interested in this measure will have to submit an investment plan on research and development and/or engineering design following BOI requirements. Actual investment must be over 1% of the projected three-year sales target starting from the day the entrepreneur submitted the plan for BOI support. In case of small and medium-sized enterprises (SMEs), operators will have to invest a minimum of 0.5% in R&D and/or develop engineering design based on its three-year target, starting from the day the operator submitted the plan for BOI support. Energy-saving machinery imported by SME entrepreneurs will exempted from import tax. Operators will also earn incentive of income tax reduction by 50% of its investment cost (excluding property and maintenance cost). The amount of income tax will be calculated based on ongoing business income.

Mechanism 2: Investment grant by the Department of Alternative Energy Development and Efficiency (DEDE) and the Energy Policy and Planning Office (EPPO), Ministry of Energy

Operators interested in applying for the investment grant, the two agencies: DEDE and EPPO will support 10-30% of the investment grant following conditions of the energy conservation fund.

Mechanism 3: Energy Service Company (ESCO) Capital Fund

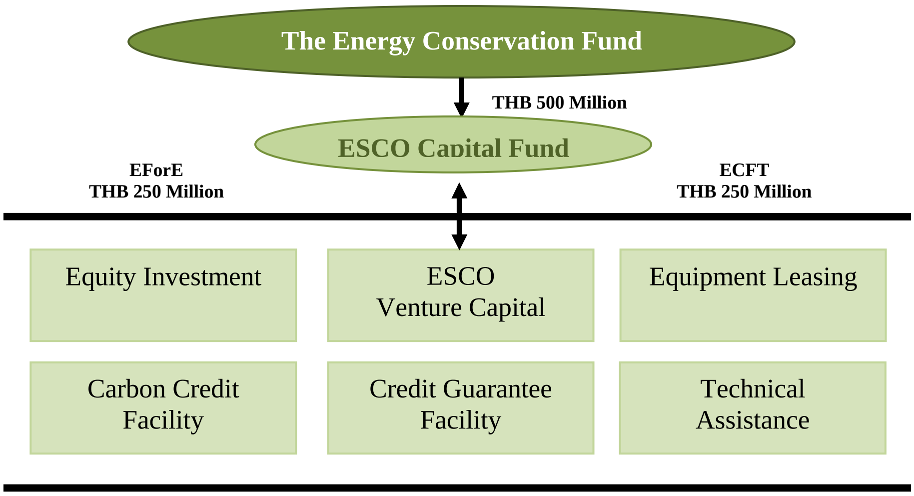
Based on the energy conservation fund, the Department of Alternative Energy Development and Efficiency (DEDE) is the main agency overseeing the ESCO Revolving Fund project aimed at supporting operators lacking funds to develop their business projects by investing more in energy conservation and renewable energy. The objectives of the project are:

1. To promote increasing investment in energy conservation and renewable energy in the private sector

2. To encourage operators to reduce their energy cost

3. To promote up-to-standard and high-quality energy management plan among business sector

4. To increase the use of energy-saving, renewable energy equipment that meets high quality and standard.



Source: Energy Policy and Planning Office, Ministry of Energy, Thailand

Figure 1.1 Model of energy-saving and renewable energy investment promotion

Type of investment

1. **Equity Investment** The ESCO Revolving Fund will be invested in energy-saving and energy conservation projects.

2. **ESCO Venture Capital** The ESCO Revolving Fund will be invested in the newly-issued shares of energy management companies so that they will have adequate fund for operating energy-saving business.

3. **Equipment Leasing** Business operators will receive lease agreement from ESCO Revolving Fund for purchasing energy-saving and renewable energy-dependent equipment. Business operators will have to return a fixed long-term rental payment including interest throughout the leasing period.

4. **Carbon Credit Facility** Through the ESCO Revolving Fund, operators will be facilitated to conduct a paper on Clean Development Mechanism (CDM) development program. Details will include Project Idea Note (PIN) and Project Design Document (PDD). The ESCO Revolving Fund will also act as a middle-man to facilitate carbon credit purchasing from energy conservation and small-scaled renewable energy projects and to bundle up these projects so that they can sell carbon credit.

5. **Credit Guarantee Facility** The ESCO Revolving Fund together with financial institutions will provide credit guarantee for business operators to access loan program from commercial banks by acting as a surety for the project valued less than 10 million-baht.

6. **Technical Assistance** The ESCO Revolving Fund will provide technical assistance for example energy audit cost or feasibility study cost within 100,000-Baht budget under the conditions that the business operator will have to follow energy-saving and renewable energy measure. Any violation in the conditions will result the business operator's obligation to full repayment to the ESCO Revolving Fund.

Chapter 2
Financial Mechanism for Energy Efficiency Support

Details in this chapter include financial mechanism for energy efficiency support (EE) on the industrial level i.e. financial programs for improving construction, machinery. The financial mechanism can also be applied to other sector for example real estate development.

2.1 The Financial Products for Energy Efficiency Projects in Thailand

Domestic funds available for supporting energy efficiency projects comes can be categorized into two sources: the government and the financial institutions. Details can be displayed in the Figure 2.1.

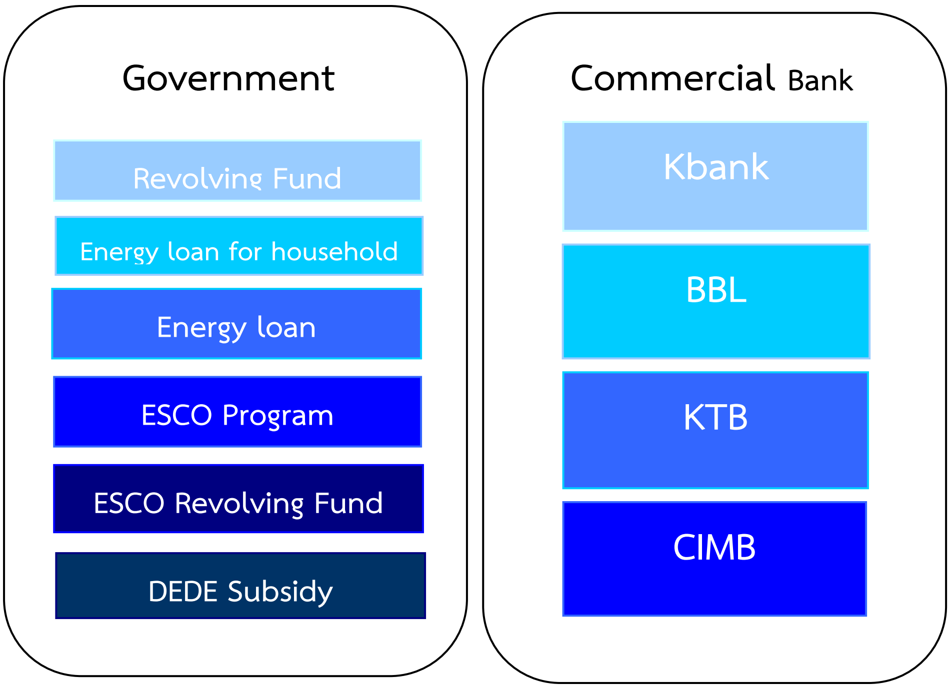


Figure 2.1 Sources of energy efficiency funding program

2.1.1 Government Sector

Different projects have been undertaken to reach out to industrial, real estate and household sectors in a bid to achieve the energy-saving goal set by the Department of Alternative Energy Development and Efficiency, Ministry of Energy. List of the projects are shown in Table 2.1.

Table 2.1 Project summary

List of Projects	Energy Efficiency Revolving Fund	Household Energy Efficiency loan	Voluntary Energy Loan Program Memorandum of Understanding	ESCO Program	ESCO Revolving Fund	DEDE Subsidy
Duration (year)	2003 - 2013	2008	2008	2008	2008 - 2014	2012
Status	End	End	End	Ongoing	Ongoing	End
Budget (Million Thai Baht)	7,000	1,000	-	32	1,500	115
Distribution channels	11 Banks	5 Banks	13 Banks	5 banks		
BBL	√	√	√			
K-Bank	√		√	√		
KTB	√	√	√	√		
SCB	√		√			
TCAP	√		√	√		
BAY	√	√	√			
TMB	√		√	√		
CIMB	√		√	√		
ICBC	√		√			
GSB		√				

List of Projects	Energy Efficiency Revolving Fund	Household Energy Efficiency loan	Voluntary Energy Loan Program Memorandum of Understanding	ESCO Program	ESCO Revolving Fund	DEDE Subsidy
EXIM	√		√			
ABANK		√				
SMEs Bank	√		√			
Asia Credit			√			
MFC			√			

Source: Department of Alternative Energy Development and Efficiency, Ministry of Energy, 2014

1) Energy Efficiency Revolving Fund

This funding program is by far the most successful financial scheme offering soft loan through commercial banks.

Table 2.2 Energy Efficiency Revolving Fund

Objective	Financial support program for industries, real estate and energy-saving companies (ESCOs) to invest in energy efficiency projects. The Energy Efficiency Revolving Fund project was introduced when financial institutions in Thailand still lacked knowhow and confidence in supporting energy efficiency loan program.
Project Duration	2003-2013 (End)
Project Supervision	Department of Alternative Energy Development and Efficiency, Ministry of Energy
Source of Funding	Energy Conservation Fund (ENCON)
Target	Factories, Building Constructions, and Energy Saving Companies (ESCOs)
Interest Rate	4% per year

Credit Limit	A maximum of 50 million THB per project. The amount beyond the maximum credit can be negotiated with the banks.
Total budget from the Government	7 billon THB
Estimated credit from commercial banks	7.7 billion THB
Term of Credit	7 years with a maximum of 12-month grace period
Co-partner Banks	1. Bangkok Bank 2. Krung Thai Bank 3. Bank of Ayudhya 4. Kasikorn Bank (K-Bank) 5. Thai Military Bank 6. CIMB Thai Bank 7. Siam Commercial Bank 8. Siam City Bank (Thanachart Bank at present) 9. Small and Medium Enterprise Development Bank of Thailand 10. ACL Bank (Industrial and Commercial Bank of China (Thai) or ICBC at present) 11. Export-Import Bank of Thailand (EXIM Thailand)

Source: Department of Alternative Energy Development and Efficiency, Ministry of Energy, 2014

2) Household Energy Efficiency Loan

The loan program is aimed at encouraging household level to purchase high efficiency electrical appliances, especially the air condition. The merit of this financial scheme is 0% interest.

Table 2.3 Household Energy Efficiency Loan

Objective	To encourage households to use high efficiency appliances especially those with No.5 labelling
Duration	2008
Project Supervision	Department of Alternative Energy Development and Efficiency, Ministry of Energy
Source of funding	ENCON Fund
Target	Household level
Interest rate	0% per year
Credit Limit	A maximum of 10,000 THB in general, except for the No.5-labeled air condition priced at a maximum of 30,000 THB
Financial Support from Government	1,000 million THB
Term of Credit	One year
Co-partner Banks	1. Bangkok Bank 2. Krung Thai Bank 3. Bank of Ayudhya 4. Bank for Agriculture and Agricultural Cooperatives(BAAC) 5. Government Saving Bank

Source: Department of Alternative Energy Development and Efficiency, Ministry of Energy, 2014

3) Voluntary Energy Loan

Initiated by the Department of Alternative Energy Development and Efficiency (DEDE), the loan program was designed to promote energy efficiency (EE) via voluntary support. Memorandum of Understanding is signed between the two parties. A total of 13 banks participating in the program agreed to provide the whole amount of loan for crediting energy efficiency projects. Meanwhile, the Ministry of Energy would provide support on project dissemination and campaign.

Table 2.4 Voluntary Energy Loan

Background	This financial scheme developed based on a concept that the Government should downplay its role in financial scheme such as the Revolving Fund and position itself as academic supporter to the energy efficiency projects (EE).
Duration	Started in 2008 (ended)
Project Supervision	Department of Alternative Energy Development and Efficiency, Ministry of Energy
Source of Funding	Domestic commercial banks
Target	Entrepreneurs at all levels
Interest rate	Depending on individual banks
Credit Limit	Depending on individual banks
Targeted credit limit	60 billion THB
Total credit approved	Estimated 1.27 trillion THB at the third quarter of Year 2010, accumulated credit of 242,164 million THB
Term of Credit	Depending on individual banks
Co-partner banks	1. Bangkok Bank 2. Krung Thai Bank 3. Bank of Ayudhya 4. K-Bank 5. Thai Military Bank 6. Bank Thai (CIMB Thai at present) 7. Siam Commercial Bank 8. Thanachat Bank 9. Siam City Bank (Thanachat Bank at present) 10. Small and Medium Enterprise Development Bank of Thailand 11. ACL Bank (Industrial and Commercial Bank of China (Thai) or ICBC at present) 12. Export-Import Bank of Thailand (EXIM Thailand) 13. MFC Asset Management plc.

Source: Department of Alternative Energy Development and Efficiency, Ministry of Energy, 2014

4) ESCO PROGRAM

Initiated by the government, the ESCO program is aimed at helping administrative expenses among the ESCO networks to promote energy-efficiency activities.

Table 2.5 ESCO PROGRAM

Objective	• To encourage efficiency of ESCO mechanism • To encourage industrial and business sectors as well as government agencies to adopt ESCO mechanism into their energy efficiency projects. • To stimulate number of ESCO services • To develop ESCO service to meet international standard
Banks-related activities	Create a network between banks and energy-saving companies (ESCO - Bank Networking via 3-4 joint seminars/year in order to create awareness of coordination and work flow leading to proper ESCO fund management.
Project Duration	From 2008-present
Project Supervision	The Institute of Industrial Energy under Federation of Thai Industries (FTI)
Target group	Industrial Factories and/or Energy Service Company – ESCO
Total budget	Estimated 34.8 million THB
Source of funding	ENCON Fund via the Department of Alternative Energy Development and Efficiency, Ministry of Energy
Co-partner banks	1. Krung Thai Bank 2. Kasikorn Bank 3. Thai Military Bank 4. CIMB Thai Bank 5. Thanachat Bank

Result of the project	As of 2013, ESCO has made Guaranteed Savings Contracts (GSC) with value of 7.5974 billion THB. Of the total, 6.81403 billion THB investment is in the industries and 77.71 million THB in building constructions.

Source: Department of Alternative Energy Development and Efficiency, Ministry of Energy, 2014

The Federation of Thai Industries' Institute of Industrial Energy plays a major role in performing as the one-stop service for ESCO activities covering areas of energy saving, energy conservation and/or renewable energy. The services cover a wide range of activities such as project analysis, installation, guarantee and energy saving verification. What makes ESCO program outstanding is that the contract will enable related stakeholders to have more technical confidence to their energy projects. At present, there are 57 ESCOs registered with the Institute of Industrial Energy. Of the total, 75% of the project is still ongoing.

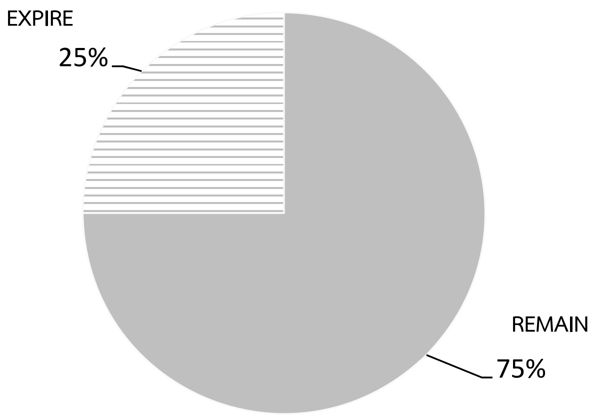


Figure 2.2 Current Situation of ESCO Factors Affecting to the Repayment Ability

The ESCO services have been categorized into two types:

1. Guaranteed Saving

The guaranteed saving will be provided to entrepreneurs investing in the project on their own. If the saving does not reach the specified guarantee, ESCO will compensate for the deficiency.

2. Shared Saving

The ESCO makes an equity investment through the shared saving agreement between the ESCO and the project owner in energy efficiency or renewable energy projects.

5) ESCO REVOLVING FUND

The project is aimed at supporting entrepreneurs having viable energy efficiency projects but lacking funds.

Table 2.6 ESCO REVOLVING FUND PROJECT

Objective	To promote investment in energy conservation and energy efficiency projects via ESCO mechanism.
Duration of the project	2008 – present
Project supervision	Department of Alternative Development and Efficiency (DEDE)
Operational agencies	1. Energy for Environment Foundation (EforE) 2. The Energy Conservation Foundation of Thailand (ECFT)
Type of services	• Equity Investment • ESCO Venture Capital • Equipment Leasing • Credit Guarantee Facility • Technical Assistance
Source of Fund	Energy Conservation Promotion Fund (ENCON Fund)

Targets	Energy Efficiency Projects under the Section 7 and Section 17 of Energy Conservation Promotion Act B.E. 2535 (1992) aimed at promote energy conservation in the country.
Credit Limit	500 million THB/year

Details of the ESCO Revolving Fund can be summarized in the Table 2.7

Table 2.7 Type of Services

Type of Services	Equity Investment	ESCO Venture Capital	Leasing	Credit Guarantee for Financial Institutions	Financial Support on Energy Audit Feasibility Study
Proportion of co-investment	10-50%	Less 30%	100%		
Maximum credit	50 million THB	50 million THB	10 million THB	10 million THB	100,000 THB
Major share holder	No	No			
Duration	5-7 Years	5-7 Years	5-7 Years		
Interest Rate	4% Flat	4% Flat	4% Flat		
Budget Administration	Administrative Board	Not specified			
Repayment	Stock selling	Stock selling			
Stock price	Following terms of agreement	Following terms of agreement			

The weakness of this financial scheme is that interest flat rate is still high compared to the effective rate.

6) Project on utilization of high efficiency equipment for energy conservation

Table 2.8 Project on utilization of high efficiency equipment for energy conservation

Objective	To promote and encourage utilization of high efficiency equipment to reduce energy consumption and to boost expansion of energy-saving technology and equipment
Duration of the project	Started in 2011
Owner of the project	Department of Alternative Energy Development and Efficiency
Organization operating the project	Thammasat University
Type of services and supports	• 20% subsidy of the total investment cost • Maximum subsidy of 3 million THB/application Minimum credit of 50,000 THB/application • Payback period within 7 years
Funding source	Energy Conservation Fund (ENCON)
Targets	Energy Efficiency Projects as directed under Section 7 and Section 17 of Conservation Promotion Act B.E. 2535 (1992) aiming to promote energy conservation in the country
Credit limit	N.A.

2.1.2 Commercial Banks

Here are details of financial products available for energy efficiency project.

- Most commercial banks do not have financial products specifically designed for energy efficiency projects. Some banks offer credit for operators looking for opportunities to invest in energy efficiency project and building construction. Some banks also offer financial products for both energy efficiency (EE) and renewable energy (RE) projects.

- Different commercial banks offer different energy efficiency credits and services for various target groups. Scale of business and its turnover will depict the amount of credit limit.
- Features of energy loan products i.e. repayment period, interest rate, fee amount and guaranteed services are distinct and different from each other.
- Individual banks will come up with their own terms of requirement for credit approval. Details in the terms of requirement are usually designed for general business investment, not specifically for energy efficiency project.
- No ESCO-certified requirement for most energy loan credits offered by most commercial banks.
- Most banks are willing to provide financial support to their old clients seeking funds for investing in energy efficiency projects.
- Due to limitation in raising deposits, interest rate of government banks is higher than commercial banks. However, most entrepreneurs, particularly those facing financial instability, lack access to credits offered by commercial banks and that they are willing to absorb the higher interest rate required by government banks.
- Some banks prioritize credits for ESCO service and adopt it as a mechanism to ensure technical risk. However, entrepreneurs are not allowed ESCOs to use their report as a guarantee for credit approval.
- Some banks will consider ESCO credibility and profiles involving energy efficiency projects prior to credit approval on case by case basis while some banks will have a list of ESCOs evaluated and approved for loan programs and technical assistance.
- Some banks prioritize credits for energy suppliers and come up with a list of energy supplies approved for loan programs and technical assistance similar to ESCOs.
- Most banks want to list ESCOs which are credible for credit approval, but do not want to negotiation or get involved in hiring system between entrepreneurs and ESCOs.

2.2 Overseas Financial Mechanism for Energy Efficiency

2.2.1 LEAP (Low Income Energy Assistant Program)

Its user-friendly method for evaluating energy use at household level makes this energy-saving scheme very unique and popular in the U.S. and Canada.

Figure 2.3 LEAP Program Website

LEAP procedures can be categorized into 9 steps.

1) **Information gathering** Consumers are responsible for gather their own information relating to energy use including lighting system, electric appliances and air cons, etc. at their households.

2) **Evaluation** can be made by filling in e-form available at www.ilikeleap.com

3) **Energy Use Report** can be printed out to learn the result of the evaluation.

4) **Participating into Leap** by registration via website www.ilikeleap.com after the system calculates 3-year cost saving result after replacing household equipment to the energy-saving ones.

5) **Coordination from Leap staff** by call centers is available for consumers to ask for further information regarding financial options for households

6) **Leap certified contractor** will contact consumers to start planning on energy-saving product installation at households.

7) **Financial support** Leap will coordinate credit application with financial institutions.

8) **Equipment installation** by Leap-certified contractor

9) <u>Applying for funding support</u> Further USD 100 grant will be provided by local administrative bodies

2.2.2 Siemens Energy Efficiency Financing

Financial scheme by SIEMENS designed to facilitate investment in energy-saving technology following the "simple, easy and convenient" principle. The scheme is based on an idea "the value of energy-saving will cover financial cost of both monthly installations plus interest rate occurred from the replacement of energy-saving equipment.

Customers are required to invest in energy-saving technology and equipment cost over £1000 have flexible repayment period of 1-7 years. Request for financial support can be made via a simple application. Credit approval or decline will be assessed within 24 hours.

2.2.3 GREEN BANK

Similar administration standard with commercial banks, this type of government bank has a policy on offering more flexible energy loan program than commercial banks. Green Bank of Kentucky (GBK) established in 2009 is the case study. The objective is to seek solutions to difficulties in supporting energy efficiency projects usually facing strict requirements set by commercial banks. GBK loan program did not require credit proportion and limit. However, thorough energy audit and study plan need to be carried out in case the project value is over 600,000 USD.

Green bank will review cost benefit analysis based on reduced energy use, risk assessment from debt repayment, appropriate credit limit and debt structure, etc. Operators interested in applying for the financial support need to pass no less than 5% of the preliminary assessment requirement by the Energy Conservation Measures (ECM). The repayment period will be less than 15 years.

Green Bank is seen as a hopeful solution to difficulties in access to source of funding and high investment in EE and RE projects. Green banks can offer more variety of financial products to meet the needs, leading better financial support on energy efficiency projects.

Some green banks prioritize energy efficiency (EE) projects to renewable energy projects (RE) due to short-term of operation and better risk management. Meanwhile some green banks will coordinate with local administrative bodies to support EE projects in a form of debt repayment, on bill repayment including co-working with local commercial banks to adjust any technical risk that may occur.

2.2.4 Green for Growth Fund

The Green for Growth Fund is the working effort between donors, international financial institutions and private investor. The aim is to support households, SMEs, and ESCOs on energy efficiency projects via three financial schemes: loan, guarantee and grants. Conditions will be different depending on individual countries.

