47202 Introduction to Future Energy - Ordinary exam 2021

Der anvendes en scoringsalgoritme, som er baseret på "One best answer"

Dette betyder følgende:
Der er altid netop ét svar som er mere rigtigt end de andre
Studerende kan kun vælge ét svar per spørgsmål
Hvert rigtigt svar giver 1 point
Hvert forkert svar giver 0 point (der benyttes IKKE negative point)

The following approach to scoring responses is implemented and is based on "One best answer"
There is always only one correct answer – a response that is more correct than the rest
Students are only able to select one answer per question
Every correct answer corresponds to 1 point
Every incorrect answer corresponds to 0 points (incorrect answers do not result in subtraction of points)

Q1. Introduction i.
A solar park in Turkey which has a nameplate (peak) power rating of 55 MW produces 72 GWh during 12 months of operation. What is the capacity factor?

Choose one answer

- A: 0.0015
- B: 0.015
- C: 0.15
- D: 1.5
- E: 15

Q2. Introduction ii.
A heat machine for making solar electricity in a desert operates between two thermal reservoirs:
1 a hot reservoir - heated by concentrated solar light to 300 degrees Celcius, and
2, a cold reservoir - cooled by desert air to 55 degrees Celcius.

What is the theoretical limit for maximum electrical power that can be extracted if the solar input power is 1 MW to the machine via the hot reservoir?

Choose one answer

- A: 1000 kW
- B: 0 kW
- C: 55 kW
- D: 57.2 kW
- E: 428 kW

Q3. Introduction iii.
What is the annual growth rate in global energy consumption for society (approx)?

Choose one answer

- A: 0.5%
- B: 2.5%
- C: 4.5%
- D: 270 GW
- E: 630 GW

Q4. Introduction iv.
How many household toasters (i.e. a typical bread toaster) can you run using electricity from a single typical nuclear power reactor?

Choose one answer

- A: 1,000,000
- B: 10,000,000
- C: 100,000,000
- D: 1,000,000,000
- E: 10,000,000,000

Q5. Wind i.

The annual wind speed distribution of an installation site for a wind turbine is given by the histogram in figure 8.29 below and it has been determined that the average wind speed is V_{ave} = 6.4 m/s. Which IEC Wind Class is characterizing the wind resource?

