November 2022

# SMALL MODULAR REACTORS 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 SMRs, 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, especially with the modern Small Modular Reactors (SMRs), 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.

SMR Nuclear Technology Pty Ltd
Governor Macquarie Tower
level 23, 1 Farrar Place
Sydney NSW 2000

www.smrnuclear.com.au
Contact: tony.irwin@smrnuclear.com.au

## Small Modular Reactors (SMRs), Solar and Wind
## Which technology has more clear advantages (shown in green)?

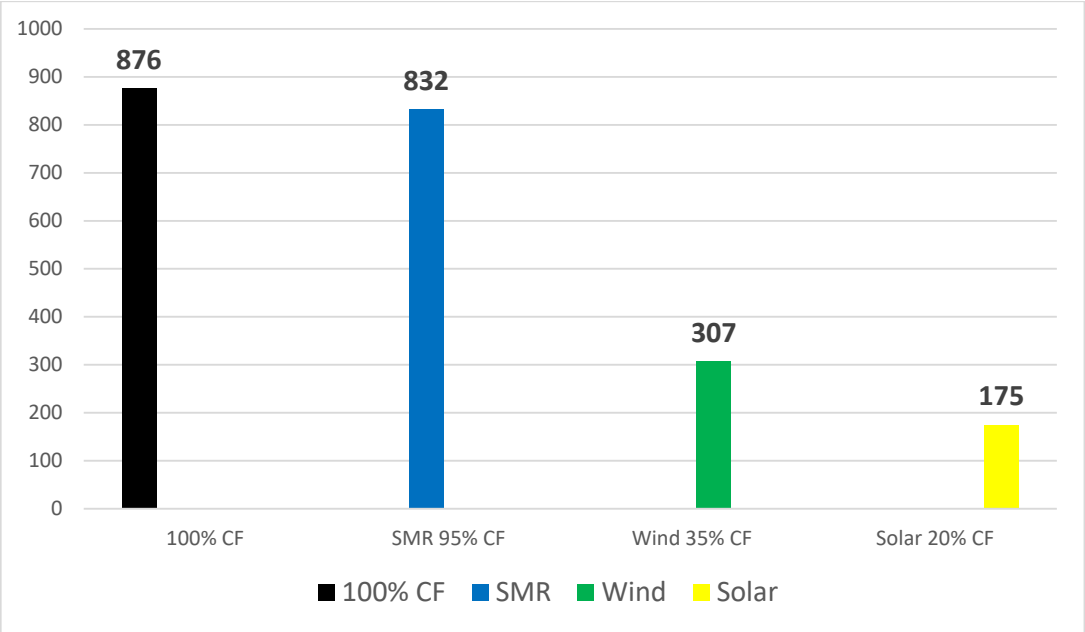
| Parameter | SMR | Utility Scale Solar | Onshore Wind |
|---|---|---|---|
| Reliability of generation | reliable | variable | variable |
| Independent of the weather | independent | dependent | dependent |
| Capacity factor | 95% | 22% - 32% | 35% - 44% |
| Load following capability | yes | no | no |
| 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 | 25 | 20 - 25 |
| Plant Technical/Operational life years | >60 | 30 | 20 - 30 |
| Land area required hectares/TWh | 2.4 | 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 | Typical Battery 4 hrs/ PHES 12 hrs | |
| Cost of storage $/kW | $0 | $1,629 battery/kW $2,711/kW PHES | |
| Additional transmission | none | >$12.7 billion | |
| Life waste included in cost | yes | no | no |
| O&M cost $/MWh | 11 | 9.7 | 8.2 |
| Fuel cost $/GJ | 0.5 | Free | Free |
| Construction time years | 3 | 0.5 | 1.0 |



SMR parameters: NuScale (USA) 12 module 924 MW plant estimate for Australia
Wind and solar: CSIRO GenCost 2021-22 Final report July 2022, transmission AEMO 2022 ISP
Pumped Hydro Energy Storage (PHES) and battery costs – CSIRO GenCost 2021-22 Table B.7
Material requirements: Bright New World (BNW) and IEA “The Role of Critical Materials in Clean Energy Transitions”
Land use: NEI April 2022
Lifecycle emissions: WNA and IPCC
O&M = Operations & Maintenance

