



## FACULTY OF SCIENCE

### DEPARTMENT OF GEOGRAPHY, ENVIRONMENTAL MANAGEMENT & ENERGY STUDIES

**MODULE**      **ENS8X05**  
ENERGY MODELLING

**CAMPUS**      **APK**

**EXAM**          **NOVEMBER 2020**

**DATE**    9 NOVEMBER 2020

**SESSION**      08:30 – 16:30

**ASSESSOR(S)**

**DR KRISTY LANGERMAN**

**EXTERNAL MODERATOR**

**DR PHILIP GOYNS**

**DURATION**    8 HOURS

**MARKS**          200

**FORMAT: OPEN BOOK EXAM WRITTEN AT HOME**    **NUMBER OF PAGES: 8 PAGES**

Dr Kristy Langerman

Dr Philip Goyns

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### INSTRUCTIONS:

1. Please answer Question 1 (compulsory) and then answer any ONE of Questions 2-3. Two questions are to be answered in total.
2. The mark allocation is shown next to each question.
3. Answers are to be written on A4 white paper.

4. Write your student number and the course code/course name clearly at the top of the first page of your answers.
5. You may type your answers or write by hand. Hand drawn diagrams may be used to supplement answers.
6. If you type your answers, please use Arial 12 font and portrait mode A4 and save all your answers in one file.
7. Clearly number the answers to the questions.
8. Since the examination is open book, you are allowed to refer to course material.
9. The use of cell phones, email and/or the internet (except for Blackboard) during the examination period is NOT allowed.
10. Calculators are permitted.
11. There is to be no communication between students whatsoever between 08:00 and 17:30.
12. The only communication permitted between 08:00 and 17:30 is with the examiner.
13. No person may assist you in any way to answer the exam questions.
14. References are not required.
15. The following schedule must be adhered to:

Time	Action
08:00	Log on to Blackboard and find the exam question paper under Energy Modelling – Course Content – Exam: 9 November 2020. Read the question paper.
08:00-08:30	Email any questions for clarification to the examiner at <a href="mailto:klangerman@uj.ac.za">klangerman@uj.ac.za</a> . The examiner will respond to the questions in the order received.
08:30-16:30	Write or type your answers to the questions. (If typing, save your file every few minutes as you go along.)
16:30	Stop writing. Exam question paper will be removed from Blackboard.
16:30-17:30	If <b>typing</b> , ensure all your answers are saved in one file, in addition to the Excel spreadsheet.  If answers are <b>hand-written</b> , scan your answers. The best

	<p>way to do this is by downloading the (free) Adobe Scan app onto your cell phone. Scan your answers by taking a series of photographs of the pages with your phone (through the app) and saving as a pdf document.</p> <p>Upload your answers to Blackboard through the <b>Exam: 9 November 2020</b> link.</p> <p>If any technical problems with Blackboard are experienced, please email exam answers to <a href="mailto:klangerman@uj.ac.za">klangerman@uj.ac.za</a>.</p>
17:30	Deadline for uploading exam answers to Blackboard.

16. Exam answers will be subject to a plagiarism test. **Answers that are plagiarised, even in part, will receive zero.** The disciplinary process will be followed for those found guilty.
17. If any technical problems are experienced during the exam, please send a screen shot and email/whatsapp to Kristy Langerman ([klangerman@uj.ac.za](mailto:klangerman@uj.ac.za); 083 704 2543).

### QUESTION 1 (COMPULSORY)

[150]

You are intending to purchase a new car, and would like to base your decision on which car to buy on the cost and CO<sub>2</sub> emissions of the car. The three options that you are considering are:

- i) A conventional internal combustion engine (ICE) vehicle using petrol
- ii) A battery electric vehicle (BEV) that you will charge using grid electricity in South Africa
- iii) A hydrogen fuel cell vehicle (FCV), for which the hydrogen is produced by electrolysis with grid electricity in South Africa

Compare the costs and CO<sub>2</sub> emissions of the three vehicles over a 5-year period by following these steps:

- a. Articulate the problem posed by identifying the focus question, key variables, time horizon, base year and scenarios. [14]

- b. Construct a causal loop diagram to show three factors that affect the greenhouse gas emissions from a motor vehicle. Then explain in words how the factors that you have identified influence greenhouse gas emissions, with reference to the causal loop diagram [40]
- c. Construct a spreadsheet model in which you calculate:
  - a. Annual CO<sub>2</sub> emissions for each of the three vehicle technologies. For each of the technologies, tabulate the fuel/electricity input, equivalent energy input, energy output and annual CO<sub>2</sub> emissions. (HINT: Start by calculating the energy output for the ICE vehicle, and then assume that all three vehicles require the same energy output per km). [40]
  - b. Total cost of ownership of each vehicle over the 5-year period. Only consider fuel and net capital costs. [24]
- d. Create two graphs comparing CO<sub>2</sub> emissions and cost of ownership of the three vehicle technologies. [12]
- e. On the basis of your calculations, discuss which vehicle you would buy and motivate your choice. Is your decision based on a trade-off, and if so, motivate the trade-off? [8]
- f. Classify the model you constructed as deterministic/stochastic, and empirical/mechanistic, and motivate your answer. [6]
- g. Identify two externalities that are not included in the model, and explain briefly how they could be included. [6]