Table 2.9 Credit Conditions

Country	Households	Companies	Duration of loan	Grace period	Collateral
Albania	11-16%	12-15%	5-15 years	General none	Mortgage for over 5 years
Bosnia and Herzegovina	8.50%	No info	Up to 10 years	1-3 years	No info
Croatia	7-9%	4.5-9%	2-30 years	6 months -3 years	Various, up to 130% of loan
Kosovo	10.90%	13.20%	Up to 10 years	None	Various
FYRo Macedonia	No info	5.5-9%	5-10 years	1 year	Various
Montenegro	No info	6%,8-13.5%	7-12 years	Up to 2 years	Various
Serbia	9%	5-7.5%	2-15 years	Up to 2 years	Various

Source : Western Balkans Investment Framework

Table 2.10 List of co-partner banks and financial products

Country	Bank Name	Name of product/ Financing source
Albania	Procredit Bank Tirana Bank	Energy efficiency Loans SME loans
Bosnia & Herzegovina	Raiffeisen Bank UniCredit bank	Energy efficiency Loans Energy efficiency Loans
Croatia	HBOR and 17 local banks listed below Banco Popolare Croatia d.d., Zagreb Banka Kovanica d.d., Varaždin Credo Banka d.d., Split Croatia Banka d.d., Zagreb Erste & Steiermrkische Bank Hrvatska Poštanska Banka d.d., Zagreb Hypo-Alpe-Adria Bank d.d., Zagreb Imex Banka d.d., Zagreb Istarska Kreditna Banka Karlovac?ka banka d.d., Karlovac OTP banka Hrvatska d.d., Zadar Partner banka d.d., Zagreb	Environmental Protection, Energy Efficiency and Renewable Energy Resources

Country	Bank Name	Name of product/ Financing source
Croatia	Podravska banka d.d., Koprivnica Privredna banka Zagreb d.d., Zagreb Slatinska banka d.d., Slatina Societe Generale-Splitska banka d.d., Split Volksbank d.d. Zagreb Zagrebacka banka d.d., Zagreb	
FYRo Macedonia	Komercijalna Banka Halkbank	SME investment loans from EIB
	Ohridska Banka	Credit line from MBDP for participation in sustainable energy project through financing energy efficiency projects and renewable energy sources projects
	NLB Tutunska Banka	Credit line from MBDP for participation in sustainable energy project through financing energy efficiency projects and renewable energy sources projects
	Unibank ad Skopje	Loan for energy efficiency
	ProCredit Bank	EKO Loans
Kosovo	ProCredit Bank Kosovo	EKO Loans
	Raiffeisen Bank	BIO Loan

Country	Bank Name	Name of product/ Financing source
Montenegro	Crnogorska Komercijalna Banka	CKB Green loans
	Atlasmont Banka	
	First Financial Bank	European loans
	Hipotekarna Banka	EIB loans for SMEs
	Erste Bank	No specific product name
	NLB Montenegrobanka	NLB EKO loan from KfW fund
Serbia	Banca Intesa	Credits for energy efficiency
	Cacanska Banka	Hit energy loans
	Erste Bank	EIB Credit Line
	KBC Banka	Long-term credit for permanent assets infrastructural projects from EIB credit line
	Komercijalna Banka	EIB Credit Line
	OTP Bank	EIB Credit Line
	Privredna Banka Beograd	EIB Credit Line
	ProCredit Bank	Energy efficiency loans
	ProCredit Leasing	Leasing for energy efficiency
	Raiffeisen Bank	Green loans/energy efficiency loans
	Socit Gnrale Bank	Credits for energy efficiency
	Sberbank	
	UniCredit Bank	EIB Credit Line
	Volksbank	Green Volksbank loans

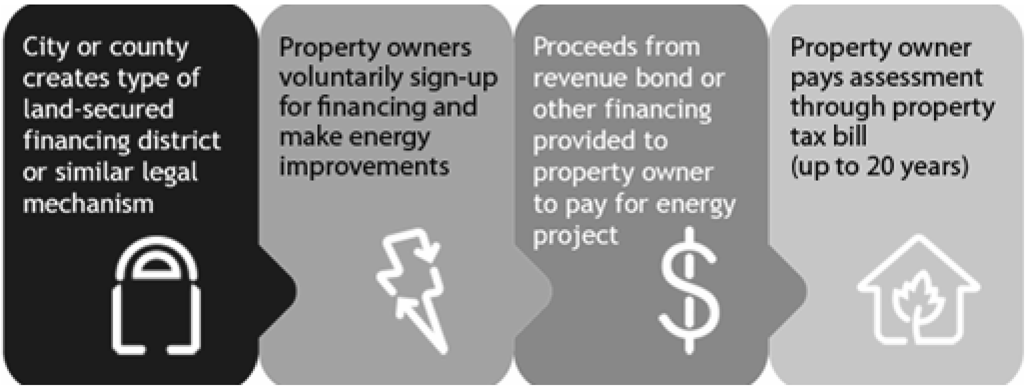
Note: EIB = Energy Investment Bank

Source: Western Balkans Investment Framework

It is crucial to know that grants once available in European countries are going to be replaced by loan programs in a bid to maximize financial utilization.

2.2.5 Property Assessed Clean Energy "PACE"

PACE is a crucial financial scheme promoted among business and household sectors by local administrative bodies. Property owners interested in the clean energy project will get the fund generate from bond revenue, but need to pay the debt in a form of property tax. Usually long-term repayment period with interest rate will be offered depending on conditions of the bond.



Source: http://energy.gov/eere/slsc/property-assessed-clean-energy-programs as of January 13, 2015

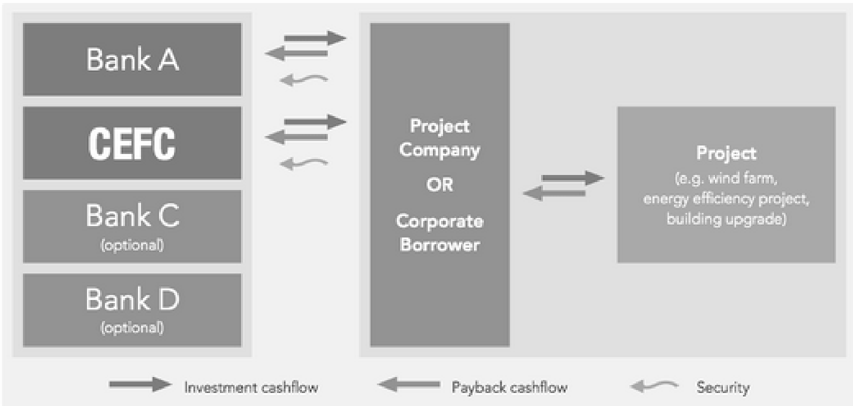
Figure 2.4 PACE mechanism

However the PACE mechanism has its weaknesses, particularly high operational cost and legal fee. It is suitable for project worth over USD 50,000.

2.2.6 Clean Energy Finance Corporation (CEFC)

Special financial institutions established to seek solutions for energy efficiency projects having difficulties to access financial support. CEFC will act as a financial supporter of the project and a co-partner with other banks. After credit approval, CEFC and the co-partner bank will proceed financial papers for three types of credit repayment.

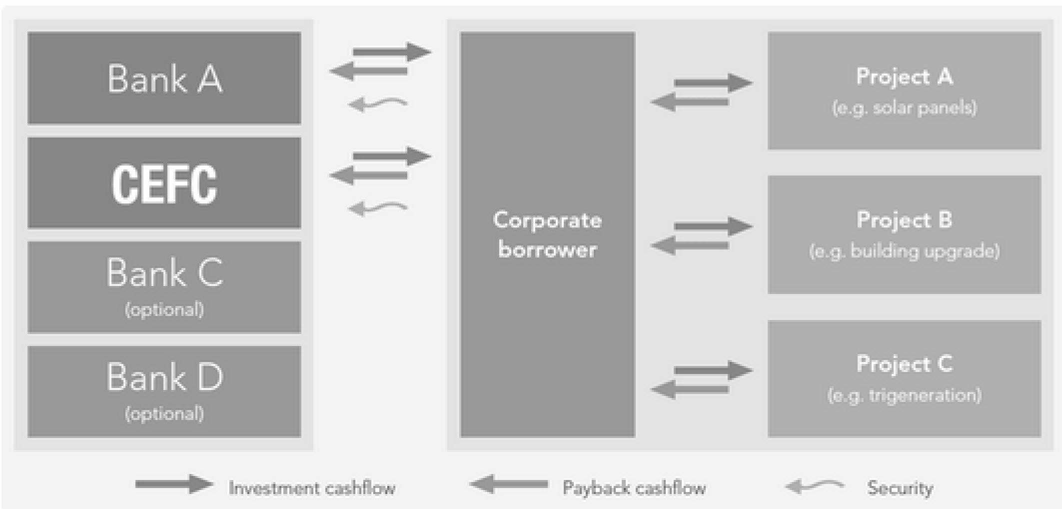
1) Project Finance (Limited Recourses): this financial product is aimed at supporting a single energy efficiency project.



Source : Clean Energy Finance Corporation

Figure 2.5 Project Finance Mechanism

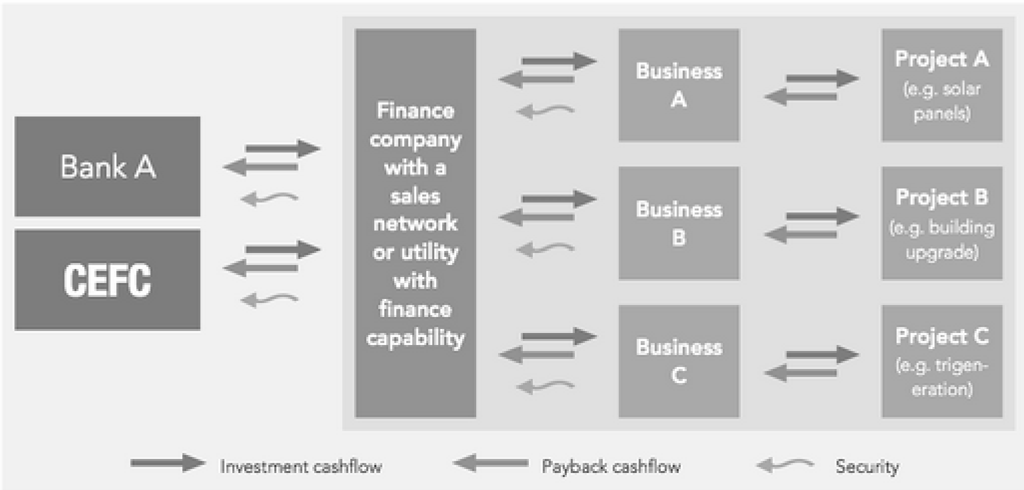
2) Corporate Loan: financial products for company having more than one energy efficiency projects.



Source : Clean Energy Finance Corporation

Figure 2.6 Corporate Finance Mechanism

3) Aggregation Funding: financial support via financial corporate working on managing small energy efficiency projects.



Source : Clean Energy Finance Corporation

Figure 2.7 Aggregation Funding Mechanism

2.2.7 Loan Loss Reserve (LLR)

The remuneration fund in case financial institutions providing loan programs for energy efficiency project facing loss due to delayed debt payment. This financial product is popular due to its simple operation. Banks will indicate a so-called "loan pool" to distribute a small amount of LLR credit to support energy efficiency projects. LLR and banks will work together to set loan pool coverage ratio and loss share ratio, if necessary.

However, LLR does not prevent risk from debt repayment. Hence, co-partner banks will have to partially take the responsibility in case of final loss.

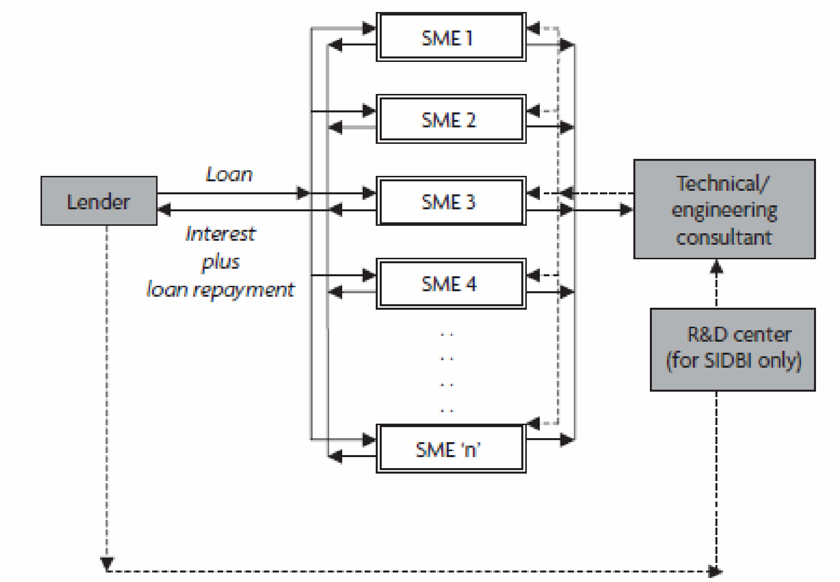
2.2.8 Loan Guarantee

This financial tool is similar to LLR, except the condition that any loss will be fully guaranteed. However the credit limit may be set. Financial reserve for remunerating any loss and Escrow account for loan loss reserve are key differences between Loan Guarantee and LLR. Loan Guarantee is usually for supporting larger projects than LLR. Loan Guarantee can also be utilized to support ESCOs following the establishment of ESCO Loan Guarantee Program by the Central Bank of China in 2003, enabling ESCOs to access funding from local banks. The Global Environment Facility (GEF) of World Bank is regarded as the largest loan guarantee provider and considered as one of the first programs introduced by the World Bank to stimulate the energy-saving projects.

2.2.9 ENERGY EFFICIENCY CLUSTER LENDING FOR SMES

Banking mechanism implemented in India to provide SMEs financial support on energy efficiency projects. Most SMEs face difficulties in getting access of source of funding due to business sizes and high transaction cost.

With simple application and model designed based on the cluster principle, this mechanism enables banks to reduce operational cost, technical risk and management.



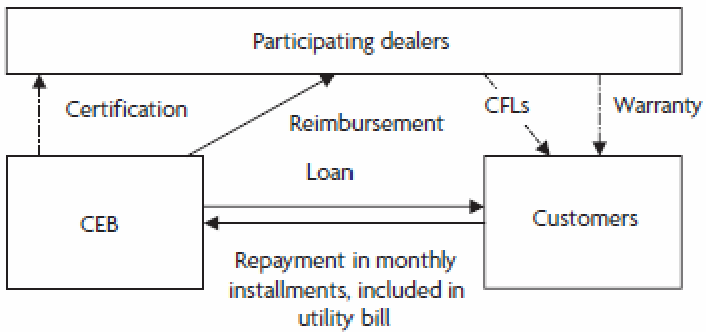
Source: Financing Energy Efficiency, Lessons from Brazil, China, India and Beyond (P.197), by Robert P.Taylor, Chandrasekar Govindarajalu, Jeramy Levin,Anke S.Meyer and William A.Ward., 2008, Washington DC : The World Bank

Figure 2.8 ENERGY EFFICIENCY CLUSTER LENDING FOR SMES

2.2.10 THE UTILITY BILL AS A LOAN REPAYMENT MECHANISM

The Ceylon Electricity Board (CLB) is the case study for this mechanism considered as low-risk. The agency is responsible for generating and distributing electricity to customers at all sectors. Realizing in the problem of power shortage, CLB seeks way to help customers reduce cost electricity consumption. Launched in 1994, those interested in participating into the program can buy electronic appliances from CLB-certified dealer and keep the utility bill for remunerating with the agency.

The decrease in electricity cost is the dividend the agency will get in return after providing customers electronic appliance remuneration.



Source: Financing Energy Efficiency, Lessons from Brazil, China, India and Beyond (P.243), by Robert P.Taylor, Chandrasekar Govindarajalu, Jeramy Levin,Anke S.Meyer and William A.Ward., 2008, Washington DC : The World Bank.

Figure 2.9 THE UTILITY BILL AS A LOAN REPAYMENT MECHANISM

There are two major debt repayment schemes for energy efficiency projects (EE). On Bill Financing (OBF) is the loan program directly operated by the government agency overseeing utility administration. On Bill Repayment (OBR) is the scheme based on the agreement between the customer, the utility administration agency and the co-partner bank. Reduced cost from utility bill will be calculated as debt repayment.

2.2.11 EBRD Regional Energy Efficiency Program (REEP)

EBRD is the case study on funding for regional energy efficiency and renewable energy projects in Eastern European countries i.e. Albania, Bosnia and Herzegovina, Croatia, the Former Yugoslav Republic of Macedonia, Kosovo, Montenegro and Serbia.

Table 2.11 Source of EBRD Fund

Types of Finance	Loan Funds	
	Previous Fund	REEP
Financing source	EBRD	EBRD
Window 1 : Policy Dialogue	-	-
Window 2 : Credit Line	EUR 60 m	EUR 75 m
Window 3 : Direct Financing	EUR 50 m	EUR 50 m

Source : Western Balkans Investment Framework

REEP funding is divided into three parts. The first part is for policymaking on encouraging more EE and RE projects. The rest is for providing credit line to public individuals and SMEs via local administrative bodies, and project investment including direct investment in ESCOs.

Chapter 3
Energy Saving Measures by Industrial Sectors

3.1 Overall energy consumption in industrial sector

Industries need electricity and/or heat power from fuel for utilities and processing procedure. The amount of fuel usage will depend on different systems and equipment as shown in Figure 3.1

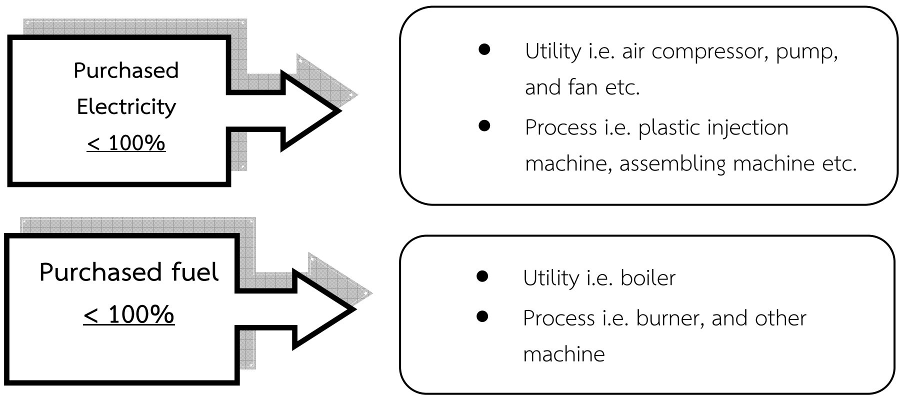


Figure 3.1 Fully energy purchase and Process-Utility in Factory

In addition, energy production from waste heating system, electricity system and cogenerating system may be considered for using in a bid to reduce energy consumption and fuel cost as shown in Figure 3.2

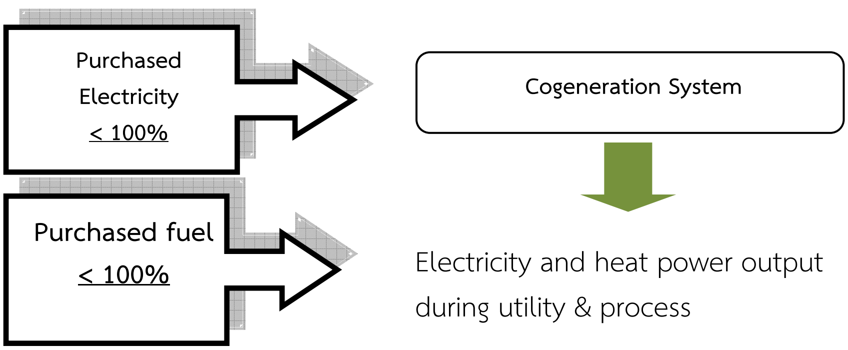
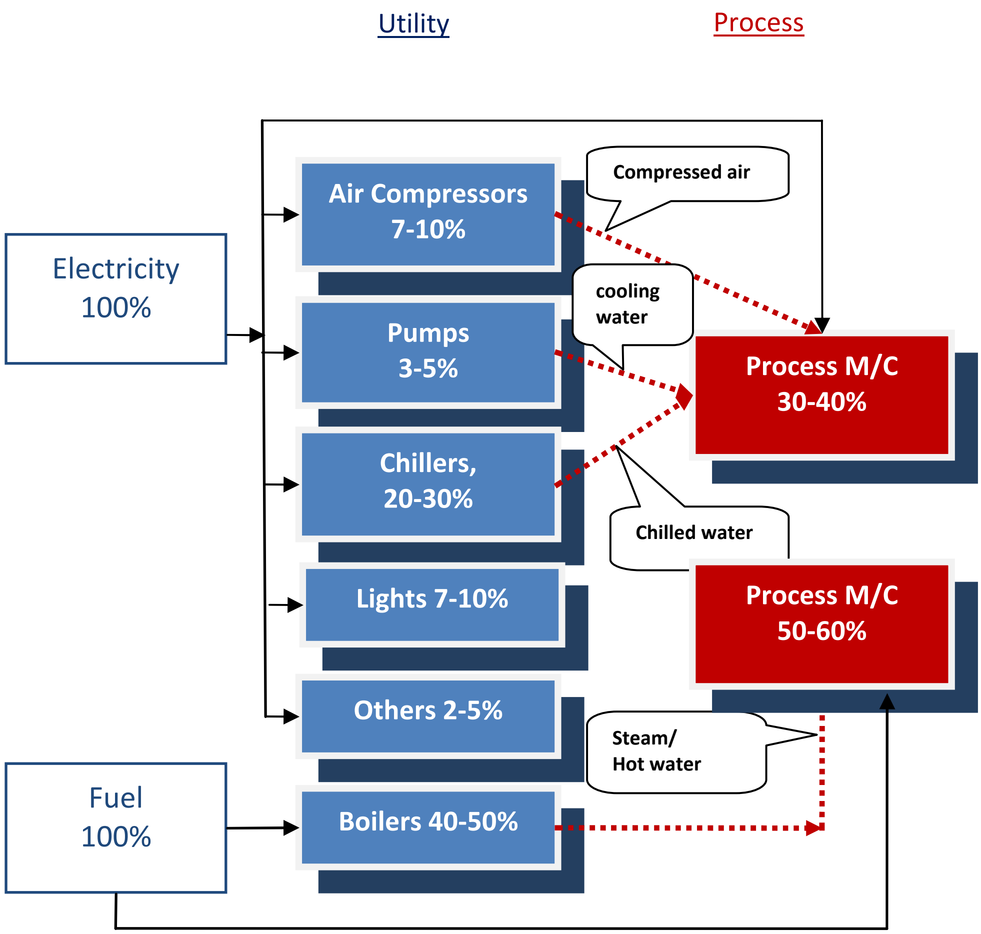


Figure 3.2 Partly Energy Purchase and Process-Utility in Factory

3.2 Types of energy use in the industrial sector

Energy use among usual industries can be explained in Figure 3.3



Source: Energetics Pty, Energy Audit Expert Review, Australia

Figure 3.3 Diagram of energy use by industries

From the diagram above, these are major equipment for utilities and processing.

- Air Compressors

  The machine needs electricity and power source to drive manufacturing system in a form of compressed air and valve controller. It is also used for blow drying moist of the products.

- **Pumps**
  Electricity is the power source of the equipment to drive liquid (e.g. water) for cooling, cleaning, mixing etc. in manufacturing process.
- **Chillers**
  Electricity is the power source of the equipment producing cool water for manufacturing machine and/or air conditioning process.
- **Lighting**
  The equipment also needs electricity power to provide sufficient lighting in the working space.
- **Boilers**
  The machine uses electricity and fuel power for steam/hot water production for heat transferring to the machine in the manufacturing process.

3.3 Energy Saving Potentials

An example of Energy conservation measure categorized into type of industries is shown in Table 3.1

Table 3.1 Energy saving potentials based on type of industries

General industries	Estimated energy saving (%)
Using high-efficiency motor	2 - 5%
Variable Speed Drive adjustment (VSD)**	30 - 50%
Boiler Economizer Measure*	1 - 5%
Waste heat recovery of air compressor)	80%
High-efficiency air compressors **	5 - 20%
High-efficiency boilers	10 - 15%
Insulation	20 - 30%
Food/steel/paper/non-metal industries	**Projected energy saving (%)**
Using Heat Exchanger/Regenerator/ Recuperator/Recuperative Burner/Regenerative Burner/Waste Heat Boiler**	10 - 50%d
Installation of cogeneration system**	30 - 40%

Source: Energetics Pty, Energy Audit Expert Review, Australia

Note: *Estimated energy saving (%) compared to previous energy consumption of the system/equipment prior to improvement.

**Details and explanation of measures and case studies are in appendices.

3.4 Case study on energy-saving project

This following energy-saving case study showcases different options for energy-saving project operations based on technology, effectiveness and price per unit. Financial factors such as investment, cost saving and breaking even as well as single or multi-investment projects will be taken into account as shown below:

Boiler (Figure 3.4)

Figure 3.4 Boiler

Input energy : Fuel (for burning), Electricity (for motor and controlling equipment)
Outputs : Steam, hot water (via heat exchanger)
Energy loss : Flue gas 15-20%, Water Blowdown 2-5%, Surface temperature 1-2%

Consideration of technical factors relating to energy saving measure

- Amount of steam use and steadiness of steam use
- Temperature and amount of flue gas
- Efficiency of boiler
- Period of boiler usage
- Others

An example of the potential and cost of improvement technology for boiler is shown in Table 3.2

Table 3.2 Example of potential and cost of improvement technology

Technology	Size (kg/hr)	Efficiency (%)	Estimated Cost	Unit	Remarks
Economizer[3)]	3,000	+4%	89	B/kg/hr	
Waste Heat Recovery Boiler[4)]	3,000	91%	1,753	B/kg/hr	Boiler eff. = 80% Overall eff. = 91%
High Eff.Boiler[5)]	3,000	94%	865	B/kg/hr	

Source : Economizer by USDOE (Energy Tips), Waste Heat Recovery Boiler by Switch Asia Program, High Eff. Boiler by MIT

Note: 1. Efficiency/unit referred in the table is based on some producers and only used as an example.

2. Estimated cost is investment in the project of steam production per unit.

3. Economizer is heat exchange equipment used for boiling water to use and for energy saving.

4. Waste Heat Recovery Boiler is the machine used for recycling heat and reducing energy consumption during the steam production process.

