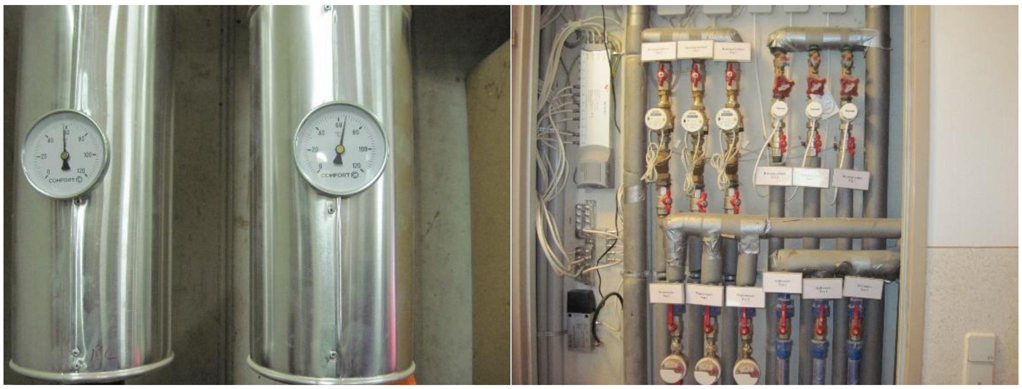
Nunduk Retreat & Spa Energy Stream Concept Design



David Coote
Analytical Engines

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Revision History

Date	Version	Description	Author(s)
13/9/2017	v1	Initial draft release for joint team project meeting	David Coote
25/01/2018	v2	Updated version includes: changed nomenclature; electric vehicle energy use calculations; more detailed water consumption/rainfall capture from CJ Arms and consequent energy use; scaled Retreat Main Building and Villa energy use based on estimated occupancy; scaled sewage pumping; new charts and tables; communications tower energy consumption; energy use for 15 villas and brief outline of control system and communications.	David Coote

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Summary

This report presents financial and energy performance modeling for a candidate offgrid renewable energy solution at the proposed Nunduk Retreat & Spa. Estimates of energy demand are included for the energy demands within scope. Candidate energy system solutions comprising a Renewable Energy Hub delivering cost-effective, reliable, innovative, low-carbon energy outcomes containing a mix of intermittent and despatchable renewables combined with energy storage and onsite energy distribution infrastructure are outlined with indicative costs and 20 year Net Present Value (NPV) analysis. An integrated approach with engagement of the other project streams is presented.

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1. Executive Summary

The candidate Nunduk Retreat & Spa energy system comprises:

- 415V 3 phase power distributed to loads from the services centre sharing trenches with the thermal bore water distribution where feasible
- Estimated loads:
    - peak 154kW
    - annual load of 900MWH
- 300kW PV, 200KWH battery, 2 x 100kW biodiesel generators
- Smart Grid/Internet of Things Control and monitoring over a data network

Initial cost estimate is $2-2.2M.

Energy System Component	Nameplate rating	Purpose	Initial cost estimate
Roof mounted PV array with 100m trenching, conduit and power cable	300kW	Cheap renewable energy	$450k
Battery storage	200KWH	Store excess renewable generation	$300k
Power distribution, switchboards, metering	NA	Required for distributing and metering power within Nunduk Retreat & Spa Renewable Energy Hub	$300k
1.5km power cable and conduit to production bore sharing thermal water pipe trench	30kW	Supply power from REH to bore pump	$300-450k
Biodiesel generators, shed, connection gear, biodiesel tanks	2 x 100kW	Despatchable generation to meet residual demand after PV and batteries	$400k
Smart Grid/Internet of Things/Energy Management system	NA	Used to monitor and control Renewable Energy Hub components	$200k
		Total	$2-2.2M

Table 1 Proposed Nunduk energy system major components and costs

2. Purpose

The purpose of this report is to define the energy demand of the Nunduk Retreat & Spa Retreat (including Geothermal activities) and to identify and cost candidate energy system solutions for this demand.

3. Context

Nunduk Retreat & Spa will be a self-sufficient development utilising off-grid renewable electricity and thermal energy. A material contribution to the energy used onsite will be in the form of bore water extracted from production bores onsite. This report lists requirements derived from the document "Nunduk Retreat & Spa: Design Brief – December 2017 v3" (NRSDB December 2017, version 3), documents from other project streams and discussions with the project executive and members from other streams.

3.1. In scope

1. Renewable energy supply to:
    a. Nunduk Retreat & Spa Main Building
    b. Villas
    c. Electric vehicles
    d. Communications equipment
    e. Desalination plant
    f. Potable water supply
    g. Nunduk Retreat & Spa blackwater/sewage/waste water
    h. Production bore
    i. Injection bore
    j. Holding pond for waste spa water
2. Supply only connection to external grid.

3.2. Out of scope

1. Energy supply for fish farm equipment and bore water supply to fish farm.
2. Bore water piping distribution network other than pumps.
3. Other agriculture and industrial/commercial activities and associated electricity and thermal loads.
4. Frequency control and other ancillary functionality have been left to subsequent project design phases.

3.3. Assumptions

1. Nunduk Retreat & Spa is designed to Passivhaus standard.
2. Nunduk Retreat & Spa domestic hot water (showers/baths, kitchen, cleaning etc) will be heated by bore thermal water through a heat-exchanger.
3. Onsite staff accommodation for 20 staff.
4. All equipment such as appliances, computers and HVAC kit at the Nunduk Retreat & Spa and villas, pumps at other zones and other is in the top category of the relevant energy efficiency rating scheme such as the Commonwealth Government Energy Rating initiative (http://www.energyrating.gov.au/about/what-we-do/labelling).
5. All pumps have variable speed drive (VSD) capability.
6. All significant loads and supply (thermal and electric) have submetering and BACnet/MODBUS interfaces for monitoring and control.
7. Zones use buffering and intermittent operation synchronised to intermittent generation where cost-effective.
8. All zones define realistic energy supply reliability requirements. Providing reliability is costly in a conventional grid and even more so in an off-grid renewable system with high percentage contribution from intermittent renewables. Realistic reliability requirements for the Nunduk Retreat & Spa and other zones are essential to inform further design phases of the Nunduk Retreat & Spa Energy System. After loads are more tightly defined during the project Detailed Design phase, Loss of Load Probability calculations and other risk assessment and mitigation techniques for the deployed energy system solution can be used to meet reliability requirements.
9. A data network utilising cable and wireless communications will be available across the Nunduk Retreat & Spa site.
10. All electrical distribution will be underground.
11. Electrical distribution cables/conduits can be colocated with thermal bore water distribution pipes.
12. Nunduk Retreat & Spa infrastructure components supplying electricity and requiring electricity supply are located as shown in the architecture document (waiting on Jose). Aggregating the electricity generation and consumption where practical minimises trenching, conduit and cabling costs.
13. Light poles on the entrance road and around the car park and services centre are solar powered by dedicated onpole PV arrays and battery sited with the pole.