# Capacity Factor

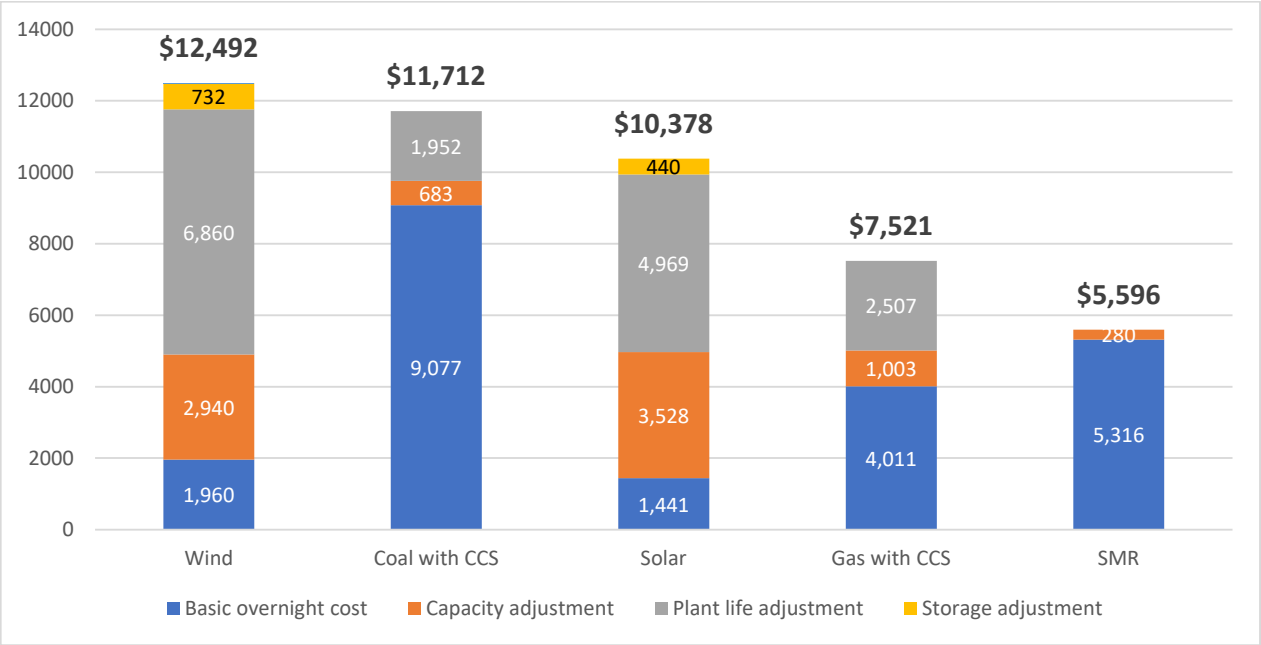
**Capacity Factor is the ratio of actual generation of a power plant compared to the generation that would be produced by continuous full power operation.**
For example a 100 MW plant at 100% capacity factor would generate 100 x 24 x 365 = 876 GWh/year
(GW = $10^9$ watts)




*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 35 MW for a wind farm (307 GWh/yr) or 20 MW for a utility scale solar plant (175 GWh/y)*

*Wind and solar capacity factors from Clean Energy Council, Clean Energy Australia report 2021, actual generation.*

