Week 6: Energy and Climate Change Part: I: Tutorial activities

In-class activity

Part A

Question 1: Energy Conversion Part 1 (Non-Renewable Resource)

Suppose you are an analyst at the Energy Market Authority in Singapore. You have been tasked by the Energy Market Authority to present the annual costs of energy consumption per capita based on a variety of energy sources.

Your research found the useful table "Energy Conversion Factor" while your team of co-workers highlighted that the estimated annual energy consumption per capita is 77.9 Btu and presented to you the costs associated with each energy source.

In the following table, you should present the annual costs differences in supplying one's needs based on the following types of fuels used, namely: (a) crude oil, (b) gasoline, (c) diesel, (d) natural gas, (e) coal and (f) direct electricity.

Using the energy conversion factor, calculate the annual cost in S$ of each of the following fuels required to supply 77.9 million Btu (average annual energy consumption per capita).

Note: Attempt the exercise while paying extra attention to the various forms of conversions across different units, as energy trades globally use USA's imperial system conversions to the metric system might be tricky (e.g., 1 Short Ton = 0.907 Metric Ton).

Fill in the following table:

Use conversion rate of US $1 = SG$ 1.41.

Energy Source	Price per unit (USD)	Amount Required	Annual Cost (SGD)
Crude Oil (Barrel)	US$119.21/barrel	13.43 (Barrel)	
Gasoline (Retail)	US$532.58/barrel	14.95 (Barrel)	
Gasoline (Wholesale)	US$154.98/barrel	14.95 (Barrel)	
Diesel (Retail)	US$11.81 /gallon	623.20 (Gallon)	
Diesel (Wholesale)	US$3.94/gallon	623.20 (Gallon)	
Natural Gas	US$6,720.29/MCF	0.08 (Million Cubic Feet)	
Coal	US$364.44/ST	3.75 (Short Ton)	
Electricity	US$0.21/kWh	22831.18 kWh	

What do you notice based on your calculations?

- Which energy/fuel source was the priciest and cheapest annually?
    - *Based on the calculations, natural gas is the cheapest.*

- Given a choice, what kind of energy source will you opt for as a consumer?

- *From a consumer's perspective, students will most likely pick the cheapest option (natural gas) for their energy consumption.*

- Think about the steps you took to calculate costs. Can you explain some basic determinants of the price of energy?
  - *Students were required to consider energy output/efficiencies and costs.*

- Why is there a discrepancy between wholesale and retail prices?
  - *Gasoline and diesel were separated into wholesale and retail costs which are indicative of supply-chain and distribution costs.*

Answers: Working out the figures

Based on the amounts required in the about table, calculate the costs. The costs need to be converted to SGD for the final answer. We standardize the currency exchange as (US$1 = SG$1.41).

Energy Source	**Price per unit (USD)**	**Amount required**	**Working [Price per unit x Amount required x 1.41 (USD to SGD]**	**Annual Consumer Price (SGD)**
Crude Oil (Barrel)	US$119.21	13.43 (Barrel)	119.21 x 13.43 x 1.41	SG$2,257.40
Gasoline (Barrel)	US$532.58 (retail) US$154.98 (wholesale)	14.95 (Barrel)	532.58 x 14.95 x 1.41 154.98 x 14.95 x 1.41	SG$7,962.01 SG$3,266.90
Diesel (Gallon)	US$11.81 (retail) US$3.94 (wholesale)	623.20 (Gallon)	11.81 x 623.20 x 1.41 3.94 x 623.20 x 1.41	SG$10,377.59 SG$3,462.13
Natural Gas (Million Cubic Feet)	US$6,720.29	0.08 (Million Cubic Feet)	6,720.29 x 0.08 x 1.41	SG$758.05
Coal (Short Ton)	US$364.44	3.75 (Short Ton)	364.44 x 3.75 x 1.41	SG$1926.98
Electricity (kWh)	US$0.21	22831.18	0.21 x 22831.18 x 1.41	SG$6,760.26

Question 2: Alternative Sources of Energy (Renewable Resource – Solar Power)

Now that you have examined examples of energy sources stemming from non-renewable resources, the Energy Market Authority wants you to consider the feasibility of harnessing solar power in Singapore.

Taking into account the following information: (a) a typical solar panel can produce 150 Watt peak (Wp) per m^2, (b)a 10 kWp solar panel system costs S$20,000 and (c) 1 KWp is estimated to produce about 1000 kWh per year.

(a) Estimate the size and cost of installing solar panels to supply 22.83 MWh (77.9 million Btu)? Compare the investment costs in solar panels versus the costs of electricity. How long will it take for consumers to break even?
(b) Given that Singapore's population is 5.943 million, estimate the total land size needed to meet her energy demands. How do the figures match up to Singapore's land size at 728.6 million m^2? In your opinion, will Singapore be able to pursue solar power as an adaptation to her energy demands?

