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Towards a viable roadmap for solar and wind waste recycling in Aotearoa New Zealand
Supplementary Material

Installed capacity time series (solar and wind)

The following table provides the cumulative installed utility-scale solar capacity in Aotearoa New Zealand over four-year intervals from 2022 to 2080, alongside the corresponding total sums of major material inputs used in those installations

Cumulative installed utility-scale solar capacity in Aotearoa New Zealand

Years	Cumulative solar capacity (MW)	Aluminium	Copper	Ferrite (iron core)	Glass	Plastic/ polymers	Silicon	Steel	Tantalum
2022-2025	453								
2026-2029	2282								
2030-2033	14000								
2034-2037	16500								
2038-2041	17800								
2042-2045	18300								
2046-2050	23300								
2051									
2052-2055		61672.33	1812.19	149.66	74131.39	4209.40	8334.90	72851.15	0.007
2056-2059		95209.29	2797.65	231.04	114443.49	6498.44	12867.36	112467.07	0.011
2060-2063		367097.22	10786.86	890.82	441258.30	25055.94	49612.50	433637.82	0.042
2064-2067		432650.30	12713.09	1049.90	520054.43	29530.22	58471.88	511073.15	0.050
2068-2071		466737.89	13714.72	1132.61	561028.41	31856.84	63078.75	551339.51	0.053
2072-2075		479848.51	14099.97	1164.43	576787.64	32751.69	64850.63	566826.58	0.055
2076-2080		610954.66	17952.42	1482.58	734379.89	41700.24	82569.38	721697.23	0.070

The following table presents the cumulative wind capacity in Aotearoa New Zealand across five-year intervals from 1996 to 2080, together with the total quantities of key materials used in the construction of those wind turbines.

Cumulative wind capacity in Aotearoa New Zealand

Years	Sum of Cumulative Capacity (MW)	Sum of Aluminium	Sum of Boron	Sum of Copper	Sum of Dysprosium	Sum of Iron	Sum of Neodymium	Sum of Steel
1996-2000	84	0	0	0	0	0	0	0
2001-2005	444.1	0	0	0	0	0	0	0
2006-2010	1980.5	0	0	0	0	0	0	0
2011-2015	3244.5	0	0	0	0	0	0	0
2016-2020	3460.5	18	0.936	108	2.628	1809.9	27.864	4361.904
2021-2025	5388.5	66.05	3.4346	396.3	9.6433	6641.33	102.245	16005.7644
2026-2030	7248.7	173	8.996	1038	25.258	17395.2	267.804	41922.744
2031-2035	19623.7	88.5	4.602	531	12.921	8898.68	136.998	21446.028
2036-2040	27900	0.5	0.026	3	0.073	50.275	0.774	121.164
2041-2045	28800	286.5	14.898	1719	41.829	28807.6	443.502	69426.972
2046-2050	29600	0	0	0	0	0	0	0
2051-2055		0	0	0	0	0	0	0
2056-2060		137.4	7.1448	824.4	20.0604	13815.6	212.695	33295.8672
2061-2065		6310	328.12	37860	921.26	634471	9767.88	1529089.68
2066-2070		13950	725.4	83700	2036.7	1402673	21594.6	3380475.6
2071-2075		14400	748.8	86400	2102.4	1447920	22291.2	3489523.2
2076-2080		14800	769.6	88800	2160.8	1488140	22910.4	3586454.4

Detailed waste projections (solar and wind)

The following table displays the annual end-of-life waste projections for wind and solar technologies in Aotearoa New Zealand from 2016 to 2080, listing each calendar year alongside the corresponding wind EoL waste material (in tonnes) and solar EoL waste (in tonnes).

