# UCC501 Homework 2 Solutions

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## 1 Energy Scales, CO2 Emissions and Renewables

### 1.1 Energy Scales

- Natural gas consumption year 2012: in Billion Cubic Feet: 2235.169.
- For natural gases btu we have

$$1cf \rightarrow 1027Btu \tag{1}$$

  source: http://www.aga.org/KC/ABOUTNATURALGAS/ADDITIONAL/Pages/HowtoMeasureNaturalGas.aspx, use MATLAB to convert units, we have

$$2012\ Yearly\ btu \ = \ 2235.169 * 10^9 * 1027 \tag{2}$$

  Evaluate the equation we get $2.2955 * 10^{15}$ $Btu$, divided by millions we get $2.2955 * 10^9$ $MBtu$.

- From this unit conversion site http://www.eia.gov/cfapps/ipdbproject/docs/units.cfm we have

$$MTOE \ = \ MBtu * 0.02520 * 10^{-6} \tag{3}$$

  Evaluate the above equation we have $57.8471 MTOE$

- Similarly we have $1MBtu = 1.05506 * 10^9 Joules$ and $1KWh = 3.6 * 10^6 Joules$, thus

  $$2012\ Yearly\ GKWh = 2.2955 * 10^9 * 1.05506 * 10^9 / (3.6 * 10^6 * 10^9) \quad (4)$$

  Evaluate the above equation we have 672.7527 $GKWh$

## 1.2 CO2 Emissions

- Assume complete combustion, we have 2235.169 $Bcf$ natural gas burned in UAE for year 2012. Assume under normal temperature and pressure the natural gas is measured, we google the bold texts **natural gas density** and get the following:

  ```
  Density
  0.656 g/L at 25 C, 1 atm; 0.716 g/L at 0 C, 1 atm;
  0.42262 g cm3; (at 111 K)
  ```

  Since we assume normal density, we use $\rho = 0.656g/L = 656kg/m^3$. Thus we have the total mass of CO2 burned in year 2012

  $$Mass\ of\ CH_4 = 4.1525 * 10^{13} kg \quad (5)$$

  Since the background is complete combustion, from chemistry we have

  $$CH_4 + 2O_2 = CO_2 + 2H_2O \quad (6)$$

  and introduce a concept from chemistry, **molecular weight** we have

  $$Mass\ of\ CO_2 = m_{CH_4} * \frac{M_{CO_2}}{M_{CH_4}} \quad (7)$$

  where $m_{CH_4}$ is the mass, the $M_{CH_4}$ is the molecular weight. This equation is deducted by **carbon equilibrium** under complete combustion. Evaluate equation (7) we have $m_{CO_2} = 1.1419 * 10^{14} kg$

## 1.3 Renewables

Since we mentioned **in total** in the question, my answer would follow the *total* CO2 generated by burning natural gas.

Thus $m1_{co_2} = 0.05 * m_{CO_2}$, evaluating it we have $m1_{co_2} = 5.7097 * 10^{12} kg$.

- Set the size of such solar plant is $x\ MW$, then from **Energy Conservation Law** we have

$$Energy_{solar} = Energy_{gas\ useful} * 0.05 \tag{8}$$

- For energy generated by a solar plant's lifetime, we have

$$E_{solar} = x * 3.6 * 10^9 * 1700 * 25 \tag{9}$$

- For energy generated by burning natural gas, we have the secondary energy as follows:

$$E_{gas_useful} = E_{gas} * 0.40 * 0.92 \tag{10}$$

  The $E_{gas}$ can be calculated and/or converted from the above. Because we get 2012 yearly gas btu $2.2955 * 10^{15}$, convert that to Joule unit

$$E_{gas} = 2.2955 * 10^9 * 1.05506 * 10^9 \tag{11}$$

  Put all these values into (8) we have $x = 291.2624$. Thus the size of such a plant is $291.2624 \simeq 300\ MW$. (I put 300MW here for *industrial term*.)

# 2 Economic Analysis

## 2.1 LCOE Calculation

From section 1 we have the scale of solar farm is close to 300MW. So to be practical we here use `Scale = 300MW`.

- The whole calculation is done through MATLAB programming, therefore, to save pages, we do not repeat the values. We list relevant equations here.

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$$Total\ Capital\ Cost = Unit\ Capital\ Cost * Solar\ Farm\ Scale \tag{12}$$

- From the values we have, we can use WACC as a **pretty rough** estimation of **project annual discount rate**. It is also listed in the UAE bureau of statistics the expected CPI of next 5 years, we would like to do another estimate adding this value, if possible.

$$WACC = (debt\ return * debt\ ratio) + (equity\ return * equity\ ratio) \tag{13}$$

- The remaining part of question is self-evident in the codes as can be seen in the reference link. Following the program, we have

$$Levelized\ cost = 0.0412\ \$/KWh \tag{14}$$

## 2.2 IRR Calculation

There is something wrong either with the question or with my calculation. But I followed the slides so...Well, this is Masdar.

# 3 Vehicle Kinetics

## 3.1 Propulsion Power

- From the question we have all the values needed, so just evaluate the equation we have $P_v = 6.2321 * 10^3\ W$. The whole calculation code is shown in reference as well as the link.

## 3.2 Annual Vehicle Energy Consumption

- For this question I tried to replace the $d$ (distance between stops) with $40,000\ Km$ but it did not work out as expected. Therefore we need to consider this problem in a *macro* scale.

- Since the given mass is $1440Kg$ we can infer that the type of engine is a $2.5L$ one. From the manual and Wikipedia[1] we have the combined fuel consumption of around $8L/100Km$. Moreover, we can get the standard reference density of marketable gasoline $0.755Kg/L$.

- The rest part is and only is calculation, and that is reflected in the source code.

[1] `http://en.wikipedia.org/wiki/Toyota_Camry_(XV50)`

# 4 Reference