Exam 2019

Side 1

Vis rigtige svar
Skjul rigtige svar

Lecture 1 (Introduction)

Spørgsmål 1

Q 1-1) Denmark consumes around 4 GW of electricity on average. Assume that we build a photovoltaic plant in Denmark to provide 4 GW of average power (annual average). How big (roughly) would it be?

- ☐ A) About 1/2 km2 (the size of DTU Lyngby campus)
- ☐ B) About 5 km2 (the size of Strynø island)
- ☐ C) About 17 km2 (the size of Salthom island)
- ☐ D) About 95 km2 (the size of Amager island)
- ☐ E) About 350 km2 (the size of Mors island)

Spørgsmål 2

Q 1-2) China is the World's most energy consuming country - what percentage of the global energy use happens in China?

- ☐ A) About 12%
- ☐ B) About 22%
- ☐ C) About 32%
- ☐ D) About 42%
- ☐ E) About 52%

Spørgsmål 3

Q 1-3) What does it mean that metal A has an inelastic supply compared to metal B.

- ☐ A) That metal A is more expensive (more $/kg) than metal B
- ☐ B) That metal A is only produced in a few places in the World, whereas metal B is produced more places
- ☐ C) That metal A has a higher elastic modulus (Young's modulus) than metal B
- ☐ D) That the production of metal A responds less strongly than that of metal B to a change in the market price of the metals
- ☐ E) That metal B is a bi-product of metal A

Side 2

Lecture 2 (Biomass)

Spørgsmål 4

Q 2-1) What is the approx. use of biomass in the Danish energy system per year?

- ☐ A) 100 PJ
- ☐ B) 60 TJ
- ☐ C) 140 TJ
- ☐ D) 140 PJ
- ☐ E) 60 PJ

Spørgsmål 5

Q 2-2) How much hydrogen from electrolysis can approx. be incorporated in biofuel production based on gasification when assuming a consumption of biomass of 10 GJ?

- ☐ A) 8 GJ
- ☐ B) 11 GJ
- ☐ C) 5 GJ
- ☐ D) 2 GJ
- ☐ E) 19 GJ

Spørgsmål 6

Q 2-3) Calculate the energy efficiency of gasification if the input is 100 MW of biomass and the output is 0.4 kmol/s of syngas containing 40 mol% H2 and 40 mol% of CO. LHV_H2 = 241.8 MJ/kmol, LHV_CO = 283 MJ/kmol

- ☐ A) 84%
- ☐ B) 92%
- ☐ C) 100%
- ☐ D) 55%
- ☐ E) 77%

Spørgsmål 7

Q 2-4) How much heat is released in the water gas shift reaction (CO + H2O -> CO2 + H2) if 0.1 kmol/s of CO is converted? LHV_H2 = 241.8 MJ/kmol, LHV_CO = 283 MJ/kmol.

- ☐ A) 4 MW
- ☐ B) 4 kW
- ☐ C) 7 MW
- ☐ D) 7 kW
- ☐ E) 24 MW

Side 3

Lecture 3 (Solar)

Spørgsmål 8

Q 3-1) If you make a photovoltaic installation of a given size how much larger would its annual total production (i.e. # of kWh) be if you build near Rome instead of near Copenhagen?

- ☐ A) About the same
- ☐ B) About 5% larger output
- ☐ C) About 50% larger output
- ☐ D) About 120% larger output
- ☐ E) About 270% larger output

Spørgsmål 9

Q 3-2) Why can tandem photoabsorbers make much more efficient solar cells than single absorber designs?

- ☐ A) Because they are simpler and fewer losses
- ☐ B) Because they get more than twice the voltage, but half the current
- ☐ C) Because their sensitivity to clouds and other non-ideal illumination is less pronounced
- ☐ D) Because they get more than twice the current, but half the voltage
- ☐ E) Because they get more than twice the current, and about the same voltage

Spørgsmål 10

Q 3-3) If you are looking for a good top-cell absorber material to use together with a silicon-based bottom cell in a photovoltaic tandem, the band-gap energy of the top-cell absorber should be in the range:

- ☐ A) 2.5 eV to 3.0 eV
- ☐ B) 1.7 eV to 1.9 eV
- ☐ C) 1.1 eV to 1.3 eV
- ☐ D) 0.3 eV to 0.5 eV
- ☐ E) -1.1 eV to 0 eV

Spørgsmål 11

Q 3-4) What is the principal advantage which Concentrated Solar Power can have over photovoltaics in generating electricity?

