Final examination Energy Analysis, 22 January 2009, 9.00 –12.00

- This exam has 4 questions, each having equal weight
- You can use the book, a dictionary and Key World Energy Statistics.
- The answers of the exercises may **not** be used.
- You can use a calculator.
- The answers can be provided either in English or Dutch.
- Provide your name and student number on each separate sheet of paper.

Introduction to questions 1 and 2

Incandescent lamps (NL: gloeilampen) have a life time of 10 000 burning hours. An 11 W Compact Fluorescent Lamp (CFL; NL: Spaarlamp) can replace a 40 W Incandescent lamp. CFL-lamps also have a life time of 10 000 burning hours. The price of an 11 W CFL lamp is €7.20 (the price of the 40 W incandescent lamp can be assumed negligible). A new generation of lamps is the LED (Light Emitting Diode) lamp. A 4 watt LED lamp has a light output equivalent to the light output of a 40 W incandescent lamp and has a life time of 40 000 burning hours. The price of the LED lamp is €25 after a cumulative production of 10 000 lamps. The electricity price for households is €0.21/kWh. The progress ratio for CFL and LED lamps is 0.823. Incandescent lamps have constant prices. Households prefer lowest payback periods not exceeding 5 years. Lamps are burning 1000 hours/year.

1. Technological learning CFL and LED lamps

(for this question do not use the information on incandescent lamps, see next question).
The government of Lumenland is considering policy options to stimulate the use of LED-lamps.

Questions:

a. How much subsidy would be needed for a LED lamp to become competitive with CFL lamps?
b. When cumulative production of CFL lamps is doubled, how many LED lamps must have been produced such that subsidy is not needed anymore?

2. Rebound effect

Suppose you get two 4 W LED lamps as a birthday present with which you replace two 40 W incandescent lamps each burning 1000 hours per year. The money you save will be spent on candy bars that you otherwise would not buy. Each bar weighs 50 gram and costs €0.70.
The production of 1 kg of candy bars requires 14.5 kWh of electricity and 18.5 MJ of fuel oil. Electricity production: 40 % in natural gas fired power plants (efficiency: 55%), 60% in coal fired power plants (efficiency: 42%). Efficiency of electricity transport: 95%.

Questions:

a. Calculate the annual electricity savings (in kWh/year), electricity cost savings (in €/year) and the amount of candy bars per year that can be bought with the electricity cost savings (do not round to a whole number of bars).
b. Calculate the primary energy savings by using the LED lamps. Use a second order approach.
c. Calculate the primary energy use of producing a candy bar. Use a second order approach.
d. Calculate the rebound effect: how much of the primary energy savings by using LED lamps disappears by spending the energy cost savings on candy bars.

3. Solar PV

You want to buy solar PV panels to generate part of your own electricity use. The investment is € 3000. The panels produce 500 kWh per year. You get a subsidy of 33 eurocent for each kWh generated with the solar panels. The electricity price for electricity bought from the grid is 23 eurocent per kWh. Electricity from the grid is generated in coal fired power stations with an efficiency of 40% (LHV basis). Transmission losses in the grid are 5%. You may assume that you use all electricity generated by the solar panel, so no electricity is sold to the grid. Each year you pay €30 for renting the electricity meter that measures the electricity produced by the solar panels.

a) Calculate the CO_2 emission of electricity from the grid in g/kWh.
b) Calculate the amount of avoided CO_2 emission per year
c) Calculate the Net Present Value of this project. The life time of the panels is 20 year, the discount rate is 5%. Is it profitable to buy these panels?
d) The government could also give an investment subsidy instead of a subsidy for the electricity produced. For the consumer: what could be an advantage of an investment subsidy. For the government: what could be an advantage of giving a subsidy per kWh generated.

4. Coke oven gas

Coke oven gas is a major by-product of the steel industry that is used as a fuel. It has approximately the following composition:

		Volume (%)	LHV (kJ/mol)
Hydrogen	H_2	58	242
Nitrogen	N_2	5.5	0
Carbon monoxide	CO	6	285
Carbon dioxide	CO_2	2	0
Methane	CH_4	28.5	800

Additional information:
Molar masses: H – 1 kg/kmol, N – 14 kg/kmol, C – 12 kg/kmol, O – 16 kg/kmol
Molar volume for any gas (or gas mixture): 22.4 m^3/kmol (so volume-% is also mol-%)
Use the book if you need more data.

a. Calculate the Lower Heating Value and the Higher Heating Value (in MJ/m^3)
b. Calculate the CO_2 emission factor in gram per MJ (LHV)

This coke oven gas is used in an electric power station with an efficiency of 40.0% (LHV based)

c. What is the efficiency on HHV basis