## Real Overnight Capital Cost - $/kW for New Build



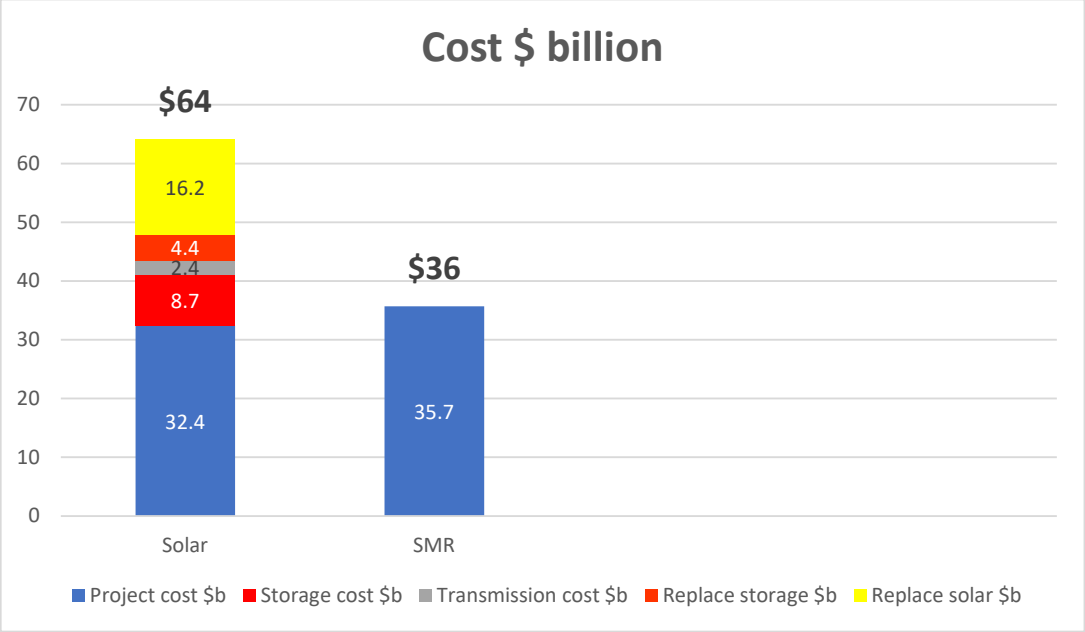

Wind > $12,492/kW, Solar > $10,378
(Solar and Wind have connection and interstate transmission costs in addition to these costs)
Coal with CCS = $11,712/kW, Gas with CCS = $7,521/kW
Costs: CSIRO GenCost 2021-22 Table B.8 for 2021

Operational capacity factors for new build: solar = 29%, wind = 40%, coal 93%, gas 80%
Operational lifetimes: solar = 30 years, wind = 25 years, coal 50 years, gas 40 years.

Storage requirements and costs from CSIRO GenCost report 2021-22 – average 0.27 kW storage capacity for each kW of wind and solar installed.

SMR $5,596/kW (NuScale estimate for 12 module 884 MWe Net in Australia), operational life > 60 years.

## Coal Fired power stations in NSW generated 49,110 GWh in 2021.
## What would be the cost of replacing this generation with utility scale solar or SMRs to2050?




**To 2050**

**Total solar cost = $64.05 billion**

Solar based on Darlington Point (NSW) 333 MWdc/275 MWac, capacity factor 28.4%
Annual generation 685 GWh/year (Edify website)
72 solar plants required at a cost of $0.45 billion each.

