Theme 4

Energy Efficiency

I-Fundamentals

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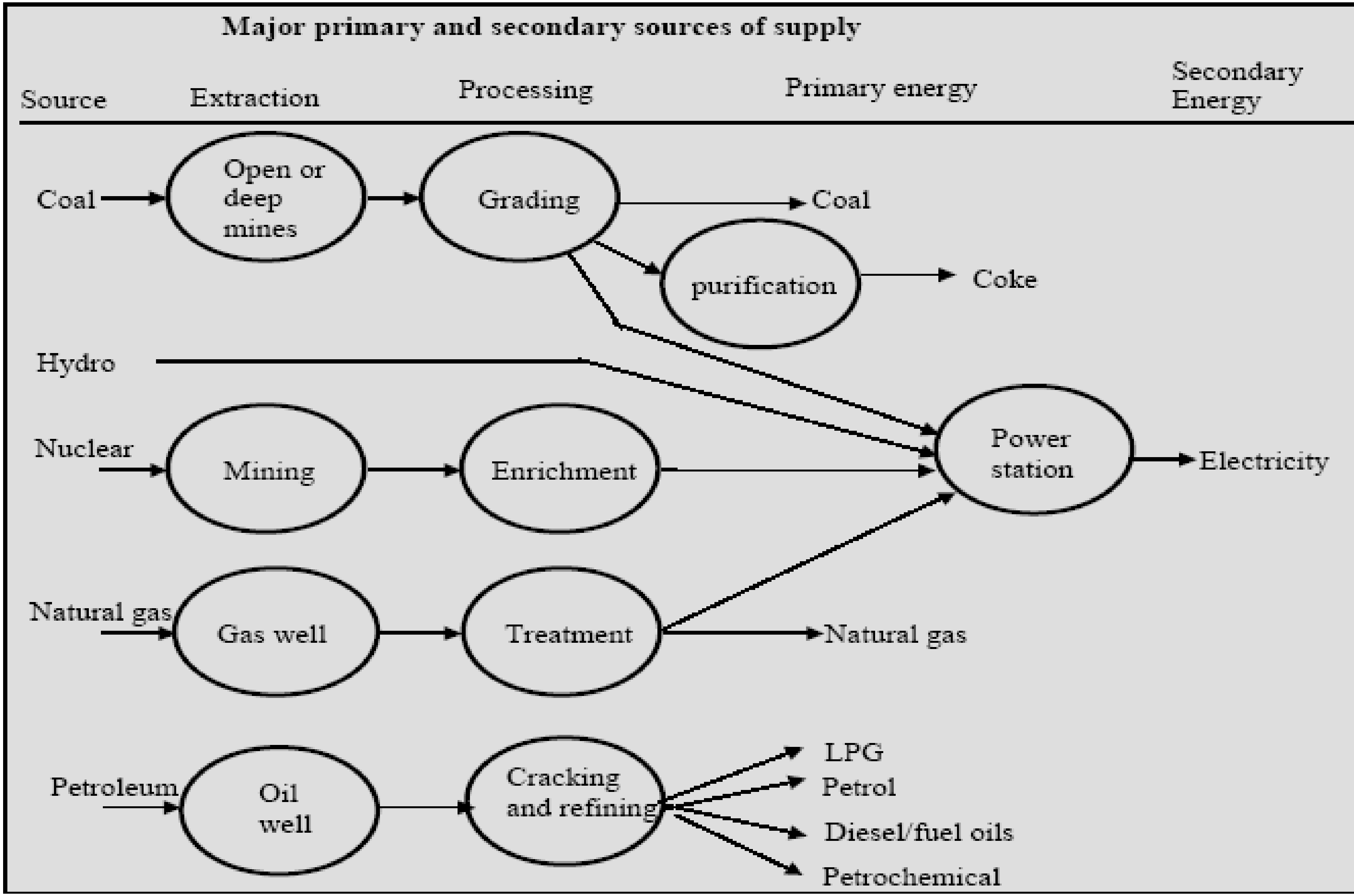
Contents

Primary and secondary energy



How to measure energy?

- Heating value: of a substance, usually a fuel or food is the amount of heat released during the combustion of a specified amount of it

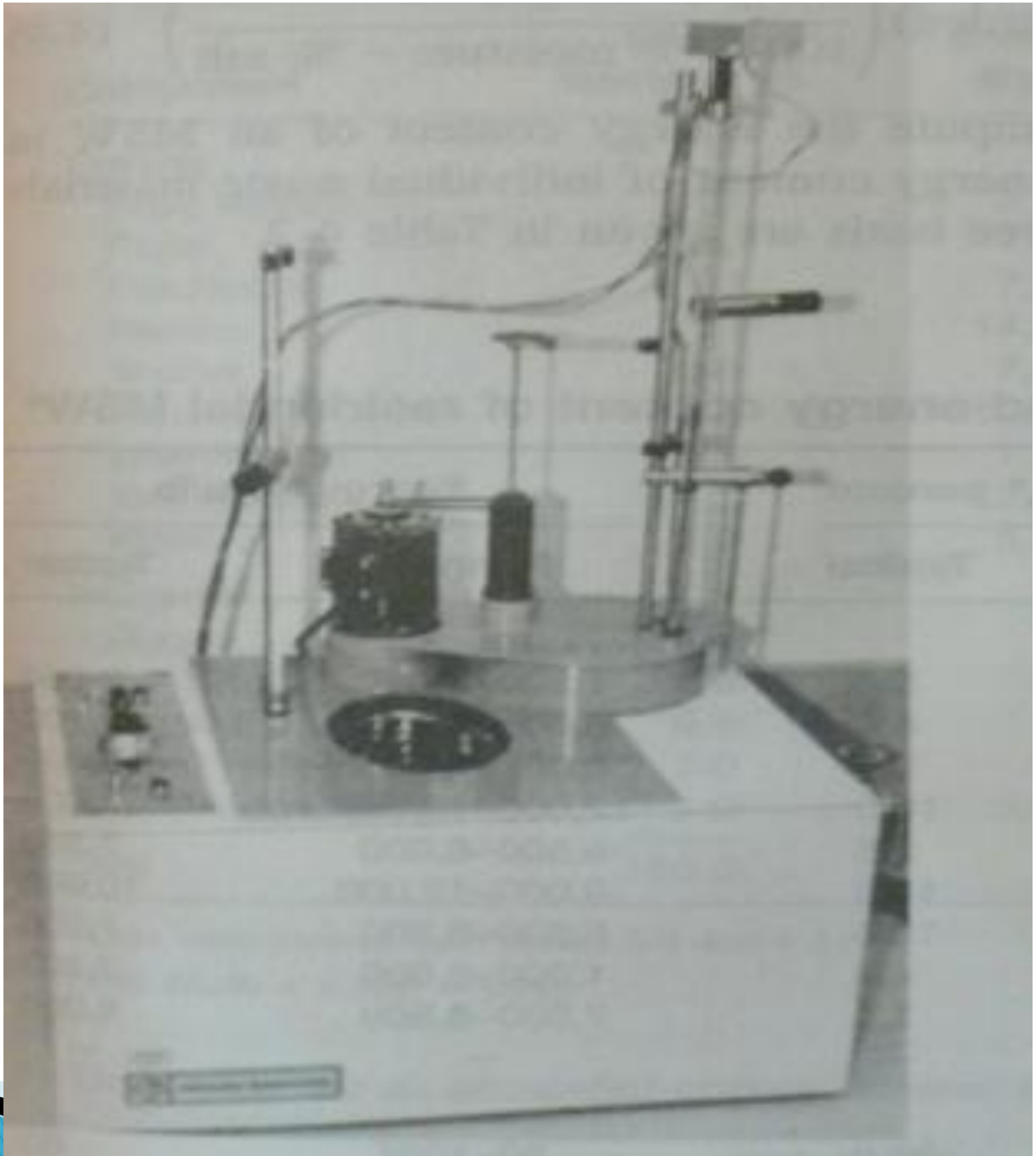
- *Higher heating value*

Gross/Higher calorific value (GCV/HCV)

Lower heating value

Net/Lower calorific value (NCV/LCV)

NCV = GCV - water evaporating heat



Units of Energy

Kilocalorie (or kcal) = 1000 calories

Kilojoule (or kJ) = 1000 joules = 0.24 kcal

Joule (J) (SI): work or energy unit

1kWh = 860kcal = 3600kJ

The difference between power and energy

- Power is the rate at which energy is transferred, used or transformed.

- Power is energy divided by time

Laws of thermodynamics

First law of thermodynamics (conservation)

Energy can be changed from one form to another, but it cannot be created or destroyed. The total amount of energy and matter in the Universe remains constant, merely changing from one form to another

Second law of thermodynamics (entropy)

In all energy exchanges, if no energy enters or leaves the system, the potential energy of the state will always be less than that of the initial state

→ Energy conversions are not 100% efficient

→ This law is used to calculate the energy efficiency

Law of conservation of mass

The mass of an isolated system (closed to all matter and energy) will remain constant over time. Mass cannot be created or destroyed, although it may be rearranged in space and changed into different types of particles.

→ This law is used in energy and mass equivalent calculation

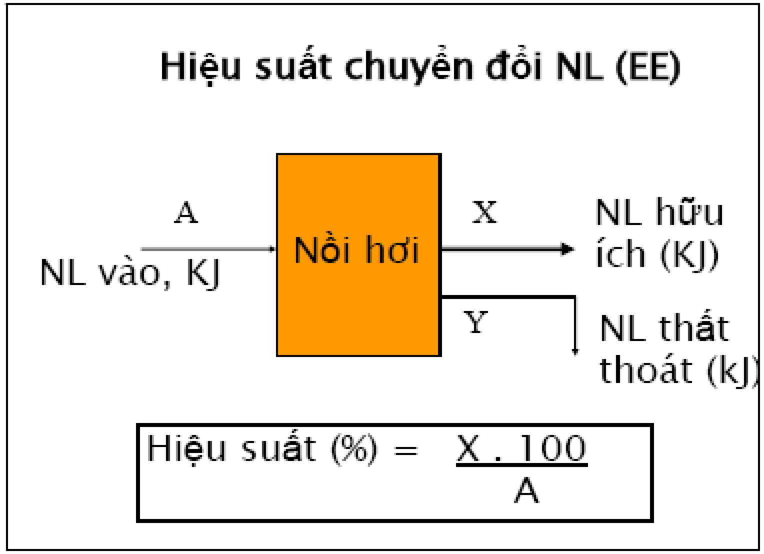
Energy efficiency (EE)

- Energy efficiency
  - (Economical) Energy used per unit of GDP of value added
  - (Building) Energy used per floor area
  - (Transportation) Energy used per a unit of distance, per capita, per weight
  - (Production) Energy used per a unit of production
- Energy conversion efficiency

  Energy efficiency

  Exergy efficiency

What is energy conversion efficiency?



Conversion	Example	EE (%)
Chemical → thermal	Boiler	70-90
Electrical→mechanical	Electric Motor	70-90
Thermal→mechanical	Steam turbine	45

Effective energy use: less energy to do the same function

Example: Use compact Fluorescent lamp instead of traditional lamp (use only 1/5 energy to do same function of lighting the room)

What is energy conversion efficiency?

Less energy, less CO_2 emission

Incandescent Lamp
100 W

CO_2 emission: 100g/hr

Compact fluorescent Lamp
18W

CO_2 emission: 20g/hr

Energy conversion efficiency

Water boiling heat→

Water evaporating heat→

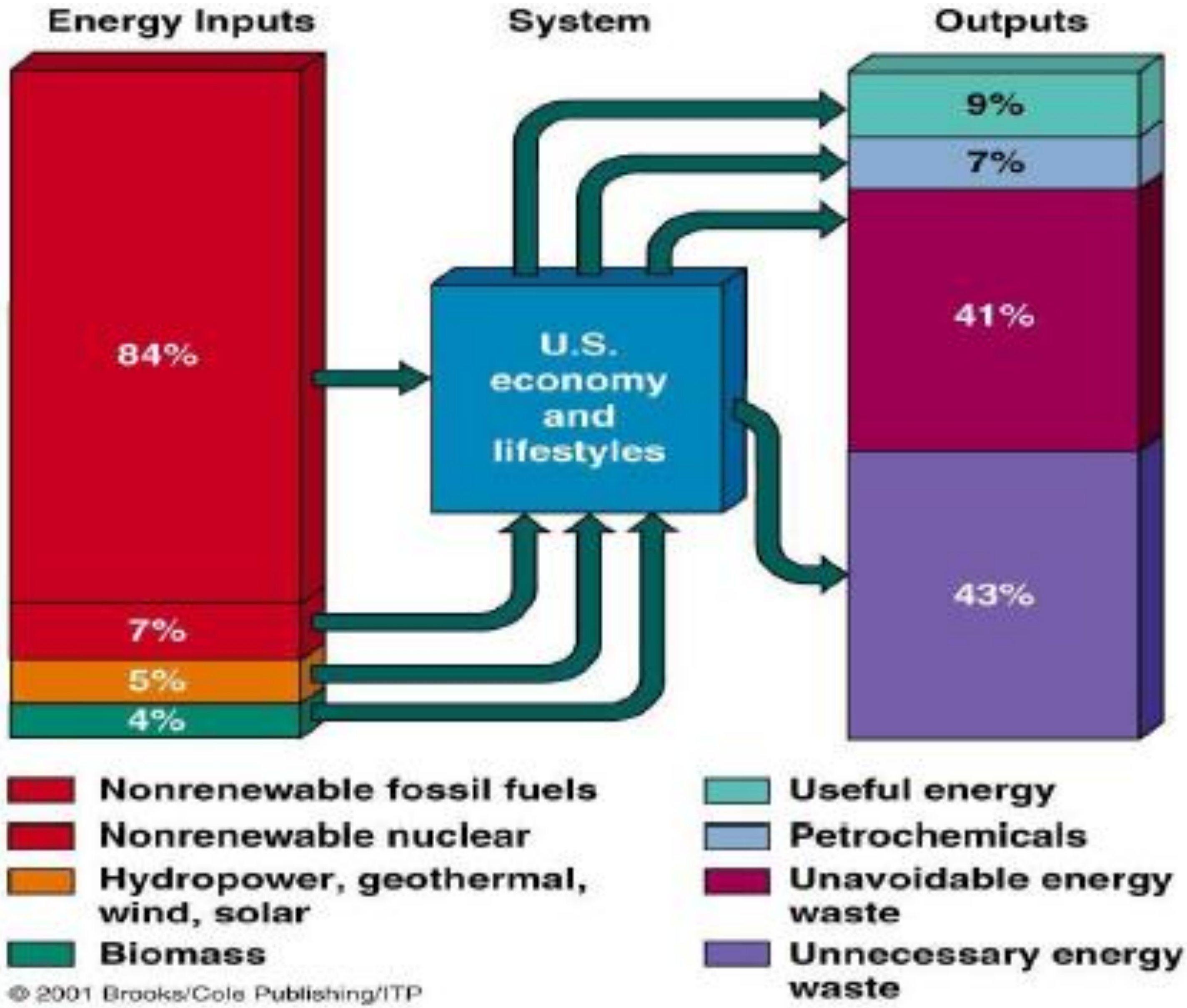
Turbine rotating work→

Electricity generating by turbine→

Electricity generating by generator→

Lamp lighting electrical energy→

The greater numbers of conversion steps, the lower of EE


Energy Inputs
System
Outputs
84%
7%
5%
4%
U.S. economy and lifestyles
9%
7%
41%
43%
Nonrenewable fossil fuels
Nonrenewable nuclear
Hydropower, geothermal, wind, solar
Biomass
Useful energy
Petrochemicals
Unavoidable energy waste
Unnecessary energy waste
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Conversion efficiency

- Definition (How much work converted from heat)

$$\eta = \frac{W}{Q_h} = 1 - \frac{Q_l}{Q_h}$$

- Limitation (Maximum conversion ratio)

$$\eta = \frac{W}{Q_h} = 1 - \frac{Q_l}{Q_h} \le 1 - \frac{T_l}{T_h}$$

(IMPORTANT) Maximum conversion ratio is given by a function of absolute temperatures.

