The Electric Edge:
Energy, Emissions and Cost Benefits of Electric Concrete Pumping

Comparing energy use, carbon emissions, and costs for electric and diesel concrete pumping at One Sydney Harbour

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Azzurri concrete
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Thank you to everyone else who has generously given their time and expertise in the creation of this report.

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1.
Executive Summary

Eliminating the use of fossil fuels in construction is an essential step in tackling climate change and reaching Lendlease's Mission Zero targets.

Working closely with our supply chain, we are prioritising using electric construction machinery and equipment and using biofuels such as biodiesel and renewable diesel where electric options are unavailable.

Our Mission Zero Targets

NET ZERO CARBON BY 2025

The reduction of greenhouse gas emmissions from business activities as far as possible, with the remainder offset with an approved carbon offset scheme.

Our net zero target applies to scope 1 & 2 emissions

ABSOLUTE ZERO BY 2040

The mitigation of all greenhouse gas emmsions produced from business activities to absolute zero, without the use of offsets.

Our absolute zero target applies to scope 1, 2 & 3 emissions

Fossil fuel free construction at One Sydney Harbour

During the construction of the third and final tower at One Sydney Harbour, Watermans Residences (R3), we piloted the use of electric machinery and equipment where options were available to understand the implications of switching from traditional diesel-powered machinery to electric equivalents on our projects. One Sydney Harbour project, Waterman's Residences in Sydney, is our first 'fossil fuel free construction' pilot project. Electric machinery and equipment used on the project included a concrete pump, two tower cranes, two hoists, elevated work platforms and a formwork hoist.

Feasibility and advantages of electrification

To help understand the implications of switching to fully electric machinery, we analysed the energy, carbon and cost associated with concrete pumping, a traditionally energy-intensive activity. This report compares a sizeable electric concrete pump used at Watermans Residences with an equivalent diesel concrete pump used on a neighbouring Lendlease building, Residence Two (R2).

Electric concrete concrete pumps, exemplified by the Schwing SP 3800 E supplied by Azzurri Concrete, showed compelling advantages over diesel concrete pumps. Our findings concluded that the electric concrete pump:

- Consumed 67% less energy, with a third of the energy used compared to the diesel equivalent.
- Produced zero emissions when powered by renewable electricity.
- Reduced operational energy costs of concrete pumping by 59.1%.
- Proved 50.8% cheaper overall to operate when considering energy costs and carbon costs of achieving carbon neutrality (purchase of carbon offsets and Renewable Energy Certificates).
- Incurs lower lifetime costs (total cost of ownership) than the diesel equivalent due to having the same upfront purchase costs and lower operating, maintenance and servicing expenses despite infrastructure upgrades and battery technology considerations.

More energy efficient

The electric concrete pump used on R3 demonstrated significant energy efficiency. In contrast to the diesel concrete pump used on R2, the electric concrete pumps used 67.3% less energy per cubic meter of concrete poured. This disparity stems from inherent characteristics of their respective energy sources and conversion to mechanical energy, whereby diesel engines are less energy-efficient due to significant heat energy lost during power generation. This energy reduction aligns with findings from other industries.

Fewer emissions

Electric concrete pumping led to a 12.9% reduction in gross carbon equivalent emissions (CO2-e) for every cubic metre of concrete pumped when powered directly by grid electricity. As renewable generation increases, anticipated reductions in grid electricity emissions further support the transition. However, the One Sydney Harbour project purchased renewable electricity, which reduced the operation emissions of the concrete pump to absolute zero.

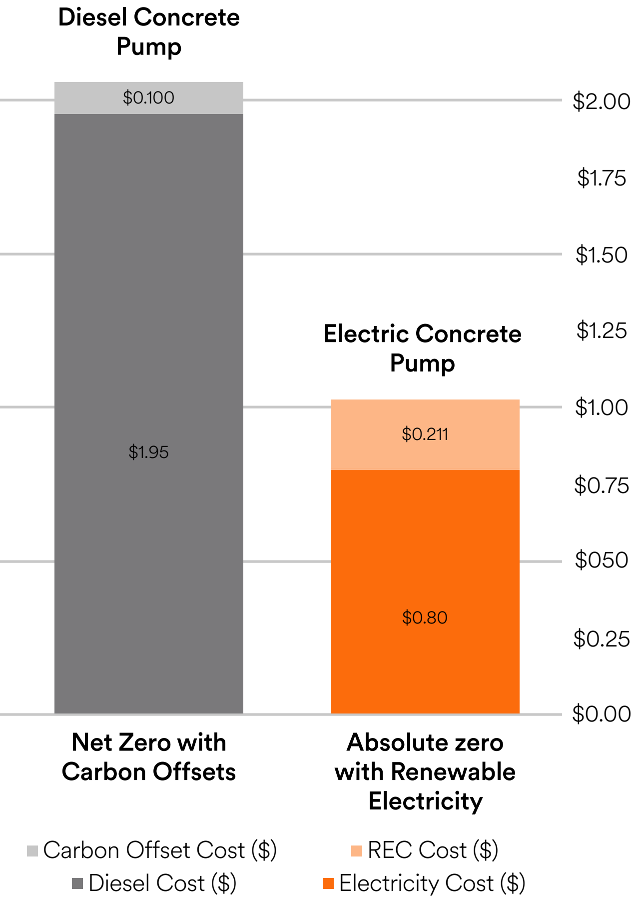
Cost implications

Electric concrete pumping led to a 59.1% reduction in energy cost compared to a diesel concrete pump due to the reduced energy usage.

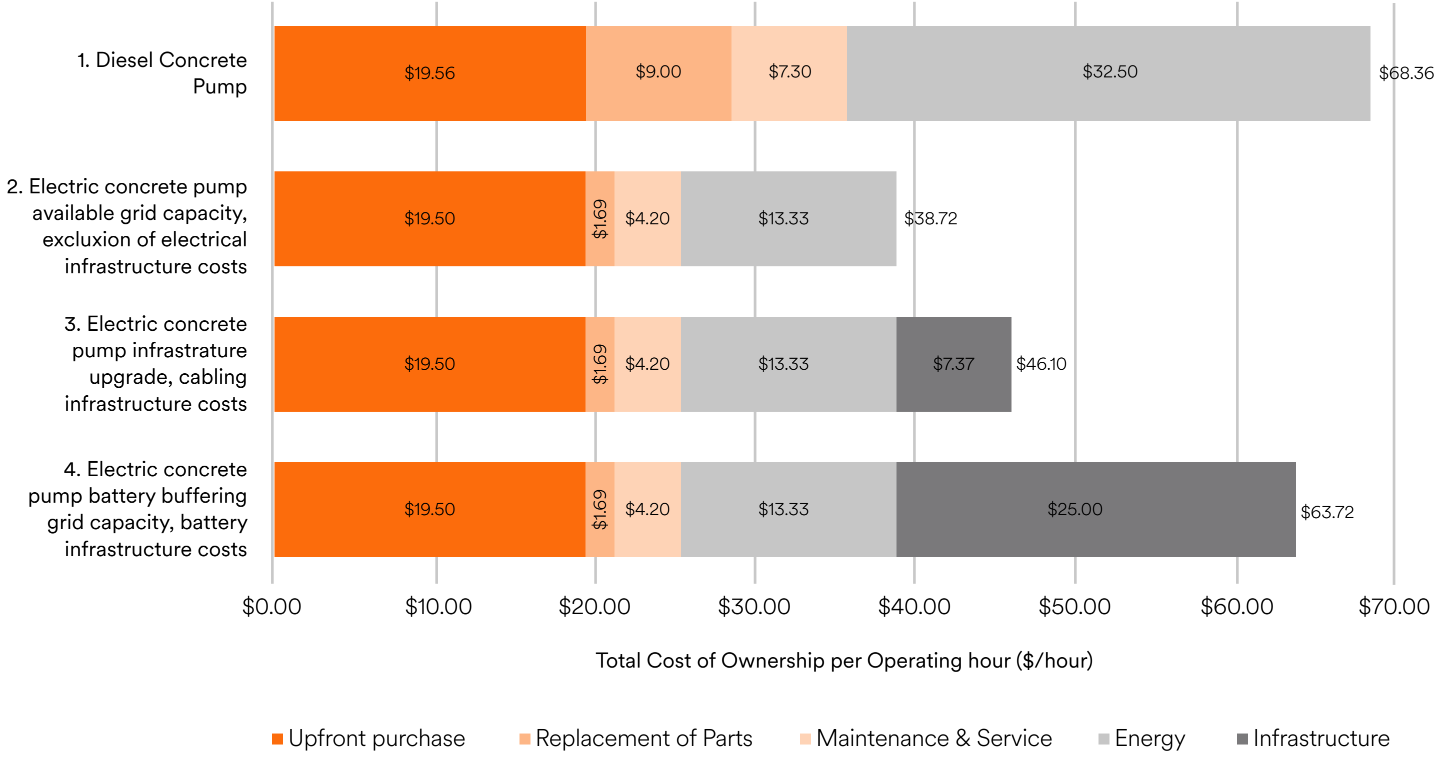
Lendlease Construction provides Climate Active certified carbon neutral construction services for the One Sydney Harbour project. Therefore, our cost analysis also considers the need to address residual carbon emissions associated with diesel usage (Scope 1) and electricity consumption (Scope 2).

Despite purchasing renewable electricity being twice as expensive as offsetting diesel emissions through carbon offsets, electric concrete pumping remains over 50% more cost-effective. This cost advantage is attributed to reduced energy demand, proving the effectiveness of electric concrete pumping in achieving absolute zero emissions. By substituting diesel usage with electricity usage, the need to purchase carbon offsets (which are increasing in price)[1] is replaced with the purchase of Renewable Energy Certificates (which are decreasing in price)[2]. It is predicted that this will significantly reduce zero carbon costs in the future for Lendlease.

Average Cost for Concrete Pumping per cubic metre



Total cost of ownership per operating hour for diesel & electric concrete pumps



In addition to operational costs, the lifetime costs of the electric and diesel concrete pumps were compared using a Total Cost of Ownership (TCO) analysis. In all scenarios, including infrastructure costs, the TCO for the electric concrete pump was less than for the diesel concrete pump. This was due to equal upfront purchase costs and lower energy, maintenance and replacement parts costs for the electric concrete pump. The purchase cost of the diesel and electric concrete pump was the same, which removes a significant barrier to the electrification of concrete pumping.