- ☐ A) Optional storage for when the sun doesn’t shine
- ☐ B) Better scalability of the plant size
- ☐ C) Much higher solar-to-electricity efficiency
- ☐ D) Lower cost (less $/Watt)
- ☐ E) Better ability to handle non-ideal weather

Side 4

Lecture 4 (Water)

Spørgsmål 12

Q 4-1) Below you will find five (5) renewable energy technologies that can produce electricity. Which technology(-ies) can be used to store energy?

- ☐ A) Wave dragon
- ☐ B) Floating power plant
- ☐ C) Tidal energy plant
- ☐ D) Hydro power plant with dam
- ☐ E) Pelamis

Spørgsmål 13

Q 4-2) There are three (3) categories or types of wave energy plants. They are:

- ☐ A) Oscillating water column, overtopping devices, and oscillating bodies
- ☐ B) Francis turbine, oscillating bodies and OTEC
- ☐ C) Overtopping devices, floating power plant, and oscillating water column
- ☐ D) Oscillating bodies, run-of-river plant, Pelton turbine
- ☐ E) Floating power plant, overtopping devices and Kaplan turbine

Spørgsmål 14

Q 4-3) Hydro power is a well developed renewable energy technology. Which statement describes best the current status of run-of-river hydro power plants?

- ☐ A) High investment, low operation cost and no environmental impact
- ☐ B) It is generating power at a high cost with no emissions
- ☐ C) Very low cost of power, no emissions and low environmental impact
- ☐ D) Can be used to store electricity and has a low investment
- ☐ E) Low environmental impact and high cost of power

Spørgsmål 15

Q 4-4) We assume that the Minister of Climate and Energy of Scotland has put forward a target of covering 50% of the electricity consumption of Scotland by wave energy by 2040. You are appointed as a consultant and asked to estimate the area needed in the sea. The average wave resource around Scotland is 70 kW/m wave front and we assume the wave energy units each rated at 4 MW are 100 x 100 m in size and are installed in the sea in a square pattern at a distance between the units of 600 m.
The annual electricity consumption of Scotland is 36 TWh (2017).

Scotland will need an area in the sea of approximately:

☐ A) < 100 km^2

☐ B) 200-300 km^2

☐ C) 500-600 km^2

☐ D) 800-900 km^2

☐ E) > 1000 km^2

Side 5

Lecture 5 (Thermodynamics and electrochemistry)

Spørgsmål 16

Q 5-1) Which one of the following quantities affects the reversible potential of an electrochemical cell?

- ☐ The resistance of the electrolyte
- ☐ The catalysts on the electrodes
- ☐ The concentration/pressure/activity of the chemical species taking part in the electrochemical reaction
- ☐ The current drawn from the cell
- ☐ The mass transport properties of the electrodes for gasses or liquids

Spørgsmål 17

Q 5-2) The maximum work obtainable from a chemical reaction is given by

- ☐ The enthalpy change of the reaction
- ☐ The free energy change of the reaction
- ☐ The enthalpy of formation
- ☐ The free energy of formation
- ☐ The entropy change of the reaction

Spørgsmål 18

Q 5-3) Can the electrical efficiency of an electrolyzer producing hydrogen and oxygen from water at room temperature be larger than 100 % based on thermodynamics?

- ☐ No, efficiencies can never be above 100 %
- ☐ Yes, the missing energy must then be supplied as heat
- ☐ Yes, the electrical energy input can be as small at one likes as long as the rest of the energy is supplied as heat
- ☐ No, it is always 100 % because energy is conserved (1^{st} law)
- ☐ No, an electrolyzer works through processes, which are irreversible and the entropy production makes even 100 % efficiency impossible

Spørgsmål 19

Q 5-4) Which of the following statements describes the thermo-neutral cell voltage correctly?

