

Worksheet IB8.1: Energy Production

Energy Density and Efficiency

1. What is the energy content of 10.0 g of petrol (gasoline)? (450 kJ)
2. How many grams of coal must you burn to get 125 kJ of heat energy? Use an specific energy of 40.0 MJ kg^{-1} . (3.13 g)
3. How many grams of petrol must you burn to raise the temperature of 750. ml of water ($C_{\text{water}} = 4186 \text{ J kg}^{-1} \text{ }^{\circ}\text{C}^{-1}$) from $15.0 \text{ }^{\circ}\text{C}$ to $100.0 \text{ }^{\circ}\text{C}$? if the stove is 100% efficient? What if it is 65.0% efficient? (5.93 g, 9.12 g)
4. A gas water heater contains 189 liters of water at $15.0 \text{ }^{\circ}\text{C}$. If it is 55.0% efficient, and it burns 0.889 kg of natural gas, what is the final temperature of the water? ($49.0 \text{ }^{\circ}\text{C}$, the ΔT is $34.0 \text{ }^{\circ}\text{C}$)
5. An on demand water heater needs to heat 17.0 liters of water per minute from a temperature of $13.0 \text{ }^{\circ}\text{C}$ to $54.3 \text{ }^{\circ}\text{C}$. How many grams of natural gas will it burn in one minute if it is 58.0% efficient? (92.1 g)
6. A gas water heater can raise the temperature of 178 liters of water from $21.0 \text{ }^{\circ}\text{C}$ to $65.0 \text{ }^{\circ}\text{C}$ by burning 1.10 kg of natural gas. What is its efficiency? (54.2%)
7. A power plant generates 125 MW of power. How much energy does it generate in a day? If it is 37.0% efficient, what is the energy input in a day? How many kilograms of coal would it burn to produce that amount of energy? (Use an specific energy of 40.0 MJ kg^{-1}) How many kilograms of Uranium would it go through in a day? ($1.08 \times 10^{13} \text{ J}$, $2.92 \times 10^{13} \text{ J}$, $7.30 \times 10^5 \text{ kg}$ or 730 metric tons, 0.365 kg of Uranium)
8. A power plant is 37.0% efficient and burns 4190 kg of natural gas a day. What is its average power output? (987 kW)
9. A natural gas generation plant generates a power output of 0.850 MW. It consumes 159 kg of natural gas per hour. What is its efficiency? (35.0%)
10. How many kg of natural gas will a 145 MW natural gas electrical generation plant that is 34.0% efficient burn in a year? ($2.45 \times 10^8 \text{ kg}$)

Fuel	Specific energy/ MJ kg^{-1}	Energy density/ MJ m^{-3}
Wood	16	1×10^4
Coal	20–60	$(20\text{--}60) \times 10^6$
Gasoline (petrol)	45	35×10^6
Natural gas at atmospheric pressure	55	3.5×10^4
Uranium (nuclear fission)	8×10^7	1.5×10^{15}
Deuterium/tritium (nuclear fusion)	3×10^8	6×10^{15}
Water falling through 100 m in a hydroelectric plant	10^{-3}	10^3

Wind Turbines

11. A giant wind turbine has a radius of 43.9 meters, and operates where the average wind speed is 6.64 m/s, and the air density is 1.31 kg m^{-3} . What is the maximum amount of power available to it? What power does it capture if the air exiting the turbine is still going 5.14 m/s? If the electrical generator is 89.0% efficient, what electrical power does it create? (1.16 MW, 622 kW, 554 kW)
12. A wind turbine slows air with a density of 1.25 kg m^{-3} from 7.12 m/s to 6.50 m/s and needs to capture 26.5 kW of power. What radius does it need to be? How many of these would you need to capture 1.20 MW of power? (12.5 m, about 45, I suppose 46 to be more than that)
13. A wind turbine with 15.0 m blades captures 45.8 kW of power from air with a density of 1.35 kg m^{-3} initially moving at 6.15 m/s. What is the speed of the air leaving the turbine? (5.15 m/s)
14. A wind farm operates in air with a density of 1.30 kg m^{-3} . The individual turbine blades are 45.1 m long, and the average wind speed is 5.40 m/s. If the turbines have an overall efficiency of 41.5%, what is its average power output of a single turbine? How many of these turbines would you need if you wanted to generate 120. MW? (271 kW, about 442)
15. A wind turbine with 35.0 m long blades slows air with a density of 1.30 kg m^{-3} from 8.15 m/s to 7.25 m/s. What power does it capture from the wind? If the electrical generator is 92.0% efficient, what is the power output? (401 kW, 369 kW)

Pumped Storage

16. A pumped storage system allows water to fall through a vertical distance of 270. m at a rate of 450. kg s^{-1} . What is the total power being transformed? If the generation system has an overall efficiency of 56.0 % what is the electrical power output? (1.19 MW, 667 kW)
17. You are designing a pumped storage system. You can raise the reservoir a height of 85.0 m above the generation site, and the overall efficiency is 62.0%. What flow rate in kg s^{-1} do you need to have to generate 125 kW? (242 kg s^{-1})
18. A pumped storage facility is generating 860. kW of electrical power with a flow rate of 712 kg s^{-1} , and an overall efficiency of 67.0%. What height is the reservoir above the generation site? (184 m)
19. A pumped storage system is generating 413 kW of electricity with a reservoir that is 312 m above the generation site, and is operating a flow rate of 237 kg s^{-1} . What is its overall efficiency? (56.9%)
20. A 72.0% efficient pumped storage plant operates with a vertical displacement of 185 m, and lets 2740 kg of water per minute into the generator. What is its power output? (59.7 kW)

Solar

21. A house has solar panels that measure 1.65 m by 0.991 m, and are 22.3% efficient. If the sunlight has an intensity of 850. W m^{-2} , what is the electrical power generated by a single panel? How many panels would you need to generate at least 4 kW? (310. W, 13)
22. A house has 12 solar panels with an efficiency of 21.5% that measure 1.57 m by 1.05 m, and are generating 4020 W of power. What is the intensity of the solar radiation? (945 W m^{-2})
23. You need to generate 5.60 kW of power for a house with solar panels that have an efficiency of 23.0% and the average intensity of sunlight is 450. W m^{-2} . What area do you need? (54.1 m^2)
24. Some solar panels measure 1.60 m by 1.02 m, each one generating 275 W of power when the sunlight intensity is 750. W m^{-2} . What is the efficiency of the panels? (22.5%)
25. A house has 35.0 m^2 total area of solar panels with an efficiency of 24.0%. What is the power output when the sunlight intensity is 1020 W m^{-2} ? (8570 W)