3.4. Constraints

1. 100% renewable energy supply.
2. Wood energy systems not considered for onsite energy production due to developer preference.
3. Grid connection only used for regenerative supply to grid of excess generation.
4. Focus on delivering cost-effective, reliable, renewable energy as against pushing the innovation envelope.

3.5. Nunduk Retreat & Spa Energy System Requirements

Supply renewable electricity (including buffer/contingency) to:

- Nunduk Retreat & Spa Main Building sufficient to run loads including:
    a. HVAC equipment
    b. Refrigeration
    c. Computers, audio-visual and control system
    d. Electric cooking
    e. Lighting
- 15 accommodation villas totaling 6000m^2 floor area. Indicative Passivhaus electricity consumption assumed.
- Onsite accommodation for 20 staff.
- Nunduk Retreat & Spa area to pump seasonally varying (peak 30 kl/day) of potable water from desalination plant/storage tank/rainwater tanks to Nunduk Retreat & Spa (including villas).
- Nunduk Retreat & Spa area to pump seasonally varying (peak 30 kl/day) of blackwater/sewage to treatment area.
- Nunduk Retreat & Spa area to pump peak seasonally varying (peak 15 kl/day) of irrigation water from desalination plant/potable water storage/rainwater tanks to irrigate Retreat roof and surrounding garden/landscaped area.
- Nunduk Retreat & Spa area to pump 400 kl from spas to holding pond between 10pm to 2am.
- Desalination plant near services centre producing peak 35 kl/day assuming average rainfall.
- Holding pond to operate pump to injection bore draining 400 kl/day.
- Production bore (1500m from Nunduk Retreat & Spa) to pump 400 kl of bore water to the Nunduk Retreat & Spa between 2am and 8am.
- Production bore (1500m from Nunduk Retreat & Spa) to pump 8 l/s warming water to the Nunduk Retreat & Spa between 8am and 8pm.
- Communication tower
- Electric vehicle chargers for onsite and offset electric vehicles comprising initially:
    a. Onsite use:
        i. 10 small cabin off-road EV with utility trays
        ii. 2 x 1.5 tonne trucks
        iii. Minibus
    b. Offsite use
        i. 4 Retreat EV cars
        ii. 4 guest EV cars

4. Nunduk Retreat & Spa Renewable Energy Hub Overview

4.1. Introduction

Large, centralised grid systems using mainly despatchable fossil fuel generators dominate energy supply in affluent nations. Concerns regarding energy resource scarcity and anthropogenic climate change have focused attention on renewables in large scale grids and offgrid solutions. Offgrid renewable systems are quantitatively and qualitatively different. Nunduk Retreat & Spa can use a mix of intermittent and despatchable renewables combined with energy storage and onsite energy distribution infrastructure. Delivering cost-effective, reliable, innovative, low-carbon energy outcomes across the project is facilitated by an integrated approach utilising a mix of intermittent and despatchable renewables, high-efficiency appliances and successful Passivhaus design and construction at the Nunduk Retreat & Spa coupled with careful attention to the nature and management of onsite energy loads, supply and distribution at both the Nunduk Retreat & Spa and other zones. Making design decisions reflecting these factors at the concept stage simplifies subsequent more detailed design, implementation, operations and maintenance.

4.2. Energy Hub overview

The Nunduk Retreat & Spa Renewable Energy Hub (REH) manages the site energy systems as a coordinated whole. The hub contains battery and thermal storage, PV, wind and biodiesel generation. Spokes distribute energy to and from zones. Zones could also supply and consume energy through the rim and buffer thermal energy.

The cost of energy supplied within the Nunduk Retreat & Spa site will be determined by energy system component installation costs, operations and maintenance costs, discount rates and any margins. Cost accounting for the energy flows between zones is straightforward. Charging for energy use will encourage cost-effective solutions and using energy efficiently within the site.

The REH contains major loads, generation, storage, distribution and energy management. These components are discussed below.

Detailed Design Phase Recommendation: Siting Nunduk Retreat & Spa components including infrastructure for potable water, sewage, thermal water production and injection bores and desalination plant has various effects on other project stream components. The cost per metre of conduits and cabling to connect loads to the REH is expensive. The cost of connecting the REH components to the services centre also depends on location. If project component locations might change during detailed design, project streams would benefit from a centrally managed working model of Nunduk Retreat & Spa component locations with clearly defined, quantified impacts of location decisions on project budget. Commercial software packages are available with relevant functionality. A simple optimisation model could be built quickly.

5. Concept design load descriptions and load curve estimates

This section contains load estimates for the Nunduk Retreat & Spa and associated infrastructure.

5.1. Scaling approach reflecting seasonality and occupancy

Some energy demands have been scaled to reflect estimates of seasonal and intra-week occupancy as used by CJ Arms (Nunduk Retreat and Spa Integrated Water Cycle Management Strategy, 12/01/2018) to estimate water consumption. Varying electricity consumption with seasonal and intra-week guest numbers can be complicated. Energy consumption from space heating and cooling would be expected to show variation with occupancy and season but a baseline consumption would be expected for HVAC in shared areas. If the pool and all spas are available year-round, the thermal water consumption and energy used to distribute this water will not vary. Simplifying assumptions are made for seasonal and intra-week energy modeling during this phase. Table 2 outlines the approach taken to scaling energy demand.