End-of-life waste projections for wind and solar technologies in Aotearoa New Zealand

Year	Cumulative Wind E-Waste (tonnes)	Cumulative Solar E-Waste (tonnes)
2016	703.248	
2017	703.248	
2018	703.248	
2019	6329.232	
2020	6329.232	
2021	6329.232	
2022	6329.232	
2023	6329.232	
2024	29536.416	
2025	29536.416	
2026	38151.204	
2027	64698.816	
2028	64698.816	
2029	90191.556	
2030	90367.368	
2031	109530.876	
2032	109530.876	
2033	109530.876	
2034	120255.408	
2035	121486.092	
2036	121661.904	
2037	121661.904	
2038	121661.904	
2039	121661.904	
2040	121661.904	
2041	145044.9	
2042	165966.528	
2043	191459.268	
2044	0	
2045	0	
2046	0	
2047	0	
2048	0	
2049	0	
2050	0	

2051	0	
2052	0	236.767812
2053	0	4143.43671
2054	222402.18	15745.0595
2055	222402.18	33502.6454
2056	222402.18	51260.2313
2057	405598.284	51260.2313
2058	458341.884	69017.8172
2059	559961.22	80856.2078
2060	931803.6	378828.4992
2061	949384.8	402505.2804
2062	984547.2	426182.0616
2063	984547.2	449858.8428
2064	1002128.4	461697.2334
2065	1019709.6	485374.0146
2066	1037290.8	497212.4052
2067	1037290.8	509050.7958
2068	1054872	520889.1864
2069	1072453.2	520889.1864
2070	1072453.2	532727.577
2071	1072453.2	532727.577
2072	1090034.4	532727.577
2073	1090034.4	544565.9676
2074	1107615.6	544565.9676
2075	1107615.6	544565.9676
2076	1125196.8	544565.9676
2077	1125196.8	544565.9676
2078	1125196.8	556404.3582
2079	1125196.8	556404.3582
2080	1125196.8	556404.3582

Material recovery value data

The following table lists the total maximum and minimum material recovery values (in NZD) for aluminium, copper, glass, and silicon recovered from end-of-life solar and wind installations, as used in Figure 4.

Maximum and minimum material recovery values (in NZ$)

Materials	Sum of Total Max Material Value (NZ$)	Sum of Total Min Material Value (NZ$)
Aluminium	8,525,830,487	5,115,498,292
Copper	895,477,487	626,834,241
Glass	570,972,317	250,976,843
Silicon	1,876,521,399	918,507,843

The following provides the annual maximum and minimum total material recovery values (in NZD) projected for the period 2052 to 2080, with each row showing the year alongside the sum of total maximum and minimum values.

Maximum and minimum total material recovery values (in NZ$) projected for the period 2052 to 2080

Years	Sum of Total Max Material Value(NZD)	Sum of Total Min Material Value (NZD)
2052	247,568.43	144,171.90
2053	4,084,879.03	2,378,836.38
2054	12,130,852.87	7,064,423.18
2055	274,677,168.53	159,958,724.78
2056	198,673,661.78	115,697,951.00
2057	102,245,759.89	59,542,995.34
2058	74,270,527.77	43,251,570.47
2059	74,270,527.77	43,251,570.47
2060	396,109,481.43	230,675,042.49
2061	420,866,324.02	245,092,232.64
2062	445,623,166.61	259,509,422.80
2063	470,380,009.20	273,926,612.96
2064	482,758,430.49	281,135,208.03
2065	507,515,273.08	295,552,398.19
2066	519,893,694.38	302,760,993.27
2067	532,272,115.67	309,969,588.34
2068	544,650,536.97	317,178,183.42
2069	544,650,536.97	317,178,183.42
2070	557,028,958.26	324,386,778.50
2071	557,028,958.26	324,386,778.50
2072	557,028,958.26	324,386,778.50
2073	569,407,379.56	331,595,373.58
2074	569,407,379.56	331,595,373.58
2075	569,407,379.56	331,595,373.58
2076	569,407,379.56	331,595,373.58
2077	569,407,379.56	331,595,373.58
2078	581,785,800.85	338,803,968.66
2079	581,785,800.85	338,803,968.66
2080	581,785,800.85	338,803,968.66

Material intensity data (solar and wind)

The following table summarizes the material intensity for PMSG-DD wind turbine manufacturing per megawatt (MW), listing each material, the corresponding intensity value (kg/MW or kg/nacelle), and its data source reference.