Additional Benefits

Beyond these advantages, electrification improves local air quality and working environments and mitigates risks associated with handling liquid fuels. It can also reduce maintenance requirements associated with combustion engines, downtime for refuelling and supply chain risks associated with supply disruptions.

Future Considerations

Electricity supply should be assessed on a project-specific basis, considering potential local grid capacity constraints and the potential for battery technology to buffer this. The supply chain's commitment to purchasing electric alternatives is crucial for a zero-emission transition.

Further research is needed to clarify electrification infrastructure costs, which are uncertain due to factors like battery use being new to the construction industry. Collecting data from future construction sites with electric concrete pumps will help determine and enhance cost certainty.

Conclusion

This research underscores the viability of electric machinery powered by renewable electricity in achieving Lendlease's Absolute Zero Carbon goal without compromising cost or quality. The study provides valuable insights for Lendlease and the broader construction industry on transitioning to fossil fuel free construction.

2.
Introduction

One Sydney Harbour Towers

Construction activities account for 23% of global greenhouse gas emissions[3]. Roughly 5.5% of these emissions are directly caused by liquid fossil fuels that power construction machinery and equipment[3], which for Lendlease is primarily mineral diesel.

Lendlease's Mission Zero ambitions include the reduction of all greenhouse gas emissions produced from business activities (Scopes 1, 2 and 3) to absolute zero without the use of offsets by 2040. We are doing this for our Scope 1 emissions on construction sites by prioritising using electric construction machinery and equipment and using biofuels such as biodiesel and renewable diesel where electric options are unavailable.

The research in this report focuses on fossil fuel free construction initiatives conducted at Lendlease's One Sydney Harbour (OSH) project. OSH is the final stage in Lendlease's Barangaroo South transformation and features three luxury residential towers, Residences One (R1) and Two (R2), and Watermans Residences (R3), designed by Pritzker Prize-winning master architect Renzo Piano in collaboration with Lendlease.

Waterman's Residences (R3) is a 30-level residential building (final height of 135m) and Lendlease's first pilot project to target construction activities without using fossil fuels in equipment and machinery. The project has substituted diesel machinery and equipment for electric alternatives across all construction activities where options are available. Electric machinery and equipment included a concrete pump, two tower cranes, two hoists, elevated work platforms, and a formwork hoist. Concrete pumping is an activity where diesel concrete pumps are commonly used, and the project team worked with Azzurri Concrete to substitute the initially proposed diesel concrete pump for an electric alternative.

This report specifically analyses the concrete pumping activity by comparing diesel and electric concrete pumping options. This report compares energy, costs, and emissions data from both the electric concrete pump used on the R3 tower and an equivalent diesel concrete pump used on the adjacent R2 building, a 68-level tower (final height of 230m).

3.
Methodology

Energy (electricity and diesel), costs and carbon emission data were recorded for R2 and R3 projects, and data from levels 15-30 was used in this analysis to compare towers at equivalent heights directly.

The following methodology was undertaken to obtain and analyse concrete pumping energy usage, operational costs, and carbon emissions data on both R2 and R3 projects.

This range of levels used for analysis reflects the period in which the electric concrete pump was exclusively used for concrete pumping of the R3 tower. A mobile diesel concrete pump was used for the lower levels due to international shipping challenges and associated delays in delivering the electric concrete pump to the project. Level 14 used a combination of both electric and diesel concrete pumping methods. The data for lower levels of R3 were not considered comparable to the level 15-30 data, pumped with a stationary concrete pump and to higher heights. Therefore, the same levels of the R2 tower have been used for direct comparison as the pump and pumping heights and lengths were similar.

Azzurri Concrete completed concrete pumping of the R2 and R3 towers. The R2 project team delivered concrete pumping of levels 15-30 using two stationary diesel trailer pumps between 18/11/2021 and 3/05/2022. The R3 project team completed pumping of levels 15-30 using the electric concrete pump between 13/03/2023 and 6/09/2023.

Table 1: Concrete Pumping Details

Tower	R2		R3
Levels	15 - 20	21 - 30	15 - 30
Timing	18 November 2021 - 17 January 2022	18 January 2022 - 3 May 2022	13 March 2023 – 6 September 2023
Energy used	Diesel (L)		Electricity (kWh) (Renewable electricity used)
Pump model	BSA 2110 HP D 	BSA 14000 HP D 	Schwing Stetter SP 3800 E 
Power rating	330 kW	470 kW	200 kW (50 Hz, IE3 Efficiency)
Max Concrete Volume Output	102 m^3/hr	102 m^3/hr	100 m^3/hr

3.1. Data Sources

The following Tables 2 and 3 detail the data and sources used in the analysis. These include details of concrete pouring, energy usage measurements, carbon emissions values used in calculations and project-specific energy costs for calculating operational costs.

Table 2: Data Sources

Data Type	Data	Project	Source	Comment
Concrete Details	Volume of concrete poured per level	R2	Concrete Volume Summaries	Concrete pours volumes include floor slab, core, columns, and stairwell structures.
		R3		
	Dates of concrete pours	R2	Pour Plans	The concrete pour dates were attributed to the months they occurred in. There are two concrete pours per level, each with separate dates.
		R3		
	Concrete Density	R2	Environmental Product Declarations (EPD)	Concrete mix densities were compared to confirm that concrete used in both projects had comparable mix densities.
		R3		
Energy Use	Monthly diesel consumption (Litres)	R2	R2 Azzurri - National Greenhouse and Energy Reporting forms	The R2 monthly diesel consumption (L) was converted to energy (kWh) to compare electricity usage in the same units. It was converted at an energy density factor of 10.72kWh/L, as provided in the National Greenhouse Accounts Factors 2022 (NGAF)[4].
	Electricity consumption (kWh)	R3	5-minute interval data from the R3 electric concrete pump dedicated NMI and electricity Invoices Data logger installed on the electric concrete pump from 2 March 2023 – 31 March 2023	The R3 electric concrete pump electricity is separately metered; energy usage (kWh) was taken from invoices for each month of operation. Data logger provided granular, detailed 15-second interval data.

Table 3: Data Values

Category	Assumption	Value	Reasoning
Values required for calculating Scope 1 and 2 emissions	Energy Intensity of Diesel	10.72 kWh/L	Taking energy content factor as 38.6 GJ/L according to NGAF[4]. Converting from GJ to kWh at 0.0036 GJ/kWh
	Emissions factor of Diesel	70.2 kg CO_2-e/GJ	Based on NGAF[4] values: CO_2 at 69.9 kg CO_2-e/GJ CH_4 at 0.1 kg CO_2-e/GJ N_2O at 0.2 kg CO_2-e/GJ
	National Grid Electricity Residual Mix Factor	0.837 (t CO_2-e/MWh)	National Scope 2 Emissions Factor of 0.68 (tCO_2-e/MWh) as per NGAF[4]. Renewable Energy Target resulted in a renewable power percentage for 2023 of 18.96%[5].
Costs	R3 Electricity cost	20.54 c/kWh	Invoicing peak energy rate averaged for monthly bills from March 2023 - September 2023. Note that this does not include supply charges. Energy rates were applied to the energy usage to show operational costs.
	R2 Diesel cost	176 c/L	Monthly diesel cost incurred by Azzurri averaged from March 2023 - September 2023. Energy rates were applied to the energy usage to show operational costs.
	Average Spot Market Renewable Energy Certificates (RECs) cost	54.41 $/MWh	Average spot market monthly cost of Large-scale generation certificates (LGC) from March 2023 – September 2023 Certificate Pricing Report[6].
	Average carbon offset cost	33.12 $/t CO_2-e	Average cost of Australian Carbon Credit Units (ACCUs) from March 2023 – September 2023 Certificate Pricing Report[6].

3.2. Analysis and Calculations

The following steps were taken to calculate and analyse the above data detailed in Tables 2 and 3.

Energy:

1. The concrete pour dates were attributed to the months they occurred in. This allowed the monthly energy data to be attributed to the month's pours.
2. The R2 monthly diesel consumption (L) was converted to energy (kWh) to compare electricity usage in the same units. It was converted at an energy density factor of 10.72kWh/L[4].
3. The energy usage was divided by the number of concrete pours each month. This created 'Average energy per pour per month' values for each month for both diesel and electricity separately.
4. 'Average energy per pour per month' values were attributed to each pour (based on the month) and then summed per level. This resulted in 'Energy per level' values.
5. 'Energy per level' values were divided by each level's concrete volume poured (cubic metres). This resulted in 'Concrete volume normalised energy per level' measurements (kWh/m³). This enables a more precise comparison of energy efficiency across distinct levels, particularly when concrete volumes vary, such as between R2 and R3.

   In this case, '*Normalised*' refers to the measurement of energy consumption per level of R2 and R3 towers, divided by the volume of concrete used for each corresponding level to calculate the usage per cubic metre of concrete pumped.
6. 'Concrete volume normalised energy per level' measurements were averaged for the range of values from levels 15-30.

Emissions:

7. Diesel usage Scope 1 emissions calculations were made using the NGAF 2022[4] guidance. It should be noted that emissions calculations were applied to the total sum of 'energy per levels' values and then averaged per level and cubic metre of concrete.
8. Electricity Scope 2 emissions calculations were made following the market-based method[7] outlined by the Climate Active Electricity Accounting standards. It should be noted that emissions calculations were applied to the total sum of 'energy per levels' values and then averaged per level and cubic metre of concrete.

Operational Costs:

9. Energy costs for the concrete pumps was calculated by multiplying the energy usage values with the energy rates (diesel and electricity) outlined in Table 3.
10. Zero Carbon costs were calculated by multiplying the electricity usage values with the average Spot Market Renewable Energy Certificates (RECs) cost and diesel usage with the Average carbon offset cost.

    Units for offset (ACCUs) and REC prices (LGCs) were appropriately adjusted to $/kWh for energy usage. ACCUs were converted from $/tonne CO_2 to $/kWh according to the emissions calculations used above for diesel. LGCs were simply converted from $/MWh to $/kWh

    The total operational cost of operating the concrete pumps is the sum of both energy and zero carbon costs.

