Lecture 1 (Introduction)

Question 1

Q 1-1) What happens to a country in the middle stage of the demographic transition?

- ☐ A) Population grows because the birth rate is high and the death rate is low
- ☐ B) Population grows fast because the country becomes more attractive to live in and people immigrate in
- ☐ C) Population decreases because death rates rise steeply
- ☐ D) Population decreases because people immigrate out of the country because it becomes less attractive to live in
- ☐ E) Population is stable because birth rates and death rates are equal

Question 2

Q 1-2) At roughly what annual rate has global energy consumption been growing in the past decade?

- ☐ A) -0.2%
- ☐ B) 0.3%
- ☐ C) 0.9%
- ☐ D) 1.8%
- ☐ E) 3.1%

Question 3

Q 1-3) How many square kilometres would a photovoltaic park giving 1 TW of annual average power be (roughly)?

- ☐ A) 3,000 km^2 (the size of the Danish island of Fyn)
- ☐ B) 50,000 km^2 (the size of the of Costa Rica)
- ☐ C) 140,000 km^2 (the size of the island of Java)
- ☐ D) 310,000 km^2 (the size of Poland)
- ☐ E) 590,000 km^2 (the size of Madagascar)

Question 4

Q 1-4) Roughly, what proportion of world energy is supplied by natural gas?

- [ ] A) 5%
- [ ] B) 16%
- [ ] C) 23%
- [ ] D) 33%
- [ ] E) 45%

Lecture 2 (Biomass)

Question 5

Q 2-1) Concerning thermal gasification. What is not true?

- [ ] A) It can convert a solid fuel to syngas
- [ ] B) It can convert lignin to gas
- [ ] C) It produces a biogas containing mainly methane
- [ ] D) It has high energy efficiency (75-93%)
- [ ] E) Heat is required for the chemical reaction producing gas from char and steam

Question 6

Q 2-2) What is the synergy between thermal gasification and electrolysis?

- [ ] A) Gasification provides heat for electrolysis
- [ ] B) Electrolysis provides heat for gasification
- [ ] C) The gasifier produces gas for electrolysis
- [ ] D) Electrolysis provides oxygen for gasification and hydrogen for syngas production
- [ ] E) Gasification provides oxygen for electrolysis

Question 7

Q 2-3) Calculate the conversion energy efficiency of the chemical reaction $4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$ given the following heating values: $LHV\_H_2 = 241.8$ MJ/kmol, $LHV\_CH_4 = 802.3$ MJ/kmol

- [ ] A) 85.1%
- [ ] B) 80.0%
- [ ] C) 83.0%
- [ ] D) 78.2%
- [ ] E) 100%

Question 8

Q 2-4) If the production of biofuel is only limited by the carbon content, what is the potential output of ethanol per kg of biomass input. The carbon content of biomass can be assumed to be 47 wt%.

- ☐ A) 0.90 kg
- ☐ B) 1.00 kg
- ☐ C) 1.11 kg
- ☐ D) 0.85 kg
- ☐ E) 0.63 kg

Lecture 3 (Solar)

Question 9

Q 3-1) Our civilization takes around 18 TW of power to run. The earth is hit by much more solar power, but how much more?

- ☐ A) 20 times more
- ☐ B) 500 times more
- ☐ C) 6,500 times more
- ☐ D) 30,000 times more
- ☐ E) 120,000 times more

Question 10

Q 3-2) What has been the approximate annual growth rate of global photovoltaic capacity (until 2017)

- ☐ A) 15%
- ☐ B) 35%
- ☐ C) 65%
- ☐ D) 90%
- ☐ E) 105%

Question 11

Q 3-3) The bandgap is a central concept of a photovoltaic cell. What is it?

- ☐ A) It is the minimum energy which a photon must have to enter the material (else, it is reflected)
- ☐ B) It is the minimum energy which a photon must have to be absorbed (to generate electron-hole pairs)
- ☐ C) It is the maximum energy which a photon can have in order not to generate “hot electrons” in the material
- ☐ D) It is a physical gap (void) in the cell structure between the n-type layer and the p-type layer
- ☐ E) It is a band of vertically oriented gaps in the cell surface (anti-refelction layer)

Question 12

Q 3-4) If you install a solar collector on a well-oriented roof in Lyngby with a 1 kW peak power (i.e.e 1000 W nameplate power). What is roughly, the annual total electricity production you would expect this to generate?