Problem: Maximum efficiency

- Assuming a coal power plant
    - Vapor temperature: 900K
    - Ambient temperature: 300K
- How about the case of nuclear power plant

- Vapor temperature: 600K
- Ambient temperature: 300K

<u>Solution:</u> Maximum efficiency

- For coal power plant

  $\eta - 1 = 1 - 300/900 = 0.66$

  (in real: η = 42% – 50% for IGCC)

  - Vapor temperature: 900K
  - Ambient temperature: 300K

- For nuclear power plant

  $\eta - 1 = 1 - 300/600 = 0.5$

  (In real: $\eta \sim 35\%$)

Empirical Law

- The heat can naturally transfer only from the medium with higher temperature to that with lower temperature.
- It is impossible to convert all the heat taken from a body of uniform temperature into work without causing other changes (Kelvin's principle).

Definition of Exergy

The exergy (W) of a system is the maximum useful work possible during a process that brings the system into equilibrium with a heat reservoir.

$$\delta W = (1 - \frac{T_0}{T}) C dT$$

$$W = \int_{T_0}^{T_1} (1 - \frac{T_0}{T}) C dT = \int_{T_0}^{T_1} C dT - T_0 \int_{T_0}^{T_1} \frac{C dT}{T} = (U_1 - U_0) - T_0 (S_1 - S_0)$$

Exergy of heat available at a temperature

$$W = Q(1 - \frac{T_0}{T_{source}})$$

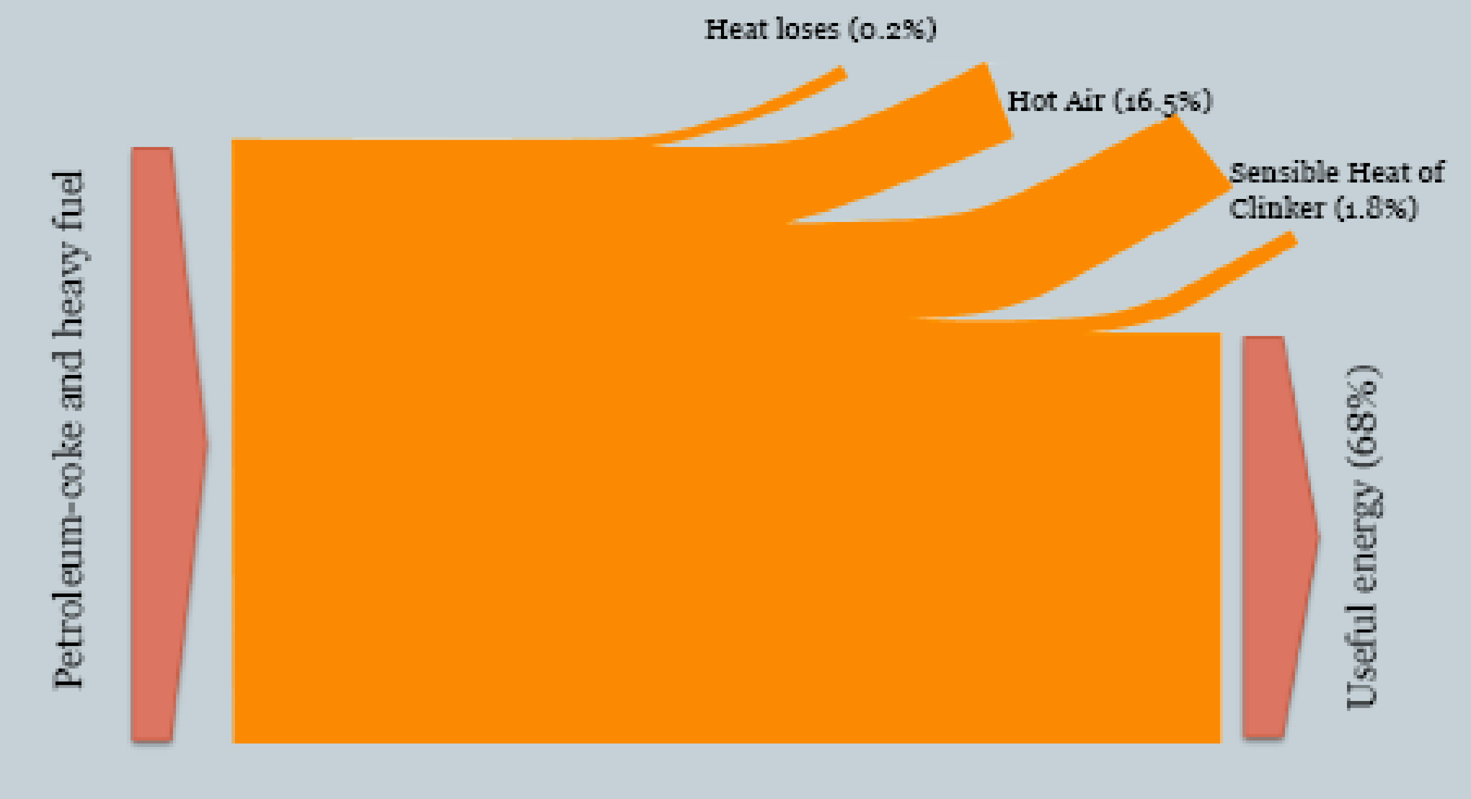
Energy and Exergy Efficiency

	Energy	Exergy
District heating boiler	0.85 - 1.05	0.15 - 0.18
Power plant boiler	0.90	0.50
Power plant	0.40	0.39
Cogeneration of power and heat	0.85	0.40
Electrical water heater	0.33	0.06
Heat pump	1.20	0.20

http://www.lcube.eu.com/relevant_links/Exergy_Builds/WHAT_IS_EXERGY.pdf

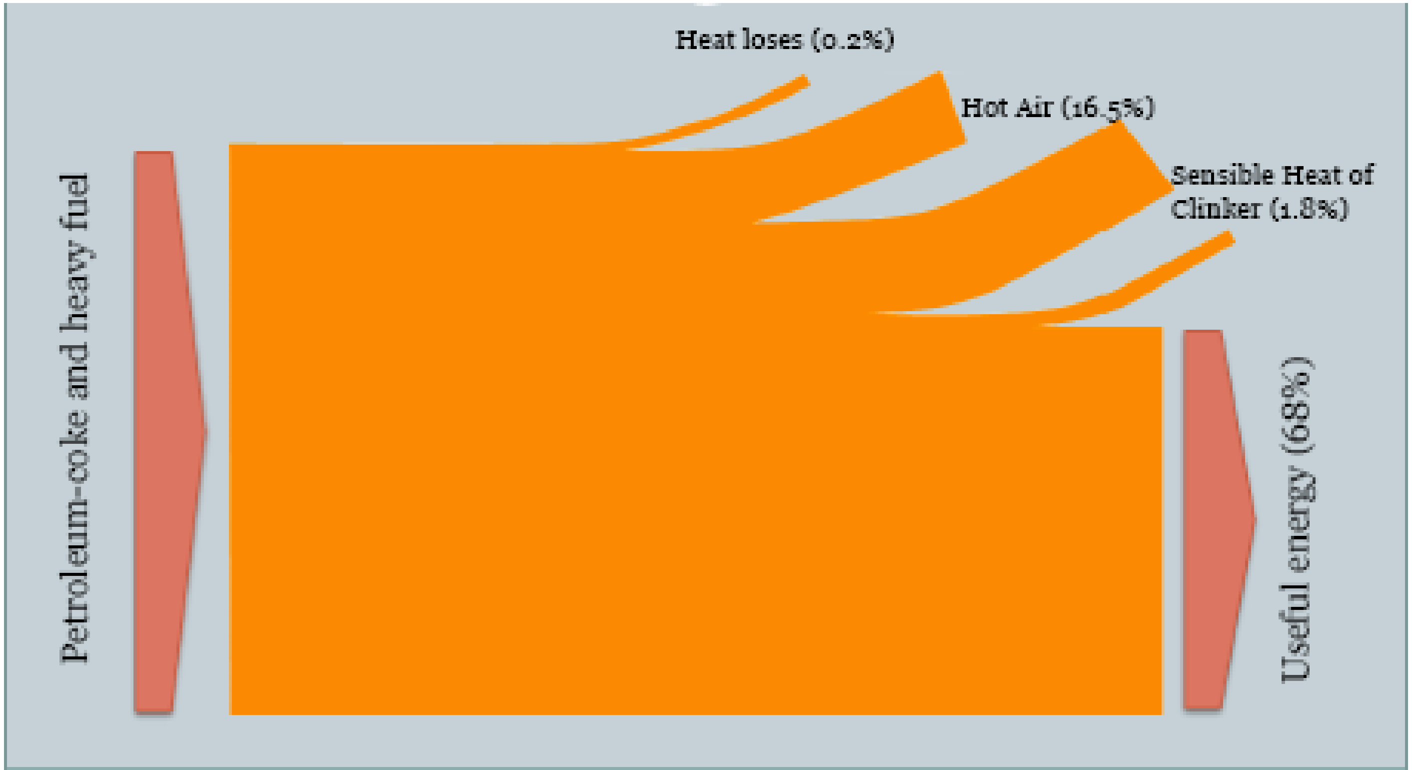
Efficiency: Ratio of Energy (Exergy) output by Energy (Exergy) input

Energy flow for cement production



C. Koroneos et al, Int. J. Exergy, Vol.2, 2005 p.55-

Exergy flow for cement production



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Theme 4

Energy Efficiency

II-Energy efficiency (Industry)

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Contents

- **Boiler**
  - Combustion reactions of fuels
  - Boiler types
  - Heat loss calculation
- **Cement production**
  - Rotary kiln, NSP kiln
  - Energy consumption and CO_2 reduction potential
- **Beer production**
  - Energy consumption
  - Technologies (VRC, CCS, Opt-Past,…)

Boiler

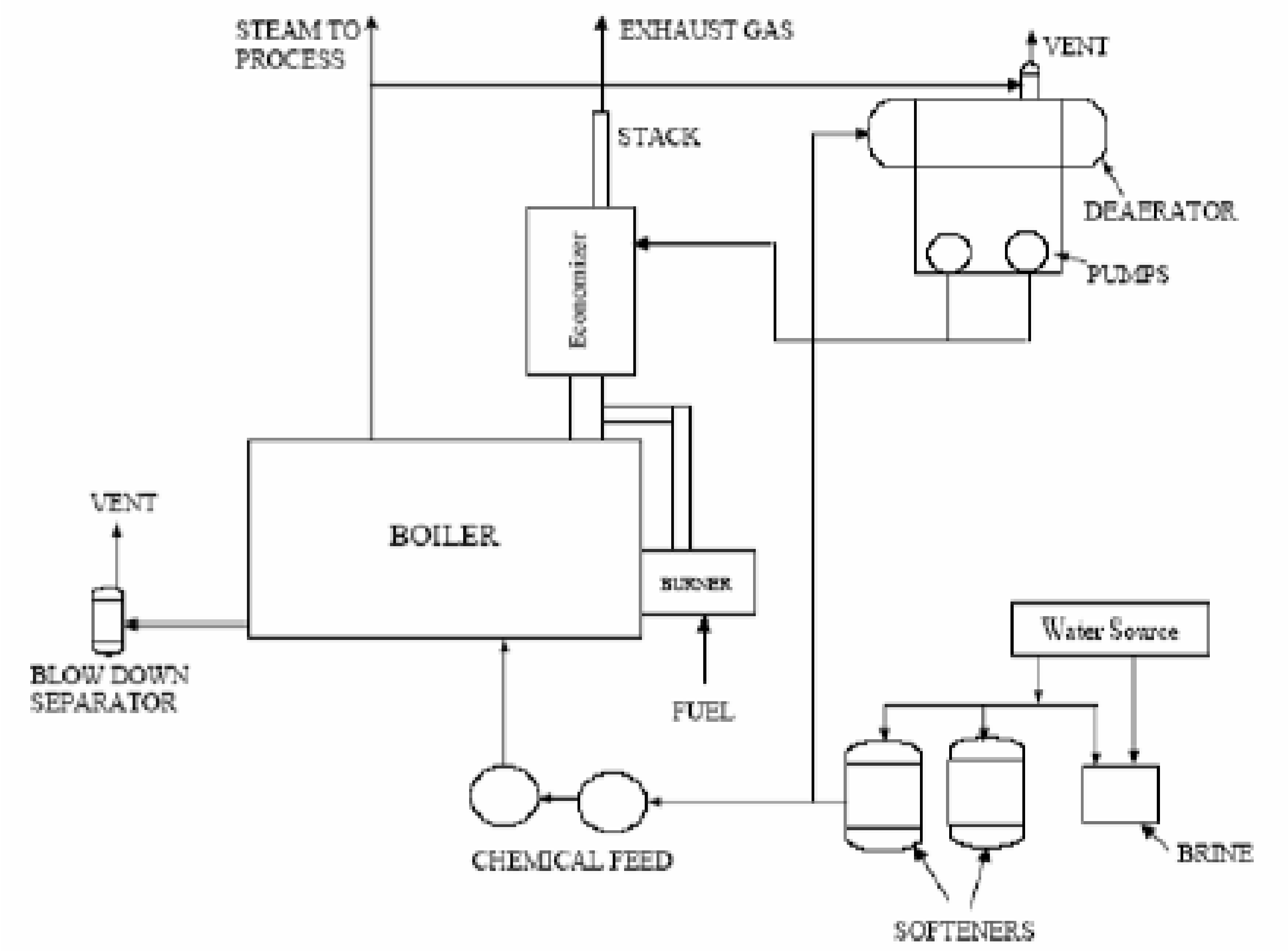


Fig: A typical Schematic of a Boiler Room

1. Combustion reactions of fuels

Complete combustion reaction

- $C + O_2 \rightarrow CO_2 + 8084\ kcal/kg\ C$

Incomplete combustion reaction

- $C + 1/2O_2 \rightarrow CO + 2430\ kcal/kg\ C^{(*)}$

H combustion

- $2H + 1/2O_2 \rightarrow H_2O + 28.922\ kcal/kg\ H$

S combustion

- $S + O_2 \rightarrow SO_2 + 2224\ kcal/kg\ S$

Combustion process (theoretical)		
Fuels	Air (kg)/Fuel (kg)	CO_2 %
Solid fuels		
Bagasse	3,3	10–12
Coal (bitumen)	10,7	10–13
Lignite	8,5	9–13
Rice husk	4,5	14–15
Wood	5,7	11,13
Liquids fuels		
Oil	13,8	9–14
low sulfur oil	14,1	9–14