Total Cost of Ownership:

The Total Cost of Ownership analysis considered actual costs and included:

11. Azzurri Concrete provided costs for both the electric (Schwing SP 3800 E) and equivalent diesel (Putzmeister BSA 2110 HP D) pumps. Costs included:
    1. upfront purchase cost,
    2. frequency and cost of replacing wear parts,
    3. routine maintenance costs.
12. Energy costs were applied as calculated by the energy comparison analysis associated with this report.
13. Equipment output and lifetimes were noted from equipment supplier technical documentation.
14. Infrastructure costs were calculated using actual costs incurred on the One Sydney Harbour R3 for HV cable reticulation costs and battery costs estimated to be $450,000 for a 450kWh battery at $1000AUD/kWh[8].

4.
Summary of Results

Table 4 shows the reductions in average energy, cost, emissions, and zero carbon cost per cubic metre pumped between the R2 electric concrete pump and the R3 diesel concrete pump. A more detailed summary can be found in Appendix 3.

Table 4: Average Energy / Cost / Emissions per cubic metre pumped

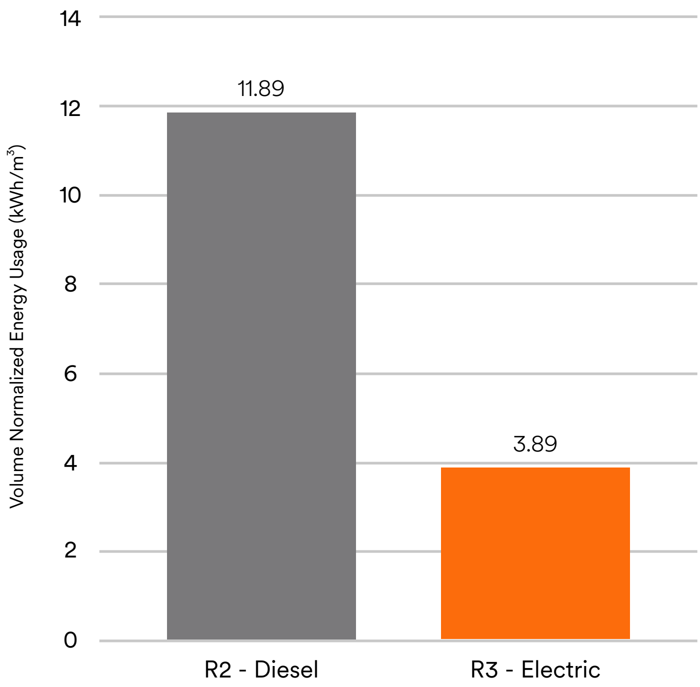
	R2 - Diesel	R3 - Electric	Difference	Difference (%)
Energy (kWh/m^3)	11.89	3.89	8.01	67.3%
Equivalent Energy in Diesel (L/m^3)	1.11	0.36	0.75	
Carbon Emissions (kg CO2-e/m^3)	3.01	2.62	0.39	12.9%
Energy Cost ($/m^3) Zero Carbon Cost ($/m^3) Total Operational Cost ($/m^3)	$1.95 $0.10 $2.05	$0.80 $0.21 $1.01	$1.15 -$0.11 $1.04	59.1% -112.4% 50.8%
Carbon emission outcome	Net zero*	Absolute zero#		

*Diesel pump diesel carbon emissions are net zero emissions with carbon offsets.
#Electric pump grid carbon emissions are absolute zero carbon emissions with Renewable Energy (RECs).

5.
Energy

During the concrete pumping of levels 15-30, the R2 diesel concrete pumps used 8,065 L of fuel, which equates to 86,471kWh of equivalent energy. The R3 electric pump used 16,966kWh of electrical energy for the same levels. Considering the variance in concrete volumes between the levels on R2 and R3, the diesel concrete pumps used a 'Concrete volume normalised energy' demand to pump a cubic metre of concrete of 11.89kWh/m^3, and the electric concrete pump only used 3.89kWh/m^3, shown in the following figure.

Figure 1: Average energy required to pump a per cubic metre of concrete



The electric concrete pump used approximately a third of the energy required to run the diesel concrete pump.

The results of this analysis showed that 67.3% less energy per cubic metre of concrete was used by the electric concrete pump when compared the diesel concrete pumps.

This significant energy reduction was expected as similar results have been shown from electrification in other industries.

According to multiple research studies, switching from diesel to electric power in heavy-duty vehicles has been found to offer substantial energy savings. For example, a New York City-based case study revealed that diesel trucks use up to three times more energy than their electric counterparts and produce 40% more greenhouse gases[9]. Similarly, a Transport & Environment (T&E) study in Europe demonstrated that electric trucks, particularly those operating in urban settings, have a higher energy efficiency than diesel trucks[10].

Efficiency differences between diesel and electric concrete pumps explain energy use differences.

Diesel engines and machinery are known to have a reduced energy efficiency compared with electric engines due to unavoidable heat energy losses during power generation. The typical efficiency of converting the available energy in diesel to useful mechanical energy is 35%[11].

Powered directly through grid connection, the electric concrete pump can directly convert electricity to mechanical energy without the same fuel associated heat losses. The Schwing SP 3800 E electric concrete pump has premium efficiency (class IE 3) according to the International Electrotechnical Commission (IEC) Motor Efficiency – Standards and Classification (IEC 60034-30-1:2014)[12]. This IE 3 classification means that the electric concrete pump is considered to have an efficiency of between 94.6-96%[13], given that it operates at 200kW and 50hz.

This analysis has confirmed that, as expected, an electrical concrete pump (Schwing SP 3800 E) can convert a much higher percentage of available energy into mechanical energy when compared to a diesel concrete pump used for the same task. The reduced energy usage has significant impacts in further reducing operational emissions and costs.

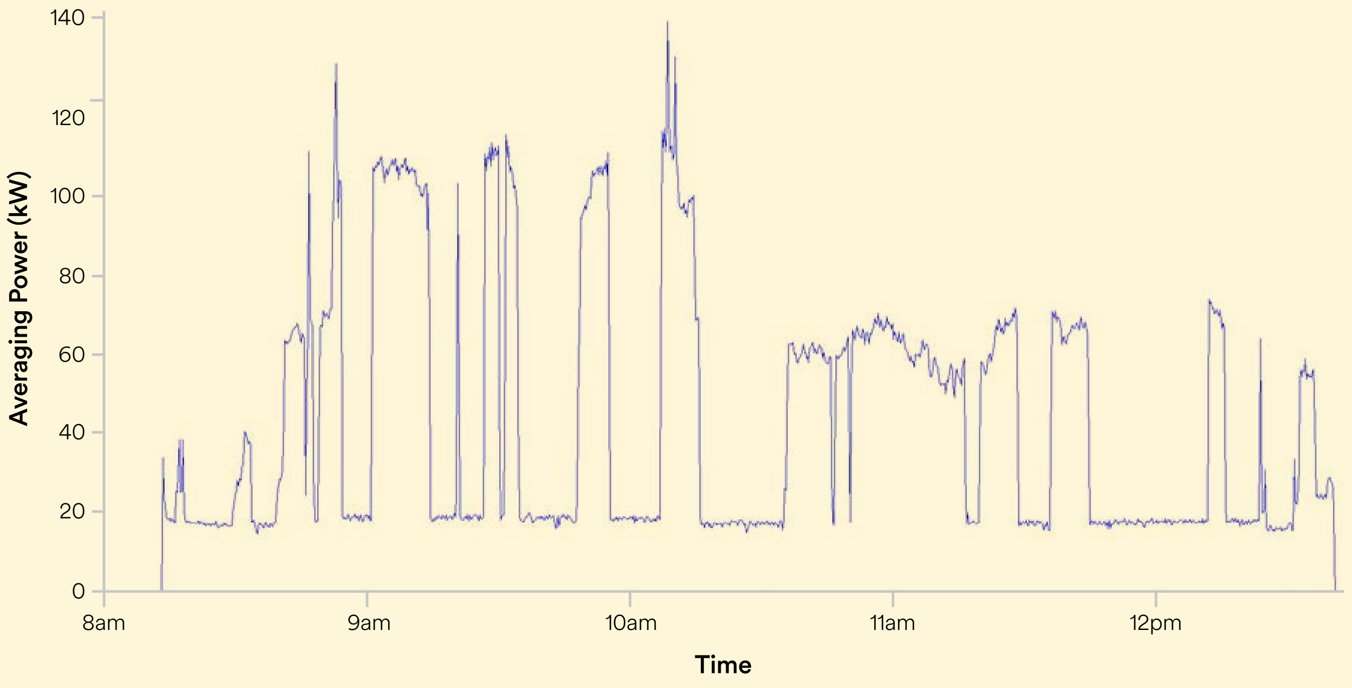
5.1. Energy Related Technical Findings

A data logger was installed on the electric concrete pump from 22 March 2023 to 31 March 2023 to monitor the power at a granular level (every 15 seconds). The summary of the findings was:

- The electric concrete pump idles at approximately 20kW/25kVA when not pumping concrete.
- The electric concrete pump was pumping concrete for only 10% of the overall operating time of the day. The operational demands of the pump are significantly lower than the nameplate rating and the pumping duration through a daily cycle means that the electrical consumption is also lower than expected.
- The 200kW pump had a start-up of 770 Amps over 1 second, around 2.5 times the operating current. The pump had contained a Delta-Wye soft starter. The start-up current was in the expected range for this soft starter type.
- An electric concrete pump is a significant load to be considered when estimating temporary electrical construction power at the site, thus requiring electrical supply and cabling infrastructure over and above a diesel concrete pump. The average power was 46kW and a highest average peak of 146kW was recorded as shown in the figure below which was over a typical day:

The data logger confirmed that the Schwing SP 3800 E pump (200kW output) idled at approximately 20kW/25kVA when not pumping concrete. This energy demand should be considered for improved accuracy of forecast energy usage on future sites. Future projects should consider readily accessible pump control options which allows the pump to be turned off when not pumping to reduce usage further.

