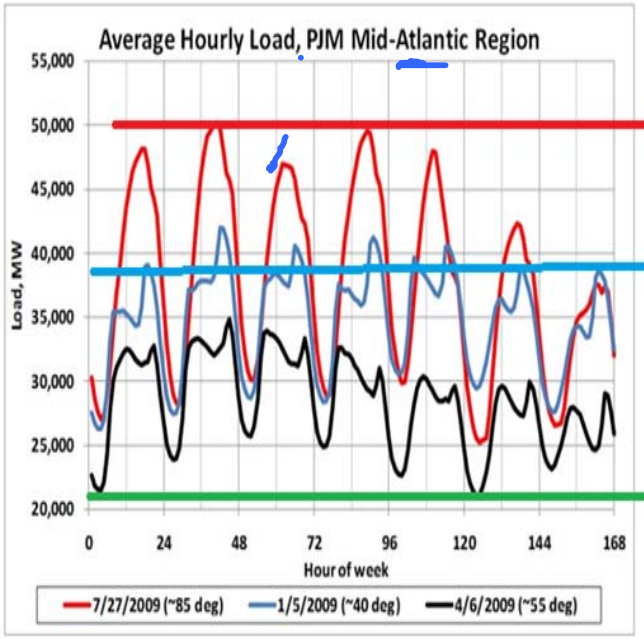
Generation Mix and Economic Dispatch

- **Different fuels are used for power generation**
  - Cost of fuel
  - Operating cost
  - Response time to the changing load