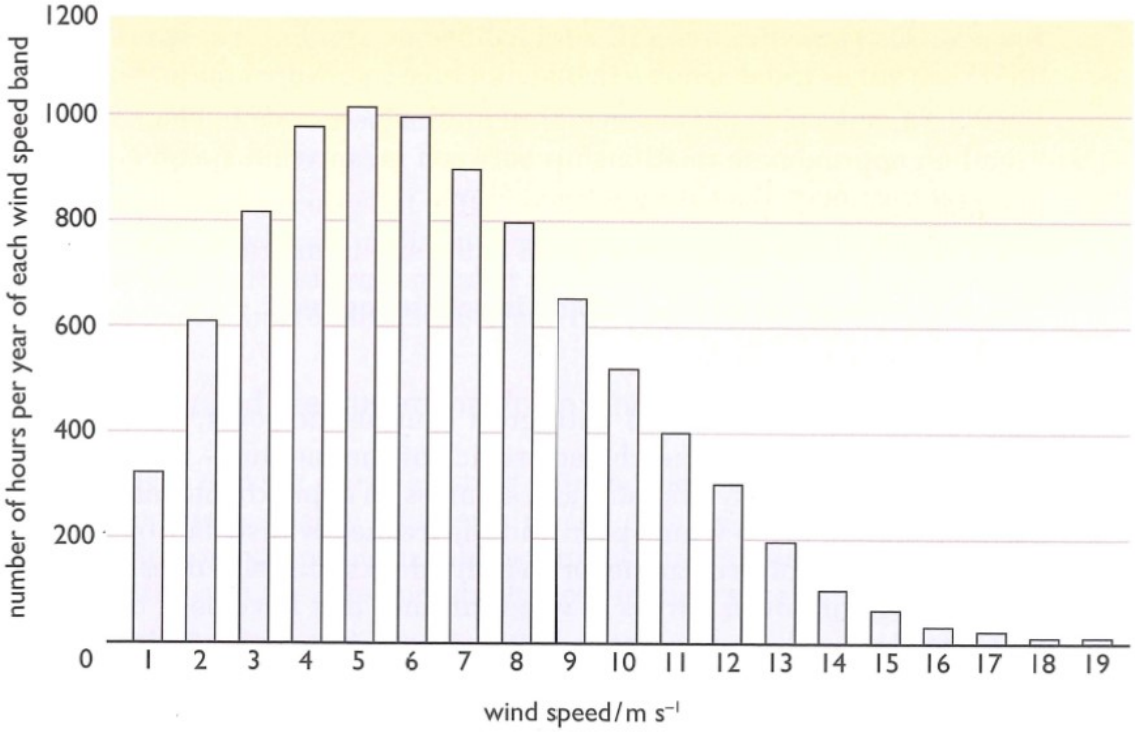

Figure 8.29 A wind speed frequency distribution for a typical site

Choose one answer

- A: IEC Class Medium
- B: IEC Class III
- C: IEC Class II
- D: IEC Class I
- E: IEC Class Low

Q6. Wind ii. One of the largest offshore wind turbines currently introduced has a rotor diameter of $D = 236$ m and the rated wind speed of the turbine is expected to be $V_{Rated} = 10$ m/s. What is the power per rotor area of the turbine at the rated wind speed, if the mass density of the wind is assumed to be $\rho = 1.225$ kg/m^3 and the power coefficient is $C_P = 0.59$?

Choose one answer

- A: 10-100 W/m^2
- B: 100-200 W/m^2
- C: 200-300 W/m^2
- D: 300-600 W/m^2
- E: 600-1000 W/m^2

Q7. Wind iii.
A wind turbine with a rotor diameter of D = 236 m is equipped with a generator of a rated power of P = 15 MW and the manufacture is stating that the Annual Energy Production(AEP) is expected to be AEP = 80 GWh/year. What is the Capacity Factor (CF) of the turbine?

Choose one answer

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

Q8. Wind iv.

Consider a wind turbine with the power curve, where the cut-in wind speed is $V_{Cut\text{-}In}$ = 3 m/s. How many hours per year will such a turbine NOT produce any energy if placed in the wind conditions shown in Figure 8.29 shown below?