Excess air coefficient

- Definition of excess air

In industry, combustion excess air is supplied in addition to theoretical amount required for combustion

- Excess air coefficient

λ = supplied amount/theoretically required amount

- Too high λ

Causes decrease in combustion temperature and thermal efficiency

- Too low λ

Incomplete combustion reaction, high CO amount, decrease in boiler efficiency, etc

Optimal λ ?

Optimal excess air coefficient		
Fuels	λ	[O2] % of exhausted gas
Gas	1,1	2,2
FO	1,2	4,0
Firewood	1,3	4,5
Coal		
Powder	1,25-1,30	4,3-4,9
Chain-grate	1,35-1,40	5,5-6,0

Typical excess air coefficient of fuels

Fuels	Combustion chamber type	Khí dư (% theo khối lượng)
Milled coal	Lò nước làm mát hoàn toàn để loại bỏ xỉ hoặc tro khô	15-20
	Lò nước làm mát một phần để loại bỏ tro khô	15-40
Coal	Buồng lửa ghi cố định	30-60
	Buồng lửa ghi di động nước làm mát	30-60
	Lò ghi xích và lò ghi di động	15-50
	Buồng lửa nhiên liệu cấp dưới	20-50
Oil	Lò đốt dầu	15-20
Gas	Lò đốt đa nhiên liệu và ngọn lửa bằng	20-30
	Lò đốt áp suất cao	5-7
Firewood	Dạng Dutch (10-23 % qua ghi lò) và dạng Hofft	20-25
Bagasse	Tất cả các lò	25-35
bitumen	Lò thu hồi khí và quá trình bột hoá soda	30-40


2. Boiler types

- Fire tube boiler
- Water tube boiler
- Package boiler
- Spreader stoker boiler
- Chain-grate or Traveling-grate Stoker boiler
- Pulverized Fuel Boiler
- Waste heat recovery boiler
- Fluidized bed combustion (FBC) boiler

Fire-tube boiler

➢ Working principle

- The heat of the gases is transferred through the walls of the tubes by thermal conduction, heating the water and ultimately creating steam.

➢ Application

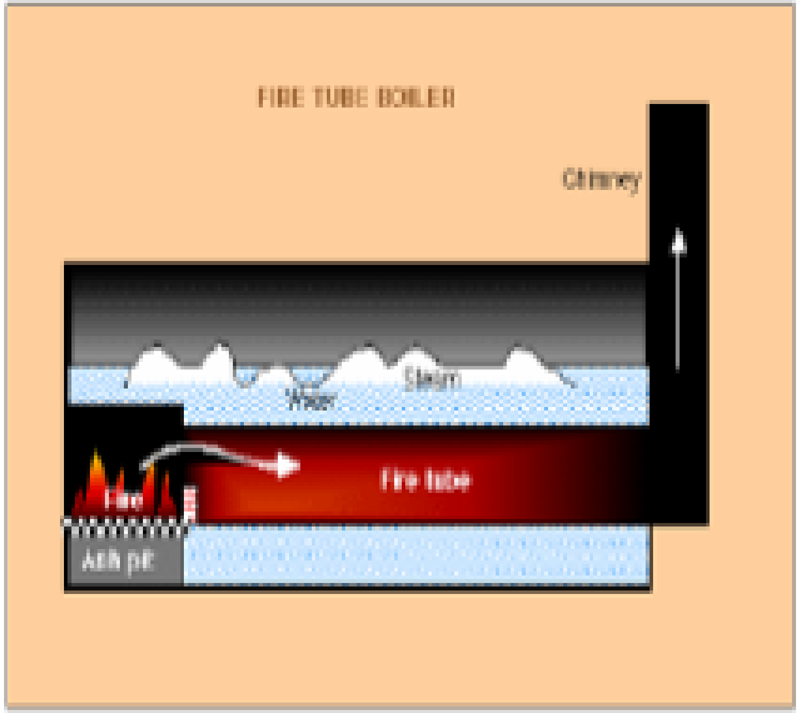
- Small capacity (12 ton/h)

- Low pressure (18kg/cm2)

➢ Fuels:

-Coal, oil, gas

➢ Package design



Schematic diagram of fire-tube boiler

Water-tube boiler

➢ Working principle

- Water circulates in tubes heated externally by the fire. Fuel is burned inside the furnace creating hot gas which heats water in the steam-generating tubes

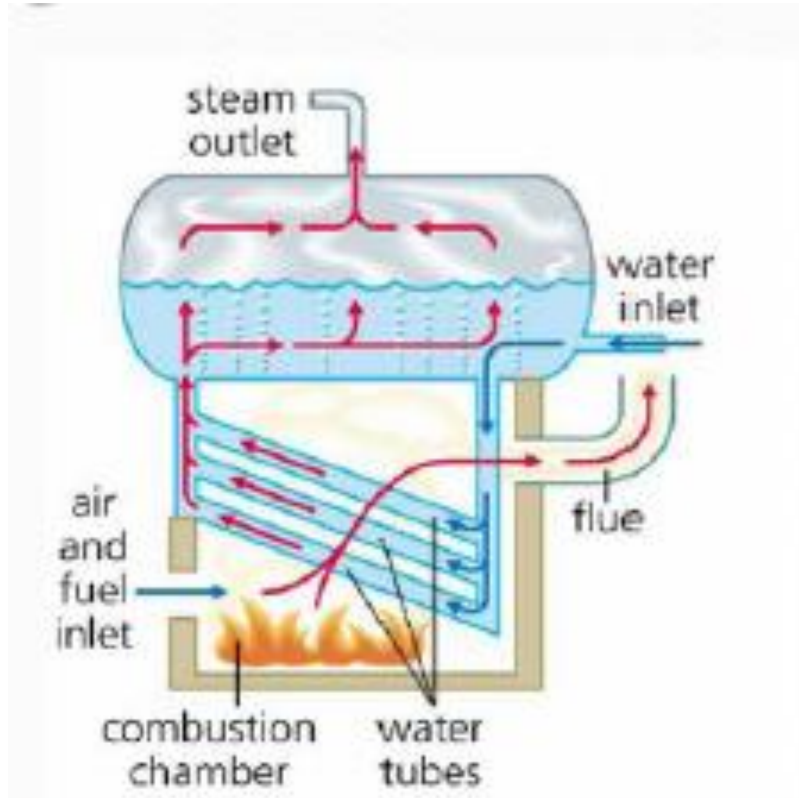
➢ Application

- Capacity: 4,5-120 ton/h

- High thermal efficiency

➢ Fuels:

- Oil, gas (package design), solid



Schematic diagram of water-tube boiler

Package boiler

- Package boilers require less fuel and electric power to operate
- Operates more efficiently if the oxygen concentration in the flue gas is reduced
- The typical package boiler is a water tube boiler or flue and smoke tube boiler with a capacity of 5 to 20 t/h (average steam generation capacity)
- The most widely used fuels are heavy oil, light oil, and gas.
- Fire-tube boiler

Schematic diagram of package boiler

Spreader stoker boiler

- Working principle

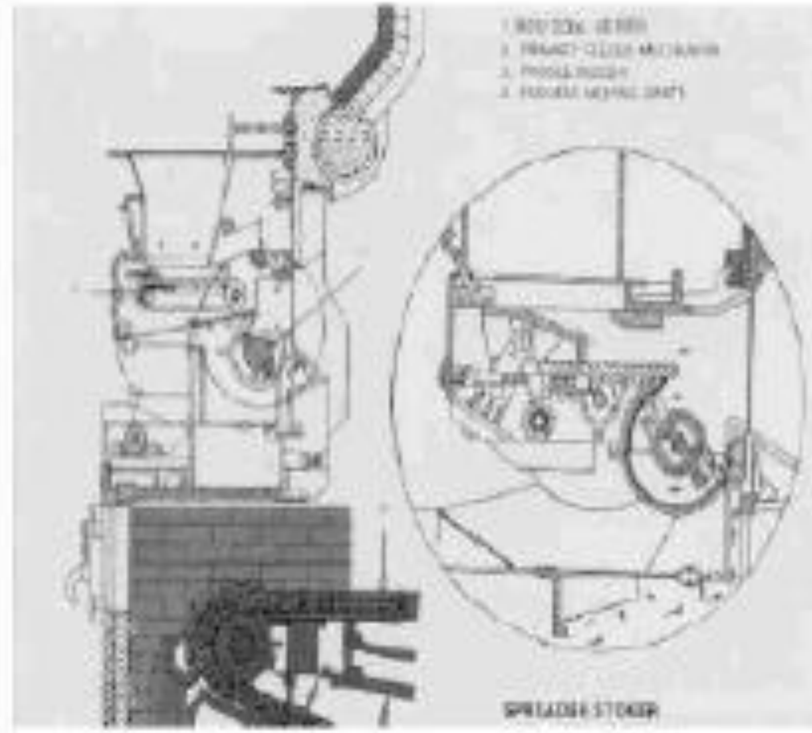
  – Spreader stokers utilize a combination of suspension burning and grate burning.

  – The coal is continually fed into the furnace above a burning bed of coal.

- Application

  – This method of firing provides good flexibility to meet load fluctuations, since ignition is almost instantaneous when firing rate is increased.

  – Be favored over other types of stokers in many industrial applications.



Schematic diagram of spreader stoker boiler

Chain-grate or Traveling-grate Stoker boiler

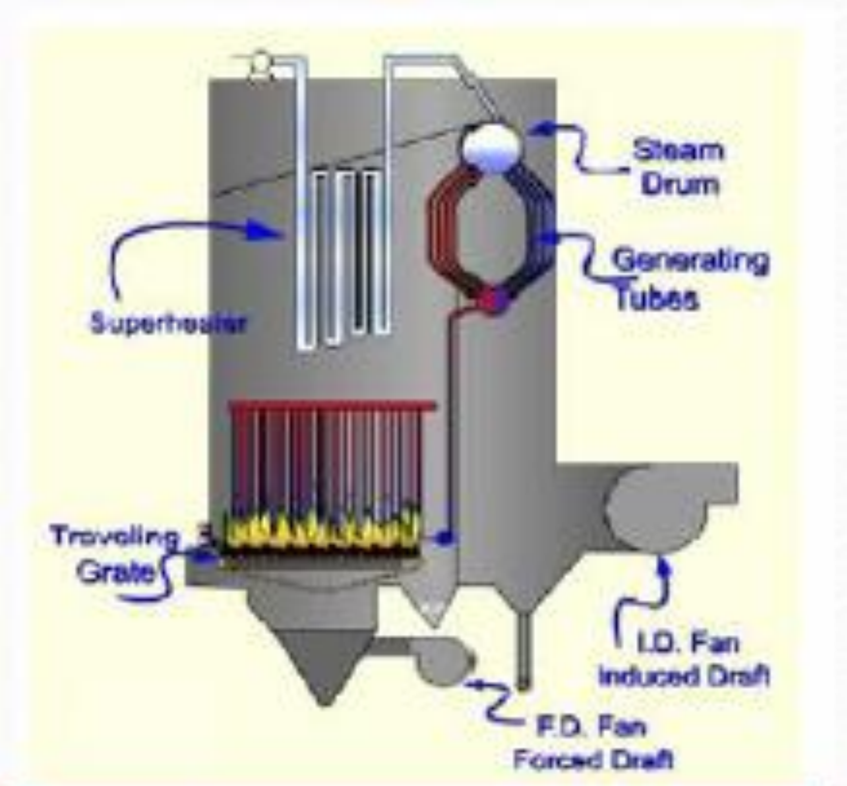
- Working principle

Coal is fed onto one end of a moving steel grate.

As grate moves along the length of the furnace, the coal burns before dropping off at the end as ash.

- The coal-feed hopper runs along the entire coal-feed end of the furnace.

A coal gate is used to control the rate at which coal is fed into the furnace by controlling the thickness of the fuel bed.