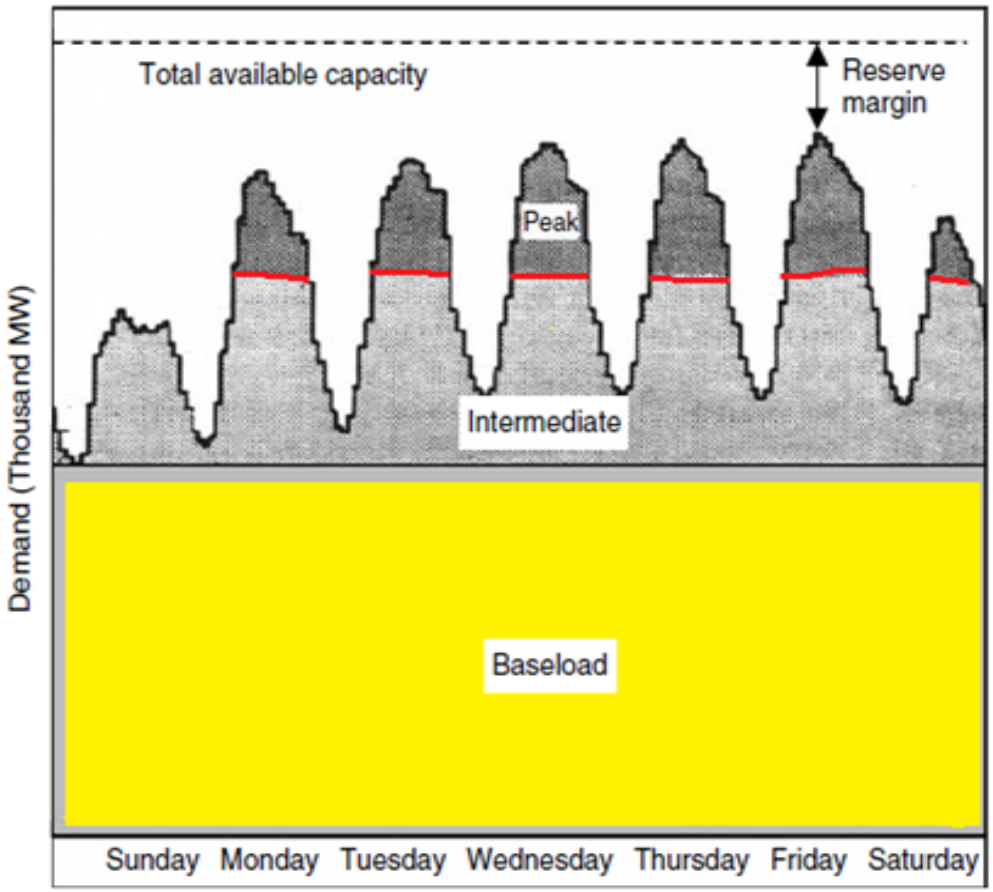
Generation Mix and Economic Dispatch

- **Dispatch:**

- **Economic dispatch**

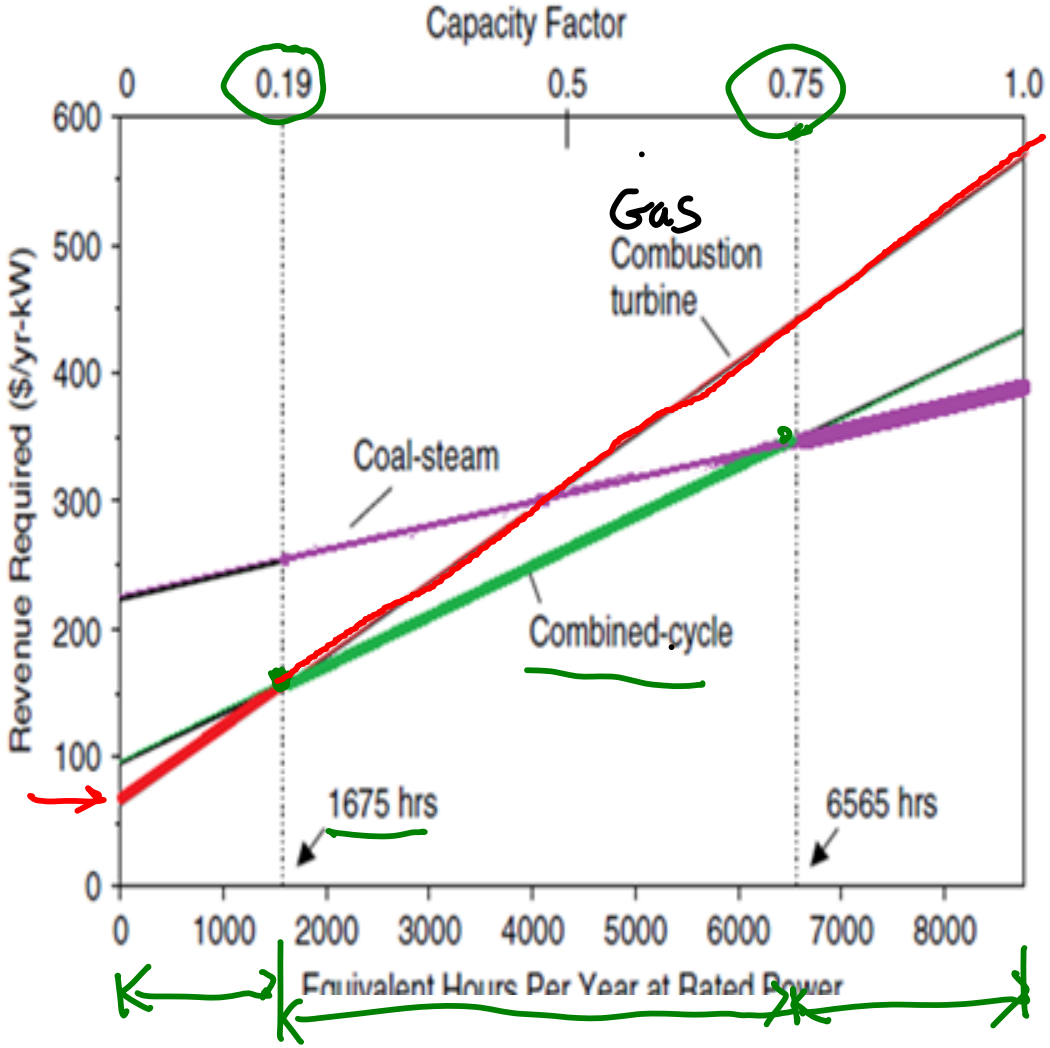
- **Coal**
- **Gas**
- Nuclear
- **Renewables**
- **Hydro**