Figure 2: Electric Concrete Pump Data Logger - 25 March 2023



6.
Carbon Emissions

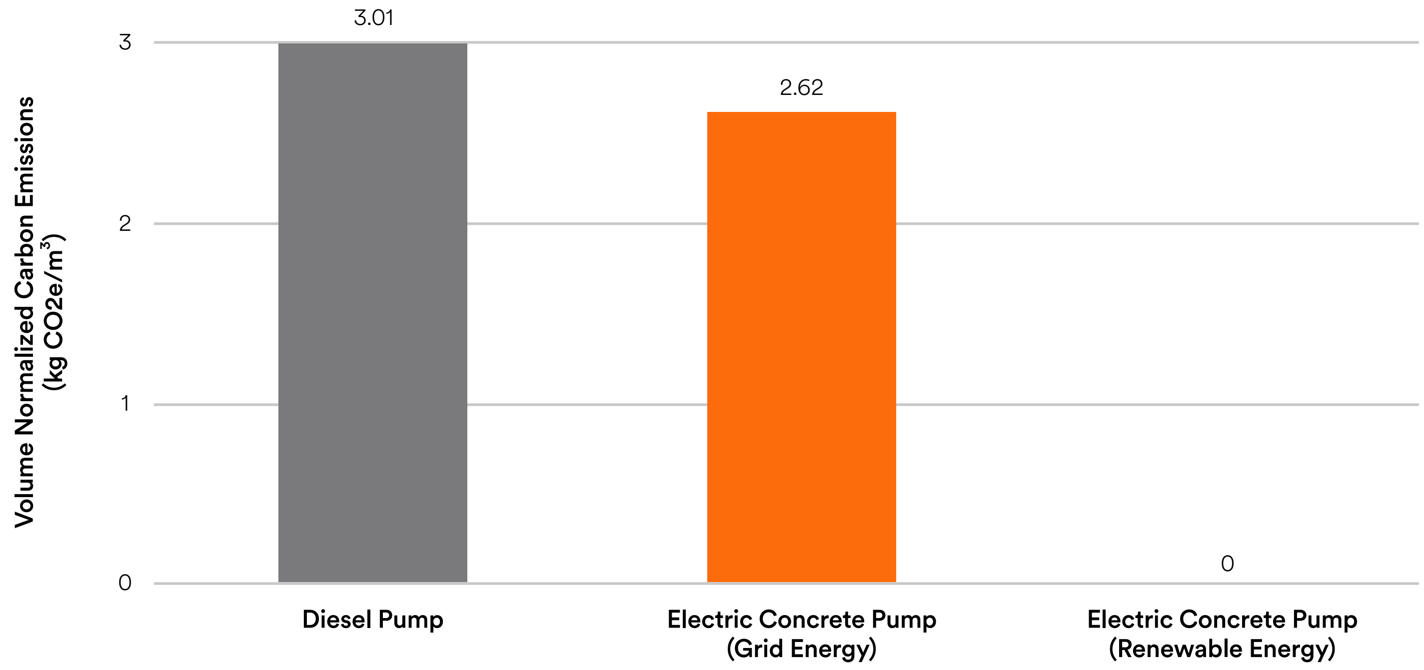
Electric concrete pumping creates less emissions than diesel concrete pumping.

Table 5 shows the calculated gross emissions from electric and diesel concrete pumping for levels 15-30 of the R2 and R3 towers. The use of the electric concrete pump provides a 12.9% reduction in gross carbon equivalent emissions (CO_2-e) for every cubic metre of concrete pumped (m^3) when considering the emissions impact of diesel[1] and using Australian grid energy[2]. Australian grid energy is comprised of 18.96% renewable electricity. A detailed breakdown of the calculation is found in Appendix 2.

Table 5: Emissions Values for Levels 15-30 per cubic metre

	Emissions from Diesel Concrete Pump[4]	Grid Emissions from Electric Concrete Pump[5]	Difference (%)
Carbon Emissions per cubic metre of concrete pumped (kg CO_2-e/m^3)	3.01	2.62	12.90%

Figure 3: Emissions produced by pumping a cubic meter of concrete



Electric concrete pump gross emissions will decrease as the grid becomes more renewable.

The emission intensity of diesel consumption remains a constant scientific figure. However, the emissions intensity of Australian grid electricity is expected to decrease as renewable generation increases. For example, the Australian Government has budgeted $45.8 million over six years toward the 'Powering Australia Plan'[14], which aims to reach a grid renewable energy percentage of 82% by 2030, approximately four times greater than the current 18.96%[5]. This transition will reduce the carbon intensity of grid electricity in the same order of magnitude.

Renewable electricity allows absolute zero operation.

The One Sydney Harbour project purchased renewable electricity, which reduced the operation emissions of the concrete pump to absolute zero. Figure 3 shows the comparison of emissions from diesel, grid electricity and renewable electricity.

7.
Costs

An electric concrete pump is cheaper to operate than the equivalent diesel concrete pump.

The results of this analysis confirmed a 59.1% reduction in energy cost using an electric concrete pump compared to a diesel concrete pump due to the reduced energy usage.

Electricity costs averaged \$0.80/m^3 per cubic metre of concrete pumped during the operation of the electric concrete pump on the R3 tower. Diesel fuel costs an average of \$1.95/m^3 per cubic metre of concrete pumped on the R2 tower (See Appendix 3 for a breakdown of the energy costs for operating diesel and electric concrete pumps).

This 59.1% reduction is due to the difference in energy use between the pumping methods, as actual energy rates showed diesel for the periods considered was cheaper per c/kWh (16.4 c/kWh for diesel, converted from 176 c/L, compared to 20.54 c/kWh for electricity).

Infrastructure costs for electrification are project-specific and dependent on local grid capacity and need to be assessed on a project-by-project basis.

The electric concrete pump required the allocation of 400 amperes in the existing temporary power capacity. Infrastructure works were therefore required on R3 to increase capacity due to the localised electricity grid constraints of adding the electric concrete pump to the existing project electric load of two tower cranes, two hoists and a formwork hoist. This included significant cabling works from the main switchboard to the electric concrete pump, circuit breaker upgrades and Current Transformer upgrades, which cost \$132,726 and were sized for a 'worst case scenario' of peak activity. It should be noted that the most cost (\$88,792) was due to the 220m of cabling upgrades.

Future projects must assess their grid capacity, temporary board capacity and equipment's location to infrastructure to determine the extent of potential cabling and capacity works depending on their access to and position from sufficient infrastructure.

The electrical demand for equipment should also be considered in relation to the demands from other construction equipment and machinery. Grid constraints are localised, and infrastructure upgrades may not be required to use an electric concrete pump on other projects within Lendlease with sufficient capacity.

Battery technology could be used to buffer grid capacity constraints on future projects.

Lendlease is currently successfully utilising battery technology to substitute diesel generators to power electric cranes on construction projects with grid capacity issues. Initial energy use data analysis shows tower cranes behave similarly to concrete pumps, and a battery is likely to provide a viable option to be used in conjunction with concrete pumps to buffer grid capacity issues where they exist on other projects. The large battery is continuously 'trickle-charged' at a lower current input which avoids unnecessary upgrades to the grid or switchboard capacity, as the battery is sized to be capable of required startup and operating currents.

Zero emissions transition of concrete pumping depends on investment from the supply chain.

Although outside the scope of this analysis, as partners in this initiative, Azzurri Concrete did purchase the electric concrete pump for use on this project, which was at their cost and not an operational cost to the project. Whilst this pump will be used on future projects in the industry, it highlights the need for Lendlease to provide clear communication on its fossil fuel free construction pathway and market signal to our supply chain. Concrete pumping is currently dominated by diesel concrete pumps, so for this high carbon-emitting activity to transition to zero-emission, the supply chain needs to purchase electric alternatives when they expand or replace their concrete pump assets.

7.1. Total Cost of Ownership

In addition to operational costs, the lifetime costs of the electric and diesel concrete pumps were compared using a total cost of ownership (TCO) analysis. TCO is more relevant than the upfront purchase cost when considering low and zero-emissions options. This is because different operating, maintenance and infrastructure costs can significantly affect the overall economic competitiveness of each option.

The variability surrounding electrification infrastructure costs is not well defined. It is impacted by multiple variables, including available grid capacity, the use of other electric machinery simultaneously on projects, and the use of batteries in construction as a new practice in the industry. Therefore, to analyse the TCO of the electric concrete pump and account for the variation of infrastructure needs on different projects, scenarios have been developed to address the complexity of forecasting electric infrastructure costs.

To analyse the TCO of the electric pump and account for the variation of infrastructure needs on different projects, the following scenarios have been developed:

(1) **Diesel concrete pump.**

(2) **Electric concrete pump - available grid capacity, exclusion of electrical infrastructure costs.**

This scenario considers all ownership costs, excluding any infrastructure-related expenses. This scenario represents when grid capacity is available, and additional infrastructure is not required.

(3) **Electric concrete pump - infrastructure upgrade, cabling infrastructure costs.**

This includes a one-off lifetime infrastructure cost equivalent to the significant HV cable reticulation costs associated with implementing the electric pump on the One Sydney Harbour R3 project, totalling \$132,726. This involved the reticulation of 220m of 300mm high voltage cabling required as the electric concrete pump was located well away from the switchboard despite sufficient grid and site capacity.

This scenario represents where infrastructure upgrades are required. The cost used is an example of infrastructure upgrade costs that may be required for some projects, although future infrastructure costs will depend on advances in grid capacity.

