Why is nuclear energy not an option in the ISP?

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Geelong Regional Engineers Group   12 December 2024

Aim

To understand an energy mix for the 21st Century and how to decide what to include in the Integrated System Plan (ISP) to achieve reliable sovereign energy independence.

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Objective

To understand the relationship between resource energy density, infrastructure, the environment, and ecology.

To be able to question the integrity of an energy system plan as fit-for-purpose.

Inquiry into nuclear prohibition: final report
26 NOV 2020
Legislative Council Environment and Planning Committee (Vic)

DESCRIPTION *(in-part)*

"Currently nuclear power plays no role in energy generation in Australia and never has. In fact, since the *Nuclear Activities (Prohibitions) Act 1983 (Vic)* was enacted, there has been a legal prohibition on the construction and operation of nuclear facilities in Victoria. In addition to the Victorian legislation, Commonwealth laws also prohibit the use of nuclear energy for electricity generation across Australia".

"In this report, the Committee makes no recommendations and does not take a strong position on nuclear power as an alternative energy source in Australia, and particularly in Victoria".

Introduction

Prerequisites for nuclear to be included in Australia's energy mix:

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Removal of legislative restrictions

Energy analysis metrics

Determination – to get it right

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- Economics – a masterful variable
- Time - stops for nobody

Resource energy density

Energy density Source Joules per cubic meter (J/m^3)

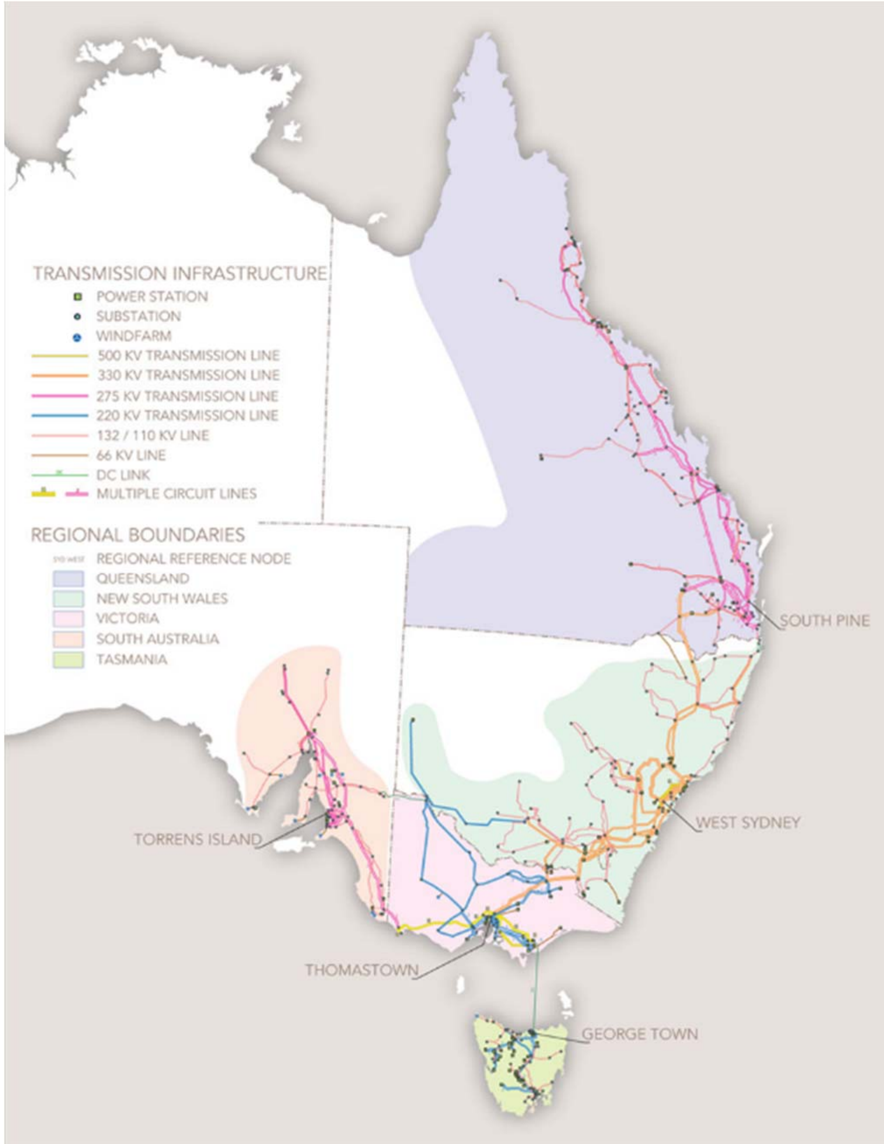
Source	Joules / cubic metre
Solar	0.0000015
Geothermal	0.05
Wind 5m/s	7
Tidal water	0.5 - 50
Oil	45,000,000,000
Petrol	10,000,000,000
Natural gas	40,000,000

Resource energy density

Energy density (MJ/kg) of a variety of different fuels.			
Fuel Type	Reaction Type	Energy Density (MJ/kg)	Typical uses
Wood	Chemical	16	Space heating, Cooking
Coal	Chemical	24	Power plants, Electricity generation
Ethanol	Chemical	26.8	Petrol mixture, Alcohol, Chemical products
Biodiesel	Chemical	38	automotive engine
Crude oil	Chemical	44	Refinery, Petroleum produ cts
Diesel	Chemical	45	Diesel engines
Petrol	Chemical	46	Petrol engines
Natural gas	Chemical	55	Household heating, Electricity generation
Uranium-235	Nuclear	3 900 000	Nuclear reactor electricity generation

