WiN Australia Inc. response to questions on notice.

Correct as at: 10 July 2020

Question on notice 1: Information about energy production and life cycle emissions across various technologies as stated in page 11 of WiN Australia submission.

Table 2 in the WiN Australia submission states the median lifecycle emission values as determined by the IPCC Working Group III – Mitigation of Climate Change. Annex III of the report looks at the technology specific cost parameters including emissions. The median values used in WiN Australia's submission are from the far right column of the full table of emissions attached below. These emissions are broken down into 5 areas direct emissions, infrastructure and supply chain, biogenic CO_2, methane emissions and the lifecycle emissions.

Table A.III.2 | Emissions of selected electricity supply technologies (gCO_2eq/kWh)[i]

Options	Direct emissions	Infrastructure & supply chain emissions	Biogenic CO_2 emissions and albedo effect	Methane emissions	Lifecycle emissions (incl. albedo effect)
	Min/Median/Max	Typical values			Min/Median/Max
Currently Commercially Available Technologies					
Coal—PC	670/760/870	*9.6*	*0*	*47*	**740/820/910**
Gas—Combined Cycle	350/370/490	*1.6*	*0*	*91*	**410/490/650**
Biomass—cofiring	n.a.[ii]	–	–	–	**620/740/890**[iii]
Biomass—dedicated	n.a.[ii]	*210*	*27*	*0*	**130/230/420**[iv]
Geothermal	0	*45*	*0*	*0*	**6.0/38/79**
Hydropower	0	*19*	*0*	*88*	**1.0/24/2200**
Nuclear	0	*18*	*0*	*0*	**3.7/12/110**
Concentrated Solar Power	0	*29*	*0*	*0*	**8.8/27/63**
Solar PV—rooftop	0	*42*	*0*	*0*	**26/41/60**
Solar PV—utility	0	*66*	*0*	*0*	**18/48/180**
Wind onshore	0	*15*	*0*	*0*	**7.0/11/56**
Wind offshore	0	*17*	*0*	*0*	**8.0/12/35**
Pre-commercial Technologies					
CCS—Coal—Oxyfuel	14/76/110	*17*	*0*	*67*	**100/160/200**
CCS—Coal—PC	95/120/140	*28*	*0*	*68*	**190/220/250**
CCS—Coal—IGCC	100/120/150	*9.9*	*0*	*62*	**170/200/230**
CCS—Gas—Combined Cycle	30/57/98	*8.9*	*0*	*110*	**94/170/340**
Ocean	0	*17*	*0*	*0*	**5.6/17/28**

Notes:

[i] For a comprehensive discussion of methodological issues and underlying literature sources see Annex II, Section A.II.9.3. Note that input data are included in normal font type, output data resulting from data conversions are bolded, and intermediate outputs are italicized.

[ii] Direct emissions from biomass combustion at the power plant are positive and significant, but should be seen in connection with the CO_2 absorbed by growing plants. They can be derived from the chemical carbon content of biomass and the power plant efficiency. For a comprehensive discussion see Chapter 11, Section 11.13. For co-firing, carbon content of coal and relative fuel shares need to be considered.

[iii] Indirect emissions for co-firing are based on relative fuel shares of biomass from dedicated energy crops and residues (5-20%) and coal (80-95%).

[iv] Lifecycle emissions from biomass are for dedicated energy crops and crop residues. Lifecycle emissions of electricity based on other types of biomass are given in Chapter 7, Figure 7.6. For a comprehensive discussion see Chapter 11, Section 11.13.4. For a description of methodological issues see Annex II of this report.

The methodological issues and literature sources used to compile this table can be found in Annex II Section A.II.9.3 from page 1306 onwards. It states that "the assessment of greenhouse gas emissions and other effects associated with electricity production technologies presented here is based on two distinct research enterprises" – being Firstly Chapter 9 IPCC Special Report Renewable Energy Sources (SRREN) including data from the Life Cycle Assessment (LCA) Harmonisation Project. Secondly, the broader lifecycle environmental impacts and resource requirements for the International Resource Panel.

Question on notice 2: Provide the most up-to-date comprehensive cost analysis of nuclear in comparison to other energy sources.