Demand	Scaling approach
Main retreat Building	Scaled for season and intra-week occupancy
Villas	Scaled for season and intra-week occupancy
Onsite staff accommodation	Not scaled
Desalination	Scaled to meet CJ Arms water consumption estimates
Potable water	As for desalination
Black water sewage	As for desalination for volume used in Retreat (not irrigation)
Bore water to retreat	Not scaled
Bore water from retreat	Not scaled
Electric vehicles	Not scaled
Communications	Not scaled

Table 2. Scaling approach for Nunduk electricity demands

5.2. Total Nunduk Retreat & Spa energy load curve and demand splits

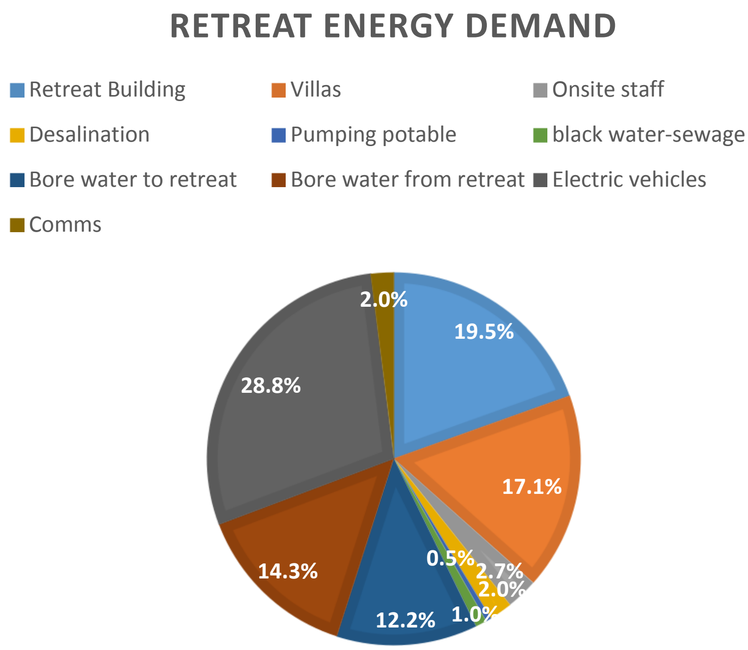

Figure 1. Nunduk Retreat & Spa energy demand split

	Retreat Building	Villas	Onsite staff	Desalination	Pumping potable	black water-sewage	Bore water to retreat	Bore water from retreat	Electric vehicles	Comms	Total
Total KWH	174,085	152,138	24,361	17,846	4,273	8,634	108,624	127,779	256,595	17,520	891,856
Max 30 min KWH	21	29	4	4	0	1	13	24	26	1	77
Min 30 min KWH	3	2	0	0	0	0	0	4	11	1	37
Max kW	42	57	8	8	1	1	27	48	51	2	154
Min kW	7	3	1	0	0	1	0	8	22	2	73

Table 3. Estimated 30 min interval data summary

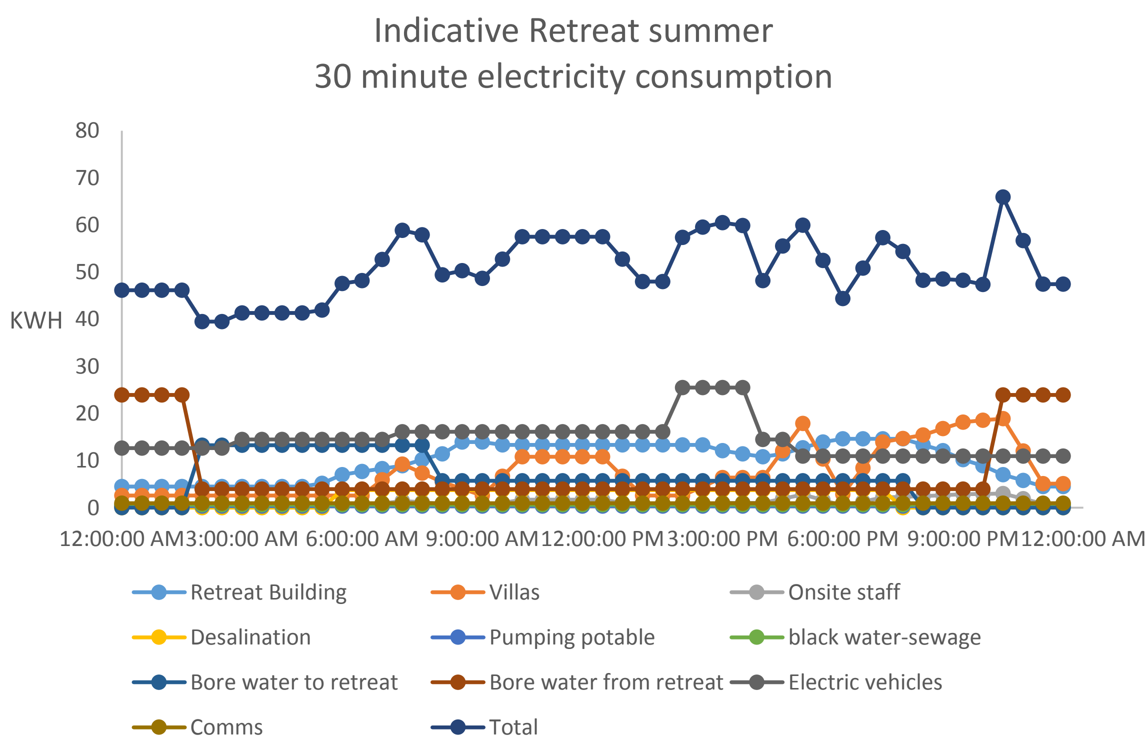

Figure 2. Indicative 30 minute interval Nunduk Retreat & Spa summer electricity consumption