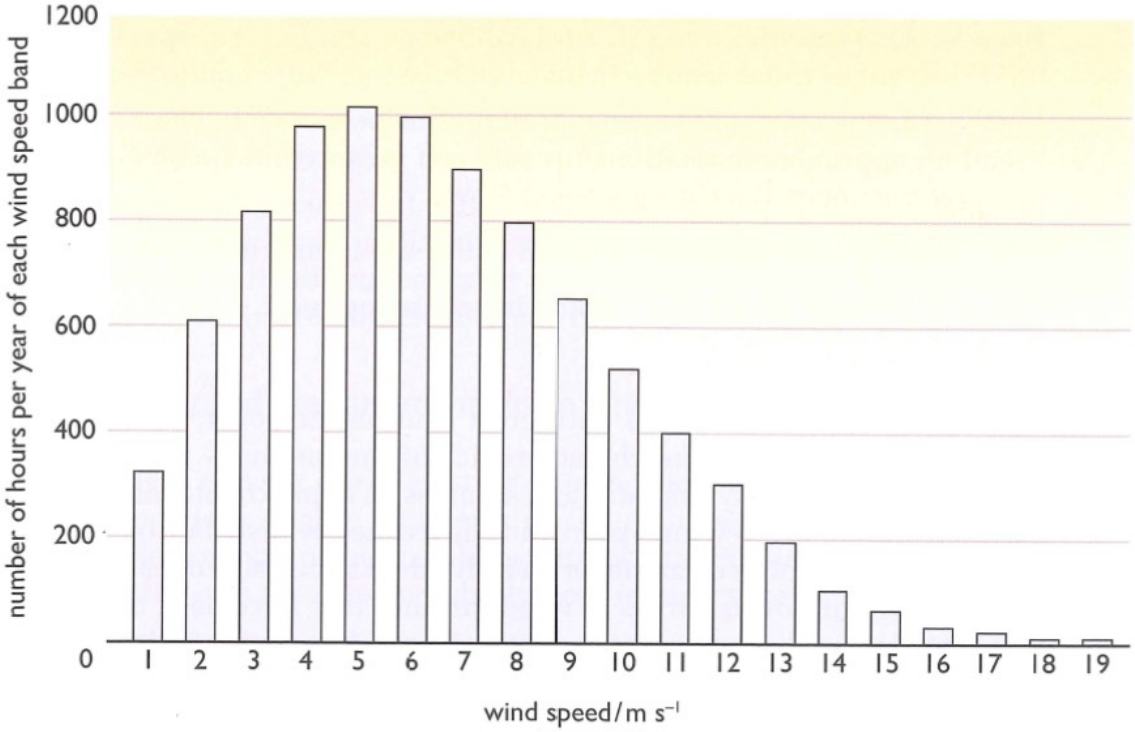

Figure 8.29 A wind speed frequency distribution for a typical site

Choose one answer

- A: 200-400 hours/year
- B: 400-600 hours/year
- C: 600-800 hours/year
- D: 800-1000 hours/year
- E: 1000-1300 hours/year

Q9. Solar i.

The optimum bandgap for a solar cell operating on a roof in Denmark is roughly 1.25 eV and such a cell should in theory achieve an open circuit voltage of ca 1.0 V. However, a solar cell with a bandgap of 2.0 eV would give an open circuit voltage of up to 1.5 V - i.e. 50% more voltage.

Why does the higher bandgap cell give a lower efficiency?

Choose one answer

- A: Because the fill factor (FF) drops for the higher bandgap cell, which harms efficiency
- B: Because it is impossible to make solar cells with a voltage much above 1.0V so the greater voltage potential of the high bandgap cell cannot be realized in practice
- C: Because the higher bandgap cell requires higher light intensity
- D: Because the diode saturation current is lower in the high bandgap cell
- E: Because the gain in voltage is more than offset by the drop in current of the high bandgap cell

Q10. Solar ii.
The dominant solar technology in 2020 (highest global rate of installation) is:

Choose one answer

- A: Crystalline silicon
- B: CdTe
- C: Perovskite
- D: Single-junction GaAs
- E: Multijunction cells

Q11. Solar iii.

The highest efficiency solar cells currently produced are:

Choose one answer

- A: Crystalline silicon
- B: CdTe
- C: Perovskite
- D: Single-junction GaAs
- E: Multijunction cells

Q12. Solar iv.

If the optimum bandgap for a single-junction solar cell for a Mars orbiting satellite is 1.4 eV and one square meter of solar panel gives 100 W in Mars orbit, how would the optimal bandgap and expected output power change the satellite was used in Venus orbit (roughly half the orbital radius of Mars) instead?

Choose one answer

- A: The optimal bandgap would be the same and the output power would be doubled
- B: The optimal bandgap would be doubled and the output power would be doubled
- C: The optimal bandgap would be the same and the output power would be quadrupled
- D: The optimal bandgap would be doubled and the output power would be quadrupled
- E: The optimal bandgap would be quadrupled and the output power would be quadrupled

Q13. Biomass i.
What type of renewable energy is primarily used in Denmark?

Choose one answer

- A: Straw
- B: Manure
- C: Waste
- D: Wind
- E: Wood

Q14. Biomass ii.
Concerning pyrolysis of biomass. What statement is not true?

Choose one answer

- A: It requires heat
- B: It produces biochar
- C: It requires oxygen
- D: It generates a gas
- E: It can be used to generate negative carbon emissions

Q15. Biomass iii.
Consider methanol production by this reaction: $CO + 2H_2 \rightarrow CH_3OH$.
Calculate the heat production if 0.6 kmol/s of H_2 is converted. LHV_H2 = 241.8 MJ/kmol, LHV_CO = 283 MJ/kmol, LHV_methanol = 638 MJ/kmol.

Choose one answer

- A: 9 MW
- B: 19 MW
- C: 29 MW
- D: 39 MW
- E: 77 MW

Q16. Biomass iv.
Calculate the energy efficiency of the water gas shift reaction: $CO + H_2O \rightarrow H_2 + CO_2$. LHV_H2 = 241.8 MJ/kmol, LHV_CO = 283 MJ/kmol.

Choose one answer

- A: 80 %
- B: 85 %
- C: 90 %
- D: 95 %
- E: 100 %

Q17. Nuclear i.
In nuclear fission, what is the typical total released energy / energy released in the decay of fission products?

Choose one answer

- A: 200 eV and 2 eV
- B: 200 keV and 2 keV
- C: 200 keV and 20 keV
- D: 200 MeV and 20 keV
- E: 200 MeV and 20 MeV

Q18. Nuclear ii.
For enrichment, uranium is converted to the chemical form:

Choose one answer

- A: UO_2
- B: U_2O_3
- C: UF_6
- D: FLiBeU
- E: None of the above

Q19. Nuclear iii.
What is the typical thermal efficiency of a nuclear power plant?