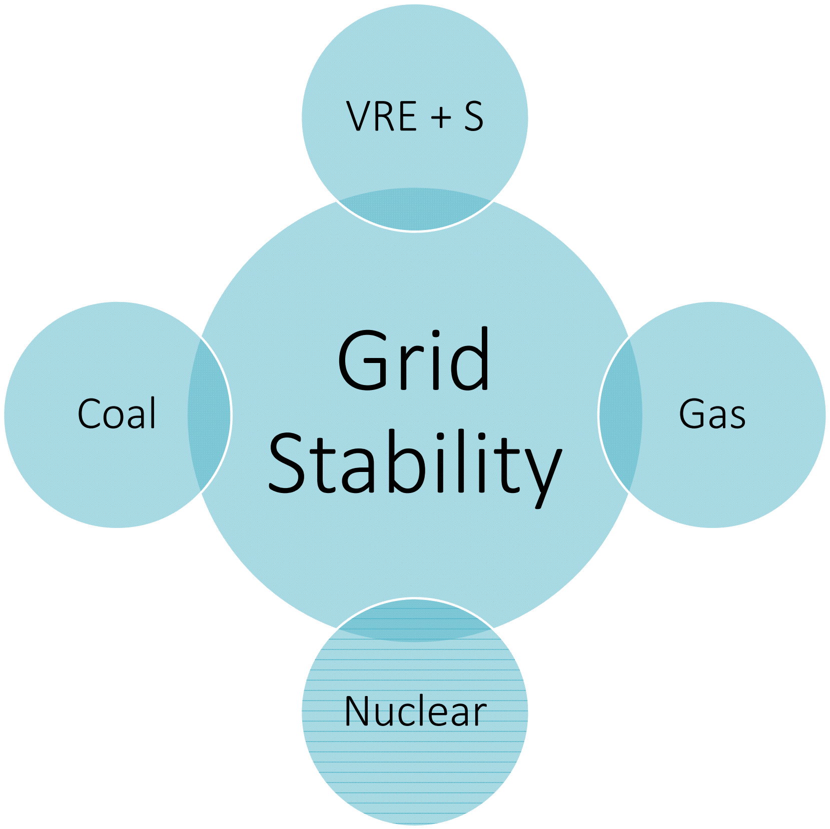
Reference: https://energyeducation.ca/encyclopedia/Energy_density

National Electricity Market Grid (NEM)



Source: Australian Energy Market Operator

Electricity Grid Energy Options



Idealist: *a conception of something perfect*

Aspirational: *Hope for an ambitious plan*