Roles of Different Power Plants



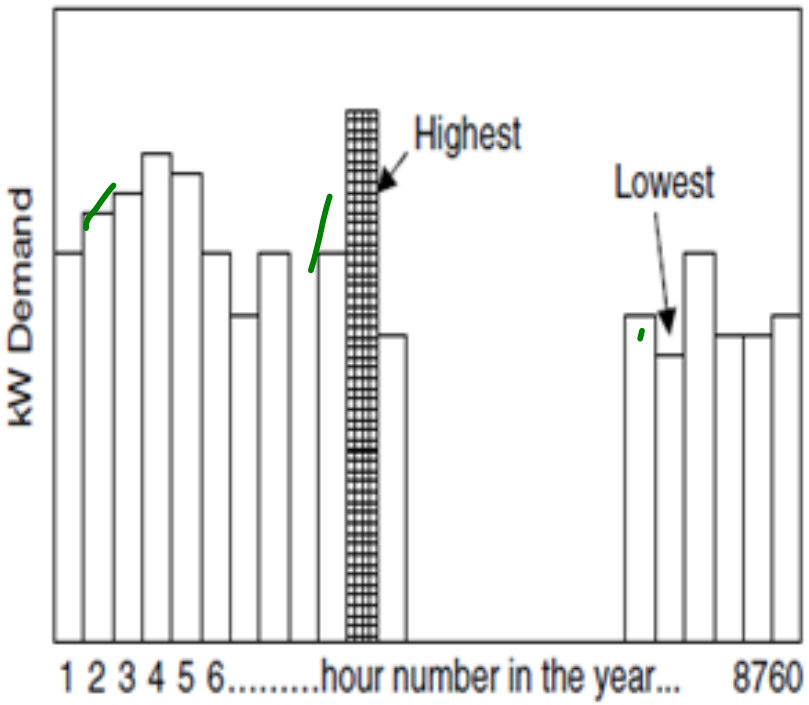
- Baseload plants:
- Intermediate load plants
- Peak load plants

