Chapter 6
Lecture # 2-3

- **Utility Cost**

Utility Cost

Utility cost depends on the cost of fuel

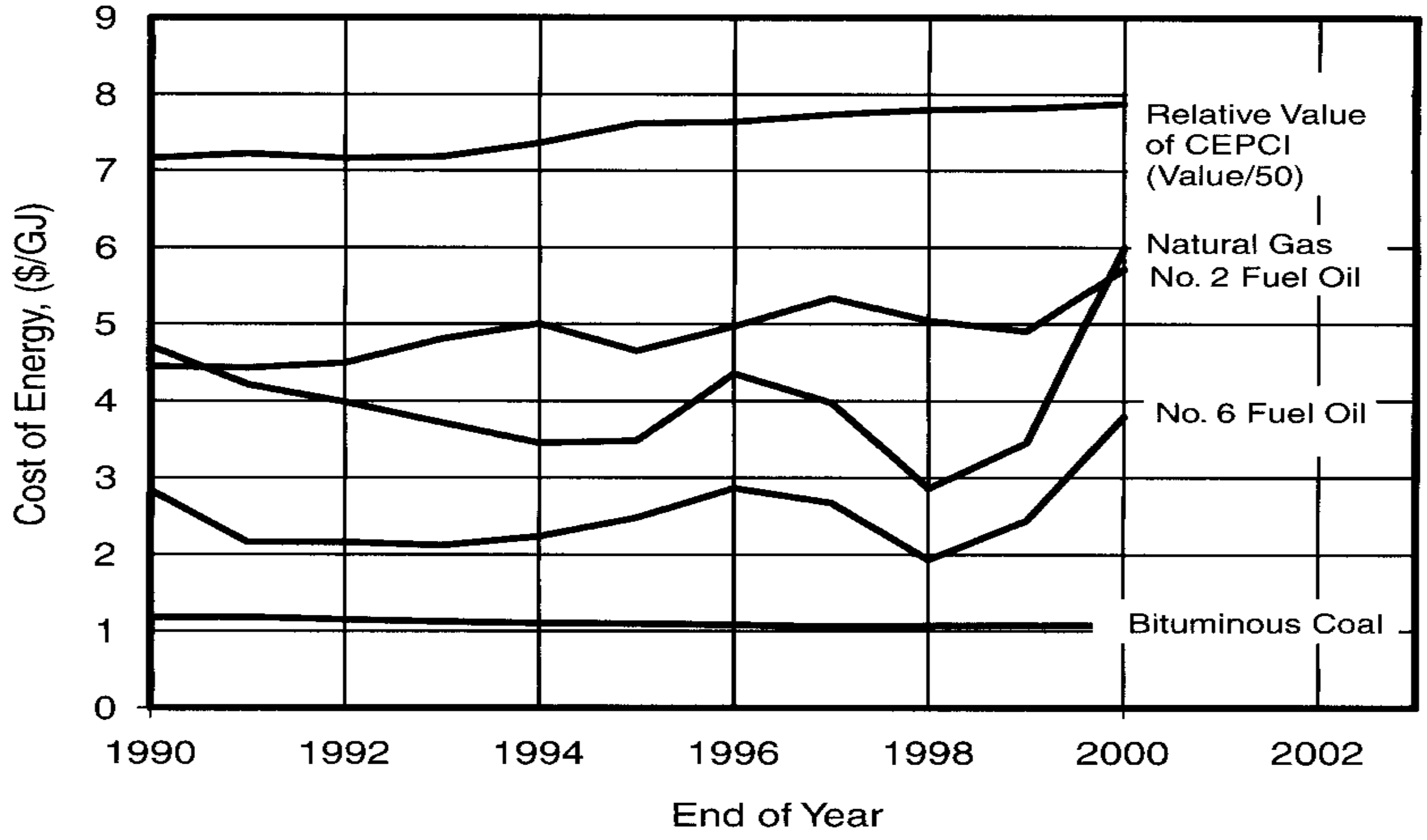


Figure 6.1 Changes in Fuel Prices from 1990 to 2000 (Information taken from Energy Information Administration [6])

Utility Cost

Utility can be supplied in a number of ways:

- Purchasing from a public or private utility.
- Off-site generation.
- On-site generation.