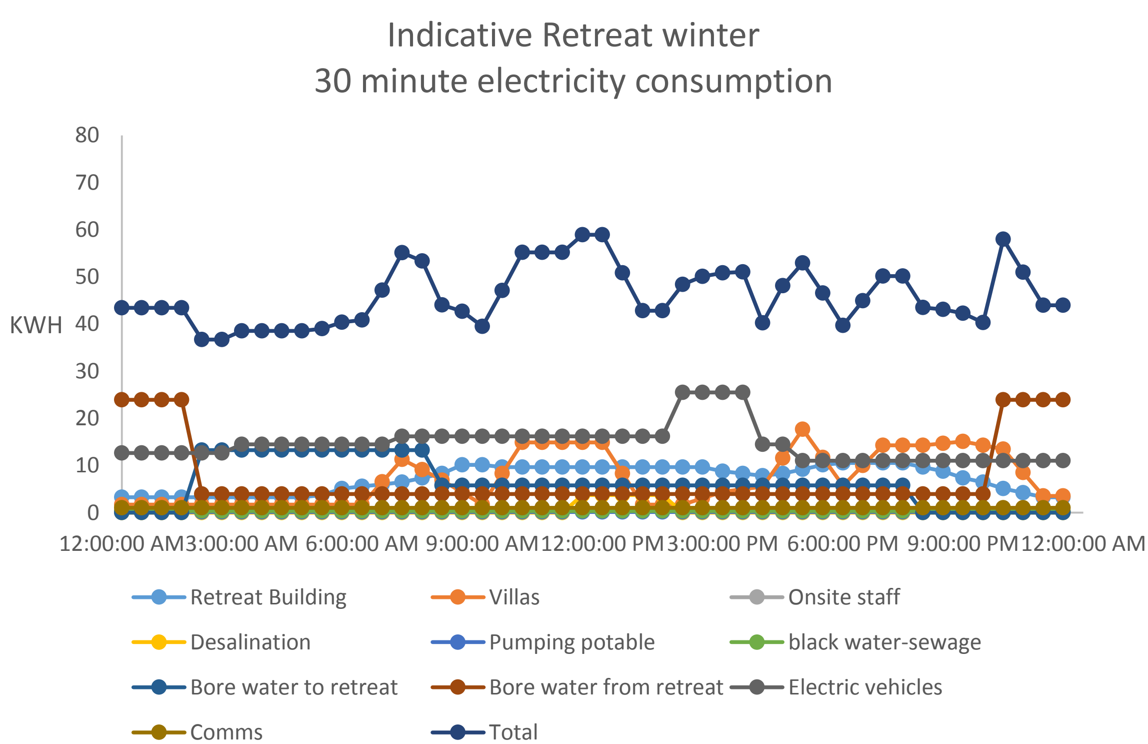

Figure 3. Indicative 30 minute interval Nunduk Retreat & Spa winter electricity consumption

The Nunduk Retreat & Spa energy demand is dominated by the electric vehicle charging consumption followed by the Main Building, guest villas and pumping bore water to and from the Nunduk Retreat & Spa (Table 2, Figure 1). The estimated indicative summer day (Figure 2) and winter day (Figure 3) load curves are reasonably flat after simulating Smart Grid capability to match demand to available generation. The total Nunduk Retreat & Spa load curve and demand was estimated as an aggregate of the load curves detailed below.

5.3. Nunduk Retreat & Spa Main Building load curve

The energy system modeling approach used in this report uses 30 minute interval data. Operational data of this nature for a comparable Passivhaus development was not available. The NABERS hotel energy use modeling tool was used to create estimated annual total splits of the energy use within the Nunduk Retreat & Spa. This data was smoothed into a simulated daily load curve. Note that Main Building interior space cooling may be required for guest amenity for short periods during summer. If this is cooling is required, Atelier Ten estimate the electricity demand to supply a lakes source heatpump and air movement will be around 60kW. This would potentially raise the peak demand above the current estimate. As this would occur during summer, it's likely that PV and storage with supplementary power from biodiesel generators would meet the demand.

Detailed Design Phase Recommendation: The next project stage should include appropriate Loss of Load Probability modelling including this cooling demand if the cooling demand is identified as required.

5.4. Villa load curve

The load curve for 15 villas was estimated using previous work by Atelier Ten on Passivhaus residential buildings.

5.5. Electric vehicles

The load curve for EV's was estimated for an indicative EV fleet and charging cycle (Table 4). Battery characteristics are based on vendor information and industry experience.

EV	Battery size (KWH)	Number	Charge loss (%)	Max DoD	% of fleet charged per day	Vehicles charged/day	charge as % of DoD	KWH required/ day
small cabin off-road EV	20	10	5%	90%	50%	5	20%	19
1.5 tonne truck	30	2	5%	90%	50%	1	50%	14
Mini-bus	100	1	5%	90%	100%	1	100%	95
Retreat EV passenger cars	100	4	5%	90%	50%	2	100%	189
Guest EV passenger cars	100	4	5%	90%	100%	4	100%	378
							Total	695

Table 4. Indicative Nunduk and guest EV fleet and daily charging assumptions

Charging estimates are based on the use of Type 2 chargers delivering 3 -7kW and Fast Type 2 chargers delivering 22kW. Type 3 EV chargers deliver up to 50kW which would represent a significant load spike on the Nunduk energy system. However, Type 3 chargers may be necessary for guest amenity. After discussion with the project executive, the proposed design approach at this point is to include a Type 3 charger which would only be used when energy supply capacity is available.

5.6. Communications

The load curves for communications equipment are based on vendor information and industry experience. A constant load of 2kW for the communications tower and NBN satellite connection were assumed.

Communications infrastructure would be required for:

- Guest and staff Internet, email, telephony and video streaming
- LAN access across the Retreat main building, villas and services infrastructure
- Communications across the broader Retreat site
- Monitoring and control of energy system components
- Other purposes as discussed in the control system section below

The bandwidth available from the proposed NBN satellite connection is limited. Connection to the nearest Internet infrastructure with significant bandwidth available will require a line-of-sight microwave connection mounted on a tower of the requisite height. Other communications will benefit from a tower at the Retreat for mounting equipment such as antennas. Initial investigation of potential connection points to Internet infrastructure would require a communications tower of 50-60m.

5.7. Desalination load curve

The desalination load curve was derived based on information supplied by CJ Arms, indicative plant operational performance data from a desalination plant vendor and industry data.

The desalination vendor provided indicative information on several items for their reverse osmosis technology:

- The desalination plant ideally runs continuously or for lengthy periods
- When turned off for more than a few minutes a plant at the envisaged scale will require 300l of fresh water to flush
- The plant runs at its nameplate value and is not suited to fractional output operation
- A larger plant running during the day to take advantage of PV generation will be more expensive than a smaller plant running continuously. Optimisation analysis can be used to identify cost-effective combinations of desalination plant size and renewable energy systems.

Other assumptions:

- Desalination efficiency: 3KWH/kl
- Total volume: scaled to meet total volume of 5.7ML/annum used for retreat potable water and irrigation.

5.8. Pumping thermal bore water from the production bore to the Nunduk Retreat & Spa

The load curve for the thermal bore supply to the Nunduk Retreat & Spa was estimated using spa pool filling and spa warming volume data from the document "Seacombe West geothermal energy project".

- Operational cycle assumes:
  - warming water supplied between 8am and 8pm
  - Spa pool filling water supplied between 2am to 8am
- Pump efficiency: 0.4KWH/kl

5.9. Draining waste spa water from the Nunduk Retreat & Spa to the holding pond and from the holding pond to the reinjection bore

The load curve to pump water from the Nunduk Retreat & Spa to the holding pond and from the holding pond to the reinjection bore was estimated using volume data from the document "Seacombe West geothermal energy project".

- Operational cycle assumes:
  - Water pumped from the Nunduk Retreat & Spa to the holding pond between 10pm to 2am
  - Water pumped continuously from the holding pond to the reinjection bore
- Pump efficiency: 0.4KWH/kl

5.10. Pumping potable water to the Nunduk Retreat & Spa

The load curve to pump potable water from the desalination plant to the Nunduk Retreat & Spa was estimated from information supplied by CJ Arms and an estimated supply operation cycle.