Pragmatist: *concerned with practical consequences and values*

Opportunist: *occurring at a time that is suitable or advantageous*

How much energy E_r?

$$E_r = VRE + S + x_r$$

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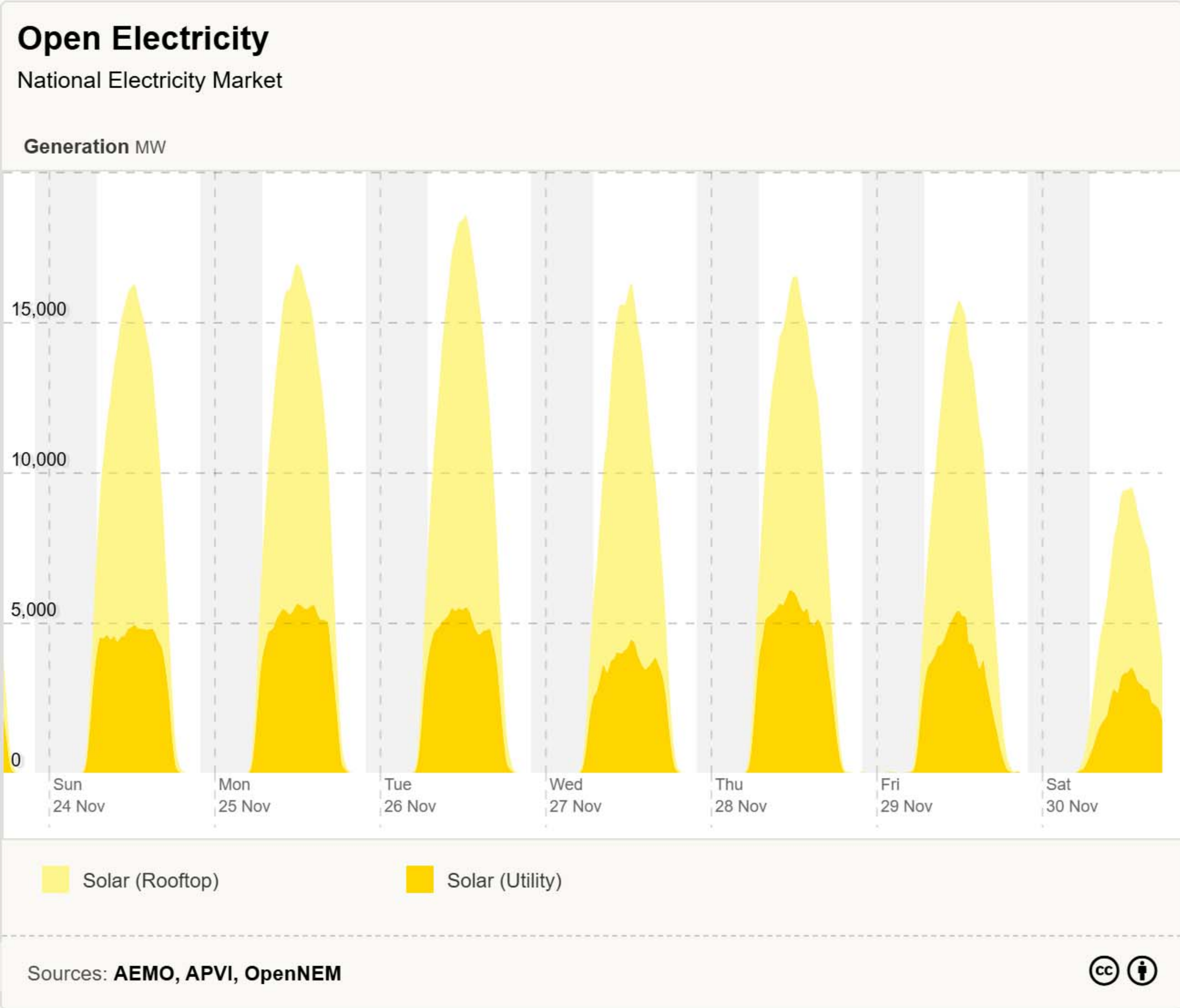
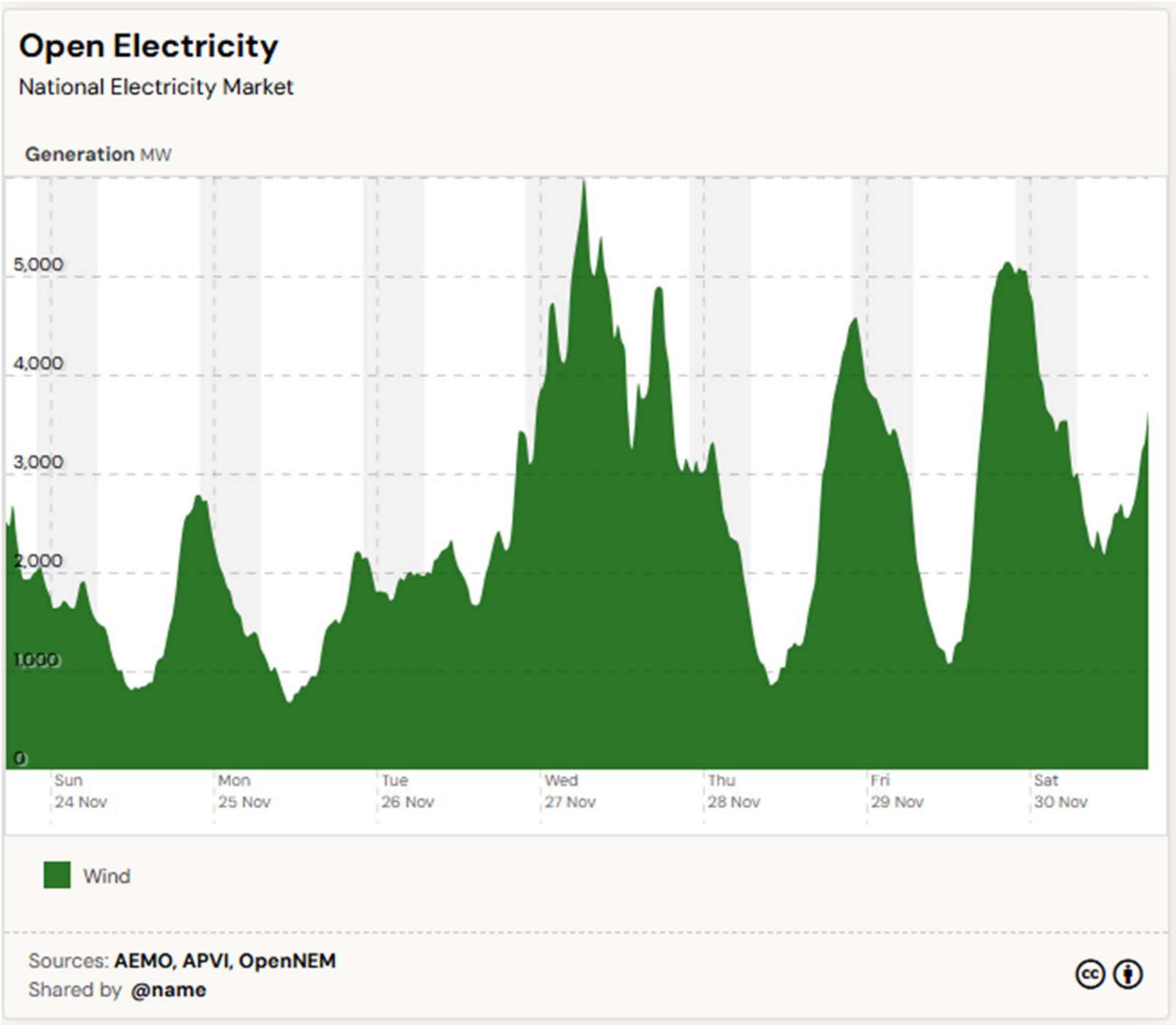
For grid stability G_s