- ☐ At the thermoneutral voltage, a water electrolyzer can be operated with no overall production or consumption of heat
- ☐ At the thermoneutral voltage, a hydrogen/air fuel cell can be operated with no overall production or consumption of heat
- ☐ The thermoneutral voltage is a thermodynamic abstraction and no real electrochemical cell can be operated at this voltage
- ☐ The thermoneutral voltage is the voltage at which the electrical energy input exactly matches the heat output of the cell
- ☐ The thermoneutral voltage is the voltage at which the electrical output exactly matches the heat input to the cell

Side 6

Lecture 6 (Fuel cells)

Spørgsmål 20

Q 6-1) If fuel cells are compared to thermally driven engines like combustion engines and turbines, then

- ☐ fuel cells are always more efficient because of Carnot's law
- ☐ fuel cells are typically more efficient because of Carnot's law, but it also depends on the overvoltages
- ☐ fuel cells are more efficient because they don't produce heat
- ☐ fuel cells are more efficient because they are operated at low temperature
- ☐ fuel cells are more efficient because they don't produce any entropy

Spørgsmål 21

Q 6-2) A fuel cell is operated at 0.65 V with pure hydrogen and pure oxygen, both at 1 bar. The thermo-neutral voltage is 1.48 V and the reversible voltage is 1.23 V. What is the electrical efficiency with reference to the higher heating value (HHV)?

- ☐ 25 %
- ☐ 44 %
- ☐ 53 %
- ☐ 58 %
- ☐ 83 %

Spørgsmål 22

Q 6-3) Which factor is important for the ion conducting membrane in a PEMFC

- ☐ Very dry operating conditions to avoid the membrane becoming too soft
- ☐ Temperatures above 100 °C to secure that the water produces is vapour
- ☐ Low water content in the membrane to provide high proton conductivity
- ☐ High water content in the membrane to provide high proton conductivity
- ☐ The membrane must have sufficiently large pores to let the electrolyte to flow through

Spørgsmål 23

Q 6-4) Today, hydrogen is stored in fuel cell cars as

- ☐ Compressed hydrogen at 200 bar
- ☐ Compressed hydrogen at 700 bar
- ☐ Liquid hydrogen
- ☐ Metal hydrides
- ☐ Methanol

Side 7

Lecture 7 (Energy Storage)

Spørgsmål 24

Q 7-1) Rank the following energy storage technologies according to their energy density (high to low)

☐ A) Compress Air Energy Storage (CAES) > Pumped Hydro Storage (PHS) > Na-S batteries > flywheels

☐ B) Na-S batteries > flywheels > Compress Air Energy Storage (CAES) > Pumped Hydro Storage (PHS)

☐ C) Pumped Hydro Storage (PHS) > flywheels > Compress Air Energy Storage (CAES) > Na-S batteries

☐ D) Na-S batteries > Pumped Hydro Storage (PHS) > flywheels > Compress Air Energy Storage (CAES)

☐ E) Flywheels > Compress Air Energy Storage (CAES) > Na-S batteries > Pumped Hydro Storage (PHS)

Spørgsmål 25

Q 7-2) The following statement about Phase Change Materials (PCM) is false:

☐ A) PCMs are substances that absorb and release thermal energy during e.g. melting and freezing

☐ B) Many different classes of materials can be PCMs

☐ C) A PCM can store different amounts of energy in its different phases

☐ D) PCMs typically operate at temperatures above 500 deg. C

☐ E) Water/ice is a commonly used PCM

Spørgsmål 26

Q 7-3) Rank the energy storage technologies according to their current levelized cost of storage (LCOS) (low to high)

☐ A) Na-S < thermo chemical < thermo latent heat < Power-2-Gas (H_2) < Pumped Hydro Storage (PHS)

☐ B) Thermo latent heat < Power-2-Gas (H_2) < Pumped Hydro Storage (PHS) < Na-S < thermo chemical

☐ C) Pumped Hydro Storage (PHS) < thermo chemical < Na-S < Power-2-Gas (H_2) < thermo latent heat

☐ D) Power-2-Gas (H_2) < Pumped Hydro Storage (PHS) < Na-S < thermo chemical < thermo latent heat

☐ E) Thermo chemical < Na-S < Pumped Hydro Storage (PHS) < thermo latent heat < Power-2-Gas (H_2)

Spørgsmål 27

Q 7-4) How much energy can 4 m^3 of granite store if it is heated from 20 to 450 deg. C (specific heat: 774 J/kgK; density: 2700 kg/m^3)?

