## Appendix A: Proposed solutions

Table A.1: Summary of the proposed changes for each nBL solution.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Solution** | **Generation** | **Storage** | **Transmission** | **Policy** |
| BAU | Mix. | Gradual introduction. | As usual. | Minimal changes to current policy. |
| ALT1 (Import/Export) | Existing renewable energy only. | Rapid introduction. | Heavy investment. | Release of smart meter data to the public with proper privacy changes.Inverter regulation.Cost-reflective pricing. |
| ALT2 (Self-Sustainable) | 100% renewables sourced in Victoria. | Rapid introduction. | As usual. | PV export limits.Release of smart meter data to the public with proper privacy changes.Local storage mandated with PV.Regulation to support grid-connected micro-grids and VPP’s. |

## Appendix B: Generation mix for each solution

Table B2.1: Proposed generation mix for each solution.

|  |  |  |  |
| --- | --- | --- | --- |
| Generation Mix | BAU | ALT1 | ALT2\* |
| Coal | 36.2% | 0% | 0% |
| Solar | 24.1% | 24.1% | 29% |
| Wind | Onshore | 29.3% | 29.3% | 41% |
| Offshore | 0% | 0% | 20% |
| Hydro | 5.2% | 5.2% | 5% |
| Bio | 5.2% | 5.2% | 5% |
| Imports | 0% | 36.2% | 0% |

\*ALT 2’s generation capacity shown below is enough to generate 115% of annual demand – values in the table have been scaled to achieve 100% collectively.

The 2030 generation mix was determined by using capacity factors determined from a report prepared by Aurecon for AEMO. This generation mix was used to estimate capacity factors for onshore, offshore, and solar PV (Aurecon, 2019), and to estimate the annual generation from all the proposed renewable projects detailed in Appendix D. The yearly demand was then estimated by viewing historical data available on OpenNEM.org.au and AEMO’s demand predictions in their 2019 Electricity Statement of Opportunities (AEMO, 2019). The difference between renewable generation and demand will be generated by coal in the BAU case, coal transitioning to imported energy by 2030 in ALT1, and coal transitioning to self-sufficient renewable production by 2030 in ALT2. Calculations are detailed below for each solution.

### BAU Generation Mix Determination

Table B.2: Summary of proposed new capacity and current generation for the BAU case

|  |  |  |
| --- | --- | --- |
| **BAU with added solar capacity (MW)** | 4090 |   |
| **BAU with added wind capacity (MW)** | 2094.5 |   |
| **Current solar generation (GWh)** | 800 | (OpenNEM, 2020) |
| **Current wind generation (GWh)** | 6412 | (OpenNEM, 2020) |
| **Other renewables (GWh)** | 5094 | (OpenNEM, 2020) |

Table B.3: Calculation of annual generation for the BAU case

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Solar Capacity Factor (%) (Aurecon, 2019)** | **Annual Solar Generation (GWh)** | **Wind Capacity Factor (%) (Aurecon, 2019)** | **Annual Wind Generation (GWh)** | **Total Generation from Renewables (GWh)** | **Annual Demand (GWh) (AEMO, 2019) & (OpenNEM, 2020)** | **Annual Coal Generation (GWh)** |
| **2021** | 29.3 | 1849.77 | 40.6 | 7156.92 | 14100.69 | 49000 | 34899.31 |
| **2022** | 29.5 | 2913.88 | 40.9 | 7912.85 | 15920.73 | 49000 | 33079.27 |
| **2023** | 29.6 | 3981.56 | 41.2 | 8679.79 | 17755.35 | 49000 | 31244.65 |
| **2024** | 29.8 | 5070.75 | 41.5 | 9457.74 | 19622.48 | 49000 | 29377.52 |
| **2025** | 29.9 | 6156.35 | 41.8 | 10246.69 | 21497.04 | 49000 | 27502.96 |
| **2026** | 30.1 | 7270.61 | 42.1 | 11046.66 | 23411.27 | 49000 | 25588.73 |
| **2027** | 30.2 | 8374.12 | 42.4 | 11857.63 | 25325.76 | 49000 | 23674.24 |
| **2028** | 30.4 | 9513.47 | 42.7 | 12679.62 | 27287.08 | 49000 | 21712.92 |
| **2029** | 30.5 | 10634.90 | 43 | 13512.61 | 29241.50 | 49000 | 19758.50 |
| **2030** | 30.7 | 11799.32 | 43.3 | 14356.61 | 31249.92 | 49000 | 17750.08 |

### ALT1 Generation Mix Determination

Table B.4: Summary of proposed new capacity and current generation for ALT1

|  |  |  |
| --- | --- | --- |
| **BAU added solar capacity (MW)** | 4090 |   |
| **BAU added wind capacity (MW)** | 2094.5 |   |
| **Current solar generation (GWh)** | 800 | (OpenNEM, 2020) |
| **Current wind generation (GWh)** | 6412 | (OpenNEM, 2020) |
| **Other renewables (GWh)** | 5094 | (OpenNEM, 2020) |

Table B.5: Calculation of annual generation for the ALT1

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Solar Capacity Factor (%) (Aurecon, 2019)** | **Annual Solar Generation (GWh)** | **Wind Capacity Factor (%) (Aurecon, 2019)** | **Annual Wind Generation (GWh)** | **Total Generation from Renewables (GWh)** | **Annual Demand (GWh) (AEMO, 2019) & (OpenNEM, 2020)** | **Annual Demand not Generated from Renewables (GWh)** | **Annual Coal Generation (GWh)** | **Annual Imported Energy (GWh)** |
| **2021** | 29.3 | 1849.77 | 40.6 | 7156.92 | 14100.69 | 49000 | 34899.31 | 34899.31 | 0.00 |
| **2022** | 29.5 | 2913.88 | 40.9 | 7912.85 | 15920.73 | 49000 | 33079.27 | 31107.04 | 1972.23 |
| **2023** | 29.6 | 3981.56 | 41.2 | 8679.79 | 17755.35 | 49000 | 31244.65 | 27300.19 | 3944.46 |
| **2024** | 29.8 | 5070.75 | 41.5 | 9457.74 | 19622.48 | 49000 | 29377.52 | 23460.83 | 5916.69 |
| **2025** | 29.9 | 6156.35 | 41.8 | 10246.69 | 21497.04 | 49000 | 27502.96 | 19614.04 | 7888.92 |
| **2026** | 30.1 | 7270.61 | 42.1 | 11046.66 | 23411.27 | 49000 | 25588.73 | 15727.58 | 9861.15 |
| **2027** | 30.2 | 8374.12 | 42.4 | 11857.63 | 25325.76 | 49000 | 23674.24 | 11840.86 | 11833.38 |
| **2028** | 30.4 | 9513.47 | 42.7 | 12679.62 | 27287.08 | 49000 | 21712.92 | 7907.31 | 13805.61 |
| **2029** | 30.5 | 10634.90 | 43 | 13512.61 | 29241.50 | 49000 | 19758.50 | 3980.66 | 15777.84 |
| **2030** | 30.7 | 11799.32 | 43.3 | 14356.61 | 31249.92 | 49000 | 17750.08 | 0.00 | 17750.08 |

### ALT2 Generation Mix Determination

Table B.5: Summary of proposed new capacity and current generation for ALT2

|  |  |  |
| --- | --- | --- |
| **BAU added solar capacity (MW)** | 4090 |  |
| **BAU added wind capacity (MW)** | 2094.5 |  |
| **ALT 2 added solar capacity (MW)** | 1733 |  |
| **ALT 2 added wind capacity (MW)** | 2386 |  |
| **ALT 2 new offshore wind capacity (MW)** | 4195 |  |
| **Current solar generation (GWh)** | 800 | (OpenNEM, 2020) |
| **Current wind generation (GWh)** | 6412 | (OpenNEM, 2020) |
| **Other renewables (GWh)** | 5094 | (OpenNEM, 2020) |

Table B.6: Calculation of annual generation for the ALT2

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Solar Capacity Factor (%) (Aurecon, 2019)** | **Annual Solar Generation (GWh)** | **Wind Capacity Factor (%) (Aurecon, 2019)** | **Annual Wind Generation (GWh)** | **Offshore Wind Capacity Factor (%) (Aurecon, 2019)** | **Annual Offshore Wind Generation (GWh)** | **Total Generation from Renewables (GWh)** | **Annual Demand (GWh) (AEMO, 2019) & (OpenNEM, 2020)** | **Annual Coal Generation (GWh)** |
| **2021** | 29.3 | 2294.58 | 40.6 | 8005.52 | 46.2 | 0 | 15394.09 | 49000 | 33605.91 |
| **2022** | 29.5 | 3809.56 | 40.9 | 9622.58 | 46.8 | 0 | 18526.14 | 49000 | 30473.86 |
| **2023** | 29.6 | 5329.64 | 41.2 | 11263.20 | 47.4 | 1422.16 | 23109.00 | 49000 | 25891.00 |
| **2024** | 29.8 | 6880.33 | 41.5 | 12927.36 | 48 | 2844.32 | 27746.01 | 49000 | 21253.99 |
| **2025** | 29.9 | 8425.92 | 41.8 | 14615.08 | 48.6 | 4266.48 | 32401.48 | 49000 | 16598.52 |
| **2026** | 30.1 | 10012.31 | 42.1 | 16326.34 | 49.2 | 5688.64 | 37121.29 | 49000 | 11878.71 |
| **2027** | 30.2 | 11583.40 | 42.4 | 18061.16 | 49.8 | 7110.80 | 41849.36 | 49000 | 7150.64 |
| **2028** | 30.4 | 13205.51 | 42.7 | 19819.52 | 50.4 | 8532.96 | 46651.99 | 49000 | 2348.01 |
| **2029** | 30.5 | 14802.10 | 43 | 21601.43 | 51 | 9955.12 | 51452.65 | 49000 | 0 |
| **2030** | 30.7 | 16459.91 | 43.3 | 23406.89 | 51.6 | 11377.24 | 56338.05 | 49000 | 0 |