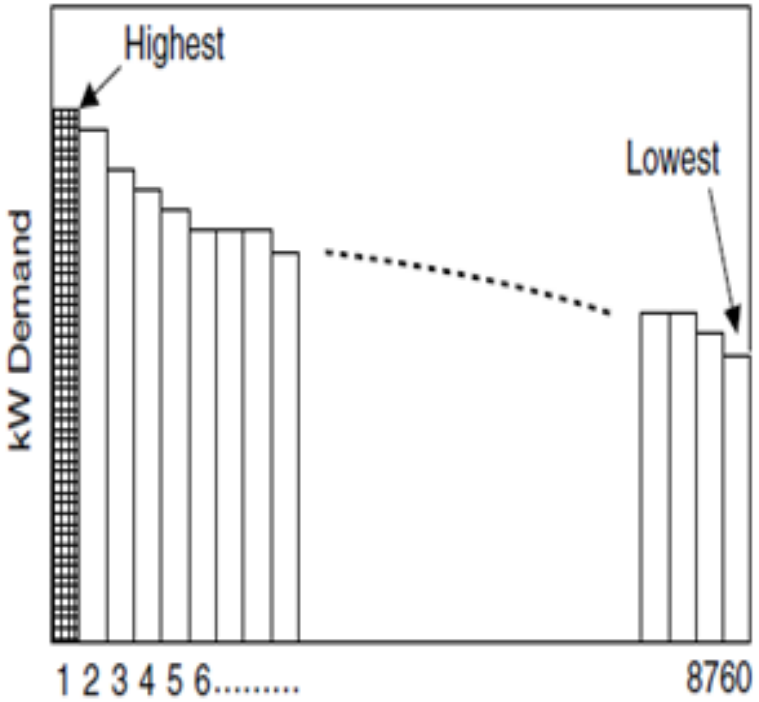
Screening Curves



Load-Duration Curves

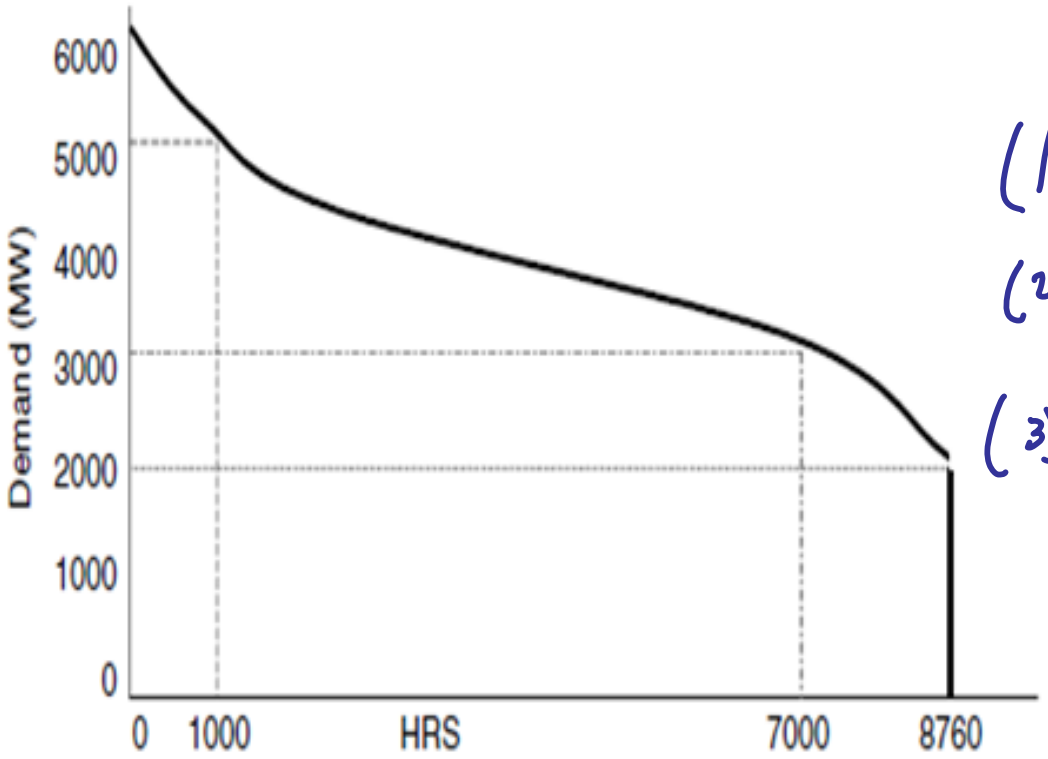
① Hourly Load Curve ⟶ ② Load Duration Curve





⌘ We plan to connect the screening curve of power plant and the load duration curve for (a) capacity of different power plants and (b) allocation of power plants for economic dispatch

Load Duration Curve



Interpretation

MW

(1) Load is between ( ) and ( )

