July 2024

NUCLEAR-WIND-SOLAR INFOGRAPHICS

SMR NUCLEAR TECHNOLOGY PTY LTD

Small Modular Reactors Infographics

Sydney-based nuclear energy consultancy SMR Nuclear Technology Pty Ltd (SMR-NT) has issued a set of infographics to provide policymakers and the Australian community with a better understanding of the real differences between Nuclear, solar, wind and fossil fuels for electricity generation.

Australians cannot afford a short-term view of generation costs. They need to take a measured approach which weighs up the costs of the different technologies over their lifetimes. Planners can then work out the real costs to the overall power system.

The cost of transmitting bulk electricity will be increased by the number of small solar and wind generators that needed to be connected to the grid.

A major advantage with nuclear generation in pursuing Australia's 2050 net zero goals, is that they can be connected to the existing power grid and avoid much of the cost of new transmission infrastructure. This could generate national savings of billions of dollars.

All low emissions technologies will be needed to achieve Australia's net zero goals: Each low emissions technology brings different advantages - the big challenge is determining the right technology mix for the minimum long-term system cost. In this respect, SMRNT's infographics will be of value to both policymakers and the general public.

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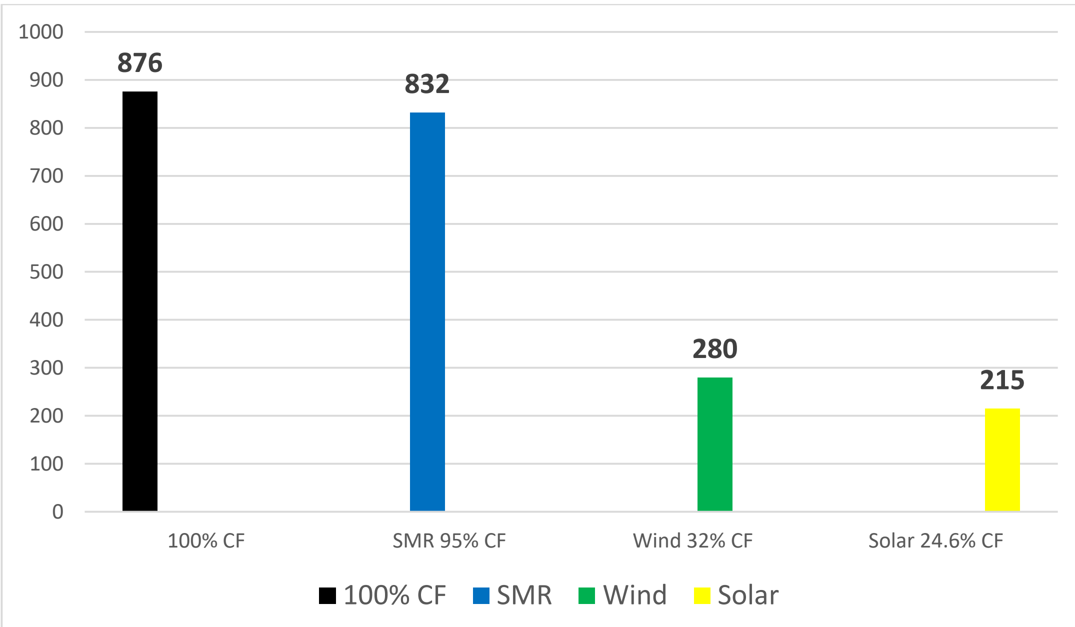
Nuclear, Solar and Wind
Which technology has more clear advantages (shown in green)?

Parameter	Nuclear	Utility Scale Solar	Onshore Wind
Reliability of generation	reliable	variable	variable
Independent of the weather	independent	dependent	dependent
Capacity factor	95%	19% - 32%	29% - 48%
Load following capability	yes	no	no
Provides frequency control	yes	no	no
Provides system inertia	yes	no	no
Black start capability	yes	no	no
Direct process heat for industry	yes	no	no
Plant Design/Economic life years	60	30	20 - 25
Plant Technical/Operational life years	>60	30	20 - 30
Land area required hectares/TWh	1.1	1,295	7,203
Visual impact	low	medium	high
Noise impact	low	low	high
Wildlife impact	low	medium	high
Major material required t/TWh	1,190	2,516	5,976
Critical minerals required t/TWh	12	124	130
Materials – concrete t/TWh	1,058	1,216	4,466
Materials – steel t/TWh	134	938	1,447
Lifecycle emissions g/kWh	12	48	11
Storage required	None	Battery 4 hrs/ PHES 24 hrs	
Cost of storage $/kW	$0	$2,367 battery/kW $5,808/kW PHES	
Additional transmission	none	>$15.9 billion	
Life waste included in cost	yes	no	no
Total O&M cost $/MWh	25.6	7.6	7.4
Fuel cost $/MWh	9.4	Free	Free
Construction time years	4	0.5	1.0