Utility Cost

Table 6.3

Off site generation

(Capital cost of utility plant is not included)

Utility Cost

Table 6.3 Utilities Provided by Off-sites for a Plant with Multiple Process Units (Costs Represent Charges for Utilities Delivered to the Battery Limit of a Process)

Utility	Description	Cost $/GJ	Cost $/Common Unit
Air supply	Pressurized and dried air (add 20% for instrument air)		
	a. 6 barg (90 psig)		$0.49/100 std m³*
	b. 3.3 barg (50 psig)		$0.35/100 std m³*
Steam from boilers	Process steam: latent heat only		
	a. Low pressure (5 barg, 160°C) from HP steam		
	with credit for power	6.08	$12.68/1000 kg
	without credit for power	7.78	$16.22/1000 kg
	b. Medium pressure (10 barg, 184°C) from HP steam		
	with credit for power	6.87	$13.71/1000 kg
	without credit for power	8.22	$16.40/1000 kg
	c. High pressure (41 barg, 254°C)	9.83	$16.64/1000 kg
Steam generated from process	Estimate savings as avoided cost of burning natural gas in boiler	6.67	

Utility Cost

Table 6.3 Utilities Provided by Off-sites for a Plant with Multiple Process Units (Costs Represent Charges for Utilities Delivered to the Battery Limit of a Process) (*continued*)

Utility	Description	Cost $/GJ	Cost $/Common Unit
Cooling tower water	Processes cooling water: 30°C to 40°C or 45°C	0.354	$14.8/1000 $m^{3\dagger}$
Other water	High purity water for		
	a. process use		$0.067/1000 kg
	b. boiler feed water (available at 115°C)‡		$2.45/1000 kg
	c. potable (drinking)		$0.26/1000 kg
	d. deionized water		$1.00/1000 kg
Electrical substation	Electric Distribution	16.8	$0.06/kWh
	a. 110 V		
	b. 220 V		
	c. 440 V		
Fuels	a. Fuel oil (no. 2)	6.0	$232/$m^3$
	b. Natural gas	6.0§	$0.23/std m^{3*}
	c. Coal (f.o.b. mine mouth)	1.07	$27.4/tonne