- ☐ A) ca 24 kWh
- ☐ B) ca 50 kWh
- ☐ C) ca 88 kWh
- ☐ D) ca 350 kWh
- ☐ E) ca 950 kWh

Lecture 4 (Nuclear)

Question 13

Q 4-1) What is the nuclear fission share of the global electricity generation?

- ☐ A) 5%
- ☐ B) 10%
- ☐ C) 15%
- ☐ D) 20%
- ☐ E) 25%

Question 14

Q 4-2) What is the approximate energy gain using breeder reactors and a closed fuel cycle, compared to a LWR once-through fuel cycle?

- ☐ A) 20%
- ☐ B) 100%
- ☐ C) 500%
- ☐ D) 2000%
- ☐ E) 10000%

Question 15

Q 4-3) In a fast reactor, the term “fast” refers to

- ☐ A) Construction time
- ☐ B) Neutron spectrum
- ☐ C) Fission fragment energy
- ☐ D) Load-following capacity
- ☐ E) Ability to use thorium fuel

Question 16

Q 4-4) In a reactor, thorium fuel is transformed to ^{233}U by

- [ ] A) Neutron capture
- [ ] B) Double beta-decay
- [ ] C) Neutron capture and double beta-decay
- [ ] D) Fission
- [ ] E) Neutron capture and fission

Lecture 5 (Wind)

Question 17

Q 5-1) What is the instant wind power density per flow area (W/m^2) if the wind speed is v = 10 m/s at 100 m height and the air density is $\rho = 1.225\ kg/m^3$?

- [ ] A) 300-400 W/m^2
- [ ] B) 400-500 W/m^2
- [ ] C) 500-600 W/m^2
- [ ] D) 600-700 W/m^2
- [ ] E) 700-800 W/m^2

Question 18

Q 5-2) If the wind speed is measured over a year at a site and found to be described by the Weibull distribution with a shape parameter $k = 2$ and an average wind speed of vave = 8.5 m/s. Which wind class should then be used for choosing a turbine for installation at that site?

- [ ] A) Class 0
- [ ] B) Class I
- [ ] C) Class II
- [ ] D) Class III
- [ ] E) Class IV

Question 19

Q 5-3) How many rotational axis, that can be rotated, does a modern horizontal axis individual blade pitch regulated wind turbine have?

- [ ] A) 2
- [ ] B) 3
- [ ] C) 4
- [ ] D) 5
- [ ] E) 6

Question 20

Q 5-4) If a 10 MW wind turbine is placed offshore and have a Capacity Factor of c = 0.50. What is the Annual Energy Production (AEP) in [GWh/year]?

- ☐ A) 30-40 GWh/year
- ☐ B) 40-50 GWh/year
- ☐ C) 50-60 GWh/year
- ☐ D) 60-70 GWh/year
- ☐ E) 70-80 GWh/year

Lecture 6 (Water)

Question 21

Q6-1) Below you will find five (5) ocean energy technologies. Which technology does NOT utilize wave energy?

- ☐ A) Wave dragon
- ☐ B) Floating power plant
- ☐ C) Aquabuoy
- ☐ D) Offshore wind farm
- ☐ E) Pelamis

Question 22

Q6-2) Hydro power is a well developed renewable energy technology.

Which statement describes best the current status of large hydro power plants with a dam?

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

Question 23

Q6-3) When locating a wave energy plant the most important to consider is the following:

- ☐ A) Short distance to the grid
- ☐ B) Short distance to shore (easy to repair) and deep water
- ☐ C) Low environmental impact and shallow water
- ☐ D) Long lifetime and far from the cost so that it cannot be seen from the shore
- ☐ E) Good wave energy resource, short distance to the grid and low environmental impact

Question 24

Q6-4 You are appointed as a consultant to the Governments in Scotland and Denmark. You are asked to estimate the area needed to cover 50% electricity consumption by wave energy both in Denmark and in Scotland. In Denmark half of the wave energy plants are located in the North Sea and the rest in the inner Danish waters.