Nuclear generation costs EIA 2022 in AUD (exchange rate 0.65)
Wind and solar: CSIRO GenCost 2023-24 Final report May 2024, transmission Table 5.2
Pumped Hydro Energy Storage (PHES) and battery costs – CSIRO GenCost 2023-24 Table B.8
Material requirements: Bright New World (BNW) and IEA "The Role of Critical Materials in Clean Energy Transitions"
Land use: NEI April 2022 and GE Hitachi
Lifecycle emissions: WNA and IPCC
O&M = Operations & Maintenance

Capacity Factor

Capacity Factor is the ratio of actual generation of a power plant compared to the generation that would be produced by continuous full power operation.
For example a 100 MW plant at 100% capacity factor would generate 100 x 24 x 365 = 876 GWh/year
(GW = 10^9 watts)



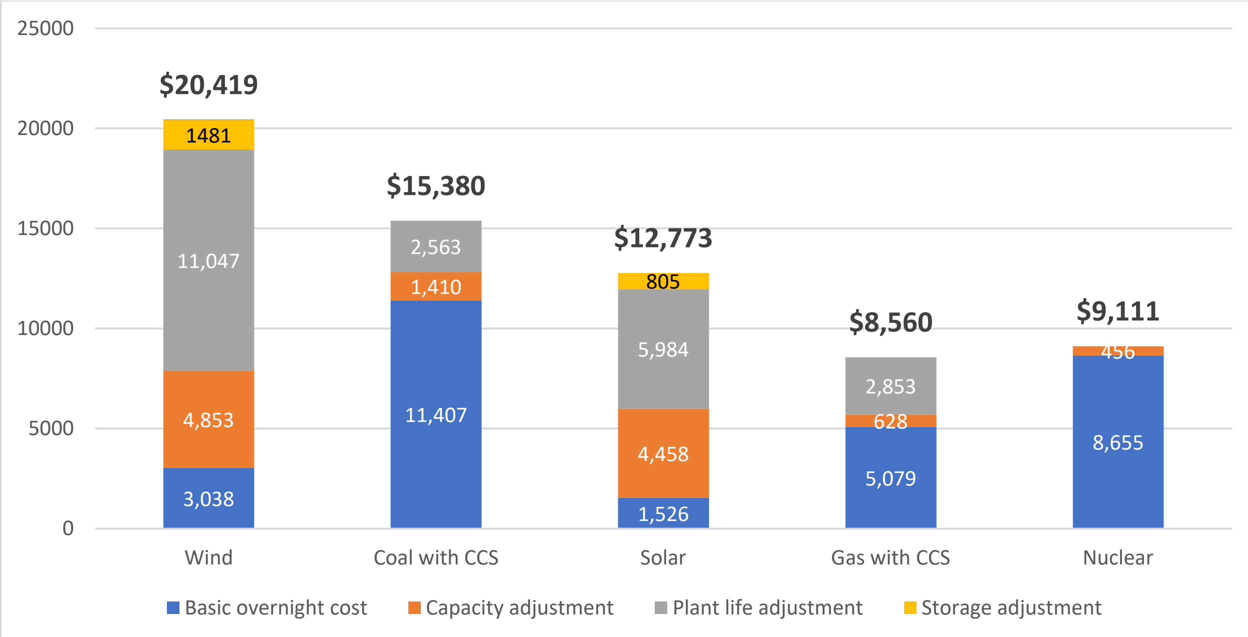
When you contract for a 100 MW power plant you actually get the generated output of 95 MW for an SMR (832 GWh/y) or 32 MW for a wind farm (280 GWh/yr) or 24.6 MW for a utility scale solar plant (215 GWh/y)