5. High Eff. Boiler is designed based on energy-saving purposes. As a result, waste proportion is very low.

Consideration of financial factor

- Fuel cost per unit including steam purchasing and selling (if any)
- Investment in equipment including installation and relocation (if any)
- Value of unused equipment
- Maintenance cost for existing and new equipments
- Cost due to any cancellation of manufacturing process
- Others

An example of the boiler's energy saving potential is shown in Table 3.3

Table 3.3 Example of energy saving potential of boiler

ECMs	Implement	Saving	Unit	Investment	Unit	Payback	Unit
1. Install Economizer	☑ Yes	266,611.61	[B/y]	266,611.61	[B]	1	[y]
2. Waste heat recovery boiler	☐ Yes	3,506,713.99	[B/y]	5,260,070.99	[B]	1.5	[y]
3. Use High Eff. Boiler	☑ Yes	1,441,096.05	[B/y]	2,593,972.88	[B]	1.8	[y]
Total (All ECMs selected)		**฿5,214,421.65**	Baht/yr	**฿8,120,655.48**	Baht	**1.56**	Years
Total (some ECMs selected)		**฿1,707,707.66**	Baht/yr	**฿2,860,584.50**	Baht	**1.68**	Years

Source : The example of calculation using information referenced from Table 3.2

Note: Energy saving calculation and the payback period in Table 3.3 is based on NG fuel price at 0.30 Baht/MJ (1MMBtu=1,055MJ)

Air Compressor (Figure 3.5)

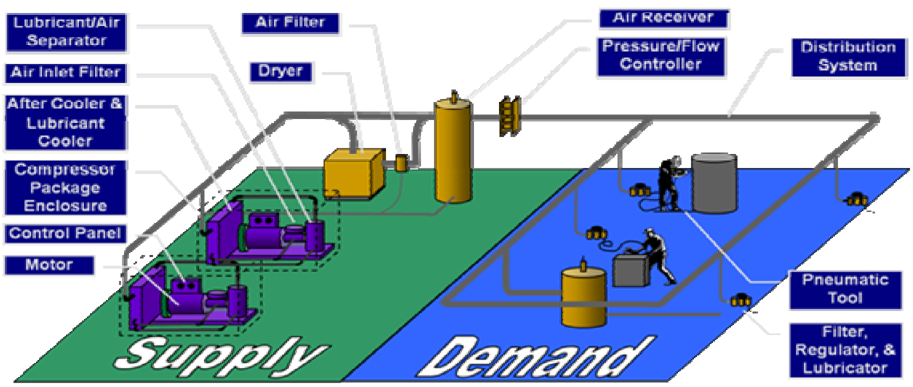


Figure 3.5 Air Compressor

Energy input : Electricity (for compressor)

Output : Compressed air

Energy loss : Heat from compressed procedure 70-80%, Loss at motor and other parts 10-15%

Consideration of technical factor relating to energy saving measure

- Type and demand for compressed air
- Pressure and leak of compressed air system
- Type of existing air compressor
- Capacity of existing air compressor
- Period of use
- Others

An example of the potential and cost of improvement technology for air compressor is shown in Table 3.4

Table 3.4 Example of potential and cost of improvement technology

Technology	Size (kW)	Performance	Estimated Cost	Unit
VSD Compressor[3)]	37	Up to - 35% less energy	40,000	B/kW
Multi-Stage Compressor[4)]	37	6 to 13% Increased eff.	20,000	B/kW
High Eff. Motors[5)]	37	2-7% higher eff. than general motors	5,000	B/kW

Source : Compressed air best practice , Sustainable Energy Authority of Ireland (SEAI) , Improving Compressed Air System Performance, Compressed air challenge, USDOE, Motor Energy Management : Opportunities & Cost Savings, www.motormatters.org, Energy Saving Potential and Opportunities for High-Efficiency Electric Motor, USDOE 2013

Note:

1. Efficiency/unit referred to in the table is based on some producers and only used as an example.
2. Estimated cost is an investment in electricity capacity per unit of the air compressor.
3. VSD Compressor is the air compressor which can adjust cycle speed of the motor in relation to workload for energy-saving purpose.
4. Multi-Stage Compressor can divide air compression in several stages. Heat will be released in between each compression stage for cooling down the temperature, leading to energy saving of the process.
5. High Eff. Boiler is designed based on energy-saving purposes. As a result, waste proportion is very low.

Consideration of financial factor

- Fuel cost per unit
- Investment in equipment including installation and relocation (if any)
- Value of unused equipment
- Maintenance cost for existing and new equipment
- Cost due to any cancellation of manufacturing process
- Others

An example of the Air compressor's energy saving potential is shown in Table 3.5

Table 3.5 Example of energy saving potential of the air compressor

ECMs	Implement	Saving	Unit	Investment	Unit	Payback	Unit	Remark
1. VSD air compressor	☑ yes	483,361.57	[B/y]	1,480,000.00	[B]	3.06	[y]	Viable for load<50%>
2. High eff. Motor*	☐ yes	14,695.05	[B/y]	185,000.00	[B]	12.59	[y]	Viable for load<75%>
3. Multi Stage compressor	☐ yes	137,398.70	[B/y]	740,000.00	[B]	5.39	[y]	Less power consumed as same amount of air produced by 1-stage
Total (All ECMs seleted)		635,455.31	Baht/yr	2,405,000.00	Baht	3.78	Years	
Total (some ECMs seleted)		483,361.57	Baht/yr	1,480,000.00	Baht	3.06	Years	

Source : The example of calculation using information referenced from Table 3.4

Note: Calculation of saving and payback per unit in the table is based on electricity price at 4 Baht/kWh and working hour at 8760 hours/year

Cogeneration (Figure 3.6)

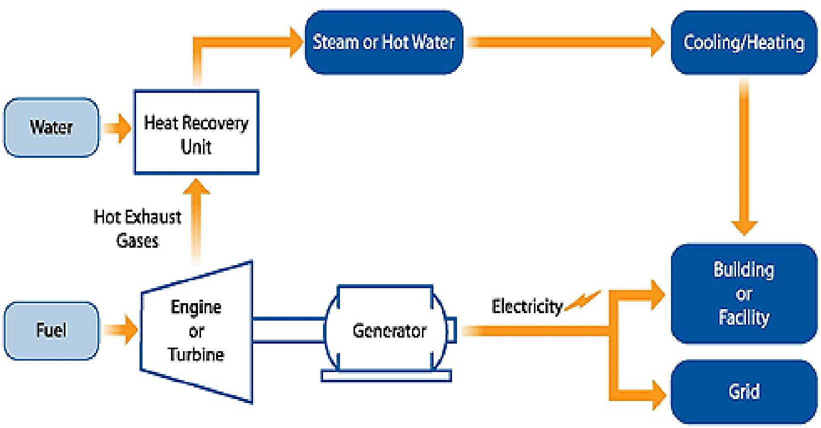


Figure 3.6 Cogeneration

Input energy : fuel (for burning)

Output : electricity, high-pressured steam

Energy loss : energy loss in the system 10-25%

<u>Consideration of other technical factor relating to energy saving measure</u>

- Heat to Power Ratio
- Peak demand on electricity
- Amount of equipment using waste heat from electricity generating
- Amount of cooling needed from waste heat by absorption chiller
- Others

An example of the efficiency and estimated cost of improvement technology for cogeneration is shown in Table 3.6

Table 3.6 Example of efficiency and estimated cost of improvement technology

Technology	Size (MWe)	Total eff. (%)	Estimated Cost[2)]	Unit	Remarks
Open Cycle-Gas Turbine	0.5-250	70-85%	31M-42M	B/MW	@32 Baht/USD
Combined Cycle-Gas/Steam Turbine[3)]	3-300+	90%	26M-114M	B/MW	@32 Baht/USD
Reciprocating Engine	0.01-5	70-80%	35M-70M	B/MW	@32 Baht/USD
Steam Turbine	0.5-250	80%	14M-35M	B/MW	@32 Baht/USD

<u>Note</u> : 1. Efficiency and per unit in the table is based on some producers and only used as a sample. (http://www.code-project.eu/wp-content/uploads/2011/04/CODE_CS_Handbook_Final.pdf, http://www.nrel.gov)

2. Estimated Cost is investment in the project per unit of electricity generation.

3. Combined Cycle Electricity = 33MWe, Steam =52.6 t/h NG fuel cost at 26 Million Baht/MW, Combined Cycle Electricity = 110MWe, Steam =630t/h Black Liquor fuel investment at 114 Million Baht /MWs

Factors affecting investment cost in general such as type of technology, money exchange rate for imported equipment, the availability of fuel or process heat as continuous energy input for cogeneration system running at 24 hours etc.

Consideration of Financial factor

- Purchasing and selling price of electricity and fuel cost per unit including steam buying and selling (if any)
- Cost of investment in equipment including installation
- Operation and maintenance cost
- Cost due to any cancellation of manufacturing process
- Others

An example of the cogeneration projects energy saving potential is shown in Table 3.7

Table 3.7 Example of energy saving potential of cogeneration projects

ECMs	Implement	Saving	Unit	Investment	Unit	Payback	Unit	Remark
Gas turbine + HRSG Boiler (Co-generation)	☑ Yes	8,188,288.45	[B/y]	31,000,000.00	[B]	3.79	[y]	
Gas turbine + HRSG Boiler +Absorption Chiller (Tri-generation)	☐ Yes	27,872,752.45	[B/y]	56,000,000.00	[B]	2.01	[y]	
Total (All ECMs selected)		36,061,040.90	Baht/yr	87,000,000.00	Baht	2.41	Years	
Total (some ECMs selected)		8,188,288.45	Baht/yr	31,000,000.00	Baht	3.79	Years	

Note: Energy saving calculation and the payback period in Table 3.7 is based on NG fuel price at 0.30 Baht/MJ (1MMBtu=1,055MJ)

In conclusion, it is crucial to evaluate energy saving potential from not only technology/new equipment for project improvement but also energy use of existing technology according to this following model:

Energy Saving = Baseline - Post Installation

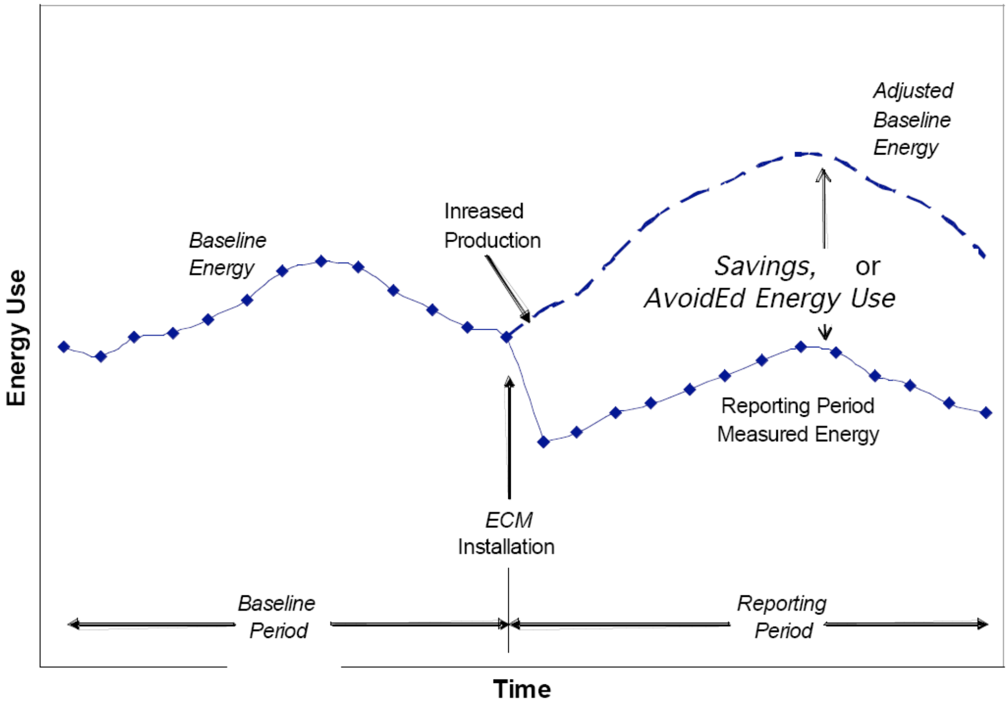
Controlled Variables are

- Hours of machinery/equipment use prior to and after improvement
- Working load (%) of machinery/equipment prior to and after improvement
- Fuel cost per unit

Chapter 4
Technical Assessment for Energy Efficiency Projects

4.1 Energy saving assessment

Result of energy saving can be assessed by comparing energy use between baseline period and the reporting period.



Source: Efficiency Valuation Organization ; EVO, Concept and Options for Determining Energy and Water Savings, Volume 1, January 2012

Figure 4.1 Model showing energy-saving assessment after improving equipment capacity (Source: IPMVP Volume 1: Concept and Options for Determining Energy and Water Savings, April 2007)

From Figure 4.1 Energy saving assessment will be carried out by separating the existing energy use from increasing productivity. Baseline energy use will have to be preliminarily assessed in order to learn the amount of energy used for manufacturing. Then energy use of boiler with improved capacity will be calculated to learn about the adjusted baseline energy.

The energy saving result from improved boiler capacity will indicate the difference between the adjusted baseline energy and the energy use of the boiler with improved capacity during the reporting period.

If increasing productivity is not the case, the difference between the baseline energy use and the energy use measured during the reporting period will be high. Hence, separating energy use-related factors is crucial so that the assessment will be precisely calculated. The following is the relations used for analyzing energy saving

Energy saving result

= (Baseline energy use – Energy use measured during the reporting period)

± Adjusted baseline energy use

[Saving = (Baseline-Period Energy Use – Reporting-Period Energy Use)

± Adjustments**]**

4.2 Basic principle of energy saving measurement and verification

Basic principles for measuring and verification for each project are the following:

4.2.1 Accuracy

Accuracy is the key to acceptable energy saving measurement and verification. Deviation may occur depending on each project. Data application and budget for energy-saving measurement and verification are factors causing deviation

1) Data Application

Data from energy saving measurement and verification can be used for various purposes i.e. calculation for energy-saving result for ESCO Project, assessment of energy conservation project and verifying energy-saving result for applying the government subsidy. Those responsible for the project will identify the accurate level or deviation of energy saving measurement and verification as well as the importance of data application.

2) Budget for energy saving measurement and verification

The proportion is not high compared to the energy-saving level. The project having high level of energy saving may have higher measurement and verification budget than those having low energy-saving level (based on similar measurement and verification method). Increasing budget enables project operators to identify and precisely calculate energy saving measurement and verification in details.

4.2.2 Complete

Measurement and verification for energy saving must be thorough. All variables having high energy use will have to be measured whereas other low-energy use variables can be estimated.

4.2.3 Conservative

In case of estimation or impact assessment due to low-energy use variables, conservative assessment will be implemented.

4.2.4 Consistency

Consistency in terms of technical calculation, the period of time for assessment, etc. should be implemented. Details can be varied, but should not be against the basic principle of energy saving measurement and verification.

4.2.5 Transparency

Transparency must be taken into account and that all related parties will have to put into practice in every step from principle, procedure, project planning to method used for measurement and verification depending on objectives of individual projects.

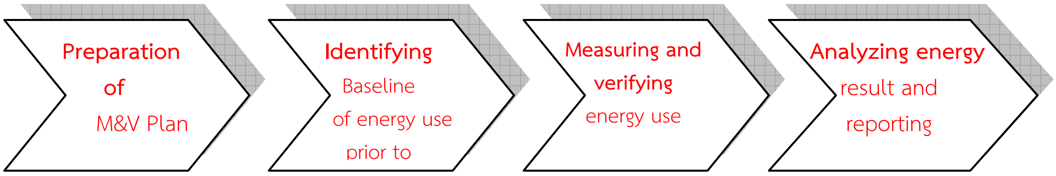
4.3 Objective and framework of energy saving measurement and verification

Measuring and verifying energy saving prior to and post equipment improvement is aimed at enhancing efficiency of the energy conservation project, or boosting investment in the project.

Major activities in the measurement and verification process can be categorized as follow:

1. Planning measurement and verification
2. Identifying baseline energy use
3. Measuring and verifying energy use after equipment improvement
4. Analyzing energy saving result and reporting energy-saving assessment

The following details explain each step of M&V plan.



4.3.1 Measurement and Verification Plan – M&V Plan

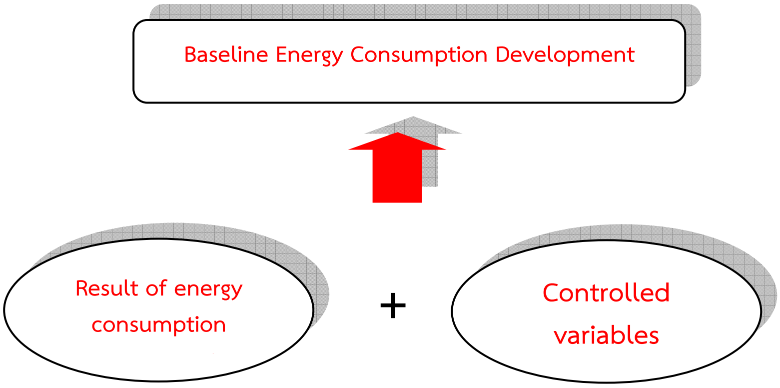
The first step begins with M&V plan preparation by a project leader or an engineer responsible for energy use of the project. The objective is to identify principle, methods, details and framework of M&V plan on energy saving. Details that should be included in the M&V plan are the following:

1) Documentation of the design and technical framework
2) Baseline energy use including controlled variables of the project or improvement measure
3) Process and methods for measuring and verifying energy saving
4) Quality control of M&V plan
5) Controlled variables relating to M&V and calculation method
6) Details about software for energy use calculation (in case of using simulation software for M&V)
7) Regulation for equipment used for measuring energy use or related controlled variables
8) Position of M&V or other related variables
9) Method and duration for testing M&V equipment or variables
10) Appropriate duration for M&V, type of project and improvement measure
11) Baseline data of controlled variables during M&V process i.e. temperature, productivity and other related variables
12) Acceptable level of deviation for M&V and adaptation method
13) Type of M&V checklist
14) Budget and personnel for M&V planning

M&V planning should be carried out during designing or improvement identification step because further equipment installation and duration of work plan may be necessary during the process which may require details relating to M&V. Such information will enable an engineer or a project leader to come up with solid M&V planning in the long run.

4.3.2 Baseline Energy Consumption Development

Baseline energy use is essential for analyzing energy saving. Precise calculation will depend on baseline energy use including energy consumption assessment and controlled variables involving energy consumption.



Result of energy consumption assessment: Usually energy use index will be implemented to identify baseline energy consumption.

Controlled variables: Energy use in the system varies based on related variables. Hence, baseline energy consumption needs to clearly identify controlled variables to conduct precise energy use assessment. M&V plan on identifying energy consumption index may vary depending on type of the project or energy conservation measure undertaken at each project.

4.3.3 Post Energy Audit Analysis

The analyzing process will be undertaken after project improvement or energy-saving equipment installation phase. The method will be similar to baseline energy consumption, improvement under controlled variables. In case controlled variables cannot be adjusted, the result of energy consumption after improvement will have to be adjusted in accordance to baseline energy consumption and reporting energy consumption periods.

4.3.4 Energy Saving Analysis and Reporting

Energy conservation project will compare baseline energy consumption with the reporting period of adjusted energy consumption in a bid to analyze energy saving as percentage (%) and prepare M & V report for executive level for implementing the project.

4.4 M&V Benefit

Apart from better understand about baseline energy and adjusted energy consumption, energy saving percentage and energy consumption cost, M&V benefit can be summarized as follow:

4.4.1 Increased Energy Savings:

Project executives and involving parties will be aware of energy conservation project. Information from M&V will enable the project leader to effectively plan the work on the project and other energy conservation projects, leading to more energy conservation.

4.4.2 Operations and Maintenance Troubleshooting:

Details from M&V will enable the project leader or the engineer responsible for energy saving to effectively identify working and maintenance instruction for the equipment particularly during the first and the second year.

4.4.3 Performance Contracting:

Precise data from M&V can be used for other energy conservation projects which may require warranty of equipment potentials or cost saving from newly-installed equipment

4.4.4 Better project engineering:

M&V procedure enables the project leader or the engineer responsible for energy saving to effectively develop engineering design and administration leading to engineering development.

4.4.5 Supporting lowing GHG emission:

Data from M&V will be used for calculating greenhouse gas emission (GHG) of agencies, companies and can be used for supporting lowering GHG emission activities.

4.5 Regulation for energy saving measurement and verification

At present, M&V regulation has been developed to meet International Performance Measurement and Verification Protocol (IPMVP) categorized into three volumes by US-based Efficiency Valuation Organization (EVO).

- **IPMVP Volume I Concepts and Options for Determining Energy and Water Savings**

The document provides definition, framework and recommendation for energy-saving measurement and verification and increasing water consumption capacity.

- **IPMVP Volume II Indoor Environmental Quality (IEQ) Issues**

The paper talks about the impact of project boosting energy capacity on environment, recommendation on measuring environment-related variables which may affect energy capacity.

- **IPMVP Volume III Applications**

The document provides details relating to application of recommendation given in the IPMVP Volume I and Volume II. Details is categorized into two parts- application to new building construction in Part I and application of renewable energy for use at the industry in Part II.

4.6 Defining framework for energy saving measurement and verification

The framework will depend on the need for energy saving measurement and verification M&V including energy-saving assessment of the industry as a whole or specific part of the industry.

Defining framework for energy saving M&V may depend on these following factors.

- **Energy saving assessment for equipment management**

For this case, only equipment which needs energy-saving measurement and verification will be assessed. Retrofit Isolation will be used as a calculation method. (Reference: International Performance Measurement and Verification Protocol, IPMVP. Details in topic 4.9)

- **Energy saving assessment for improving energy management at facilities**

Energy saving measurement and verification need to cover the total energy use of each industrial facility. Energy use data from a meter set by energy provider to the facility. The so-called "Whole Facility" will be used as a calculation method. (Reference: IPMVP, details in the 4.9 topic)

- **Energy saving assessment for improving energy management at facilities due to insufficient details about baseline energy consumption**

For this case, M&V framework will cover energy consumption either by equipment or by the whole facility. The so-called "calibrated simulation" will be used a calculation method. (Reference: IPMVP, details in the 3.9 topic)

Nevertheless, energy use for equipment or system with energy-saving M&V may affect energy consumption of other equipment that has not yet been assessed. For this case, energy use among that equipment is called "interactive effects" or "leakages" and will be used as a part of energy-saving M&V. If the amount of interactive effect or leakages is high, the M&V framework has to be planned. If the amount and the impact of interactive effect are minimal, assessment may be set aside.

4.7 Measurement Period Selection

Identifying period of measurement will enable the project leader or the engineer responsible for the energy-saving project of the facility to come up with an effective energy saving M&V plan. Measurement period can be categorized into three steps.

4.7.1 Baseline Period

Here are the relations between baseline period and baseline energy consumption measurement:

1. A period that cover all operational modes of the equipment or the system with energy saving M&V from the lowest to the highest energy consumption equipment.
2. A period that can represent energy consumption in all operating conditions during normal operating cycle.
3. A period that covers both fixed and variable energy consumption.
4. A period that happened prior to equipment improvement. The framework for M&V should not be long before equipment improvement as the baseline energy use may not be accurate or timely.

4.7.2 Reporting Period

Those responsible for energy conservation project should identify reporting period. The identified period should cover a normal operating cycle in all normal operating modes. Period of the project and depreciation of the equipment should also be taken into account.

4.7.3 Adjacent Measurement Periods – On/Off Test

Baseline energy use and reporting can be undertaken continuously and cost-saving measure can be implemented or cancelled without causing any impact on the system and energy consumption can go back to the baseline energy use. The amount of energy use is still valid to calculate energy saving. However framework for measuring and verification should be well planned and cover changing conditions such as climate and productivity ratio.

4.8 Basis for Adjustment

To calculate cost of saving, the basis for adjustment needs to be calculated to assess actual energy consumption and framework for measuring and verifying energy saving. The basis for adjustment can be categorized into two methods.

- Routine Adjustments – Any variables affecting energy consumption for example climate, productivity need to be recorded or calculated by using equation to learn about energy consumption rate.
- Non-Routine Adjustments – Any variables that affects unstable energy use for example facility size, working hours of the newly-installed machine. Data monitoring and calculation are necessary for these variables to adjust energy use. Relations for analyzing energy saving assessment with non-routine adjustments can be shown as follow:

Energy saving result = (Baseline energy consumption – Energy saving during the reporting period) ± Routine adjustment ± Non-routine adjustment

[Saving = (Baseline-Period Energy Use – Reporting-Period Energy Use) ± Routine Adjustments ± Non-Routine Adjustments**]**

Such equation can be adapted for assessing energy saving based on similar environment. Energy-saving calculation must be based on these following periods:

4.8.1 Reporting-Period Basis Or Avoided Energy Use

Actual saving during the measuring period can also be called energy-saving during the reporting period.