**Total SMR cost = $35.7 billion**

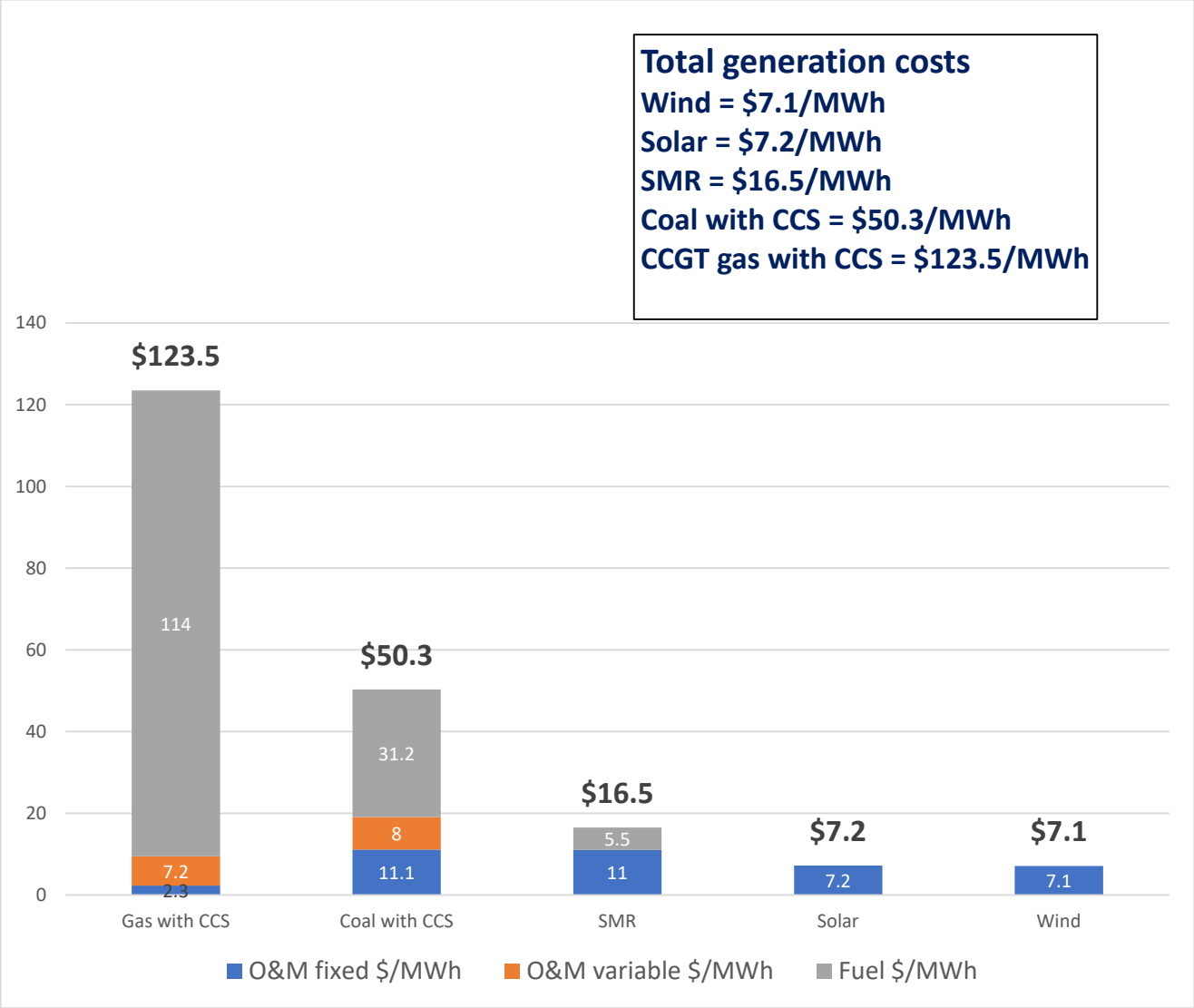
SMR based on NuScale 12 module 884 MWe net. 7 plants required at a cost of $5.1 billion each.

Storage requirements and cost based on CSIRO GenCost GenCost 2021-22 report, average 0.27 kW storage capacity for each kW of solar installed.

Additional transmission required based on a proportion of AEMO ISP 2022 (2050) – 10,000 km required for total variable renewable energy (wind and solar)
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 SMR – 60 year design life).