Wind and solar capacity factors actual generation in 2023 (without network and economic curtailment factors) – WattClarity.com.au

Actual average wind with network and economic curtailment = 30.0%
Actual wind seasonal variation 25.8% (April) – 41.2% (June)

Actual average solar with network and economic curtailment = 21.51%
Actual utility solar seasonal variation 13.4% (June) – 27.5% (December)

Real Overnight Capital Cost - $/kW for New Build

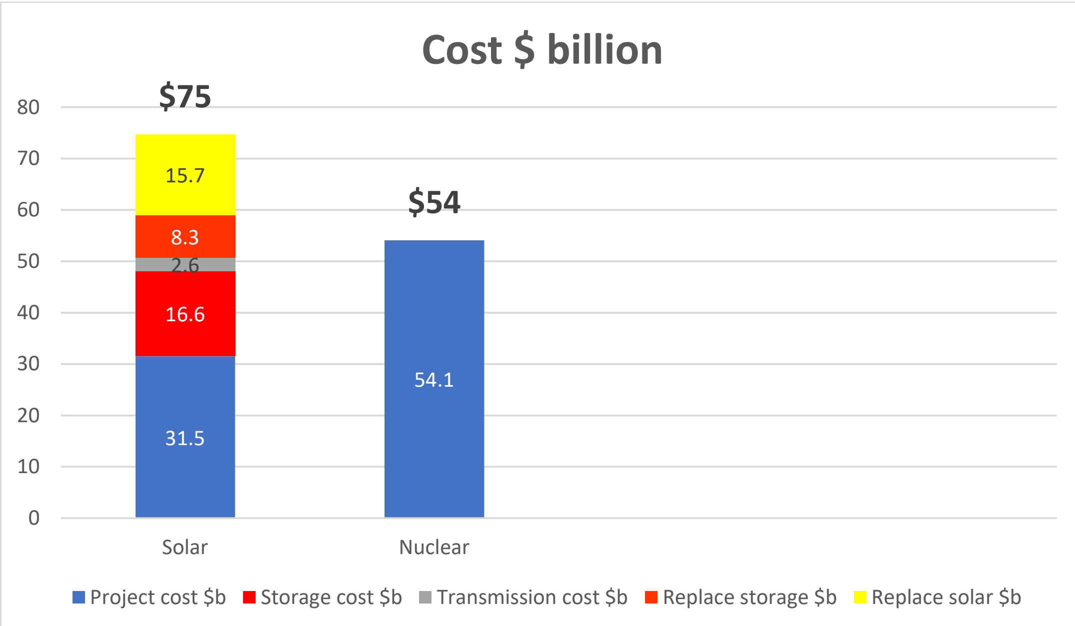


Wind > $20,419/kW, Solar > $12,773
(Solar and Wind have connection and transmission costs in addition to these costs)
Coal with CCS = $15,380/kW, Gas with CCS = $8,560/kW, Nuclear $9,111
Costs: CSIRO GenCost 2023-24 Table B.9 for 2023

Operational capacity factors for new build: solar = average 25.5%, wind = average 38.5%, coal 89%, gas 89%, nuclear 95%
Operational lifetimes: solar = 30 years, wind = 25 years, coal 50 years, gas 40 years, nuclear 60 years.
All lifetimes adjusted to 60 years.

Storage requirements and costs from CSIRO GenCost report 2023-24 Page 76 – average 0.34 kW storage capacity for each kW of wind and solar installed (2030 figure, 2023 would be higher but not quoted).

Coal Fired power stations in NSW generated 45,976 GWh in 2022.
What would be the cost of replacing this generation with utility scale solar or Nuclear to 2050?



To 2050

Total solar cost = $75 billion

Solar based on 275 MWac, average new build capacity factor 25.5%

75 solar plants required at a cost of $0.42 billion each.

Total Nuclear cost = $54.1 billion

Nuclear based on Westinghouse AP-1000. 5 reactors required at a cost of $10.8 billion each.

Storage requirements and cost based on CSIRO GenCost GenCost 2023-24 report, average 0.34 kW storage capacity for each kW of solar installed.