[Energy Saving = (Baseline-Period Energy Use) ± Routine Adjustments to reporting period conditions ± Non-Routine Adjustments to reporting period conditions) – Reporting-Period Energy Use**]**

4.8.2 Fixed Conditions Basis Or Normalized Saving

Adjustment undertaken prior to the fixed conditions or routine period and compared prior to or after measurement is called normalized saving based on this following model:

[Normalized Saving = (Baseline-Period Energy Use ± Routine Adjustments to fixed conditions ± Non-Routine Adjustments to fixed conditions) – (Reporting-Period Energy Use ± Routine Adjustments to fixed conditions ± Non-Routine Adjustments to fixed conditions**]**

4.9 Measurement and Verification (M&V) Options

4.9.1 Option A : Retrofit Isolation : Key Parameter Measurement

A selection of variables for measurement and projecting energy-saving measure which could lead project to success. Data and statistics from the manufacturer can be collected for calculation based on period needed for reporting.

Energy consumption prior to and post adjustment will be calculated based on actual measurement of major variables and others within identified framework and reporting period.

A suitable measurement method will be calculated based on equipment or system with fixed energy saving i.e. lighting improvement. Electric power will be a major variable needed to be measured throughout consumption period. Working hours can be calculated from using period and consumption behavior.

4.9.2 Option B : Retrofit Isolation : All Parameter Measurement

Similar to Option A, but all variables will have to be measured. Data collection can be undertaken by both actual calculation and engineering calculation. This option is suitable for equipment or system having various energy saving modes depending on period of use i.e. energy saving cost of water pumps with adjustable cycle speed. Change will depend on cycle speed water pump. Water flow will also depend on the system. Data collection therefore needs to be continuously collected together with water pump usage in order to calculate energy saving cost.

4.9.3 Option C : Whole Facility

For this case, the energy-saving result will be assessed from electricity use of the whole facility. Different sectors of the facility can also be assessed. Data collection for this option will be carried out based on electricity meter at the facility prior to and after improvement. This option is suitable for energy conservation measure which affects overall energy consumption of the facility.

4.9.4 Option D : Calibrated Simulation

Calculation for this option will need a software to estimate the facility's overall energy consumption. For operators adopting this option at their facilities, it is crucial to compare a result from the actual measurement with a result from calibrated simulation both prior to and after adopting energy-saving measure. This option is suitable for calculating energy-saving cost at different facility sections which specific period of consumption may not be applied.

4.10 Life Cycle Cost Analysis

In some case, only cost-saving energy assessment may not be sufficient for overall project outlook. Life-cycle cost analysis (LCCA) will come in handy for analyzing cost effectiveness of the investment throughout life cycle of the project.

LCCA is an economic tool for considering cost during the beginning period of the project, working process, maintenance and dissolving in a bid to determine options for operating the project. Cost may vary depending on different processes. The key is the long-term plan to ensure the highest cost effectiveness and lowest cost.

Life-Cycle Cost (LCC) will be used for determining energy efficiency index of the facility. LCC is an economic index used for assessing suitability of the project including capital cost, operational cost, fuel cost, maintenance, and scrap from the system. Cost throughout the process will be analyzed and changed into present value depending on variations of resale and scrap value, fuel, water and maintenance cost in according to the following model:

$$LCC = I_0 + Repl - Res + E + W + OM\&R + O$$

LCC = Total Life Cycle Cost in Present Value of given alternative

I_0 = Initial Investment Cost

Repl = Present Value capital replacement cost

Res = Present Value residual (resale value, scrap value, salvage value) less disposal costs

E = Present Value Energy Cost

W = Present Value Water Cost

OM&R = Present Value non-fuel operating, maintenance, and repair costs
O = Present Value of Other costs (e.g. contract costs)

Calculation Example: LCC- Base Case : Conventional Design

Cost effectiveness of project investment is based on two conditions-usual condition with constant air volume (CAV) and non-heat control and utilization design and alternative option of constant air volume with night-time setback and economizer mode. The condition with lower LCC will be considered for investment.

Source : Life Cycle Costing Manual, USDOE

Information overview:

Location	Washington, DC; DOE Region 3
Discount Rate	3%
Fuel cost	Electricity $0.08/kWh
Equipment life cycle	20 years

Cash flow can be calculated based on the information above as follow:

- Initial investment cost ; Lump sum cost = $103,000
- Cost of changing fan at the end of the 12th year = $12,000
- Scrap and salvage value at the 20th year = $3,500
- Fuel cost per year = $20,000 (250,000 kWh at $0.08/kWh
- Annual maintenance cost = $7,000

Cash Flow Projection model can be shown in Figure 4.2

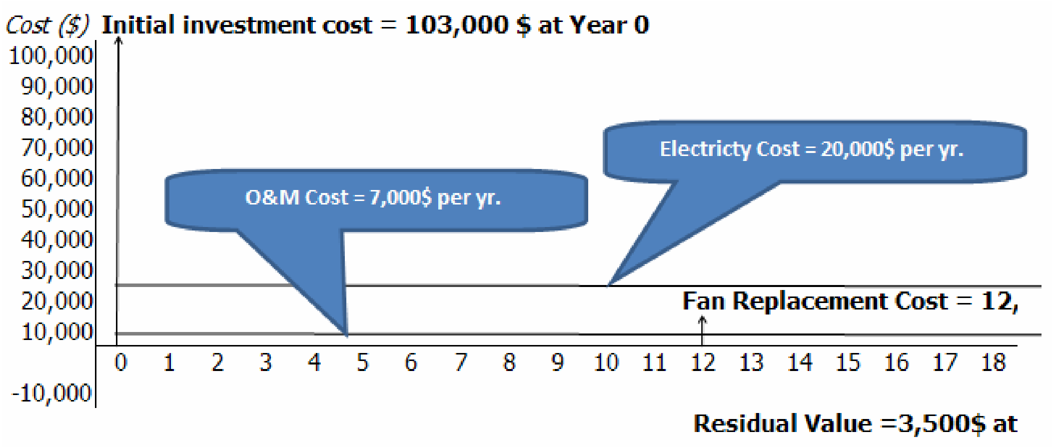


Figure 4.2 Cash Flow Diagram for Conventional HVAC Design

Present value also have to be calculated to evaluate cost at different period as shown in Table 4.1

Table 4.1 Present Value Calculations for Conventional HVAC Design

Cost ($)	Value (1)	Discount rate (r) = Discount Factor = $1/(1+r)^n$ (2)	3% Present Value (1)x(2)	Remark
Initial investment	103,000	1.000	103,000	n= 0 (year 0)
Fan replacement	12,000	0.701	8,412	n=12 (year12)
Electricity	20,000	14.875	297,500	n=1-20 (year1-20)
O&M	7,000	14.875	104,125	n=1-20 (year1-20)
Total Cash out-Flow			**513,037**	
Residual value	3,500	0.554	1,939	n=20 (year20)
Total Cash in-Flow			**1,939**	
Total Life Cycle Cost			**511,098**	

(Total Cash out-Total Cash in)

Source : Life Cycle Costing Manual, USDOE

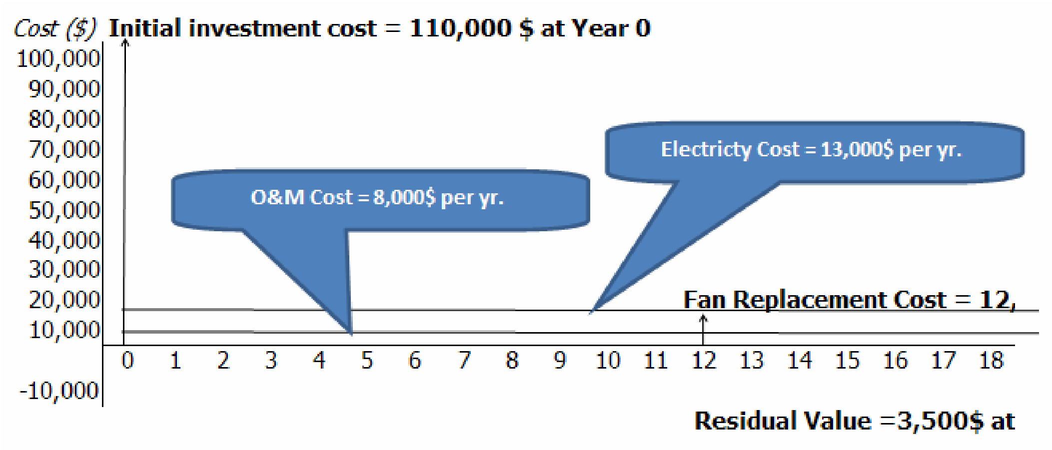
<u>Conclusion</u> **Base Case:** Conventional HVAC Design with Life-Cycle Cost (LCC) = **$511,098** throughout the life cycle of 20th year.

<u>Calculation Example: LCC- Alternative Case : Energy Saving Design</u>

According to energy-saving HVAC designed with night time set-back for heating and air-conditioning and economizer cycle, cash flow model can be displayed as follow:

- Initial investment cost ; Lump sum cost = $110,000
- Cost of changing fan at the end of the 12th year = $12,500
- Scrap and salvage value at the 20th year = $3,700
- Fuel cost per year = $13,000 (162,500 kWh ที่ $0.08/kWh
- Annual maintenance cost= $ 8,000

Cash Flow Projection can be displayed in Figure 4.3



Source : Life Cycle Costing Manual, USDOE

Figure 4.3 Cash Flow Diagram : Energy Saving HVAC Design

Present value also has to be calculated to evaluate cost at different period as shown in Table 4.2

Table 4.2 Present Value Calculation for Energy Saving HVAC Design

Cost ($)	Value (1)	Discount rate (r) = Discount Factor = $1/(1+r)^n$ (2)	3% Present Value (1)x(2)	Remark
Initial investment	110,000	1.000	110,000	n= 0 (year 0)
Fan replacement	12,500	0.701	8,763	n=12 (year12)
Electricity	13,000	14.875	193,375	n=1-20 (year1-20)
O&M	8,000	14.875	119,000	n=1-20 (year1-20)
Total Cash out-Flow			**431,138**	
Residual value	3,700	0.554	2,050	n=20 (year20)
Total Cash in-Flow			**2,050**	
Total Life Cycle Cost			**429,088**	

(Total Cash out- Total Cash in)

Source : Life Cycle Costing Manual, USDOE

Conclusion **Base Case:** Conventional HVAC Design with Life-Cycle Cost (LCC) = **$429,088** throughout the life cycle of 20th year.

Hence, comparison of Life-Cycle Cost between using the general air conditioning system and the energy-saving one can be displayed in Table 4.3

Table 4.3 LCC Selection

Ranking	Alternative Analyzed	Present Value (PV)				
		Initial	Energy	O&M	Other	Total LCC
2	Conventional HVAC Design	103,000	297,500	104,125	6,473	511,098
1	Energy Saving HVAC Design	110,000	193,375	119,000	6,713	429,088

The Lower LCC (Energy Saving HVAC Design) is selected with net saving = 511,098 - 429,088 = 82,010$ in 20 years.

Conclusion: Decision is made by using Energy Saving HVAC Design operation mode which has lower LCC. Net savings = $82,010 ($511,098 - $429,088) at present value when calculating based on 3% discount rate.

Chapter 5
Financial Evaluation for Energy Efficiency Projects

Operators can adapt the concept of money value to evaluate financial projection and return analysis by using general financial tools i.e. simple payback period, net present value and internal rate of return. Ice-processing factory is a case study. Feasibility study on three-million Baht compressor replacement is carried out in a bid to reduce electricity consumption regarded as the major operational cost. Final projection of the project can be shown in Table 5.1. Cash flow between pre and post replacement period will be considered. After calculation, internal rate of return is at 49.69%. Net present value of 10% is at 8 million Baht and simple payback period is at 2.3 years.

Table 5.1 Estimated cash flow of compressor replacement

List	Unit	Year 2014	Year 2015	Year 2016	Year 2017	Year 2024
Non-changing COMPRESSOR						
Maintenance cost of old COMPRESSOR	Baht	-	(100,000)	(110,000)	(121,000)	(235,795)
Electricity cost old COMPRESSOR	Baht		(5,019,705)	(5,571,507)	(6,197,745)	(13,063,530)
Changing new COMPRESSOR						
Maintenance cost of new COMPRESSOR	Baht	-	(40,000)	(40,000)	(60,000)	(60,000)
Electricity cost COMPRESSOR	Baht		(3,945,606)	(4,412,634)	(4,908,614)	(10,346,316)
Cost of new COMPRESSOR	Baht	3,000,000				
Selling old COMPRESSOR	Baht	50,000				
Selling new COMPRESSOR	Baht					500,000
Installing new COMPRESSOR	Baht	150,000				
Dismantling old COMPRESSOR	Baht	25,000				
Damage cost by cancellation of production	Baht	50,000				
Net cash	Baht	(2,725,000)	1,104,099	1,228,274	1,350,131	3,393,009

NPV (10%)	Baht	8,010,869
IRR		50%
SIMPLE PAYBACK	Year	2.3 ปี

Apart from simple payback period analysis, operators can also adopt other financial tools to consider net value of the energy efficiency project as follows:

5.1 Discount Payback Period

Similar to simple payback period, discount payback period is used for calculation the duration that each EE project can break even. However, net present value and internal rate of return are the additional factors for calculation.

5.2 Life Cycle Cost Analysis

Life Cycle Cost Analysis will indicate the total cost of investment in equipment installation and operational cost until the present year such as energy cost, maintenance and repair. The analysis will reflect the total cost of investment necessary for considering all feasible options.

5.3 Levelized Cost of Energy (LCOE)

LCOE will be used for calculating energy cost per unit of the equipment. The calculation will be done by adding life-cycle cost including net present value, maintenance, repair, insurance, tax and interest with equipment purchase and installation. The result will then be divided by power capacity of the equipment. The final result will be considered as a ratio for entrepreneurs investing in energy efficiency projects to compare their options when buying any equipment for use.

5.4 Saving to Investment Ratio

This ratio reflects the proportion of life-cycle savings resulted from equipment replacement and investment cost. The calculation method is simple enabling the bank responsible for loan approval to get the overall idea about benefits and cost of investment. It is also useful for the bank during the project screening process.

Meanwhile, considering capacity of debt repayment among EE projects is significant. Unlike other projects that money for debt repayment will be from net operating cash flow increasing from the investment, each EE project's debt repayment will be from reduced energy cost.

DSCR is a major ratio used for considering loan approval, credit limit and debt repayment capacity of EE industries with small-sized, low-risk investment. Since debt repayment capacity is based on non-market-risk reduced cost, DSCR can be considered at the lower than usual level, while the ratio of loan to value can be higher than usual.

In the meantime, those involving with credit approval may adapt financial ratio usually used among energy projects including industrial energy efficiency projects. For example the case of three-million baht compressor replacement. Operator applied for 2.5 million baht loan program from commercial banks under a condition of 10% annual interest rate. The credit period is five years. Operator needs to bear 750,000 Baht payment including interest rate. The amount is lower than the estimated energy-saving cost of one-million Baht. DSCR after replacing new compressor will be increased from the previously estimated 1.4 and 1.53 in 2015 and 2016 to 1.41 and 1.62 in the 2015 and in 2016 respectively.

Table 5.2 Projected earnings prior to new compressor replacement

List		Unit	2013	2014	2015	2016	2017	2018
1.	Income	Baht	30,935,961	33,744,946	36,808,987	40,151,243	43,796,976	47,773,741
2.	Selling Cost	Baht	0,907,978	3,537,711	5,963,818	8,648,494	2,228,451	35,581,341
3.	Depreciation	Baht	1,064,000	1,064,000	1,064,000	1,064,000	1,024,000	1,024,000
4.	Preliminary Profit	Baht	8,963,983	3,143,234	9,781,169	10,438,749	10,544,525	11,168,400
5.	Selling And Operation Cost	Baht	6,779,645	7,299,490	79,864,137	8,477,580	9,144,176	9,868,673
6.	Profits Before Tax And Tax (EBIT)	Baht	2,184,337	1,843,745	1,917,032	1,961,169	1,400,350	1,299,728
7.	Interest	Baht	525,000	375,000	225,000	75,000	0	0
8.	Profit Before Tax	Baht	1,659,337	1,468,745	1,692,032	1,886,169	1,400,350	1,299,728
9.	Tax	Baht	331,867	293,749	338,406	377,234	280,070	259,946
10.	Net Profit	Baht	1,327,470	1,174,996	1,353,626	1,508,935	1,120,280	1,039,782

Table 5.3 Projected financial status prior to new compressor replacement

Assets		Unit	2013	2014	2015	2016	2017	2018
1.	Cash Flow	Baht	2,788,789	3,318,920	4,012,339	4,840,818	6,714,027	8,486,739
2.	Debtor	Baht	2,577,997	2,812,079	3,067,416	3,345,937	3,649,748	3,918,145
3.	Products in stock	Baht	154,986	174,402	192,352	212,242	238,795	263,605
4.	Raw materials in stock	Baht	577,760	654,998	742,572	841,866	954,447	1,082,096
5.	Total Assets	Baht	6,099,441	6,960,400	8,014,679	9,240,862	11,557,017	13,813,585
6.	Preliminary Assets	Baht	44,000,000	44,000,000	44,000,000	44,000,000	44,000,000	44,000,000

Assets	Unit	2013	2014	2015	2016	2017	2018
7. Accumulative Depreciation	Baht	18,128,000	19,192,000	20,256,000	21,320,000	22,344,000	2,368,000
8. Net Assets	Baht	25,872,000	24,808,000	23,744,000	22,680,000	21,656,000	20,632,000
9. Total Assets	Baht	31,971,441	31,768,400	31,758,679	31,920,862	33,213,017	3,445,585
Debt and Investment Cost	Unit	2013	2014	2015	2016	2017	2018
10. Creditor	Baht	1,013,681	1,135,645	1,272,298	1,425,546	1,597,422	1,790,208
11. Long-Term Loan	Baht	4,500,000	3,000,000	1,500,000	0	0	0
Equity	Baht						
12. Registered Cost	Baht	17,000,000	17,000,000	17,000,000	17,000,000	17,000,000	17,000,000
13. Collective Profits	Baht	9,457,759	10,632,755	11,986,380	13,495,315	14,615,595	15,655,377
14. Total Debts And Cost	Baht	31,971,441	31,768,400	31,758,679	31,920,862	33,213,017	34,445,585

Table 5.4 Projected cash flow (before changing compressor)

List	Unit	2013	2014	2015	2016	2017	2018
1. Cash From Selling	Baht	30,721,364	33,510,864	36,553,650	39,872,722	43,493,165	47,442,344
2. Cash Paid For Production	Baht	20,911,949	23,512,493	25,932,688	28,614,429	32,195,710	35,541,013
3. Cash Paid For Services	Baht	6,779,645	7,299,490	7,864,137	8,477,580	9,144,176	9,868,673
4. Cash For Tax Payment	Baht	331,867	2,937,449	338,406	377,234	280,070	259,946
5. Net Cash In On Operation	Baht	2,697,902	2,405,132	2,418,419	2,403,478	1,873,209	1,772,713
6. Loan Interest	Baht	525,000	375,000	225,000	75,000	0	0
7. Net Cash In 2	Baht	2,172,902	2,030,132	2,193,419	2,328,478	1,873,209	1,772,713
8. Total Investment	Baht	0	0	0	0	0	0
9. Net Cash In 3	Baht	2,172,902	2,030,132	2,193,419	2,328,478	1,873,209	1,772,713
Source of financial investment	Baht						
10. Cost of registered investment	Baht						
11. Long-Term Loan: Deposit-Withdrawal	Baht						
12. Long-Term Loan: Repayment	Baht	1,500,000	1,500,000	1,500,000	1,500,000		
13. Net Cash In 4	Baht	672,902	530,132	693,419	828,478	1,873,209	1,772,713
14. Remaining Cash-Beginning Period	Baht	2,115,886	2,788,789	3,318,920	4,012,339	4,840,818	6,714,027
15. Remaining Cash-End Period	Baht	2,788,789	3,318,920	4,012,339	4,840,818	6,714,027	8,486,739

Table 5.5 Projected earnings (after changing compressor)

List		Unit	2013	2014	2015	2016	2017	2018
1.	Income	Baht	30,935,961	33,744,946	36,808,987	40,151,243	43,796,976	47,773,741
2.	Selling Cost	Baht	20,907,978	23,543,120	24,737,295	27,291,219	30,712,874	33,889,655
3.	Depreciation	Baht	1,064,000	1,309,250	1,309,250	1,309,250	1,269,250	1,269,250
4.	Preliminary Profit	Baht	8,963,983	8,892,575	10,762,442	11,550,774	11,814,852	12,614,836
5.	Selling And Operation Cost	Baht	6,779,645	7,299,490	7,864,137	8,477,580	9,144,176	9,868,673
6.	Profits Before Tax And Tax (EBIT)	Baht	2,184,337	1,593,085	2,898,305	3,073,194	2,670,676	2,746,163
7.	Interest	Baht	525,000	475,000	400,000	200,000	75,000	25,000
8.	Profit Before Tax	Baht	1,659,337	1,118,085	2,498,305	2,873,194	2,595,676	2,721,163
9.	Tax	Baht	331,867	223,617	499,661	574,639	519,135	544,233
10.	Net Profit	Baht	1,327,470	894,468	1,998,644	2,298,555	2,076,541	2,176,930

Table 5.6 Projected financial status (after changing compressor)

Assets		Unit	2013	2014	2015	2016	2017	2018
1.	Cash Flow	Baht	2,788,789	2,558,602	3,550,475	4,904,764	7,467,755	10,109,829
2.	Debtor	Baht	2,577,997	2,812,079	3,067,416	3,345,937	3,649,748	3,981,145
3.	Products in stock	Baht	154,986	174,443	183,204	202,187	227,566	251,071
4.	Raw materials in stock	Baht	577,760	654,998	742,572	841,866	954,447	1,082,096
5.	Total Assets	Baht	6,099,441	6,200,122	7,543,667	9,294,754	12,299,516	15,424,414
6.	Preliminary Assets	Baht	44,000,000	46,725,000	46,725,000	46,725,000	46,725,000	46,725,000
7.	Accumulative Depreciation	Baht	18,128,000	19,437,250	20,746,500	22,055,750	23,325,000	24,594,250
8.	Net Assets	Baht	25,872,000	27,287,750	25,978,500	24,669,250	23,400,000	22,130,750
9.	Total Assets	Baht	31,971,441	33,487,872	33,522,167	33,964,004	35,699,526	37,554,750
	Debt and Investment Cost	Unit	2013	2014	2015	2016	2017	2018
10.	Creditor	Baht	1,013,681	1,135,645	1,171,295	1,314,577	1,473,548	1,651,993
11.	Long-Term Loan	Baht	4,500,000	5,000,000	3,000,000	1,000,000	5,000,000	
	Equity	Baht						
12.	Registered Cost	Baht	17,000,000	17,000,000	17,000,000	17,000,000	17,000,000	17,000,000
13.	Collective Profits	Baht	9,457,759	10,352,227	12,350,872	14,649,427	16,725,968	18,902,898
14.	Total Debts And Cost	Baht	31,971,441	33,487,872	33,522,167	33,964,004	35,699,516	37,554,891

Table 5.7 Projected cash flow (after changing new compressor)

List		Unit	2013	2014	2015	2016	2017	2018
1.	Cash From Selling	Baht	30,721,364	33,510,864	36,553,650	39,872,722	43,493,165	47,442,344
2.	Cash Paid For Production	Baht	20,911,949	23,517,943	24,797,979	27,266,214	30,691,863	33,862,365
3.	Cash Paid For Services	Baht	6,779,645	7,299,492	7864137	8,477,580	9,144,176	9,868,673
4.	Cash For Tax Payment	Baht	331,867	223,617	499,661	574,630	519,135	544,233
5.	Net Cash In On Operation	Baht	2,697,902	2,469,814	3,391,873	3,554,289	3,137,991	3,167,074
6.	Loan Interest	Baht	525,000	475,000	400,000	200,000	75,000	23,000
7.	Net Cash In 2	Baht	2,172,902	1,994,814	2,991,873	3,354,289	3,062,991	3,142,074
8.	Total Investment	Baht	0	2,725,000	0	0	0	0
9.	Net Cash In 3	Baht	2,172,902	-730,186	2,991,873	354,289	3,062,991	3,142,074
Source of financial investment		Baht						
10.	Cost of registered investment	Baht						
11.	Long-Term Loan: Deposit-Withdrawal	Baht		2,500,000				
12.	Long-Term Loan: Repayment	Baht	1,500,000	2,000,000	2,000,000	2,000,000	500,000	500,000
13.	Net Cash In 4	Baht	672,902	-230,186	991,873	1,354,289	256,991	2,642,074
14.	Remaining Cash-Beginning Period	Baht	2,115,886	1,788,789	2,558,602	3,550,433	4,904,764	7,467,755
15.	Remaining Cash-End Period	Baht	2,788,789	2,558,602	3,550,475	4,904,764	7,467,755	10,109,829

DEBT SERVICE COVERAGE		1.33	1.00	1.41	1.62	5.46	6.03

Annex A.
Details of Energy Saving Technologies

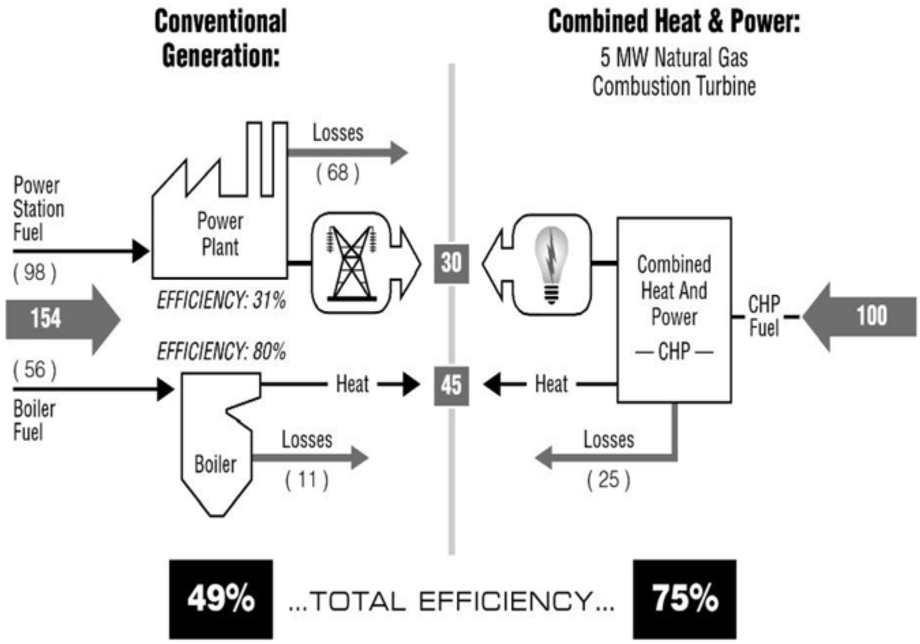
The energy conservation measures mentioned below are applicable for various types of industries and mostly identified based on the following utility machines and process machines:

- The cogeneration system for food, textile, cement, metal, glass and chemical industries.
- The boiler system mostly used among food, textile and non-metal industries.
- The air compressor system used among industries requiring high-pressured air consumption e.g. food, metal and non-metal industries.