Schematic diagram of Chain-grate boiler

Pulverized Fuel Boiler

- Working principle

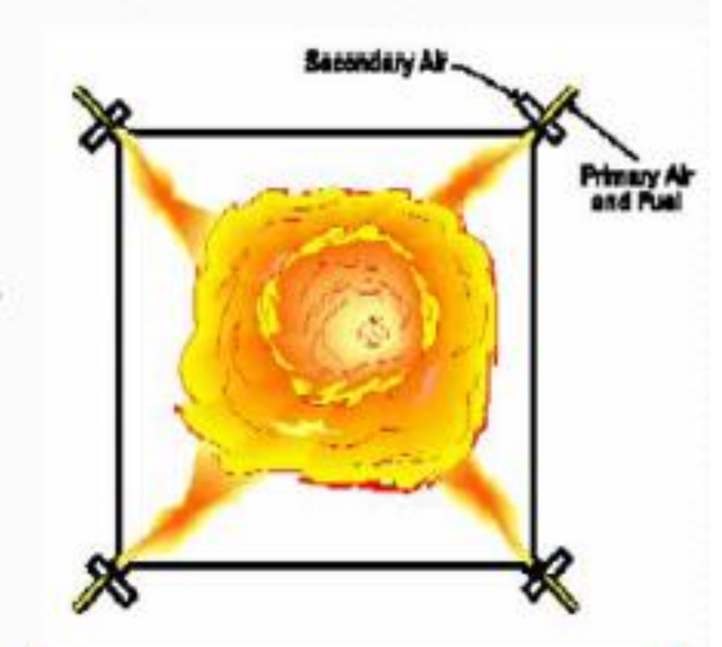
- The coal is ground to a fine powder, blown with part of the combustion air into the boiler plant through a series of burner nozzles.

- Secondary and tertiary air may also be added. Combustion takes place at temperatures from 1300-1700°C

- Application

- For coal power plants and industrial water-tube boiler

- One of the most popular systems for firing pulverized coal is the tangential firing using four burners corner to corner to create a fireball at the center of the furnace



Schematic diagram of Pulverized fuel boiler

Waste heat recovery boiler

- ➢ Working principle

- Generate steam by recovering the heat value in the stream.

Salvage waste heat (at high-medium temperature)

- ➢ Application

Widely applied to waste heat from gas turbines or diesel engines

Directly use for heat processes

Common in the process industries.

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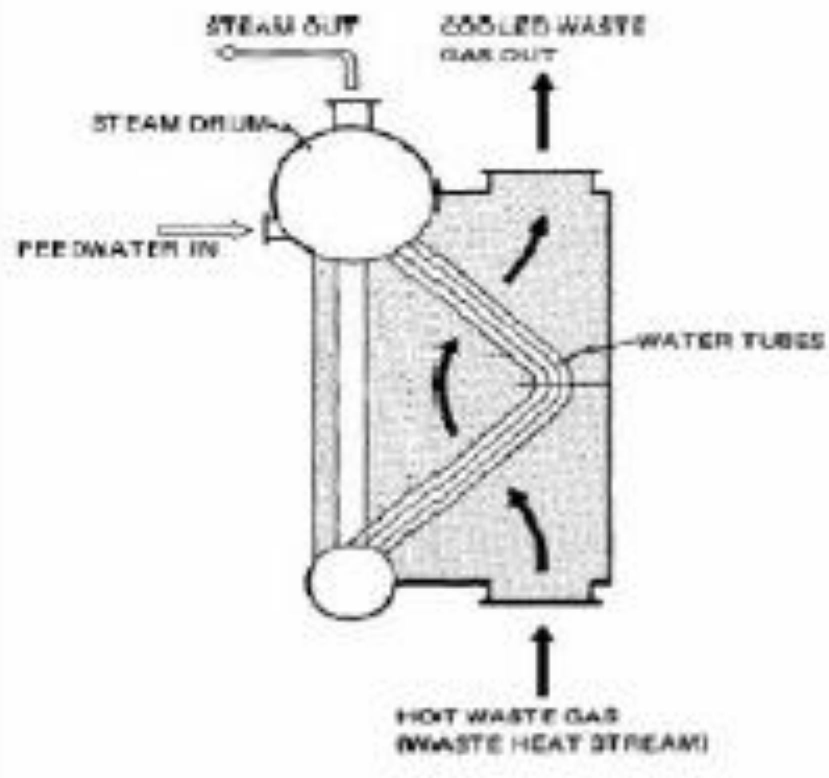


Schematic diagram of
Waste heat recovery boiler

Fluidized bed combustion (FBC) Boiler

- Combustion at 840oC – 950oC

- High combustion efficiency and less pollutants of SOx and NOx

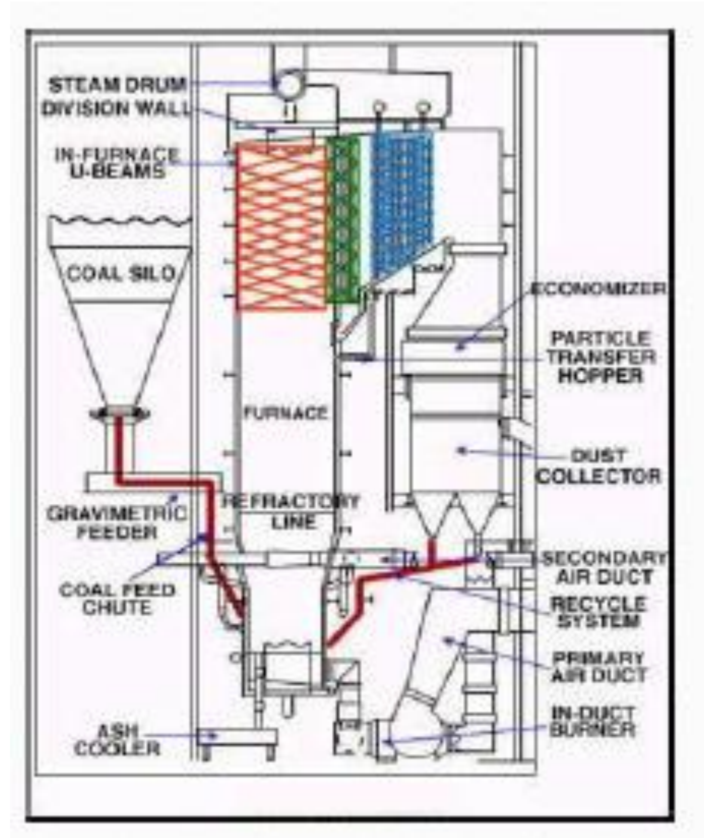
- Fuels: Coal, rice husk, bagasse, agricultural by-products

- Types:

AFBC: pressurized fluidized bed combustion

PFBC: pressurized fluidized bed combustion

CFBC: circulating fluidized bed combustion



3. Boiler efficiency assessment

- Evaporation ratio
- Boiler efficiency
- Energy balance and heat loss
  - Heat loss in flue gases
  - Bottom blow-down calculation
  - Boiler waste water treatment

Evaporation ratio

$$\text{Evaporation Ratio} = \frac{\text{Quantity of Steam Generation}}{\text{Quantity of fuel Consumption}}$$

Typical evaporation ratios:

Coal combustion boiler at pressure of 10 bar: 6

Oil combustion boiler at pressure of 10 bar: 13

Means:

1 tons of coal can generate 6 ton of steam

1 tons of oil can generate 13 ton of steam

Boiler efficiency

- Definition

$$\text{Boiler Efficiency, } \eta = \frac{\text{Heat output}}{\text{Heat Input}} \text{x } 100$$

$$= \frac{\text{Heat in steam output (kCals)}}{\text{Heat in Fuel Input (kCals)}} \text{x } 100$$

- Calculation method

  - Direct
  - Indirect

Direct	Indirect

Direct

$$\eta_{lh} = \frac{M_h.(H-h)}{m_{nl}.q_{nl}}.100$$

trong đó:

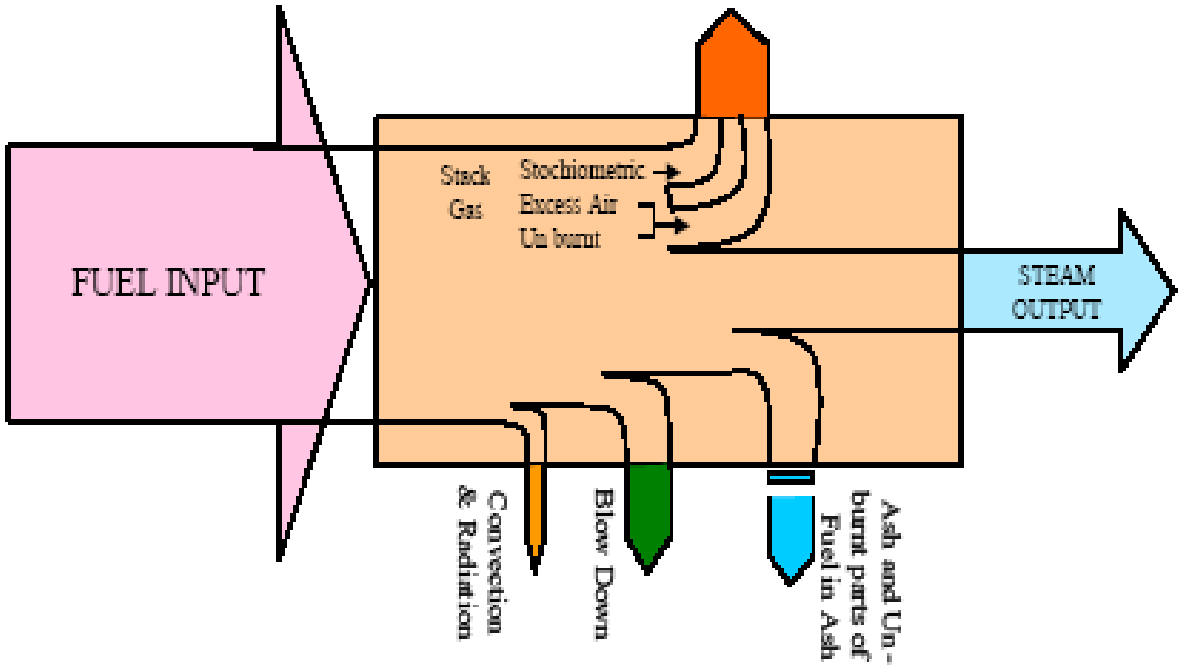
- η_{lh}: *hiệu suất nồi hơi*
- M_h: *lượng hơi sinh ra, kg/h*
- M_{nl}: *lượng nhiên liệu sử dụng, kg/h*
- *H: enthapi của hơi, kcal/kg*
- Q_{nl}: *nhiệt trị của nhiên liệu, kcal/kg*

Indirect

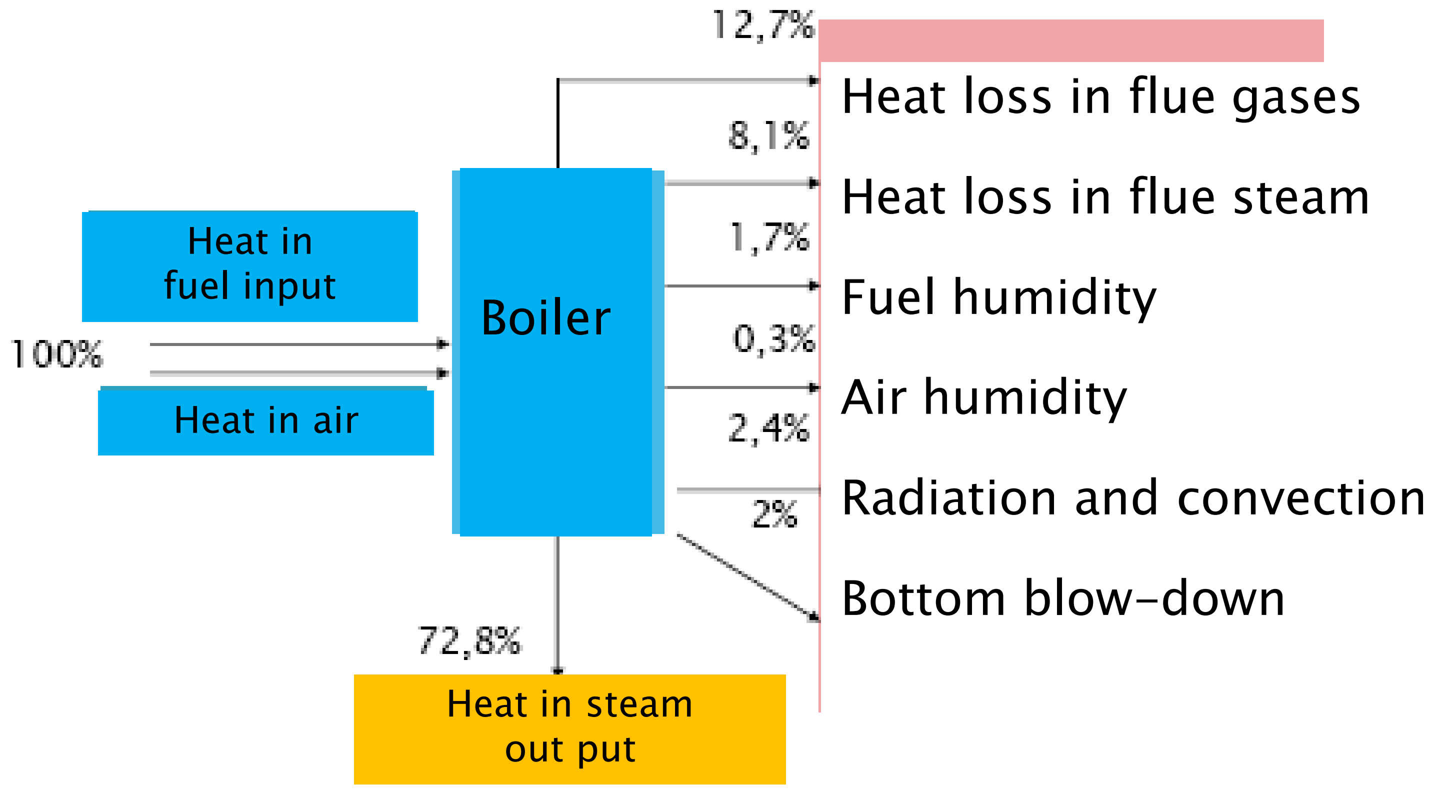
$$\eta_{lh} = 100 - \sum_{i=1}^{7} q_i$$

- q_1: *% nhiệt TT qua khói lò*
- q_2: *% nhiệt TT do bay hơi nước (H trong nhiên liệu)*
- q_3: *% nhiệt TT do nước trong nhiên liệu bay hơi*
- q_4: *% nhiệt TT do hơi ẩm trong không khí*
- q_5: *% nhiệt TT do nhiên liệu không cháy hết*
- q_6: *% nhiệt TT qua bức xạ*
- q_7: *% nhiệt TT do xả đáy*

Energy balance of boiler



Heat loss of boiler



Heat loss in flue gases

- Formula

$$Q = m \cdot C_p \cdot \Delta T$$

- Simplify:

$$\text{Heat loss }(\%) = \frac{\alpha \cdot (T_{khoi\_lo} - T_{xung\_quanh})}{\text{Measure CO2 directly }(\%)}$$

$\alpha = 0.53$ Gas
$\alpha = 0.56$ Oil
$\alpha = 0.65$ Coal

Problem: calculate heat loss in flue gases

For a coal boiler:

- Operated at excess air mode (excess O_2: 205-236%)
- Coal consumption: 6 tons/day
- Flue gas temperature: 425oC
- Flue gas composition: O_2 = 12,0%;

CO_2 = 9,0%; CO = 13236mg/m3; NO = 20-27mg/m3, NO_2 = 4-8mg/m3; SO_2 = 249-436mg/m3; C_xH_y = 499-533ppm

Calculate % heat loss in flue gases?