Working out the figures – (a)

	Working	**Output**
Solar power required	22.83 / 1	22.83 kWp
Size Required	22.83 x 1000 / 150	152.2m^2
Installation costs	22.83 / 10 x S$20,000	S$45, 660
Taking that electricity costs for natural gas is S$758.05 per annum	Breakeven = 45,600 / 6, 760.26	= 6.75 years

- *Do you think that this is a worthwhile investment for solar panels with breakeven figures at 6.75 years?*
- *Are there any costs that we are neglecting? (e.g., maintenance etc)*

Working out the figures – (b)

	Working	**Output**
Total size required	152.2m^2 x 5 843 000	904.52 million m^2

Points of discussion:

- *The size required for solar panels exceeds Singapore's land size.*
- *Should Singapore abandon the use of solar power – especially when it is the most feasible renewable energy source that can be implemented in Singapore? (View the following points below)*

Question 3: Carbon Tax Charge

Carbon Tax Charge is the most efficient & effective mitigation tool to combat climate change & reduce air pollution (IMF).

The amount of Carbon Tax Charge (CTC) can be estimated as:

CTC = Electricity used x GEF-OM x Carbon Tax Rate

where Electricity used is based on metered consumption, GEF-OM refers to Grid Emission Factor – Average Operating Margin published by Energy Market Authority (EMA).

GEF is a measure of average CO_2 emission per unit of net electricity generated based on the average operating margin.

GEF-OM in 2020 = 0.4080 kg CO_2/kWh (0.4080 tCO2e/MWh)

Calculate the following:

	1-Room/2-Room	**3-Room**	**4-Room**	**5-Room & Executive**	**Commercial Building (35,000m^2)**
Electricity, kWh	171.4	288.7	395.6	482.2	215305.1
CTC* at 5/tCO2e					
CTC* at 25/tCO2e					
Tariff at 18 ¢/kWh					
Tariff at 30 ¢/kWh					

Working out the figures – (3)

Answers:

	1-Room/2-Room	**3-Room**	**4-Room**	**5-Room & Executive**	**Commercial Building (35,000m^2)**
Electricity, kWh	171.4	288.7	395.6	482.2	215305.1
CTC* at 5/tCO2e	$0.35	$0.59	$0.81	$0.98	$439.22
CTC* at 25/tCO2e	$1.75	$2.94	$4.04	$4.92	$2,196.11
Tariff at 18 ¢/kWh	$30.85	$51.97	$71.21	$86.80	$38,754.92

Tariff at 30 ¢/kWh	$51.42	$86.61	$188.68	$144.66	$64,591.54

Calculations:

1 – 2 Room
*Note, convert kWh to mWh CTC@5 = 0.1714 x 0.4080 x 5 = $0.35 CTC@25 = 0.1714 x 0.4080 x 25 = $1.75
*Note, prices are at kWh Tariffs@0.18 x 171.4 = $30.85 Tariffs@0.30 x 171.4 = $51.42

3-Room
*Note, convert kWh to mWh CTC@5 = 0.2887 x 0.4080 x 5 = $0.59 CTC@25 = 0.2887 x 0.4080 x 25 = $2.94
*Note, prices are at kWh Tariffs@0.18 x 288.7 = $51.97 Tariffs@0.30 x 288.7 = $86.61

4-Room
*Note, convert kWh to mWh CTC@5 = 0.3956 x 0.4080 x 5 = $0.81 CTC@25 = 0.3956 x 0.4080 x 25 = $4.04
*Note, prices are at kWh Tariffs@0.18 x 395.6 = $71.21 Tariffs@0.30 x 395.6 = $118.68

5-Room & Executive
*Note, convert kWh to mWh CTC@5 = 0.4822 x 0.4080 x 5 = $0.98 CTC@25 = 0.4822 x 0.4080 x 25 = $4.92
*Note, prices are at kWh Tariffs@0.18 x 482.2 = $86.80 Tariffs@0.30 x 482.2 = $144.66

Commercial
*Note, convert kWh to mWh CTC@5 = 215.305 x 0.4080 x 5 = $439.22 CTC@25 = 215.305 x 0.4080 x 25 = $2,196.11
*Note, prices are at kWh Tariffs@0.18 x 215305.1 = $38,754.92 Tariffs@0.30 x 215305.1 = $64,591.53

PART B: Open-ended discussions

Question 4: Unequal Impacts and Implications for Communities

(a) What are some constraints and barriers certain countries have in dealing with their energy needs?
(b) Find two relevant articles that illustrate these points.
(c) Can you think of any potential solutions to these problems?