1. Cogeneration System

The cogeneration system is the electricity and heat generation process which utilizes energy input into a single system. The overall efficiency of the cogeneration system is as high as 75 - 80% compared to the efficiency of the isolate generation at 40-50%. This system is also known as “CHP” or “Combined Heat and Power”.

The cogeneration system and conventional system are shown in Figure 1.



Source: U.S.EPA, Combined Heat and Power Partnership, "Efficiency Benefits"

Figure 1 The overall efficiency of the usual power generation system vs. the cogeneration system

The cogeneration system could be categorized into 2 types based on the thermal energy utilized before and after electricity produced. The so-called "topping cycle cogeneration" is defined when electricity is produced prior to heat Applications. Food, pulp & paper and refinery industries most use this system. In contrast, the so-called "bottoming cycle cogeneration" is defined when heat consumption happens prior to electricity generation. Cement, metal, glass and chemical industries usually depend on the bottoming cycle cogeneration system.

1.1 Types of the cogeneration system

The system can generate mechanical power mainly by the three 3 prime mover systems: steam turbine, gas turbine and internal combustion engine.

The cogeneration system will work at its best when H/P of the cogeneration system is on par with the H/P of the plant. Hence, factors such as the heat to power ratio, fuel type, load profiles, capital cost, and environmental concerns are crucial and taken into account when selecting different cogeneration system.

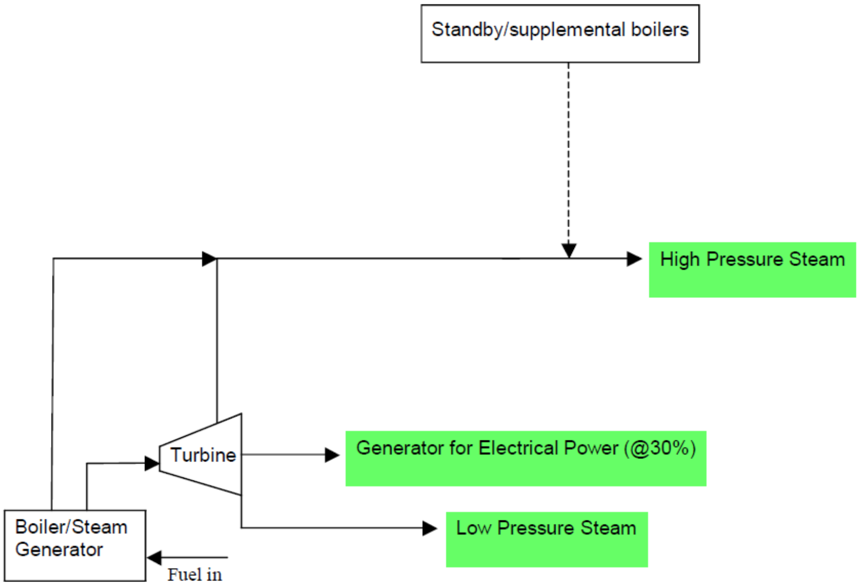
Table 1 Comparison of different types of the cogeneration system

Details	Steam Turbine (back pressure)	Gas Turbine	Internal Combustion Engine
System size	500 kW-100 MW	500 kW-100 MW	100 kW-10 MW
Overall Efficiency	max. 80%	55-75%	50-80%
Heat to Power Ratio (H/P)	5 – 20	2 - 5	1 - 3
Heat Output	Steam (150°C)	Hot gas (450-550°C)	Hot water 50% Hot gas at 450°C 50%
Fuel Input	Liquid and Solid Gas (depending on types of boiler)	Liquid Gas	Liquid Gas

1) Steam Turbine Cogeneration

The main component of this system comprises steam boiler and steam turbine using liquid and solid gas as fuel. In principle, fuel is injected into the combustion chamber. The heat generated from thermal reaction at high temperature and pressure is then transformed into hot water, steam and superheat steam. The steam at this high energy level will drive mechanical parts e.g. turbine compressor and eventually transform into electricity. The medium pressure steam after passing through turbine will be utilized for other process system.

The steam turbine cogeneration systems can be classified into two types: back pressure steam turbine and extraction steam turbine. Steam passing trough the turbine at 3-20 Bar for back pressure type will be used for other heating processes. For the extraction type, steam will be partly released at the midst of the turbine. The steam can be released at pressure points suitable for the procedure. The rest of steam will be released through the turbine for generating electricity until the pressure becomes low.



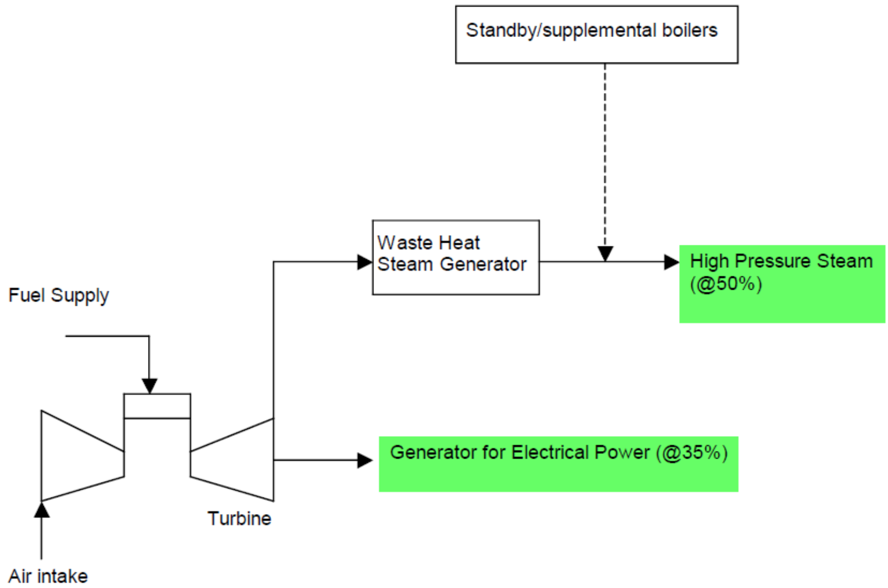
Source: Doanh Van, Union University, Co-generation-A Feasibility Screening Analysis Using Excel Spreadsheet

Figure 2 Steam Turbine Cogeneration

2) Gas Turbine Cogeneration

Compressed air and fuel will be feeded into the combustion chamber. The mixing between compressed air and fuel will ignite, leading to expansion of hot gas driving the turbine and the generator. Waste heat boiler will be used for generating hot flue gas with the temperature of 450-550°C producing low-pressured steam.

Figure 3 illustrates the gas turbine cogeneration system.



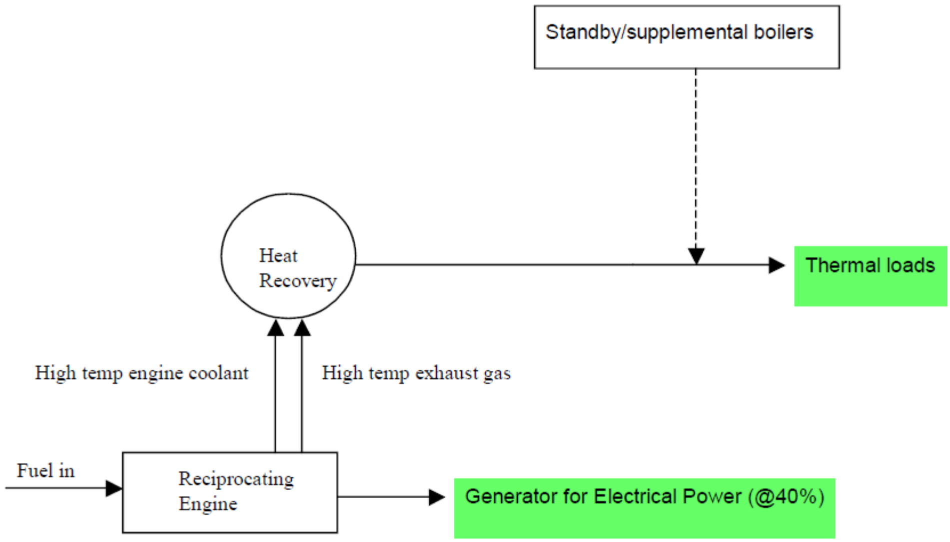
Source: Doanh Van, Union University, Co-generation-A Feasibility Screening Analysis Using Excel Spreadsheet

Figure 3 Gas Turbine Cogeneration

3) Reciprocating Engine Cogeneration

There are two types of engines: spark-ignition engine (liquid or NG as fuel) and compression-ignition engines (diesel or bunker oil as fuel). Electricity generated is between 100 kW to 10 MW. Waste heat in a form of flue gas, cooling water and lubricant could be recovered from the waste heat boiler to produce steam and/or hot water.

The reciprocating engine cogeneration is shown in Figure 4.



Source: Doanh Van, Union University, Co-generation-A Feasibility Screening Analysis Using Excel Spreadsheet

Figure 4 Reciprocating Engine Cogeneration

Pros and cons of the cogeneration system

Pros:

- Up 10-30% of energy consumption can be saved, thanks to the efficiency of the cogeneration system approximately at 80% compared with 50% of the isolated heat and 35% of the electricity generation
- Initial investment cost of cogeneration system is much less than large scale power plant.
- The cogeneration system could reduce peak load of the utility agencies Provincial Electricity Authorities and Metropolitan Electricity Authorities and consequently reduce the demand of large scale power plant.

Cons:

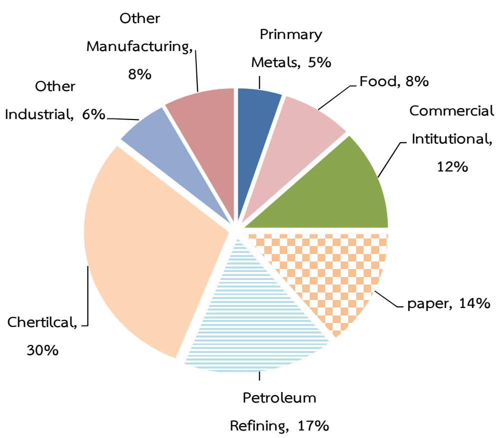
- Design, construction and operation of the cogeneration system are complicated and that experts in each task are required.
- High capital cost and operation and maintenance (O&M) cost.
- If installing overcapacity of heat and power in the cogeneration system, it will be difficult to manage exceeding energy and steam existing in the system.

1.2 Energy saving in the cogeneration system

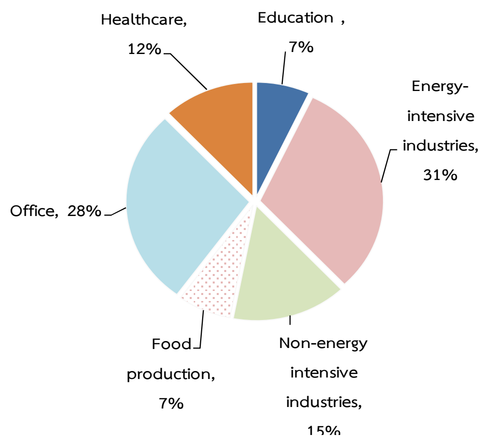
Energy saving in the cogeneration system can be achieved in a form of

1) The amount of generated electricity
2) Heat as by-product of electricity generation

In general, the cogeneration system could be beneficial for both savings and the outstanding return in the investment. The cogeneration system is now widely applied to energy intensive industries for example, chemical (30%), petro-chemical (17%) and pulp & paper (14%) due to a large amount of waste heat shown in the following pie charts:



Source: ORNL 2008



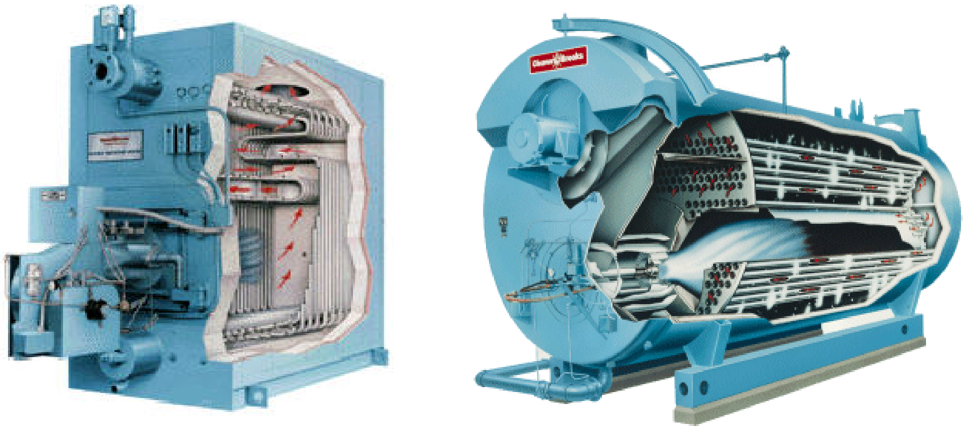
Source: Mckinsey's Estimates of Cost-Effective Cogeneration Potential for 2020 by Sector

2. Boilers

2.1 Type of Boilers

There are two categories: water-tube boiler and fire-tube boiler as illustrated in Figure 5

- **Water-tube boiler:** Water inside the tube is heated by flame outside the tube.
- **Fire-tube or shell boiler:** Flame inside the tube will transfer the heat to water surrounding the boiler.



(a) Water-tube boiler (b) Fire-tube boiler

Figure 5 Type of Boilers

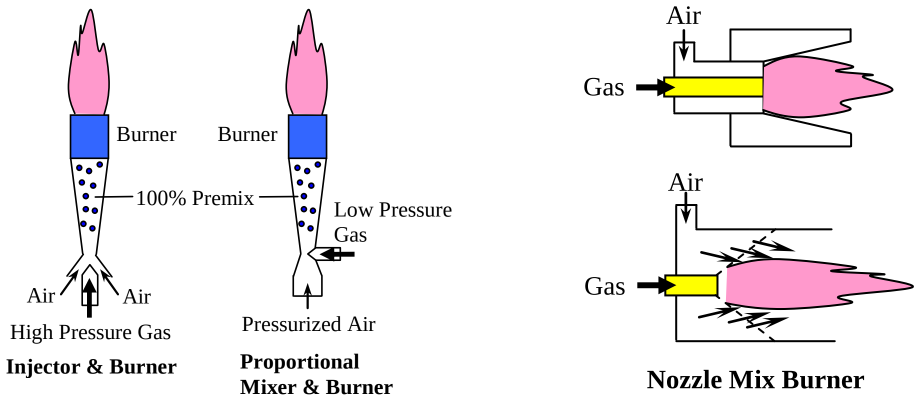
It will take longer time for the fire-tube boiler than the water-tube boiler to produce water steam. The water-tube boiler is more efficient in responding to the change in steam demand.

For the fire-tube boiler, the more tubes it is equipped, the better its capacity and efficiency will be due to the longer duration that hot gas will flow into the boiler. Small-sized fire tube-boiler may be equipped with 2 passes of fire tubes going back and forth while the large size boiler could have up to 3-4 passes or more.

2.1.1 Burner

Burner is the equipment for fuel injection mixed with combustion air in the appropriate ratio. There are two types of gas burner (Figure 6)

a) Pre-mix Burner
b) Nozzle-mix Burner



(a) Pre-mix Burner (b) Nozzle-mix Burner

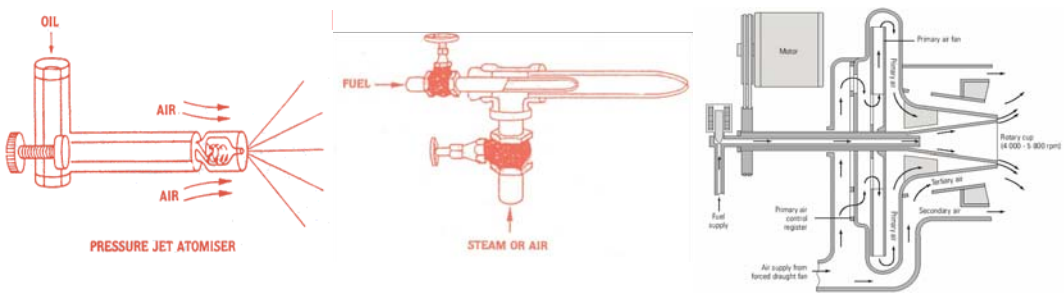
Figure 6 Types of gas burner

There are three types of oil burner (Figure 7)

a) Pressure Atomized

b) Steam or Air Atomized

c) Rotary Cup



(a) Pressure Atomized (b) Steam or Air Atomized (c) Rotary Cup

Figure 7 Types of oil burner

Burner can also be classified based on operation characteristic. Selecting different types of burner to meet the need will maximize energy efficiency.

- **Modulating Burner:** Fuel consumption of the modulating burner depends on the amount of heat required for steam production and maintaining air pressure. When steam pressure is reduced, fuel rate in the burner will be increased accordingly. On the other hand, fuel rate in the burner will be decreased when the steam pressure exceeds the set point.

- **High/Low-Fire Burner:** This type of burner could supply fuel at high and low levels. Suitable for steam load that does not change much.

- **Constant-Fire or ON-OFF Burner:** This type of burner is suitable for the constant steam load. The burner will be automatically ON when steam pressure is lower than the set point and be automatically OFF when steam pressure is higher than the set point. The fuel is then supplied to the boiler according to the ON-OFF status.

The turn down ratio, reflecting proportion between the maximum and the minimum firing rate which doesn't affect the burning capacity, is one of the selection criteria. If there is much change in the steam load, user should select the burner with the high rate of the turn down ratio, leading to the high capacity of steam production. Variation of the turn down ratio also depends on the steam load. It is worth to say that the high-fire/low-fire burner has the turn down ratio of 3:1 whereas the modulating burner has the turn down ratio of 10:1. Hence the modulating burner is better than the turn down ratio 3:1 of High-fire/Low-fire burner or ON-OFF burner.

2.2 Energy Conservation Measures of the Boiler

1) Waste Heat Recovery

Waste heat could be in a form of liquid phase e.g. hot water, hot oil and a form of gas phase e.g. hot gas. Factors needed for waste heat recovery assessment include the rate of temperature flow and the composition of waste heat i.e. liquid or gas. These factors would help determine optimum Applications based of the amount of waste heat recovery available. There are several options for waste heat recovery such as combustion air preheat for boiler or electricity generation by recuperator, heat exchanger etc.

Source of industrial waste heat recovery

Heat is usually used in every procedure in the industry. There is always have waste heat relased as by-process and can be recovered. There are two types of waste heat: hot liquid and hot gas.

1. Hot liquid:
   - Hot water (could be contaminated)
   - Hot oil
   - Other hot liquid

2. Hot gas:
   - Hot gas from furnace and oven
   - Hot air from cooling process
   - Hot gas/air from other sources

There are three levels of temperature range measured from waste heat.

1. High temperature > 650°C See Table 2
2. Medium temperature 230-650°C See Table 3
3. Low temperature < 230°C See Table 4

Table 2 Example of high temperature waste heat

Source of Waste Heat	Temperature (°c)
Nickel Refining Furnace	1,371 - 1,649
Aluminum Refining Furnace	649 - 760
Zinc Refining Furnace	760 - 1,093
Copper Refining Furnace	760 - 816
Steel Heating Furnace	927 - 1,038
Glass Melting Furnace	982 - 1,538
Solid Waste Incinerators	649 - 982

Table 3 Example of medium temperature waste heat

Source of Waste Heat	Temperature (°c)
Steam Boiler Exhausts	232 - 482
Gas Turbine Exhausts	371 - 538
Reciprocating Engine Exhausts	316 - 593
Heat Treating Furnace	427 - 649
Drying and Baking Ovens	232 - 593

Table 4 Example of low temperature waste heat

Source of Waste Heat	Temperature (°c)
Process Steam Condensate	54 - 88
Cooling Water from :	
Furnace Doors	32 - 54
Bearings	32 - 88
Welding Machines	32 - 88
Injection Molding Machines	32 - 88
Air Compressor	27 - 49
Internal Combustion Engine	66 - 121
Condenser of Air Conditioner and Refrigerator	32 - 43

How to evaluate waste heat quantity and quality

This topic will look into different mehods to assess waste heat quantity and quality in the industry. Liquid form of the waste heat can also assessed.

Since hot gas as waste heat is generally occurred along the high temperature process, the energy efficiency of the system could also be increased by waste heat recovery. These are the following factors to be assessed:

- Flow rate of waste heat
- Temperature of waste heat
- Gas composition of waste heat

In practice, the flow rate and temperature of waste heat could be measured and initially assessed for using measuring device in the factory. The accuracy of $\pm$10% is appropriate for preliminary assessment. Gas composition and duration of waste heat released can be assessed to confirm more detail analysis which third-party will be required for this task.

Table 5 Standard of flue gas temperature in the boiler (°C)

Boiler Size	Solid Fuel	Liquid Fuel	Gas Fuel	Waste gas from the process
Large boiler for electricity generation	-	145	110	200
Other boilers : 30 Ton/hr or larger	200	200	170	200
10 - 30 Ton/hour	200	200	170	-
5 - 10 Ton/hour	-	220	200	-
< 5 Ton/hour	-	250	220	-

Remarks: The above figures are based on ambient temperature of 20°C , 100% load and clean heat exchange on the surface.

Energy Saving Potential for Waste Heat Recovery

After assessment of waste heat quantity and quality, the next step is to assess energy saving efficiency. A few aspects to be considered are:

Cost-effectiveness Use of Waste Heat

Space heating is frequently taken as a sample to show cost-ineffectiveness use of waste heat. Its benefits can be used for only a few months during the winter. The recommended cost-effectiveness is to immediately bring back waste heat for use. Below are some of the benefits.

- Reduce fuel consumption
- Minimize heat transfer loss in distribution loop
- Help balance energy demand and supply

(**Remarks:** The most cost-effectiveness method is to recover waste heat at the highest teperature to reduce fuel use at the lowest rate.)

The most value of heat transfer is when it contains the highest temperature. Utilizing waste heat recovery at its highest temperature will help reduce both surface area and capital cost of heat exchanger. However, in practice, mixing hot gas with ambient air could cause lower temperature and require more rate of waste heat flow, leading to the lower heat transfer effciency.

Available Options of Using Waste Heat

Waste heat recovery can be implemented by

1. Preheating combustion air for burner or by recuperator or regenerator
2. Charge Preheating (Stock) before entering furnace
3. Furnace Regenerator
4. Brick drying
5. Space heating or hot water heating
6. Steam generation for power plant
7. Low pressure steam for heating processes
8. Preheat oil e.g. fuel oil

a) Pre-heating Combustion Air

This is the most commonly used method of waste heat recovery due to its high efficiency and high return on investment. Here are the benefits.

- Heat exchange with the source of waste heat and the source where the waste heat is used.
- Reduce fuel at primary source
- Maximum waste heat Applications
- Direct use of waste heat without mixing with other media to ensure maximum efficiency

The well-known technology for preheating combustion air nowadays are recuperator and regenerator. Recuperator allows hot gas and cool air exchange heat in an opposite direction while regenerator collects the heat by cyclic heat storage device. However, the efficiency and the location of regenerator for furnace should be considered based on the temperature inside furnace. Therefore, modeling of physical dimension of the furnace and the burner should be taken into account for maximizing the benefits.