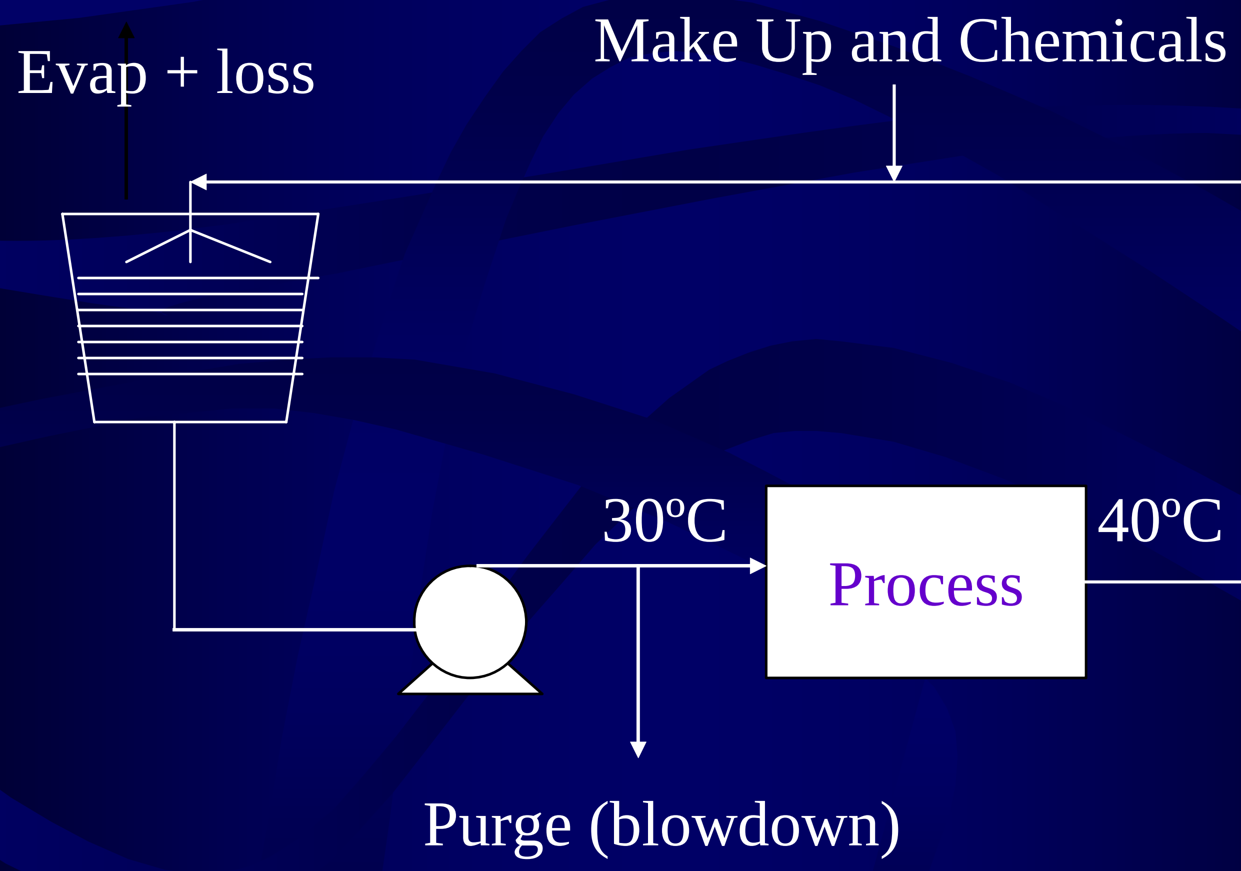
Utility Cost

Table 6.3 Utilities Provided by Off-sites for a Plant with Multiple Process Units (Costs Represent Charges for Utilities Delivered to the Battery Limit of a Process) (*continued*)

Utility	Description	Cost $/GJ	Cost $/Common Unit
Refrigeration	a. Moderately low temperature Refrigerated water in at T = 5°C and returned at 15°C	4.43	$0.185/1000kg
	b. Low temperature Refrigerant available at T = –20°C	7.89	
	c. Very low temperature Refrigerant available at T = –50°C	13.11	Based on Process Cooling Duty
Thermal systems	Cost based on thermal efficiency of fired heater using natural gas		
	a. 90% efficient	6.67	Based on Process Heating Duty
	b. 80% efficient	7.5	
Waste disposal (solid and liquid)	a. Non-hazardous		$36/tonne
	b. Hazardous		$200–2000/tonne°
Waste water treatment	a. Primary (filtration)		$41/1000 m^3
	b. Secondary (filtration + activated sludge)		$43/1000 m^3
	c. Tertiary (filtration, activated sludge, and chemical processing)		$56/1000 m^3

Utility Cost

Cooling Water



Utility Cost

Cooling Water

- Make – up based on Δ*T* (40 - 30) !
- Should charge cw based on energy used
  - Table 6.3
- Does not matter (much) if cw returned at 40ºC or 45ºC – same energy
- 45ºC is absolute max – due to fouling

Utility Cost

Cooling Water

Example 6.3

Estimate the utility cost for producing a circulating cooling water stream using a mechanical draft cooling tower. Consider a basis of 1 GJ/h of energy removal from the process units. Flow of cooling water required to remove this energy = $\dot{m}$ kg/h.

An energy balance gives

$$\dot{m}c_p\Delta T = 1 \times 10^9 \Rightarrow (\dot{m})(4180)(40 - 30) = 41{,}800\,\dot{m} = 1 \times 10^9 \text{ J/h}$$

Therefore, $\dot{m} = \dfrac{1 \times 10^9}{41{,}800} = 23{,}923$ kg/h

Latent heat of water at average temperature of 35°C = 2417 kJ/kg
Amount of water evaporated from tower, W_{tower}

$$W_{tower} = \frac{Heat\ Load}{\Delta H_{vap}} = \frac{1 \times 10^9}{2417 \times 10^3} = 413.7 \text{ kg/h}$$

This is (413.7)(100)/(23,923) = 1.73% of the circulating water flowrate.

