Tampere University

EE.EES.460 *Electrical Energy Storages and Electric Vehicles*, 5 cr.

Answer all the **five (5)** questions. The use of calculator is allowed. Answers in Finnish *or* English.

1. Answer TRUE or FALSE (+0.5 for correct answer, -0.5 for incorrect, 0 for empty, total max 6 p.)
   1. Battery technology innovations generally enter the market after about 10 years
   2. C-rate describes the battery maximum temperature rating
   3. All lithium-ion battery chemistries have same voltage
   4. Specific power is rated in Wh/kg or Wh/litre
   5. Electric vehicles normally require a gear box
   6. DC charging means that the AC-DC converter is in the vehicle
   7. All global markets have same plug standards for EV charging
   8. Green hydrogen is primarily needed for transportation and logistics like trucks and ships
   9. Considering the energy storages operating today in power system applications, most of the energy capacity is in lithium-ion battery energy storages.
   10. Electricity to hydrogen to electricity round trip efficiency is over 40%
   11. Annual worldwide demand for crude oil has been decreasing over the last years.
   12. Virtual power plant is a concept where several small devices are aggregated as one resource and provided as controllable energy device.

2. Energy storages (6 p.)

   a) Explain what is Power-to-X-to-Power. What are the costs and efficiency? To which applications it would be best suited?

   b) Pumped hydro: describe how PHS can be used for both short and long term energy storages and on which kinds of electricity/power markets can it participate. (3 p)

3. Lithium-ion batteries (6 p.)
   a) Explain with illustration and in writing how charging and discharging a lithium-ion battery works. (4 p.)
   b) Why is battery management system (BMS) important with li-ion batteries? Describe the key functionalities of BMS. (2 p.)

4. Electric vehicles (6 p.)
   a) Explain what are the differences between ICE, hybrid, plug-in hydrid and full electric vehicles (3 p.)
   b) How will electromobility affect the consumption of electric energy and why is smart charging needed in the future? (3 p.)

5. Financial value and investing (6 p.)

Calculate the total cost of ownership when replacing a city diesel bus with an electric bus.

	Diesel bus	Electric bus
Price	200 000 €	400 000 €
Energy consumption	30 l / 100 km	1.0 kWh/km
Energy cost	1.6 € / l (diesel)	0.20 €/kWh (electricity)
Driving distance per year	150 000 km	
Bus lifetime	12 years	

Electric bus has a battery of 50 kWh, cycle life of 12000 cycles and battery replacement cost is 50 000 €.

Compare the net present value of the two options when discount rate is 8%. (Hint: discount coefficient at i^{th} year: $\dfrac{1}{\left(1+\frac{p\%}{100\%}\right)^{i}}$).