Example 1 A total of 10-ton steel billet has been preheated for eight hours in the furnace at 1,250 $^{\circ}$C. The furnace is operated 15 hours per day and 45 weeks per year. Three different burners: cold air burner, self-recuperative burner and regenerative burner are used for energy balance purposes. as illustrated in Figure 8. The specific energy consumption for each type are:

Cold air burner	32.6	GJ/Ton
Self-Recuperative burner	22.8	GJ/Ton
Regenerative burner	16.2	GJ/Ton

Regenerative burner and Self-Recuperative burner generally save fuel consumption at approximately 50% and 30% respectively compared to the cold air burner.

Regenerative burner for reheating furnace will additionally reduce the specific energy consumption of the furnace by 10-15%, thanks to reduced heat losses through improvement of furnace insulation.

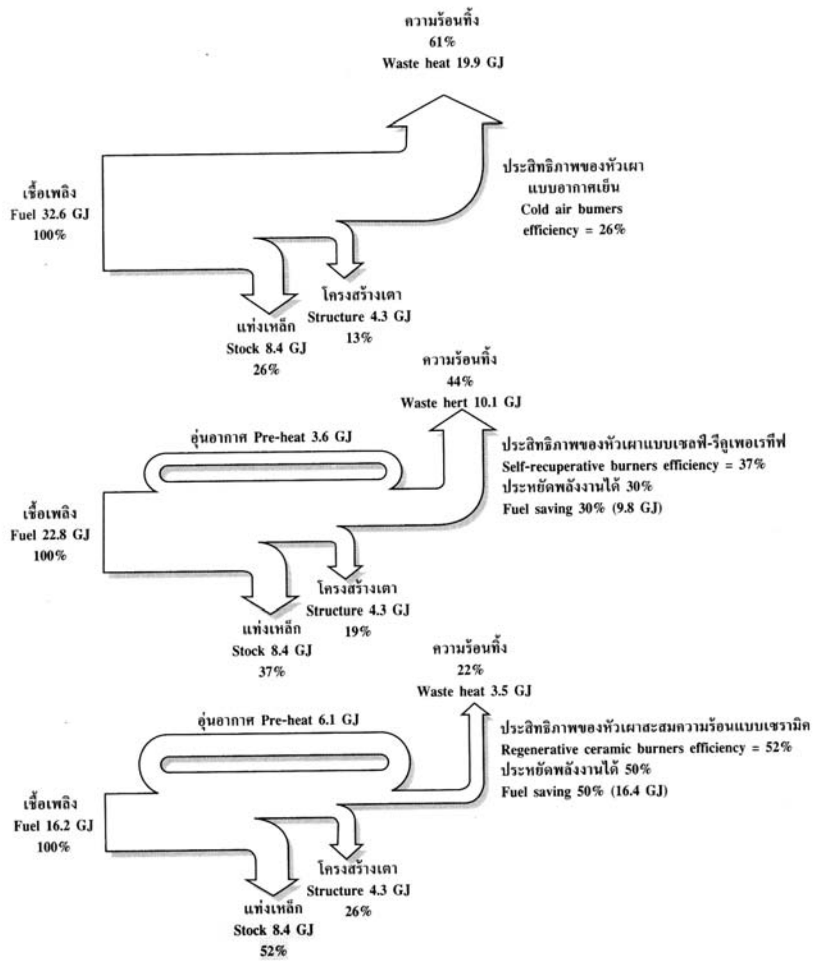


Figure 8 Energy balance of the furnace using cold air burner, self-recupeative burner and regenerative burner

b) Charge Pre-Heating and Drying

Charge pre-heating is commonly used by the existing charge recuperator technology, which enables hot gas to pass directly to the incoming stock through pipe. The dimension of the furnace has also been increased, resulting in more initial investment cost and less maintenance cost. The investment cost in the combustion air preheating technology is also reduced.

Recuperator is the typical equipment for steel blast furnaces and tunnel kiln for ceramics. The temperature of the exhaust gas released from the recuperator is as low as 400°C or even lower in industries e.g. aluminums or copper casting. Heat transfer from the charge preheating is normally affected by configuration of raw material, conduction properties, rate of hot gas flow and temperature of furnace. Typically, the energy saving is approximate 10 - 30%.

c) Steam Generation

For many years, heat recovery of steam boiler has been implemented for use during heating process. The average payback is 2-3 years. The efficiency of waste heat recovery boiler is as high as 80%. However installation and maintenance cost are the main issues needed to be taken int consideration at the beginning design step.

The followings are typical questions regarding waste heat recovery boiler.

- Any continuous waste heat available?
- Any continuous demand on steam in the process?
- Any suitable water treatment system available for operation?
- Any area to install a large boiler near the source of waste heat?
- Capable of implementing operation and maintenance to ensure the system will be at the best condition?

In summary, the demand on the amount of steam in process and/or waste heat for cooling equipment such as absorption chillers are important factors needed to be taken into consideration.

d) Power Generation

In chemical and petrochemical industry, waste heat is always utilized for electricity plant for cost-effectiveness purpose. Ethylene cracking, ammonia production, petrochemical refining are among the industries demanding electricty and low pressure steam from waste heat recovery. The electricity or power generation using waste heat must contain:

- Source of continued waste heat
- Pre-treatment water plant
- Regular maintenance
- High pressure steam boiler and condensing steam turbine

The last equipment mentioned above results high investment cost. The average payback is then around 3-6 years.

Waste Heat Recovery Technology

The waste heat recovery technology has been developed over 30 years. The technology is now adopted for use with high temperature waste heat to better energy efficiency, return on investement and environmental solutions.

The relationship between preheat air temperature and percentage of fuel saving at various flue gas temperature, i.e. high flue gas temperature, high preheat temperature, high fuel saved, is illustrated in Figure 9.

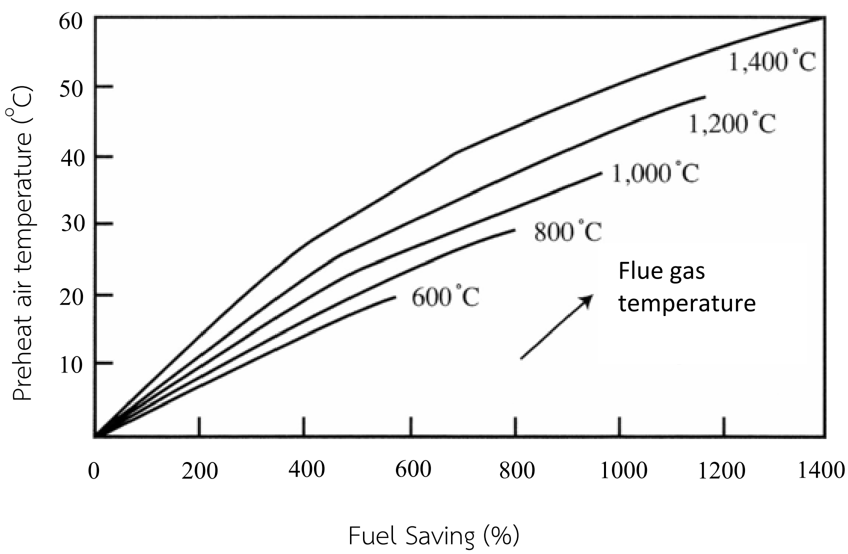


Figure 9 Fuel saving of waste heat recovery for air preheater

Generally, the waste heat recovery unit is equipped with most of the furnace system. The estblished technolgy described below will explain more details about the process, how to put into practice and its benefits.

Established Technology

The following is the summarized details of industrial equipment installed with the established technology of waste heat recovery with the temperature of over 400°C.

(Note: Users should contact manufacturers and suppliers to learn more information essential for making a consideration which technology is most applicable to their industries.)

a) Heat Exchanger

Heat could be transferred or exchanged through different kinds of sources e.g. combustion, boiler and others.

- **Plate Heat Exchanger**

Cold air and hot flue gas will exchange the heat plate by plate in the counterflowing direction (see Figure 10). This operation is limited by the oxidation of gases with the temperature of less than 800°C, except that the product is made by special alloys. The feature of plate heat exchanger is also summarized as shown in Table 6.

Table 6 The feature of plate heat exchanger

Applications	- Space heating - Preheat of combustion air
Temperature range	- Waste heat temperature < 800°C
Efficiency	- 40 - 60%
Pros	- Complete set - Various size to be installed
Cons	- Leaking may occur - Maintenance problem due to blocking dirt - Regular maintenance required

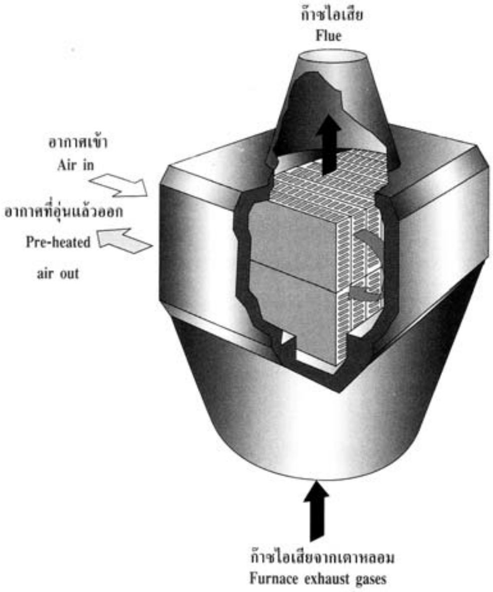


Figure 10 Plate Heat Exchanger (Ceramic cross flow heat exchanger)

Ceramic cross flow heat exchanger has been developed for high temperature duty of 900 - 1,100^{o}C. However, the market demand on this type of exchanger is low due to leakage problem that may occur during the process.

- **Shell-and-Tube Heat Exchanger**

Each unit is constructed from a bundle of tubes covered with shell. This type of exchanger is normally used for exchanging heat between liquid and liquid. However heat exhange between high pressure gas and low pressure gas is also applicable in some case. The outstanding benefit compared to other equipment is cleaning convenience, especially for the gas-to-gas operation. The feature of shell-and-tube heat exchanger is also summarized in Table 7.

Table 7 The feature of shell-and-tube heat exchanger

Applications	- Gas-to-Gas e.g. Space heating
Temperature range	- Waste heat temperature of up to 550°C
Efficiency	- 70 - 90%
Pros	- Applicable for high pressure gas
	- Easy to clean
Cons	- Expensive
	- Need specific design for each application

b) Recuperator

Recuperator is one of waste heat recovery exhangers. It is used for transferring heat from hot flue gas to cold air for combustion. Heat is transferred back to the furnace to enhance the efficiency. Flame temperature will also be increased.

- **Radiation Tubes with Recuperator**

Cold air and hot flue gas passing in the counterflowing direction. The radiation effect comes from the tube surface (see Figure 11). The radiation tubes with recuperator is appropriate for large furnace which the gas flow rate of 5-10 m^3/sec maximum. There is less contamination compared to other types of heat exchanger. The recuperator is typically located at the flue stack. The feature of recuperator is also summarized in Table 8.

Table 8 The feature of Radiation Tubes with Recuperator

Applications	- Preheat combustion air - Commonly used in steel industry: reheating furnace, soaking pit
Temperature range	- Waste heat of hot gas up to 1,400 °C
Efficiency	- 10-20%
Pros	- Applicable to high ambient temperature and contaminated hot gas - Simply constructed - Low investment cost
Cons	- Low thermal efficiency

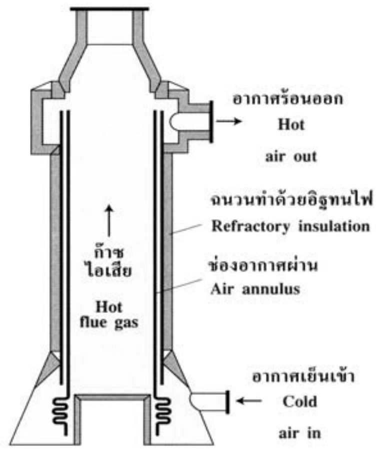


Figure 11 Double Shell Type Recuperator

- **Convection Tubes with Recuperator**

Convection tubes with recuperator is constructed so that the cold air can pass inside the tubes while the hot gas is passing through outside the tubes (see Figure 12). Turbulent flow of hot gas causes convection heat transfer. Tubes could be made from either metal or ceramic. Ceramic tubes used with higher temperature could cause leakage. Its cost is also high. The feature of recuperator is also summarized in Table 9.

Table 9 The feature of Convection Tubes with Recuperator

Applications	- Preheat combustion air
Temperature range	- Waste heat gas up to 1,200 °C
Efficiency	- 30 - 50%
Pros	- Tolerance with high temperature and some of contaminated gas
Cons	- Expensive - Leakage at seal, tube or wall may occur

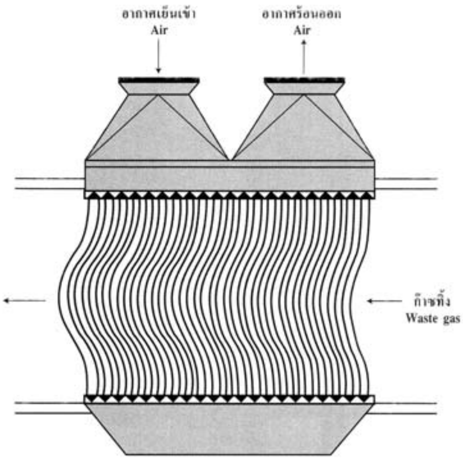


Figure 12 Tubular Convection Recuperator

- **Recuperative Burner System and Self-Recuperative Burner**

Waste heat in the flue gas will be transferred to recuperator fixed separately to preheat combustion air within burner itself. After exchanging heat, the low tempearture flue gas will be exhausted through flue gas eductor (See Figure 13).

Self-recuperative burner could replace existing burner used among different sizes of factories to better heat distribution in the furnace. The feature of self-recuperative burner can be summarized in Table 10.

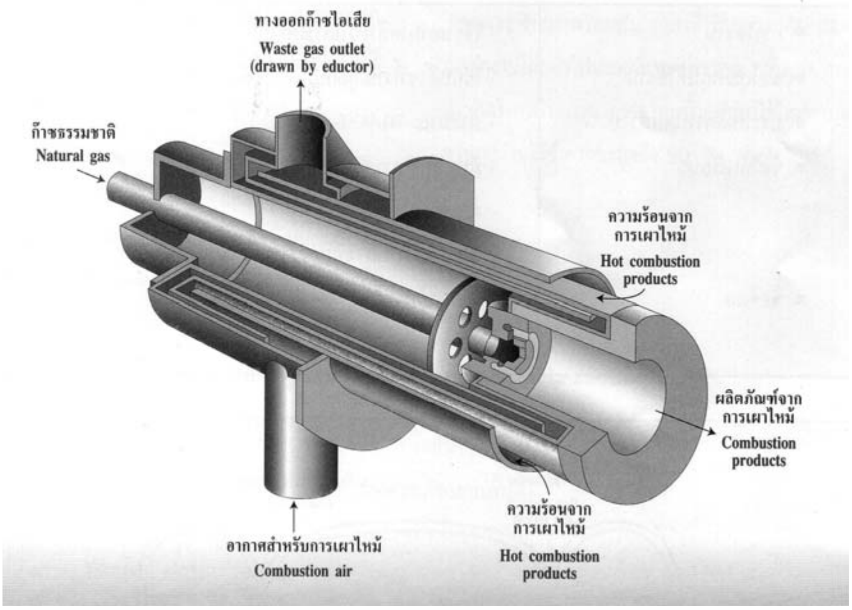


Figure 13 Self-recuperative burner

Table 10 The feature of convection tubes with recuperator

Applications	- Preheat combustion air
Temperature range	- For flue gas with the temperature of up to 1,500 °C
Efficiency	- 20 - 40%
Pros	- Compact size and convenient to install
Cons	- Require uncontaminated flue gas

c) Regenerator

Waste heat in flue gas could be stored by ceramic and regenerated heat to combustion air of single burner or a pair of burners. In case of rotary regenerator the cycle time could be set up for 30 seconds to 30 minutes

- **Static Regenerator**

Having been used for many years particularly in the glass and steel industry, the structure of static regenerator is quite large and strong (see Figure 14). Some times the static regenerator is adopted for use with usable for contaminated flue gas. The feature of self-recuperative burner are also summarized in Table 11.

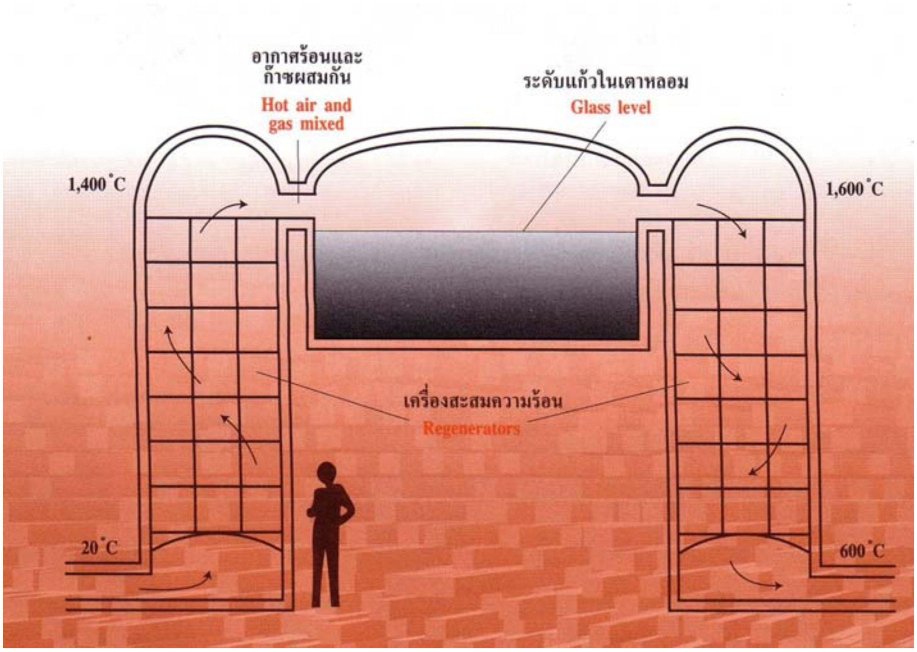


Figure 14 Static regenerator with refractory brick for glass furnace

Table 11 The feature of Static Regenerator

Applications	- Preheat combustion air
Temperature range	- For flue gas with temperature of up to 1,500 °C
Efficiency	- 70 - 90%
Pros	- High efficiency
	- Require low maintenance
	- Usable for contaminated flue gas
Cons	- Large size
	- High investment cost

- **Rotary Regenerator**

Rotary regenerator is assembled with cylindrical refractory matrix drum with 10-meter diameter 2-meter depth. The heat will be exchanged with cold combustion air when rotating. This type of regenerator is suitable for high rate of air flow rate.

Leakage and contamination are disadvantages needed to be concerned. The feature of self-recuperative burner are summarized in Table 12.

Table 12 The feature of rotary regenerator

Applications	- Preheat combustion air
	- Space heating
Temperature range	- Flue gas with temperature of up to 1,700 °C
Efficiency	- 70 - 90%
Pros	- Compact size
	- Usable for large amount of flue gas
	- Continuous operation
Cons	- High Pressure Drop
	- Easy to leak
	- Not applicable for dirt flue gas because of cross contamination
	- Expensive

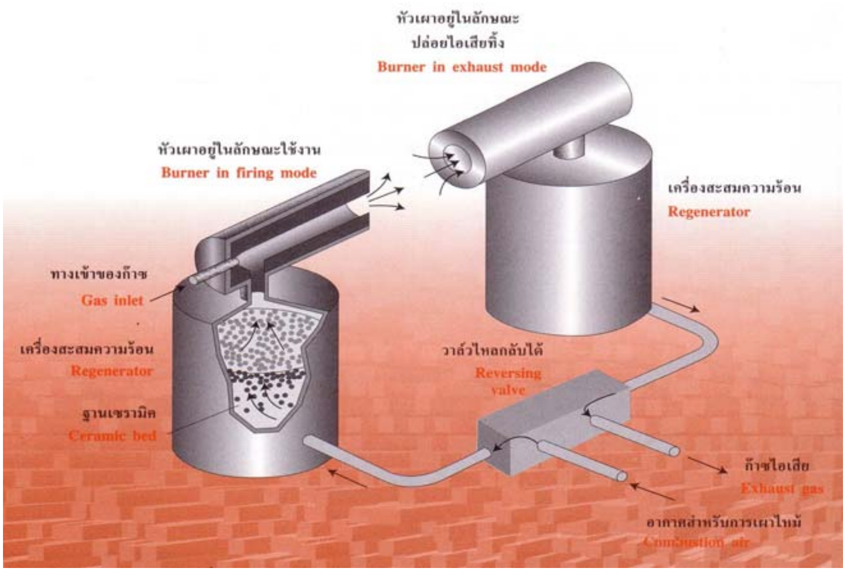


Figure 15 Rotary Regenerator

- **Compact Ceramic Regenerator**

This type of regenerator is widely used among metal and glass melting industry/processing including annealing, heat treatment of Steel, Aluminium Remelting. The regenerator and burner are operating simultaneously every 60-120 seconds with very high efficiency (90%). The recommended cleaning period is every 3 weeks for aluminium factory and every year for steel factory. The feature of compact ceramic regenerator is shown in Table 13.

Table 13 The feature of compact ceramic regenerator

Applications	- Preheat combustion air
Temperature range	- Flue gas with temperature up to 1,500 °C
Efficiency	- 70 - 90%
Pros	- Compact size
	- Applicable for some contaminated gas
	- Easy to clean
Cons	- Dirt blocked in some cases

- **Impulse-Fired Regenerative Burner**

One of the regenerative burners which will be operated during high and no-heating periods so the air-fuel ratio and the combustion air-flue gas ratio could be easily adjusted. There is combustion exhaust fan to draw flue gas therefore no reversing valves is required for this type (see Figure 16). Controlled by thermocouple in the furnace, a pair of burners will cycle for 15 seconds.

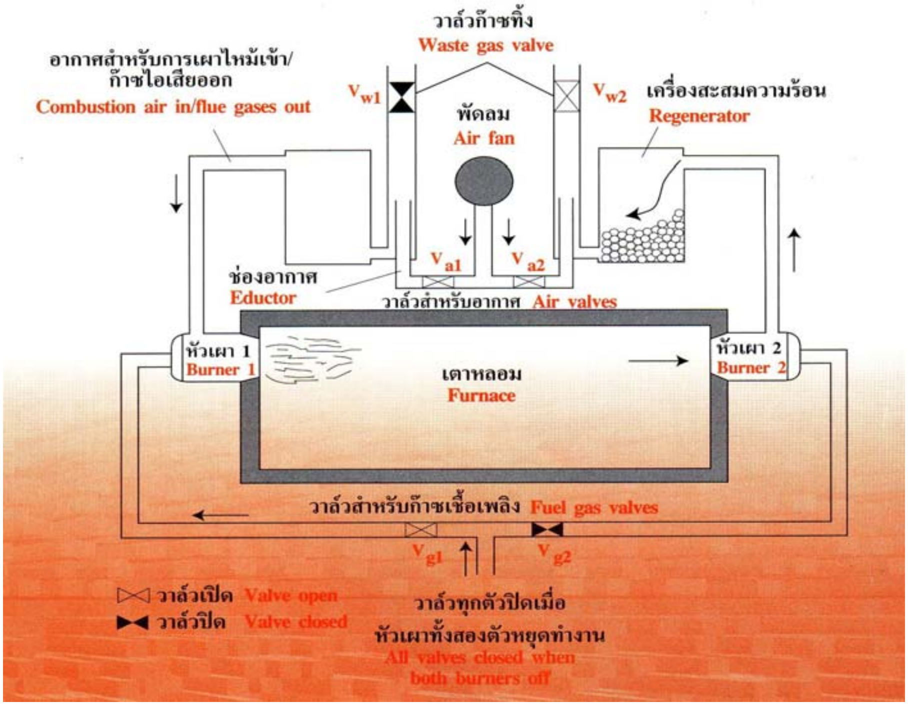


Figure 16 Impulse-fired Regenerative Burner

- **New Development**

Self-recuperative burner and regenerative burner have been improved, thanks to new development.

a) Radial Plate Recuperative Burner

This type of burner uses radial plate with higher convection heat transfer coefficient (see Figure 17)

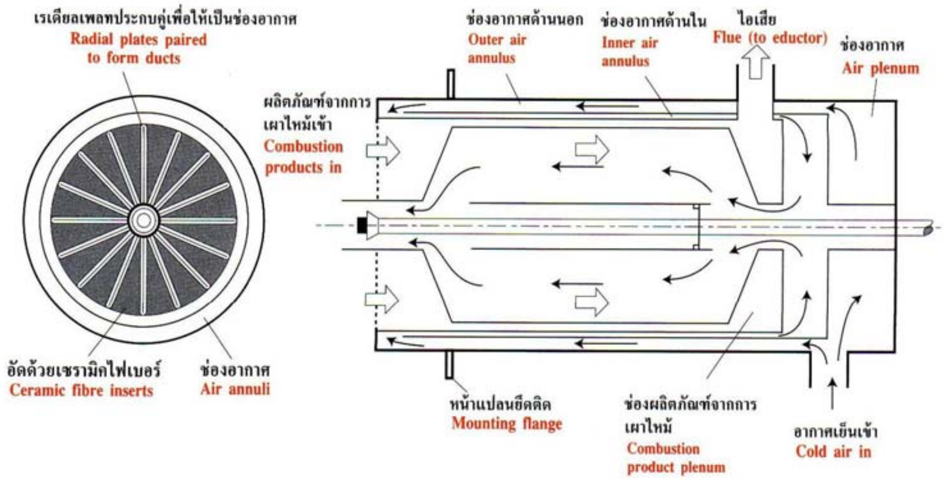


Figure 17 Radial Plate Recuperative Burner

The Radial plate recuperative burner can be both in stand-alone unit and/or integral unit with high temperature burner. The size ranges between 0.65-1.62 GJ/h (180-450 kW) at temperature range 700-1,100°C. The heat can be used for improving efficiency of various processes such as heat treatment of steel, ceramic or refractory brick, mold etc. The feature of radial plate recuperative burner is also shown in Table 14.

