PHYS-C6370 Fundamentals of New Energy Sources (5 cr)
Exam December 14, 2016 (1 page)

You may use calculator of any type; inquires Peter Lund 0405150144
You may respond in English, Finnish, Swedish or German languages. Answer all 5 questions.

1. Short energy technology analysis (each 2 p)
a) How much will the output of a 3 MW wind power plant change if the wind speed drops from 15 m/s to 3 m/s?
b) How does the power of a 10 MW photovoltaic system change when the solar radiation intensity increases from 300 to 900 W/m²?
c) Up to how much biogas in primary energy terms (MJ or MWh) could you get from 1 ha of land area in Finland (or in your country)?

2. Detailed energy analysis (6p). Production of ethanol (EtOH) from barley starch takes place through the following reactions: Hydrolysis of starch into maltose: $(C_6H_{10}O_5)$ n + H_2O → $(C_6H_{10}O_5)$ n-2 + $C_{12}H_{22}O_{11}$ Fermentation of maltose into ethanol: $C_{12}H_{22}O_{11}$ + H2O → 4 C_2H_5OH + 4 CO_2

    If 1/3 of the current 2,100,000 tons per year barley crops in Finland were dedicated to ethanol fuel production, which portion of our present 2200 million liter (1630 million kg) yearly gasoline consumption would the amount of ethanol thus available correspond to? Consider in your calculations that the average starch content of barley is about 62 wt.-%, and that lower heating values (LHV) for 95E gasoline and ethanol are 42.2 MJ/kg and 26.8 MJ/kg respectively.

3. Global energy analysis (each 3p). To meet the goals of the Paris Climate Agreement, carbon neutrality in energy production should be reached during the second half of the century. In Europe, the annual average carbon emissions CO_2 should decrease to a level of 1 tons of CO_2 per capita by 2050. The carbon footprint of an average EU28 citizen was 8.7 tons of CO_2 in 2014.

    a) Calculate how fast should energy technology improve (annual % decrease in the ratio of $CO_2(kg)/GDP(€)$) if we want to achieve the above goal in Europe while preserving a 2% annual increase in real GDP (in 2014 euros). Average GDP in EU28 was 28,800 € per capita in 2014. (3p)

    b) If technology cannot be improved at all, how much would the GDP per capita need to decrease (annual % decrease) to reach the goal? (3p)

4. Specific technology analysis (6p). Explain the key technologies to harness solar energy as electricity. Your answer should cover description of the principles of the conversion technology, typical conversion efficiencies, present technology stand, and future outlook.

5. Energy quiz (each 1p): Short answers only (max 1/4 of page).
a) Composition of biogas
b) Hotelling's rule
c) Explain the term "peak oil"
d) Diffusion or penetration curve (also "draw" the answer)
e) Learning or experience curve (also "draw" the answer)
f) What does energy harvesting mean?