The input parameters and assumptions that you are to use in your calculations are as follows:

**Input and assumptions:**

1. You are intending to keep the car for 5 years and then sell it.
2. The car will drive for 20 000 km/year.
3. The ICE vehicle consumes 10 litres of petrol per 100 km.

4. The energy content of petrol is 0.033152 GJ/litre
5. CO<sub>2</sub> emission factors are:
  - a. Petrol: 69.3 kg/GJ
  - b. Grid electricity: 1.06 kg/kWh
6. The efficiencies of the vehicles are:
  - a. ICE vehicle: 30%
  - b. BEV: 75% (includes charging and electric motor efficiency)
  - c. FCV: 35% (includes hydrogen-to-electricity conversion and electric motor efficiency)
7. The efficiency of the production of hydrogen through hydrolysis (using grid electricity) is 70%. Do not consider any other inefficiencies in the transport of petrol or electricity.
8. All costs should be in 2020 Rand (do not consider inflation).
9. Input energy costs are:
  - a. Petrol: R14.50/litre
  - b. Electricity: R2.1/kWh
10. Cars lose 50% of their value over 5 years
11. The purchase prices of the new vehicles in 2020 South African Rand are:
  - a. ICE vehicle: R470 000
  - b. BEV: R700 000
  - c. FCV: R1 000 000
12. Conversion factors:
  - a. 1 MWh = 3.6 GJ

Answer any **ONE** of the following TWO questions:

## QUESTION 2

[50]

In an essay, describe the modelling approach that is used for the Integrated Resource Plan, considering the inputs, output, scenarios and exclusions.

**QUESTION 3****[50]**

Answer all components of this question. Answer section 2.3 with reference to China's energy balance table (Table 1)

- 2.1 Explain what the energy balance is, and why it underpins energy system models. [10]
- 2.2 Discuss the use of optimization in energy system modelling, and give two examples. [10]
- 2.3 Answer the following questions with reference to China's energy balance table for 2018 (Table 1):
- a) Is China a net importer or net exporter of energy? [2]
  - b) What proportion of China's primary energy supply is derived from coal? [4]
  - c) What energy source accounts for over 50% of China's energy imports? [2]
  - d) What energy source generates the second most electricity in China? [2]
  - e) What is the difference between total energy supply and total final consumption? Account for the difference in terms of the law(s) of thermodynamics. [6]
  - f) Which energy source/carrier has the highest losses, and why? [4]
  - g) What sector of the economy uses the most energy? [2]
  - h) Comment on the main energy sources used by the residential sector, and whether you consider this to be typical of a developed or developing country. [4]
  - i) What energy source is used most by the agriculture/forestry sector, and what do you think that energy source is used for? [4]

**TOTAL [200]**

**Table 1: Energy balance table for China for 2018** (source, IEA data and statistics, <https://www.iea.org/data-and-statistics/data-tables?country=CHINAREG&energy=Balances&year=2018>)

[illegible]

	Coal	Crude oil	Oil products	Natural gas	Nuclear	Hydro	Wind, solar, etc.	Biofuels and waste	Electricity	Heat	Total
Liquefaction plants	-10 573	5 815									-4 758
Other transformation											
Energy industry own use	-42 256	-3 082	-36 718	-30 113					-65 303	-13 390	-190 861
Losses		-476	-12	-2 668					-28 913	-1 212	-33 282
<b>Total final consumption</b>	<b>635 903</b>	<b>536</b>	<b>538 459</b>	<b>153 894</b>			<b>34 269</b>	<b>79 602</b>	<b>520 642</b>	<b>103 332</b>	<b>2 066 636</b>
Industry	495 570	536	45 681	65 460			482		320 591	69 351	997 672
Transport	2		290 492	22 269				2 311	12 162		327 235
Residential	45 329		43 877	41 301			26 626	77 286	85 253	27 042	346 713
Commercial and public services	17 122		16 387	14 599			5 606	3	38 439	2 806	94 962
Agriculture / forestry	13 790		18 884	111			1 472		10 914	34	45 204
Fishing											
Non-specified	18 776						82	3	53 283	4 100	76 243
Non-energy use	45 314		123 138	10 154							178 606