- Volume: scaled to meet total supply of 10.7ML comprising desalination and rainwater capture used by the retreat and irrigation
- Operational cycle held constant assuming buffers within potable water reticulation network
- Pump efficiency: 0.4KWH/kl

5.11. Pumping black water from the Nunduk Retreat & Spa

The load curve to pump black water from the Nunduk Retreat & Spa was estimated from information supplied by CJ Arms and an estimated waste water disposal operation cycle as per potable water supplied to the Retreat (non-irrigation).

6. Electricity Generation

Solar, wind and biodiesel were considered for the concept design as modular, scalable, proven renewable generation technologies. Modularity and scalability in the generation energy system components allow flexibility as loads are added and subtracted during subsequent design phases and for future growth.

6.1. Solar

Photovoltaics generating electricity are a well-proven technology with over 400GW installed globally. PV can be deployed in sizes from a few W's powering a calculator to hundreds of MW. Insolation data from the East Sale Airport was used in the PV-Watts application to derive a PV generation curve with conservative estimates of inverter and other losses and panel efficiency. PV design and installation contractor Lean Energy supplied indicative prices for PV installation in the 100kW – 500kW range as rooftop and ground mounted arrays. Indicative costs for rooftop arrays at this scale cost are $1.50/W installed and ground mounted arrays $1.70/W. Connection to the services centre for a ground-mounted array could cost several hundred dollars/metre depending on array size. Rooftop area available for PV includes the villas and the carpark/services centre. PV installations modeled were assumed to be roof-mounted on the carpark/services centre.

6.2. Wind

The estimated total concept design Nunduk Retreat & Spa load curve is well suited to a mix of PV and wind with substantial night load. The consultancy Enhar used 10m wind speed data from the East Sale Bureau of Meteorology (BOM) weather station and turbine performance characteristics to derive a generation curve for an indicative Northwind 100kW turbine with a 37m hub height. Enhar also supplied indicative installation and operations and maintenance costs for the 100kW turbine.

Concept design energy and cost performance modeling below indicates the 100kW turbine reduces the quantity of biodiesel generation required but at estimated higher system cost over 20 years on the turbine cost and performance characteristics supplied. However, the generation data provided for the wind turbine indicates a conservative capacity factor of ~20% (Capacity factor is defined as total energy generated / (nameplate rating x hours in year)). 20% is at the low end of capacity factor for modern wind turbines in a reasonable wind regime which might expect to achieve up to 45%. Turbines can be optimised for a range of outcomes including output at various wind speeds, synthetic frequency control and minimum and maximum operational wind speeds. Multiple smaller turbines as against one larger turbine provide redundancy but may be more costly per installed kW. Factors influencing turbine location include ground mechanical qualities, distance from trees and obstructing landforms, prevalent wind direction, connection distance to the services area with consequent trenching, cable and conduits capex, shade from the turbine on PV arrays, noise and visual amenity. While the East Sale BOM data is likely to be a reasonable basis for the wind turbine energy modelling in the concept design, measuring onsite windspeed at multiple heights is straightforward. Subsequent design phases would need to consider these factors to determine optimal wind turbine deployment at Nunduk Retreat & Spa.

Detailed Design Phase Recommendation: A short feasibility study focused on:

- optimising wind turbine potential at the site
- suitability of the site to a turbine with ~40m – 60m hub and appropriate foundation and other civil works for the weight of the tower and turbine

would support a decision on whether or not to proceed with more detailed engineering on wind energy as part of the initial REH and would inform future REH enhancement to supply new loads.

The wind turbine would operate as an embedded system supplying energy to the offgrid Retreat and infrastructure. No energy is supplied to the grid. This may simplify planning permission for the wind turbine.

6.3. Biodiesel

Biodiesel from sustainable sources is regarded as a renewable, low-carbon fuel. The Australian Government National Greenhouse Accounts Factors (August 2016) reports biodiesel emissions as 0.27kg CO_2-e/GJ and 34.6GJ/KL. A well-maintained generator running efficiently will generate ~3.2KWH/l. 20% of an indicative 1000MWH annual total Nunduk consumption would require 200MWH of generation using biodiesel or 63KL/annum for total emissions of less than a tonne of CO_2-e using these figures. Biodiesel can be made from a variety of sources. The sustainability of biodiesel made from palm oil plantations replacing forest is regarded by many commentators as poor. Sources such as the UK Renewable Transport Fuel Obligation (see https://www.gov.uk/government/publications/renewable-transport-fuel-obligation-rtfo-guidance-year-9) report GHG emissions from palm oil biodiesel and broadscale oil seed farming as higher than from biodiesel made from waste cooking oil and tallow. Sourcing Nunduk biodiesel made from waste vegetable oil and tallow will use a waste product and cause minimal environmental impact.

Biodiesel generators can be deployed in a scalable, modular manner to provide despatchable, reliable energy. However, while biodiesel generators are cheap, fuel and operations and maintenance costs make this an expensive form of renewable energy. Because liquid renewable fuels made from sustainable feedstock are extremely useful but limited in supply and likely to remain so for the immediate future, the biodiesel price may rise in the short-term. Consideration of these factors suggest that while biodiesel has a useful role in the Nunduk Retreat & Spa REH, other intermittent renewables combined with storage should provide the majority of energy supply.

The 2x100kW biodiesel generators proposed in the REH concept design modelling are capable of supplying the entire load if required. Generators selected for deployment will be capable of operational despatch down to 25% of the Maximum Continuous Rating with reasonable efficiency. Multiple generators installed with this degree of modulation contribute flexibility to a reliable, efficient REH.

6.4. Battery storage

Storage is an essential component of a renewable energy system with high usage of intermittent generation. While a topic of considerable media attention at the time of writing, larger scale storage deployment using Li batteries is still relatively uncommon. Tesla, the focus of much of the attention, have announced the Powerpack 2. Tesla claim this unit has 220KWH storage, 50kW power interface and support for frequency control and power quality. Units of this type are inherently modular and can be installed as demand increases with appropriate charging energy available. However, as this market is in considerable flux at the time of writing, the approach taken for REH modelling is to assume an indicative unit as follows:

Storage size	200KWH
Cost	$1500/KWH
Charge/Discharge	100kW maximum
Depth of discharge	90%
Charge loss	5%
Discharge loss	7%

Table 5. Indicative battery parameters

This cost may fall appreciably in timeframes relevant to the Nunduk Retreat & Spa development. During detailed design the module size, charge/discharge power, inverter size and other factors can be optimised for the site loads.