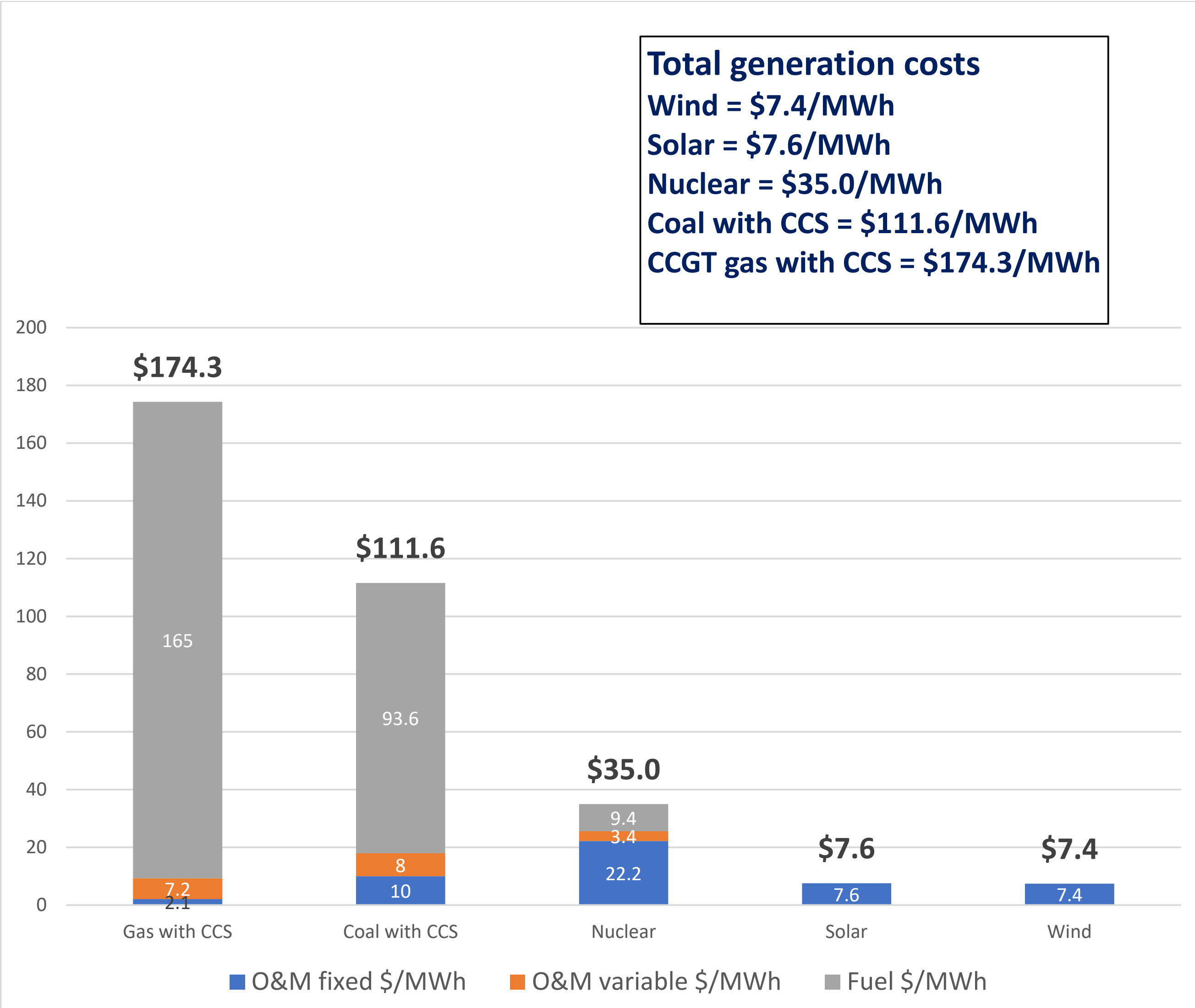
Additional transmission required based on a proportion of AEMO ISP 2024 (2050) cost $16 billion.

Solar cost includes storage (4 hr battery), additional transmission cost and replacement of the solar plant and battery during lifetime at half cost.

No allowance for battery round trip losses or transmission losses.

(No additional storage or transmission or replacement required for Nuclear – 60 year design life).