Table 14 The feature of Radial Plate Recuperative Burner

Applications	- Preheat combustion air
	- Stand alone burner or integral burner
Temperature range	- Flue gas with temperature up to 700 - 1,100 °C
Efficiency	- Approx. 60%
Pros	- High efficiency and applicable for low temperature process
	- Convenient to replace existing burner
Cons	- Not applicable for contaminated gas

b) Integral Bed Regenerative Burner

This newly-developed burner is equipped with the bed of ceramic spheres in the dual furnace (see Figure 18). When the first burner is activated, the flue gas will pass through the ceramic bed of the other inactivated burner. The cold combustion air is then continuously warmed by this heat. Such working process will be cycled continuoulsy. Each cycle time takes between 30-180 seconds.

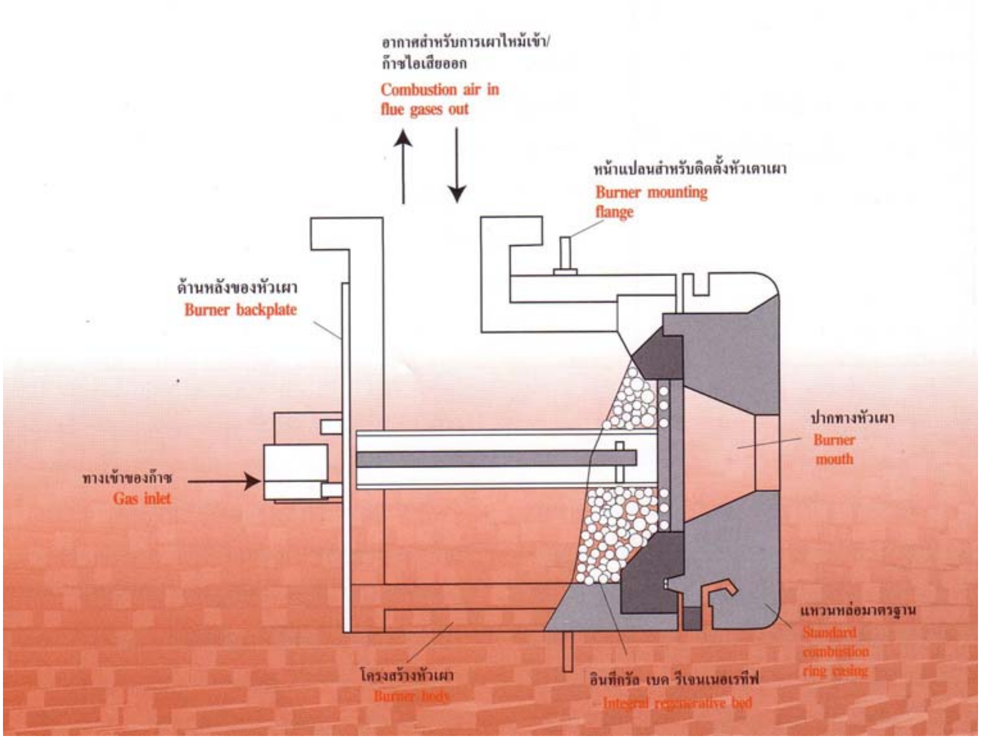


Figure 18 Integral Bed Regenerative Burner

Since the bed of ceramic spheres is installed within furnace structure, this type of burner requires less installed area compared to others. Hence, a small furnace with sizes ranging from 0.2 GJ/h (0.65 kW) to 18.6 GJ/h (5,160 kW) is applicable for this burner. The feature of integral bed regenerative burner is also shown in Table 15.

Table 15 The feature of integral bed regenerative burner

Applications	- Preheat combustion air
Temperature range	- Flue gas with temperature up to 1,500 °C
Efficiency	- 70 - 80%
Pros	- Compact size
	- Applicable for small furnace
	- Convenient to replace existing burner
Cons	- Fouling occurred due to some application

c) Energy Optimising Furnace, EOF

The electric arc furnace is the energy intensive machine of this metal melting process. Over 20% of energy input to the furnace will be the flue gas loss. Such amount of energy is suficient for heating up metal up to 600-850°C. The temperature is worth for heat recovery and for use in the melting furnace. Brazil and India are the two model countries in adopting the electric arc furnace for use in metal meting process (see Figure 19).

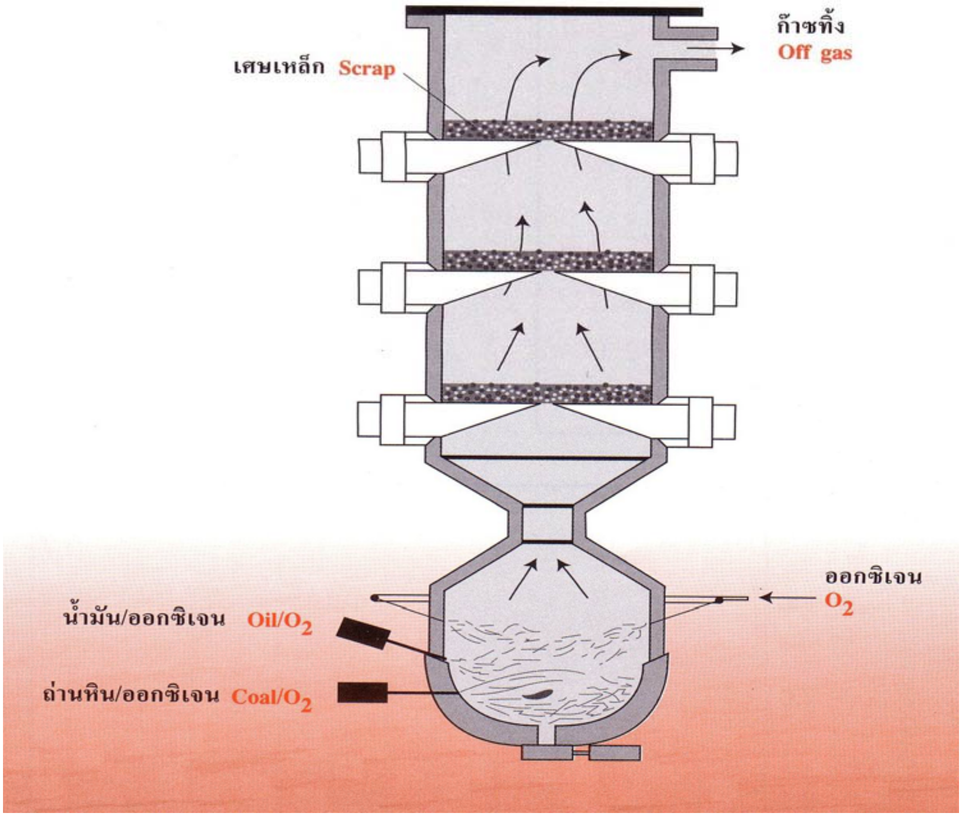


Figure 19 Energy Optimising Furnace, EOF

Selection of the heat recovery technology

Energy experts, consultants, and technology suppliers can provide the users recommendation concerning the heat recovery technology suitable for each industry. They can also recommend the most appropriate option for either existing burner replacement or new furnace construction. The diagram below is a sample of showing decision making on the best option for burner replacement/renovation.

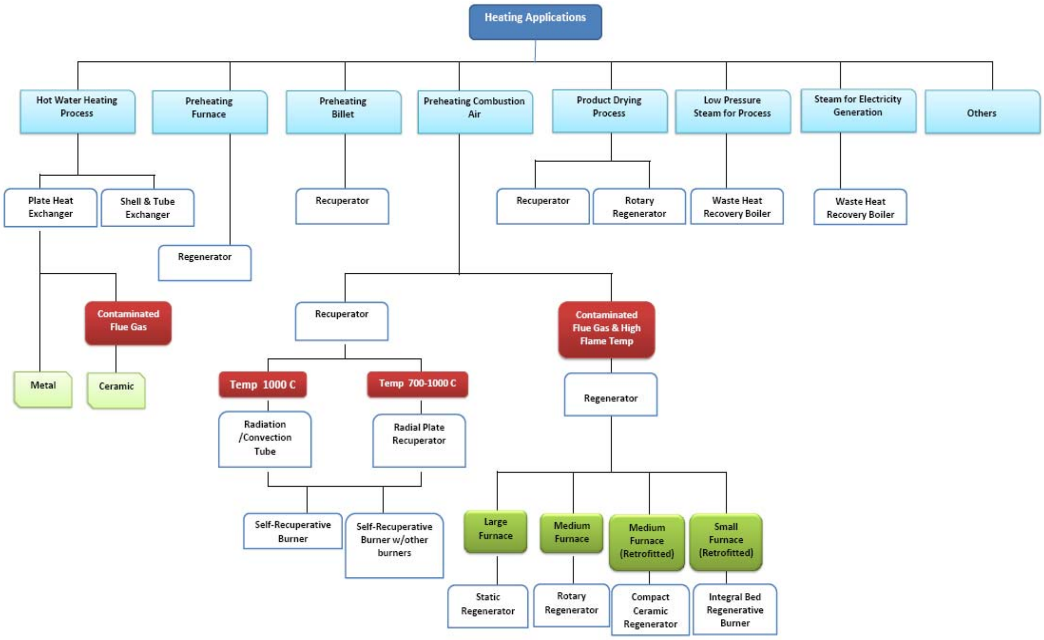


Figure 20 Decision tree for the selection of heat recovery technology

Checklist for Heat Recovery Project

The following checklist can be considered before implementing the heat recovery project.

1. Do you know the quantity & quality of waste heat in your factory?
2. Do you know the specific heat of flue gas?
3. Did you ever implement the good housekeeping measures and the low investment cost for loss reduction of the project?
4. Do you have any cost-effective option for waste heat reduction?
5. Are your staff aware of waste heat recovery.?
6. Do you have any experience with hands-on practice?
7. Is your waste heat technology the cost-effective one?
8. Have you ever considered these following issues?
   - Operating and maintenance cost
   - Source of heat recovery equipment
   - Feasibility study in fluctuated operation
   - Fouling problem, condensation and corrosion, etc.
   - Green house gas emission e.g. NO_x
   - Impact of productivity and quality

9. Is the project feasible in terms of economic return?
10. Has the waste heat recovery been efficiently reviewed?
11. Does the project comply to any environmental law and any upcoming enforcement?
12. Is the information you have sufficient to propose for the subsidy?

Summary

Most industries use thermal energy and waste heat is usually released during the process either hot liquid or hot gas. The waste heat can be categorized by temperature as follows:

- High Temperature (> 650˚C)
- Medium Temperature (230˚C - 650˚C)
- Low Temperature (< 230˚C)

It is unavoidable that heat loss will happen during the process. The energy-saving efficiency will be enhanced by adopting waste heat recovery to use. However there are variables need to be considered in both quantity and quality aspects.

- Flow rate of flue gas
- Temperature of flue gas
- Composition of flue gas

The potential of energy saving efficiency is also needed to be considered.

Heat recovery technologies can be implemented in many cases for example, preheating of combustion air by recuperator, stock/billet preheating by regenerator, furnace regenerator, brick drying, space heating or hot water heating, steam producing for power generation or processes, preheating of fuel etc.

Heat exchanger in the heat recovery equipment is functioned to transfer heat from one source of fluid to the other source, normally for cooling or heating process or in between.

Recuperator is the heat exchanger transferring heat from flue gas to preheat combustion air in order to increase furnace efficiency and flame temperature.

Regenerator is the heat exchanger transferring heat through a collection of heat by ceramic materials connected to a dual burner. The flue gas from the activated burner passed through the ceramic collector. The heat in the ceramic is then released to preheat cold combustion air in the other inactivated burner. When the first burner is activated, the flue gas will pass through the ceramic bed of the other inactivated burner. The cold combustion air is then continuously warmed by this heat. Such working process will be cycled continuoulsy. Each cycle time takes between 30 seconds and 30 minutes depending on different types of regenerator.

An installation measure of waste heat recovery or preheat feed water

The flue gas temperature of 200-250°C can be utilized by an economizer to preheat feed water for the boiler. The energy-saving efficiency will be maximized when there is no condensate return in the system.

The economizer is implemented with the boiler having at least 3 MW (Steam generation 3.6Ton/hr) in size. However, bypassing low-temperature flue gas could happen to avoid condensation and stack corrosion in the operation load.

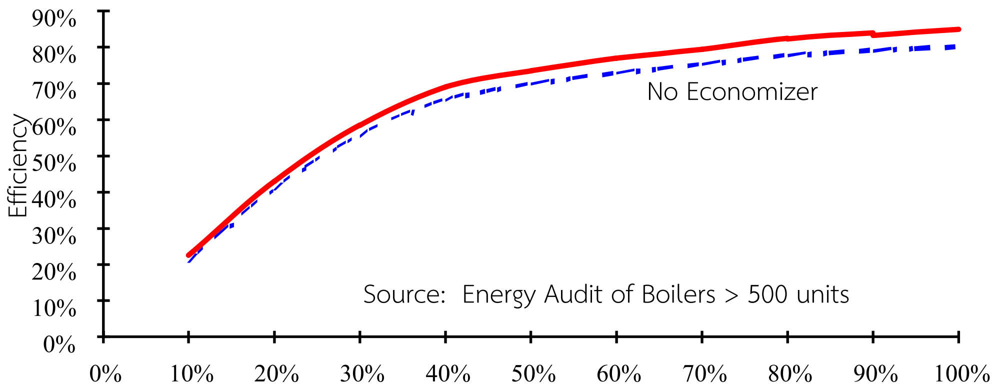


Figure 21 The efficiency of the large boiler

3. Air Compressor

An electric appliance widely-used in buildings and factories for producing compressed air with 2-8 times higher pressure than atmosphere to proceed machines and pneumatic tools. Typically, the oversized air compressor is chosen to handle air consumption at various pressure levels. Therefore several types of air compressor have to be carefully selected to meet the need because of its energy- intensive machine which could cause air leakage feasibility in the system.

3.1. Types of compressor

3.1.1. Compressor characteristics

a. Turbo

(1) Axial flow compressor

Gas is compressed while passing between moving blades on the impeller and stationary blades on the casing.

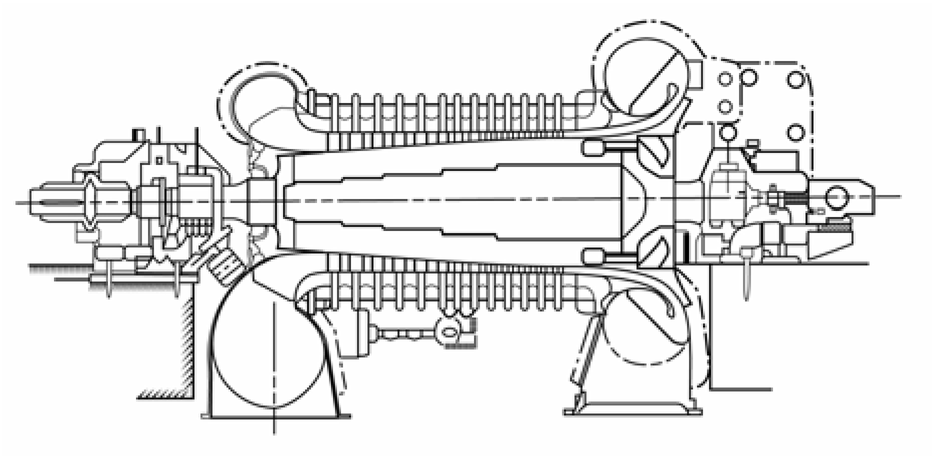


Figure 22 Axial Air Compressor

(2) Centrifugal compressor

For this type of compressor, the air is sucked through the centre of the impeller by the centrifugal force of the rapidly rotating impeller, which creates an air passage discharged to the periphery. The centrifugal compressor is suitable for the work that highly demands air quantity, oil free and less corroded blade. The illustration of centrifugal compressor is displayed in Figure 23. It should be noted that the centrifugal air compressor is not often found in general factory due to its design for a high air quantity with less pressure.

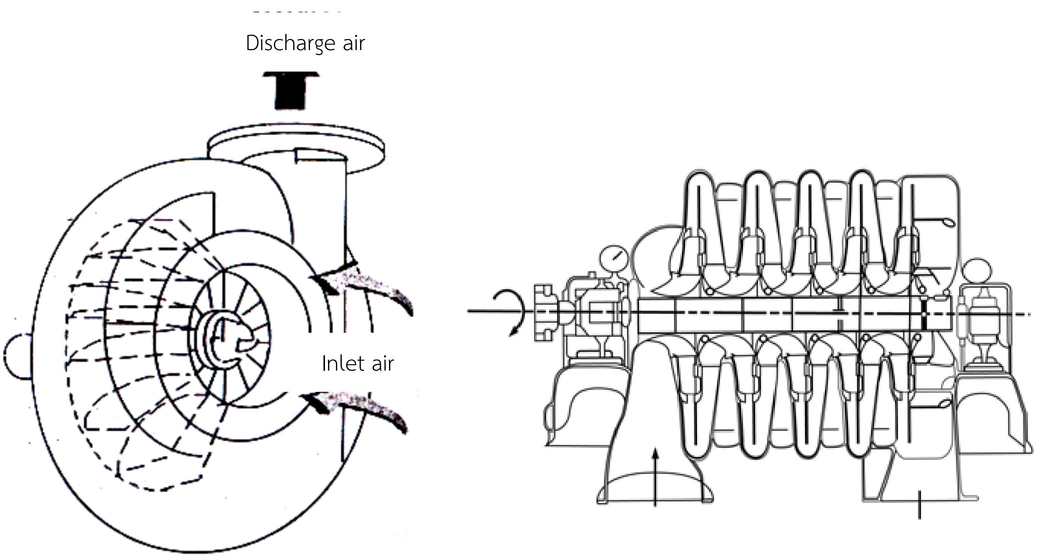


Figure 23 Centrifugal compressor

b. Positive displacement

(1) Reciprocating Compressor

Air is sucked and compressed by the reciprocating motion of a piston. This compressor type has been used before the development of rotary compressor or centrifugal compressor. Nevertheless, the reciprocating has high maintenance cost and vibration issue.

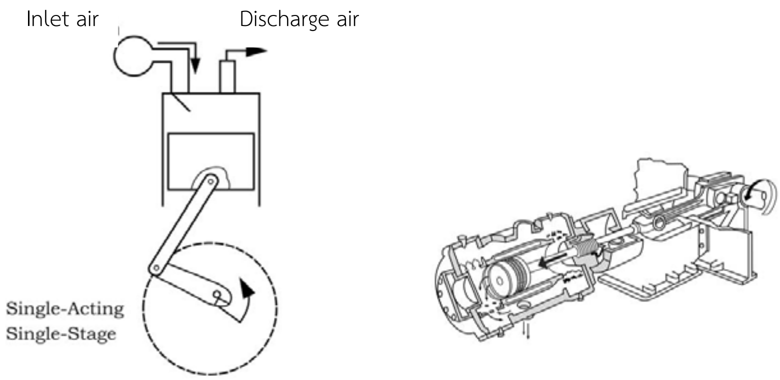


Figure 24 Reciprocating compressor

(2) Screw Compressor

The air is sucked and discharged by the volume changes between the gap and the casing generated by rotation of the male and female rotors.

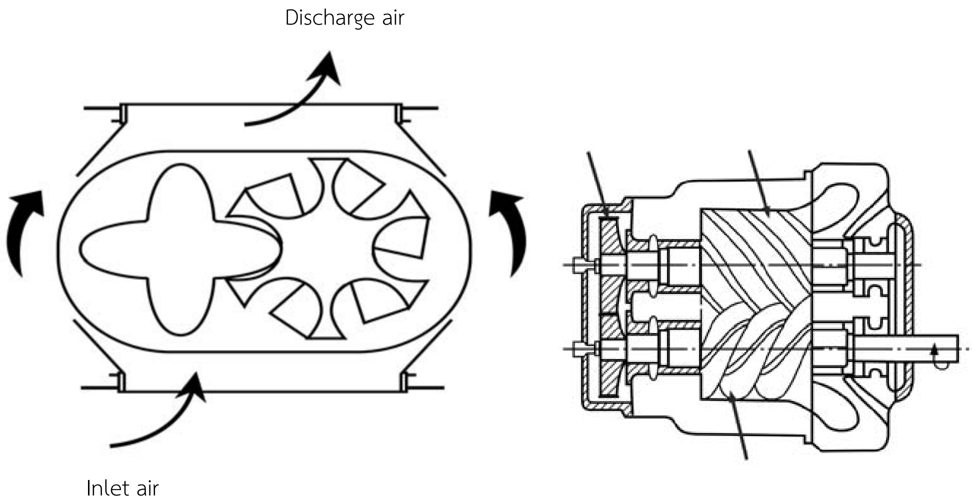


Figure 25 Screw compressor

(3) Rotary Vane Compressor

Rotating shaft fixed with sliding vanes will be used. The rotor is mounted offset in a larger housing. As the rotor turns, blades will slide in and out of the slots, thus the air is sucked and compressed.

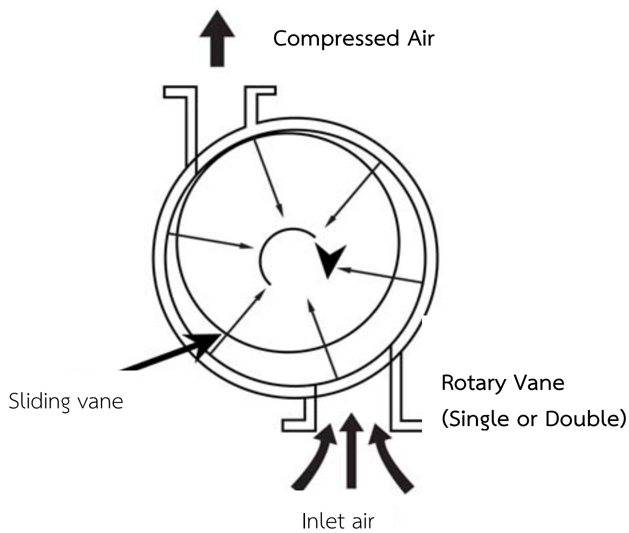


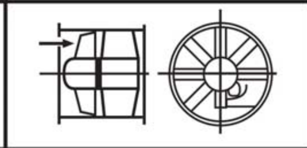
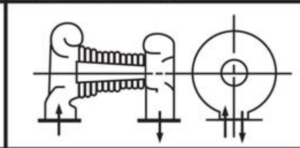
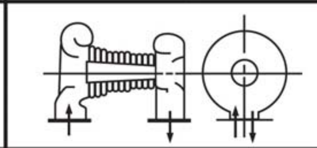
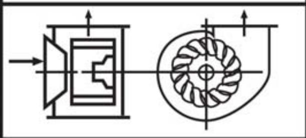
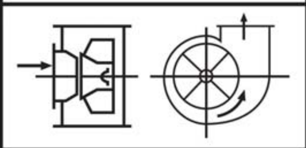
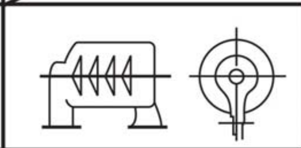
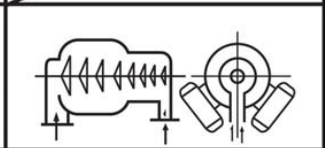
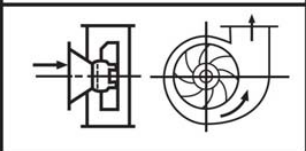
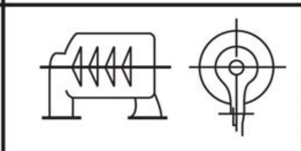
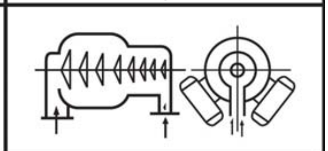
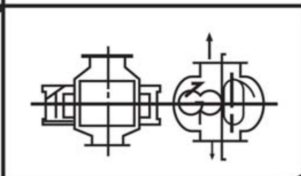
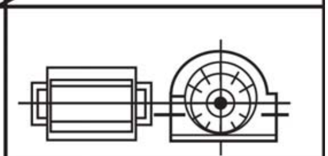
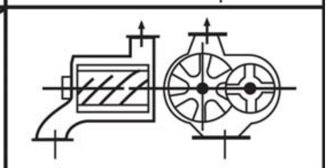
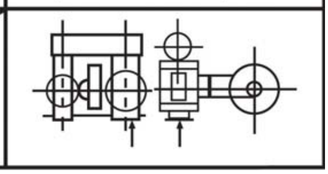
Figure 26 Rotary Vane Compressor

3.1.2 Classification of air compressors

There are various types of air-compressors. The selection of air-compressor depends on air quantity and pressure demand. Table 16 illustrates the classification of air-compressor. Generally, it can be distinguished into 3 pressure ranges: low pressure (fan), medium pressure (blower), and high pressure (compressor). In addition, the air-compressor can be classified by turbo and positive-displacement types. Turbo type uses centrifugal force by blades to increase the velocity and the gas pressure, while the positive-displacement type increases the pressure by adjusting the volume using piston or movable vane.