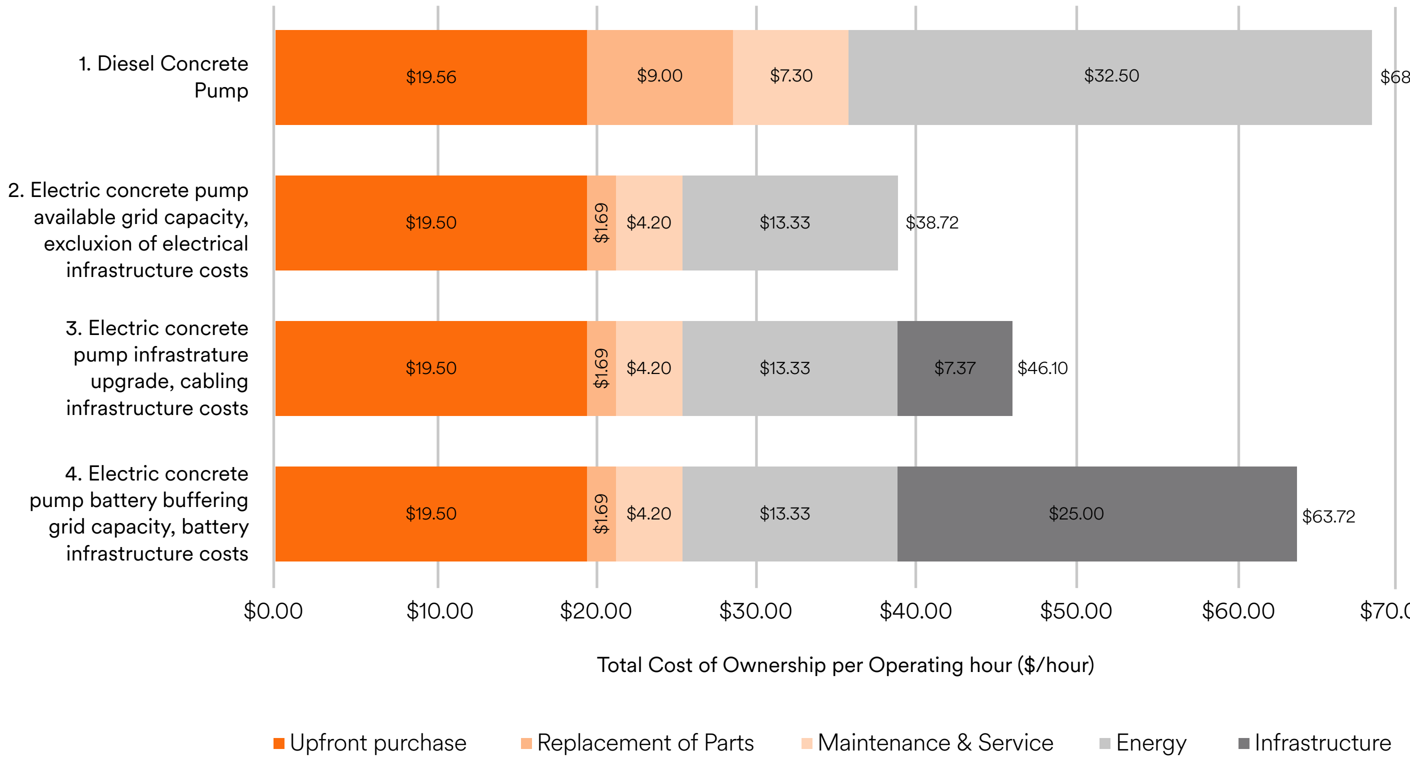
(4) **Electric concrete pump - battery buffering grid capacity, battery infrastructure costs.**

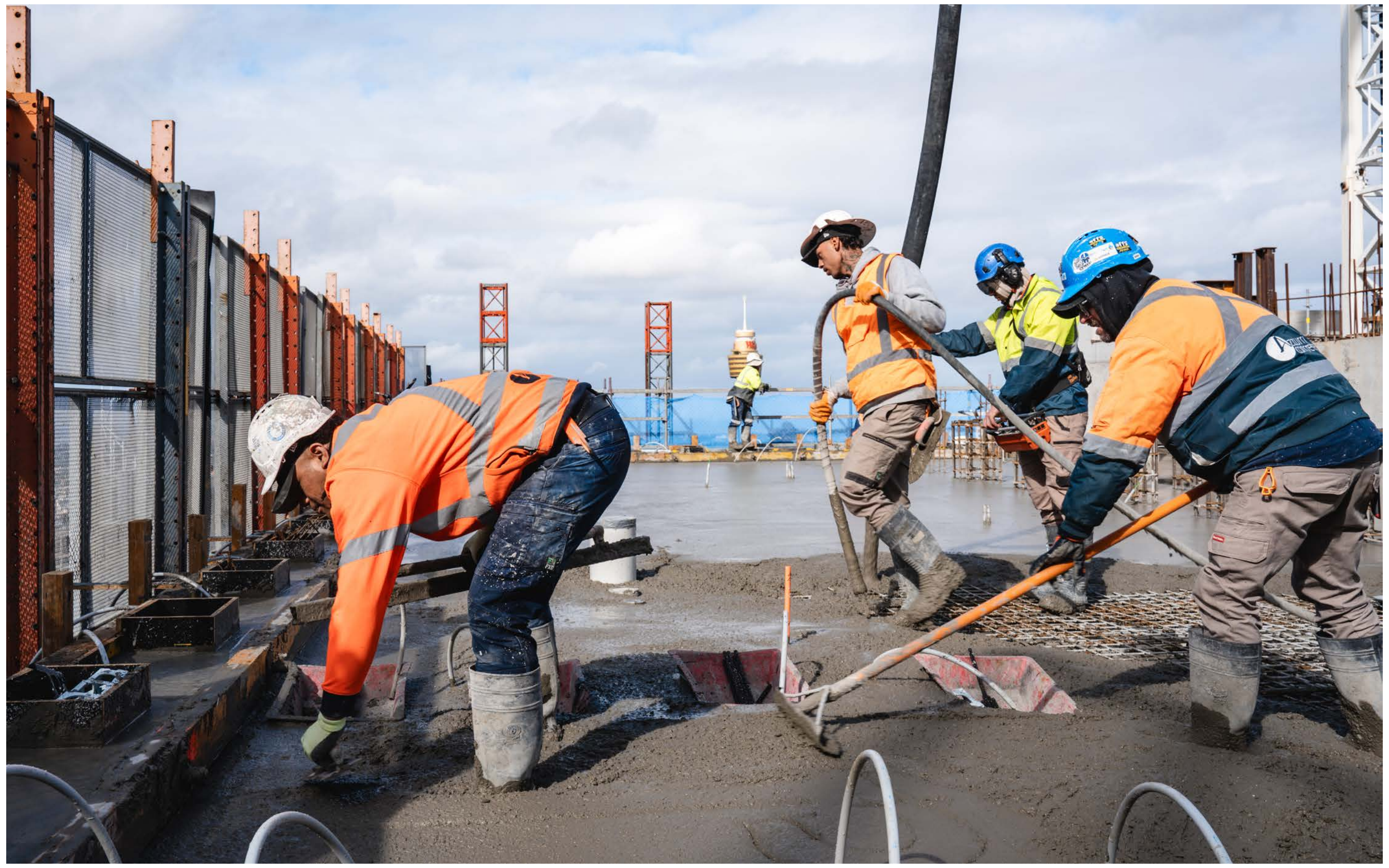
This includes an estimated initial purchase price of a large container battery sized to buffer grid capacity constraints to meet the requirements of the electric concrete pump. This was estimated to be \$450,000 for a 450kWh battery, assuming a price of \$1,000AUD per kWh of capacity as aligned with an ARENA-backed ANU study on community battery costs[8].

This scenario represents where battery technology can buffer grid capacity constraints instead of paying for infrastructure upgrades. Batteries can be shared with other equipment, such as cranes and hoists, to utilise the full capacity of the battery which shares the battery infrastructure costs and reduces the TCO for each piece of equipment. Battery technology for use in construction activities is a new market within very limited competition making current battery costs high. Battery costs are expected to be reduced for future projects as the market matures and uptake increases. This aspect underscores the need for future research with more comprehensive data from future construction sites to understand the variability in these costs better.

Figure 4 shows a breakdown of TCO per operating hour for the electric and diesel concrete pump scenarios. Tabulated TCO calculations for each scenario are in Appendix 4, 5 and 6.

Figure 4: Total cost of ownership per operating hour for diesel and electric concrete pumps





Electric and diesel concrete pumps have equivalent upfront purchase costs.

Pricing details provided by Azzurri Concrete showed that the Schwing SP 3800 E was purchased for $351,000 while the Putzmeister BSA 2110 HP D was purchased for $352,000. This differs from most other electric equivalent models, removing a significant barrier in transitioning to electric.

Replacement of worn parts and regular maintenance are cheaper for the electric concrete pump.

The wear parts (wear plate and wear ring) used on the electric concrete pump have a longer lifespan before replacement of 40,000 to 60,000 m^3 compared to 10,000 to 15,000 m^3 for the diesel concrete pump. Furthermore, the electric concrete pump utilises a 'Rock Valve', which does not require replacement as it can be effectively hard-faced between projects. In contrast, the diesel concrete pump uses a 'S-Tube', which requires occasional replacement as hard facing is challenging due to its length. The diesel concrete pump also has a higher maintenance and servicing cost of $3,650 compared to $2,100 every 500 hours. Over the lifespan of the pumps, these factors result in substantially more ownership costs for the diesel concrete pump.

"Hard facing" adds a tough, wear-resistant material to the valve's surface. This can be done between projects or during regular maintenance, greatly extending the valve's lifespan. It means the valve can be refurbished instead of entirely replaced, offering a cost-effective and efficient way to maintain equipment long-term.

Energy costs are cheaper for the electric concrete pump.

As per the analysis detailed in this report, the electric concrete pump uses less energy and requires 59.1% less energy costs.

In all scenarios where infrastructure varies, the total cost of ownership for the electric concrete pump is cheaper.

Although forecasting infrastructure costs is complex, the TCO analysis has shown that the electric concrete pump is ultimately cheaper than the diesel concrete pump when comparing the various scenarios considered.

Future research is needed to clarify infrastructure costs.

The variability surrounding electrification infrastructure costs needs to be better defined and is impacted by multiple variables, including the use of batteries in construction being new to the industry. To increase understanding of infrastructure costs, data can be collected and analysed from future construction sites utilising electric concrete pumps to help quantify the cost range and improve certainty of costs.

8.

What does this mean for Climate Active Certification?

Lendlease Construction provides Climate Active certified carbon neutral construction services for the One Sydney Harbour project, which requires eliminating or abating any carbon emissions associated with energy use from powering construction activities, such as diesel (Scope 1) and electricity (Scope 2).

Scope 1 emissions are abated by purchasing and retiring carbon offsets, and Scope 2 emissions are replaced by using renewable energy, achieved by purchasing and surrendering Renewable Energy Certificates (RECs).

Zero carbon electricity is more expensive than zero carbon diesel, but less is required.

Zero carbon costs refer to 'carbon offsets' for Scope 1 emissions and 'RECs' for Scope 2 emissions.

Third-party carbon offsets for diesel Scope 1 emissions are purchased and retired. Australian carbon credit units (ACCUs) have an average price of $33.12/ tonne CO2-e from March to September 2023[6], equating to $8.37/MWh of diesel energy based on emissions calculations.

Renewable energy is purchased (by purchasing and surrendering RECs) to cover Scope 2 emissions for electricity usage, less the renewable power percentage which is 18.96% for 2023[5]. In Australia, there are two types of REC: Large Scale Generation Certificates (LGCs) and Small-scale technology certificates (STCs)[15]. LGCs are awarded to renewable energy projects, such as wind and solar farms, and hydroelectric schemes for every 1MWh generated. In March to September 2023, LGCs had an average cost of $54.41/MWh[6].