$$G_s = E_r + E_v + E_c$$

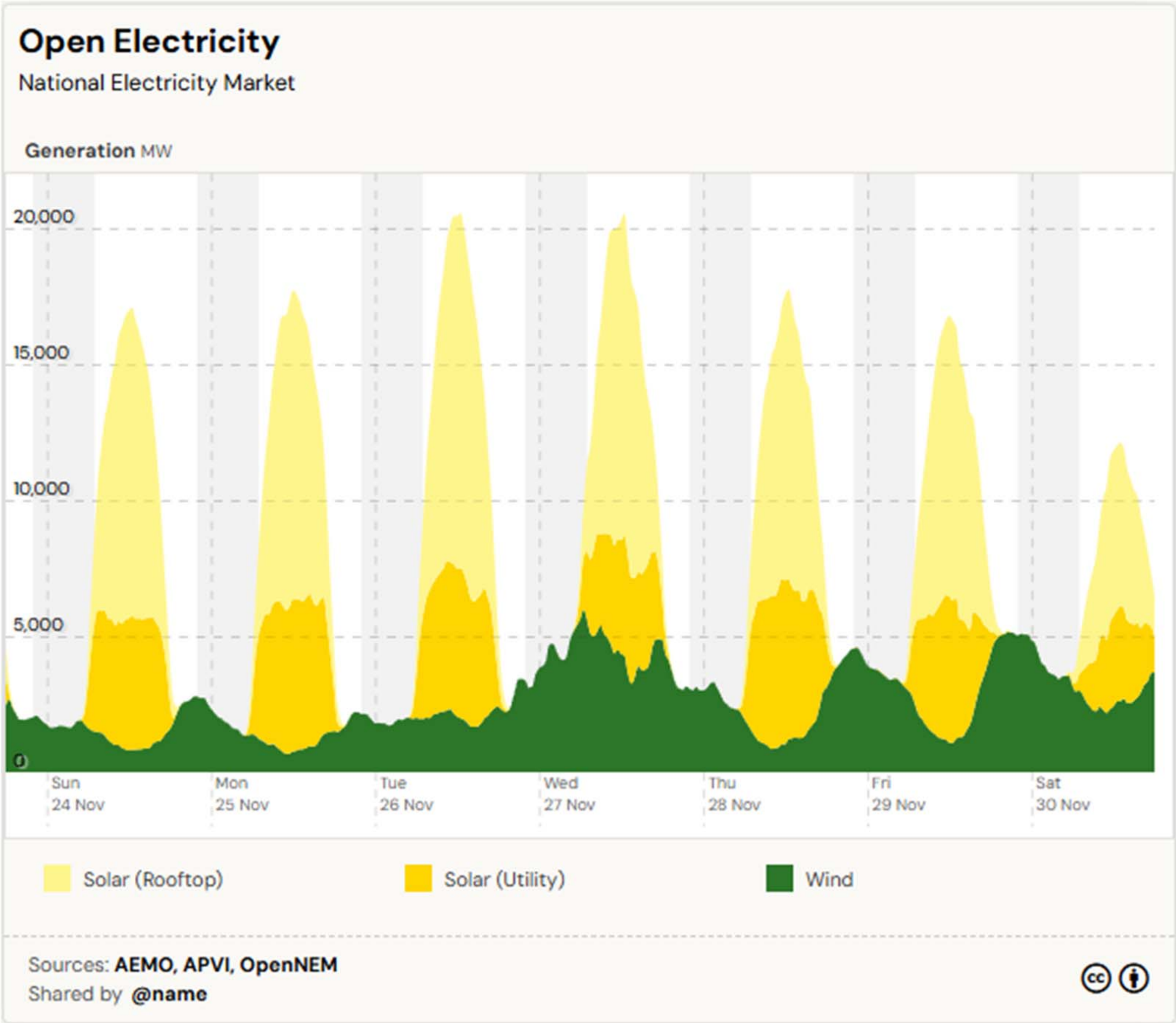
NEM Solar Generation MW



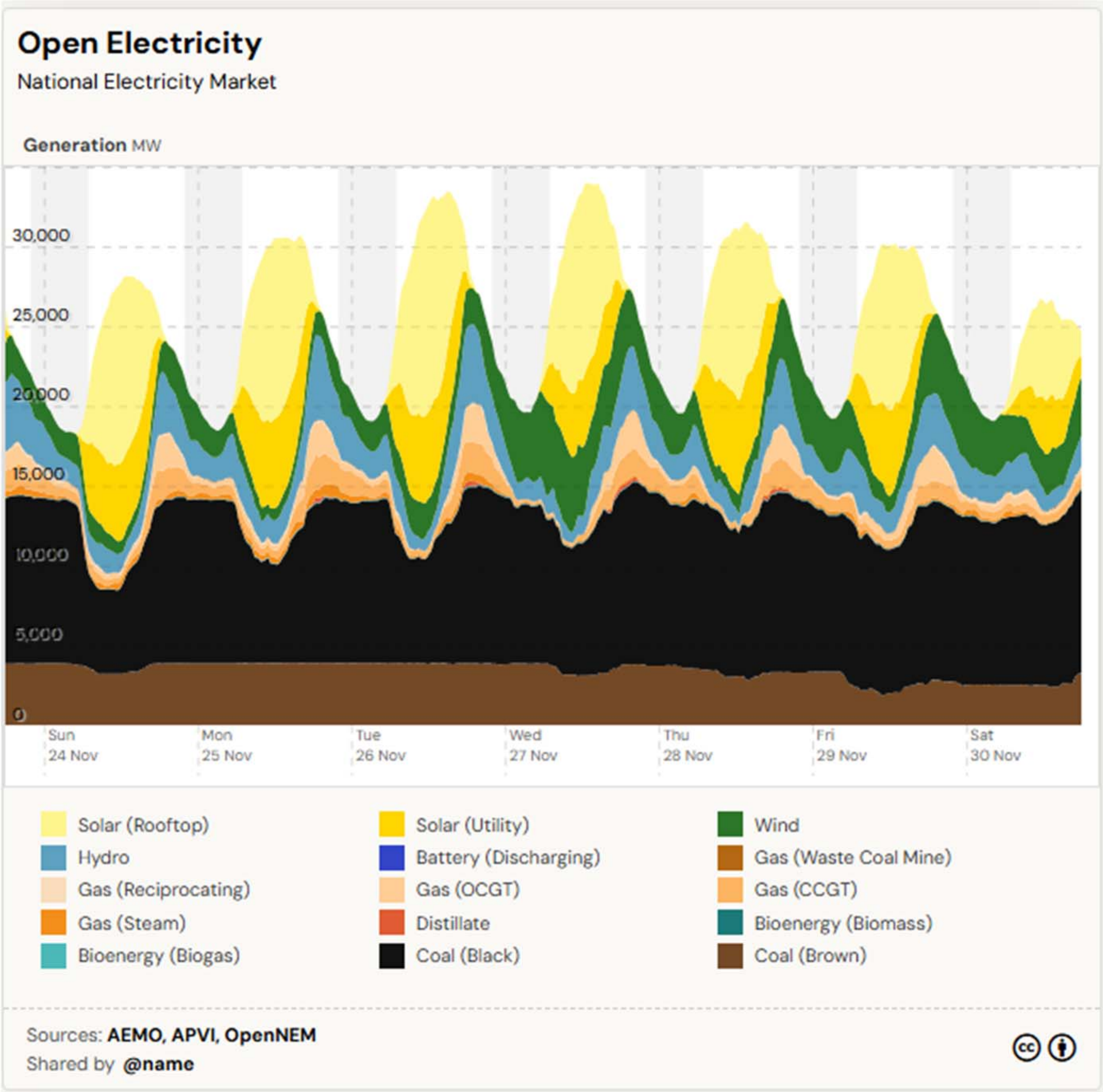
NEM Wind Generation MW



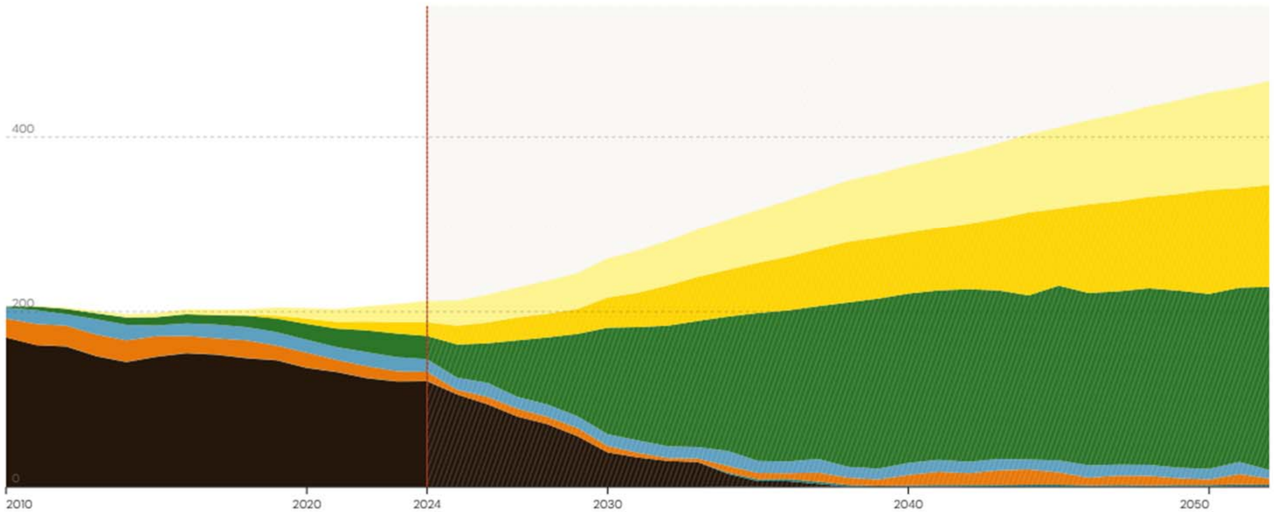
NEM
Solar &
Wind
Generation
MW



NEM Total Generation MW



AEMO Step Change 2024