- ☐ A) ~1 kWh
- ☐ B) ~1 MWh
- ☐ C) ~1 kJ
- ☐ D) ~1 MJ
- ☐ E) ~1 GJ

Side 8

Lecture 8 (Batteries)

Spørgsmål 28

Q 8-1) Arrange the following battery chemistries according to their gravimetric energy density (energy per weight), from highest to lowest

- ☐ A) Ni-MH > Pb-acid > Li-ion > Ni-Cd
- ☐ B) Pb-acid > Li-ion > Ni-MH > Ni-Cd
- ☐ C) Li-ion > Ni-MH > Ni-Cd > Pb-acid
- ☐ D) Pb-acid > Ni-Cd > Ni-MH > Li-ion
- ☐ E) Li-ion > Ni-Cd > Pb-acid > Ni-MH

Spørgsmål 29

Q 8-2) What is the theoretical capacity of a graphite electrode material in a Li-ion battery

- ☐ A) ~400 kWh/L
- ☐ B) ~400 Wh/kg
- ☐ C) ~400 kWh/kg
- ☐ D) ~400 mAh/g
- ☐ E) ~4000 mAh/g

Spørgsmål 30

Q 8-3) A battery with a capacity of 10.000 C is charged at a C-rate of 1C. How long time does it take to charge the battery fully?

- ☐ A) 1 sec
- ☐ B) 10 sec
- ☐ C) 1 min
- ☐ D) 1 h
- ☐ E) 10.000 sec

Spørgsmål 31

Q 8-4) The following reactions take place in a rechargeable alkaline zinc-air ($Zn\text{-}O_2$) battery. Negative electrode: $Zn + 4OH^- <-> ZnO + H_2O + 2OH^-$; Positive electrode: $O_2 + H_2O + 4e^- <-> 4OH^-$; Overall: $2Zn + O_2 <-> 2ZnO$. Which component is being reduced and which is oxidized during charging of the battery?

- ☐ A) Neither zinc nor oxygen is reduced or oxidized
- ☐ B) Both oxygen and zinc are reduced
- ☐ C) Both zinc and oxygen are oxidized
- ☐ D) Oxygen is oxidized and zinc is reduced
- ☐ E) Zinc is reduced and oxygen is oxidized

Side 9

Lecture 9 (Nuclear)

Spørgsmål 32

Q 9-1) What is the nuclear fission share of the electricity generation in France?

- ☐ 5%
- ☐ 15%
- ☐ 35%
- ☐ 50%
- ☐ 75%

Spørgsmål 33

Q 9-2) A country **without** nuclear power plants

- ☐ Finland
- ☐ Sweden
- ☐ Poland
- ☐ Ukraine
- ☐ Hungary

Spørgsmål 34

Q 9-3) In fission reactors, plutonium is the result of

- ☐ By-product from uranium mining
- ☐ Fission of natural uranium
- ☐ Neutron capture in natural uranium
- ☐ Radioactive decay of natural uranium
- ☐ Radioactive decay of enriched uranium

Spørgsmål 35

Q 9-4) In a "thermal" fission reactor, the term "thermal" refers to

- ☐ Reactor temperature
- ☐ Water coolant temperature
- ☐ Any reactor using liquid coolant
- ☐ The neutron spectrum
- ☐ The fission fragment energy

Side 10

Lecture 10 (Wind)

Spørgsmål 36

Q 10-1) When is it necessary to change the yaw angle of a wind turbine?

- ☐ A) When the wind speed is changing
- ☐ B) When the air temperature is changing
- ☐ C) When the turbulence is changing
- ☐ D) When the wind direction is changing
- ☐ E) When the grid voltage is changing

Spørgsmål 37

Q 10-2) The worlds largest wind turbine has a rotor diameter of D = 220 m. What is the maximum available power of the wind if the turbine is placed in a wind speed is v = 10 m/s at 150 m height and the air density is ρ = 1.225 kg/m^3?

- ☐ A) 1-5 MW
- ☐ B) 5-10 MW
- ☐ C) 10-20 MW
- ☐ D) 20-30 MW
- ☐ E) 30-40 MW

Spørgsmål 38

Q 10-3) If the wind speed is measured over many years at a site and found to be described by the Weibull distribution with a shape parameter k = 2 and an average wind speed of v_{ave} = 10.1 m/s. Which wind class should then be used for choosing a turbine for installation at that site?

- ☐ A) IEC Class 0
- ☐ B) IEC Class 1
- ☐ C) IEC Class 2
- ☐ D) IEC Class 3
- ☐ E) IEC Class 4

Spørgsmål 39

Q 10-4) The worlds largest wind turbine with a power rating of 12 MW has been claimed to produce an Annual Energy Production (AEP) of 67 GWh at an IEC wind class I. What is the corresponding Capacity Factor of the turbine ?