## Appendix C: Peak Load Estimation

Table C.1: Tabulation of Victoria’s annual peak load and projection from 2022 – 2030.

|  |  |  |
| --- | --- | --- |
| Year | No. | Peak Load |
| 2000 | 1 | 8019.00 |
| 2001 | 2 | 7581.00 |
| 2002 | 3 | 8041.00 |
| 2003 | 4 | 8583.00 |
| 2004 | 5 | 8492.00 |
| 2005 | 6 | 8742.00 |
| 2006 | 7 | 9080.00 |
| 2007 | 8 | 9830.00 |
| 2008 | 9 | 10490.00 |
| 2009 | 10 | 10088.00 |
| 2010 | 11 | 9906.00 |
| 2011 | 12 | 9155.00 |
| 2012 | 13 | 9670.00 |
| 2013 | 14 | 10308.00 |
| 2014 | 15 | 8635.00 |
| 2015 | 16 | 9523.00 |
| 2016 | 17 | 8730.00 |
| 2017 | 18 | 9159.00 |
| 2018 | 19 | 9318.00 |
| 2019 | 20 | 9618.00 |
| 2020 | 21 | 8391.00 |
| 2021 | 22 | 9665.44 |
| 2022 | 23 | 9715.72 |
| 2023 | 24 | 9766.00 |
| 2024 | 25 | 9816.28 |
| 2025 | 26 | 9866.55 |
| 2026 | 27 | 9916.83 |
| 2027 | 28 | 9967.11 |
| 2028 | 29 | 10017.39 |
| 2029 | 30 | 10067.67 |
| **2030** | **31** | **10117.95** |

Figure C.1: Graphical interpretation of Victoria’s annual peak load, including a linear projection.

## Appendix D: Proposed Projects Required for Each Solution

### BAU Projects

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Projects | Capacity (MW) | Est. Cost ($m) | Jobs Created | Source |
| Solar | Axedale | 160 | 240 (1) | 250 (2) | 1: (CoreLogic, n.d)2: (UPC\AC Renewables Australia, 2018) |
| Baringhup | 75 | 192 (1) | 213 (2) | 1: (Bendigo Advertiser, 2019)2: (Bloch, 2020) |
| Bendigo | 55 | 66\* | 156\* |   |
| Carisbrook | 90 | 100 (1) | 250 (1) | 1: (Maisch, 2019) |
| Carwarp | 100 | 121\* | 342 (1) | 1: (Victoria State Government, 2020) |
| Congupna | 68 | 48 (1) | 250 (2) | 1: (Adams, 2021)2: (Murray, 2018) |
| Derby | 100 | 121\* | 194\* |   |
| Gannawarra Stage 2 | 300 | 400 (1) | 170 (1) | 1: (Gannawarra Shire Council, n.d) |
| Girgarre | 85 | 103\* | 181\* |   |
| Glenrowan | 140 | 170 (1) | 350 (2) | 1: (Numerical, 2018)2: (Glenrowan West Solar Farm, 2020) |
| Goorambat | 75 | 120 (1) | 172\* | 1: (South Energy, 2019) |
| Goorambat Stewarton East | 250 | 400 (1) | 358 (1) | 1 - (Goorambat Solar Farms, n.d) |
| Horsham | 130 | 200 (1) | 150 (1) | 1: (Werner, 2017) |
| Kennedys Creek | 150 | 181\* | 254 (1) | 1: (South Energy, 2020) |
| Kerang 1 | 60 | 60 (1) | 140 (1) | 1: (Gannawarra Shire Council, n.d) |
| Kerang 2 | 60 | 60 (1) | 140 (1) | 1: (Gannawarra Shire Council, n.d) |
| Kerang Greenswitch | 50 | 50 (1) | 140 (1) | 1: (Gannawarra Shire Council, n.d) |
| Laceby | 70 | 94 (1) | 175 (2) | 1: (NGH Environmental, 2019)2: (Laceby Solar Farm, n.d) |
| Lancaster | 80 | 110 (1) | 176\* | 1: (Country News, 2018) |
| Lemnos | 100 | 121\* | 194\* |   |
| Macorna | 100 | 140 (1) | 140 (1) | 1: (Gannawarra Shire Council, n.d) |
| Mallee | 250 | 302\* | 330\* |   |
| Moira 3 IB VOGT | 90 | 109\* | 185\* |   |
| Murra Warra | 235 | 310 (1) | 134 (1) | 1: (Essential Economics, 2017) |
| Naring | 60 | 57 (1) | 303 (1) | 1: (Urbis, 2018) |
| Perry Bridge | 50 | 70 (1) | 125 (1) | 1: (Eishold, 2021) |
| Prairie | 240 | 300 (1) | 207 (2) | 1: (Potter, 2018)2: (PacificHydro, 2020) |
| Campbells Forest | 200 | 241\* | 306 (1) | 1 - (South Energy, 2021) |
| Tragowel | 430 | 500 (1) | 492\* | 1: (AltEnergy, 2019) |
| Winton | 85 | 103\* | 159 (2,3) | 1: (Winton Solar Farm, n.d) |
| Wodonga | 50 | 80 (1) | 85 (1) | 1: (RAW Energy, 2018) |
| Wungnhu Solar | 102 | 200 (1) | 400 (1) | 1: (X-ELIO, 2021) |
| Wind | Berrimal | 72 | 150 (1) | 110 (1) | 1 - (Acciona, 2020) |
| Hawkesdale | 106.8 | 151\* | 222\* |   |
| Rifle Butts | 40 | 150 (1) | 120 (2) | 1: (CoreLogic, n.d)2: (Parkinson, 2018) |
| Ryan Corner | 235.4 | 332\* | 286\* |   |
| Woolsthorpe | 72 | 150 (1) | 205\* | 1: (Woolsthorpe Wind Farm, 2021) |
| Jung | 8.4 | 12\* | 173\* |   |
| Berrybank | 332 | 468\* | 489 (1) | 1: (GPG Naturgy Group, 2019) |
| Diapur (formerly Nhill) | 8.4 | 12\* | 173\* |   |
| Moorabool | 321 | 370 | 320 (1) | 1: (Vorrath, 2020) |
| Mortlake South | 157.5 | 280 (1) | 100 (1) | 1: (Acciona, 2020) |
| Murra Warra | 209 | 180 (1) | 400 (1) | 1: (Partners Group, 2020) |
| Stockyard Hill | 532 | 700 (1) | 435\* | 1: (Power Technology, n.d) |
| Storage | Moorabool Battery ('Big Battery') | 300 | 393\* | 85 (1) | 1: (Prytz, 2020) |
| Bulgana | 20 | 26\* | 35\* |   |
| Longwarry | 5 | 7\* | 30\* |   |
| Transmission | Western Victoria Transmission Network Project (WVTNP) | 900 | 300 (1) | 300 (1) | 1: (Western Victoria TNP, n.d) |
| VNI 6 | 1800 | 1335\* | 600\* |   |
| VNI 7 | 1800 | 1855\* | 600\* |   |
| VNI 8 | 800 | 1445\* | 267\* |   |
| Note: \* means the value for cost or jobs created was calculated; the calculation methods are explained in the report |

### ALT1 Projects

Note: ALT1 includes BAU projects plus those shown in the following table

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Project | Generation (MW) | Est. Cost ($m) | Jobs Created | Source |
| Storage | Murray River REZ | 450 | 590 (1) | 128\* | 1: (AEMO, 2020) |
| Western REZ | 350 | 459 (1) | 100\* |
| South West REZ | 350 | 459 (1) | 100\* |
| Central North REZ | 200 | 262 (1) | 57\* |
| Transmission | Marinus Link | 2500 | 3500 (1) | 1400 (1) | 1: (TasNetworks, 2020) |
| East-West Interconnector 1 | 1500 | 2500 (1) | 840\* | 1: (Bartlett, 2019) |
| East-West Interconnector 2 | 1664 | 2500 (1) | 932\* |
| Note: \* means the value for cost or jobs created was calculated; the calculation methods are explained in the report |