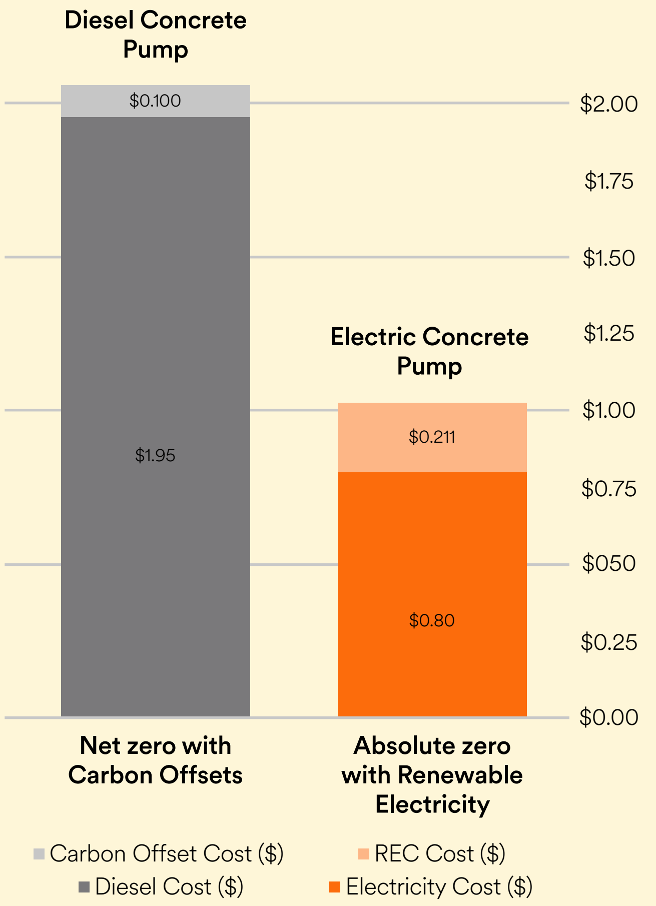
The OSH project purchases LGCs and ACCUs to abate and eliminate Scope 1 and 2 carbon emissions ultimately. Applying these costs to the energy usage of the pumping methods, it costs $0.211/$m^3$ for the electric concrete pump and $0.100/$m^3$ for the diesel concrete pumps per cubic metre of concrete poured.

Table 6: Zero Carbon Costs for Diesel and Electricity

Zero Carbon Cost	Diesel - ACCU	Electricity - REC
Cost by energy usage	$8.37/MWh	$54.41/MWh
Cost by cubic meter of concrete pumped	$0.100/$m^3$	$0.211/$m^3$

Figure 5 demonstrates the difference in volume normalised costs for both energy and costs of carbon offsets and renewable energy methods.

Figure 5: Average Cost for Concrete Pumping per cubic metre



Considering energy and zero carbon costs, the electric concrete pump is still much cheaper to operate at 50.8% less per cubic meter.

Energy costs are significantly larger than the cost of achieving a zero carbon outcome. Therefore, although the zero carbon cost of electricity is more than twice as expensive as diesel, zero carbon electricity is still half as cheap to operate as zero carbon diesel. This is due to low energy demand and the previously discussed 59.1% reduction in energy cost.

9.
What does this mean for Mission Zero?

The carbon emissions from the diesel used in the diesel concrete pumps on R2 are offset and give a **net zero outcome**. The electricity used to power the electric concrete pump on R3 is sourced from renewable electricity, creating an **absolute zero outcome**.

An absolute zero emissions outcome is achievable with an electric concrete pump rather than a net zero outcome with a diesel concrete pump.

0.39 less kg CO_2-e of carbon emissions per cubic metre of concrete needed to be eliminated for the electric concrete pump compared with the diesel concrete pump's carbon emissions. The diesel concrete pump emissions were abated using carbon offsets which achieved a net zero outcome. The electric concrete pump's emissions were eliminated using renewable energy. The electric concrete pump has enabled an absolute zero emission outcome. Without electrification, this could not be achieved.

Renewable electricity is the cheapest pathway to zero emissions for concrete pumping.

Electric concrete pumping has shown that contributing to Lendlease's absolute zero emission by 2040 can also save operational costs. Although the cost of RECs for the electric concrete pump is more expensive than the cost of carbon offsets (RECs $0.211/$m^3$ vs Offsets $0.100/$m^3$ of concrete), these additional costs are mitigated by the overall significant reduction in operational costs. Therefore, the combined energy and zero carbon costs for electric concrete pumping were still 50.0% less.

What is the difference between net zero and absolute zero emissions?

Lendlease has set ambitious 'Mission Zero' targets[16] related to reducing and eliminating carbon emissions.

MISSION ZERO • NET ZERO CARBON BY 2025 •

Our **net zero** target refers to reducing all Scope 1 and 2 greenhouse gas emissions from business activities as far as possible, with the remainder offset with an approved carbon offset scheme.

If mineral diesel is used, Scope 1 emissions have been produced and a net zero outcome can be achieved with offsets.

MISSION ZERO • ABSOLUTE ZERO BY 2040 •

Our **absolute zero** target refers to mitigating all Scope 1, 2 and 3 greenhouse gas emissions from business activities to zero without offsets.

When **renewable electricity** is used, no emissions are produced, and an absolute zero outcome is achievable.

10.
Future Cost Implications

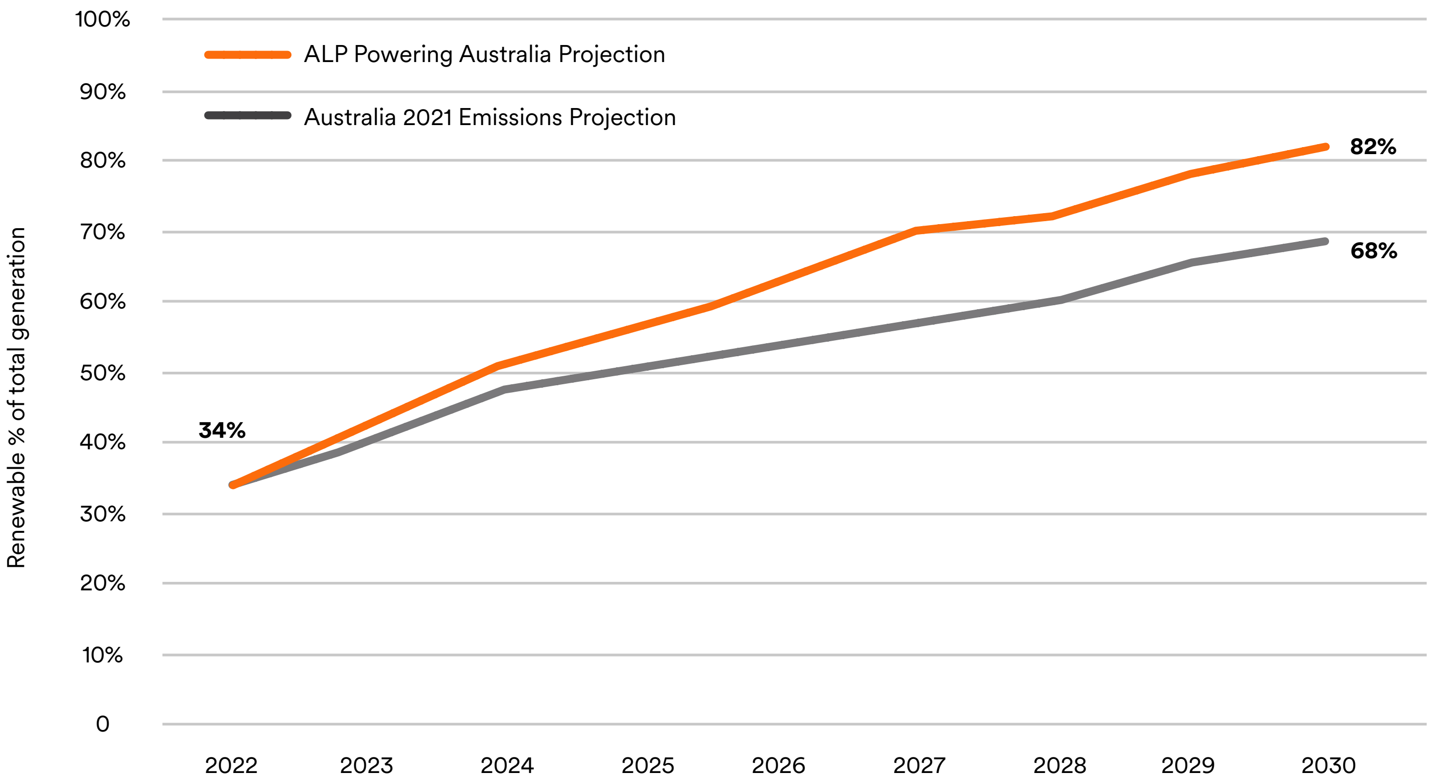
Price trends suggest that costs to achieve zero carbon will decrease for electrified equipment and increase for diesel equipment.

The below trends demonstrate that by substituting diesel usage with electricity usage, the need to purchase carbon offsets (which are increasing in price)[1] is replaced with the purchase of RECs (which are decreasing in price)[2]. It is predicted that this will significantly reduce zero carbon costs in the future for Lendlease.

Zero carbon costs diminish for electrified concrete pumping as the grid becomes increasingly green. Future REC costs for Lendlease are expected to be minimal.

Trends suggest that as the grid becomes increasingly renewable, the price of purchasing RECs will reduce. The Australian Government aims to reach a grid renewable energy percentage of 82% by 2030[14] as shown in Figure 6. The supply of LGCs will increase in proportion to this projection; simultaneously, the demand for LGCs will decrease given the reduced emissions intensity of the grid. Due to this supply imbalance, futures markets indicate that the value of LGCs will decrease potentially to as low as zero by 2030. Simultaneously, purchasing fewer LGCs will be required as less grid energy will contribute to emissions.