Li batteries require specified climate conditions to meet warranty obligations and avoid operational failure. Fire suppression systems would be required for batteries of the size envisaged. Anticipated Passivhaus Nunduk Retreat & Spa design internal space temperatures would satisfy the Li battery requirements. However, the batteries in operation may require ventilation and/or cooling beyond what is supplied for the internal Nunduk Retreat & Spa guest spaces. Battery room fire control could roll up under the Nunduk Retreat & Spa requirements but again may require fire suppression beyond what is provided for internal Nunduk Retreat & Spa guest spaces. Siting the batteries at the Nunduk Retreat & Spa rather than the services centre complicates managing the REH energy despatch strategy as a whole. Containerised battery solutions exist with climate control and fire suppression included. These containerised storage solutions can be installed at the Retreat services centre.

Depending on the actual battery vendor selected, the system energy despatch strategy for the REH as a whole and for the battery subsystem will depend heavily on the battery control capabilities. To encourage efficient electricity use the Nunduk Retreat & Spa REH is likely to have a cost accounting allocation of energy costs possibly expressed through a defined tariff structure with demand charges. This would assist cost-effectively delivering energy to parties operating fish farms and other commercial activities onsite. This system would encourage optimised use of battery storage to reduce peak demand and peak tariff period consumption.

Detailed Design Phase Recommendation: The next project stage should include an initial analysis of the cost of supplying energy from the REH to loads covered in the concept design with respect to volume (KWH), peak demand (kW) and tariff period. Once built, this model can be used to derive energy cost data for currently envisaged loads and prospective demands. The International Energy Agency suggest the Levelised Cost of Energy technique for objective analysis of energy costs.

6.5. Thermal storage

Although the concept design stage has focused on battery storage, discussion with the bore zone and sustainability/architecture streams indicates the potential to buffer thermal energy at the Nunduk Retreat & Spa and within the bore water distribution network. Other potential zones such as the fish farm and agriculture could also buffer thermal energy from the bore and also using excess intermittent generation. Thermal storage design and implementation at this scale is straightforward and cheap. The project architect states that plant room space will be available at the Nunduk Retreat & Spa for insulated thermal storage. Other buffers in the field could be cheap UV stabilised polyethylene tanks for short-term storage or more expensive insulated tanks if required. Thermal storage will be defined in subsequent project phases with the relevant project streams.

7. Electricity Distribution

The concept design is based on a 415V 3-phase network between the services centre and load, all cabling underground and dedicated links and switching for the PV installation, batteries and wind turbine. Electrical engineering consultancy Atillies provided indicative installation prices for switchboards, cables, conduits and ancillary equipment.

Using bore water pipe trenches for electrical conduits and cables would potentially save considerable trenching costs. Regulatory requirements for colocating electrical conduits and cables with water pipes must be considered in trenching design, costing and implementation.

The concept design siting for the production bore pump is 1.5km from the services centre. Supplying AC power over this distance for a 30kW pump requires expensive cables to minimise voltage drop. The indicative costing for concept design includes electrical supply of this pump from the services centre. However, it may be cheaper to have the production bore supplied by a standalone hybrid energy system comprising generator, PV and batteries. Using Li batteries in the field complicates climate control for the batteries. Internal temperature in exposed sheds in an Australian summer can reach temperatures over 60C. A remote hybrid system would also complicate maintenance.

Detailed Design Phase Recommendation: A shed (with appropriate vegetation shading to reduce internal temperature) containing a hybrid renewable solution for the remote production pump including battery technology more suited to higher temperatures should be investigated early in the next phase.

Grid connection for supply to grid was examined during concept design. Ballpark engineering estimates for a 3km connection from the services centre to the 22kV line on the property boundary are around several million dollars. Supply to the grid in the form of excess generation from a REH tailored for Nunduk Retreat & Spa supply will not be cost-effective.

8. Energy Management System

Smart Grid/Internet of Things technology controlling and monitoring energy system components are essential for complex renewable energy solutions. Indicative price estimates for the Nunduk Retreat & Spa REH control system are based on industry experience. The REH energy management system will roll up under a broader Nunduk Retreat & Spa Control/Management System that will provide security services, monitor occupancy, display alarms and other functions as discussed below.

9. REH cost and energy performance modelling

Renewable energy systems have an installed cost, operations and maintenance costs and fuel for biodiesel generators. Biodiesel systems are cheap to install but expensive to operate. A useful way to compare candidate REH components is to sum installation and annual costs over a relevant time period and apply a time value of money technique with a suitable discount factor. The REH concept design analysis incorporates Net Present Value (NPV) over 20 years using these costs and discount rates.

Energy system component	Real discount rate[1]	Installation cost	Operations and maintenance cost
PV 100kW PV	10%	$150,000	$0.01/W/annum
Battery 200KWH (nominal) battery and BMS/controller	10%	$300,000	$3000/annum
Wind turbine 100kW	10%	$800,000	$30,000/annum
Generator[2] 100kW	10%	$100,000	$0.09/KWH

Notes

[1] Real rate can be set to value requested by investor. Nominal rate can be used. Analytical Engines can also model WACC, various debt/taxation structures as required.

[2] NPV calculations include 20 year biodiesel consumption (@ $1.20/litre, 3.2KWH/litre) to meet residual demand after intermittents and batteries.

Table 6. Major proposed energy system components NPV calculation inputs

Costs are as provided by specialist consultancies and industry experience. The discount factor of 10% can be adjusted for investor requirements. This analysis can be adjusted to calculate debt/taxation structures, Weighted Average Cost of Capital, use inflators/nominal rates and other. This analysis is also the basis of the Levelised Cost of Energy (LCOE) technique discussed earlier.