### ALT2 Projects

Note: ALT2 includes BAU projects plus those shown in following table

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Project | Generation (MW) | Est. Cost ($m) | Jobs Created | Source |
| Solar | Bookaar | 200 | 280 (1) | 156 (2) | 1: (Bloch, 2021)2: (Bookar Renewables, 2021) |
| Bostocks Creek | 5 | 6 (1) | 75 (1) | 1: (Bison Energy, 2020) |
| Corop | 400 | 520 (1) | 730 (1) | 1: (Leeson Group, n.d) |
| Cosgrove | 5 | 6 (1) | 75 (1) | 1: (Bison Energy, 2020) |
| Greengold Numurkah | 5 | 6\* | 109\* |   |
| GVCE Mooroopna | 18 | 32 (1) | 120\* | 1: (GVCE Mooroopna Solar Farm, 2019) |
| Hepburn Energy Park | 7 | 18 (1) | 110\* | 1: (CoreLogic, n.d) |
| Inverleigh | 19 | 26 (1) | 121\* | 1: (CoreLogic, n.d) |
| Kiamal Stage 2 | 150 | 250\* | 239\* |   |
| Mangalore | 5 | 6 (1) | 109\* | 1: (CoreLogic, n.d) |
| Morwell | 70 | 105 (1) | 100 (1) | 1: (Vorrath, 2021) |
| Ravenswood | 63 | 105 (1) | 100 (1) | 1: (Carroll, 2021) |
| Stawell | 5 | 6\* | 109\* |   |
| Toolern Vale | 16 | 32\* | 119\* |   |
| Viewbank | 75 | 140 (1) | 155 (2) | 1: (CoreLogic, n.d)2: (FRV, n.d) |
| West Mokoan | 190 | 285 (1) | 306 (1) | 1: (South Energy, n.d) |
| Winton North | 100 | 175\* | 155 (1) | 1: (FRV, n.d) |
| Goorambat Stewarton West | 400 | 520\* | 465\* |   |
| Wind | Brewster | 24 | 10 | 181\* | 1: (CoreLogic, n.d) |
| Delburn | 200 | 360 (1) | 210 (2) | 1: (Gippsland Times, 2021)2: (OSMI, 2021) |
| Golden Plains | 1290 | 1600 (1) | 770 (2) | 1: (WestWind Energy, 2018)2: (WestWind Energy, 2020) |
| Inverleigh | 142 | 200 (1) | 396 (1) | 1: (Inverleigh Wind Farm, n.d) |
| Mount Fyans | 400 | 720\* | 369\* |   |
| Wimmera Plains | 300 | 540\* | 319\* |   |
| Wombelano | 30 | 50 | 184\* |   |
| Star of the South  | 2200 | 8700 (1) | 2000 (2) | 1: (The Australian, 2021)2: (Star of the South, 2020) |
| Project Gippsland | 1500 | 5931\* | 1364\* |   |
| Victoria Offshore Windfarm Project | 495 | 1957.5\* | 451\* |   |
| Storage  | Melton | 600 | 786\* | 171\* |   |
| Mortlake | 300 | 393\* | 86\* |   |
| Mornington Peninsula | 240 | 314\* | 69\* |   |
| Loy Yang | 200 | 262\* | 57\* |   |
| Yallourn | 350 | 459\* | 100\* |   |
| Transmission | Kerang to Red Cliffs (via Wemen) | 800 | 514 (1) | 267\* | 1: (Victoria State Government, 2021) |
| Elaine to Moorabool | 600 | 90 (1) | 201\* |
| Mortlake to North Ballarat | 3000 | 530 (1) | 1005\* |
| Note: \* means the value for cost or jobs created was calculated; the calculation methods are explained in the report |

## Appendix E: Technical Performance Metric

### Conversion Losses (%)

Given the variability in the generation type proposed by renewable methods, analysis of losses that occur in the initial conversion of potential energy to mechanical energy is critical to understanding the performance of each method as a long-term, viable option from a technical efficiency standpoint. The 2030 generation mix for each solution in Appendix A was utilised to calculate the overall efficiency of each solution. The load level of each generation type was treated as a critical value. The generation demand for 2030 was calculated by linearly projecting the trend of demand change into the next ten years, and the results for this projection are in Appendix C.

Each solution's energy loss percentage was calculated using each generation type's inefficiencies. Kabir (2014) and Seligman (2010) agree that raw materials are converted to energy at an efficiency of 28%. It is assumed that this rate of efficiency holds until 2030. In reviewing costs and technical parameters for the Australian Energy Market Operator (AEMO), Aurecon (2019) postulate efficiency values of 30.7%, 43.3% and 51.6% for solar, onshore wind and offshore wind, respectively. Finally, the Clean Energy Council attribute an efficiency value of 90% for pumped hydropower (Clean Energy Council, 2012), while the Environmental Protection Agency (EPA) maintains a regulatory value of 65% for all waste to energy plants installed globally after 31st December 2008 (2013). Total conversion losses as a percentage are calculated by first finding each generation type's total potential energy following Equation 1.

|  |  |
| --- | --- |
| $$Potential Energy=\frac{L\_{G}}{e\_{G}}$$ | $$(1)$$ |

Where $L\_{G}$ is the individual load generated by each type, and $e\_{G}$ is the efficiency of the generation type. Hence, the energy lost in MW can be found by subtracting the delivered load from potential energy. The sum of all energy lost and potential energy can then be found for the entire solution, and Equation 2 delivers a final percentage of conversion loss. The final calculations are shown below in Table E.1.

|  |  |
| --- | --- |
| $$e\_{T}=\frac{\sum\_{}^{}Energy Lost}{\sum\_{}^{}Potential Energy}\*100$$ | $$(2)$$ |

Table E.1: Summary of conversion loss calculations, including the generation share from Appendix B and the individual loss percentages for each generation type.



### Transmission Losses (%)

Identification of energy losses from grid infrastructure (e.g., transformers and conduction) is proposed by Pramangioulis et al. (2019) as a key metric to describe smart grid energy systems in kWh/year. Conversely, Huang et al. (2016) present energy losses occurring across smart microgrids systems as a percentage, which assists in comparing systems of varying magnitude in size. Hence, this method is preferred. In their analysis on estimating distribution losses, Dortolina (2005) suggests that 9.5% of energy is lost due to step-down transformer and distribution loss, while Bahrman (2006) estimates a line loss of 6.93% per 1000km. These values were adopted when estimating the losses attributable to the transmission for each of the three proposals. Only transmission occurring across state borders was considered in this analysis since 5% of power is lost once it falls within the boundaries of distribution companies (AusNet Services, 2018). Current transmission lines were analysed via AEMO’s Transmission Map (n.d.), while future transmission lines were included in the *Future Projects* for each solution (see Appendix D). The total percentage loss for each line was calculated using Formula 3.

|  |  |
| --- | --- |
| $$\% loss=9.5\%+\frac{Length of line in km}{1000}\*6.93\%$$ | $$(3)$$ |

A weighting method was applied to calculate the percentage loss across each proposal's entire transmission network. For each transmission line, the allocated weighting was dependent on the length ratio for the combined length of the network, as outlined in Formula 4.

|  |  |
| --- | --- |
| $$Weighted Loss \left[\%\right]=Line loss \left[\%\right]\*\frac{Individual line length [km]}{Total line length [km]}$$ | $$(4)$$ |

The sum of all individually weighted loss percentages is then calculated to find the total network loss. The full calculations are provided below in Table E.2.

Table E.2: Summary of transmission loss calculations following the weighting method described.



### Storage Capacity (MW)

The benefits of storage capacity in a smart grid are well documented among global literature on smart grid technologies, namely through the improvement of grid reliability and asset utilisation (Kolokotsa, et al., 2019; Roberts & Sandberg, 2011; Petinrin & Shaaban, 2013). Hence, storage capacity was included as a key metric to describe the technical performance of each proposal. The total storage capacity available for each proposal was inferred from the *Future Projects* table for each solution (see Appendix D).

### Data Transparency (-)

The final technical performance metric analysed addresses issues raised with data sharing across grid stakeholders. The purpose of this metric is to capture the capability of each solution to create and share accessible data between stakeholders such as DB’s, grid operators, retailers, government, and consumers. European distribution system operators (DSO’s) quantify this (Brazier, et al., 2020). The full calculation formula and justifications are provided below.

$$Transparency Data Access Sharing=TDAS\*\frac{\sum\_{i=1}^{9}(KI 5.i\*w\_{TDASi})}{\sum\_{i=1}^{9}w\_{TDASi}}$$

Where $w\_{TDASi}$ is a weighting factor between 0 and 1 attributable to each of the below inputs. Table E.3 summarises the inputs adapted from Brazier et al. (2020).

Table E.3: Description of each variable included in the formula for data transparency.

|  |  |
| --- | --- |
| **Code** | **Description** |
| TDAS | A value equal to 0 or 1. Describes the ability of data access and sharing between stakeholders (1 if available, 0 if not). |
| 5.1 | A value equal to 0 or 1 describes the availability of consumer data to distribution operators (i.e., AEMO). |
| 5.2 | A value equal to 0 or 1 describes the availability of real-time consumer data to distribution operators (i.e., AEMO). |
| 5.3 | A value equal to 0 or 1 describes the availability of consumer data to distribution businesses (e.g., AusNet). |
| 5.4 | A value equal to 0 or 1 describes the availability of real-time consumer data to distribution businesses (e.g., AusNet). |
| 5.5 | A value equal to 0 or 1 describes the ability of distribution operators (i.e., AEMO) to provide real-time data to distributed energy resource operators. |
| 5.6 | A value equal to 0 or 1 describes the ability of distribution operators (i.e., AEMO) to provide non-real-time data to distributed energy resource operators. |
| 5.7 | A value equal to 0 or 1 describes the ability of smart meters installed at the customer interface to provide real-time data to customers. |
| 5.8 | A value equal to 0 or 1. Describes the ability of smart meters installed at customer interface to provide non-real-time data to customers. |
| 5.9 | A value equal to 0 or 1. Describes whether data is shared between system operators and retail businesses. |

Table E.4 summarises the attributed values for each of the proposals.

Table E.5: Applied values for data transparency metric.



## Appendix F: Social Metric

### Employment

A primary factor in evaluating the social performance of the different transition proposals is the level of employment generated from the wind, solar, storage and transmission projects for each proposal. The number of jobs measured for each project included construction and permanent ongoing jobs. Due to the insignificant number of permanent jobs running each farm and the analysis taking place early in the lifespan of the farms, the permanent jobs were in the count of jobs as they had an insignificant impact on results. Furthermore, the jobs lost from the closures of Yallourn, Loy Yang A and Loy Yang B were not in the total, due to the minimal number of jobs lost, compared to the jobs created.