Typical windage losses from mechanical draft towers are between 0.1 and 0.3% [9, 10], use 0.3%.

Utility Cost

Cooling Water

To calculate the blowdown, we must know the maximum allowable salt (inorganics) concentration factor, S, of the circulating water compared with the makeup water. Where S is defined as

$$S = \frac{\text{concentration salts in cooling water loop}}{\text{concentration salts in make-up water}} = \frac{s_{loop}}{s_{in}}$$

Typical values are between 3 to 7 [9]. Here a value of 5 is assumed. By performing a water and salt balance on the loop shown in Figure 6.3, the following results are obtained:

$$W_{MU} = W_{tower} + W_{wind} + W_{BD}$$

$$s_{in}W_{MU} = s_{loop}W_{wind} + s_{loop}W_{BD}$$

Because $s_{loop} = 5s_{in}$, it follows that

$$s_{in}(W_{tower} + W_{wind} + W_{BD}) = s_{loop}W_{wind} + s_{loop}W_{BD}$$

Utility Cost

Cooling Water

$$W_{BD} = \frac{s_{in}W_{tower} + W_{wind}(s_{in} - s_{loop})}{s_{loop} - s_{in}} = \frac{s_{in}W_{tower}}{s_{loop} - s_{in}} - W_{wind} = \frac{W_{tower}}{4} - W_{wind} = \frac{1.73\%}{4} - 0.3\% = 0.133\%$$

$$W_{MU} = 1.73 + 0.3 + 0.133 = 2.163\% = 517\text{kg/h}$$

Pressure drop around cooling water loop is estimated as follows, ΔP_{loop} = 15 psi (pipe losses) + 5 psi (exchanger losses) + 10 psi (control valve loss) + 8.7 psi of static head (because water must be pumped to top of cooling water tower estimated to be 20 ft above pump inlet) = 38.7 psi =266.7 kPa.

Power required for cooling water pumps with a volumetric flow rate $\dot{V}$, assuming an overall efficiency of 75%, is

$$\text{Pump Power} = \frac{1}{\varepsilon}\dot{V}\Delta P = \frac{1}{(0.75)}\frac{(23{,}923)}{(1000)(3600)}(266.7) = 2.36 \text{ kW}$$

Power required for fans:

From reference [11], the required surface area in the tower = 0.5 ft²/gpm (this assumes that the design wet-bulb air temperature is 26.7°C [80°F]). From the same reference, the fan horsepower per square foot of tower area is 0.041 hp/ft².

$$\text{Power for fan} = \frac{(23{,}923)(2.2048)}{(60)(8.337)}(0.5)(0.041) = (2.16)(0.746) = 1.61 \text{ kW}$$

Utility Cost

Cooling Water

From a survey of vendors, the cost of chemicals is \$0.156/1000 kg of makeup water.

Using an electricity cost of \$0.06/kWh and a process water cost of \$0.067/1000 kg, the overall cost of the cooling water is given by:

Cost of cooling water = cost of electricity + cost of chemicals for make-up water + cost of make-up water

Using the cost values for electricity and process water given in Table 6.3:

$$\text{Cooling water cost} = (0.06)(2.36 + 1.61) + \frac{(517.3)(0.156)}{1000} + \frac{(517.3)(0.067)}{1000}$$

$$= \$0.354/\text{hr} = \$0.354/\text{GJ}$$

Utility Cost

Steam

- Pressure Levels
  - Low (30 – 90 psi)
  - Medium (150 – 250 psi)
  - High (525 – 680 psi)
- Available saturated but sometimes superheated