Choose one answer

- A: 33%
- B: 43%
- C: 53%
- D: 63%
- E: 73%

Q20. Nuclear iv.
Today, the most common power reactor is the

Choose one answer

- A: BWR
- B: PWR
- C: CANDU
- D: AGR
- E: None of the above

Q21. Water i.
Which of the following technologies is the most developed?

Choose one answer

- A: Wave power
- B: Tidal power
- C: Oceanic thermal energy conversion (OTEC)
- D: Geothermal power
- E: Saline power

Q22. Water ii.

Why is the deep ocean water always around 4 °C?

Choose one answer

- A: It is continuously heated from above and cooled from below. 4 °C is a balance
- B: Certain heat generating/heat consuming microorganisms live there and maintain the temperature
- C: Water from the melting ice flow down due to high density but is heated by the seabed 4 °C is a balance
- D: It is changing very slowly due to diffusion. 4 °C is the original temperature from when the oceans were created
- E: At this temperature water has the highest density

Q23. Water iii.
Ocean current turbines are stouter than wind turbines, because of stronger forces due to the higher density of water as compared to air. How much denser is water?

Choose one answer

- A: Ca. 100 times
- B: Ca. 400 times
- C: Ca. 800 times
- D: Ca. 1200 times
- E: Ca. 2000 times

Q24. Water iv.
A geothermal heat source provides hot water at 90 C. Heat at this temperature is normally used for domestic heating, but if used for power generation, what is the maximum efficiency thermodynamically possible, if the cold sink reservoir available is seawater at 10 ^{o}C

Choose one answer

- A: 9 %
- B: 13 %
- C: 22 %
- D: 31 %
- E: 89 %

Q25. Thermodynamics and electrochemistry i.
Which one of the following statements about kinetics and thermodynamics is correct?

Choose one answer

- A: Kinetics is controlled by thermodynamics
- B: Thermodynamics is controlled by kinetics
- C: Thermodynamics can be changed by a catalyst
- D: Kinetics can be changed by a catalyst
- E: Only thermodynamics matter in practical electrochemical cells for energy conversion

Q26. Thermodynamics and electrochemistry ii.
Calculate the *enthalpy of combustion* of dimethyl ether (CH_3OCH_3) from the following standard thermodynamic functions of formation

	C	CO_2	H_2	O_2	H_2O	CH_3OCH_3
ΔH_f (kJ/mol)	716.7	-393.5	0	0	-241.8	-184.1
ΔG_f (kJ/mol)	671.3	-394.4	0	0	-228.6	-112.6

Choose one answer

- A: -451.2 kJ/mol
- B: -510.4 kJ/mol
- C: -1328.3 kJ/mol
- D: -1362.0 kJ/mol
- E: -1460.4 kJ/mol

Q27. Thermodynamics and electrochemistry iii.
Which of the follow statements is **WRONG**?: The electrolyte of an electrochemical cell must be

Choose one answer

- A: a good ion conductor
- B: a good electron conductor
- C: a good gas separator
- D: a good mechanical separator of the electrodes
- E: chemically stable in the given environment

Q28. Thermodynamics and electrochemistry iv.
An overvoltage (or overpotential) can be described as

Choose one answer

- A: The deviation of the cell potential from the equilibrium potential (can be higher or lower)
- B: The deviation of the cell potential from the equilibrium potential (is always higher)
- C: The potential difference between two electrodes in a cell (the higher minus the lower)
- D: The useful voltage of a battery or a fuel cell
- E: A critical voltage that will destroy one or more components in an electrochemical cell

Q29. Storage i.
Rank the following energy storage technologies according to their globally installed storage power capacity: (I) Compressed Air Energy Storage (CAES); (II) thermal energy storage (thermal); (III) redox flow batteries (flow batteries); (IV) Pumped Hydro Storage (PHS)

Choose one answer

- A: Flow batteries > CAES > PHS > thermal
- B: PHS > thermal > flow batteries > CAES
- C: CAES > PHS > flow batteries > thermal
- D: CAES > flow batteries > thermal > PHS
- E: Thermal > CAES > PHS > flow batteries

Q30. Storage ii.
Which of the following statements is **true**:

Choose one answer

- A: Thermal energy storage can be divided into CAES, sensible, and thermo-chemical energy storage
- B: Hydrogen is suitable for short time-scale and high-efficiency energy storage
- C: A phase change material (PCM) can absorb or release energy when it changes between different phases
- D: Na-S batteries are not suitable for stationary energy storage
- E: Pumped hydro storage accounts for <50% of the installed global energy storage capacity

Q31. Storage iii.
By heating 1.000 liters of water from room temperature (20 deg C) to 80 deg C, it is possible to store the following amount of energy:

Choose one answer

- A: The same as in ~10 kg hydrogen
- B: The same as in ~100 kg Li-ion batteries @250 Wh/kg
- C: ~25 kWh
- D: The same as in ~10 ton water pumped 1.000 meters up (PHS)
- E: ~250 MJ

Q32. Storage iv.
Rank the following energy storage technologies according to their charge time: (I) Compressed Air Energy Storage (CAES); (II) Li-ion; (III) flywheels

Choose one answer

- A: Flywheels < CAES < Li-ion
- B: CAES < flywheels < Li-ion
- C: Li-ion < CAES < flywheels
- D: CAES < Li-ion < flywheels
- E: Flywheels < Li-ion < CAES

Q33. Fuel cells and hydrogen i.
A fuel cell is operated at 0.78 V. What is the conversion efficiency with respect to the higher heating value (HHV)?

Choose one answer

- A: 53 %
- B: 63
- C: 62
- D: 68
- E: 70

Q34. Fuel cells and hydrogen ii.
Which of the following automotive companies have supplied the majority of the fuel cell powered vehicles today?

Choose one answer

- A: Nissan and Mazda
- B: BMW and Ford
- C: General motors and Volkswagen
- D: Tesla and Audi
- E: Hyundai and Toyota

Q35. Fuel cells and hydrogen iii.
Which fuel cells function well without noble metals as catalysts?

Choose one answer

- A: PEMFC, PAFC and SOFC
- B: AFC, PEMFC and SOFC
- C: SOFC, PAFC and AFC
- D: AFC, SOFC and MCFC
- E: SOFC PEMFC and MCFC

Q36. Fuel cells and hydrogen iv.
Which technology is used for hydrogen storage on-board personal fuel cell vehicles?

Choose one answer

- A: Compressed hydrogen at 200 bar
- B: Compressed hydrogen at 700 bar
- C: Metal hydrides
- D: Liquid organic hydrogen carriers (LOHC)
- E: Roughly an equal share of compressed and liquid hydrogen

Q37. Batteries i.

Which of the following statements about batteries is **false**:

Choose one answer

- A: The open circuit voltage (OCV) is the difference between the electrochemical potentials of the positive and negative electrodes
- B: The storage capacity goes up if you increase the capacity or the cell voltage
- C: The energy and power density can be scaled independently in a Li-ion battery
- D: The volumetric energy density is ranked as follows: Li-ion > Ni-MH > Ni-Cd > Pb-acid
- E: Li-ion batteries typically have a higher efficiency than fuel cells

Q38. Batteries ii.
Please rank the following battery materials according to their half-cell standard reduction potentials

Choose one answer

- A: Li < Na < K < Mg < Ca
- B: Ca < Mg < K < Na < Li
- C: Li < K < Ca < Na < Mg
- D: Li < Na < K < Mg < Ca
- E: Mg < Na < Ca < K < Li

Q39. Batteries iii.

The following overall reaction can take place during charging of a lithium-metal - iron phosphate battery ($FePO_4$/Li(s)): $LiFePO_4$ -> $FePO_4$ + Li(s)

Choose one answer

- A: Phosphorous is oxidized, while iron and lithium are reduced
- B: Iron is oxidized and lithium is reduced, while phosphorous is neither oxidized nor reduced
- C: Lithium and phosphorous are oxidized, while iron is reduced
- D: Neither lithium, iron nor phosphorous is reduced or oxidized
- E: Lithium is oxidized, phosphorous is reduced and iron neither oxidized nor reduced

Q40. Batteries iv.
Assuming a cell voltage of 3.2 V, how many grams of $LiFePO_4$ would be needed to store 11 Wh ($M_{LiFePO4}$=157,7574 g/mol; F = 96485,33289 C/mol)?