NPV (20 years)	Generation/storage capacity				Initial load		Excess			Biodiesel generator(s)/Residual		
	PV (kW)	Wind (kW)	Batteries (KWH)	Generator (kW)	Peak (kW)	load (KWH)	Peak (kW)	KWH	% generation	Peak (kW)	KWH	% initial
$3,730,686	0	0	0	200	154	891,856	0	0	0%	154	891,856	100%
$3,796,570	0	100	0	200	154	891,856	41	4,583	2%	148	641,901	72%
$3,107,446	100	0	0	200	154	891,856	0	0	0%	143	694,384	78%
$3,457,269	100	100	0	200	154	891,856	87	22,439	3%	143	516,153	58%
$3,042,155	100	0	200	200	154	891,856	0	0	0%	115	595,659	67%
$3,353,204	100	100	200	200	154	891,856	92	10,203	1%	115	407,634	46%
$2,792,083	200	0	0	200	154	891,856	78	23,903	8%	143	574,682	64%
$3,284,408	200	100	0	200	154	891,856	166	82,338	9%	143	432,447	48%
$2,679,208	200	0	200	200	154	891,856	83	8,933	3%	115	463,938	52%
$3,145,103	200	100	200	200	154	891,856	171	58,515	6%	115	315,026	35%
$3,379,707	200	100	400	200	154	891,856	171	32,515	3%	115	292,056	33%
$2,720,001	300	0	0	200	154	891,856	163	109,259	25%	143	516,433	58%
$3,286,943	300	100	0	200	154	891,856	246	186,543	17%	143	393,047	44%
$2,566,307	300	0	200	200	154	891,856	167	81,108	19%	115	395,378	44%
$3,131,251	300	100	200	200	154	891,856	251	156,823	15%	115	271,487	30%
$2,769,059	300	0	400	200	154	891,856	167	46,002	8%	115	364,361	41%
$3,301,920	300	100	400	200	154	891,856	251	112,543	9%	115	232,366	26%
$2,760,270	400	0	0	200	154	891,856	247	222,995	39%	143	486,565	55%
$3,367,278	400	100	0	200	154	891,856	330	310,400	26%	143	373,298	42%

Table 7. NPV, excess generation and residual demand met by biodiesel generation for combinations of PV, wind and battery storage

NPV in this analysis represents time value adjusted total costs, a smaller NPV total represents a cheaper energy solution over 20 years for these input costs and estimated generation curves, battery performance and load curves.

The lowest (most cost-effective) NPV solution in Table 2 has 300kW PV and 200KWH of battery storage supplying 56% of the load curve with the biodiesel generators supplying 44% and 19% of the PV generation wasted. Adding a further 200KWH of storage has slightly higher NPV but has reduced the biodiesel contribution to 41% and reduced the excess to 8% of intermittent generation. Adding 100kW of wind reduces the biodiesel contribution to 26% but increases the NPV. These results highlight the benefit of a focused wind study as recommended above to define the potential contribution of wind to the REH. Cheaper storage would also improve utilisation of intermittent generation with lower NPV impact. These outcomes represent high annual penetration of intermittent energy sources compared to existing isolated grids.

Varying items such as the amount of PV and battery storage and including or omitting the wind turbine provides an initial sensitivity analysis for the NPV. Further sensitivity analysis during detailed design in subsequent project stages will assist energy system deployment decisions. Deploying PV as ground mounted array in orientations other than northerly can be examined to examine the NPV and other impacts of higher generation in the morning and evening. Sensitivity analysis can be extended to examine the NPV or LCOE sensitivity to changes in installation or fuel costs.

10. Control System

10.1. Introduction

The control system will be a key infrastructure component within the Nunduk Retreat & Spa project. Working with the Nunduk Retreat and Spa communications system the control system will provide Building Management System and other capability including:

- Security including interior and exterior space monitoring, alarms and locks
- Biometric access if required
- Automated, staff and guest (where appropriate) control and monitoring of lights, HVAC, drapes, windows, pools and other Retreat infrastructure and fittings
- System component monitoring and control using Smart Grid and Internet of Things capability
- Staff and guest dashboard and other displays of infrastructure and assets realtime and historic data
- Fault finding and remediation assistance
- Asset tracking including onsite vehicles
- Assistance in detection of fraud and other crimes

10.2. Control System/Energy System Project Stream Design and implementation factors

Efficient control and monitoring of energy system components is an essential part of the Nunduk Retreat & Spa control system. Factors that should be considered by project streams during project design and implementation include:

Storage/Buffering

When onsite generated energy is available but not required, storage can assist load smoothing and other desirable outcomes. Common storage forms include thermal in the form of hot water used for hygiene and heating and electricity in batteries. Storage can also act as a buffer to improve energy supply reliability and resilience. For example, the geothermal zone could supply hot water to a buffer (a large tank) at a fish farm on the site for use when supply from the geothermal plant is interrupted.

Detailed Design Phase Recommendation: Project streams should include buffering/storage where appropriate and cost-effective for the project as a whole.

Matching loads to supply

Intermittent renewables like solar and wind generate power when sun or wind is available. This means that at times Nunduk Retreat & Spa PV or wind will be generating electricity beyond the immediate demand. While this excess generation can be stored and also possibly exported into the grid, storage generally loses energy through conversion and self-discharge and excess generation sold to the grid will likely be at a relatively low price per KWH. Onsite loads that match onsite generation profiles can cost-effectively use onsite generated energy and thus reduce excess generation.

Detailed Design Phase Recommendation: Project streams should design processes to match onsite energy generation cycles.

Deferring/dispatching loads

Some energy loads can be deferred or turned on or off to accommodate peaks and troughs in energy availability. A familiar example is hot water for bathing which needs to be available for showers but can be preheated and stored in a tank. Demand response initiatives on the conventional grid turn off some demand at participating factories or commercial buildings at peak times. Cool rooms used to store produce can be pre-chilled at times when energy is available to reduce demand during later peak periods.

Detailed Design Phase Recommendation: Project streams should design to include equipment that can be deferred and dispatched in this fashion and ensure that all equipment used for major loads has appropriate interfaces to allow monitoring and control by protocols such as BACnet or MODBUS.

Distribution

Energy can be distributed within Nunduk Retreat & Spa to and from the various project streams. A micro-grid can distribute electricity and a District Heating System (DHS) supply heat.

Detailed Design Phase Recommendation: Project streams should determine what electricity and thermal energy supply they will require, the volume, peak loads and where micro-grid and any DHS connections will be required.

Monitoring loads and supply

As well as potentially controlling loads and supply, the Renewable Energy Hub will need to monitor energy system components.

All electrical equipment with material loads will be submetered. Energy meters will monitor thermal energy loads. This information will be collated and presented as part of the site Energy Management System.

Energy supply reliability

What is the cost to a project stream of an interruption to energy supply? The Nunduk Retreat & Spa will need high supply reliability as part of the guest experience. Other streams may cope with shorter or longer supply interruptions. A fish farm, for example, will need reliable supply for lighting and water oxygenation but could perhaps tolerate brief interruptions to hot water supply.

Detailed Design Phase Recommendation: Project streams should consider the energy supply reliability they require for successful operation.

Energy supply cost

The cost of energy supplied within the Nunduk Retreat & Spa site will be determined by energy system component installation costs, operations and maintenance costs, discount rates and any margins. Project streams will be allocated energy system costs to at least cover these costs.

Detailed Design Phase Recommendation: Project streams will should consider the range of energy costs they can afford as part of their business operations.

