PHYS-C6370 Fundamentals of New Energy Sources (5 cr)
Exam February 20, 2019 (2 pages)

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

1. Energy quiz (each 1p): Short answers only (max 1/5 page each)
   a) What is the combined share of coal and oil of world CO_2 emissions?
   b) Hotelling's rule
   c) Why does hydrogen (H_2) need to be handled very carefully?
   d) What is the electricity output of 1 kW_p of photovoltaics in Helsinki per year?
   e) Diffusion or penetration curve ("draw" the answer)
   f) Composition of biogas

2. Global energy analysis (each 3p). To meet the goals of the Paris Climate Agreement, energy production in industrialized countries should in practice be CO_2 free by 2050. In Europe, the carbon footprint of an average EU28 citizen was 8.7 tons of CO_2 in 2016.

   a) Calculate how fast should energy production improve as annual %-decrease in the ratio of $CO_2(kg)/GDP(\$)$ to achieve the above goal in Europe while targeting for a 2% annual increase in real GDP (in 2016 $). Average GDP in EU28 was $32,263 per capita (2016). (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)

3. Specific technology analysis (6p). Explain how to produce electricity from waves. Your answer should cover description of the principles of the conversion technology, typical conversion efficiencies, present technology stand, and future outlook.

4. Short energy technology analysis (each 2 p)
   a) How much will the output of a 10 MW off-shore wind power plant change if the wind speed decreases from 22 m/s to 16 m/s?
   b) How much will the power of a 5 kWp silicon solar cell plant change in full sunshine if the ambient temperature changes from +25 °C to +15°C ?
   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)?

5. Detailed energy analysis (6p).
   a) Explain the principle of the learning curve in mathematical terms (2p)
   b) On the next page you'll find different forms of learning curvea. Using the theory of the learning curves, explain the reasons for the deviations from the linear classical model (log-log scale, case a) in cases b-f. (4p)

(a)

unit cost

cumulative volume

(b)

unit cost

cumulative volume

(c)

unit cost

cumulative volume

(d)

unit cost

cumulative volume

(e)

unit cost

cumulative volume

(f)

unit cost

cumulative volume

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