Figure 6: Projected renewable energy generation in Australia's National Electricity Market[17]



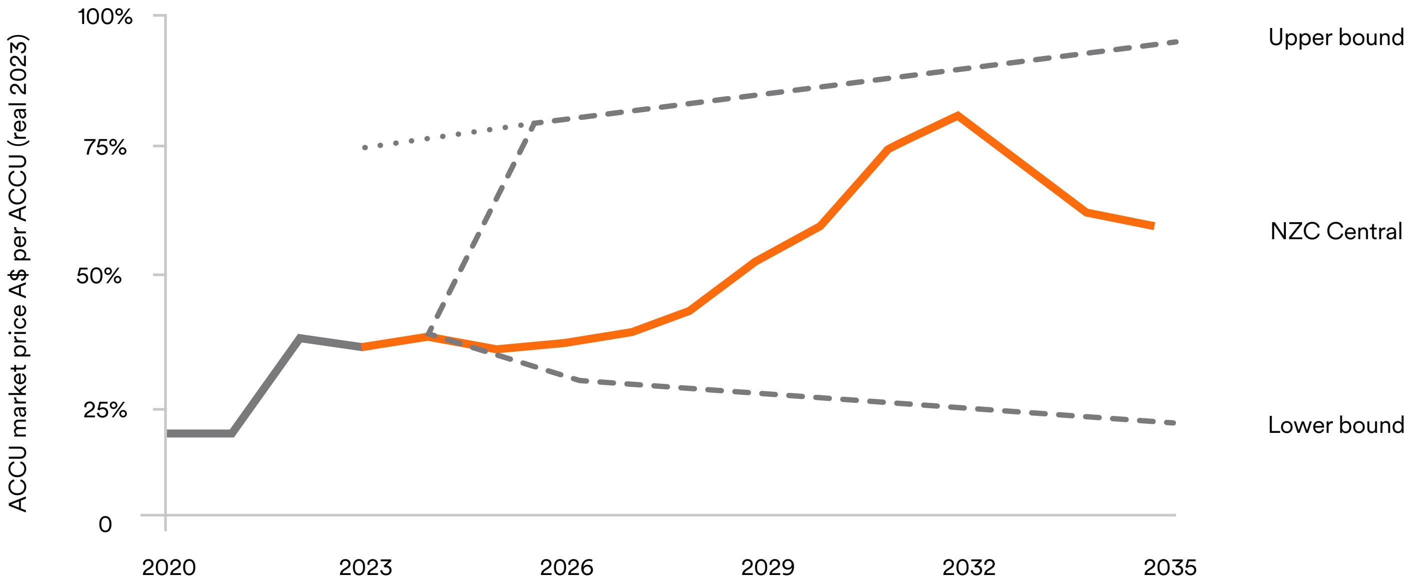
Zero carbon costs will increase for diesel concrete pumping as offset prices increase.

In contrast, offsetting prices are forecast to continue increasing over the following decades. The Australian Government's Safeguard Mechanism (SGM) sets requirements for certain high-emitting facilities to reduce emissions gradually. Reforms to the SGM include a cost containment measure that ensures these facilities have a set maximum price for ACCUs at $75 per tonne of CO_2-e in 2023-24 and increasing with the consumer price index (CPI) plus 2% each year[18].

Market modelling from the EY Net Zero Centre as shown in figure 7 forecasts market-priced ACCUs will double between 2023 and 2035 to approximately $80AUD[1], just beneath the SGM contained price. Although below-market prices may be agreed on in de-risked, long-term offtake contracts, general prices are forecast to trend upward.

It should be noted that the SGM does not apply to Lendlease. However, market price ACCUs are exposed to the increased demand of those impacted facilities, resulting in higher offset prices for Lendlease in the future and a higher cost of offsetting diesel.

Figure 7: SGM reforms drive increase in carbon price to 2035[2]



11.
Potential Whole-Tower Impact

The electric concrete pump was only used to pump approximately half the concrete used in the R3 tower. To determine potential savings between diesel and electric methods for the entire building (R3 tower), the normalised average energy use / energy costs / emission values/ zero carbon cost per cubic metre was projected to total all 30 levels.

In total, 9140 cubic metres of concrete was poured into the R3 tower (30 levels); Table 7 shows the estimated energy use / energy costs / emission figures for concrete pumping methods at this scale.

Potential cost, energy and emission savings from electrification are significant.

If the electric concrete pump was used for the full scope of pumping when compared to the diesel options analysed, approximately:

- $9,512 in operating costs would be saved.
- 73,182kWh of energy would be saved, equivalent to the annual electricity usage of 13.2 homes, given an average annual usage of approximately 5,529kWh[19] for NSW homes connected with Ausgrid.
- 27.5 tonnes of CO_2-e of gross carbon emissions would be avoided as the electric concrete pump achieves an absolute zero carbon outcome.

Table 7: Estimated Usage for the entire R3 Tower

	R2 - Diesel	R3 - Electric	Difference	Difference (%)
Energy (kWh/m^3)	108,707	35,526	73,182	67.3%
Energy - Equivalent in Diesel (L)	10,139	3313	6825	
Carbon Emissions (kg CO_2-e/m^3)	27,466	23,923	3544	12.9%
Energy Cost ($/$m^3$)	$17,833	$7,298	$10,535	59.1%
Carbon offset / REC Cost ($/m3)* **	$910	$1,933	-$1,023	-112.4%
Total Cost ($/m3)	$18,743	$9,231	$9,512	50.8%
Carbon emission outcome	Net zero*	Absolute zero**		

*Diesel concrete pump carbon emissions are net zero emissions with carbon offsets.
**Electric concrete pump grid carbon emissions are absolute zero carbon emissions with RECs.
***See table 6 for cost assumptions.

12.
Additional Benefits of Electrification

The electric concrete pumping provides additional benefits to reductions in energy use, carbon emissions, and operational costs.

12.1. Benefits to workers

Electric concrete pumping improves local air quality compared to diesel concrete pumping, reducing health impacts.

Diesel engine exhaust contains carcinogens and pollutant emissions which negatively impact human health and the air quality of the local environment. The Cancer Council considered diesel engine emissions to be a cancer-causing agent which has the second-most exposure among Australian workers. Inhalation risks long-term health impacts such as lung and bladder cancer[20]. Diesel engine exhaust also contains carbon monoxide (CO), hydrocarbons (HC), particulate matter (PM), and nitrogen oxides (NOx)[21] which all have negatively impact human respiratory health and local environment air quality. The electric concrete pump, by comparison, has no negative impact on local air quality, which is healthier for operators, workers, and the community. Additionally, this enables electric concrete pumps to operate with less ventilation and could be utilised in more confined spaces where diesel concrete pumping has traditionally not been possible due to significant impacts on air quality.

Electric machinery generates less heat than diesel equivalents, improving the local working environment.

In converting diesel fuel into usable mechanical energy, a large portion of potential energy is emitted as heat energy. Electric equipment can significantly reduce the heat produced by machinery, which, in small areas, can impact the immediate local area and comfort for workers.

Electric machinery is generally quieter than diesel equivalents, although there is still significant noise from the piston side of the pump for an electric concrete pump.

Research has shown that, in some cases, electric machinery can produce less noise than diesel options[3]. However, despite the electric concrete pump not requiring an engine, there remains unavoidable noise resulting from the piston side of the pump that physically pumps the concrete.

12.2. Operational benefits

Electrification prevents the need for storage and handling of diesel fuel on-site and reduces associated safety and environmental risks.

By replacing diesel usage with electrified equipment, storage and handling of diesel and other fuels can be minimised on-site. This increases safety and environmental risks by reducing potential fuel spills and fires.

Electric machinery requires less servicing and maintenance, leading to cost savings and less downtime.

Electric machinery and equipment can have reduced maintenance requirements due to the absence of an engine and many moving components. Reduced friction and degradation of components can result in lower ongoing costs and maintenance downtime. Additionally, by replacing diesel usage with electrified equipment, downtime for refuelling is also avoided.

12.3. Supply chain benefits

Electrification reduces project risks from supply chain disruptions.

Australian diesel supply is vulnerable to impacts on the global supply chain with recent geopolitical events impacting diesel availability and pricing in Australia. Electrification enables greater energy security and reduces project impacts from broader supply chain challenges.

13.
Operational Performance

Operating Team Lessons Learnt

Azzurri Concrete pump operates noted that the Schwing SP 3800 E had several operational advantages to the Putzmeister BSA 2110 HP D. They reported that it was noticeably quieter, easy to operate, cleaning of the hopper was easier and used less water, and the wear plate and wear ring last significantly longer before replacement is required. However, the operators noted that the electric concrete pump had an aggressive ram, which caused more increased movement in the static line and required more pump support surrounding bends. This was addressed by a Schwing technician manually reducing the accumulator pressure to reduce these movement effects. The diesel concrete pump had an adjustable pressure regulator for this purpose that could be adjusted by the operator instead.

Project Team Lessons Learnt

The OSH project team provided lessons learnt from implementing the electric concrete pump. As electric concrete pumping was new to the project team, our plant onboarding processes were updated to include aspects applicable to the electric concrete pump:

- inspection checklists.
- operator and technician training requirements.
- alignment of the Concrete Pumping Association of Australia logbook and original equipment manufacturer (OEM) manual.
- additional considerations included electrical certificates, independent power supply, power outage protocol.

14.
Conclusion

The potential cost, energy and emission savings from electrification are significant. This analysis has confirmed:

- Electric concrete pumping uses 67.3% less energy than diesel concrete pumping.
- Electric concrete pumping produces 12.9% less emissions than diesel concrete pumping.
- Electric concrete pumping requires 59.1% less energy costs than diesel concrete pumping.
- Absolute zero electric concrete pumping through the use of renewable electricity is 50.8% cheaper than net zero diesel concrete pumping.
- The total cost of ownership analysis highlighted that electric and diesel concrete pumps have equivalent initial purchase prices.
- In all scenarios where infrastructure varies, the total cost of ownership for the electric concrete pump is still cheaper.
- An absolute zero emissions outcome is achievable with an electric concrete pump rather than a net zero outcome with a diesel concrete pump.
- Price trends suggest that zero carbon costs will decrease for electrified equipment and increase for diesel equipment.
- Capital costs for electrification are project-specific and dependent on local grid capacity and need to be assessed on a project-by-project basis.
- In addition to the energy, emission and cost benefits, electrified equipment benefits workers, operational improvements, and reduced supply chain risk.

This initiative on One Sydney Harbour R3 has confirmed the findings of Lendlease and University Queensland's 2022 research into Fossil Fuel Free Construction[3] and demonstrates that electrification of construction machinery and equipment is critical in achieving Absolute Zero emissions for all Scopes by 2040.

