

**PHYS-C6370 Fundamentals of New Energy Sources (5 cr)**  
**Exam December 12, 2018 (1 page)**

(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 1/4 of page).

- What is the share of fossil fuels of world energy?
- Three main technologies for Concentrated Solar Plant (CSP).
- What kind of information of market penetration of a new technology does the technology diffusion curve contain?
- Explain if a fuel cell can in theory have a conversion efficiency  $>100\%$ ?
- What is the electricity output of  $1 \text{ kW}_p$  of photovoltaics in Helsinki per year?
- Explain the principle of the learning curve?

2. 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  $\text{CO}_2$  should decrease to a level of 1 tons of  $\text{CO}_2$  per capita by 2050. The carbon footprint of an average EU28 citizen was 8.7 tons of  $\text{CO}_2$  in 2014.

- Calculate how fast should energy technology improve (annual % decrease in the ratio of  $\text{CO}_2(\text{kg})/\text{GDP}(\text{€})$ ) 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)
- 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 the technology paths (principles, main processes, technologies) to produce methane  $\text{CH}_4$  from renewable energy.

4. Short energy technology analysis (each 2 p)

- How much will the output of a 3 MW wind power plant change if the wind speed increases from 2 m/s to 25 m/s?
- How much will the power of a 10 kW silicon solar cell plant change in full sunshine if the ambient temperature changes from  $-25^\circ\text{C}$  to  $+25^\circ\text{C}$ ?
- How much does the power of a wave change if the period of the waves doubles, but the wave height is halved?

5. Detailed energy analysis (6p). Assume that the nonrenewable energy resource is 200 units. Extraction of the resource has no cost. The resource has a linear price-demand dependence such that  $Q_t = 100 - P_t$ , where  $Q_t$  and  $P_t$  are demand and price of the resource on year  $t$ , respectively. To the proprietor, \$1 earned immediately is 2% more valuable than \$1 earned a year later.

How should the proprietor price the resource in order to maximize its present value? What is the present value of the resource stock? Use the Hotelling rule. In the beginning of the final year, both demand and remaining amount of resource are equal to 1. (6p)