Exam “Energy & Economy” 0EM72, 20-01-2014, 9-12h

Please read these instructions first.

This exam consists of 5 main questions, each comprising several sub-questions. Total number of pages is 9. Each main exam question can earn you a maximum of 20 points.

The total time for the exam is 3 hours for all students.

Laptops, notes, books etc not allowed during the exam. You may use a calculator.

Students who have not passed any assignments should complete the full exam. This exam will count for 100% of your final course grade.

Students who have completed assignment 1 with a pass grade may skip question 5. This exam will count for 80% of your final course grade, and the grade of assignment 1 will count for the remaining 20%.

Students who have completed assignment 2 with a pass grade may skip question 4. This exam will count for 80% of your final course grade, and the grade of assignment 2 will count for the remaining 20%.

Students who have passed assignments 1 and 2, may thus skip both questions 4 and 5. This exam will count for 60% of your final course grade, and the grades for assignments 1 & 2 will count for the remaining 40%.

However, if you have passed assignment 1 and or 2, but you still want to score a higher grade for those course components, you are welcome to complete the questions pertaining to assignment 1 (= Q5) and/or assignment 2 (=Q4). The highest-scoring attempt will then count towards your final grade.

Question 1

[a 4 pt; b 6 pt; c 6 pt; d 4 pt]

Please refer to the two tables on the following pages, which show the Energy Balances of Indonesia for 1990 and 2010 respectively, in thousand tonnes of oil equivalent (ktoe).

a) According to Bhattacharyya (Chapter 2), a disadvantage of using "tonnes of oil (or coal) equivalent" in Energy Balances is that this measurement unit is rather imprecise. He discusses another unit of measurement called "tonnes of oil (or coal) replacement". Explain in what way(s) this tor/tcr measure is more precise than toe/tce.

b) Looking at the figures in the top section (PES) of the two tables, what do you conclude about main trend(s) in the energy supply mix in Indonesia over the period 1990-2010? Calculate some relevant statistics to support your argument, and discuss possible implications of the trends you identified for Indonesia's national energy security.

c) The total Gross Domestic Product (GDP) and the population of Indonesia in 1990 and 2010 were as follows:

	GDP	population
2010	377.80 (in billion US$, valued at 2005 prices)	239.87 million
1990	150.09 (in billion US$, valued at 2005 prices)	184.35 million

Combining (some) of these data with data from the Energy Balance tables, what can you say about trends in energy intensity in Indonesia over the period 1990-2010?

d) Changes in national energy intensity are usually analysed by means of so-called decomposition analysis. Briefly describe this technique and list the three main components that can cause changes in energy intensity over time.

Indonesia: Balances for 1990

in thousand tonnes of oil equivalent (ktoe) on a net calorific value basis

1990 ▾ | Indicators | Balances | Coal and Peat | Electricity and Heat | Natural Gas | Oil | Renewables and Waste

	Coal and peat	Crude oil	Oil products	Natural gas	Nuclear	Hydro	Geothermal, solar, etc.	Biofuels and waste	Electricity	Heat	Total*
Production	5847	74589	0	42099	0	491	1934	43549	0	0	168509
Imports	426	6521	2905	0	0	0	0	0	0	0	9852
Exports	-2724	-38849	-10959	-26295	0	0	0	-50	0	0	-78877
International marine bunkers**	0	0	-533	0	0	0	0	0	0	0	-533
International aviation bunkers**	0	0	-325	0	0	0	0	0	0	0	-325
Stock changes	0	0	-3	0	0	0	0	0	0	0	-3
TPES	3549	42261	-8915	15804	0	491	1934	43499	0	0	98623
Transfers	0	-2468	2729	0	0	0	0	0	0	0	262
Statistical differences	917	1262	-487	-1057	0	0	0	0	0	0	636
Electricity plants	-2324	0	-3967	-210	0	-491	-1934	0	2809	0	-6117
CHP plants	0	0	0	0	0	0	0	0	0	0	0
Heat plants	0	0	0	0	0	0	0	0	0	0	0
Gas works	0	0	0	0	0	0	0	0	0	0	0
Oil refineries	0	-38901	37758	0	0	0	0	0	0	0	-1143
Coal transformation	-16	0	0	0	0	0	0	0	0	0	-16
Liquefication plants	0	0	0	0	0	0	0	0	0	0	0
Other transformation	0	0	0	0	0	0	0	-1507	0	0	-1507
Energy industry own use	0	0	-2029	-8197	0	0	0	0	-103	0	-10329
Losses	0	0	0	-318	0	0	0	0	-274	0	-592
Total final consumption	2127	2154	25090	6022	0	0	0	41992	2433	0	79817
Industry	2127	0	5539	1928	0	0	0	7245	1251	0	18090
Transport	0	0	10711	0	0	0	0	0	0	0	10712
Other	0	0	7715	18	0	0	0	34747	1182	0	43662
Residential	0	0	6158	5	0	0	0	34682	783	0	41627
Commercial and public services	0	0	320	13	0	0	0	65	400	0	798
Agriculture / forestry	0	0	991	0	0	0	0	0	0	0	991
Fishing	0	0	0	0	0	0	0	0	0	0	0
Non-specified	0	0	246	0	0	0	0	0	0	0	246
Non-energy use	0	2154	1124	4075	0	0	0	0	0	0	7353
-of which petrochemical feedstocks	*0*	*2154*	*440*	*4075*	*0*	*0*	*0*	*0*	*0*	*0*	*6669*