15.
Appendix

Appendix 1: Detailed Analysis Results

	R3 - Electric Concrete Pump					R2 - Diesel Concrete Pump				
Level	Volume (m3)	Electricity (kWh)	Energy Cost ($)	Volume Normalised Energy (kWh/m3)	Volume Normalised Energy Cost ($/m3)	Volume (m3)	Diesel (kWh)	Cost ($)	Volume Normalised Energy (kWh/m3)	Volume Normalised Energy Cost ($/m3)
15	282	892.95	$183.43	3.17	$0.65	443	5063.27	$830.61	15	$1.88
16	288	892.95	$183.43	3.11	$0.64	443	5063.27	$830.61	16	$1.87
17	286	889.78	$182.78	3.11	$0.64	444	5807.87	$952.75	17	$2.15
18	285	886.61	$182.13	3.12	$0.64	449	5807.87	$952.75	18	$2.15
19	289	1106.90	$227.38	3.83	$0.79	442	5807.87	$952.75	19	$2.12
20	282	1106.90	$227.38	3.92	$0.81	442	5325.37	$873.60	20	$1.98
21	253	1106.90	$227.38	4.38	$0.90	433	5504.07	$902.92	21	$2.04
22	253	1090.15	$223.94	4.31	$0.89	532	5682.78	$932.23	22	$2.15
23	248	1073.39	$220.49	4.33	$0.89	496	5682.78	$932.23	23	$1.75
24	253	1073.39	$220.49	4.24	$0.87	453	6969.44	$1,143.31	24	$2.31
25	253	1073.39	$220.49	4.24	$0.87	456	6969.44	$1,143.31	25	$2.52
26	248	1226.35	$251.91	4.94	$1.02	450	5669.38	$930.04	26	$2.04
27	260	1226.35	$251.91	4.72	$0.97	441	4369.31	$716.76	27	$1.59
28	367	1379.77	$283.43	3.53	$0.73	451	4297.33	$704.96	28	$1.60
29	229	766.59	$157.47	3.72	$0.76	455	4225.36	$693.15	29	$1.54
30	333	1173.59	$241.08	3.52	$0.72	456	4225.36	$693.15	30	$1.52
Average	275	1060.37	$217.82	3.89	$0.80	455	5404.42	$886.57	Average	$1.95
Total	**4408**	**16965.96**	**$3,485.12**	-	-	**7286**	**86470.78**	**$14,185.14**	**Total**	-

Appendix 2: Emissions Calculations

R3 Electricity Emissions (LV 15-30)	Renewable Status	
	Procured 100% RE	Assuming 0% RE
Gross Electricity (MWh)	16.97	16.97
2023 Renewable Power Percentage (18.96%) - (MWh)	3.22	3.22
Surrendered LGCs (MWh)	13.75	0.00
Total Renewable Electricity (MWh)	16.97	3.22
Residual Electricity (MWh)	0.00	13.75
Residual Mix Factor (t CO_2-e/MWh)	0.84	0.84
Electricity Emissions (t CO_2-e)	0.00	11.54

R2 Diesel Emissions (Levels 15-30)	
Diesel Used (Litres)	8,065
Energy Content (GJ/kL)[4]	38.6
Energy Content (GJ/kWh) - General	0.0036
Energy Content (kWh/Litre) - Diesel	10.72
Diesel Used (kWh)	86,471
Emission factor - Diesel (kg/GJ)	70.2
Diesel Emissions (t CO_2-e)	21.853

[4] National Greenhouse Accounts Factors (2022)

Appendix 3: Detailed Summary Table

		R2	R3	
Concrete Pump		Stationary Diesel Trailer Pumps	Stationary Electric Trailer Pump	
Renewable Status		Not Renewable	100% RECs	*0% RECs
Levels Poured		15 - 30	15 - 30	
Average concrete pour volume per level (m^3)		454.5	275.5	
Energy Usage	Diesel used (L)	8065	-	
	Total energy used (kWh)	86471	16966	
	Average energy per level (kWh)	5404	1060	
	Concrete volume normalised average energy (kWh/m^3)	11.89	3.89	
Emissions	Total Emissions (t CO_2-e)	21.85	0	11.54
	Emissions per level (t CO_2-e)	1.37	0	0.72
	Volume normalised emissions (kg CO_2-e/ m^3)	3.01	0	2.62
Energy Cost	Energy Cost (cents per L / kWh)	175.9 c/L[1]	20.54 c/kWh[2]	
	Total Energy Cost ($)	$14,185	$3,485	
	Average cost of energy per level ($)	$887	$218	
	Concrete volume normalised average energy cost ($/$m^3$)	$1.95	$0.80	
Climate Active Cost[3]	Cost of purchasing offsets or RECs to ensure Climate Active certification ($/MWh)	$8.37	$54.41	$0.00
	Concrete volume normalised Climate Active certification costs ($/$m^3$)	$0.100	$0.211	$0.00

* Market-based Scope 2 emissions included for comparison purposes only. The project used 100% renewable electricity.

[1] Average diesel cost from March 2023 - September 2023

[2] Average peak electricity usage rate from March 2023 - September 2023

[3] The cost of RECs (LGCs) and ACCUs from March 2023 - September 2023. With ACCUs factored to MWh equivalent using consistent emissions calculation methods. REC cost only applied to the necessary percentage of electricity usage (less the RET).

Appendix 4: Total Cost of Ownership – Base Scenario

Lifespan (hours) †	18000 hours (15 Years)	
Annual operating hours (hours) †	1,200 hours (8h / 5 days)	
Annual Output (m3/year) †	20000	
Lifetime Output (m3) †	300000	
Equipment	Schwing SP 3800 E Electric 	Putzmeister BSA 2110 HP D Diesel 
Upfront purchase cost ($) *	$351,000	$352,000
Output until replacement of wear parts (m3) *	40,000 - 60,000 m3	10,000 - 15,000 m3
Cost of replacing wear parts ($) *	$5,073	$5,930
Lifetime cost of replacing wear parts ($) *	$30,438	$142,320
Output until replacement of valve (m3) §	Nil	100,000 - 150,000 m3
Cost of replacing valve (m3) *	Nil	$8,200
Lifetime cost for replacement of tube/valve ($)	Nil	$19,680
Maintenance and Service Frequency *	500 Hrs	500 Hrs
Maintenance and Service Cost *	$2,100	$3,650
Lifetime Maintenance and Service Cost	$75,600	$131,400
Average Energy Cost ^	20.54 c/kWh	175.9 c/L
Energy Cost per cubic metre ($/m3) ^	$0.80	$1.95
Lifetime Energy Cost	$240,000	$585,000
Total Cost of Ownership	$697,038	$1,230,400
Total Cost of Ownership per hour	$38.72	$68.36

† provided by equipment supplier technical documentation

* provided by Azzurri Concrete

§ provided by Azzurri, Schwing SP 3800 E does not require valve replacement as it can be effectively surface hardened between projects

^ provided from report results

Appendix 5: Total Cost of Ownership – One Sydney Harbour Scenario

Lifespan (hours) †	18000 hours (15 Years)	
Annual operating hours (hours) †	1,200 hours (8h / 5 days)	
Annual Output (m3/year) †	20000	
Lifetime Output (m3) †	300000	
Equipment	Schwing SP 3800 E Electric 	Putzmeister BSA 2110 HP D Diesel 
Upfront purchase cost ($) *	$351,000	$352,000
Infrastructure - OSH Cable Reticulation ($) #	$132,726	$0
Output until replacement of wear parts (m3) *	40,000 - 60,000 m3	10,000 - 15,000 m3
Cost of replacing wear parts ($) *	$5,073	$5,930
Lifetime cost of replacing wear parts ($) *	$30,438	$142,320
Output until replacement of valve (m3) §	Nil	100,000 - 150,000 m3
Cost of replacing valve (m3) *	Nil	$8,200
Lifetime cost for replacement of tube/valve ($)	Nil	$19,680
Maintenance and Service Frequency *	500 Hrs	500 Hrs
Maintenance and Service Cost *	$2,100	$3,650
Lifetime Maintenance and Service Cost	$75,600	$131,400
Average Energy Cost ^	20.54 c/kWh	175.9 c/L
Energy Cost per cubic metre ($/m3) ^	$0.80	$1.95
Lifetime Energy Cost	$240,000	$585,000
Total Cost of Ownership	$829,764	$1,230,400
Total Cost of Ownership per hour	$46.10	$68.36

† provided by equipment supplier technical documentation

* provided by Azzurri Concrete

Infrastructure cost of reticulation of HV cabling specific to the One Sydney Harbour project

§ provided by Azzurri, Schwing SP 3800 E does not require valve replacement as it can be effectively surface hardened between projects

^ provided from report results

Appendix 5: Total Cost of Ownership – Initial Battery Purchase Scenario

Lifespan (hours) †	18000 hours (15 Years)	
Annual operating hours (hours) †	1,200 hours (8h / 5 days)	
Annual Output (m3/year) †	20000	
Lifetime Output (m3) †	300000	
Equipment	Schwing SP 3800 E Electric 	Putzmeister BSA 2110 HP D Diesel 
Upfront purchase cost ($) *	$351,000	$352,000
Infrastructure - Initial Battery Purchase ($) #	$450,000	$0
Output until replacement of wear parts (m3) *	40,000 - 60,000 m3	10,000 - 15,000 m3
Cost of replacing wear parts ($) *	$5,073	$5,930
Lifetime cost of replacing wear parts ($) *	$30,438	$142,320
Output until replacement of valve (m3) §	Nil	100,000 - 150,000 m3
Cost of replacing valve (m3) *	Nil	$8,200
Lifetime cost for replacement of tube/valve ($)	Nil	$19,680
Maintenance and Service Frequency *	500 Hrs	500 Hrs
Maintenance and Service Cost *	$2,100	$3,650
Lifetime Maintenance and Service Cost	$75,600	$131,400
Average Energy Cost ^	20.54 c/kWh	175.9 c/L
Energy Cost per cubic metre ($/m3) ^	$0.80	$1.95
Lifetime Energy Cost	$240,000	$585,000
Total Cost of Ownership	$1,147,038	$1,230,400
Total Cost of Ownership per hour	$63.72	$68.36

† provided by equipment supplier technical documentation

* provided by Azzurri Concrete

Assumed cost of purchasing a sufficient battery (450kWh at $1000AUD/kWh)

§ provided by Azzurri, Schwing SP 3800 E does not require valve replacement as it can be effectively surface hardened between projects

^ provided from report results

Schwing SP 3800 E

Putzmeister BSA 14000 HP D

Putzmeister BSA 2110 HP D

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