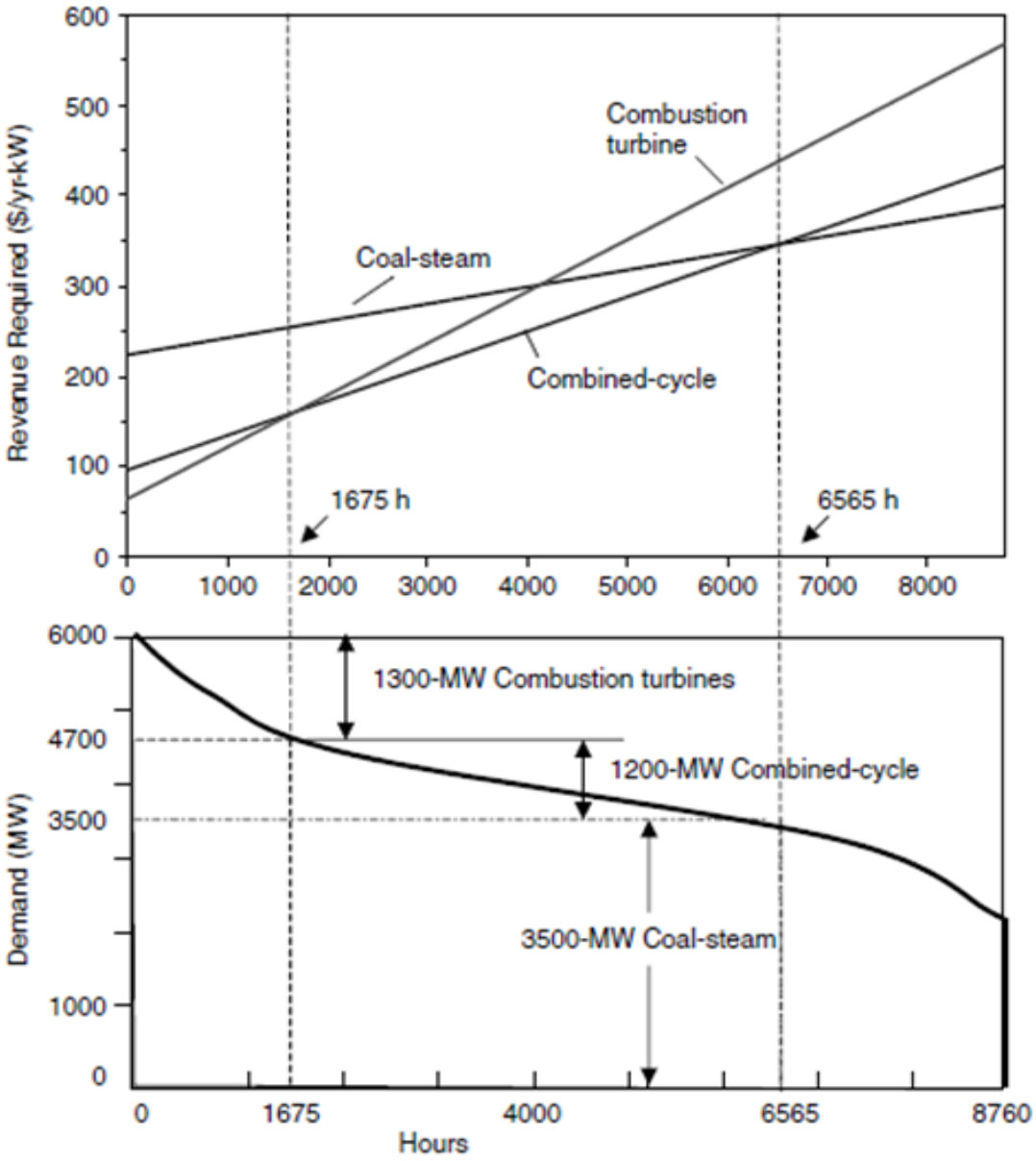
(2) Load > 5000 MW for ( ) hours

(3) Load > 3000 MW for ( ) hours

3000 < Load < 5000 for ( ) hours

Optimum Mix through Screening Curve and Load-Duration Curve

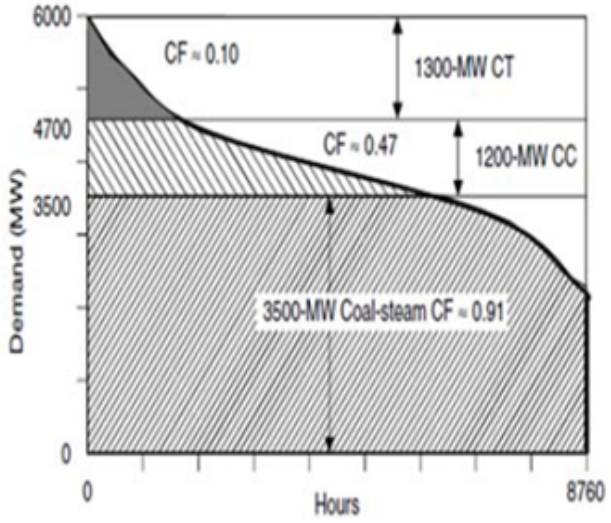
- Determination of on **optimum mix** of power plants
- Crossover Points for the first Cut Estimate of Generation Mix



Generation Mix – Example/Handout

Generation Mix Handout

Using the Generation mix and cost table, fill the boxes for each of the generation types.



Generation Type	Rated Power (MW)	CF	Fixed Cost ($M/yr)	Variable Costs ($/kWh)
Coal-Steam	3500	0.91	784.0	0.0189
Combine-Cycle (CC)	1200	0.47	115.2	0.0390
Combustion Turbine (CT)	1300	0.10	83.2	0.0556

(a) Coal:

Cost Items	Amount	Unit
Annualized Fixed Cost		[$/yr]
Annualized Variable Cost		[$/yr]
Total Annualized Cost = Annualized Fixed Cost + Annualized Variable Cost		[$/yr]
Eout = Rated Power * CF * 8760 hours		[kWh/yr]
Electricity Cost = Total Annualized Cost / Eout		[$/kWh]

(b) Combined Cycle

Cost Items	Amount	Unit
Annualized Fixed Cost		[$/yr]
Annualized Variable Cost		[$/kWh]
Total Annualized Cost = Annualized Fixed Cost + Annualized Variable Cost		[$/kW]
Eout = Rated Power * CF * 8760 hours		[kWh/yr]
Electricity Cost = Total Annualized Cost / Eout		[$/kWh]

(c) Combustion Turbine

Cost Items	Amount	Unit
Annualized Fixed Cost		[$/yr]
Annualized Variable Cost		[$/kWh]
Total Annualized Cost = Annualized Fixed Cost + Annualized Variable Cost		[$/kWh]
Eout = Rated Power * CF * 8760 hours		[kWh/yr]
Electricity Cost = Total Annualized Cost / Eout		[$/kWh]