Employment numbers for the wind and solar projects with public information were plotted, and then projects with no public information were positioned on the plot based on their MW scale, shown in Figures F.1 and F.2.

|  |  |
| --- | --- |
| **Figure F.1: Relationship between jobs and project size for solar projects Chart, scatter chart  Description automatically generated** | Chart, scatter chart  Description automatically generated**Figure F.2: Relationship between jobs and project size for wind projects** |
| **Table F.1: Calculated number of jobs for unknown solar projects** | **Table F.2: Calculated number of jobs for unknown solar projects** |

Additionally, the storage and transmission project job estimates missing from public data were estimated as a scaled factor of the project capacity of those where data was available. The total number of jobs created for each solution and the average annual jobs between 2021 and 2030 are shown in Table F.3. The annual jobs were calculated by dividing the overall jobs by five years, assuming that the projects will commence construction in an even distribution between 2021 and 2029. Each project's construction period is approximately two years in length. The final jobs created for each infrastructure type for each proposal is broken down and displayed in Table F.3 below.

Table F.3: Employment outcome for each proposal

|  |  |
| --- | --- |
|  | **Number of jobs created** |
|  | **BAU** | **ALT1** | **ALT2** |
| **Solar**  | 7121 | 7121 | 10474 |
| **Wind**  | 2860 | 2860 | 4944 |
| **Offshore wind** |  - |  - | 3370 |
| **Storage**  | 150 | 535 | 1018 |
| **Transmission** | 1767 | 4939 | 3240 |
| **Total**  | 11898 | 15455 | 23046 |
| **Annual Average** | 2380 | 3091 | 4609 |

### Health

Another measure used to quantify the social outcomes of the energy transition is the physical health impacts of ageing brown coal-fired plants in Victoria. Information on air pollution was found in an *Air Pollution Inquiry* by Dr Henry Jennens (2021). Jennens highlighted that there are 195 premature deaths, 248 cases of low birth weight in babies, and 4188 cases of asthma symptoms in young children directly resulting from air pollution from coal-fired power plants in Victoria. Health impact, according to Jennens, was calculated for Yallourn, Loy Yang A and Loy Yang B coal power stations by GHG emissions. Yallourn, Loy Yang A and Loy Yang B emit 15, 20 and 10 million tonnes of CO2 equivalent annually (Kilvert, 2019), and thus their health impacts at the current year are shown in Table F.4.

Table F.4: Health impact attributed to each power plant (2021)

|  |  |
| --- | --- |
|  | **Current health impacts from power plants** |
|  | Yallourn | Loy Yang A | Loy Yang B | Total |
| Annual deaths | 65 | 87 | 43 | 195 |
| Babies born underweight | 83 | 110 | 55 | 248 |
| Asthma symptoms in children | 1396 | 1861 | 931 | 4188 |
| Total persons affected | 1544 | 2058 | 1029 | 4631 |

Yallourn coal power station (Yallourn) will be decommissioned in 2028. For all three solutions, the health impacts of Yallourn were linearly reduced between 2021 and 2028. The health impacts used in this research included the reduced health effect after the estimated power station closures. The overall estimated physical health outcomes for BAU, ALT1 and ALT2 are shown in Table F.5, Table F.6 and Table F.7, respectively.

Table F.5: Total physical health impact BAU

|  |
| --- |
| **BAU** |
| Station | Impact | Yallourn, Loy Yang A & Loy Yang B | Loy Yang A & Loy Yang B | Total persons affected |
| 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
| Yallourn | Deaths | 65 | 56 | 46 | 37 | 28 | 19 | 9 | 0 | 0 | 0 | 260 |
| Underweight births | 83 | 71 | 59 | 47 | 36 | 24 | 12 | 0 | 0 | 0 | 332 |
| Child asthma | 1396 | 1197 | 997 | 798 | 598 | 399 | 199 | 0 | 0 | 0 | 5584 |
| Loy Yang A | Deaths | 87 | 87 | 87 | 87 | 87 | 87 | 87 | 87 | 87 | 87 | 870 |
| Underweight births | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 110 | 1100 |
| Child asthma | 1861 | 1861 | 1861 | 1861 | 1861 | 1861 | 1861 | 1861 | 1861 | 1861 | 18610 |
| Loy Yang B | Deaths | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 430 |
| Underweight births | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 550 |
| Child asthma | 931 | 931 | 931 | 931 | 931 | 931 | 931 | 931 | 931 | 931 | 9310 |
| Total |   | 4631 | 4411 | 4189 | 3969 | 3749 | 3529 | 3307 | 3087 | 3087 | 3087 | 37046 |

Table F.6: Total physical health impact ALT1

|  |
| --- |
| **ALT1** |
| Station | Impact | Yallourn, Loy Yang A & Loy Yang B | Loy Yang A & Loy Yang B | None | Total persons affected |
| 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
| Yallourn | Deaths | 65 | 56 | 46 | 37 | 28 | 19 | 9 | 0 | 0 | 0 | 260 |
| Underweight births | 83 | 71 | 59 | 47 | 36 | 24 | 12 | 0 | 0 | 0 | 332 |
| Child asthma | 1396 | 1197 | 997 | 798 | 598 | 399 | 199 | 0 | 0 | 0 | 5584 |
| Loy Yang A | Deaths | 87 | 77 | 68 | 58 | 48 | 39 | 29 | 19 | 10 | 0 | 435 |
| Underweight births | 110 | 98 | 86 | 73 | 61 | 49 | 37 | 24 | 12 | 0 | 550 |
| Child asthma | 1861 | 1654 | 1447 | 1241 | 1034 | 827 | 620 | 414 | 207 | 0 | 9305 |
| Loy Yang B | Deaths | 43 | 38 | 33 | 29 | 24 | 19 | 14 | 10 | 5 | 0 | 215 |
| Underweight births | 55 | 49 | 43 | 37 | 31 | 24 | 18 | 12 | 6 | 0 | 275 |
| Child asthma | 931 | 828 | 724 | 621 | 517 | 414 | 310 | 207 | 103 | 0 | 4655 |
| Total |   | 4631 | 4068 | 3503 | 2941 | 2377 | 1814 | 1248 | 686 | 343 | 0 | 21611 |

Table F.7: Total physical health impact ALT2

|  |
| --- |
| **ALT2** |
| Station | Impact | Yallourn, Loy Yang A & Loy Yang B | Loy Yang | None | Total persons affected |
| 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 |
| Yallourn | Deaths | 65 | 56 | 46 | 37 | 28 | 19 | 9 | 0 | 0 | 0 | 260 |
| Underweight births | 83 | 71 | 59 | 47 | 36 | 24 | 12 | 0 | 0 | 0 | 332 |
| Child asthma | 1396 | 1197 | 997 | 798 | 598 | 399 | 199 | 0 | 0 | 0 | 5584 |
| Loy Yang A | Deaths | 87 | 76 | 65 | 54 | 44 | 33 | 22 | 11 | 0 | 0 | 392 |
| Underweight births | 110 | 96 | 83 | 69 | 55 | 41 | 28 | 14 | 0 | 0 | 495 |
| Child asthma | 1861 | 1628 | 1396 | 1163 | 931 | 698 | 465 | 233 | 0 | 0 | 8375 |
| Loy Yang B | Deaths | 43 | 38 | 32 | 27 | 22 | 16 | 11 | 5 | 0 | 0 | 194 |
| Underweight births | 55 | 48 | 41 | 34 | 28 | 21 | 14 | 7 | 0 | 0 | 248 |
| Child asthma | 931 | 815 | 698 | 582 | 466 | 349 | 233 | 116 | 0 | 0 | 4190 |
| Total |   | 4631 | 4025 | 3417 | 2811 | 2206 | 1600 | 992 | 386 | 0 | 0 | 20068 |

### Public satisfaction

A measure of complaints against each proposal was used to generate a measurement of the general public's satisfaction with renewable infrastructure. The data for this evaluation was obtained from an Annual Report of the Office of the National Wind Farm Commissioner (2019). The report highlighted the recorded complaints between 2015 and 2019, ranging from topics of project planning processes, construction, and amenity to those of general community engagement, health, and safety. The figures in the report for the whole of Australia were used to calculate an average complaint rate per project, shown in Table F.8 below.

 Table F.7: Total physical health impact ALT2

|  |  |
| --- | --- |
|  | Actual complaints between November 2015 and December 2019 |
|  | Complaints | number of farms | Approx. complaints per farm |
| Operating wind farms | 70 | 14 | 5.0 |
| Proposed wind farms | 234 | 58 | 4.0 |
| proposed solar farms | 6 | 5 | 1.2 |

As seen in Table F.8, the wind farm related complaints are divided between ‘operating’ wind farms and ‘proposed’ wind farms. The complaints per wind farm were summed together to form a ‘9.0’ ratio for wind farms. The calculated ratios for each form of the project were multiplied by the predicted projects. It must be noted that there were several ‘other’ complaints in response to unspecified types of projects. Therefore, some additional complaints were added to each solution as an average between the wind-related complaints and solar-related complaints. The total number of predicted complaints about each solution are shown in Table F.8 below

Table F.7: Total physical health impact ALT2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Wind** | **Solar** | **Other** | **Total** |
|  | Number of proposed wind farms | Estimated complaints per wind farm | Total complaints | Number of proposed solar farms | Estimated complaints per solar farm | Total complaints | Total complaints |
| BAU  | 12 | 9.0 | 108 | 32 | 1.2 | 38.4 | 73.2 | 219.6 |
| ALT1 | 12 | 9.0 | 108 | 32 | 1.2 | 38.4 | 73.2 | 219.6 |
| ALT2 | 17 | 9.0 | 153 | 50 | 1.2 | 60 | 106.5 | 319.5 |

## Appendix G: Economic Cost Metrics

### Capital Cost

For most of the projects in each solution, the estimated capital cost was derived from project information available online, such as information on the company’s website or estimates from sources such as AEMO. This estimated capital cost data allowed the estimation of a large proportion of the proposed projects, which allowed us to find trends in the capital cost of the projects as a per MW value. The total capital expenditure required for each solution is detailed in Table G.1. Since these projects will be commencing over the following ten years, the values were discounted across the timeline between now and 2030 to give an approximate Net Present Cost (NPC) value in 2030. For this report, it was assumed that expenditure is to be evenly distributed across each year, which will provide a reasonable estimate of capital expenditure for comparison between the solutions. The NPC is detailed in Table G.2. The Australian Government commonly uses a 7% discount rate for infrastructure projects (Deans, 2018) and therefore, a 7% discount rate was used. However, a sensitivity analysis revealed that any sensible discount rate did not influence the outcome of this metric.