Generation Costs $/MWh

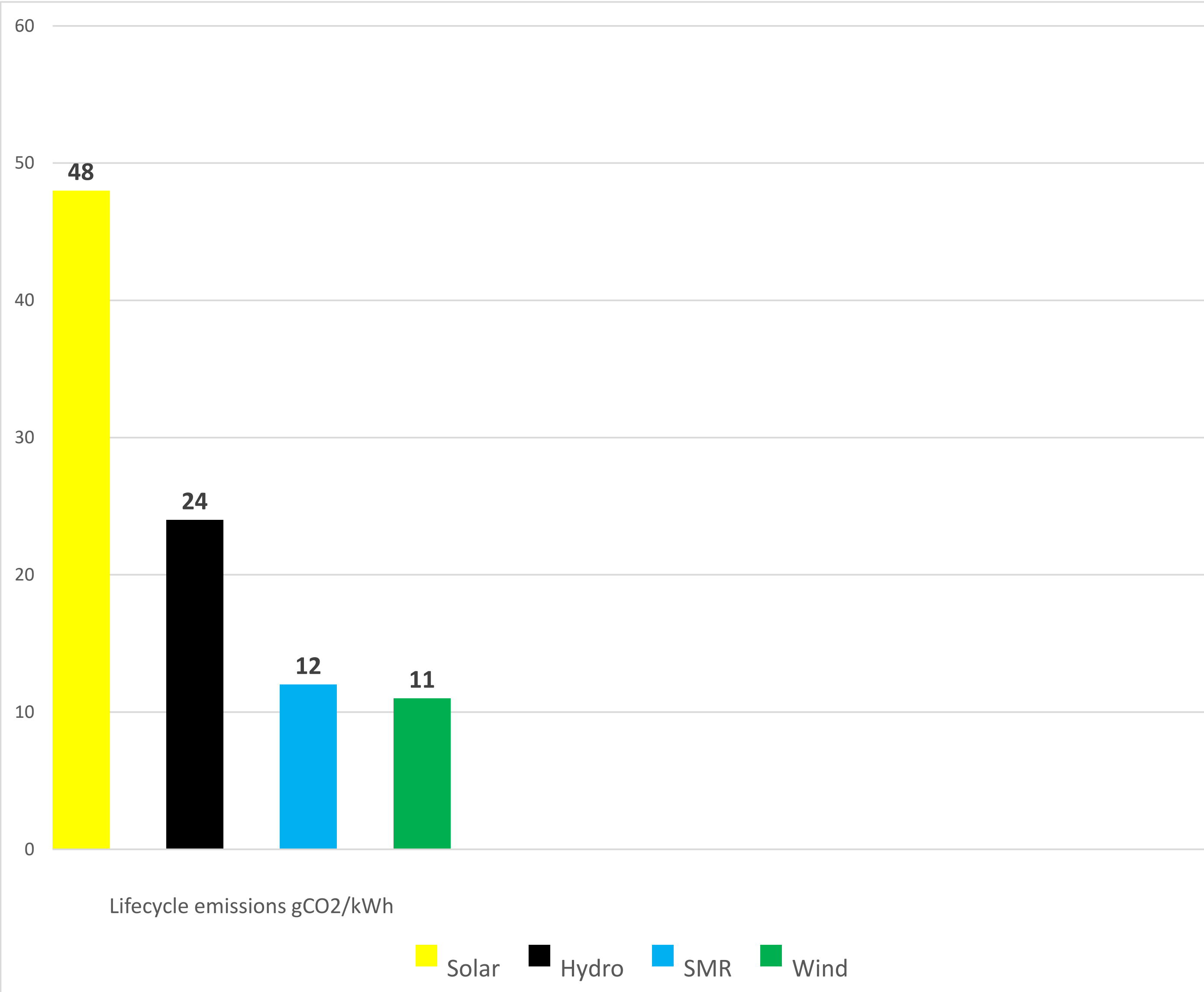


Nuclear costs: EIA 2022
Other technology costs: CSIRO GenCost 2023-24 report table B.9 for 2023

O&M = Operations and Maintenance.
Fixed costs are incurred regardless of the generated electricity.
Variable costs relate to the MWh of generation.
Fossil fuel costs are very sensitive to fuel costs.
Nuclear fuel costs are a smaller proportion of generation costs and are more predictable

Note: In addition to the market wholesale price, solar and wind receive the Large Generation Certificate, currently worth ~ $45/MWh

Life Cycle CO_2-equivalent Emissions gCO_2/kWh



Low Emissions Technologies:

All these technologies have zero emissions during operation. Whole of life cycle emissions include mining, materials, construction, decommissioning, waste management.