The Levelised Cost of Electricity (LCOE) is often used to compare the cost of various energy sources. What is important in the long term is the total system cost, i.e. how the various electricity generation technologies are working together to 1) ensure low emissions, 2) ensure reliability and security, and 3) ensure the lowest possible costs.
There are studies that show that the most cost effective way to achieve deep decarbonisation is through a combination of renewables and nuclear (for example, see the MIT study below).

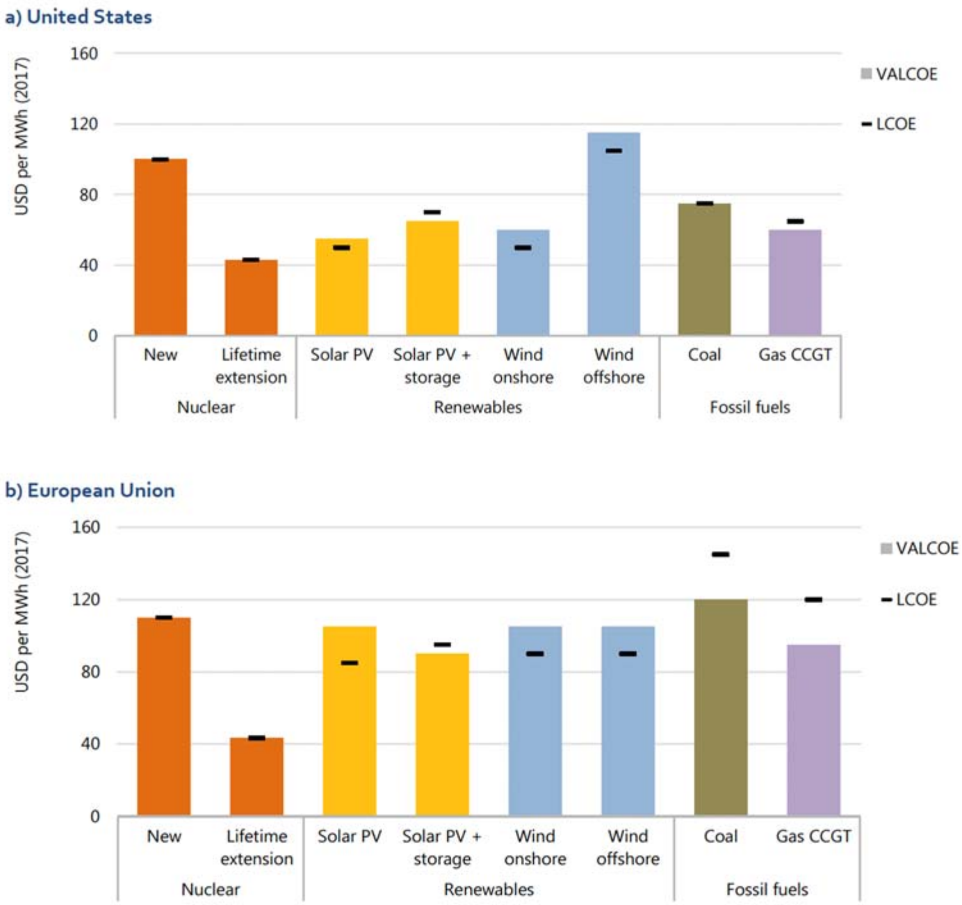
As variables over the lifetime of a technology differ significantly, it's not easy to provide an absolute figure when it comes to energy cost comparisons. Another underlying issue with providing a comprehensive cost analysis of nuclear is that there is no nuclear supply chain or construction industry in Australia to base costs on. In addition, the costs vary worldwide depending on what technology is being built, where it is being built, and who is doing the building. Since there is no data for Australia, western markets (United States and Europe) are used for cost comparison below. What results are relatively high capital costs to establish a nuclear energy capability that would reduce with time over multiple reactor builds as a well-established supply chain is developed (as seen in China with its new reactor builds and South Korea with it refurbishment of nuclear facilities).

Costs of new nuclear builds can be significantly cheaper than the US and Europe figures quoted below for nations that have been building nuclear power plants for the last few decades, for example, Russia, South Korea and China.

Three significant studies will be used to compare costs.