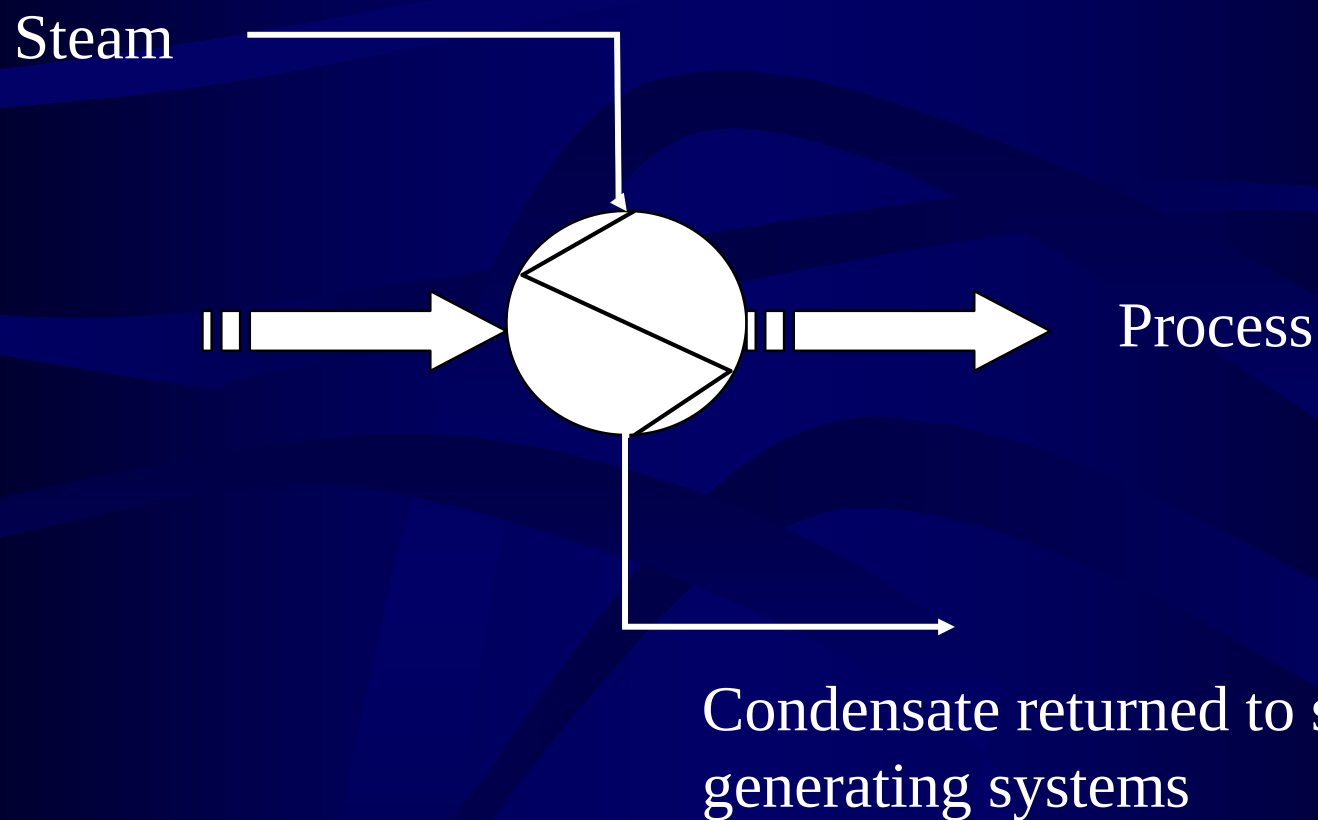
Utility Cost

Steam

- Large chemical complexes generate high pressure steam and use excess pressure to generate electricity – Figure 6.6.
- Steam can be used as a drive medium for compressors and pumps

