

1. CONCEPTS IN CLIMATE-CHANGE MITIGATION (7 points, 1 each)

- Given typical technology for today, which is the more climate-friendly water-heater energy source: natural gas or electricity?
- An electric range has an efficiency of 74%. How much electrical energy (kWh) is required to deliver 1 MJ of thermal energy to a cooking pot using this range?
- According to Pacca and Horvath, a solar photovoltaic power plant would have effective greenhouse-gas emissions of $\sim 60 \text{ gC}_{\text{eq}}/\text{kWh}$, averaged over the first 10 y of its life. What is the cause of GHG emissions from a solar PV power plant?
- What is the most common means of producing H_2 today?
- Excluding cost, name a key issue that limits the widespread use of bioethanol as a transportation fuel to mitigate against climate change.
- Cooking for perhaps half of the world's population is done using unprocessed solid fuels. Disregarding the health consequences of exposure to cooking smoke, which is better for climate, to cook with dung or to cook with LPG (liquified petroleum gas)? Justify your answer with a brief explanation.
- Explain the technological difference between a halogen bulb and a standard incandescent bulb.

2. EFFICIENCY OF RENEWABLES (4 points, 2 each)

- Figure 1 shows a power curve for a wind turbine. If the power-generation efficiency is 40% at a wind speed of 10 m/s, what is the efficiency at a wind speed of 20 m/s?
- Figure 2 shows the theoretical maximum efficiency of a solar photovoltaic device for converting photon energy into electrical energy as a function of the wavelength of light. Explain the underlying physical processes that cause the efficiency curve to have this shape.

Figure 1. Power curve

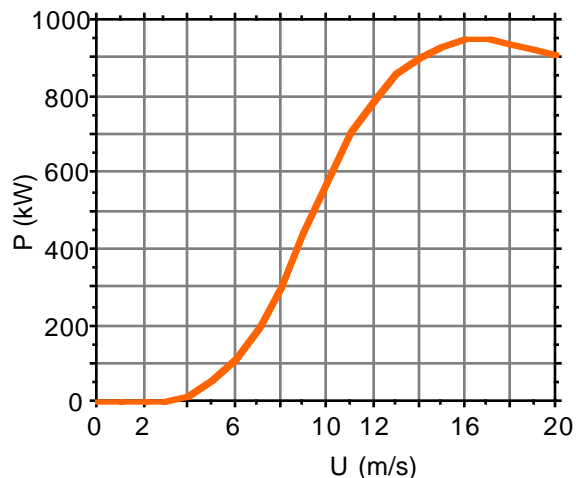
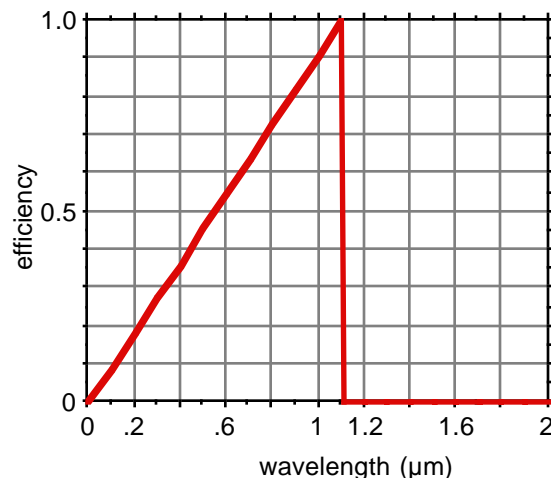


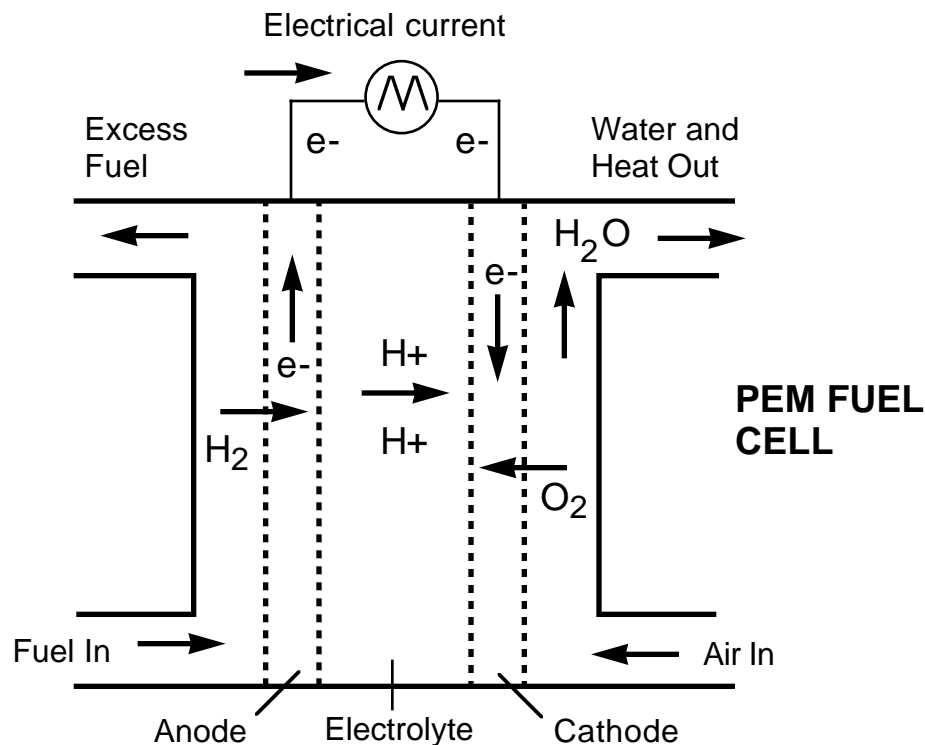
Figure 2. Solar PV efficiency



3. FUEL CELLS (5 points, 1 each)

Answer the following questions about PEM fuel cells, illustrated schematically below.

- The maximum electrical potential from the unit shown is 1.2 V. How does one achieve higher voltages using fuel cells?
- The power delivered by a fuel cell is the product of the voltage and the current. What is the key variable in a fuel-cell power device that can be altered to increase the current?
- The typical operating temperature of a PEM fuel cell is 80 °C. What important failure mode occurs if the operating temperature increases significantly above this value?
- Describe the structure and chemical composition of the electrodes (anode and cathode).
- What is meant by the acronym “PEM”?



4. CLIMATE IMPACT OF BUILDING VENTILATION (4 points)

Given the following data, compute the annual fossil-C emissions attributable to heating the ventilation air of a single-family house.

DATA

HDD = 2510 K-day y ⁻¹	annual heating degree days
V = 400 m ³	house volume
λ = 0.35 h ⁻¹	air-exchange rate
ρ = 1.2 kg m ⁻³	air density
C _p = 1.0 kJ kg ⁻¹ K ⁻¹	heat capacity of air
HV = 50 MJ kg ⁻¹	heating value of natural gas
η = 0.80	furnace efficiency
CH ₄	composition of natural gas