Table G.1: Total capital expenditure required for each proposed solution

|  |  |  |  |
| --- | --- | --- | --- |
|  | **BAU ($m)** | **ALT1 ($m)** | **ALT2 ($m)** |
| **Solar** | 5549.6 | 0 | 2518 |
| **Wind** | 2954.8 | 0 | 3480 |
| **Offshore Wind** | 0 | 0 | 16588.5 |
| **Storage**  | 425.8 | 2169.55 | 4383.45 |
| **Transmission** | 4935.0 | 13435 | 6069 |
| **From BAU** | 0 | 8530.63 | 8530.63 |
| **Total Capital Cost**  | 13865.18 | 24135.18 | 41569.58 |

Table G.2: Final capital expenditure NPC to be used in nBL analysis

|  |  |  |
| --- | --- | --- |
| **BAU** | **ALT 1** | **ALT 2** |
| **Year** | **Capital cost ($m)** | **Present cost ($m)** | **Year** | **Capital cost ($m)** | **Present cost ($m)** | **Year** | **Capital cost ($m)** | **Present cost ($m)** |
| 1 | 1386.52 | 1295.81 | 1 | 2413.52 | 2255.62 | 1 | 4156.96 | 3885.01 |
| 2 | 1386.52 | 1211.04 | 2 | 2413.52 | 2108.06 | 2 | 4156.96 | 3630.85 |
| 3 | 1386.52 | 1131.81 | 3 | 2413.52 | 1970.15 | 3 | 4156.96 | 3393.32 |
| 4 | 1386.52 | 1057.77 | 4 | 2413.52 | 1841.26 | 4 | 4156.96 | 3171.32 |
| 5 | 1386.52 | 988.57 | 5 | 2413.52 | 1720.81 | 5 | 4156.96 | 2963.85 |
| 6 | 1386.52 | 923.90 | 6 | 2413.52 | 1608.23 | 6 | 4156.96 | 2769.96 |
| 7 | 1386.52 | 863.45 | 7 | 2413.52 | 1503.02 | 7 | 4156.96 | 2588.74 |
| 8 | 1386.52 | 806.97 | 8 | 2413.52 | 1404.69 | 8 | 4156.96 | 2419.39 |
| 9 | 1386.52 | 754.17 | 9 | 2413.52 | 1312.79 | 9 | 4156.96 | 2261.11 |
| 10 | 1386.52 | 704.84 | 10 | 2413.52 | 1226.91 | 10 | 4156.96 | 2113.19 |
| **NPC** |  | **9738.32** | **NPC** |  | **16951.54** | **NPC** |  | **29196.73** |

### Annual Operation and Maintenance Cost

The annual operation and maintenance costs for each proposal were gathered through research conducted to approximate the annual O&M costs of all the proposed new infrastructure. The methods were:

* O&M costs were gathered from a report prepared by Aurecon for AEMO. This report uses Aurecon’s internal database of projects, recent bid information from EPC (Energy Performance Contract), competitive tendering processes, industry publications, and publicly available data to generate approximate costs for a range of energy generation infrastructure (Aurecon, 2019).
* The operational costs of coal were first estimated through analysis of AGLs annual reports. While no exact figure was stated, all costs associated with coal were analyzed. However, they included all AGLs coal mines (black and brown coal). Estimates from this data revealed a $30-$45/MWh range. However, it is known that brown coal is much cheaper than black coal. In 2017 the marginal cost of generating power from an existing black coal-fired station was $40/MWh, with brown coal-fired power even cheaper (Hasham, 2019). Therefore, the generation cost for Victorian brown coal-fired power was estimated to be $30/MWh.
* For ALT1, as coal is phased out, the gap formed between demand and generation is filled by interstate imports. The cost of these imports was estimated from historical data available on OpenNEM’s generation statistics. Due to the large variation in the cost of imports year to year, an approximate median value of $120/MWh was chosen.
* The annual OPEX of different Australian TNSP’s and their network length was used to determine a $/km value for the operational cost of the additional transmission infrastructure. This information was gathered from an annual benchmarking report by the Australian Energy Regulator shown in Table G.3.

Table G.3: Transmission network OPEX determination (Australian Energy Regulator, 2020)

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Network Length (km)** | **O&M ($'000)** | **O&M ($'000/km)** |
| **ElectraNet** | 5520 | 92859 | 16.82 |
| **PowerLink** | 14619 | 220027 | 15.05 |
| **AusNet** | 6589 | 91203 | 13.84 |
| **TasNetworks** | 3556 | 34744 | 9.77 |
| **TransGrid** | 13057 | 172309 | 13.20 |
| **Average ($/km)** | 13736.39 |

A summary of the new operational costs from the proposed projects at 2030 is shown in Table G.4, with Tables G.5 – G.7 detailing the yearly changes in O&M costs for all three solutions, followed by the NPC calculation in Table G.8, again using a 7% discount rate.

Table G.4: Additional infrastructure O&M costs in 2030. Unit Cost source: (Aurecon, 2019)



Table G.5: BAU O&M costs each year

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Year** | **Coal O&M ($m)** | **New Renewable O&M ($m)** | **Existing renewable O&M ($m)** | **Renewables O&M ($m)** | **Total O&M ($m)** |
| 2021 | 1046.98 | 0 | 73.83 | 73.83 | **1120.81** |
| 2022 | 992.38 | 16.3 | 73.51 | 89.81 | **1082.18** |
| 2023 | 937.34 | 32.6 | 73.20 | 105.80 | **1043.14** |
| 2024 | 881.33 | 48.9 | 72.89 | 121.79 | **1003.11** |
| 2025 | 825.09 | 65.2 | 72.59 | 137.79 | **962.88** |
| 2026 | 767.66 | 81.5 | 72.28 | 153.78 | **921.44** |
| 2027 | 710.23 | 97.8 | 72.00 | 169.80 | **880.02** |
| 2028 | 651.39 | 114.1 | 71.70 | 185.80 | **837.18** |
| 2029 | 592.75 | 130.4 | 71.42 | 201.82 | **794.57** |
| 2030 | 532.50 | 147 | 71.13 | 218.13 | **750.63** |

Table G.6: ALT1 O&M costs each year

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Coal O&M ($m)** | **New Renewable O&M ($m)** | **BAU new Renewable O&M ($m)** | **Existing renewable O&M ($m)** | **Renewables O&M ($m)** | **Import Costs ($m)** | **Total O&M ($m)** |
| 2021 | 1046.98 | 0 | 0 | 73.83 | 73.83 | 0.00 | **1120.81** |
| 2022 | 933.21 | 14.19 | 12.87 | 73.51 | 100.56 | 236.67 | **1270.44** |
| 2023 | 819.01 | 28.38 | 25.73 | 73.20 | 127.32 | 473.34 | **1419.66** |
| 2024 | 703.82 | 42.57 | 38.60 | 72.89 | 154.06 | 710.00 | **1567.88** |
| 2025 | 588.42 | 56.76 | 51.47 | 72.59 | 180.82 | 946.67 | **1715.91** |
| 2026 | 471.83 | 70.95 | 64.34 | 72.28 | 207.57 | 1183.34 | **1862.73** |
| 2027 | 355.23 | 85.14 | 77.20 | 72.00 | 234.34 | 1420.01 | **2009.57** |
| 2028 | 237.22 | 99.33 | 90.07 | 71.70 | 261.10 | 1656.67 | **2154.99** |
| 2029 | 119.42 | 113.52 | 102.94 | 71.42 | 287.87 | 1893.34 | **2300.63** |
| 2030 | 0.00 | 127.72 | 115.81 | 71.13 | 314.65 | 2130.01 | **2444.66** |

Table G.7: ALT2 O&M costs each year

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Year** | **Coal O&M ($m)** | **New Renewable O&M ($m)** | **BAU New Renewable O&M ($m)** | **Existing renewable O&M ($m)** | **Renewables O&M ($m)** | **Total O&M ($m)** |
| **2021** | 1008.18 | 0 | 0 | 73.83 | 73.83 | **1082.01** |
| **2022** | 914.22 | 93.16 | 12.87 | 73.51 | 179.53 | **1093.75** |
| **2023** | 776.73 | 186.31 | 25.73 | 73.20 | 285.25 | **1061.98** |
| **2024** | 637.62 | 279.47 | 38.60 | 72.89 | 390.96 | **1028.57** |
| **2025** | 497.96 | 372.62 | 51.47 | 72.59 | 496.68 | **994.64** |
| **2026** | 356.36 | 465.78 | 64.34 | 72.28 | 602.40 | **958.76** |
| **2027** | 214.52 | 558.94 | 77.20 | 72.00 | 708.13 | **922.65** |
| **2028** | 70.44 | 652.09 | 90.07 | 71.70 | 813.86 | **884.30** |
| **2029** | 0 | 745.25 | 102.94 | 71.42 | 919.60 | **919.60** |
| **2030** | 0 | 838.40 | 115.81 | 71.13 | 1025.33 | **1025.33** |