## Generation Costs $/MWh

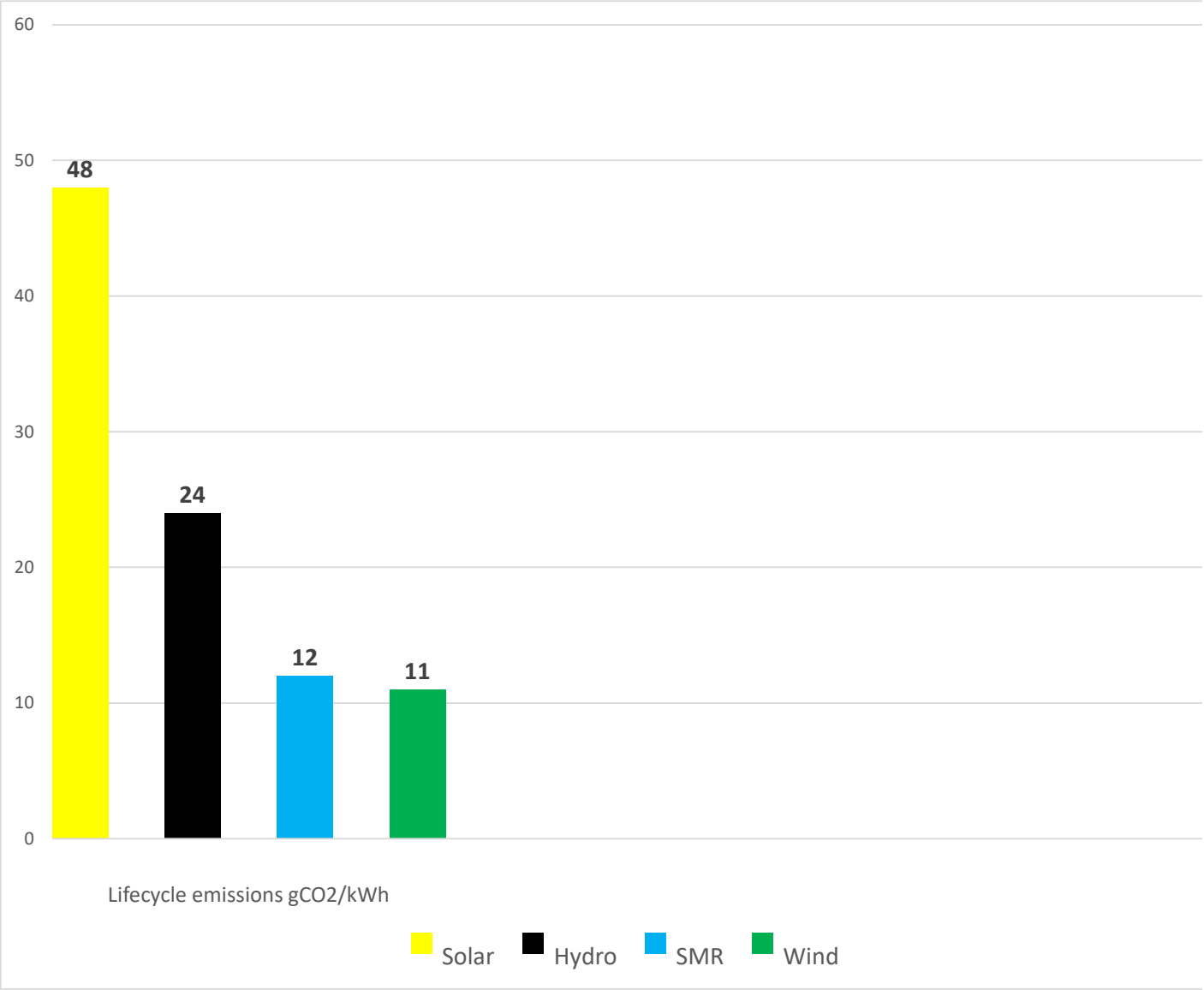



SMR costs: NuScale estimates for Australia

Other technology costs: CSIRO GenCost 2021-22 report table B.8 for 2021

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

## 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 $gCO_2/kWh$

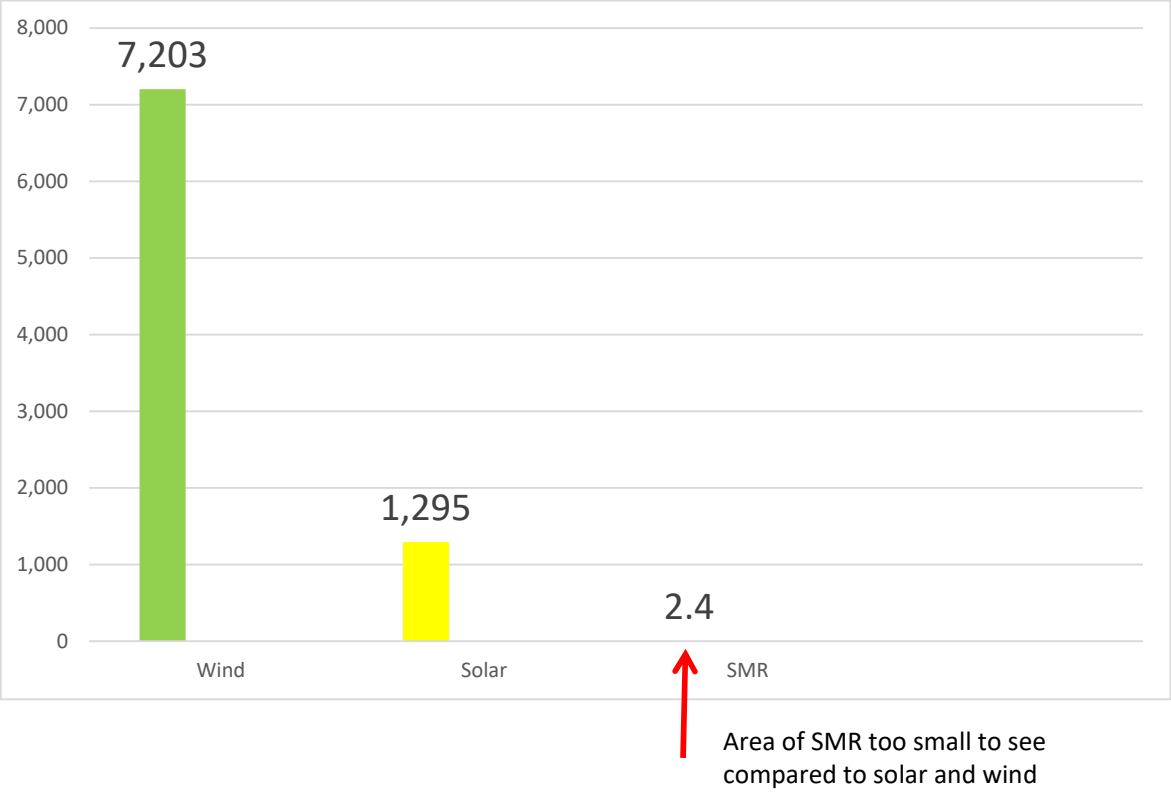