Choose one answer

- A: ~5 g
- B: ~20 g
- C: ~50 g
- D: ~200 g
- E: ~5 kg

Q41. Electrolysis and synfuels i.
Theoretically, water electrolyzers can have electrical efficiencies above 100 %. Which of the following explanations is correct?

Choose one answer

- A: It is only a theoretical claim and cannot be realized practically due to the first law of thermodynamics (energy conservation)
- B: The second law does not apply, because an electrolyzer is not a heat machine
- C: An electrolyzer is like a heat pump. The efficiency is in principle be unlimited, and a better term would be *coefficient of performance* (COP), like for a heat pump
- D: It is only true, if the electricity is supplied at room temperature and the cell is operating at high temperature. The temperature difference adds entropy to the electrical energy and this entropy generation lowers the demand for electrical energy
- E: The reaction scheeme leads to a net increase of entropy and consequently, part of the energy to run the process can be supplied as heat

Q42. Electrolysis and synfuels ii.
An electrolyzer is operated at 1.9 V. What is the conversion efficiency with respect to the higher heating value (HHV)?

Choose one answer

- A: 51
- B: 65
- C: 71
- D: 78
- E: 128

Q43. Electrolysis and synfuels iii.
Rank (as higher to lower) the following technologies by round-trip efficiency (electricity to fuel to electricity or work)

Choose one answer

- A: Batteries > Hydrogen > Carbon based synthetic fuels
- B: Batteries > Carbon based synthetic fuels > Hydrogen
- C: Hydrogen > Batteries > Carbon based synthetic fuels
- D: Hydrogen > Carbon based synthetic fuels > Batteries
- E: Carbon based synthetic fuels > Batteries > Hydrogen

Q44. Electrolysis and synfuels iv.
Which process can be used for making larger hydrocarbon molecules?

Choose one answer

- A: Haber-Bosch
- B: Haber-Tropsch
- C: Sabatier
- D: Fischer-Tropsch
- E: Sabatier-Bosch

Q45. Infrastructure i.
Assume you are considering a 3 year venture for which the projected annual expenses is:
E1 = 100, E2 = 20, E3 = 25
Meanwhile the projected revenue (turnover) generated by the project is:
R1 = 0, R2 = 80, R3 = 80
This means that the net cash flow for the three years will be -100, 60 and 55.
Assume that the project has no revenue or expenses beyond the third year.

What is the discounted net cash flow (rounded to nearest integer) for each of the three years if the annual discount rate is 10% after the first year?

Choose one answer

- A: -100, 55, 45
- B: 0 , 80, 80
- C: -100, 60, 55
- D: -100, 73, 66
- E: -100, 18, 21

Q46. Infrastructure ii.
Same setup as in Q45:
-
Assume you are considering a 3 year venture for which the projected annual expenses is:
E1 = 100, E2 = 20, E3 = 25
Meanwhile the projected revenue (turnover) generated by the project is:
R1 = 0, R2 = 80, R3 = 80
This means that the net revenue for the three years will be -100, 60 and 55.
Assume that the project has no revenue or expenses beyond the third year.
-
What is the internal rate of return of the project?

Choose one answer

- A: 15
- B: 0.15 (15%)
- C: 10
- D: 0.1 (10%)
- E: 0

Q47. Infrastructure iii.
What does LCOE stand for

Choose one answer

- A: Legal Costs Of Enterprize
- B: Lower Cost Of Energy
- C: Levelized Cost Of Equilibrium
- D: Litigation Cost Of Energy
- E: Levelized Cost Of Energy

Q48. Infrastructure iv.
Assume that a photovoltaic installation can give 100 W/m2 of power (nameplate power). Installed in Denmark, assume the capacity factor of a Danish photovoltaic installation to be 0.12 (12%).
Make a Fermi Estimate of how big such a Danish solar farm would need to be in order to provide as much annual electricity as is needed by 2.5 million electric cars (i.e. if roughly all cars in Denmark were electric and got all their power from the solar farm).
Hint. Guesstimate how many kilometers a Danish car drives annually on average and assume an average energy efficiency of the cars of 5 km/kWh for mixed driving.

Choose one answer

- A: 9.5 km^2 (13x DTU Lyngby campus)
- B: 95 km^2 (125x DTU Lyngby campus)
- C: 950 km^2 (1250x DTU Lyngby campus)
- D: 9500 km^2 (140% the area of the island of Zealand (Sjælland))
- E: 95000 km^2 (210% the area of Denmark