Firstly, an International Energy Agency (IEA) study into Nuclear Power in a Clean Energy System projected the Levelised Cost of Electricity (LCOE) for the US and Europe as being between 100-110 USD per MWh as shown below. This study concluded that hurdles to investment in new nuclear projects in advanced economies are daunting, however without nuclear investment achieving a sustainable energy system will be much harder.

Figure 11. Projected LCOE and value-adjusted LCOE by technology, 2040



Notes: VALCOE = value-adjusted levelised cost of electricity; LCOE = levelised cost of electricity; PV = photovoltaics; coal = coal supercritical; CCGT = combined-cycle gas turbines. Nuclear lifetime extension LCOE is based on 1.1 billion USD investment to extend operations for 20 years. Storage paired with solar PV is scaled to 20% of the solar capacity and 4-hours duration. LCOEs are calculated based on an 8% weighted-average cost of capital for all technologies. Other cost assumptions are from the World Energy Outlook 2018 and are available at https://www.iea.org/weo/weomodel/.

The second study by Massachusetts Institute of Technology (MIT) The Future of Nuclear Energy in a Carbon-Constrained World found that the cost of new nuclear plants is high, however in order to achieve deep carbonisation for the electricity sector (well below 50g CO2/kWh), inclusion of nuclear in the mix helped to minimise or constrain rising system costs. Overall system costs for deep decarbonisation are lowest when nuclear and renewables are used in combination. Use of modularisation and standardisation in construction would reduce costs.

Third, an OECD study by the Nuclear Energy Agency (NEA) looked at The Costs of Decarbonisation: System Costs with High Shares of Nuclear and Renewables. It concluded that a “diversity of energy sources drives down total costs of energy in a low carbon system, whereas taking options off the table – such as nuclear – creates extra costs to society”. The lifetime in years of nuclear and hydro power plants (60-80 years or longer) in comparison to other energy options should be taken into consideration when conducting a cost comparison of technologies as outlined below. Load factor is also an important consideration.

Table 2. Cost assumptions for generating plants and storage capacities

Technology	Discount rate (%)	Size (MWe)	Electrical efficiency (%)	Load factor (%)*	Construction time (years)	Lifetime (years)	Overnight cost (incl. contingency) (USD/kW)	Annualised investment costs (USD/MW/year)	Fuel costs (USD/MWh)	O&M costs	
										Fixed (USD/MW/ year)	Variable (USD/MWh)
Gas – OCGT	7%	300	38.0%	100%	2	30	700	58 380	80.81	20 000	15.30
Gas – CCGT	7%	500	58.0%	100%	2	30	1 050	87 580	52.94	26 000	3.50
Coal	7%	845	45.0%	100%	4	40	2 200	183 170	21.84	37 000	5.00
Nuclear	7%	1 000	33.0%	100%	7	60	4 700	413 880	10.00	100 000	1.50
Onshore Wind	7%	50		30%	1	25	2 000	171 620	0.00	62 000	0.00
Offshore Wind	7%	250		40%	1	25	5 000	429 050	0.00	175 000	0.00
Solar PV	7%	1		15%	1	25	1 600	137 300	0.00	36 000	0.00
Hydro – run-of-the-river	7%	10		50%	5	80	4 300	347 750	0.00	65 000	0.00
Hydro – reservoir	7%	10		20%	5	80	3 250	262 830	0.00	50 000	0.00
Hydro – pump storage	7%	10		NA	5	80	4 450	359 890	0.00	65 000	0.00
Battery storage	7%	1	90.0%	NA	1	10	1 146	163 164	NA	17 190	0.00
Onshore Wind – low-cost scenario	7%	50		30%	1	25	1 333	114 410	0.00	41 333	0.00
Offshore Wind – low-cost scenario	7%	250		40%	1	25	2 500	214 530	0.00	87 500	0.00
Solar PV – low-cost scenario	7%	50		30%	1	25	640	54 920	0.00	14 400	0.00

* The load factors of different power generation technologies used in economic modelling differ widely among countries as well as according to location and plant. Box 3.1 above spells out the ranges on which the VRE technologies have been based. With regard to dispatchable technologies (Gas-OCGT, Gas-CCGT, coal and nuclear), this study has chosen for modelling purposes a 100% load factor. This is an upper bound. Readers may prefer to make their own judgements based on the specific circumstances of the country and technology in question.