Utility Cost

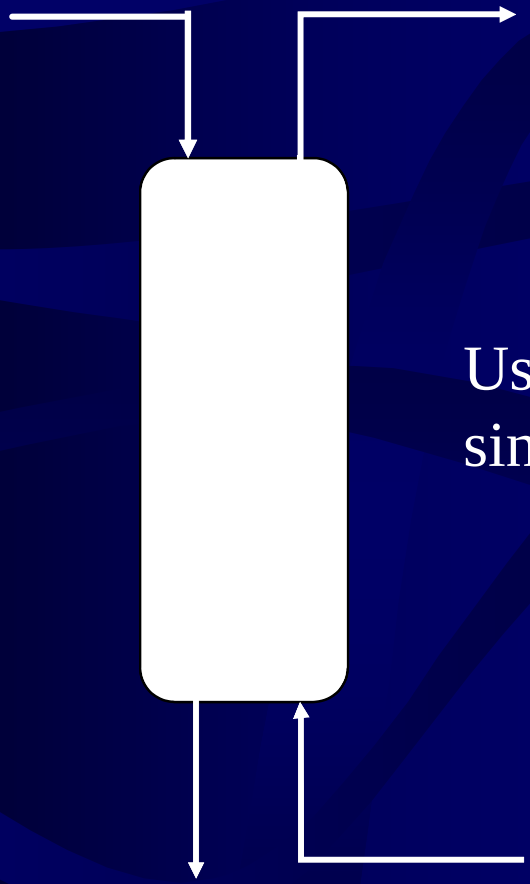
Steam



* Just use Steam Costs

Utility Cost

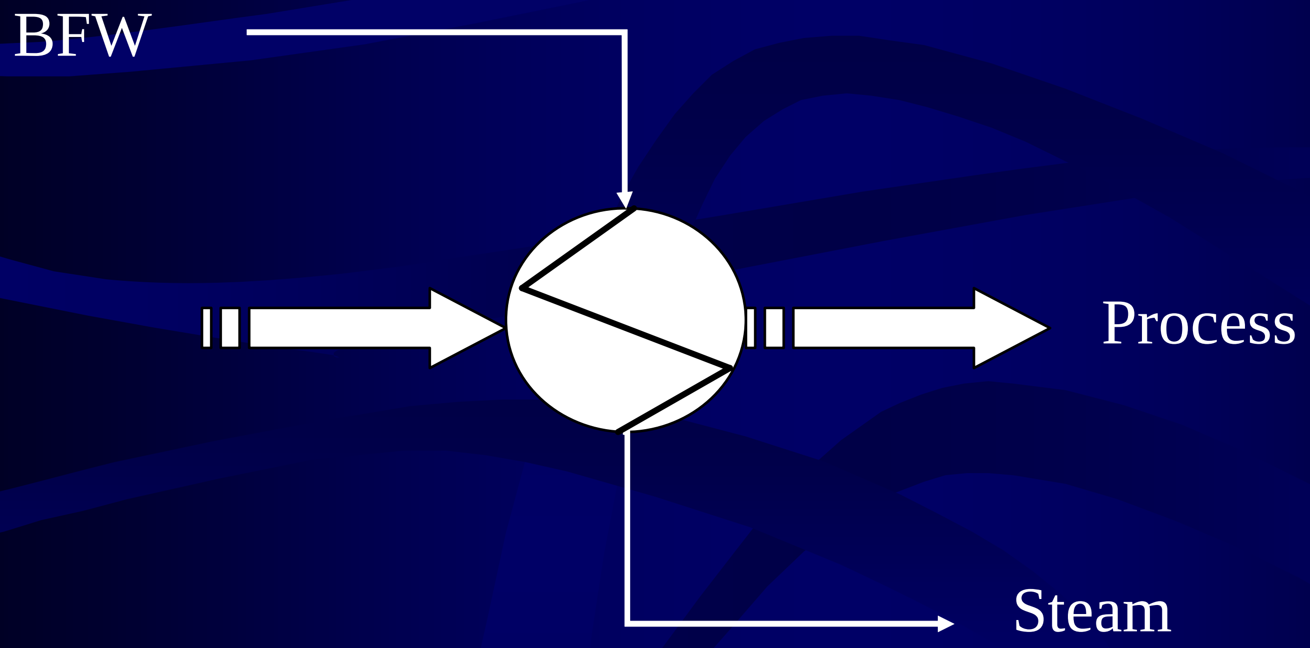
Steam



Use Steam Cost + BFW
since Condensate is not returned