CF and Generation Mix -Example

- Coal Steam

Generation Type	Rated Power (MW)	CF	Fixed Cost ($M/yr)	Variable Costs ($/kWh)
Coal-Steam	3500	0.91	784.0	0.0189
Combine-Cycle (CC)	1200	0.47	115.2	0.0390
Combustion Turbine (CT)	1300	0.10	83.2	0.0556

COAL

$CF := 0.91 = 0.91$

$RatedPower := 3500 \cdot 10^3$ kW

$N := RatedPower = 3.5 \cdot 10^6$

$AnnFixedCost := 784 \cdot 10^6$ $/yr

Note - price is NOT given as per kW
Instead the fixed cost is given
for the entire Rated Power

$VarCost := 0.0189$ $/kWh

$H := 8760 \cdot CF = 7971.6$

$AnnVarCost := N \cdot VarCost \cdot H = 5.273213 \cdot 10^8$ $/yr

$AnnTotalCost := AnnFixedCost + AnnVarCost = 1.311321 \cdot 10^9$ $/yr

$AnnEout := N \cdot 8760 \cdot CF = 2.7901 \cdot 10^{10}$ kWh / yr

$Ecost := \frac{AnnTotalCost}{AnnEout} = 0.047$ $/kWh

Cost Items	Amount	Unit
Annualized Fixed Cost		[$/yr]
Annualized Variable Cost		[$/yr]
Total Annualized Cost = Annualized Fixed Cost + Annualized Variable Cost		[$/yr]
Eout = Rated Power * CF * 8760 hours		[kWh/yr]
Electricity Cost = Total Annualized Cost / Eout		[$/kWh]

CF and Generation Mix -Example

- Combined-Cycle (CC)

Generation Type	Rated Power (MW)	CF	Fixed Cost ($M/yr)	Variable Costs ($/kWh)
Coal-Steam	3500	0.91	784.0	0.0189
Combine-Cycle (CC)	1200	0.47	115.2	0.0390
Combustion Turbine (CT)	1300	0.10	83.2	0.0556

CC

$CF := 0.47$

$RatedPower := 1200 \cdot 10^3$ kW

$AnnFixedCost := 115.2 \cdot 10^6$ $/yr

$N := RatedPower = 1.2 \cdot 10^6$

Note - price is NOT given as per kW
Instead the fixed cost is given
for the entire Rated Power

$VarCost := 0.039$ $/kWh

$H := 8760 \cdot CF = 4117.2$

$AnnVarCost := N \cdot VarCost \cdot H = 1.9268 \cdot 10^8$ $/yr

$AnnTotalCost := AnnFixedCost + AnnVarCost = 3.0788 \cdot 10^8$ $/yr

$AnnEout := N \cdot 8760 \cdot CF = 4.9406 \cdot 10^9$ kWh / yr

$Ecost := \frac{AnnTotalCost}{AnnEout} = 0.0623$ $/kWh

Cost Items	Amount	Unit
Annualized Fixed Cost		[$/yr]
Annualized Variable Cost		[$/yr]
Total Annualized Cost = Annualized Fixed Cost + Annualized Variable Cost		[$/yr]
Eout = Rated Power * CF * 8760 hours		[kWh/yr]
Electricity Cost = Total Annualized Cost / Eout		[$/kWh]

CF and Generation Mix -Example

- Combined-Cycle (CC)

Generation Type	Rated Power (MW)	CF	Fixed Cost ($M/yr)	Variable Costs ($/kWh)
Coal-Steam	3500	0.91	784.0	0.0189
Combine-Cycle (CC)	1200	0.47	115.2	0.0390
Combustion Turbine (CT)	1300	0.10	83.2	0.0556

CC

$CF := 0.47$

$RatedPower := 1200 \cdot 10^3$ kW

$AnnFixedCost := 115.2 \cdot 10^6$ $/yr

$N := RatedPower = 1.2 \cdot 10^6$

Note - price is NOT given as per kW
Instead the fixed cost is given
for the entire Rated Power