Appendix 1: Grid and off-grid energy systems

The electricity grid supply in higher-income countries comprises mainly centralised large scale fossil fuel generators (with large-scale hydro a major contributor in some grids) distributing electricity over complex networks that can stretch across continents. The electricity supply sector has seen enormous investment since inception in the 1800's. For example, there is around $2 trillion dollars invested in coal power in the northern hemisphere. The large investments in supply and infrastructure and extensive engineering experience developed by the electricity sector coupled with the inherent redundancy afforded by mesh networks and multiple despatchable generators achieves remarkable supply reliability levels in many grids. Most home owners turn on residential appliances and lights without thinking about how the power is generated.

However, even in the modern grid, turning on all the appliances in a home simultaneously may exceed the supply limit and cause a supply interruption through various safety mechanisms in the switchbox. Recent large-scale blackouts in South Australia's grid highlight supply interruptions due to a series of distribution failures in an affluent nation.

Offgrid supply systems have existed in Australia for decades. Where the broader grid is not available these range from small residential scale supply through larger systems at mines, to isolated grids supplying large remote towns using diesel generators. Recent offgrid focus is on decarbonised projects using intermittent renewables and battery storage. From industry experience a number of characteristics are common to many residential offgrid supply sites using solar with batteries:

- Very strong focus on energy efficiency and generally reducing electricity load. Offgrid homes may use wood heating and gas refrigerators to further reduce electricity load.
- Close attention to battery storage levels.
- Acceptance of no electricity during extended periods of reduced sunlight or extensive use of a generator.

Energy system expectations at Nunduk Retreat & Spa are higher than those for many previous renewable offgrid sites including reliable 100% renewable supply. Industry experience in offgrid systems can inform design of a system to satisfy expectations at Nunduk Retreat & Spa. The Nunduk Retreat & Spa offgrid energy supply system could, for example, incorporate:

- Sophisticated energy management capability to monitor and control the components of the energy system to achieve desired outcomes and to provide data for quick fault finding and remediation. This capability fits within the broader theme of what's commonly called Smart Grid/Internet of Things technology of which some examples are:

    - Controlling batteries, PV and dispatchable renewable energy generators (using sustainable feedstock) to supply required loads.
    - Matching despatchable/deferrable loads to available intermittent generation.
    - Demand response where loads such as air-conditioning are reduced at times of peak load.
- Selected onsite components supplying well characterised thermal and electricity loads.
- Intermittent renewables in the form of PV or wind generation in a coordinated energy system
- Both thermal (hot water in tanks) and battery storage to smooth thermal and electricity loads and store excess generation from PV (battery and thermal through a resistance heater and/or variable load heatpump)
- Strong focus on energy efficient appliances and Passivhaus design in the Nunduk Retreat & Spa.

As mentioned previously, the conventional grid has massive investment in various components and redundancy to provide the reliability levels enjoyed by electricity users in wealthy nations. For example, it's common in these grids to have roughly 20% of the total capacity – which can represent billions of dollars of investment – only used for a small number of hours per annum during peak demand periods. In Australia this peak demand is typically late in a hot afternoon during summer when air-conditioning units are running flat out. System load shedding and other load management approaches may be used during these periods.

In the conventional grid, costs for convenience of use and reliability are amortised across many users and large consumption volumes. Obviously this is qualitatively and quantitatively different for an offgrid site like Nunduk Retreat & Spa. Useful examples are provided by what are commonly called "island grids" supplying power to islands, mines and remote communities. Instead of one diesel generator they will have multiple generators with some comprising what is called spinning reserve ie running at low power ready to ramp up quickly when the current generator fails. These island grids will also often limit the percentage (commonly called the penetration) of intermittent renewables such as wind or solar to simplify grid reliability.

However, with sufficient battery storage – particularly as this becomes cheaper - and other system approaches discussed below the penetration of intermittent renewables can increase.

But with current technology an offgrid system is inherently different to a grid supply system.

The challenge at Nunduk Retreat & Spa is to balance system components, cost, convenience of use and system reliability to achieve acceptable performance.

Appendix 2: Electric vehicles and boats onboard battery charging and supply

Introduction

Electric vehicles and boats (EVB) at Nunduk Retreat & Spa will require onsite charging. This means that the energy hub will need to cater for any initial EVB electricity demand and under the general energy supply modularity framework will need to cater for increased future demand. EVB also potentially offer supply/buffering capacity where excess renewable generation is stored in the batteries and used to meet onsite demand.

Likely initial demand

Electric vehicles

While some countries such as Norway have seen substantial government support for electric vehicles to the point where they now form a significant fraction of new car sales, very few electric vehicles have been sold in Australia for onroad use. Rapidly improving EV range and sale price reduction combined with any new government EV support initiatives may increase Australian EV uptake. An indicative initial Retreat and guest EV complement is included in the concept design. A modular REH design will allow rapid expansion of onsite energy supply to meet this demand as it develops.

The SE development could mandate use of EV's onsite where practical for internal transportation. Vendors such as Alke (https://www.alke.com/electric-vehicles) supply a range of relevant electric vehicles. Off-road side-by-sides exist such as http://www.polaris.com/en-au/ranger-utv/ranger-ev-avalanche-gray). Electric forklifts (if required by Nunduk) are common. The Retreat could mandate EV's for any Nunduk Retreat & Spa owned onroad vehicles. A mandate of this nature would help with branding the project.

Electric boats

This sector is very small with few electric boats sold in Australia. If Nunduk mandates electric boats - again a branding differentiator - the energy demand will depend on factors such as how many boats, when and how often the boats are used, when they are available for recharging and boat battery sizes. This demand can be also be defined in later stages of the project as required.

Using EVB's onboard batteries for supply

With wider EV deployment expected, a common suggestion is to use the vehicle batteries for supply. At Nunduk Retreat & Spa, batteries in boats and EV's could potentially be used to supply energy to the Nunduk Retreat & Spa and other development energy uses and also to the external grid as a demand response measure. However, EV batteries are likely to be optimised for the operational cycles within the manufacturer's design envelope. And warrantied specifically for this usage. Occasional use of onboard batteries in emergency situations such as a Prius supplying power during 2017 grid interruptions in South Australia or during Hurricane Sandy in New York are quite different to using EV batteries on a regular basis as part of a planned, coordinated energy supply. If the car manufacturers don't support use of onboard EVB batteries for supply, the warranty may be voided by this use. This would deprecate the use of guest and Nunduk Retreat & Spa owned EV's for this purpose. Possibly individual manufacturers would support this use and governments may require this capability within the large vehicle fleets they operate or more generally. Analytical Engines suggests a watching brief on this issue for the moment.