Utility Cost

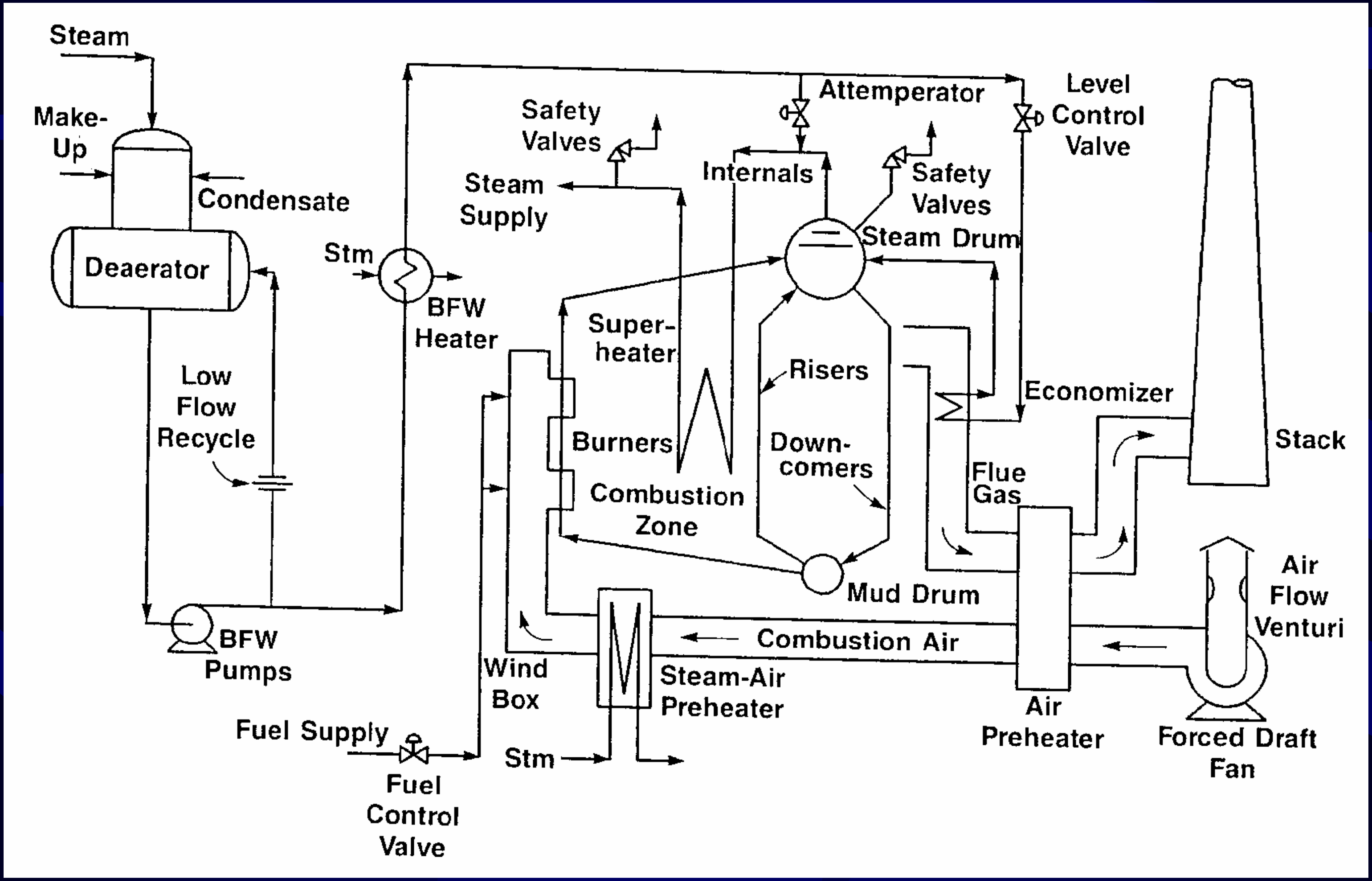
Steam



* Just Take Credit for Steam – unless Steam is lost in Process

Utility Cost

Steam



Utility Cost

Compressed Air