Material intensity for PMSG-DD wind turbine manufacturing per megawatt (MW)

Inventory for PMSG-DD wind turbine manufacturing.				
Material	**Material Intensity**	**Source**		
Steel	121,164 kg/MW	(Carrara, Alves Dias, Plazzotta, & Pavel, 2020, p. 74)		
Copper	3,000 kg/MW	(Carrara, Alves Dias, Plazzotta, & Pavel, 2020, p. 74)		
Aluminium	500 kg/MW	(Carrara, Alves Dias, Plazzotta, & Pavel, 2020, p. 74)		
Iron	50,275 kg/MW	(Carrara, Alves Dias, Plazzotta, & Pavel, 2020, p. 74)		
Neodymium	774 kg/MW	(Carrara, Alves Dias, Plazzotta, & Pavel, 2020, p. 74)		
Dysprosium	73 kg/MW	(Carrara, Alves Dias, Plazzotta, & Pavel, 2020, p. 74)		
Boron	26 kg/MW	(Carrara, Alves Dias, Plazzotta, & Pavel, 2020, p. 74)		
Praseodymium	151 kg/MW	(Carrara, Alves Dias, Plazzotta, & Pavel, 2020, p. 74)		
Terbium	30 kg/MW	(Carrara, Alves Dias, Plazzotta, & Pavel, 2020, p. 74)		
Zinc	23,650 kg/MW	(Carrara, Alves Dias, Plazzotta, & Pavel, 2020, p. 74)		
Glass fibre in the nacelle	3,083 kg/nacelle	Ecoinvent v.3.9.1		
Glass fibre in the set of blades	27,567 kg/set of blades	(Carrara, Alves Dias, Plazzotta, & Pavel, 2020, p. 74) & Ecoinvent v.3.9.1		
Carbon fibre	1,782 kg/MW	(Carrara, Alves Dias, Plazzotta, & Pavel, 2020, p. 74)		
Epoxy resin	4,600 kg/MW	(Carrara, Alves Dias, Plazzotta, & Pavel, 2020, p. 74) & (Li, Mogollón, Tukker, & Steubing, 2022, pp. 11,567–11,577)		

The following table details the material composition of a utility-scale monocrystalline silicon PV installation per megawatt (MW), including each material (steel, aluminium, glass, copper, silicon, plastics/polymers, glass fibre, ferrite, tantalum), the source component, total amount (kg/MW), and recyclability status.

Material composition of a utility-scale monocrystalline silicon PV installation per megawatt (MW),

Utility-scale solar PV installation of 1 MW capacity using monocrystalline silicon technology			
Material	**Source Component**	**Total amount(kg/MW)**	**Recyclability**
Steel (all types)	Mounting structure, inverter	34416	Yes
Aluminium	PV modules, mounting structure, inverter	29135	Yes
Glass	PV modules, inverter	42025	Yes
Copper	PV modules, transformer, inverter, cabling	856	Yes
Silicon	PV modules	4725	Yes
Plastics/Polymers	PV modules, inverter, transformer	5965.7	Partially
Glass Fiber	PV modules	1050	No
Ferrite (iron core)	Transformer	212	Yes
Tantalum	Inverter	0.006	Yes

Detailed material composition and recyclability

The following table summarises the composition of a typical crystalline silicon PV panel, detailing material weights, estimated value ranges in AUD (converted to NZD), recyclability, recovery rates, and their relevance to wind turbine components.