Indonesia: Balances for 2010

in thousand tonnes of oil equivalent (ktoe) on a net calorific value basis

2010 | Indicators | Balances | Coal and Peat | Electricity and Heat | Natural Gas | Oil | Renewables and Waste

	Coal and peat	Crude oil	Oil products	Natural gas	Nuclear	Hydro	Geothermal, solar, etc.	Biofuels and waste	Electricity	Heat	Total*
Production	166328	49442	0	74741	0	1501	16088	54328	0	0	381429
Imports	37	19954	25955	0	0	0	0	0	0	0	45945
Exports	-135882	-17783	-5232	-35952	0	0	0	-290	0	0	-215140
International marine bunkers**	0	0	-178	0	0	0	0	0	0	0	-178
International aviation bunkers**	0	0	-680	0	0	0	0	0	0	0	-680
Stock changes	0	266	-350	0	0	0	0	3	0	0	-82
TPES	**30483**	**50879**	**19515**	**38789**	**0**	**1501**	**16088**	**54041**	**0**	**0**	**211296**
Transfers	0	-1868	2066	0	0	0	0	0	0	0	199
Statistical differences	1112	140	1544	-835	0	0	0	-1	97	0	2058
Electricity plants	-18826	0	-8188	-8642	0	-1501	-16088	-40	14504	0	-39081
CHP plants	0	0	0	0	0	0	0	0	0	0	0
Heat plants	0	0	0	0	0	0	0	0	0	0	0
Gas works	0	0	0	0	0	0	0	0	0	0	0
Oil refineries	0	-47313	47133	0	0	0	0	0	0	0	-180
Coal transformation	-1	0	0	0	0	0	0	0	0	0	-1
Liquefaction plants	0	0	0	0	0	0	0	0	0	0	0
Other transformation	0	0	0	0	0	0	0	-664	0	0	-664
Energy industry own use	0	0	-2175	-9740	0	0	0	0	-504	0	-12419
Losses	0	0	0	-3723	0	0	0	0	-1372	0	-5095
Total final consumption	**12768**	**1838**	**59596**	**15849**	**0**	**0**	**0**	**53336**	**12726**	**0**	**156113**
Industry	**12768**	**0**	**10402**	**11786**	**0**	**0**	**0**	**6331**	**4405**	**0**	**45692**
Transport	**0**	**0**	**35791**	**10**	**0**	**0**	**0**	**174**	**0**	**0**	**35975**
Other	**0**	**0**	**10616**	**151**	**0**	**0**	**0**	**46832**	**8321**	**0**	**65920**
Residential	0	0	6208	19	0	0	0	46630	5169	0	58025
Commercial and public services	0	0	1087	132	0	0	0	202	3152	0	4574
Agriculture / forestry	0	0	2965	0	0	0	0	0	0	0	2965
Fishing	0	0	0	0	0	0	0	0	0	0	0
Non-specified	0	0	356	0	0	0	0	0	0	0	356
Non-energy use	**0**	**1838**	**2787**	**3902**	**0**	**0**	**0**	**0**	**0**	**0**	**8527**
-of which petrochemical feedstocks	*0*	*1838*	*2323*	*3902*	*0*	*0*	*0*	*0*	*0*	*0*	*8063*

* Totals may not add up due to rounding

** International marine and aviation bunkers are included in transport for world totals

Question 2

[a 2 pt; b 2 pt; c 6 pt; d 5 pt; e 5 pt]

The load duration curve is a useful tool for the efficient management of an electricity system.

a) Draw a stylized load duration curve with its typical shape, indicating base, intermediate and peak load.

b) Based on the load duration curve, the system-wide load factor can be determined. What is meant by this concept? Give a formula and/or illustrate graphically.

c) Different algorithms (decision methods) can be used by system operators to try to maximize the system-wide load factor in an energy system. Discuss two of these algorithms briefly.

d) Below is a graph of aggregated energy bids and offers during a one-hour period at the Amsterdam Power Exchange. Redraw this graph under the assumption of a much larger energy supply from wind and solar systems.

