Exercise: ‘Solar Impulse’ electric aircraft

Motor power:	4 electric engines of each 13 kWe max
PV installed:	monocrystalline Si, 20% efficiency total area: 275 m^2
Batteries installed:	650 kg Li-ion type with energy density of 250 Wh/kg; PV-to-battery charging efficiency = 90%
Aircraft speed:	average speed is 80 km/h at day, and 60 km/h at night
Flight altitude:	8-10'000 m (assume 10% albedo at this altitude)
Latitude of flight:	25° North
Solar constant:	1367 W/m^2

<u>Questions</u>:

a) Estimate the maximal electrical energy that can be delivered from the PV panels on July 1st, in favorable conditions.

b) Estimate the propulsion efficiency (PV-to-engine).
(Assume the same propulsion efficiency for battery-to-engine in question (c) below).

c) ‘Solar Impulse’ on one of its longest non-stop flights took off from Nagoya (Japan) towards Hawaii, some 7000 km away, for a flight of 5 days and 5 nights.
(Assume it took off with fully charged batteries which were discharged during the night.) Assume a maximum ‘depth-of-discharge’ of 95%, i.e. batteries cannot be discharged to below 5% of their full capacity.
Assume that the same amount of solar energy as on July 1st can be harvested on all 5 consecutive days needed to cover the trip (i.e. June 29th to July 3rd).
At day, it flies on PV power and recharges the battery fully.
At night, it flies on battery power only.

Estimate the maximum specific consumption (kWhe/km) ‘Solar Impulse’ must not exceed during the flight at day, and at night, so that it could carry out this challenging trip successfully.

d) At which average engine power was it running in this limiting case described in question (c), at day, and at night?