Heat loss reduction solutions?

Solution

- Heat loss in flue gases

% loss = 0,65.[(425-200)/9] = 16.25%

- Heat loss reduction:

- Solid particulates at the bottom (too high flue gas temperature)

→Treat input water

→Remove solid particulates

- High excess O2 → reduce input air

- Recover waste heat

- Improve thermal isolation

Flue gas temperature and heat loss

Flue gas temperature (T) influences heat loss

- T_{high} → heat loss
- T_{low} → high humidity → corrosion (due to the presence of SO2, SO3)
- Optimal temperature: 180-200oC

Flue gas heat recovery

- Due to large amount of heat, flue gas heat can be recovered to:

- Dry air before entering the combustion chamber

- Heat feedwater before entering the boiler

- Benefits

Reduce the flue gas temperature

Increase the temperature of feedwater

Improve efficiency and reduce fuel amount

Heat loss in bottom blown-down

Formula

$$Q = V \,.\, (H_{ns} - H_{nc}), \qquad kJ/s$$

Where:

V: Bottom blown-down water (kg/s)

Hns: specific heat of boiling water

Nc: specific heat of feedwater

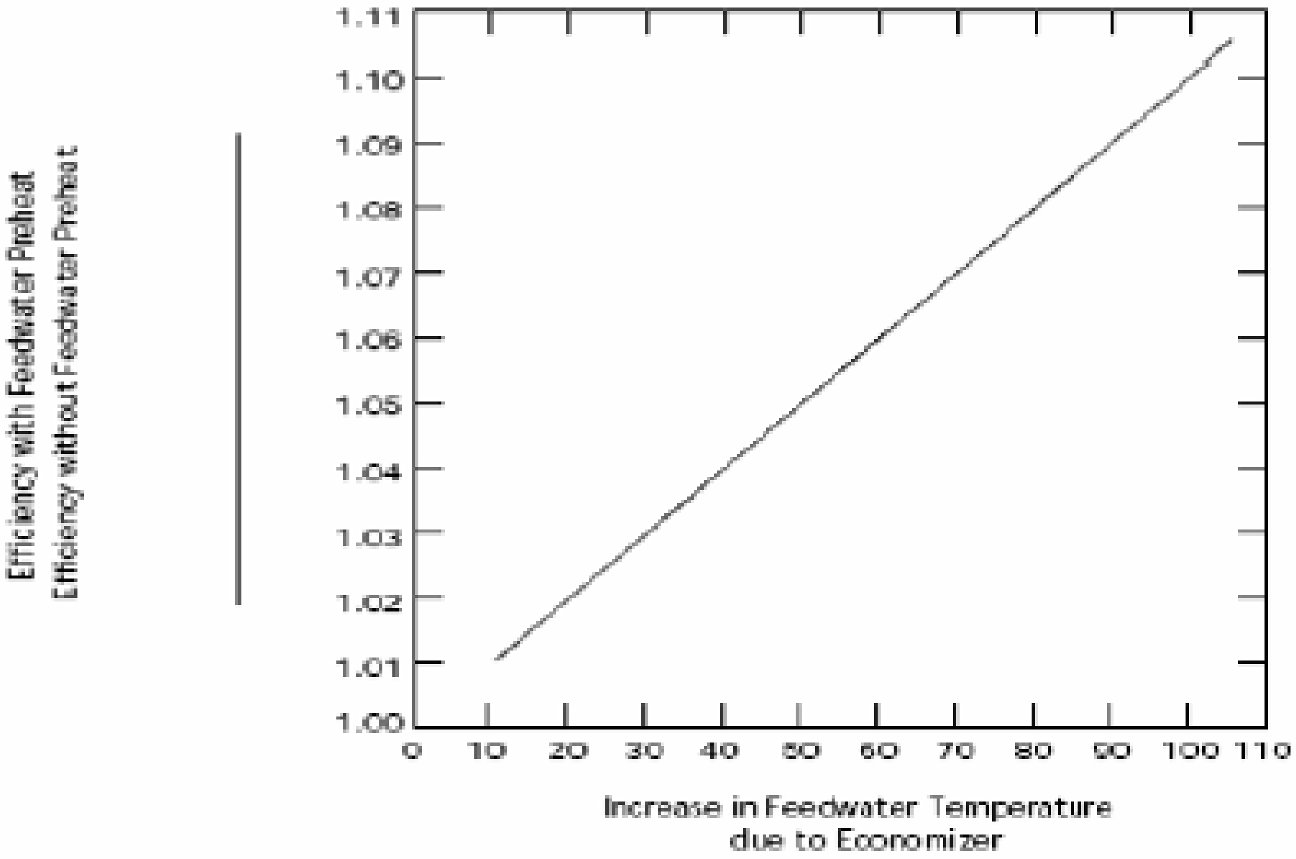


Figure 5.2: Effects of Feedwater Preheat on Boiler System Efficiency

Bottom blown-down calculation

- Formula

$$\text{Blowndown} = \frac{\text{TDS x \% feedwater volume}}{\text{Maximum TDS of boiler water}}$$

- Reduce operation and treatment cost by control the blowdown rate
  - Reduce consumption of treated feedwater
  - Reduce the maintanance time
  - Increase the life-span of the boiler
  - Reduce chemical amount

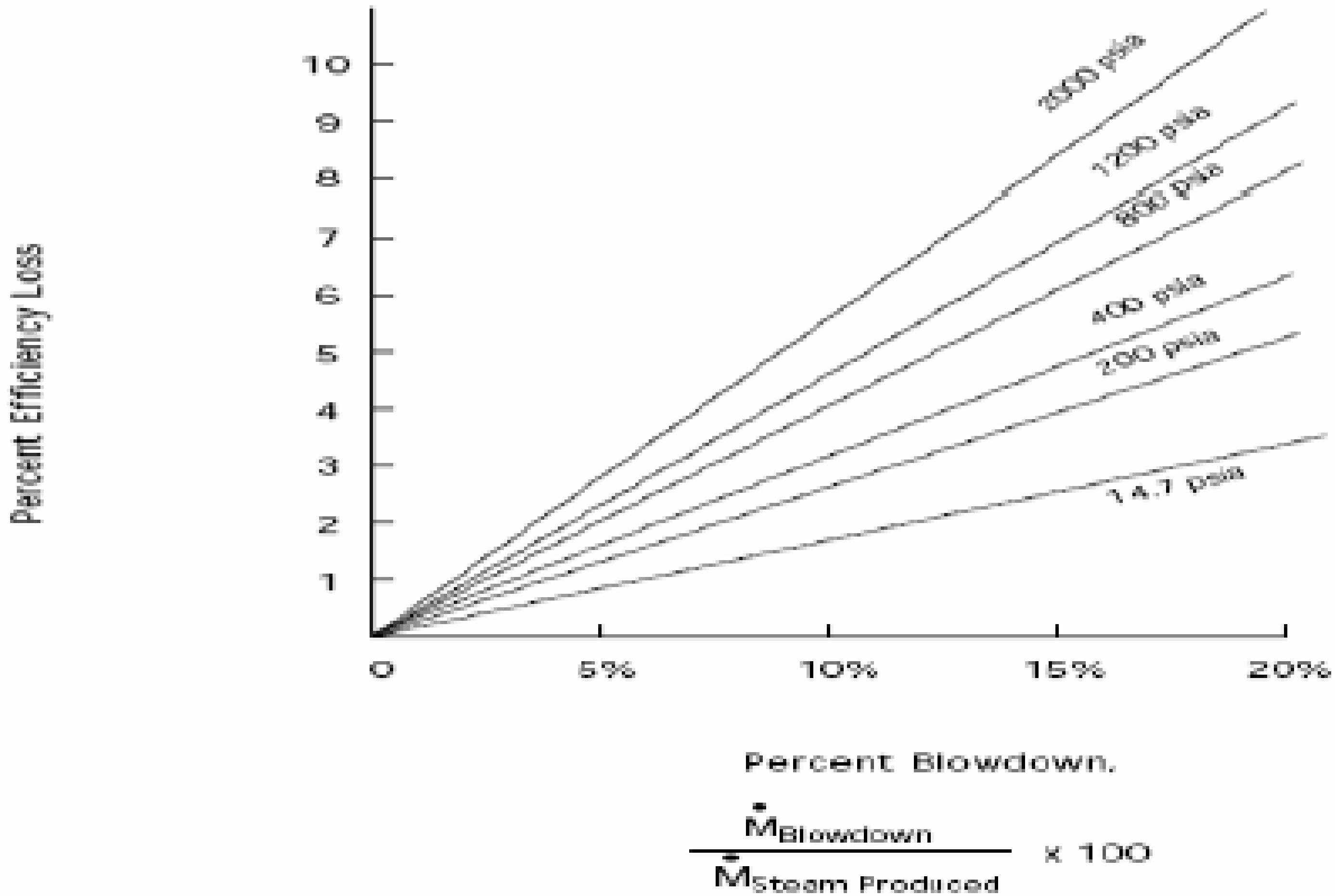


Figure 5.3: Efficiency Loss Due to Blowdown

Heat loss from steam pipes

- Causes:

  Bad steam pipe isolation

  Inappropriate distance with the boiler

  Steam pipe leakage

- Formula

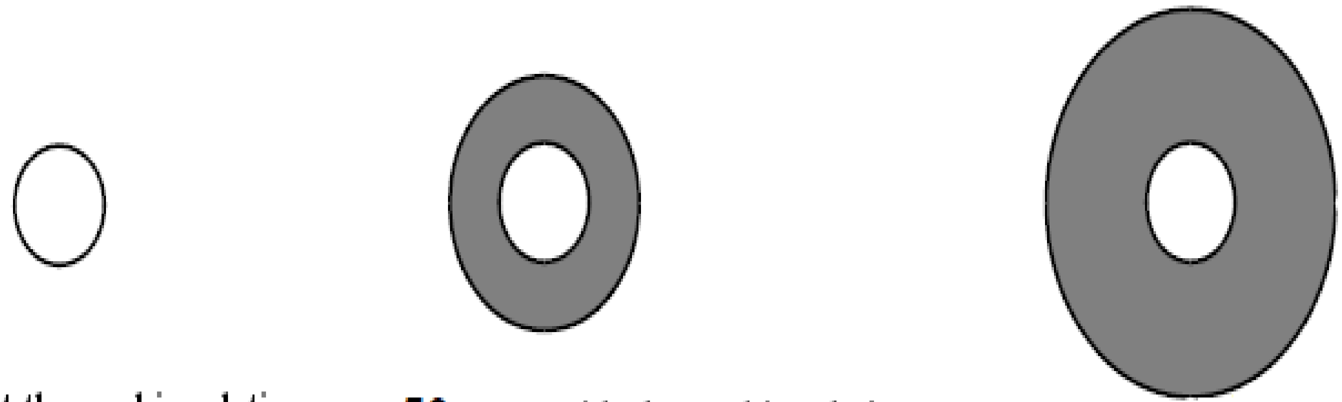
$$S = \left[10 + \frac{T_{bm} - T_{mt}}{20}\right](T_{bm} - T_{mt})$$

S: Heat loss (through pipe surface), kcal/h.m2

Tbm: pipe surface temperature

Tmt: surrounding temperature

Fail Thermal Insulation



	Without thermal insulation	50 mm with thermal insulation	100 mm with thermal insulation
heat loss	320 W/m	29 W/m	19 W/m

Comparison between 50 mm with thermal insulation and the case without thermal insulation
320-29=291 W per m (263 lits/year)

Comparison between 50 mm with thermal insulation and 100 mm with thermal insulation
29-19=10 W per m (9 lits/year)

Oil Loss Because of not using thermal insulation for pipes (lit/meter/year)