- ☐ A) 20 - 30 %
- ☐ B) 30 - 40 %
- ☐ C) 40 - 50 %
- ☐ D) 50 - 60 %
- ☐ E) 60 - 70 %

Side 11

Lecture 11 (Electrolysis)

Spørgsmål 40

Q 11-1) Which type of electrolyzer is known for a gap configuration (in contrast to zero gap)?

- ☐ The traditional alkaline electrolyzer
- ☐ The PEM electrolyzer
- ☐ The solid oxide electrolyzer
- ☐ All three types
- ☐ None of them

Spørgsmål 41

Q 11-2) Why are solid oxide electrolyzers always operated at high temperature (typically 700-900 °C)?

- ☐ Some of the metal oxide ceramic materials they are made from cannot tolerate liquid water (they dissolve)
- ☐ The electrolyte must be molten before it can conduct the oxygen ions
- ☐ The high temperature is necessary for cooling the cells
- ☐ It is the easiest way to evaporate water and then it takes less energy to electrolyze water vapour
- ☐ The electrolyte is a solid metal oxide that conducts oxygen ions. The ion movement between the position in the structure requires high thermal energy

Spørgsmål 42

Q 11-3) Methane can be produced by the Sabatier process from H_2 and CO_2 and this way, large amounts of energy can be stored in the natural gas grid and underground caverns. Which one of the following arguments against this process is correct?

- ☐ The energy efficiency is limited. The reaction enthalpy is negative and thus the process is exothermic (waste heat producing). Besides, energy is needed to collect and concentrate CO_2 from a suitable source
- ☐ The enthalpy of reaction is highly negative and thus a large-scale high temperature heat source is needed for the process. This may not be available
- ☐ When the stored methane is used later, it releases CO_2 and therefore it sit just as harmful to the climate as fossil natural gas
- ☐ Methane is flammable and flammable fuels should always be avoided for safety reasons
- ☐ There are no arguments against making methane by the Sabatier process

Spørgsmål 43

Q 11-4) Rank hydrogen, synfuels (methanol, methane etc.) and batteries in terms of practical energy density (i.e. including tank/casing) for medium and large-scale application (cars, trucks ships)

- ☐ Hydrogen > synfuels > batteries
- ☐ Hydrogen >batteries > synfuels
- ☐ Synfuels > batteries > hydrogen
- ☐ Synfuels > hydrogen > batteries
- ☐ Batteries > synfuels > hydrogen

Side 12

Lecture 12 (Infrastructure and cost)

Spørgsmål 44

Q 12-1) The LCOE compares different electricity sources on a (discounted) total cost basis, but what does it not take into account.

- ☐ A) Externalities and dispatchability costs
- ☐ B) Maintenance costs
- ☐ C) Financing costs
- ☐ D) Procurement and contracting costs
- ☐ E) Permitting costs

Spørgsmål 45

Q 12-2) What is the capacity factor?

- ☐ A) The ratio of renewable energy to total energy in the grid
- ☐ B) The ratio of CO_2 emissions of two different sources of power - such as natural gas or coal
- ☐ C) The ratio of CAPEX to OPEX of a project
- ☐ D) The ratio of annual average power produced to the ideal case power
- ☐ E) The ratio of annual average power produced to the installed cost

Spørgsmål 46

Q 12-3) If you increase the lifetime (n) of an electricity generating installation - say from 30 years to 31 years, while keeping everything else constant (i.e. interest rates, fuel costs, maintenance costs, etc.) how does this effect the LCOE?

- ☐ A) LCOE is unaffected
- ☐ B) LCOE goes up substantially because the gain is not discounted many years ahead
- ☐ C) LCOE goes up goes up slightly because the gain is strongly discounted
- ☐ D) LCOE goes down substantially because the gain is not discounted many years ahead
- ☐ E) LCOE goes up goes down slightly because the gain is strongly discounted

Spørgsmål 47

Q 12-4) The global annual production of nickel (Ni) is about 1.25 billion kg. If we assume a car battery contains 0.75 kg/kWh, how many year's production of nickel would be required to convert the global car fleet to battery-electric vehicles? Assume an average car battery size of 70 kWh

- ☐ A) 0.1 years of global Ni production
- ☐ B) 2.5 years of global Ni production)
- ☐ C) 10 years of global Ni production
- ☐ D) 45 years of global Ni production
- ☐ E) 130 years of global Ni production