NEM Capacity 71 GW



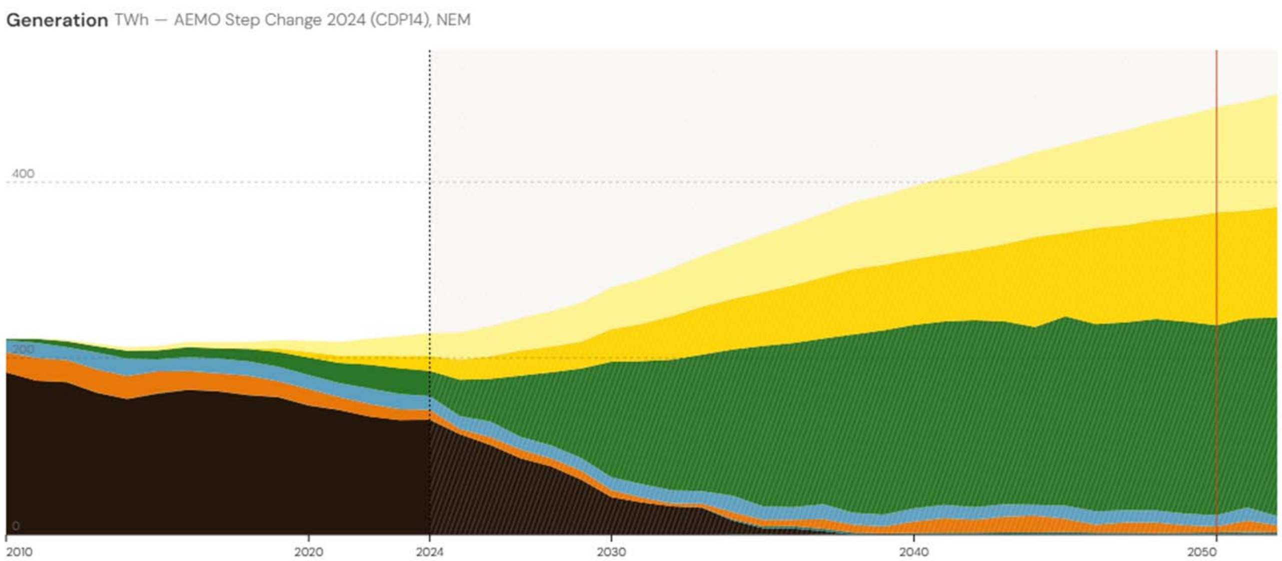
Include Storage and Loads

2024

Technology: Simplified	Generation TWh	Capacity GW
Sources	**212**	**71**
Solar (Rooftop)	24	19
Solar (Utility)	16	5
Wind	27	8
Hydro	14	8
Gas	10	10
Distillate	0	1
Bioenergy	0	0
Coal	121	21
Demand Response	–	–