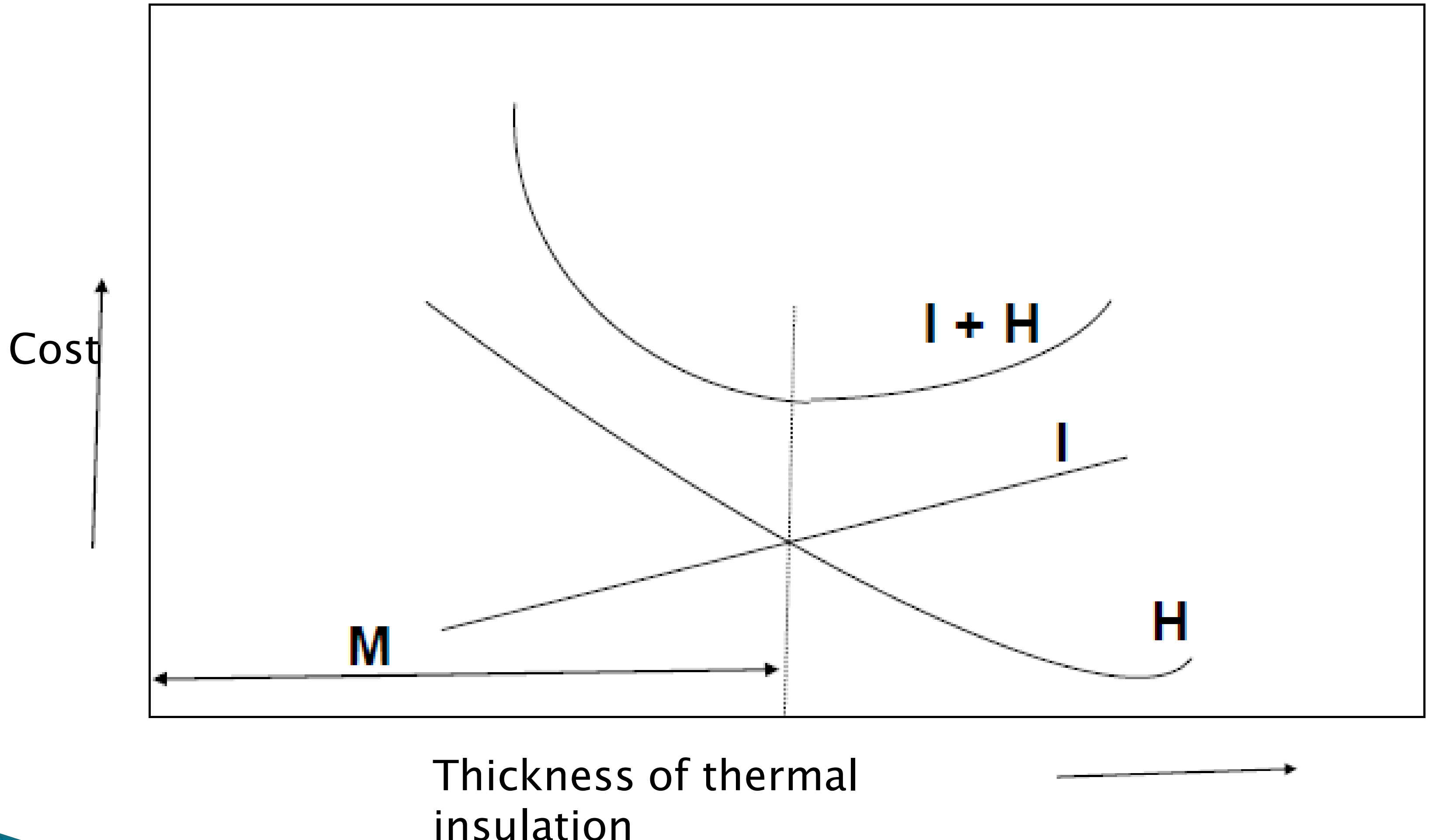
Temp. (^oC)	φ (25 mm)	φ (50 mm)	φ (75 mm)	φ (100 mm)	φ (150 mm)
50	15	28	40	50	68
100	74	133	190	250	360
150	160	288	410	472	680
200	248	426	620	786	1136
250	340	628	916	1182	1713
300	482	895	1290	1628	2428

Thickness of thermal insulation

Temperature	Tube diameter (mm)					Flat surface
	25	50	75	100	150	
< 100°C	25	25	50	50	65	50
100-150°C	25	25	50	50	65	75
150-200°C	25	40	50	65	75	90
200-250°C	25	50	50	65	75	90
250-300°C	25	50	50	75	90	100

The thickness of thermal insulation can be determined by balancing the cost of heat loss and the cost of thermal insulation

Thickness of thermal insulation



Graph determining the efficient thickness of thermal insulation

Thermal insulation materials

types	Applications	Advantages/Disadvantages
Polystyrene is made from the monomer styrene	Work in low temperature, -167oC - 82oC, mainly used in refrigeration room	Hard, light weight/combustible, low-melting point
Polyurethane is polymer composed of a chain of organic units joined by carbamate (urethane) links.	Work in low temperature, -178oC - 4oC, mainly used in refrigeration room	Closed structure, low density/combustible, generate poison gas
Mineral fibre Is made by melting basalt mineral at 1500oC. Other materials of phenol family are also put into	Work well even with 820°C. Used for thermal insulation in industrial furnace, dried devices, boiler, high-temperature tubes	A large range for density, is inert material, anticorrosion

types	Applications	Advantages/Disadvantages
Fibreglass is a fiber reinforced polymer made of a plastic matrix reinforced by fine fibers of glass	Work well even with 540°C. Used for thermal insulation in industrial furnace, dried devices, boiler, high-temperature tubes	Agelessness/slight alkalinity
Silicate carbon It is one of group of compounds obtained by reacting calcium oxide and silica in various ratios	Work well even with 1050°C. Used for thermal insulation in furnace wall, refractory materials	Low heat conductibility, maintain shape in working temperature, light materials, stable structure, moisture less, anti-corrosion
ceramic fibre is an aluminosilicate based refractory fiber, white and odorless	Work well even with 1430°C. Used for thermal insulation in calcinatory furnace, incinerator,	Suitable with different applications

ROTARY KILN FOR CEMENT PRODUCTION

CO2 REDUCTION POTENTIAL IN CEMENT INDUSTRY

Energy Efficiency Improvement

- Fuels: clinker kiln, drying
- Electricity: grinding, other drives

Alternative Fuels

- Switch to lower emitting fuels, including wastes

Product Changes

- Limestone addition
- Blending (slags, fly ash, pozzolans)

Other

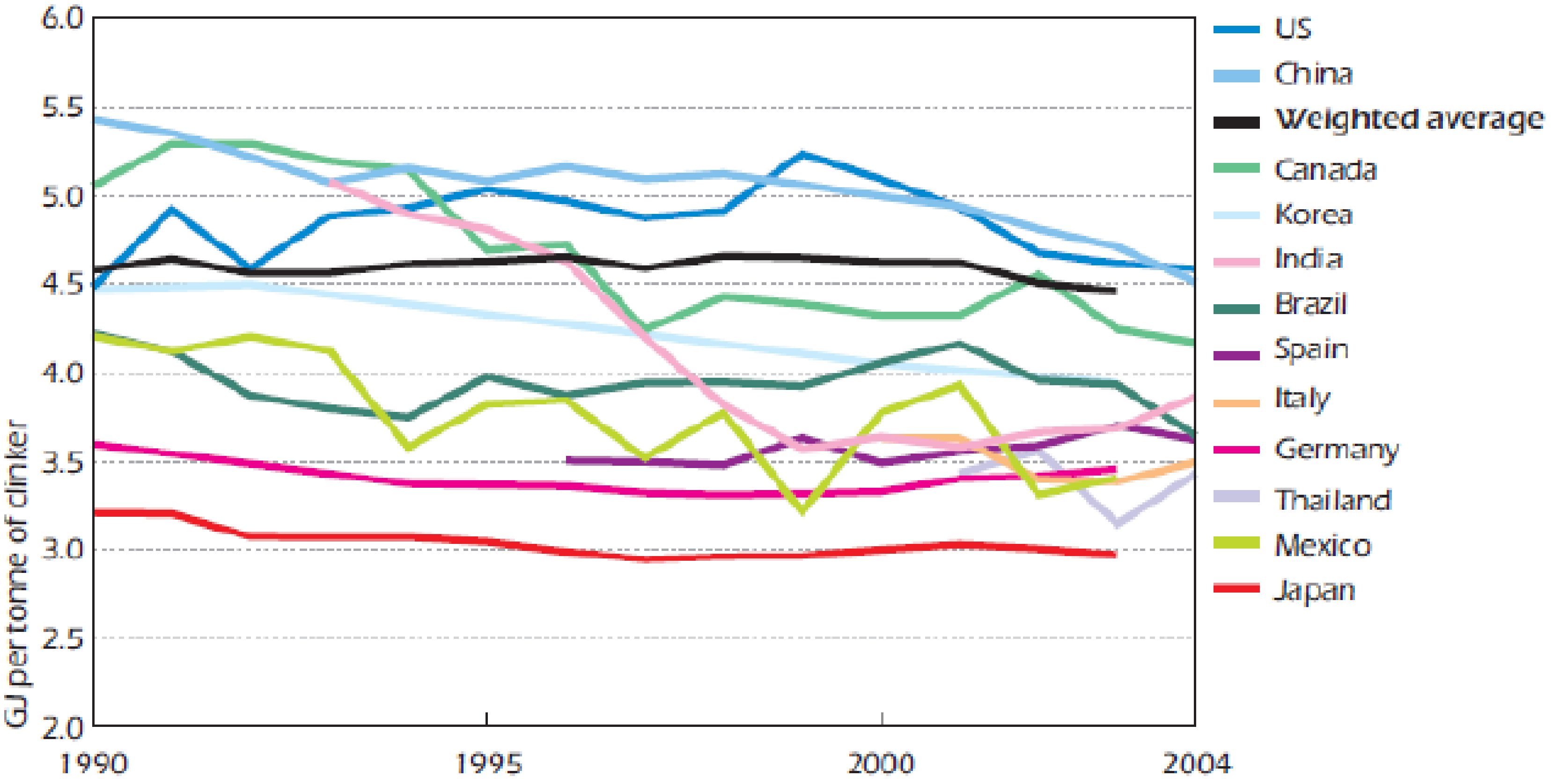
- Raw meal mix (steel slags)
- Product changes (alkaline/CKD)

Long-Term

Geo-polymers

Carbon sequestration

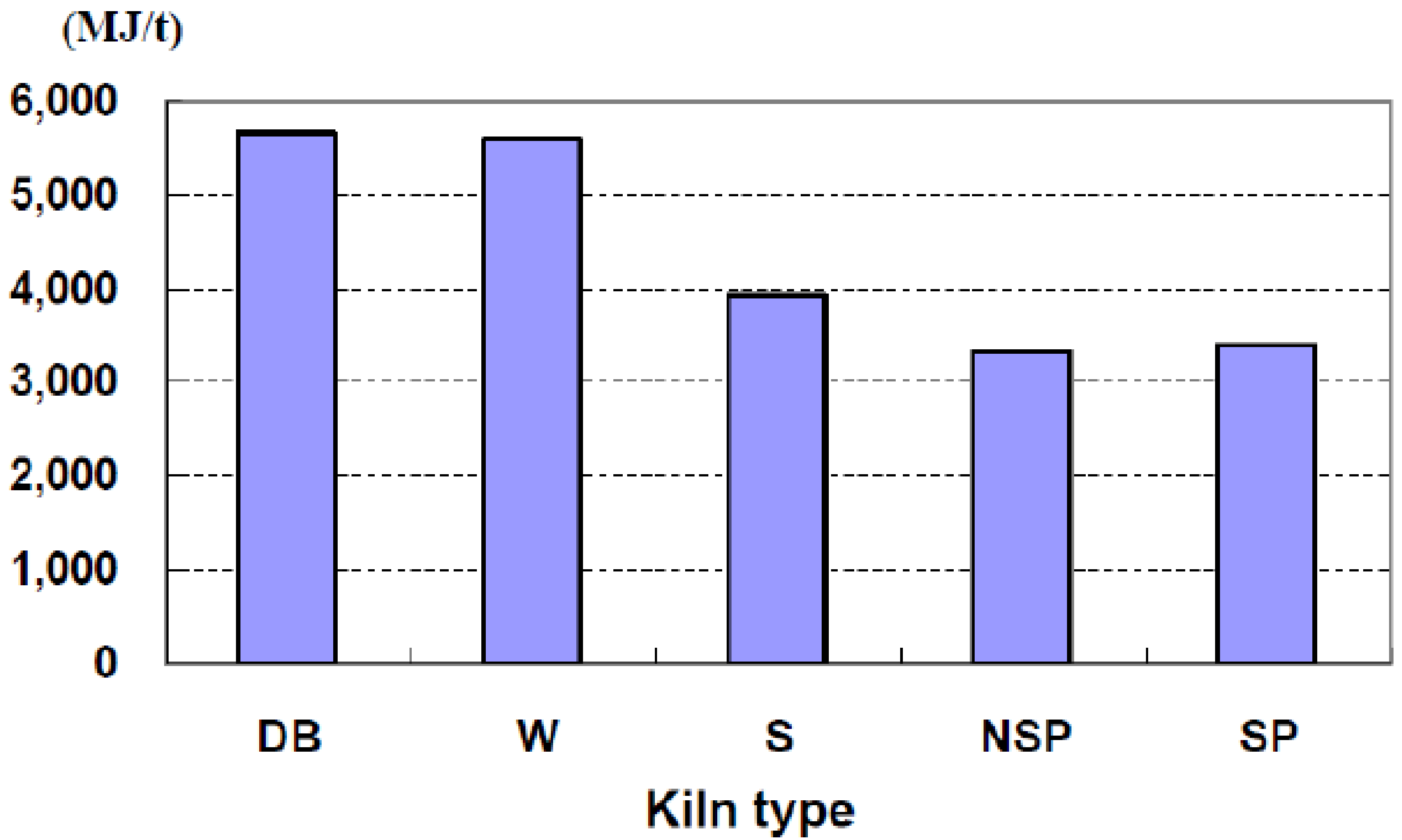
ENERGY CONSUMPTION PER TONNE OF CLINKER BY COUNTRY, INCLUDING ALTERNATIVE FUELS



Source: IEA, 2007a.

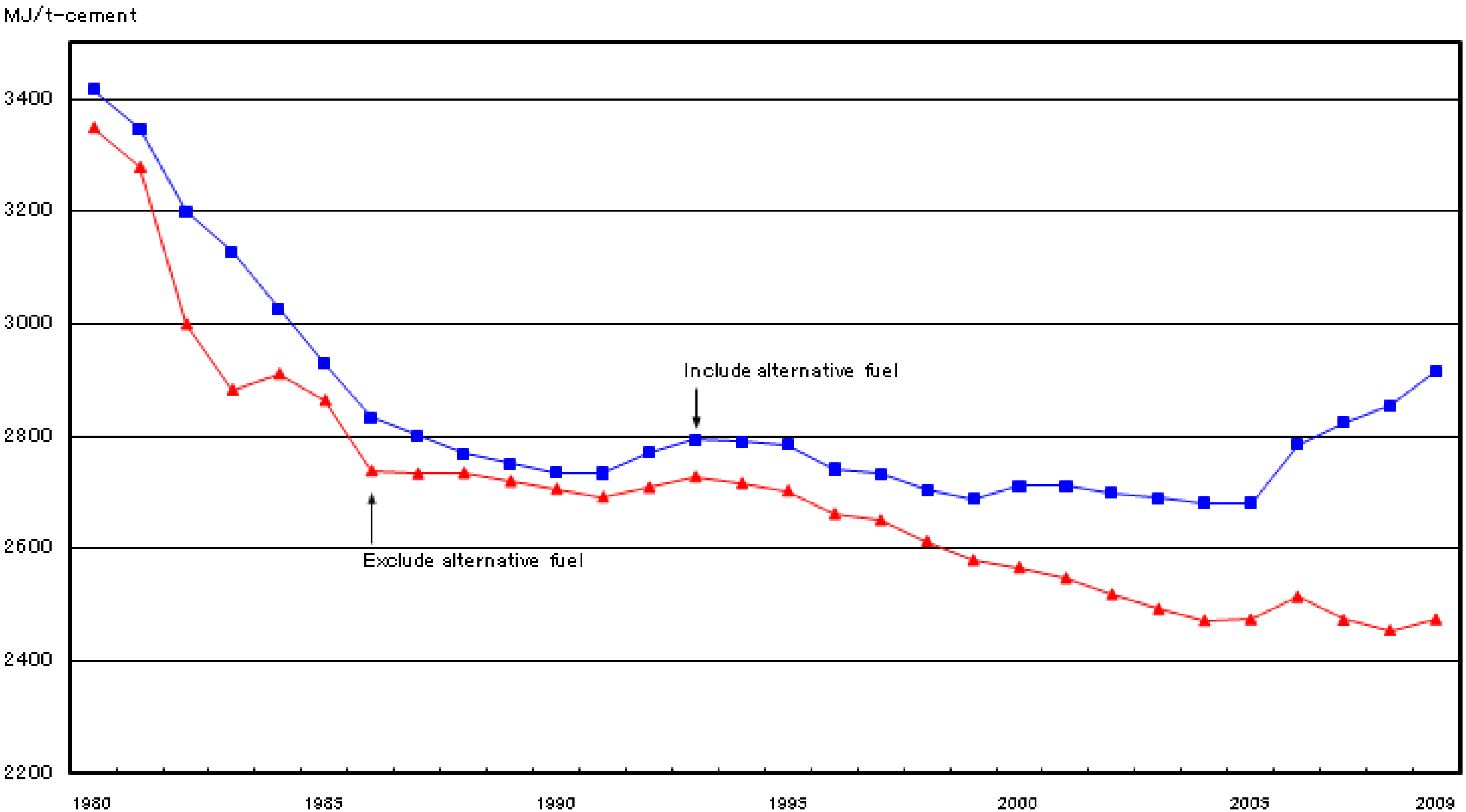
Note: Care must be taken in interpreting the absolute values in this figure, due to the possibility that countries are using different boundaries and definitions.