Utility scale solar = 48 gCO_2/kWh

Hydro = 24 gCO_2/kWh

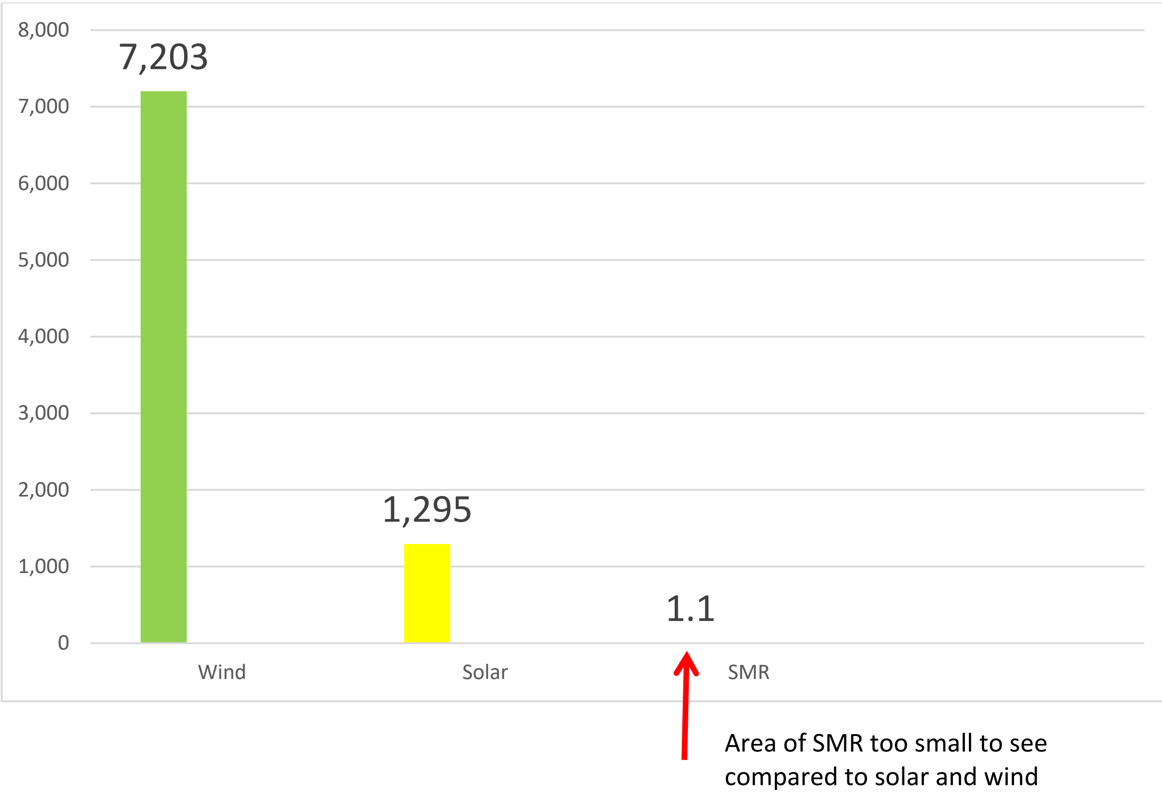
SMR = 12 gCO_2/kWh

Onshore wind = 11 gCO_2/kWh

United Nations Economic Commission for Europe (UNECE) report 2022

Nuclear = 5.1 – 6.4 gCO_2/kWh, reducing due to less emissions from latest mining/enrichment technologies