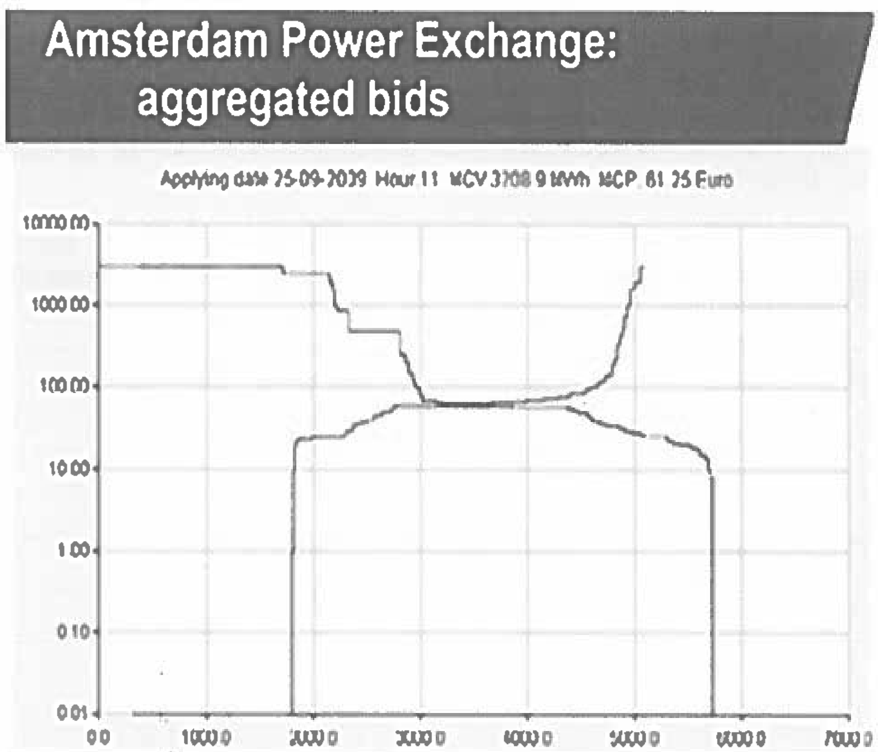

Figure 1: APX aggregated bids example (5P435 college sheet)

e) Explain the principle of marginal cost pricing. If marginal cost-pricing is used on the Amsterdam Power Exchange, what will be the effect of a major increase in supply from wind and solar systems on the revenues received by the *non*-renewable plant operators, and on their capacity utilisation ratio? Also discuss the concept of capacity payments in this connection.

Question 3

[a 5 pt; b 5 pt; c 5 pt; d 5 pt]

In the overview of the development of the world's energy system, 5 crucial phases in the history of energy were distinguished. In each of these phases, new ways to exploit and use energy are discovered and diffused, followed by problems and limits, and attempts to overcome these problems and limits. The start of success of these attempts heralds the beginning of a new phase.

a) Describe how this process operated and what it involved concretely in one of the phases. Which energy source(s) was/were in dominant use for which purposes, which limitations/problems arose, and which innovations occurred to overcome these limitations?

b) The dynamics of this process give support to the view expressed by (most) economists that limitations to energy resources will always be overcome by new energy innovations. They argue that this will always happen because of high/rising energy prices due to increasing scarcity of the existing energy resources. However, others (geologists, environmental scientists, some engineers) dispute the validity of this view for the long term. Explain the essence of their reasoning.

c) The people who dispute the universal validity of the innovation mechanism in Qb promote the use of the EROI (or EROEI) as an alternative tool to assess the social desirability of new energy investments projects, instead of the conventional technique of Cost-Benefit Analysis favoured by economists. Briefly explain the key differences between these two techniques.

d) The processes in the five historical phases are full of rebound effects. Explain what is meant by this concept, and give a brief historical illustration of a rebound effect, e.g. from Fouquet's article.

