Estimate book: How much metal does the future need?

Name _____ Class _____ Date _____

My estimates

A Fermi estimate breaks a big question into factors you can guess, then multiplies or divides them. Write your guesses and your estimate before you look at any data. Then show the data on the screen and write it in.

To find how many times out you were, divide the bigger of the two numbers by the smaller.

	Question	My guesses and working	My estimate	The data	Times out
1	How many wind turbines would it take to make as much electricity as Eraring power station?				
2	How many kilograms of lithium are in the battery of one electric car?				
3	How many cubic metres of concrete are in the foundation under one large wind turbine?				
4	How many hectares of solar farm would make as much electricity as Eraring?				
5	How many tonnes of rock have to be mined to get the copper for one electric car?				
6	How many million tonnes of greenhouse gas does Eraring emit in a year?				
7	How many years of NSW's copper production would it take to make every vehicle in NSW electric?				
8	How many terawatt hours of electricity would NSW need in a year if every vehicle ran on electricity?				
9	My own question:				

A year of output, and inside the machines

Screens 1 and 2

Capacity factor

Capacity factor = electricity made ÷ (capacity × 8,760 hours). Work out each one as a percentage.

Power station	Kind	Capacity (MW)	Made in 2024–25 (MWh)	Capacity factor (%)
Eraring Power Station	Black coal	2,880	15,439,046	
Rye Park Wind Farm	Wind	396	1,147,264	
Nyngan Solar Plant	Solar	102	212,865	
Snowy Hydro in NSW	Hydro	4,100	4,235,447	

What the machines are made of

Take each machine apart in the model and write what each part is made of.

Machine	Part	Made of
Solar panel	Glass cover	
	Frame	
	Solar cells	
	Contact lines on the cells	
	Ribbons joining the cells	
	Sealing layers and backsheet	
Wind turbine	Foundation	
	Tower	
	Blades	
	Generator	
	Hub and drive shaft	
	Cables and transformer	
	Coatings	
Motor or generator	Coils	
	Core	
	Permanent magnets	
	Shaft and bearings	
	Housing	
Lithium-ion battery	Cathode	
	Anode	
	Foil behind the anode	
	Foil behind the cathode	
	Electrolyte and separator	
	Case	

Building, and land

Materials to build a power station

Copy the figures from the model, in tonnes for each TWh of electricity.

Material and source	Coal	Gas	Nuclear	Hydro	Wind	Solar farm
Concrete and cement, US DOE, 2015						
Concrete and cement, Bright New World, 2021						
Steel and iron, US DOE, 2015						
Steel and iron, Bright New World, 2021						
Copper, US DOE, 2015						
Copper, Bright New World, 2021						

Which kind of power station needs the most material to build for each TWh, and which needs the least? Give figures from both sources and say where they disagree.

Land

Kind of power station	Hectares for each TWh a year	Hectares for Eraring's 15.4 TWh	Side of a square that size (km)
Nuclear	7.1		
Gas, footprint	410		
Hydro	650		
Coal	1,000		
Solar farm	2,000		
Wind farm, footprint	130		
Wind farm, with the land between the turbines	12,000		

Compare the land needed by a solar farm, a wind farm and a coal-fired power station for the same electricity. What else would you want to know about the land before judging which is better?

Mining

Ore for a tonne of copper

Ore for one tonne of copper = 1 ÷ (grade × recovery), with the grade and the recovery written as decimals.

Ore from	Grade (%)	Recovery (%)	Ore for 1 tonne of copper (t)	Ore for one electric car, 53.2 kg of copper (t)
Cadia, 2025	0.34	84.3		
Northparkes reserve	0.51	81		
Chile, 2017	0.65	85		
Chile, 2001	1.25	85		

Fuel is mined every year

Fuel	Mined in a year	Electricity in a year	Tonnes for each TWh
Coal for Eraring	about 5.5 million tonnes	15.4 TWh	
Uranium ore for a 1,000 MW reactor	20,000 to 400,000 tonnes	about 8 TWh	

Rock mined for each TWh

Shade the columns that each range covers. Each column is ten times bigger than the one before.

	100 to 1,000 t	1,000 to 10,000 t	10,000 to 100,000 t	100,000 to 1 million t
Coal burnt at Eraring				
Uranium ore for a reactor				
Copper ore for a solar farm				
Copper ore for a wind farm				
Copper ore for a hydro scheme				
Copper ore for a nuclear station				

Use the mining data to compare a coal-fired power station with a solar farm or a wind farm. Which needs more rock mined for each TWh, and how sure can you be?

A year of running, and copper

A year of running

Power station	Emissions intensity (t CO_2-e for each MWh)	Fuel	Wastes	Will the fuel last?
Eraring (black coal)				
Tallawarra (natural gas)				
A 1,000 MW reactor (nuclear)				
Snowy Hydro in NSW (hydro)				
Rye Park Wind Farm (wind)				
Wellington North Solar Farm (solar)				

Copper

Analyse the demand for copper. Why is it rising, what limits supply, and what are the implications for mining in NSW and the rest of Australia?

Less oil, and my answer

Using less crude oil for transport

Effect	A benefit, a cost or a risk, some of each, or not enough evidence?	Evidence
Greenhouse gas emissions		
Fuel security		
Mining and minerals		
The electricity grid		
Trucks, buses and freight		
Costs to households		

My answer

How much metal does the future need? Give your best estimates for NSW, with their uncertainty.

What are the implications for mining in NSW and the rest of Australia? Include one benefit, one cost and one thing that is still uncertain.