The positive-displacement type is classified into rotary and piston types. The rotary type is divided into two-lobe, movable vane, and screw types.

Table 16 Classification of air compressors

Name			Blower		Compressor
			Fan	Blower	
Type \ Press			Balow 1000mmaq	Aboue 1000mmaq and balow 10maq	Aboue 1kg/cm2
Turbo	Axial Flow	Axial Flow			
Turbo	Centrifugal	Multiblade			
Turbo	Centrifugal	Radial			
Turbo	Centrifugal	Turbo			
Positive displacement type	Rotary	Root's			
Positive displacement type	Rotary	Moriable varne			
Positive displacement type	Rotary	Screw			
Positive displacement type	Raciproceting	Raciproceting			

3.1.3 Application range of blowers and compressors

The application of compressors is depended on the condition of usage such as the gas type, pressure and volume. Figure 27 shows the general application range of each blower and compressor.

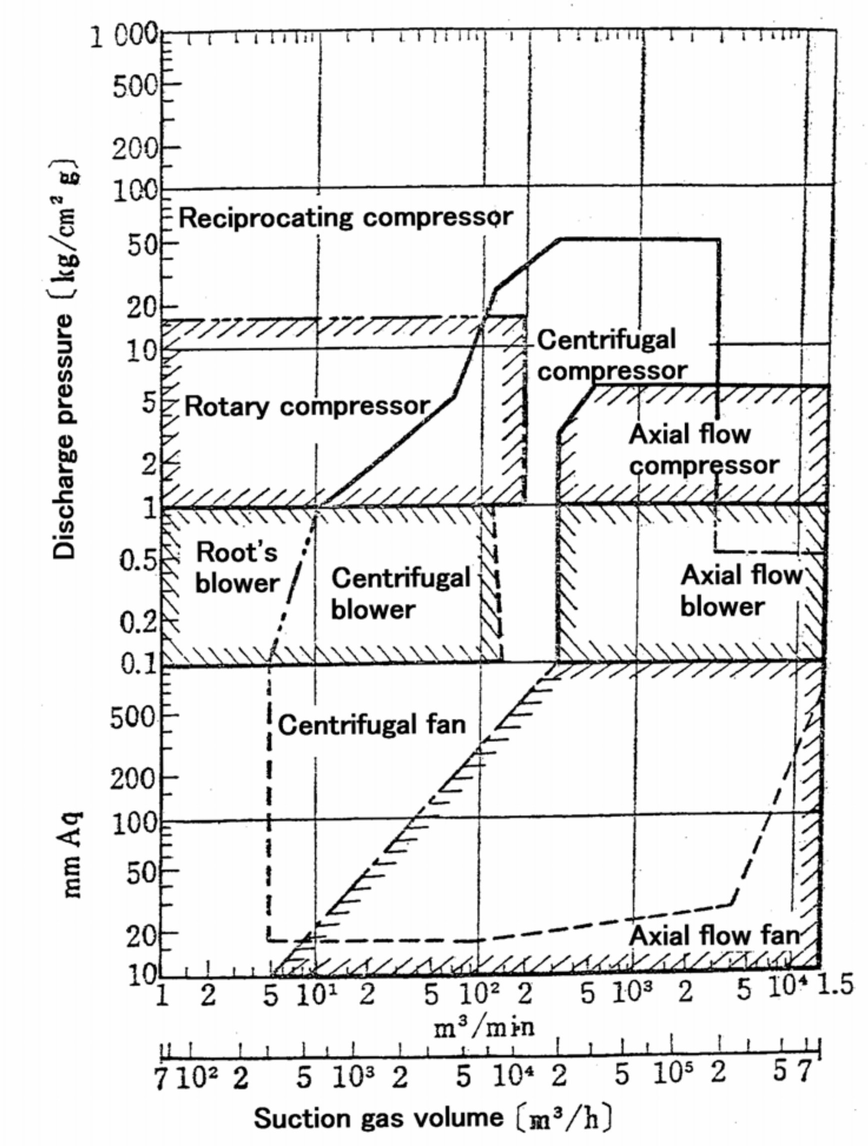


Figure 27 Application range of blowers and compressors

1 mmAq	=	1	kgf/m^2	=	9.8 Pa
1 mAq	=	0.1	kgf/cm^2	=	9.8 kPa
10 mAq	=	1	kgf/cm^2	=	0.098 MPa

3.2 Energy saving efficiency measure of air compressor

The energy-saving efficiency measure of the air-compressor consists of the good design of the system, the selection of appropriate compressor type and capacity, the tank size that provides enough air quantity to work on, and the diameter of the main pipe that helps create suitable air velocity and separate the condensate.

In addition, the pressure system should be properly designed. Reducing the air pressure from one point to another could unstabilize the pressure system while setting very high pressure will cause high-energy consumption. Selection of good equipment suitable for the function will help. Operation and maintenance should also be put in place. The energy conservation in air-compressor can be operated as following.

3.2.1 The use of high efficiency air compressors

(1) Reciprocating air compressor

The more compression stages, the higher efficiency the reciprocating air compressor will be. Generally, the two-stage compression will be used. The air compressor with water-cooling system is better because it helps reduce air temperature during the compression. It can also be said that its isothermal process is of high efficiency.

Using double acting compressor will increase the efficiency, reduce wearing down, and help compress much air volume compared to the same size. The reciprocating type is suitable for unstable loads since it has good un-load equipment. The energy consumption in un-load period is small compared to other types. The control can be used multi-step in the part load operation, leading to higher efficiency. The reciprocating air compressor is shown in Figure 28.

Figure 28 Reciprocating air compressor

(2) **Rotary Screw air compressor**

The two untouched screws function this type of air compressor having low wear down. Rotary screw type has moderate efficiency due to the screw type structure which is determined constant pressure ratio, if being operated in low load and low rated pressure, its energy efficiency will be reduced. Therefore, the rotary screw air-compressor is suitable for full and stable load. This will make higher efficiency. The rotary screw air compressor is shown in Figure 29.

Figure 29 Rotary Screw Air Compressor

(3) **Centrifugal air compressor**

This type of air compressor as shown in Figure 30, is of high efficiency and suitable for the amounts of large air quantity.

Figure 30 Centrifugal air compressor

(4) Variable Speed Air Compressor

Equipped with variable speed drive (VSD), this type of air compressor is suitable for the wide range of operation especially in the part load operation. It could help reduce air speed by 20% of full capacity. The machine can produce compressed air to meet the demand on consumption. Therefore this technology is appropriate for replacing reciprocating, rotary vane and screw air compressor.

The VSD cost is high but it could reduce losses of existing compressors in transmission e.g. gear or belt. However, it is necessary to ensure that this machine will operate on the low speed with oil coolant system to avoid resonant frequency.

The rule of thumb for air compressor is every 0.5 of pressure reduction it will save energy consumption of the air compressor by 3%.

The VSD air compressor is feasible for a variety of operation e.g. replacement of screw air compressor with load fluctuated by half of the time or more (see standard measure of DEDE). Figure 31 represents power consumption vs compressed air consumption. Table 6 and Table 7 represent example of energy efficiency evaluation and performance and cost effectiveness of different types of air compressors needed for improvement respectively

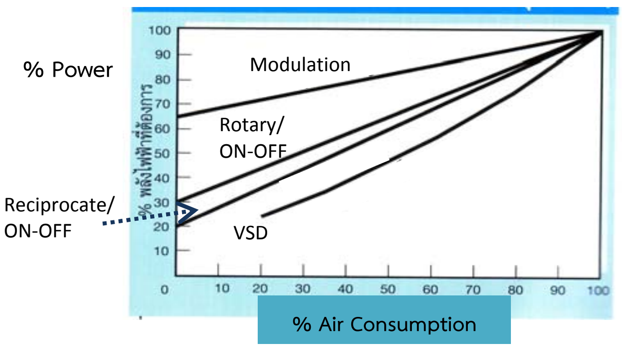


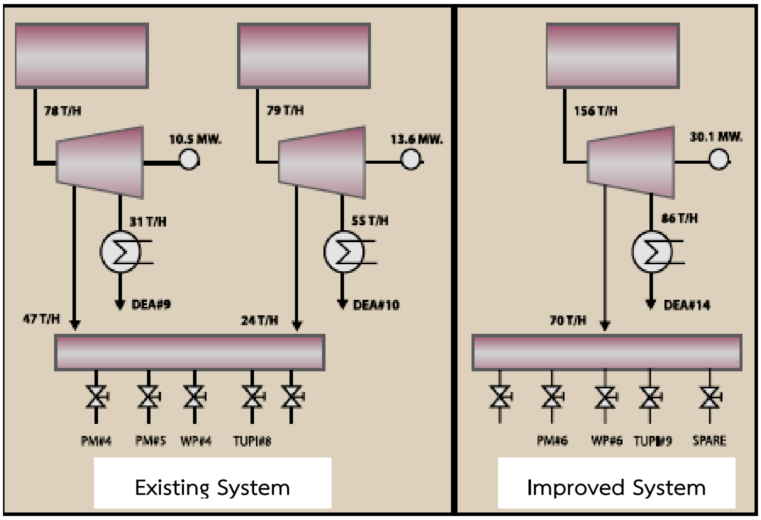
Figure 31 VSD compressor characteristic

Annex B.

Case Study on Energy Conservation Measures

(Source: Department of Alternative Energy Development and Efficiency)

Case Study 1 : Cogeneration System

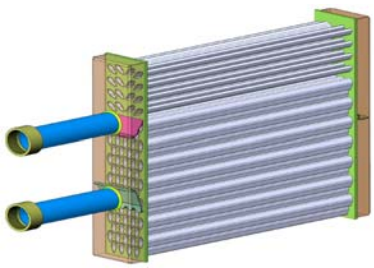


Factory	:	Siam Kraft Industry Co.,Ltd.	
Province	:	Kanchanaburi	
Type of Industry	:	Paper	
Details of measure	:	More energy source is required for factory expansion. CFB boiler woodchip and sludge with fuel-production capacity of 45 ton/day and 60 ton/day respectively have been installed to replace the existing boiler, leading to an increase in energy saving efficiency compared to the previous high-pressure steam which needs up to 156 ton/hr fuel for its 30MW power generation.	
Investment cost	:	650	Million Baht
Energy Cost Saving	:	7.6	Million Baht/year (coal reduction)
Payback Period	:	N/A	Year (No information of other cost saving)

Case Study 2 : Cogeneration System

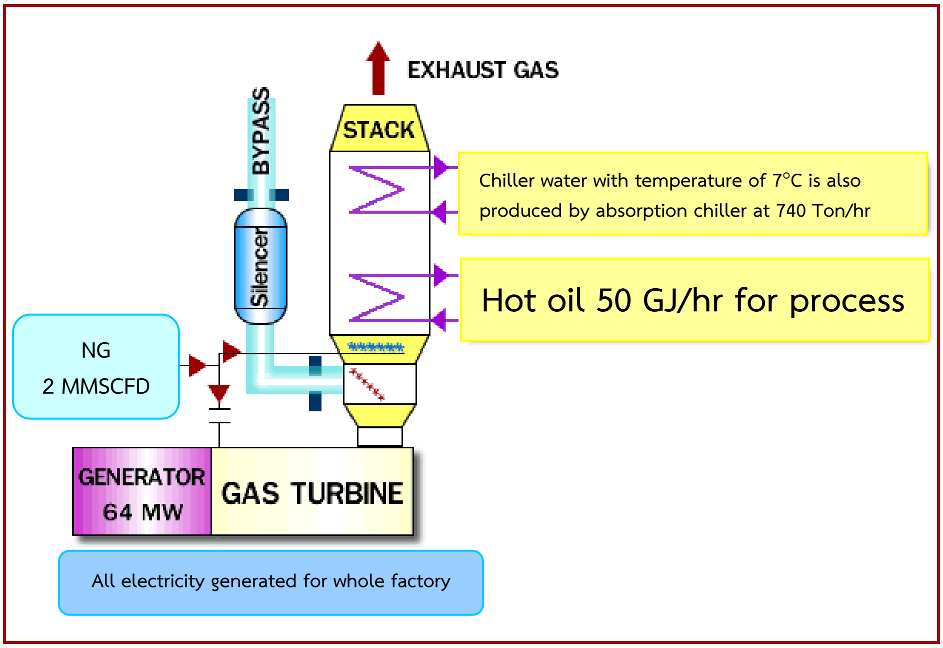
Factory	:	Thai Union Paper PCL.
Province	:	Samutprakarn
Type of industry	:	Paper
Detail of measures	:	Twin screws press-type of water pressing machine aimed at reducing humidity of fiber used as fuel together with coal fire. The boiler could produce up 34.5 tons of steam with 65-barpressure within an hour to feed into the steam turbine for generating 3.56MW electricity.
Investment Cost	:	2.9 Million Baht (Twin Screws Press)
Energy Cost Saving	:	3 Million Baht/yr (Coal reduction 6.67 ton/day and sludge disposal cost 864,000 Baht/year)
Payback Period	:	1 year

Case Study 3 : Waste heat recovery by the economizer



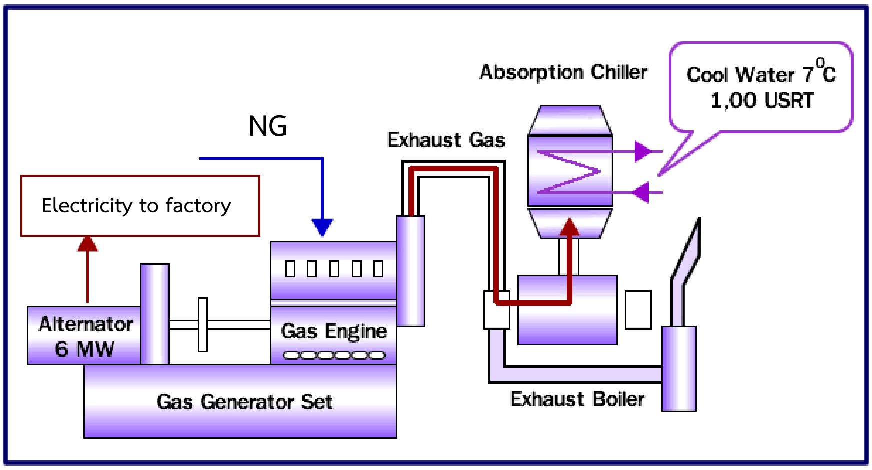
Factory	:	Green Spot (Thailand) Co., Ltd.
Province	:	Pathumthani
Type of industry	:	Food & Beverage
Details of measure	:	Install economizer to exchange heat recovery from 240°C flue gas totaling 14 tons/hour for preheating feed water in the boiler from 88°C to 130°C. The economizer help reduce natural gas consumption by 5%
Investment Cost	:	1.7 Million Baht
Energy Cost Saving	:	2.2 Million Baht/year
Payback Period	:	0.7 Year

Case Study 4 : Gas Turbine Cogeneration & Absorption Chiller Installation



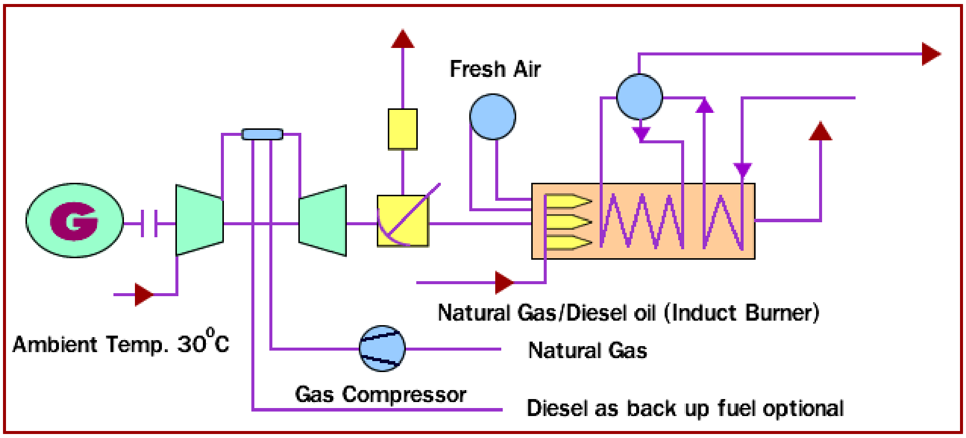
Factory	:	Bangkok Polyester Co.,Ltd.
Province	:	Rayong
Type of industry	:	Chemical (Plastic Pellets)
Details of measure	:	Gas Turbine Cogeneration with electricity generation capacity of 6.4 MW is installed. The waste heat from absorption chiller is recovered to exchange with hot oil at 50GJ/hr. Cooling water with temperature of 7°C is also produced by absorption chiller at 740 Ton/hr
Investment Cost	:	N/A Million Baht
Energy Cost Saving	:	N/A Million Baht/year
Payback Period	:	N/A Year

Case Study 5 : Gas Turbine Cogeneration & Absorption Chiller Installation



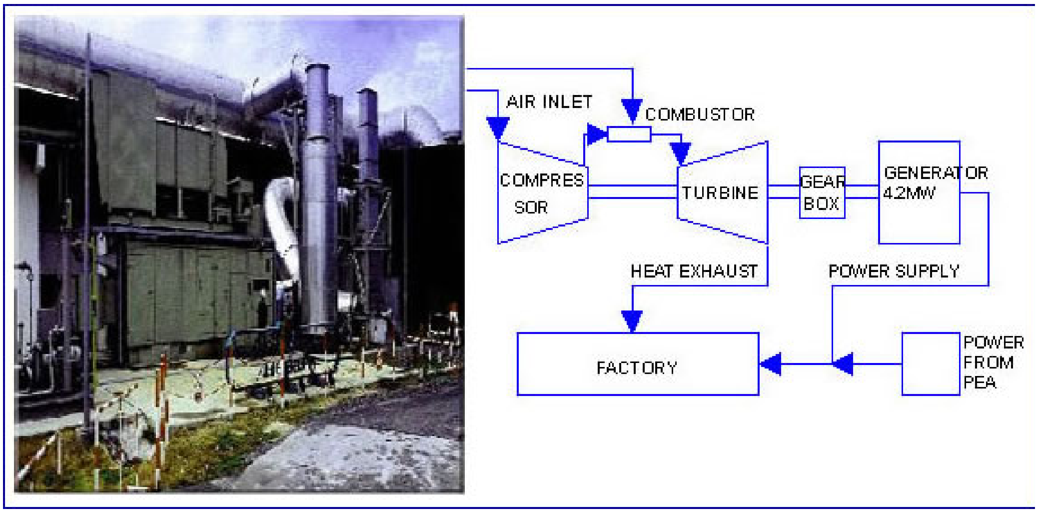
Factory	:	Crown Seal PCL.
Province	:	Bangkok
Type of industry	:	Metal products (Caps of can/bottle)
Details of measure	:	Install Gas Turbine Cogeneration 6 MW, waste heat recovered for absorption chiller at 1,080 tons/hr. Cool water with the temperature of 7°C is produced.
Investment Cost	:	N/A Million Baht
Energy Cost Saving	:	N/A Million Baht/year
Payback Period	:	N/A Year

Case Study 6 : Gas Turbine Cogeneration Installation



Factory	:	Central Paper Industry PCL.	
Province	:	Samutprakarn	
Type of industry	:	Paper	
Details of measure	:	Install Gas Turbine Cogeneration 4.4 MW electricity, Waste heat producing steam at 30 tons/hr, 170°C, 7Bar for process.	
Investment Cost	:	N/A	Million Baht
Energy Cost Saving	:	N/A	Million Baht/year
Payback Period	:	N/A	Year

Case Study 7 : Gas Turbine Cogeneration Installation



Factory	:	Thai Gypsum Co.,Ltd.
Province	:	Chonburi
Type of industry	:	Non Metallic (Gypsum)
Details of measure	:	Install Gas Turbine Cogeneration 4.2 MW electricity, waste heat 71.1 tons/hr at 30°C utilized in process.
Investment Cost	:	N/A Million Baht
Energy Cost Saving	:	N/A Million Baht/year
Payback Period	:	N/A Year

Case Study 8 : Gas Turbine Cogeneration & Absorption Chiller Installation

Factory	:	Thai Taffeta Co.,Ltd.
Rayong	:	Rayong
Type of industry	:	Textile (Export)
Details of measure	:	Install gas turbine cogeneration 10 MW electricity, waste heat producing steam 24 ton/hr for absorption chiller to produce chilled water
Investment Cost	:	N/A Million Baht
Energy Cost Saving	:	N/A Million Baht/year
Payback Period	:	N/A Year

Case Study 9 : An installation of recuperator utilizing waste heat from the furnace to preheat combustion air

Factory	:	PPG-Siam Silica Co.,Ltd.
Province	:	Rayong
Type of industry	:	Chemical (Silica Powder)
Details of measure	:	Install recuperator recover waste heat from flue gas with temperature of 1,100°C for preheating combustion air from 35°C to 550°C. The rest of the waste heat will be used for producing 70-80°C hot totalling 6,000 litre/hr for cleaning during the process.
Investment Cost	:	10 Million Baht
Energy Cost Saving	:	3 Million Baht/yr
Payback Period	:	3.3 Years

Case Study 10 : An installation of the regenerator utilizing waste heat from melting furnace to preheat combustion air

Factory	:	Tha Glass Industry PCL.
Province	:	Bangkok
Type of industry	:	Container Glass
Details of measure	:	Install regenerator 2 units with the furnace using heat with the temperature of 1,500°C to preheat combustion air from 35°C to 1,200-1,300°C. Help save energy by 30%.
Investment Cost	:	20 Million Baht
Energy Cost Saving	:	12.2 Million Baht/year
Payback Period	:	1.6 Years

Case Study 11 : Waste Heat Boiler Installation

Factory	:	Thai Carbon Black PCL.
Province	:	Rayong
Type of industry	:	Petro-Chemical (Carbon Black Powder)
Details of measure	:	Install waste heat boiler utilizing waste gas from the process at 150,000 m^3/h to produce 400°C steam totalling 130 ton/hr at 42 Bar and drive steam turbine for generating electricity totalling 17.5 MW. The low pressure steam at 3.5 Bar can be sold to other factories. The energy efficiency rate is at 25-30%.
Investment Cost	:	300 Million Baht
Energy Cost Saving	:	300 Million Baht/year
Payback Period	:	1 Year

Case Study 12 : Waste Heat Boiler & Absorption Chiller Installation

Factory	:	Crown Seal PCL.
Province	:	Bangkok
Type of industry	:	Metal Products (end caps)
Details of measure	:	Install gas engine cogeneration + waste heat boiler+ absorption chiller using gas engine at 3x2MW. Waste flue gas with 500°C temperature at 150-210 m^3/h per unit, totalling 3 units provided to waste heat boiler totalling 3x1.56 tons/hr at 6 Bar. The steam generated could also provided to absorption chiller at 3x360 tons/hr producing chilled water for the process and space cooling.
Investment Cost	:	160 Million Baht
Energy Saving	:	25%
Payback Period	:	10 Years

Case Study 13 : Installing VSD for air compressor

Factory	:	Carpet Inter Thailand PCL.	
Province	:	Pathumthani	
Type of industry	:	Textile	
Detailsof measure	:	Install Variable Speed Drive (VSD) for Screw Air Compressor 250kW (Existing Unload time 40%)	
Investment Cost	:	550,000	Baht
Energy Cost Saving	:	423,000	Baht/year
Payback Period	:	1.3	Years

Case Study 14 : Installing High Efficiency Air Compressor

Factory	:	DEDE case study project.	
Details of measure	:	Install a unit of two-stage screw air compressor 150kW to replace a unit of 37kW air compressor and a unit of 112 kW.	
Investment Cost	:	2,600,000	Baht
Energy Cost Saving	:	553,429	Baht/year
Payback Period	:	4.7	Years

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