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Feasibility analysis of stand-alone renewable energy supply options for a large hotel

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Abstract

This paper provides a feasibility analysis of renewable energy supply (RES) for a stand-alone supply large-scale tourist operation (with over 100 beds). The analysis utilises the power load data from a hotel located in a subtropical coastal area of Queensland, Australia. The assessment criteria of the analysis are net present cost, renewable factor and payback time. Due to the limited number of RES case studies in tourist operations and the absence of studies for large resorts, requiring facilities with a higher degree of comfort such as air-conditioning, it is not possible to establish with confidence the viability of RES in this industry. The specific operational characteristics of the tourism accommodation sector, such as 24-h operation, comfort provision and low tolerance for failure necessitates a separate assessment of RES viability for this sector, rather than relying on similar assessments from other commercial sectors. This study uses RES assessment software tools, HOMER (National Renewable Energy Laboratory, US) and HYBRIDS (Solaris Homes, Queensland, Australia), in order to compare diesel generator-only, RES-only and RES/diesel hybrid technologies. HOMER uses hourly load data, whilst HYBRIDS uses average daily energy demand for each month. The modelling results demonstrate that RES, in principle, has the potential to adequately and reliably meet power demand for a stand-alone large-scale tourist accommodation. Optimisation modelling demonstrates that 100% of power demand can be supplied by a RES-only configuration. A hybrid diesel/RES configuration provides the lowest NPC result with a resultant RF of 76%. In comparison to the diesel generator-only configuration, NPC is reduced by 50% and Greenhouse Gas (GHG) emissions by 65%. The payback time of the hybrid RES scenario is 4.3 years. Results indicate that wind energy conversion systems (WECS), rather than photovoltaics, are the most economically viable RES for large-scale operations. Large-scale WECS (over 1000 kW) are more efficient and economical than multiple small-scale WECS (0.1–100 kW). Both modelling tools produced similar results, with HYBRIDS producing on average slightly higher NPC results than HOMER. The modelling and resulting data from the analysis indicate that RES is technically feasible and economically viable as a replacement for conventional thermal energy supply for large-scale tourist operations dependent on stand-alone power supplies.

Keywords: Renewable energy systems; Micro-generation; Stand-alone power systems; Large-scale tourist hotel accommodation; Optimisation software; Payback time

1. Introduction

Tourist destinations do not always have the benefit of grid-connected electricity for power supply and must rely on diesel generator stand-alone power supply (SPS) systems [1]. The Australian tourist accommodation sector's consumption of diesel accounts for approximately 6% of the total diesel used by general industry [2]. As such, it contributes significantly to greenhouse gas (GHG) emissions and impacts locally where situated in environmentally sensitive locations [3].

Abbreviations: SPS, stand-alone power supply; RES, renewable energy supply; Hybrid RES, renewable energy supply with diesel generator; IC, initial cost including installation costs; O/M, operation and maintenance costs; NPC, net present cost; RF, renewable fraction; PV, photovoltaics; WECS, wind energy conversion systems; DOD, depth of discharge; NREL, National Renewable Energy Laboratory

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GHG emissions can be reduced by either of two processes, namely:

(1) implementation of energy efficiency measures and/or
(2) production of power by renewable energy supply (RES) initiatives, such as passive and active solar, wind, hydro-power, bio fuels, etc.

The implementation of energy efficiency measures is well studied [4–7] and is not considered in this paper. Studies of successful RES installations have been carried out on many non-tourist enterprises and may be split into two configuration categories:

(1) RES for complete autonomous supply, such as photovoltaic (PV-only) configurations [8], wind energy conversion systems (WECS-only) [9] and combinations of PV/WECS-only [10–12].
(2) RES in 'hybrid' combinations with diesel generator, such as PV hybrids [13], WECS hybrids [14,15], PV/WECS hybrids [16,17] and large-scale PV/WECS hybrids [18].

Load patterns for tourist destinations differ from commercial or domestic operations, due to their relatively high power consumption rate that can operate over extensive periods in a 24-h cycle [7]. Because of these considerations, energy studies of domestic and commercial utilities may not be representative of tourist operations.

Only two comprehensive feasibility case studies appear in the literature examining the feasibility of RES in SPS tourist accommodation. Bakos [19] reported a successful PV set-up for a small-scale tourist operation (up to 10 beds) in Greece, concluding that the configuration was economically viable. Bechrakis et al. [20] also demonstrated the viability of a proposed wind/hydrogen system for a small-scale hotel in Greece. Whilst other case studies considering functional SPS RES operations have been reported, they do not conduct rigorous feasibility analysis. These studies include a successful wind/diesel hybrid implementation in a small-scale tourist operation in the Cocos Islands [21,22] and PV/wind diesel hybrid implementation in Sarawak [23] and Australia [24]. Successful PV/diesel generator hybrids are reported in a medium-sized tourist operation (10–50 beds) in Belize [25,26] and a medium-large resort (50–100 beds) in Australia [27].

As indicated, these RES studies have been conducted on small and medium-sized, mostly "ecotourist" type, SPS operations. Large mainstream tourist resorts (over 100 beds) have not been extensively studied. Large-scale accommodation operations have unique operational characteristics in comparison to their smaller counterparts, demanding larger load capacity due to increased air-conditioning requirements and more expansive comfort facilities. Assessment of RES feasibility for large-scale tourist accommodation operations will thus be the focus of this paper.