Material composition and recyclability potential of solar and wind components

Component	Material	Weight (%)	Weight (kg)	Value (AUD$/kg)	Total Value per Panel (AUD$)	Recyclability	Recovery Rate (%)	Potential Applications	Wind Turbine Applications
Frame	Aluminum	16-20%	3.2 to 4.0	2.1 to 2.8	6.72-11.20	High	>95%	New aluminium products, frames	Nacelle components, structural elements
Front Cover	Glass	67-70%	13.4 to 14.0	0.06 to 0.13	0.80-1.82	High	>95%	New glass products, construction materials	N/A
Encapsulant	EVA (Ethylene Vinyl Acetate)	6-7%	1.2 to 1.4	Negligible	Negligible	Low	<50%	Energy recovery through incineration	N/A
Solar Cells	Silicon	3-5%	0.6 to 1.0	3.1 to 3.8	1.86-3.80	Medium	80-90%	New solar cells, silicon alloys, battery anodes	N/A
	Silver	0.03-0.05 %	0.006 to 0.01	746 to 1084	4.48-10.84	High	90-95%	Electronics, conductive pastes	Electronic components
Interconnections	Copper (ribbons)	0.80 %	0.16	7 to 10	1.12-1.60	High	>90%	New copper products, electronics	Electrical systems, generators
	Tin	0.10 %	0.02	22	0.44	Medium	70-80%	Soldering, alloys	Electrical connections
	Lead	0.01 %	0.002	3	0.006	Medium	70-80%	Batteries, radiation shielding	N/A
Junction Box	Copper	0.30 %	0.06	7 to 10	0.42-0.60	High	>90%	Electronics, wiring	Electrical systems
Backsheet	PVF/PET	3-4%	0.6 to 0.8	Negligible	Negligible	Low	<50%	Energy recovery	N/A

The following table presents the percentage weight and unit price (AU$/kg) of the major materials in a typical crystalline silicon photovoltaic (PV) panel, listing each component, the material, the weight range (in % of total panel mass), and the price range (AU$/kg), as reported in the Australian Scoping Study.

Weight and value composition of major materials in a typical crystalline silicon photovoltaic panel

Component	Material	Weight	Price(AUD/kg)
Solar cells	Silicon	3–5	3.1–3.8
	Silver	0.03–0.05	746–1084
Ribbon	Copper	0.8	7–10
	Tin	0.1	22
	Lead	0.01	3
Frame	Aluminium	16–20	2.1–2.8
Glass	Glass	67–70	0.06–0.13
Junction box	Copper	0.3	7–10
Encapsulant	EVA	6–7	Negligible
Backsheet	PVF/PET	3–4	Negligible

The following diagram shows a wind turbine components and how they are typically processed at the end of service (source: NREL 2024)

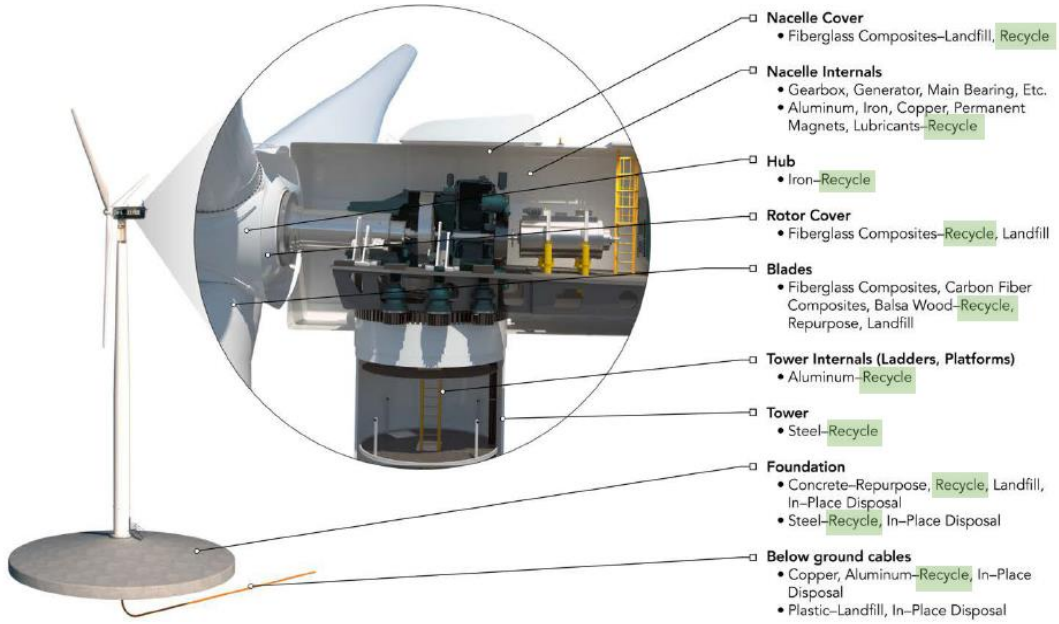

Diagram showing wind turbine components and how they are typically processed at the end of service
(source: NREL 2024)