Land Requirements hectares/TWh

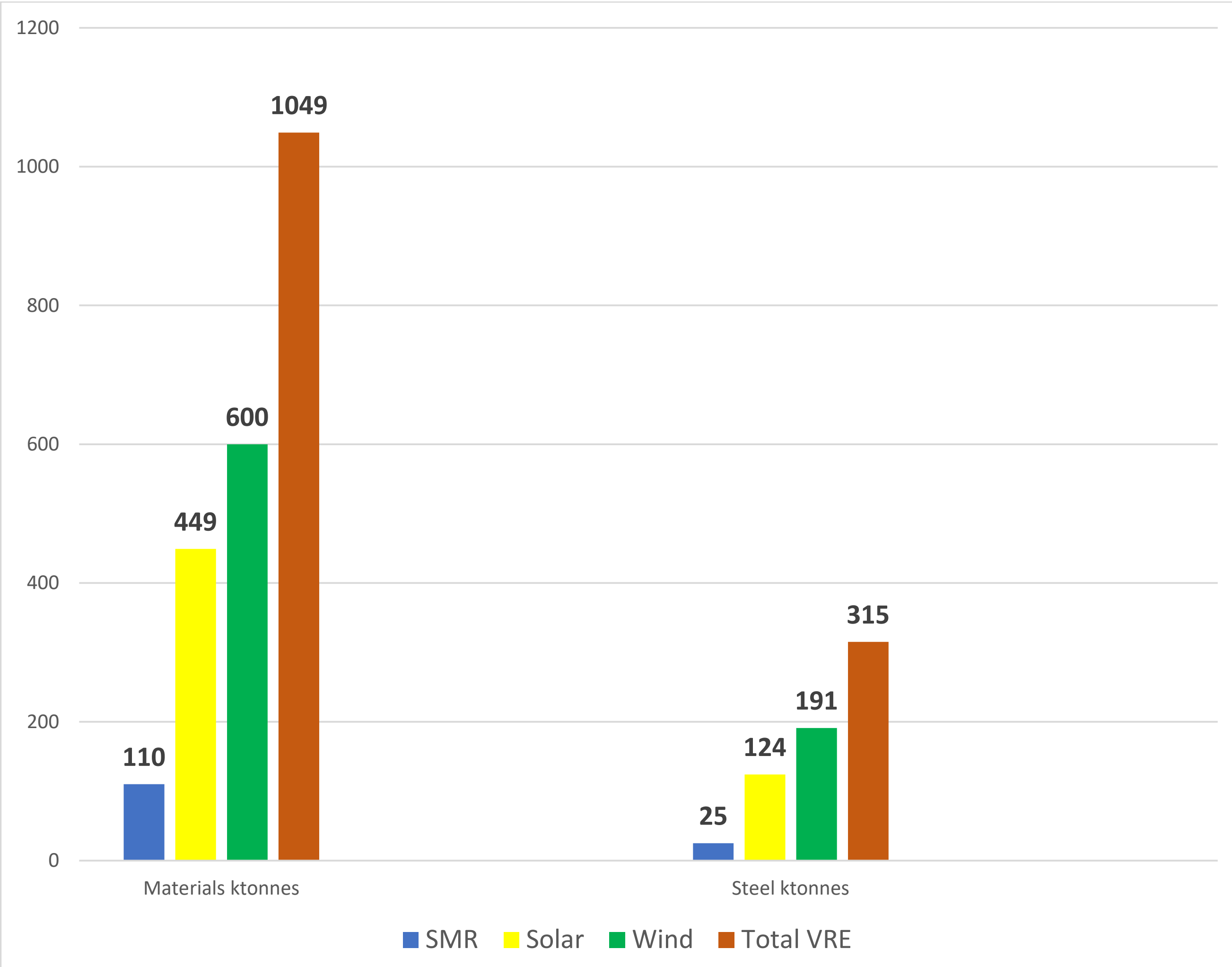


Ref: Wind and solar – NEI April 2022

SMR example: GE Hitachi BWRX-300, site area 2.63 hectares, 1.1 hectares/TWh

Solar example: Darlington Point (NSW) 1,182 hectares/TWh
275 MWac on 810 hectares, annual generation 685 GWh/year (Edify Energy)
1 million SAT (single axis tracking) solar panels
Cost $450 million