$VarCost := 0.039$ $/kWh

$H := 8760 \cdot CF = 4117.2$

$AnnVarCost := N \cdot VarCost \cdot H = 1.9268 \cdot 10^8$ $/yr

$AnnTotalCost := AnnFixedCost + AnnVarCost = 3.0788 \cdot 10^8$ $/yr

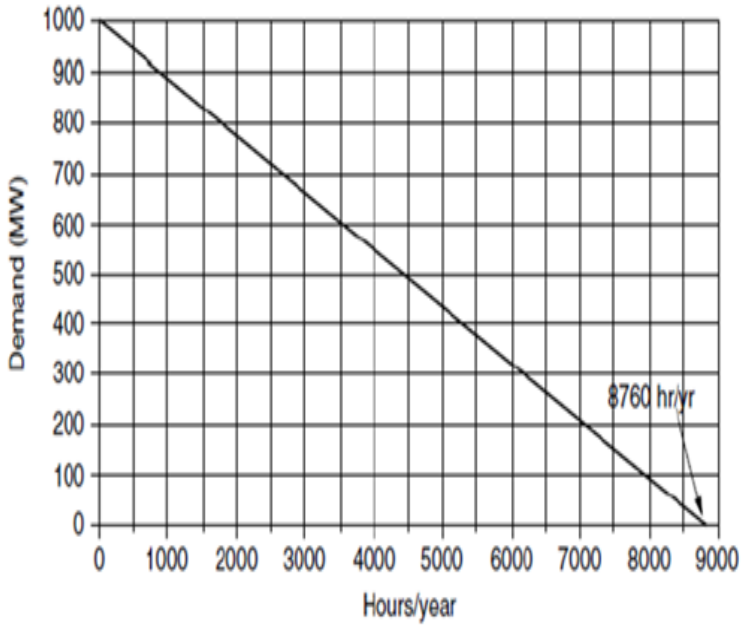
$AnnEout := N \cdot 8760 \cdot CF = 4.9406 \cdot 10^9$ kWh / yr

$Ecost := \frac{AnnTotalCost}{AnnEout} = 0.0623$ $/kWh

Cost Items	Amount	Unit
Annualized Fixed Cost		[$/yr]
Annualized Variable Cost		[$/yr]
Total Annualized Cost = Annualized Fixed Cost + Annualized Variable Cost		[$/yr]
Eout = Rated Power * CF * 8760 hours		[kWh/yr]
Electricity Cost = Total Annualized Cost / Eout		[$/kWh]

Generation Mix and Electricity Cost - Homework

A utility company has the following very simplified load duration curve.