Impact	Volume ktCO2e	Intensity kgCO2e/MWh

AEMO Step Change 2050
NEM Capacity 238 GW



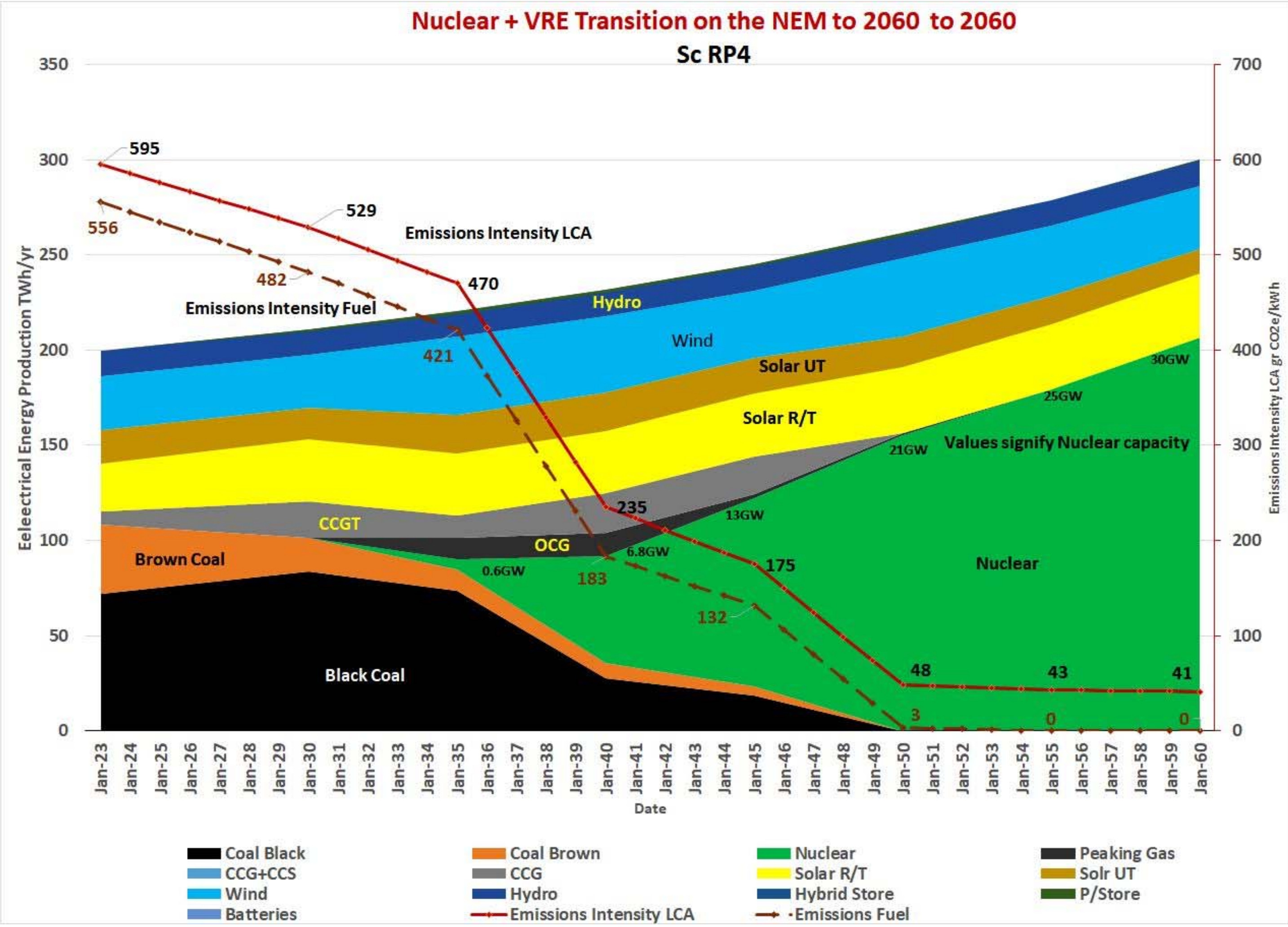
Include Storage and Loads

2050

Technology: Simplified	Generation TWh	Capacity GW
Sources	**451**	**238**
Solar (Rooftop)	111	86
Solar (Utility)	119	58
Wind	200	69
Hydro	12	7
Gas	6	15
Distillate	–	–
Bioenergy	2	0
Coal	–	–
Demand Response	1	3

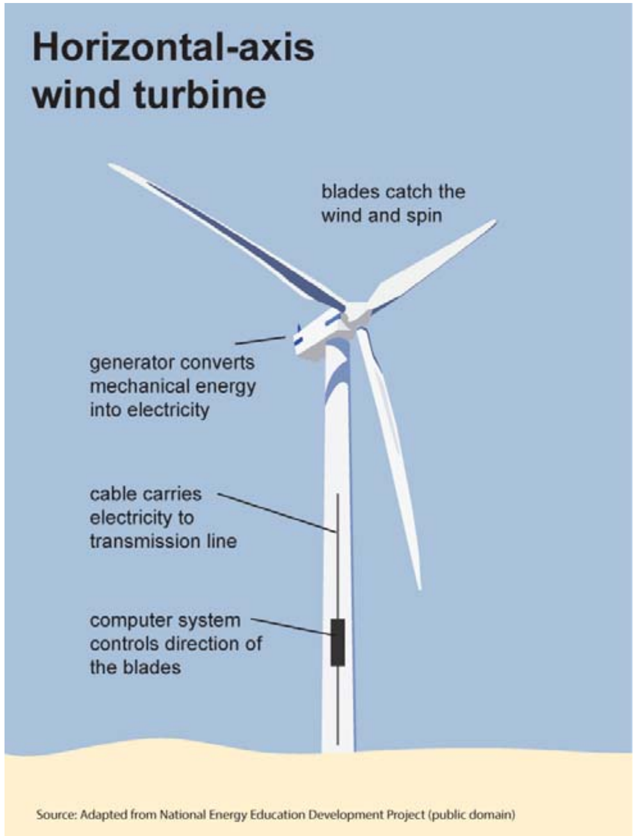
Impact	Volume ktCO2e	Intensity kgCO2e/MWh

Nuclear for Climate Australia



Wind power generation

Renewable energy collectors



Utility Solar – PV arrays

Wind power blades

Golden Plains Wind Farm
Victoria

756MW from 122 wind turbines, each 200m high

The Victorian government plans to have 95% of energy provided from renewable resource by 2035.

Ref: Geelong Times, V4, 39, p7, 29th September, 2023.

Power plant capacity factor

Capacity factor by energy source in 2020.

Reference: U.S. Energy Information Administration

Nuclear	92.5%
Geothermal	74.3%
Natural gas	56.6%
Hydropower	41.5%
Coal	40.2%
Wind	35.4%
Solar	24.9%

The Capacity Factor indicates how often a power plant operates at its capacity.