SPECIFIC HEAT CONSUMPTION BY KILN TYPE (TOTAL HEAT OF THE CLINKER BURNING PROCESS)



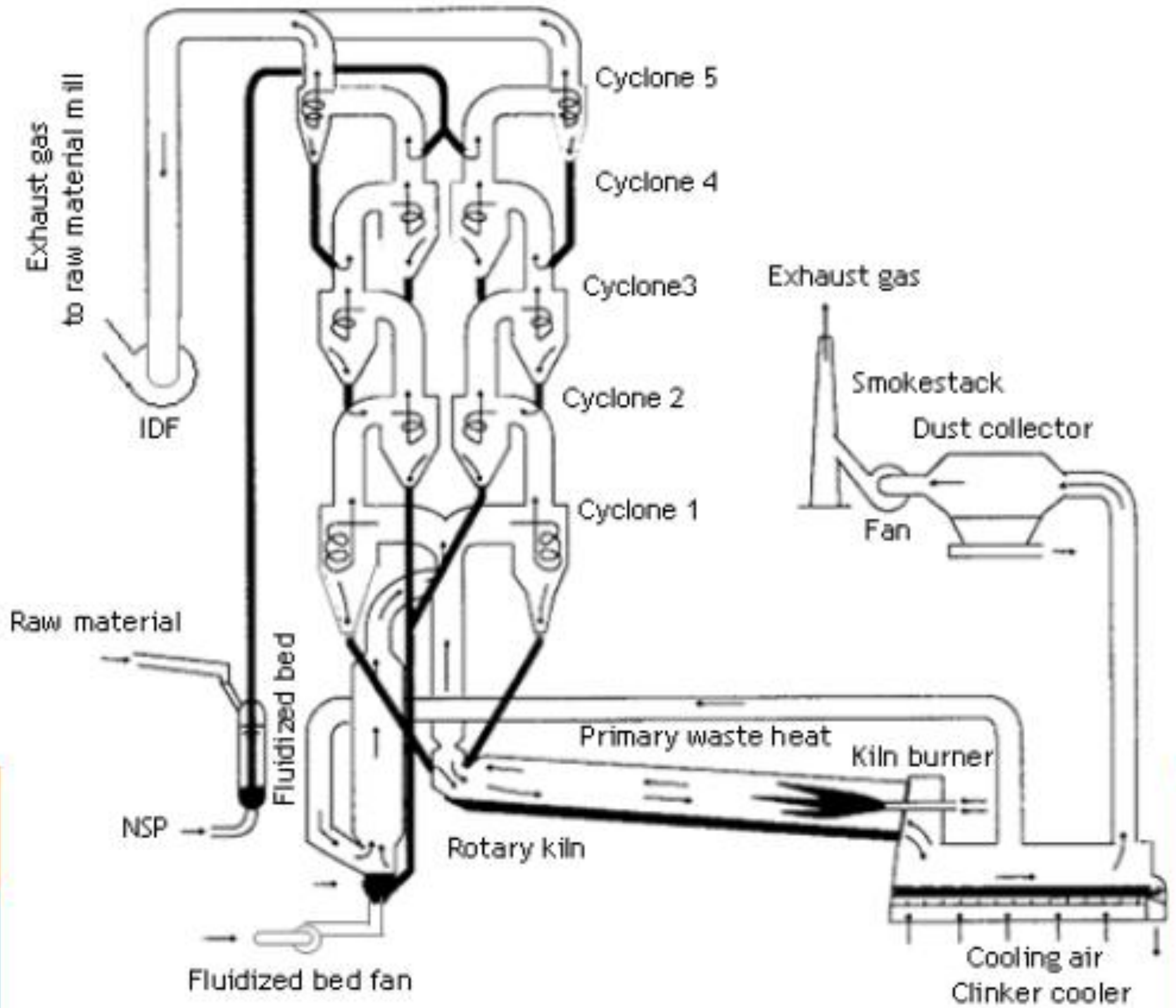
W: Wet, S: Semi-wet, NSP: New Suspension Preheated, SP Suspension Preheated

Thermal Energy Consumption



http://www.jcassoc.or.jp/cement/2eng/eh1.html

NSP KILN



http://62.160.8.20/eetkb/technologies/details.aspx?id=62

ROTARY KILN FOR CEMENT PRODUCTION

http://www.tokuyama.co.jp/recruit/jobnet/lecture/field.html

Details of alternative resources

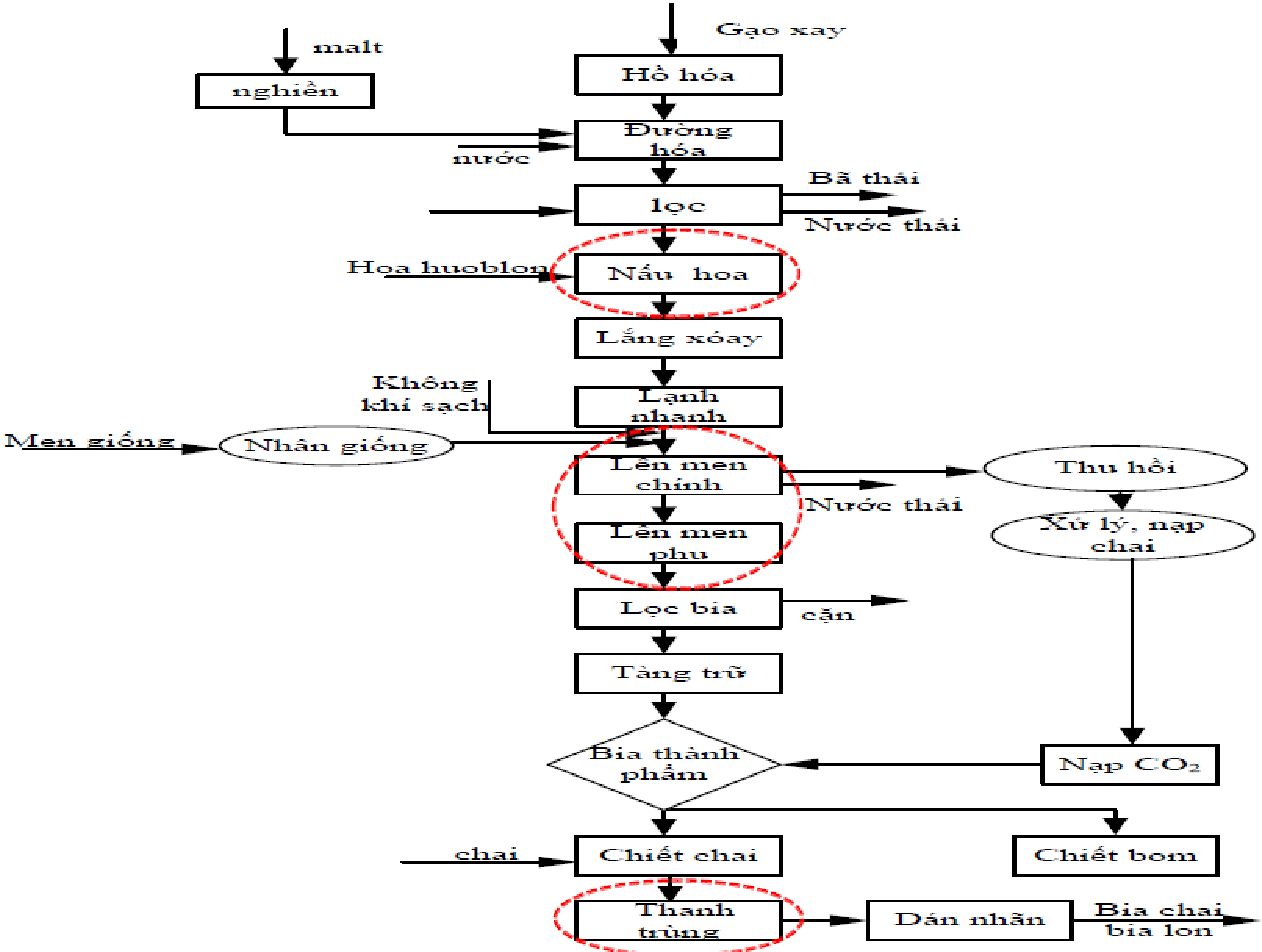
(unit: million tons)

Item	2005	%	2006	%	2007	%	2008	%	2009	%
Blast furnace slag	9.2	100.0	9.7	105.4	9.3	95.9	8.7	93.5	7.6	87.4
Coal ash	7.2	104.3	7.0	97.2	7.3	104.3	7.1	97.3	6.8	95.8
Sewage,Sludge	2.5	96.2	3.0	120.0	3.2	106.7	3.0	93.8	2.6	86.7
by-product Gypsum	2.7	103.8	2.8	103.7	2.6	92.9	2.5	96.2	2.1	84.0
Waste soil from construction	2.1	123.5	2.6	123.8	2.6	100.0	2.8	107.7	2.2	78.6
Nonferrous slag	1.3	100.0	1.1	84.6	1.0	90.9	0.9	90.0	0.8	88.9
Cinder,soot	1.2	109.1	1.0	83.3	1.2	120.0	1.1	91.7	1.1	100.0
Steel mfg.slag	0.5	100.0	0.6	120.0	0.5	83.3	0.5	100.0	0.3	60.0
Wood chips	0.3	100.0	0.4	133.3	0.3	75.0	0.4	133.3	0.5	125.0
Waste plastic	0.3	100.0	0.4	133.3	0.4	100.0	0.4	100.0	0.4	100.0
Others	2.3	100.0	2.3	100.0	2.3	100.0	2.1	91.3	1.9	90.5
Total	29.6	102.8	30.9	104.4	30.7	99.4	29.5	96.1	26.3	89.2
(kg/t-cem.)	400		423		436		448		451	

http://www.jcassoc.or.jp/cement/2eng/eh3.html

Heating and Cooling in beer Production

(Effective Energy Use)



malt
nghiền
Gạo xay
Hồ hóa
Đường hóa
nước
lọc
Bã thải
Nước thải
Hoa huoblon
Nấu hoa
Lắng xóay
Không khí sạch
Lạnh nhanh
Men giống
Nhân giống
Lên men chính
Thu hồi
Nước thải
Xử lý, nạp chai
Lên men phụ
Lọc bia
cặn
Tàng trữ
Bia thành phẩm
Nạp CO_2
chai
Chiết chai
Chiết bom
Thanh trùng
Dán nhãn
Bia chai bia lon

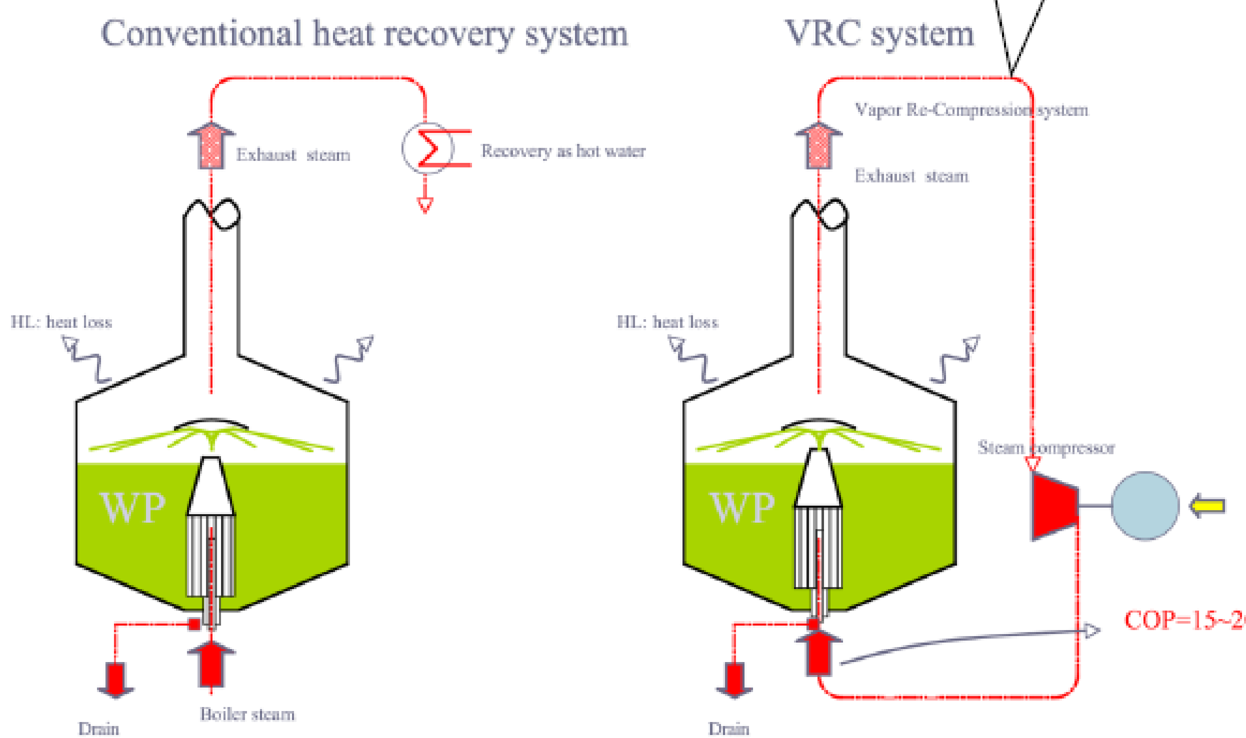
Energy distribution and energy consumption in beer factory