We assume that the electricity consumption of Scotland and Denmark are 36 and 32 TWh respectively (2017).

In order to satisfy 50% of the above electricity consumption by wave energy Denmark will need an area in the sea that is larger by a factor of X than Scotland needs (other conditions assumed equal):

X is:

☐ A) 1 - same area

☐ B) 3 to 5

☐ C) 5 to 7

☐ D) 7 to 9

☐ E) > 10

Lecture 7 (Energy Storage)

Question 25

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

☐ A) Flywheels > Pumped Hydro Storage (PHS) > flow batteries > Compress Air Energy Storage (CAES) > hydrogen

☐ B) Compress Air Energy Storage (CAES) > Pumped Hydro Storage (PHS) > flow batteries > hydrogen > flywheels

☐ C) Pumped Hydro Storage (PHS) > flow batteries > flywheels > hydrogen > Compress Air Energy Storage (CAES)

☐ D) Hydrogen > flywheels > Compress Air Energy Storage (CAES) > flow batteries > Pumped Hydro Storage (PHS)

☐ E) Pumped Hydro Storage (PHS) > flywheels > hydrogen > Compress Air Energy Storage (CAES) > flow batteries

Question 26

Q 7-2) BaCl2 can be used for thermochemical energy storage as it can bind 8 NH_3 gas molecules with an enthalpy of reaction of 37.7 kJ/ (mol NH_3). How much energy must be supplied to release the 8 NH_3 molecules again (the molar mass of $Ba(NH_3)_8Cl_2$ is 344.48 g/mol)?

☐ A) 876 kJ/(g of $Ba(NH_3)_8Cl_2$)

☐ B) 109 kJ/(kg of $Ba(NH_3)_8Cl_2$)

☐ C) 876 J/(kg of $Ba(NH_3)_8Cl_2$)

☐ D) 243 Wh/(kg of $Ba(NH_3)_8Cl_2$)

☐ E) 30.4 Wh/(kg of $Ba(NH_3)_8Cl_2$)

Question 27

Q 7-3) How large was the fraction of thermal storage in new installations in utility-scale energy storage made in 2015 and 2016?

- ☐ A) <1%
- ☐ B) ~5%
- ☐ C) ~10%
- ☐ D) ~50%
- ☐ E) >90%

Question 28

Q 7-4) Rank the energy storage technologies according to their power density (low to high)

- ☐ A) Li-ion < flywheels < fuel cells < CAES < PHS
- ☐ B) CAES < fuel cells < PHS < Li-ion < flywheels
- ☐ C) Fuel cells < Li-ion < flywheels < PHS < CAES
- ☐ D) Flywheels < PHS < Li-ion < CAES < fuel cells
- ☐ E) PHS < CAES < fuel cells < flywheels < Li-ion

Lecture 8 (Thermodynamics)

Question 29

Q 8-1) Which of the following processes is NOT performance of work?

- ☐ A) Compressing a gas
- ☐ B) Stirring a liquid
- ☐ C) Shaking a drink
- ☐ D) The process that follows adding an ice cube to a drink
- ☐ E) Passing an electrical current through an electrolyte

Question 30

Q 8-2) What is the theoretical basis for Carnot's law?

- ☐ A) Conservation of energy alone
- ☐ B) Conservation of entropy alone
- ☐ C) Conservation of heat alone
- ☐ D) Conservation of energy and entropy
- ☐ E) Conservation of heat and entropy

Question 31

Q 8-3) Which of the five reaction are expected to have the highest generation of entropy per mole reaction as written?

☐ A) $C + O_2 \rightarrow CO_2$ (at 25 °C)

☐ B) $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$ (at 300 °C)

☐ C) $N_2 + 3H_2 \rightarrow 2NH_3$ (at 500 °C)

☐ D) $2H_2 + O_2 \rightarrow 2H_2O$ (l) (at 25 °C)

☐ E) $2H_2O$ (l) $\rightarrow 2H_2 + O_2$ (at 25 °C)

Question 32

Q 8-4) What is the standard enthalpy of combustion of ethane gas (C_2H_6) (the higher heating value):

Enthalpies of formation are:

$\Delta h_f°$ (C_2H_6): -84.0 kJ mol^{-1}

$\Delta h_f°$ (CO_2): -393.5 kJ mol^{-1}

$\Delta h_f°$ (H_2O (l)): -285.8 kJ mol^{-1}

☐ A) -1560.4 kJ mol^{-1}

☐ B) -595.3 kJ mol^{-1}

☐ C) -84.0 kJ mol^{-1}

☐ D) -763.3 kJ mol^{-1}

☐ E) -393.5 kJ mol^{-1}

Lecture 9 (Electrochemistry)

Question 33

Q 9-1) What is meant by the term “overvoltage”

☐ A) A thermodynamic property of an electrochemical reaction

☐ B) The magnitude that the anode potential is higher than the cathode potential

☐ C) The magnitude that the cathode potential is higher than the anode potential

☐ D) A kinetic property. A measure of electrode polarization when a current is drawn

☐ E) An always positive voltage added to the equilibrium voltage when a current is drawn

Question 34

Q 9-2) Which part of an electrochemical cell for energy conversion is typically causing the major part of the ohmic energy loss?

- ☐ A) The anode catalyst
- ☐ B) The cathode catalyst
- ☐ C) The electrolyte
- ☐ D) The sealing of the cell
- ☐ E) The connecting cables

Question 35

Q 9-3) In the lead acid battery, the standard reduction potentials for the electrode processes are the following:

a) $PbSO_4 + 2e^- \rightarrow Pb + SO_4^-$: - 0.3588 V

b) $PbO_2 + SO_4 + 2e^- \rightarrow PbSO_4 + 2H_2O$: + 1.6913 V

What is the cell voltage of the battery based on this (*all activities = 1*)?

- ☐ A) 1.3325 V
- ☐ B) 1.6913 V
- ☐ C) 2.0501 V
- ☐ D) 2.665 V
- ☐ E) 4.1002 V

Question 36

Q 9-4) What is the Nernst equation used for?

- ☐ A) Calculation of overvoltage of one electrode
- ☐ B) Calculation of the combined overvoltage of two electrodes
- ☐ C) Calculation of electrode kinetics
- ☐ D) Calculation of equilibrium potentials
- ☐ E) Calculation of electrical efficiency

Lecture 10 (Fuel cells and electrolyzers)

Question 37

Q 10-1) Why is the electrical efficiency of a fuel cell not limited by Carnot's Law?

☐ A) A fuel cell does not produce heat at all, and therefore Carnot's Law cannot be applied

☐ B) A fuel cell produces electricity directly and not via a heat to power process. It is not a heat engine

☐ C) A fuel cell is heat consuming and this would lead to a negative efficiency if Carnot's law were applied

☐ D) Thermodynamics have developed since Carnot. He could not foresee the fuel cell and therefore his law does not address fuel cells

☐ E) A fuel cell is indeed limited by Carnot's Law. Carnot's Law is based on thermodynamics and is therefore always the ultimate limit

Question 38

Q 10-2) The size of the standard free energy of the reaction $2H_2 + O_2 \rightarrow 2H_2O$ decreases with temperature. This causes a corresponding lowering of the equilibrium cell voltage of hydrogen powered fuel cells. Why is a solid oxide fuel cell at 800 °C not less efficient than the low temperature fuel cells at 80 °C?

☐ A) The individual cell is actually much less efficient, but the cells are thinner and more cells are applied in the stack

☐ B) The electrons contain much more energy at high temperature

☐ C) The high temperature lead to higher gas pressures (the ideal gas law) and consequently higher activities, which lead to a higher cell voltage

☐ D) Carnot's law compensate for the low free energy (higher temperature, higher efficiency)

☐ E) The electrode kinetics are much faster at high temperature leading to a lower overvoltage

Question 39

Q 10-3) Which one of the following arguments for converting hydrogen into carbon containing synthetic fuels is NOT sound?

☐ A) The process consumes CO_2 that would otherwise be emitted to the surroundings. Thus, it has a long-term positive effect on the global warming

☐ B) Biogas contains a significant amount of CO_2 from the fermentation process. It can increase the value of the biogas if it is upgraded by methanation of the CO_2

☐ C) Fuels like these are already common in our energy system and can therefore be used directly in the present energy infrastructure

☐ D) Synthetic fuels are generally easier or less expensive to store than hydrogen

☐ E) Carbon containing fuels are more energy dense than hydrogen

Question 40

Q 10-4) The PEM electrolyzer has become very popular in recent years. Why is that?