Loy Yang A Power Station

By Marcus Wong Wongm - Own work,
https://commons.wikimedia.org/w/index.php?curid=5567783

Nameplate capacity 2,210MW
Capacity factor 73.51%
Ref. Coal capacity factors in the NEM 2017-18

A brief history of radioisotopes

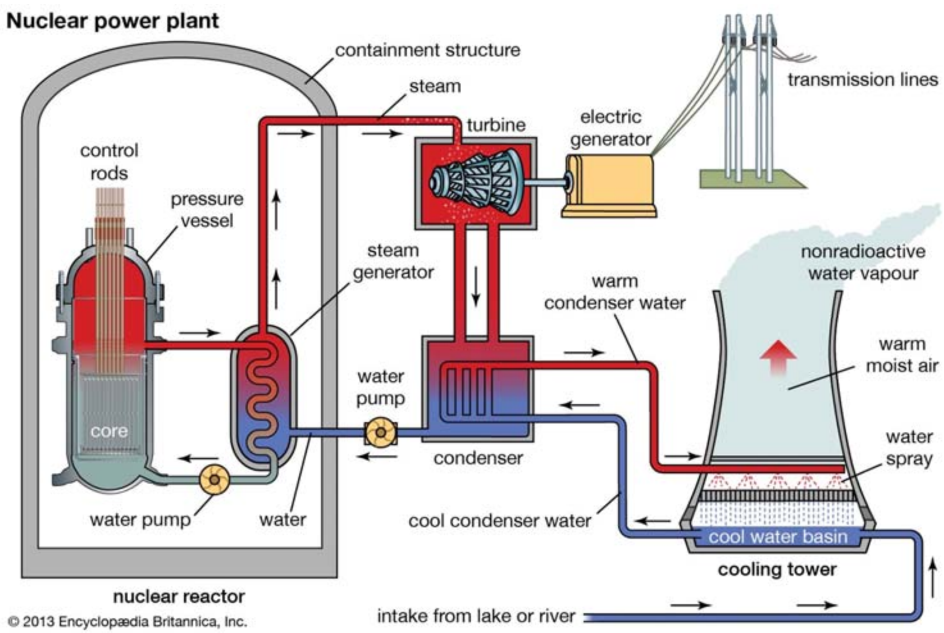
A brief history of human activity with radioisotopes or nuclear energy is necessary to remind us why we hold our beliefs in a difficult mindset.

- Marie Curie 1867 – 1934 describes the "radioactivity" phenomenon
- Albert Einstein 1879 – 1955 $E = mc^2$ Energy = mass x speed of light squared: fission and fusion
- Robert Oppenheimer 1904 – 1967 Manhattan Project
- Sir Mark Oliphant 1901 – 2000 nuclear physicist

A brief history of radioisotopes *cont*.

- Australian Atomic Energy Commission 1952 - nuclear science, engineering, and research
- USA 1950s. The USS Nautilus (SSN-571, United States Navy) was the world's first operational nuclear-powered submarine. It took two years to construct and in 1958 it became the first submarine to complete a submerged transit of the North Pole. *Ref: Wikipedia*.
- Jervis Bay Nuclear Power Plant 1960s plan
- ANSTO & AINSE 1987 more than 70 years of expertise
- ARPANSA 1999

Nuclear power plant



Leibstadt NPP, Switzerland. BWR Nameplate capacity 1,220MW, Capacity factor 87.6%.

The cost of nuclear

It is difficult to provide precisely the cost of nuclear energy for a location without working, at least, in conjunction with a vendor. Additionally, there are many variables involved.

Energy security must be considered in terms of national security – this is the starting and the endpoint. Energy-producing assets must be considered in terms of the value that they add to the system and the number built. The first-of-a-kind (FOAK) will always be more expensive than the N^{th}-of-a-kind.

Nuclear energy reactor plant costs by region

Total capital costs ($US/kW)

West	US, France, Finland, UK	$8,000 to $12,000
Middle East	UAE	$4,000
East	Japan, Russia, Korea, China	$2,000 to $5,000

Electricity prices in Canada 2023 (~ 19% nuclear)

Average Electricity Prices (¢/kWh)

@energyhub.org

	Monthly Electricity Consumption	600 kWh	750 kWh	1000 kWh	1250 kWh	1500 kWh	2000 kWh	2500 kWh
	Alberta	28.8	27.3	25.8	24.9	24.4	23.6	23.2
hydro	British Columbia	13.7	12.8	11.4	10.5	10.0	9.2	8.8
hydro	Manitoba	10.9	10.6	10.2	10.1	9.9	9.8	9.7
nuclear	New Brunswick	15.3	14.6	13.9	13.4	13.2	12.8	12.6
hydro	Newfoundland & Labrador	15.9	15.4	14.8	14.5	14.3	14.0	13.9
	Nova Scotia	19.5	18.9	18.3	17.9	17.6	17.3	17.1
	Northwest Territories	40.0	39.4	41.0	42.5	43.4	44.7	45.4
	Nunavut	30.8	30.8	35.4	40.6	44.1	48.4	51.1
nuclear	Ontario	16.2	15.1	14.1	13.4	13.0	12.4	12.1
	Prince Edward Island	20.0	19.2	18.4	17.9	17.6	17.2	16.3
hydro	Quebec	8.7	8.3	7.8	7.7	8.1	8.6	8.9
	Saskatchewan	22.0	20.9	19.9	19.2	18.8	18.3	17.9
	Yukon Territory	19.7	19.2	18.7	18.6	18.5	18.5	18.4
	Canada Average	20.1	19.4	19.2	19.3	19.4	19.6	19.6

A brief history of nuclear reactors

Gen I Mid 1950s – mid 1960s Early prototypes: Magnox

Gen II Late 1960s – mid 1980s First commercial: PWRs, BWRs, CANDU

Gen III Mid 1980s – mid 2000s Advanced LWR: CANDU 6, AP600

Gen III+ Mid 2000s – mid 2020s Evolutionary designs with improved economics: AP1000, EPR

