Final examination Energy Analysis, 27 January 2005, 9.00 –12.00

- You can use the reader and books like BINAS 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.

1. **Policy instruments.**
   There are three distinct mechanisms that play a role in influencing human behaviour. Argue which mechanisms play a role in the following policy instruments:
   a. Emission trading
   b. Voluntary agreements

2. **Exergy**
   a. What is the exergy content of an energy carrier?
   b. Why is it useful to use the exergy content of an energy carrier instead of the energy content? Supplement your answer with an example
   c. What is the exergetic efficiency of a heat pump with a COP of 4, which produces hot water of 80°C?

3. Comparing energy efficiencies

The dairy industry in the country X produces butter, cheese and milk powder. Production quantities and energy consumption in 1998 and 2003 are given in the following Table. An analysis carried out in the year 1990 showed the following best-practice values for the energy specific energy consumption for each of these: butter: 3 GJ/ton; cheese: 5 GJ/ton; milk powder: 10 GJ/ton.

Year	Production of butter (million tons)	Production of cheese (million tons)	Production of milk powder (million tons)	Primary energy consumption (PJ)
1998	2.0	2.0	1.0	36
2003	1.0	3.0	1.0	28

a. The specific energy consumption of milk powder is relatively high because a lot of water needs to be evaporated. The dairy industry in country X moved from 3-stage evaporators to 6-stage evaporators. Explain why this saves energy.
b. Determine how much more efficient the dairy industry in country X has become, taking into account the change in product mix.
c. Is it a problem that best-practice values are only known for 1990?

4. Energy conservation

A company has an annual natural gas consumption of 100 TJ. The company pays 3 Euro/GJ for the natural gas. An inventory of the possibilities to save energy gives the following results. Costs for operation and maintenance can be neglected.

Option	Savings on natural gas (%)	Investment (Euro)	Lifetime
A	5	30.000	20
B	20	450.000	20
C	10	100.000	20
D	5	20.000	5

a. Construct an energy conservation supply curve for the company. Use a discount rate of 15%.
b. The company uses the rule that all measures are taken with a pay-back time less than 3 year. How much is the company going to save?
c. The company suddenly discovers that the government provides an energy conservation investment subsidy regulation that provides a 20% subsidy on all investments that save energy. How much is the company going to save now? What is the free-rider share in the amount of subsidy that the company gets?
d. The government stops with providing subsidies and introduces an emission trading system for carbon dioxide. A market for CO_2 emission permits develops. How high should the price of permits be to make the company invest in all the options presented above? The CO_2 emission factor for natural gas is 56 kg/GJ.

5. Wind energy in Europe

a. Nowadays wind turbines cost 1000 €/kW. Calculate the production costs of electricity from wind energy. Use a discount rate of 15%
b. The installed wind energy capacity in the European Union nowadays is 15,000 MW. It is expected that this will grow to 60,000 MW in 2010. What production costs of wind energy do you expect for electricity from new wind turbines in 2010?

Use the following figures:
The load factor of wind turbines: 25%.
Progress ratio for wind turbines: 0.8
Lifetime of wind turbines: 20 years.
Annual operation and maintenance costs: 4% of investment costs.

Elaboration Final examination Energy Analysis, 27 January 2005

1.

Emission trading:

- normative mechanism: because a certain limit is set to the amount of emissions
- economic mechanism: the emissions can be traded and hence there is a financial incentive to reduce emissions

Voluntary agreement:

- communication mechanism: there is a negotiation process that makes companies and government exchange information (also after the agreement communication often plays an important role)
- normative mechanism: the voluntary agreement has the form of a contract that obliges companies to take action
- (in many cases also economic mechanisms are involved, e.g. a subsidy system can be part of the deal)

2

a. The exergy content of an energy carrier is the maximum amount of work that can be extracted from the energy carrier.
b. Exergy reflects the usefulness of an energy carrier in a broad sense, not only the degree to which work (e.g. electricity) can be produced, but also the degree to which e.g. heat of a certain temperature can be produced. An example is the exhaust heat of a power plant of 30 °C. This heat represents a large amount of energy but the exergy content is low. This reflects that it is hardly useful in a practical way.
c. Out of 1 unit of electricity (= 1 unit of exergy), 4 units of heat are produced. The exergy factor is 0.106 (formula 2.4). So the exergy produced out of one unit is 0.43. The exergetic efficiency is 43%.

3.

a. In a multi-stage evaporator water that is evaporated is condensed again. The condensation heat is not lost but used to evaporate water in a following stage (that of course should have a somewhat lower pressure to be able to evaporate at a lower temperature). By moving from 3-stage to 6-stage, the heat for the initial evaporation is used 6 times instead of 3 times. So, the energy needed for evaporation drops by about 50%.
b. An EEI can be defined as follows:
   $EEI = E_{total} / (P_{butter} \times SEC_{ref,\ butter} + P_{cheese} \times SEC_{ref,\ cheese} + P_{milkpowder} \times SEC_{ref,\ milkpowder})$
   In 1998 the EEI = 36 PJ / 26 PJ = 1.38
   In 2003 the EEI = 28 PJ / 28 PJ = 1.00
   The energy savings are 28% in 5 years.
c. Using old reference values in the EEI is not a problem as long as the reference drops gradually and more or less in the same way for the three products involved (which often is the case). But for instance, if a completely new process would have been invented for one of the products, with much lower energy use, it would become problematic to use the old reference values.

4

a. Specific costs C_{spec}= I * CRF – EB (everything per GJ saved)
CRF is 16% for A-C; 30% for D.
A: C_{spec} = (30,000/(100,000 GJ * 5%))*16% - 3 = 0.70 – 1 = -2.04Euro/GJ
B: +0.6 Euro/GJ
C: -1.40 Euro/GJ
D: -1.8 Euro/GJ

b. Paybacktime PBP = I/EB
A: 30.000Euro/ (5000 TJ/yr * 3 Euro/GJ) = 2 years
B: 7.5 years
C: 3.33 years
D: 1.33 years.
So only A and D will B selected, savings 10 TJ/year (or 10%).

c. Due to the subsidy the PBP of measure C will fall below the critical level. Total savings will now be 20 TJ/year. Subsidy is 20% * (30,000+100,000+20,000) = 30,000 Euro. Of this 1/3 is free-rider.

d. Savings should become a factor 2.5 bigger to bring down PBP from 7.5 to 3 years. This means a 150% higher natural gas price or an increase of 4.5 Euro/GJ.
One GJ of natural gas causes 0.056 tonnes of CO_2. The increase should be 4.5 Euro for 0.056 tonne of CO_2, i.e. 80 Euro/tonne of CO_2 (note that such a high carbon price is not expected for the time being).

5.

a. For one kW, the annual capital costs are 1000 € x 0.16 = 160 €.
   The O&M costs are 1000 € x 0.04 = 40 €
   Electricity production 0.25 x 8760 h x 1 kW = 2190 kWh.
   Production costs: 200 € / 2190 kWh = 9.1 ct/kWh.
b. Cumulative production doubles twice from nowadays to 2010. This means that productions costs will become 9.1 x 0.8 x 0.8 = 5.8 ct/kWh.