SMR = 12 $gCO_2/kWh$

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

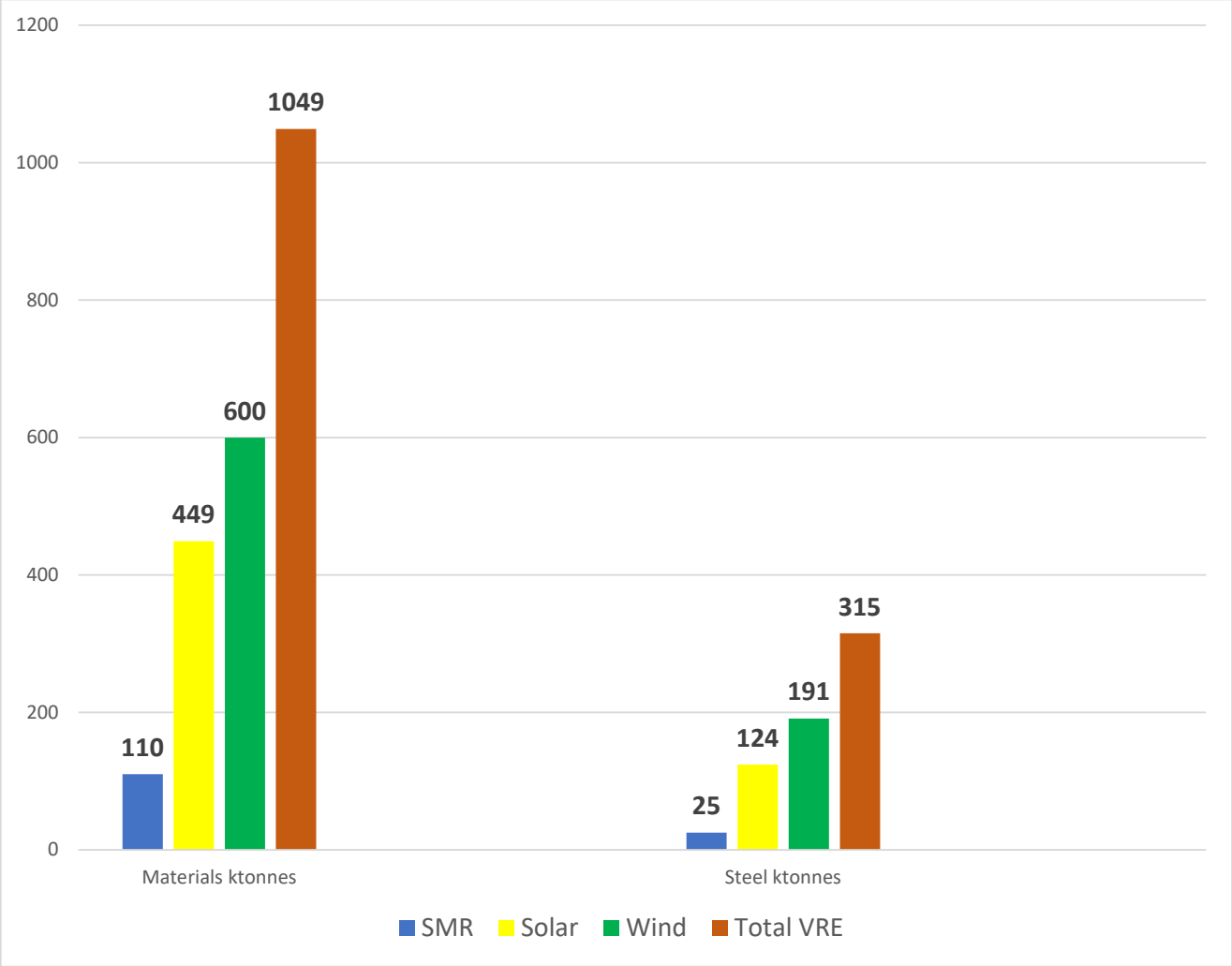



Ref: Wind and solar – NEI April 2022

SMR: NuScale 12 module 924 MWe (Gross) on 18 hectares, annual generation 7,357 GWh/year

Solar example: Darlington Point (NSW)
275 MWac on 1,000 hectares, annual generation 685 GWh/year