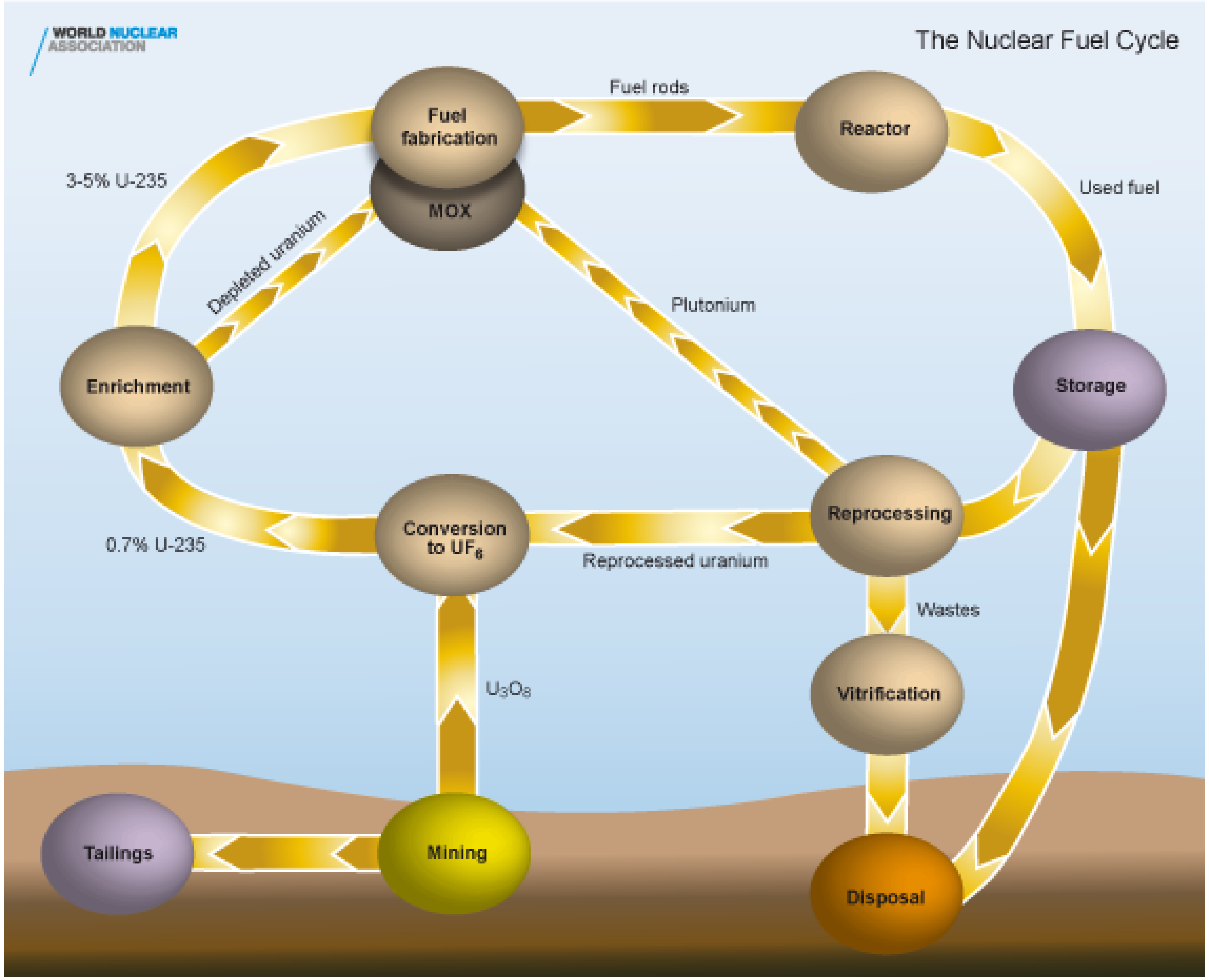
Gen IV Mid 2020s – mid 2030s Revolutionary designs to be safe, sustainable, economical, proliferation resistant and physically secure.

Reference: www.gen-4.org/Technology/evolution.htm

Overview of GEN IV Reactors

System	Neutron spectrum	Coolant	Outlet Temperature °C	Fuel cycle	Size (MWe)
VHTR (Very-high-temperature reactor)	Thermal	Helium	900-1000	Open	250-300
SFR (Sodium-cooled fast reactor)	Fast	Sodium	500-550	Closed	50-150 300-1500 600-1500
SCWR (Supercritical-water-cooled reactor)	Thermal/fast	Water	510-625	Open/closed	300-700 1000-1500
GFR (Gas-cooled fast reactor)	Fast	Helium	850	Closed	1 200
LFR (Lead-cooled fast reactor)	Fast	Lead	480-570	Closed	20-180 300-1200 600-1000
MSR (Molten salt reactor)	Thermal/fast	Fluoride salts	700-800	Closed	1000

Nuclear Fuel Cycle



Reference: World Nuclear Association

World Nuclear Association (WNA)

World Nuclear Power Reactors

Nuclear electricity generated in 2023 2602 TWh c.9%

Operable reactors 439

Reactors under construction 66

Planned reactors 87

Proposed reactors 344

International Atomic Energy Agency (IAEA)

A path to nuclear energy IAEA Milestones Approach

IAEA has developed a nuclear power infrastructure development programme. Three programmed phases are designed to achieve three milestones, resulting in the first nuclear power project. At each phase, nineteen infrastructure issues are considered.

Milestone 1: the country is ready to make a knowledgeable commitment to a nuclear power programme (or to decide not to proceed).

Milestone 2: The country is ready to invite bids or negotiate a contract for its first nuclear power plant.

Milestone 3: The country is ready to commission and operate its first nuclear power plant.

Summary

An energy mix can be simplified by looking at how much and what energy is required ($\boldsymbol{E_r}$) for now and for future generations. Low-energy-density sources, such as VRE, require significantly more infrastructure than high-energy-density sources, such as nuclear. The same applies to the environmental footprint, which must be considered for each option including the ecology.

Base load and firming energy requirements must be dispatchable and provided from high energy density sources or large amounts of stored energy. Existing non-renewable energy sources are required until their output is replaced.

To dismiss the nuclear energy opportunities that other like-minded nations are adopting on the basis that Australia will never need them must be seriously questioned. Nuclear waste disposal, reactor construction timeframes, and reactor costs have not been a problem for those countries determined to get it right from the outset. This is evident by lower electricity costs and significantly reduced carbon dioxide emissions while maintaining industrial productivity.

SMR nuclear energy may have some advantages over the larger output reactors, however, the customer power cost will remain unclear until overseas plants become operational which is likely to be before the end of this decade.

While our legislation, both federal and state, prohibits nuclear activities for anything other than medicine, our work in the field of civil nuclear energy can only be academic. As demonstrated by ANSTO, this input can still be recognised as internationally valuable.

Reference material

House of Reps. Select Committee on Nuclear Energy.
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