Table G.8: Final O&M NPC used in nBL analysis

|  |  |  |
| --- | --- | --- |
| **BAU** | **ALT 1** | **ALT 2** |
| **Year** | **Annual O&M ($m)** | **Present cost ($m)** | **Year** | **Annual O&M ($m)** | **Present cost ($m)** | **Year** | **Annual O&M ($m)** | **Present cost ($m)** |
| 1 | 1120.81 | 1047.49 | 1 | 1120.81 | 1047.49 | 1 | 1082.01 | 1011.22 |
| 2 | 1082.18 | 945.22 | 2 | 1270.44 | 1109.65 | 2 | 1093.75 | 955.32 |
| 3 | 1043.14 | 851.51 | 3 | 1419.66 | 1158.86 | 3 | 1061.98 | 866.89 |
| 4 | 1003.11 | 765.27 | 4 | 1567.88 | 1196.13 | 4 | 1028.57 | 784.69 |
| 5 | 962.88 | 686.52 | 5 | 1715.91 | 1223.42 | 5 | 994.64 | 709.16 |
| 6 | 921.44 | 614.00 | 6 | 1862.73 | 1241.22 | 6 | 958.76 | 638.86 |
| 7 | 880.02 | 548.03 | 7 | 2009.57 | 1251.46 | 7 | 922.65 | 574.58 |
| 8 | 837.18 | 487.25 | 8 | 2154.99 | 1254.22 | 8 | 884.30 | 514.67 |
| 9 | 794.57 | 432.19 | 9 | 2300.63 | 1251.39 | 9 | 919.60 | 500.20 |
| 10 | 750.63 | 381.58 | 10 | 2444.66 | 1242.74 | 10 | 1025.33 | 521.23 |
| **NPC** |  | **6759.07** | **NPC** |  | **11976.59** | **NPC** |  | **7076.84** |

### External Costs of GHG emissions

In order to evaluate the external economic costs of GHG emissions resulting from each proposal, an estimate of the social cost of carbon (SCC) will be used. The value to be used has been derived from the literature “Environmental and Economic Sustainability” by Paul Hardisty, in which Hardisty summarized numerous estimates on the social cost of carbon. Hardisty found that there was significant variability in estimates of the SCC, with estimates ranging from US$5.5-500/t CO2e. Most notably, he described the work of Nicholas Stern. *The Stern Report* examined the economic implications for society from the effects of climate change by examining a wide range of literature. Stern’s estimates concluded a value within the range of US$12-85/t CO2e. His estimates were based on achieving 450-550 ppm CO2e stabilization (lower end of the value range) and BAU projections (upper end of the value range). Since we are not on track to achieve CO2e stabilization at 450-550 ppm, the BAU estimate will be adopted, namely US$85/t CO2e. However, this value was estimated in 2009, with multiple other estimations available in the literature stating that this value should be increased by 2% per annum. Therefore, for 2021 the value to be used will be US$107.8/t CO2e and was not converted to AUD as it would make no difference to the analysis. The external costs of GHG were estimated from the operational cost of the additional transmission infrastructure (Table G.9).

Table G.9: Final external cost of GHG emissions used in nBL analysis

|  |  |  |  |
| --- | --- | --- | --- |
|  | GHG emissions (kt CO2e) | Social Cost of Carbon (USD/t CO2e) | External Cost of GHG Emissions (US$m) |
| BAU  | 269691.51 | 107.8 | 29072.75 |
| ALT1 | 183653.94 | 107.8 | 19797.89 |
| ALT2 | 157240.08 | 107.8 | 16950.48 |

## Appendix H: Environmental Metric

### GHG Emissions

Greenhouse Gas Emission (GHG) for each proposal was determined using production rates against the intended infrastructure required to fund projects for each solution. A constant CO2 equivalent per kWh was sourced for implementing solar, wind (on-shore/off-shore), storage and transmission infrastructure. For a comprehensive analysis of the energy transition, we need to account for the phasing out of coal generation. The deceleration of coal generation was made for each solution progressively until 2030, when the analysis is to take place. ClimateXChange reflects carbon emissions from coal at 1000 g CO2 eq/kWh (Thomson & Harrison, 2015). The energy produced was reflected for each solution. The alternative one had a faster rate of phasing out of coal generation than the business as usual, and the alternative two had an even more rapid rate. Table H.1 below was used to determine the overall energy generation, and subsequently, the GHG emissions linked to each solution.

Table H.1: CO2 Emissions from Coal Generation.

|  |  |  |  |
| --- | --- | --- | --- |
|  | BAU | ALT1 | ALT2 |
| Year | Coal (GWh) | Coal (GWh) | Coal (GWh) |
| 2021 | 34899.31 | 34899.31 | 33605.91 |
| 2022 | 33079.27 | 31107.04 | 30473.86 |
| 2023 | 31244.65 | 27300.19 | 25891.00 |
| 2024 | 29377.52 | 23460.83 | 21253.99 |
| 2025 | 27502.96 | 19614.04 | 16598.52 |
| 2026 | 25588.73 | 15727.58 | 11878.71 |
| 2027 | 23674.24 | 11840.86 | 7150.64 |
| 2028 | 21712.92 | 7907.31 | 2348.01 |
| 2029 | 19758.50 | 3980.66 | 0 |
| 2030 | 17750.08 | 0 | 0 |
| Total (GWh) | 264588.17 | 175837.81 | 149200.63 |
| Total CO2e (t) | 264588168.80 | 175837813.60 | 149200632 |

Renewable infrastructure and consequent storage and transmission systems were introduced at a steady growth until net-zero emissions are intended for in the analysis in 2030. The expansion rate depended on the level of infrastructure needed to meet each planned solution.

The National Renewable Energy Laboratory deemed GHG Emissions throughout the life cycle of solar photovoltaics being 40 g CO2 eq/kWh (National Renewable Energy Laboratory, 2012), which was quantified against the proposed solar projects for each solution and is represented below in Table H.2.

Table H.2: CO2 Emissions from Solar Panels.

|  |  |  |  |
| --- | --- | --- | --- |
|  | BAU | ALT1 | ALT2 |
| Year | Solar (GWh) | Solar (GWh) | Solar (GWh) |
| 2021 | 1849.77 | 1849.77 | 2294.58 |
| 2022 | 2913.88 | 2913.88 | 3809.56 |
| 2023 | 3981.56 | 3981.56 | 5329.64 |
| 2024 | 5070.75 | 5070.75 | 6880.33 |
| 2025 | 6156.35 | 6156.35 | 8425.92 |
| 2026 | 7270.61 | 7270.61 | 10012.31 |
| 2027 | 8374.12 | 8374.12 | 11583.40 |
| 2028 | 9513.47 | 9513.47 | 13205.51 |
| 2029 | 10634.90 | 10634.90 | 14802.10 |
| 2030 | 11799.32 | 11799.32 | 16459.91 |
| Total (GWh) | 67564.72 | 67564.72 | 92803.26 |
| Total CO2e (t) | 2702588.60 | 2702588.60 | 3712130.42 |

Research undertaken by ClimateXChange on the GHG emissions produced throughout the life cycle of on-shore and off-shore wind turbines found rates of 15 g CO2 eq/kWh and 12 g CO2 eq/kWh (Thomson & Harrison, 2015). Table H.3 details the results for corresponding renewable wind production.

Table H.3: CO2 Emissions from Wind Turbines.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | BAU | ALT1 | ALT2 | ALT2 |
| Year | Wind (GWh) | Wind (GWh) | Wind (GWh) | Offshore Wind (GWh) |
| 2021 | 7156.92 | 7156.92 | 8005.52 | 0 |
| 2022 | 7912.85 | 7912.85 | 9622.58 | 0 |
| 2023 | 8679.79 | 8679.79 | 11263.20 | 1422.16 |
| 2024 | 9457.74 | 9457.74 | 12927.36 | 2844.32 |
| 2025 | 10246.69 | 10246.69 | 14615.08 | 4266.48 |
| 2026 | 11046.66 | 11046.66 | 16326.34 | 5688.64 |
| 2027 | 11857.63 | 11857.63 | 18061.16 | 7110.80 |
| 2028 | 12679.62 | 12679.62 | 19819.52 | 8532.96 |
| 2029 | 13512.61 | 13512.61 | 21601.43 | 9955.12 |
| 2030 | 14356.61 | 14356.61 | 23406.89 | 11377.24 |
| Total (GWh) | 106907.12 | 106907.12 | 155649.09 | 51197.72 |
| Total CO2e (t) | 1603606.74 | 1603606.74 | 2334736.32 | 614372.67 |

 For the utility-scale lithium-ion batteries intended to be installed to store the energy captured from renewables, the power supplied by the storage systems will be distributed over time. The average discharge duration per day is 1.7 hours for battery storage systems but can see figures reaching up to 4 hours and will be used to capture the full potential of CO2 emissions (Solar Energy Technologies Office, 2019). The carbon intensity for implementing batteries systems for storing electricity is 100 g CO2 eq/kWh, and results are presented in Table H.4 below (Martini, 2020)

Table H.4: CO2 Emissions from Utility-Scale Batteries.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| BAU (MW) | BAU (MWh) | ALT1 | ALT1 (MWh) | ALT2 | ALT2 (MWh) |
| 300 | 438000 | 300 | 438000 | 300 | 438000 |
| 20 | 29200 | 5 | 7300 | 5 | 7300 |
| 5 | 7300 | 450 | 657000 | 450 | 657000 |
|  |  | 350 | 511000 | 350 | 511000 |
|  |  | 350 | 511000 | 350 | 511000 |
|  |  | 200 | 292000 | 200 | 292000 |
|  |  |  |  | 600 | 876000 |
|  |  |  |  | 300 | 438000 |
|  |  |  |  | 240 | 350400 |
|  |  |  |  | 200 | 292000 |
|  |  |  |  | 350 | 511000 |
| Total (MWh) | 474500 |  | 2416300 |  | 4883700 |
| Total CO2e (t) | 47450 |  | 241630 |  | 488370 |

Nature Sustainability addresses embodied GHG emissions for power transmission units, which are directly applied to planned projects for each scenario based on typical projects from 2017 (Wei, et al., 2021). Table H.5 below outlines projected lines, km’s, and corresponding electric potential emissions.