Question 4

[a 4 pt; b 4 pt; c 6 pt; d 6 pt]

a) What is the main rationale behind the liberalisation of energy markets undertaken in many countries from the 1980s/90s onwards?

b) Briefly discuss the 4 main aspects involved in energy market liberalisation.

c) "Market failure" is a major reason why the expected benefits from liberalisation are not always being realised in practice. What is meant by this concept? Illustrate your point with one example that is relevant to a developed country context (e.g. USA or Germany) and one example that is especially relevant to a rural area in a developing country.

d) In discussing the scope for (and barriers on) diffusion of renewable energy technologies (RETs) in developing countries, Painuly distinguishes between technologies with technical potential, techno-economic potential, economic potential, and market potential. What are the essential differences between these 4 different types of potentials?

Question 5

[a 3 pt; b 7 pt; 5 pt; d 5 pt]

A South African team of researchers has investigated the feasibility of various investments for increasing energy efficiency in various poor public housing estates. Their overall key results, based on the Net Present Value (NPV) criterion, are displayed in the figure below.

Cost–benefit analysis of energy efficiency in urban low-cost housing 597

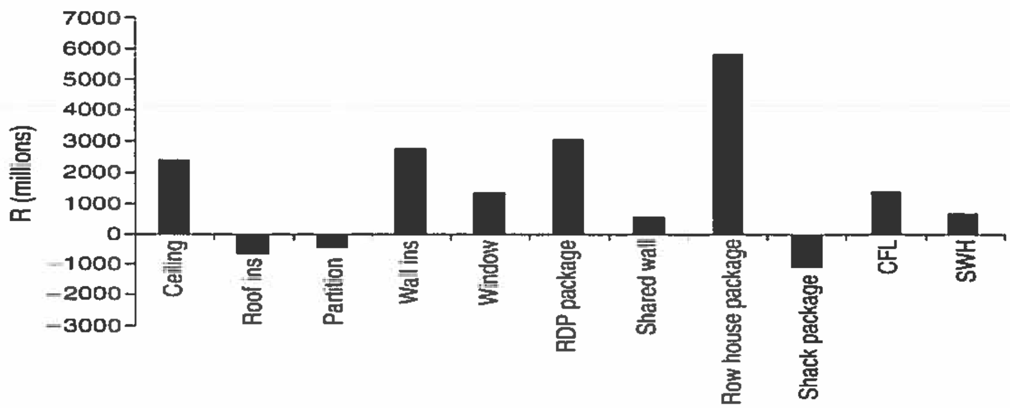

Figure 1: NPV of energy-efficiency interventions nationally, assuming social discount rate and including externalities (1999 Rands)

a) The results displayed above pertain to a *socio-economic (societal)* cost benefit analysis. In which respects does this differ from a *financial* cost-benefit analysis?

b) In your opinion, do the NPVs given above, along with the fact that all the suggested investment measures have the same time-horizon of 50 years, provide sufficient information for a government decision maker to draw up an unambiguous investment priority ranking, or not? Motivate your answer. [nb: any need for replacement of equipment/materials in the course of the 50 year time period have been fully taken into account in the NPV estimates].

The estimated *private* costs and benefits of a 100 l. household solar water heater with a 1.8 m.sq. collector are given in the table below (in S. African Rands). It is assumed (to make calculations less onerous for you) that the lifetime is only 5 years, but that the household will resell the installation at the end of 5 years for half of its new value. All values are in constant prices of the initial investment year.

	SWH cost	Comments
Initial investment + installation costs	5000	Includes the costs of back up facility for times when the SWH does not yield sufficient hot water.
Life	5 years	
Remaining resale value after 5 years	2500	
Energy savings	60% of conventional electric water heating	Conventional electric water heating (without SWH installation) draws 2000 kWh per year. The retail fuel cost per kWh is 0.50 Rand
Private real interest rate (i.e. using constant prices).	20%	This rate is high due to the fact that poor households cannot get bank credit. They have to rely on private "loan sharks" who charge exploitative interest rates.

c) Draw up a cash flow chart for the cash flows of "non-financial operations", and use this to calculate the private NPV of one SWH system using the data and assumptions above, and assuming that there is no separate investment year. What do you conclude from your result?

d) Calculate the levelised unit cost of the SWH system, using the same assumptions, and compare this with the unit cost of conventional electric water heating. What do you conclude from this comparison?