Energy Consumption	Thermal Energy consumption	Electric Energy consumption
Cooking systems	50% ÷ 60%	10% ÷ 20%
Pasteurization systems	30% ÷ 40%	-
Cooling systems	-	40% ÷ 50%
Device cleaning systems	10% ÷ 20%	20% ÷ 30%
Lighting systems	-	10% ÷ 20%

A. VRC –Vapor Re-Compression

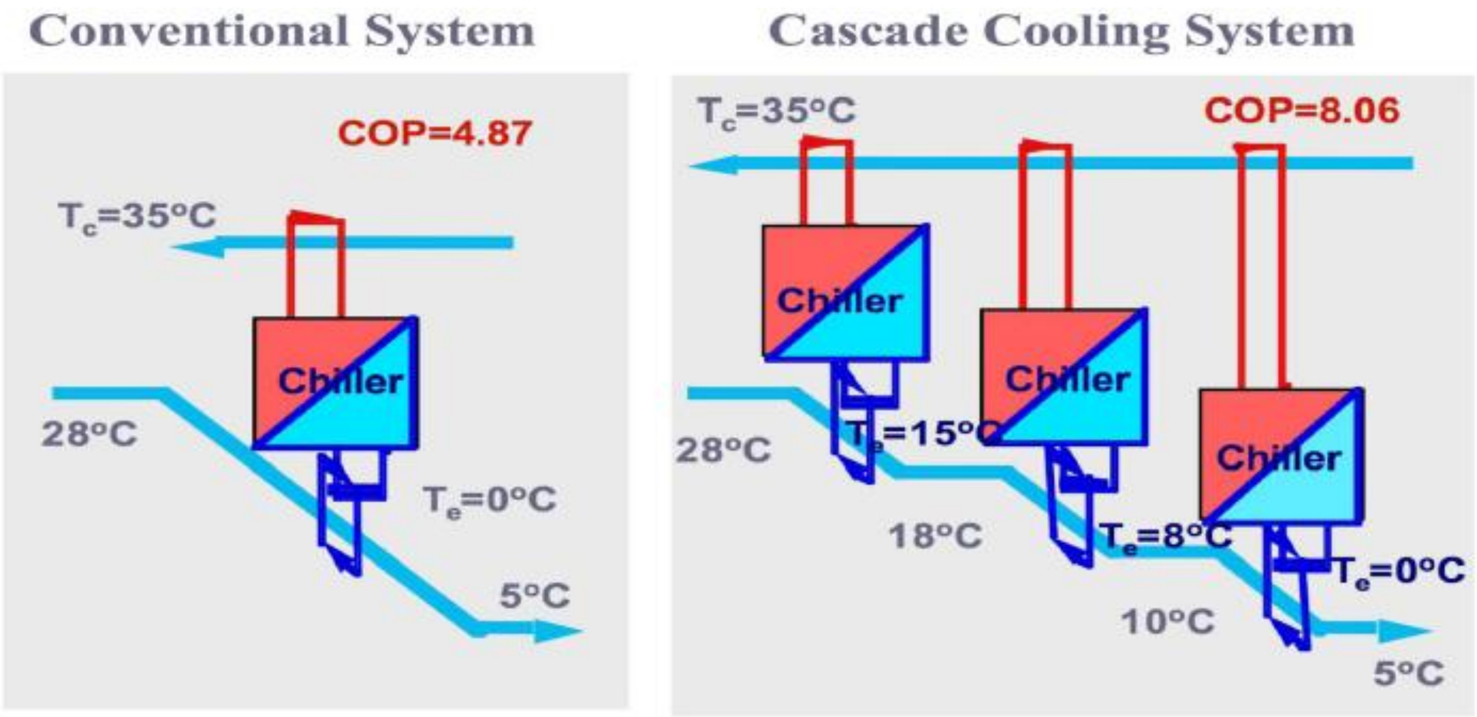
Save energy by gas reuse

Gas generated with high energy



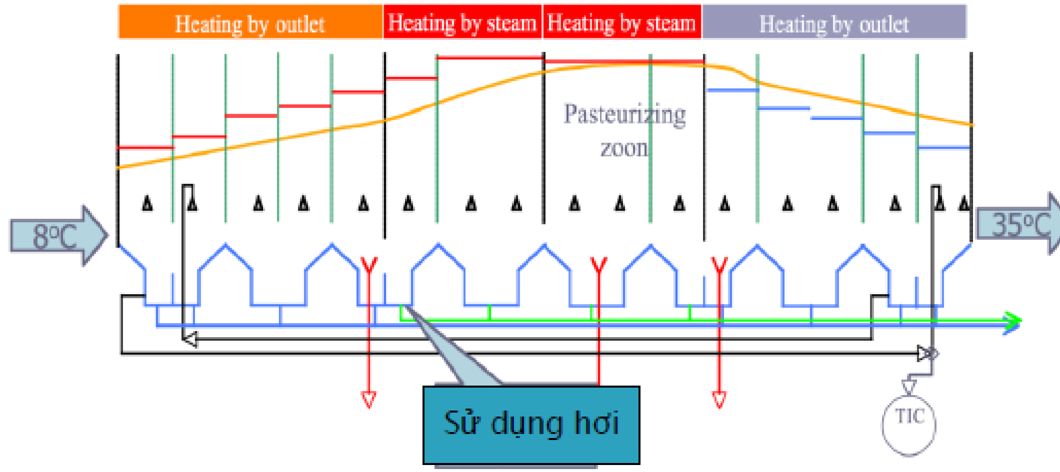
CCS-Cascade Cooling System

- Consume less energy than the conventional system

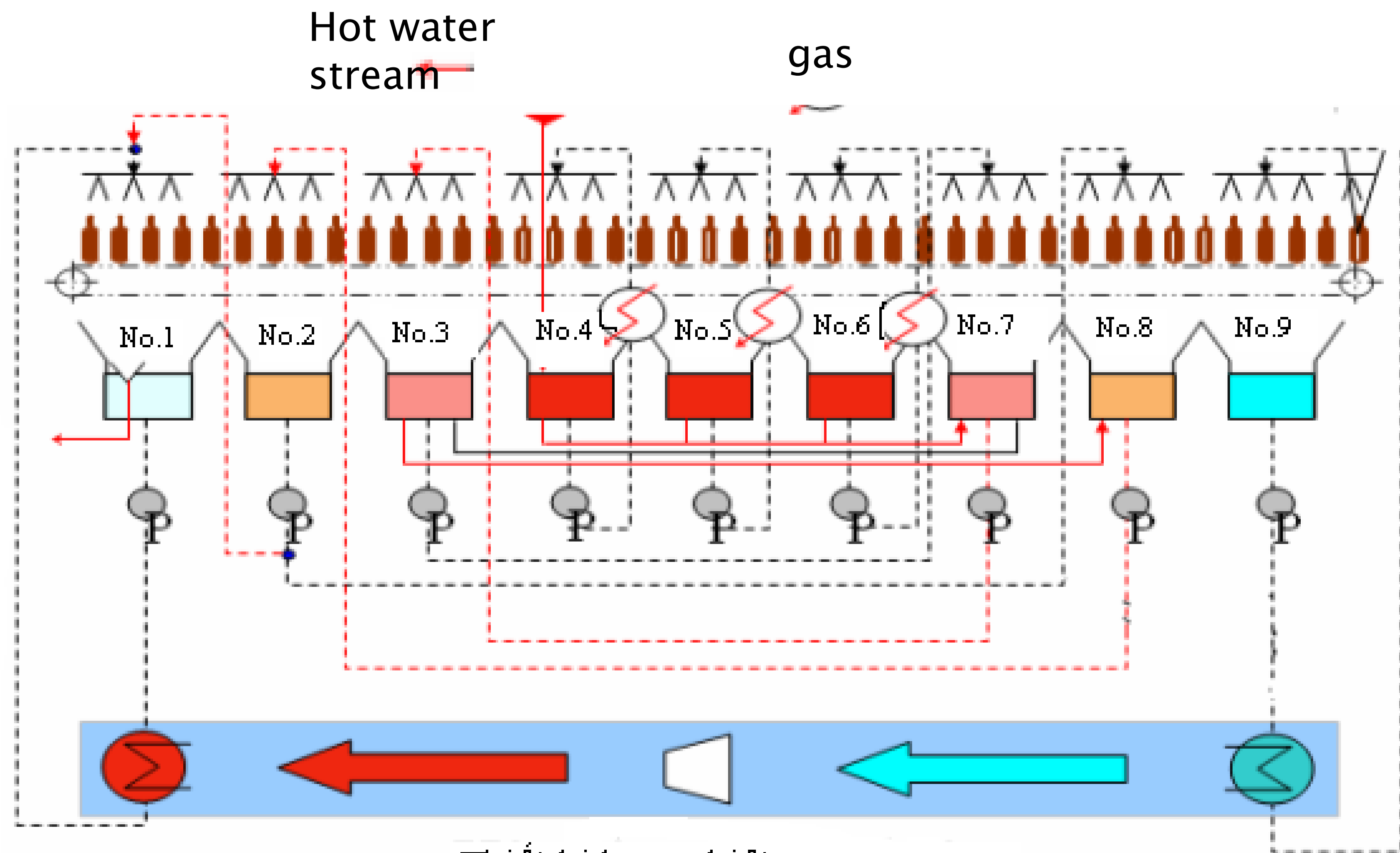


C. Opt. Past system

- Past-pasteurizer: keep bear in 60°C in 10 minutes → needs a large amount of gas
- After that, keep bear in 35°C before another process



Opt-past: save gas via improving efficiency

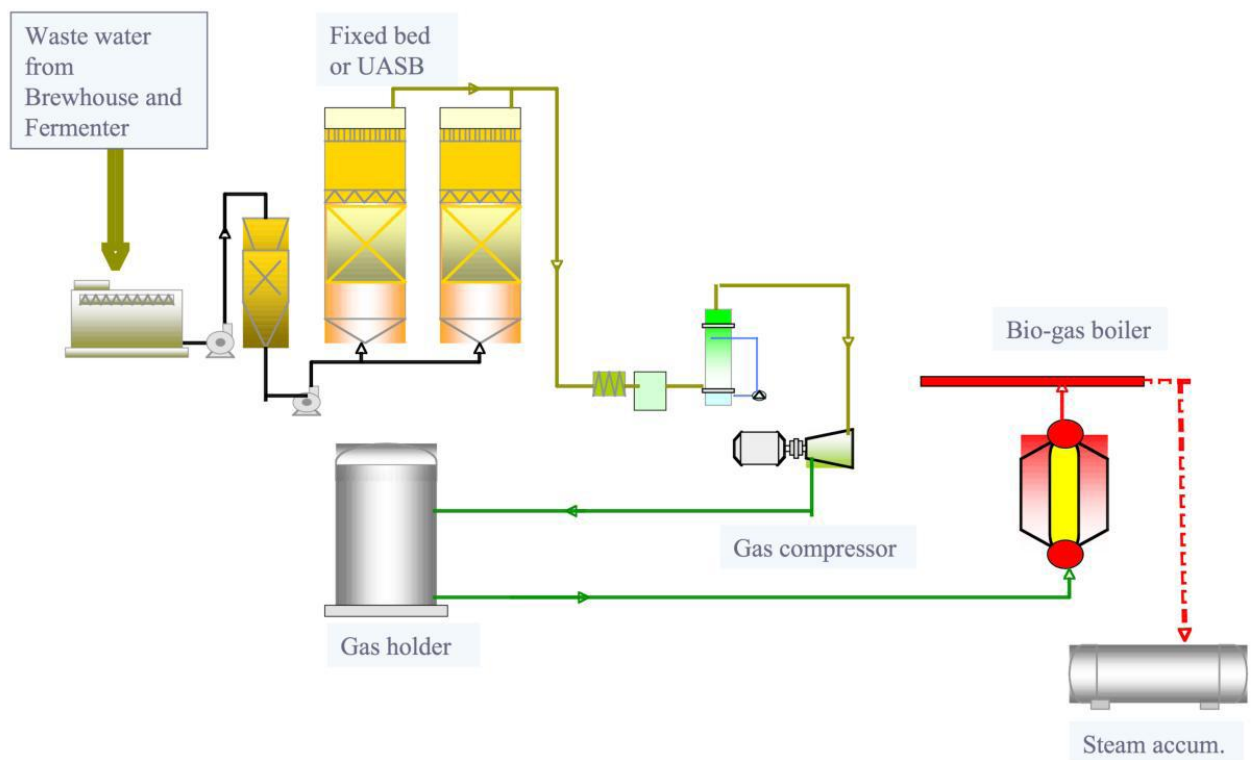


Thermal pump device

pasteurization system when using thermal pump device

D. Sewage purification by anaerobic waster water treatment and biogas boiler

- Consumed water volume 10 times larger than beer volume
- Organic waste content in Sewage is high, and it should be treated by anaerobic WWT
- Biogas generated is used as input fuel for boiler



Thanh Hoa beer factory

- Vapor re-compression
- Improving Ice Thermal Storage, Cascade Cooling
- Optimization of Pasteurizer
- Sewage purification by anaerobic disintegration process

Gas from cooking system

Fermentation devices

Energy benefits and environment

Thanh Hoa beer factory: 100% installed in Vietnam

- Energy save: 63.487 toe/year
- KNK emission reduction:196.425 tons CO_2/year

Conclusions

- There is a limit to convert thermal energy to other form of energy.
- Exergy analysis is useful to evaluate the efficiency
- To raise the efficiency, the efficient use of thermal energy should be focused.
- For the future, total energy management system will be effective.

Thank you !