Table H.5: CO2 Emissions from Transmission.

|  |
| --- |
| BAU |
| kV | kms | t CO2e/km | Total CO2e (t) |
| 220 | 95 | 280 | 26600 |
| 500 | 85 | 490 | 41650 |
| 500 | 440 | 490 | 215600 |
| 500 | 605 | 490 | 296450 |
| 300 | 605 | 280 | 169400 |
| TOTAL |  |  | 749700 |
| ALT 1 |
| kV | kms | t CO2e/km | Total CO2e (t) |
| 500 | 340 | 490 | 166600 |
| 500 | 1800 | 490 | 882000 |
| 500 | 3000 | 490 | 1470000 |
| 220 | 95 | 280 | 26600 |
| 500 | 85 | 490 | 41650 |
| 500 | 440 | 490 | 215600 |
| 500 | 605 | 490 | 296450 |
| TOTAL |  |  | 3268300 |
| ALT 2 |
| kV | kms | t CO2e/km | Total CO2e (t) |
| 220 | 230 | 280 | 64400 |
| 220 | 43 | 280 | 12040 |
| 500 | 130 | 490 | 63700 |
| 220 | 95 | 280 | 26600 |
| 500 | 85 | 490 | 41650 |
| 500 | 440 | 490 | 215600 |
| 500 | 605 | 490 | 296450 |
| 300 | 605 | 280 | 169400 |
| TOTAL |  |  | 889840 |

The GHG emissions for each solution were the sum of each energy resource to be implemented/phased out for each scenario until the planned net-zero dates of 2030.

The best- and worst-case scenarios for all potential solutions are outlined below, with the highlighted figures used to standardise the analysis (Table H.6). The best-case scenario is immediately ceasing coal generation using the BAU approach, and the worst-case scenario having coal generation continue at current rates until 2030 using the BAU approach.

Table H.6: GHG Emissions Best- and Worst-Case Scenarios.

|  |  |  |
| --- | --- | --- |
| Units kt CO2e | Best | Worst |
| BAU | **5103.35** | **270221.98** |
| ALT 1 | 7816.13 | 184184.41 |
| ALT 2 | 8039.45 | 157770.55 |

### Pollutants

GHG Emissions are a key component of pollutants and damage to the planet's health, but a life cycle assessment needs to be assessed against standard industry life span. While we have current technology to manufacture such renewable infrastructure, the de-manufacturing processes are not in place to appropriately recycle infrastructure at the end of their useful life (Berg, 2018). Therefore, an analysis will reflect infrastructure capacity to power the energy system over its useful life. Energy System capacities for the project proposal are described below, which will be used to quantify and justify the useful life capacity for each solution (Table H.7).

Table H.7: Energy Systems.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Units: MW | Solar | Onshore wind | Offshore wind | Storage | Transmission | Total (MW) |
| BAU | 4090 | 2094.5 | 0 | 325 | 5300 | 11809.5 |
| ALT 1 | 4090 | 2094.5 | 0 | 1655 | 10964 | 18803.5 |
| ALT 2 | 1722 | 2386 | 4195 | 3345 | 9700 | 21348 |

Renewable resources useful life was determined for solar (photovoltaics) and wind turbines as 25 and 20 years (National Renewable Energy Laboratory, n.d.). Utility-scale batteries for grid connection useful life of nine years (Smith, Saxon, Keyser, & Lundstrom, 2017). The transmission lines to transport the given electricity has a useful life of 60 years (Power and Water Corporation, 2018).

The useful life was then quantified against the capacity for each energy system and presented below in (Table H.8).

Table H.8: Useful Life Capacity over Useful Life.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Units MW Y | Solar | Onshore wind | Offshore wind | Storage | Transmission | Total (MW Y) |
| BAU | 102250 | 41890 | 0 | 2925 | 318000 | 465065 |
| ALT 1 | 102250 | 41890 | 0 | 14895 | 657840 | 816875 |
| ALT 2 | 43050 | 47720 | 83900 | 30105 | 582000 | 786775 |

The best- and worst-case scenarios for Pollutants due to useful life from LCA are highlighted below (Table H.9). In the best-case scenario, renewables have a 60-year useful life as transmission lines, but in the worst-case (utility-scale battery) have a 9-year useful life.

Table H.9: Pollutants Best- and Worst-Case Scenarios.

|  |  |  |
| --- | --- | --- |
| Units MW Y | Best | Worst |
| BAU | 708570 | 106285.5 |
| ALT 1 | 1128210 | 169231.5 |
| ALT 2 | 1280880 | 192132 |

### Materials

#### Initial Assessment

Energy System capacities for the project proposal are described below, which will be used to quantify and justify material usage for each solution (Table H.10).

Table H.10: Energy Systems.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Units: MW | Solar | Onshore wind | Offshore wind | Storage | Transmission |
| BAU | 4090 | 2094.5 | 0 | 325 | 5300 |
| ALT 1 | 4090 | 2094.5 | 0 | 1655 | 10964 |
| ALT 2 | 1722 | 2386 | 4195 | 3345 | 9700 |

Firstly, appropriate identification of the link between materials required for given infrastructure was made using the importance scale by the International Energy Agency, with a scale from 1-3 (3 most important) given and outlined below in Table H.11 (International Energy Agency, 2021). A relative conclusion was made on which materials were regarded as critical in the analysis. Silicon and “Other” minerals were omitted from the analysis as having low importance.

Table H.11: Relative importance of minerals for clean energy technology.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Material Scale 1-3 | Solar | Onshore Wind | Offshore Wind | Storage | Transmission | Avg. |
| Copper | 3 | 3 | 3 | 3 | 3 | 3 |
| Nickel | 1 | 2 | 2 | 3 | 1 | 1.8 |
| Manganese | 1 | 3 | 3 | 3 | 1 | 2.2 |
| Cobalt | 1 | 1 | 1 | 3 | 1 | 1.4 |
| Chromium | 1 | 2 | 2 | 1 | 1 | 1.4 |
| Molybdenum | 1 | 2 | 2 | 1 | 1 | 1.4 |
| Zinc | 1 | 3 | 3 | 1 | 1 | 1.8 |
| Rare earths | 1 | 3 | 3 | 3 | 1 | 2.2 |
| Silicon | 1 | 1 | 1 | 1 | 1 | 1 |
| Others | 1 | 1 | 1 | 1 | 1 | 1 |
| Lithium | 1 | 1 | 1 | 3 | 1 | 1.4 |

#### Clean Energy

International Energy Agency data was used to find minerals used in clean energy technologies for each of our three scenarios. A clear comparison between other power generation sources was concluded from Table H.12.

Table H.12: Minerals used in clean energy technologies compared to other power generation sources (International Energy Agency, 2021)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| kg/MW | Offshore wind | Onshore wind | Solar | Nuclear | Coal | Natural gas |
| Copper | 8000 | 2900 | 2822.1 | 1473 | 1150 | 1100 |
| Nickel | 240 | 403.5 | 1.3 | 1297.4 | 721.04 | 15.75 |
| Manganese | 790 | 780 | 0 | 147.69 | 4.63 | 0 |
| Cobalt | 0 | 0 | 0 | 0 | 201.46 | 1.8 |
| Chromium | 525 | 470 | 0 | 2190 | 307.5 | 48.34 |
| Molybdenum | 109 | 99 | 0 | 70.8 | 66.25 | 0 |
| Zinc | 5500 | 5500 | 29.99 | 0 | 0 | 0 |
| Rare earths | 239 | 14 | 0 | 0.5 | 0 | 0 |
| Silicon | 0 | 0 | 3948.3 | 0 | 0 | 0 |
| Others | 6 | 0 | 31.95 | 94.28 | 33.9 | 0 |

Densities for each critical mineral was able to be used to determine the overall intended requirements to fund each solution and detailed below, Table H.13.

Table H.13: Critical Clean Energy Minerals.

|  |  |  |  |
| --- | --- | --- | --- |
| Units: kg | BAU | ALT 1 | ALT 2 |
| Copper | 17616439 | 17616439 | 45339056 |
| Nickel | 850447.8 | 850447.8 | 1971790 |
| Manganese | 1633710 | 1633710 | 5175130 |
| Chromium | 984415 | 984415 | 3323795 |
| Molybdenum | 207355.5 | 207355.5 | 693469 |
| Zinc | 11642409 | 11642409 | 36247143 |
| Rare earths | 29323 | 29323 | 1036009 |
| Silicon | 16148547 | 16148547 | 6798973 |
| Others | 130675.5 | 130675.5 | 80187.9 |

The best- and worst-case scenarios for Clean Energy are highlighted below (Table H.14). The best-case scenario for no new projects to go ahead, and the worst-case scenario is 50% more projects than anticipated.

Table H.14: Clean Energy Best- and Worst-Case Scenarios.

|  |  |  |
| --- | --- | --- |
| Units kg | Best | Worst |
| BAU | 0 | 49446149.03 |
| ALT 1 | 0 | 49446149.03 |
| ALT 2 | 0 | **140679587.40** |

#### Storage Systems

kWh ratings for battery storage systems were determined from capacities and addressed from planned projects. Proposed systems in the alternative solutions used discharge rates of four hours per day to determine energy rating (Solar Energy Technologies Office, 2019). Therefore, storage for each solution is outlined below from the discharge assumptions outside of known values (Table H.15).