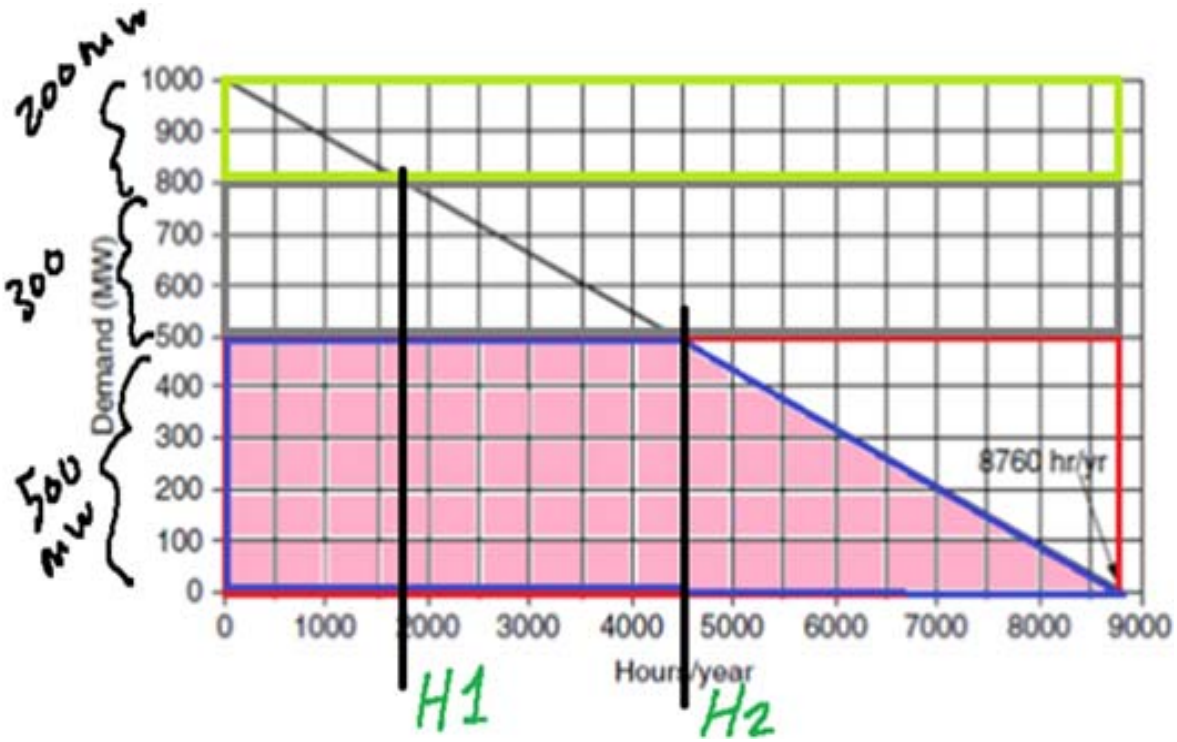


To serve the customers, the company runs 3 power plants: 500 MW coal-steam to cover the base load, 300 MW combined-cycle for the intermediate load, and 200 MW gas turbine for the peak load. The cost parameters of the power plants are as shown below. The fixed charge rate (FCR) for the capital cost is 0.16 per year.

Generation Type	Capital Cost ($/kW)	Heat Rate (Btu/kWh)	Fuel Cost ($/M Btu)	Variable Costs ($/kWh)
Coal-Steam	1,400	9,700	1.50	0.0043
Combined-Cycle	600	7,700	4.50	0.0037
Gas Turbine	600	9,100	4.50	0.0050

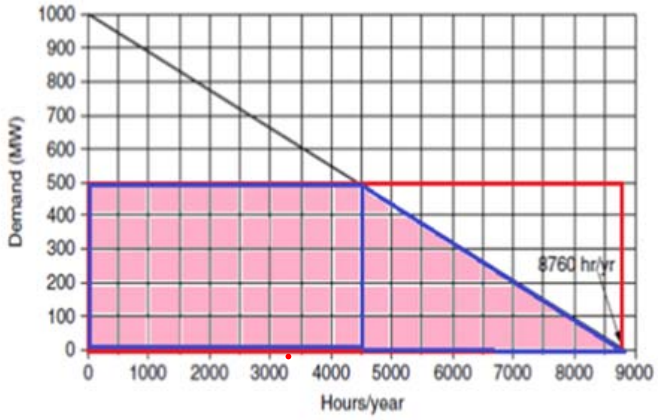
Q) Fill out the table below. Show your works.

Generation Type	CF	Annualized Fixed Cost ($/Yr)	Annualized Variable Cost ($/Yr)	Total Annualized Cost ($/yr)	Annual Generation (kWh/yr)	Electricity Cost ($/kWh)
Coal-Steam						
Combined-Cycle						
Gas Turbine						
Overall Company						


200 MW
300
500 MW
Demand (MW)
1000
900
800
700
600
500
400
300
200
100
0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
8760 hr/yr
Hours/year
H1
H2

Solution for Coal

$$H(L) := \frac{8760}{1000} \cdot (1000 - L)$$



COAL

$RatedPower := 500 \cdot 10^3$ kW

$HeatRate := 9700$

$N := RatedPower$

$CapitalCost := 1400$

$FCR := 0.16$

$H2 := H(500) = 4380$

$FuelCost := 1.5 \cdot 10^{-6}$

$OM := 0.0043$

$$CF := \frac{N \cdot H2 + \frac{N \cdot (8760 - H2)}{2}}{N \cdot 8760} = 0.75$$

$HOUR := CF \cdot 8760 = 6570$ Number of operation hours (Calc from CF)

$AnnFixedCost := N \cdot CapitalCost \cdot FCR = 1.12 \cdot 10^8$ $/yr

$AnnVarCost := N \cdot (FuelCost \cdot HeatRate + OM) \cdot HOUR = 6.192225 \cdot 10^7$ $/yr

$TotalAnnCost := AnnFixedCost + AnnVarCost = 1.739223 \cdot 10^8$ $/yr

$AnnE := N \cdot 8760 \cdot CF = 3.285 \cdot 10^9$ kWh/yr

$$Ecost := \frac{TotalAnnCost}{AnnE} = 0.052944$$ $/kWh

Generation Type	CF	Annualized Fixed Cost ($/Yr)	Annualized Variable Cost ($/Yr)	Total Annualized Cost ($/yr)	Annual Generation (kWh/yr)	Electricity Cost ($/kWh)
Coal-Steam						
Combined-Cycle						
Gas Turbine						
Overall Company						