1 million SAT (single axis tracking) solar panels

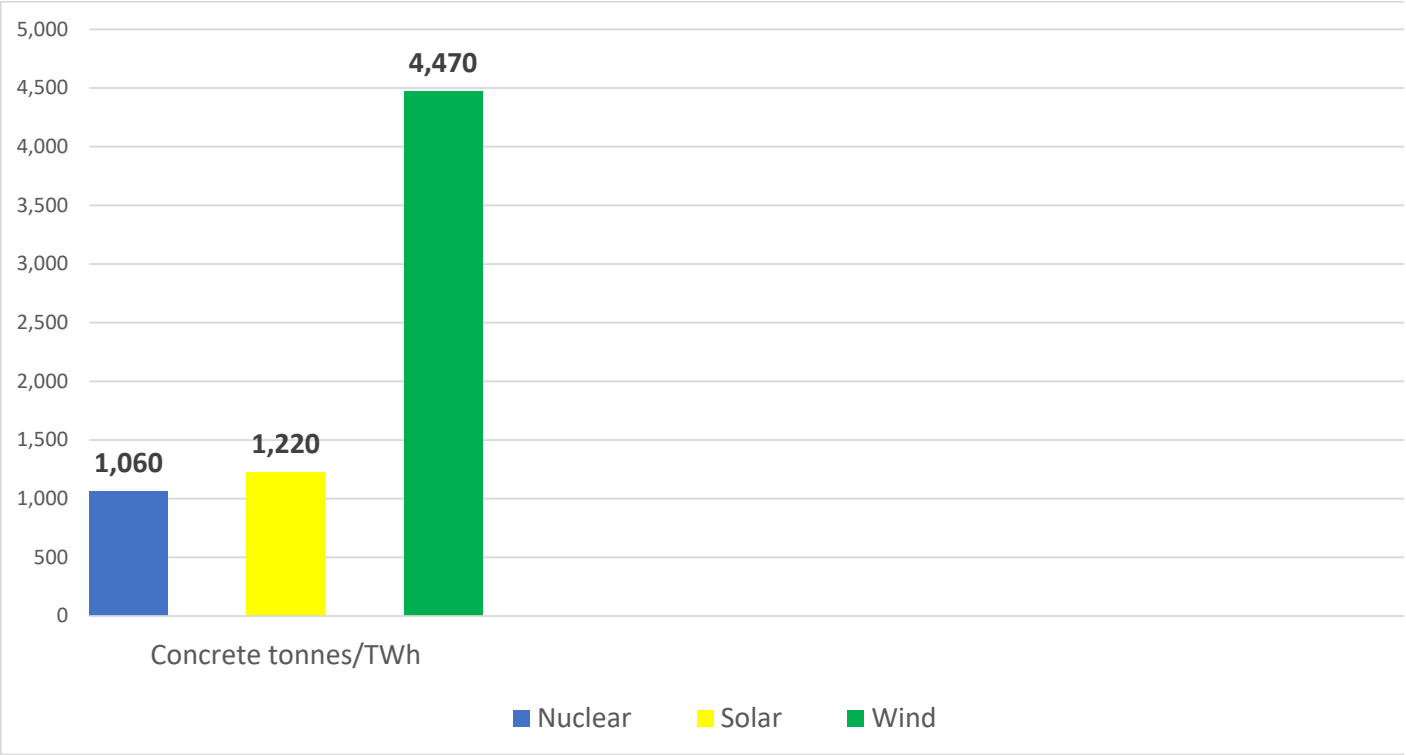
## AEMO 2022 Integrated System Plan (ISP) requires 60 GW of additional wind and 64.1 GW of additional solar for the most likely scenario.
## What are the quantities of critical materials required for these GWs of solar and wind compared to required GWs of SMR?