Table H.15: Storage Energy Ratings.

|  |  |
| --- | --- |
| Units: kWh | Storage |
| BAU | 491500 |
| ALT 1 | 5557500 |
| ALT 2 | 10137500 |

While specific battery make-ups, such as the Tesla Megapack intended to be installed in Moorabool, could not be explicitly broken down. Lithium-ion battery packs can be assumed to consume most of the storage systems, and analysts show no move away from the technology anytime soon (Castelvecchi, 2021). Therefore, an assessment will be made assuming a single-car lithium-ion battery (NMC532) containing 9kg of Lithium, 35kg of Nickel, 20kg of Manganese and 14kg of Cobalt (Castelvecchi, 2021).

Lithium-ion batteries have an expected make-up, containing a capacity of 160 g / kWh of lithium (Kushnir, 2015). A reasonable conclusion of materials used for batteries can be determined by applying the materials used in batteries. (Table H.16).

Table 1: Storage Materials.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Units: kg | Lithium | Nickel | Manganese | Cobalt |
| BAU | 8170.39 | 35745.45 | 20425.97 | 14298.18 |
| ALT 1 | 92384.42 | 404181.81 | 230961.04 | 161672.70 |
| ALT 2 | 168519.48 | 737272.73 | 421298.70 | 294909.10 |

The best- and worst-case scenarios for Storage Systems are highlighted below (Table H.17). The best-case scenario for no new projects to go ahead, and the worst-case scenario was 50% more projects than anticipated.

Table H.17: Storage Systems Best- and Worst-Case Scenarios

|  |  |  |
| --- | --- | --- |
| Units kg | Best | Worst |
| BAU | 0 | 117960 |
| ALT 1 | 0 | 1333800 |
| ALT 2 | 0 | 2433000 |

#### Transmission Systems

The transmission was assessed on the distance of lines (km to suit each solution) extracted from the proposed installation (Table H.18).

Table H.18: Storage Distance

|  |  |
| --- | --- |
| Units: kms | Transmission |
| BAU | 1830 |
| ALT 1 | 6970 |
| ALT 2 | 2233 |

The best- and worst-case scenarios for Transition Systems are highlighted below (Table H.19). The best-case scenario for no new projects to go ahead and the worst-case scenario was 50% more projects than anticipated.

Table H.19: Transmission Systems Best- and Worst-Case Scenarios

|  |  |  |
| --- | --- | --- |
| Units km | Best | Worst |
| BAU | 0 | 2745 |
| ALT 1 | 0 | 10455 |
| ALT 2 | 0 | 3349.5 |

#### Third-level Analysis

As each energy system is not transparent in comparing material used, a third level analysis was conducted against each section by breaking down the analysis into Clean Energy, Storage Systems and Transmission Systems. The weighting between all three metrics in the third-level analysis was equal, as generation, transmission and distribution of electricity are all vital in coordinating a functional power system (Stenclik, Denholm, & Chalamala, 2017)

Third-level results are outlined, with best- and worst-case justifications presented to normalise results (Table H.20).

Table H.20: Material Third-level Analysis

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Data** | **Best** | **Worst** | **Normalised** |
| **Metric** | **BAU** | **ALT1** | **ALT2** | **Value** | **Evidence** | **Value** | **Evidence** | **BAU** | **ALT1** | **ALT2** |
| **Clean Energy Material (kg)** | 32964099 | 32964099 | 93786392 | 0 | No new projects to go ahead | 140679587.4 | 50% more projects go ahead than anticipated (ALT 2) | 0.77 | 0.77 | 0.33 |
| **Storage (kg)** | 78640 | 889200 | 1622000 | 0 | No new projects to go ahead | 2433000 | 50% more projects go ahead than anticipated (ALT 2) | 0.97 | 0.63 | 0.33 |
| **Transmission (km)** | 1830 | 6970 | 2233 | 0 | No new projects to go ahead | 10455 | 50% more projects go ahead than anticipated (ALT 1) | 0.83 | 0.33 | 0.79 |

Further, aggregations for each solution are presented, which will be inputted into the second level metrics results to standardise results (Table H.21).

Table H.21: Aggregation from Weightings

|  |  |  |
| --- | --- | --- |
|  | **Aggregation** | **Weighting** |
| **BAU** | 0.28 | 0.33 |
| **ALT1** | 0.19 | 0.33 |
| **ALT2** | 0.16 | 0.33 |

#### Final Assessment

The best- and worst-case scenarios for materials was based on the highest aggregation (best – 1) and lowest aggregation (worst - 0) for normalizing the material second level metric.

## Appendix I: Raw Metric Weighting Data

Table I.1: Tabulation of interview results recorded about the preference of individual metrics within each bottom line, used to derive weightings.



## Appendix J: Raw Bottom Line Weighting Data

Table J.1: Tabulation of interview results recorded about the preference of each bottom line, used to derive weightings.



# Appendix K: Interview Questions

Table K.1: Section A of the interview questions.

|  |
| --- |
| Please rate the statements according to their importance to a successful energy transition and the likelihood of its success during the transition. For example, for Q2, how important is interconnector lines' role in sending energy between states in the energy transition, and how likely are we to succeed in setting up the necessary transmission network required?. Any thoughts or comments that you have will be appreciated but unnecessary.  |
|   |   | Importance? 1-7 (1 = High, 7 = Low) | How likely are we to succeed? 1 = High Chance, 7 = Low Chance (comments welcome) |
| 1 | Victorian Government's role in facilitating a transition to zero emissions. |   |   |
| 2 | Role of interconnector lines to transmit energy between states. |   |   |
| 3 | Change in rules and policies for companies to create more renewable energy.  |   |   |
| 4 | Federal Government intervention in Victoria's energy transition. |   |   |
| 5 | Victorian Government engaging in consultation with the public. |   |   |
| 6 | Victorian Government engaging in consultation with private industry. |   |   |
| 7 | Relationships between Victoria and interstate renewable energy suppliers. |   |   |
| 8 | Role of AEMO in interstate renewable energy transfers (including storage). |   |   |
| 9 | Educating households on how to reduce emissions. |   |   |
| 10 | Gaining social licence and public approval to embark on this transition. |   |   |
| 11 | Construction of renewable infrastructure (i.e., large-scale batteries, wind farms) in Victoria |   |   |
| 12 | Upskilling of workers in renewable energy |   |   |
| 13 | Implementation of home and/or community-based battery storage devices. |   |   |
| 14 | Meeting reasonable economic costs from transition |   |   |

Table K.2: Section B of the interview questions.

|  |
| --- |
| Please rank the components listed in Q14 - 18 in terms of importance compared to the other options presented in the question. (for example, for question 14, please rank environmental concerns, social responsibility, economic gain, and technical performance in terms of their importance relative to each other, 1 being the most important and 4 being the least important). |
| 14 | Please rank these in order of importance: | Ranking |   |
|   | Environmental Concerns |   | Environmental impacts of new energy projects. |
|   | Social Responsibility |   | Societal outcomes from the energy transition |
|   | Economic Gain |   | Economic impacts of the energy transition |
|   | Technical Performance |   | Engineering performance of energy assets. |

|  |  |  |  |
| --- | --- | --- | --- |
| 15 | Please rank these social metrics in order of importance: | Ranking |   |
|   | Employment |   | The difference in jobs created and jobs lost in the transition |
|   | Physical health outcomes |   | Changes in health risks due to renewable energy replacing coal |
|   | Public engagement |   | Energy distributors engage with and educate customers throughout the transition (e.g., smart metres) |

|  |  |  |  |
| --- | --- | --- | --- |
| 16 | Please rank these technical performance metrics in order of importance: | Ranking |   |
|   | Network losses |   | Amount of energy lost across the grid network in transmission. |
|   | Conversion losses |   | Amount of energy lost when potential energy is converted to electricity by the generation type. |
|   | Battery storage |   | The cumulative capacity of storage infrastructure in Victoria.  |
|   | Data transparency |   | Transparency in data access and sharing between relevant stakeholders. |

|  |  |  |  |
| --- | --- | --- | --- |
| 17 | Please rank these economic metrics in order of importance: | Ranking |   |
|   | Externality costs of GHG emissions (social cost of carbon) |   | The indirect external costs of greenhouse gas emissions on the economy (i.e., the costs to society incurred by the effects of GHG emissions) --> including embodied and operating GHG emissions |
|   | Installation costs (CAPEX) |   | The cost to procure and install any required infrastructure to set up systems used in the transition |
|   | O&M Costs (OPEX) |   | i.e., lifetime costs excluding initial installation cost |

|  |  |  |  |
| --- | --- | --- | --- |
| 18 | Please rank these environmental metrics in order of importance: | Ranking |   |
|   | GHG emissions |   | GHG emissions created from renewable infrastructure (i.e., large-scale batteries, wind farms) |
|   | Pollutants |   | Pollutants from created from renewable infrastructure (i.e., large-scale batteries, wind farms) |
|   | Materials |   | Materials used to create renewable infrastructure (i.e., large-scale batteries, wind farms) |

Table K.3: Section C of the interview questions.

|  |
| --- |
| Please supply a worded response to the following questions. Please feel free to go into as much, or as little, detail as you like. |
| 19 | Who are the prime movers/catalysts in the transition? |   |
| 20 | What important policies or rule changes need to be made to facilitate net zero emissions? |   |
| 21 | What are the predominant risks in this energy transition? |   |
| 22 | What will distribution businesses do to help or hinder the transition? |   |
| 23 | What relative roles should the following have in energy policy? Social, Economy, Environmental and Political. |   |
| 24 | What method of electricity generation do you believe will be most prominent in Victoria's transition |   |