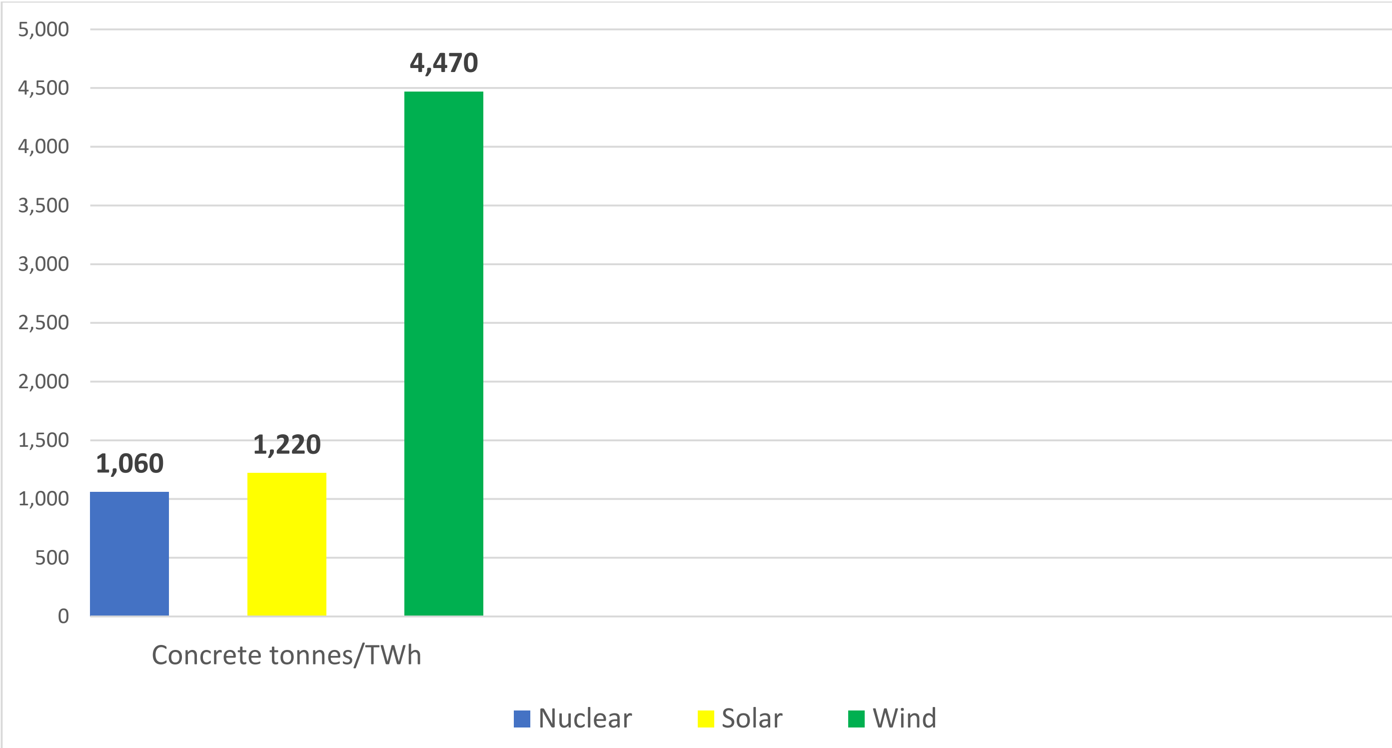
AEMO 2022 Integrated System Plan (ISP) requires 60 GW of additional wind and 64.1 GW of additional solar for the most likely scenario.
What are the quantities of critical materials required for these GWs of solar and wind compared to required GWs of SMR?



Nuclear 5,000 kg/MW, critical materials chromium, copper, nickel
Utility Solar 7,000 kg/MW, critical materials silicon, copper, silver
Onshore wind 10,000 kg/MW, critical materials copper, zinc, manganese, chromium, nickel, molybdenum, rare earths

Ref: IEA "The Role of Critical Materials in Clean Energy Transitions" May 2021
Steel quantities: Bright New World (BNW) June 2021

How much concrete is required per TWh of electricity generated?



Quantities Ref: Bright New World (BNW)

Wind example:
Kennedy Energy Park, Hughenden, QLD
12 x 3.45 MW Vestas wind turbines, design life 20 years
Foundations for each wind turbine: 1,667 tonnes concrete + 67 tonnes reinforcing steel.
Supports 132m high tower (hub height), 600 tonnes turbine