- ☐ A) It is very compact, due to high current density at a reasonable cell voltage
- ☐ B) It is less expensive than any other type of electrolyzer on the market
- ☐ C) It is the only well-proven system on the market
- ☐ D) It can be manufactured without the use of noble metals
- ☐ E) The fundamental thermodynamics are more attractive for the PEM electrolyser than for other types

Lecture 11 (Batteries)

Question 41

Q 11-1) How much energy can be stored in a battery with a capacity of 3000 C and a cell voltage of 3.6 V?

- ☐ A) 10.8 Wh
- ☐ B) 3.0 Wh
- ☐ C) 10.8 W
- ☐ D) 3.0 W
- ☐ E) 10.8 kWh

Question 42

Q 11-2) The following statement is true for Vanadium Redox Flow Batteries:

- ☐ A) The accessible energy and power can be scaled independently & the cost of vanadium and the cycle-life are both low
- ☐ B) The accessible energy and power cannot be scaled independently & the cost of vanadium and the cycle-life are both low
- ☐ C) The accessible energy and power can be scaled independently & the cost of vanadium and the cycle-life are both high
- ☐ D) The accessible energy and power cannot be scaled independently & the cost of vanadium and the cycle-life are both high
- ☐ E) The accessible energy and power can be scaled independently & the cost of vanadium is high and the cycle-life is low

Question 43

Q 11-3) The following reaction takes place in a sodium-sulphur battery: $4S + 2Na \rightarrow Na_2S_4$. Which component is oxidized and which is reduced?

- ☐ A) Neither sodium nor sulphur is reduced or oxidized
- ☐ B) Both sulphur and sodium are reduced
- ☐ C) Both sulphur and sodium are oxidised
- ☐ D) Sulphur is oxidized and sodium is reduced
- ☐ E) Sulphur is reduced and sodium is oxidized

Question 44

Q 11-4) A battery with a capacity of 3000 mAh is discharged at a C-rate of 2C. How long time does it take to discharge the battery fully?

- [ ] A) 180 min
- [ ] B) 120 min
- [ ] C) 60 min
- [ ] D) 30 min
- [ ] E) 15 min

Lecture 12 (Infrastructure and cost)

Question 45

Q 12-1) If the cost of equity is much higher than the cost of debt (i.e. the shareholders demand much higher dividends then the bondholders demand interest) why would a business still chose some equity financing despite giving a higher WACC (weighted average cost of capital)?

- [ ] A) To make shareholders happy
- [ ] B) In order to decrease leverage
- [ ] C) Due to legal requirements
- [ ] D) Because the WACC doesn't matter when raising capital
- [ ] E) Because the WACC, although important, shouldn't be too low

Question 46

Q 12-2) Why is the DCF (discounted cash flow) of a future revenue stream less than the raw sum of that future revenue stream?

- [ ] A) Because DCF discounts future cash flow by the assumed business risks
- [ ] B) Because DCF discounts future cash flow by the inflation rate
- [ ] C) Because DCF discounts future cash flow by the cost of capital
- [ ] D) Because DFC discounts CAPEX by OPEX
- [ ] E) Because DFC adjusts the WACC over time

Question 47

Q 12-3) How much higher is the capacity factor of nuclear power compared to photovoltaic power, roughly?

- [ ] A) ~ 100 times higher
- [ ] B) ~ 15 times higher
- [ ] C) ~ 4 times higher
- [ ] D) ~ 1.5 times higher
- [ ] E) roughly the same

Question 48

Q 12-4) Denmark consumes around 3.5 GW of electricity on average. Roughly, how many typical family car engines (running at full power) does that power level correspond to?

- ☐ A) ~50.000 cars (2% of the Danish car fleet)
- ☐ B) ~250.000 cars (10% of the Danish car fleet)
- ☐ C) ~850.000 cars (34% of the Danish car fleet)
- ☐ D) ~1.300.000 cars (52% of the Danish car fleet
- ☐ E) ~5.000.000 cars (200% of the Danish car fleet)