**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

There are 47 operating coal-fired units in the NEM on 16 sites, total capacity 22,701 MW.

AEMO lists announced closure dates and expected closure years.

| Region | Name | Owner | Capacity MW | Closure date |
|---|---|---|---|---|
| NSW | Liddell | AGL | 4 x 500 | Unit 3 shutdown 1/4/2022<br>Units 1, 2, 4 closure 1/4/2023 |
| NSW | Eraring | Origin Energy | 4 x 720 | 18/8/2025 |
| VIC | Yallourn | Energy Australia | 2 x 350<br>2 x 375 | 2028 |
| QLD | Callide B | CS Energy | 2 x 350 | 2028 |
| NSW | Vales Point B | Delta Electricity | 2 x 660 | 2029 |
| NSW | Bayswater | AGL | 3 x 660<br>1 x 685 | 2033 |
| QLD | Gladstone | Gladstone PS | 6 x 280 | 2035 |
| VIC | Loy Yang | AGL | 3 x 560<br>1 x 530 | 2035 |
| QLD | Tarong | Stanwell Corporation | 4 x 350 | 2036/7 |
| QLD | Tarong North | Stanwell Corporation | 1 x 450 | 2037 |
| NSW | Mount Piper | Energy Australia | 1 x 730<br>1 x 660 | 2040 |

**All the coal-fired power stations in NSW are scheduled to be shut down by 2040.**
**They generated 49,110 GWh in 2021 = 70% of NSW generation.**

| Region | Name | Owner | Capacity MW | Closure date |
|---|---|---|---|---|
| QLD | Kogan Creek | CS Energy | 1 x 744 | 2042 |
| QLD | Stanwell | Stanwell Corporation | 4 x 365 | 2043-46 |
| VIC | Loy Yang B | Gippsland Power | 2 x 580 | 2047 |
| QLD | Millmerran | Millmerran Power | 2 x 426 | 2051 |
| QLD | Callide C | Callide Energy | 2 x 420 | 2051 |

**Retiring coal-fired power station sites can be re-powered with SMRs:**

- **Reuse existing transmission connections**
- **Reuse much of the existing site infrastructure, e.g cooling water systems, water supplies, buildings**
- **There are existing transport links for heavy machinery**
- **SMR would fit on any power station site, e.g. Liddell site = 116 hectares, NuScale 12 module 884 MWe = 188 hectares**
- **Most importantly – retrain and staff and save the local communities**