A recent survey of Australian tourist operators identified a reluctance to adopt RES systems [28]. Only a limited number of operations in that study incorporated RES (10%, including passive solar).[1] Studies reveal that a perception exists within the tourist sector that RES is incapable of supplying sufficient power [28,33], is unreliable [28,34] and, most importantly, is not economically viable [28,34,35] with extensive payback times [36]. Few case studies have examined whether these perceptions are valid, especially with regard to large-scale SPS-dependent tourist operations.

This paper addresses the following research gaps:

1. Can RES, in principle, adequately and reliably supply power for a large-scale tourism SPS accommodation operation?
2. Which RES configuration provides the most economically viable solution, using NPC as the basis of comparison?
3. Which RES components are the most suitable to provide power at this scale, considering net present cost (NPC) and the footprint required?
4. How long does it take to achieve a positive cash flow for the optimal RES configuration?

To address these research questions, a RES feasibility analysis was conducted using load data determined from a large-scale resort, situated in the subtropical Gold Coast area of south-eastern Queensland in Australia. This resort, a grid-connected operation, was deemed typical of other large-scale remote non-grid connected tourist operations with regard to guest capacity and load demand. The site was selected due to its convenient location and on-site energy management system which enabled access to year-long hourly load data. The load data were utilised as a proxy data file input for a large-scale SPS tourist accommodation operation.

Modelling software for distributed power was used to examine the above research aims; namely HOMER (a public domain software produced by National Renewable Energy Laboratory, US [37]) and HYBRIDS (a commercially available application produced by Solaris Homes, Queensland, Australia [38]). Both programs assess the technical potential of RES for a given configuration, determining the potential renewable fraction (RF) and evaluating economic viability based on NPC. The two programs used adopt different methods for RES assessment. HOMER is a time-step simulator using hourly load and environmental data inputs, whereas HYBRIDS is a simple spreadsheet-based RES assessment application.

HOMER software facilitates the optimisation of RES configurations based on NPC for a given set of constraints

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[1] Note, that while passive solar heating is a well-established technology and is successfully deployed in tourist destinations [29–32], it does not produce electricity, and will not be included in the RES technologies considered in this study.

and sensitivity variables. The time-step simulation method is the most commonly used RES assessment routine. Other applications which use a time-step method include Baring-Gould et al. [39] and Notton et al. [40], which use incremental time-scales of 1 h and 1 min, respectively. The time-step simulation method's main disadvantage is that it requires significant computational effort. Furthermore, time-stepped environmental input data, especially wind data, may not be available for many locations. Much research has been conducted to improve the performance of RES assessment software in order to decrease simulation time and/or reduce the number of variables used. Celik [41] developed a predictive algorithm requiring monthly average values of wind speed distribution parameters and PV irradiance, enabling the estimation of system performance using simple wind distribution parameters and thus eliminating the necessity for a simulation program and hourly data. Protogeropoulos [42] simplified this process further by using an annual average method, whilst Morgan [43] used a worst month case scenario method. Muselli [44] and Kaye [45] developed these predictive algorithms further in the form of stochastic and dynamic optimisation models, incorporating uncertainties in demand, component failure and weather behaviour in the estimation of RES potential. Dufo-Lopez [46] and Seeling [47] used 'genetic' algorithms (GA) reducing simulation time significantly, addressing the problems of uncertain renewable energy supplies, load demand and the non-linear characteristics of some components by incorporating past and future demand.

However, none of these models are either publicly or commercially available. HOMER was chosen as the primary application for this study as it has been used extensively in previous RES case studies [48–55] and in RES validation tests [46,56–62]. Although simulations can take a long time, depending on the number of variables used (up to 48 h on a standard PC for some hydrogen storage configurations), its operation is simple and straightforward. The program's limitation is that it does not enable the user to intuitively select the appropriate components for a system, as algorithms and calculations are not visible or accessible.

The second model used in this paper is HYBRIDS. It is a Microsoft Excel [63] spreadsheet-based application and design tool, requiring daily average load and environmental data estimated for each month of the year. NPC is processed transparently using basic RES equations, without the use of time-step simulation. Unlike HOMER, HYBRIDS can only simulate one configuration at a time, and is not designed to provide an optimised configuration. Optimisation can only be achieved by manually changing the configuration settings and re-simulating, which can lead to operator error due to the number of changes required for each simulation. HYBRIDS is comprehensive in terms of RES variables and the level of detail required and necessitates a higher level of knowledge of RES configurations than HOMER. It is designed so that the user improves their RES design skills through its application. HYBRIDS has been recently released and this study contributes to its validation by comparison of its results to that of HOMER.

A comparison will be made of the results from the two models considering the four research areas mentioned above. The models will also be compared with respect to consistency of result and ease of use. The results will enable the assessment of RES for other similar large-scale tourist accommodation operations in locations with comparable climatic and geographic characteristics. All costs are in Australian dollars (AUD$).

2. Software tools

2.1. HOMER

HOMER [37] is primarily an optimisation software package which simulates many system configurations and scales them on the basis of NPC. HOMER first estimates whether a system is technically feasible, i.e. if the RES system can adequately serve the electrical and thermal loads and any other constraints imposed by the user. Secondly, it estimates NPC of the system, which is the total cost of installing and operating the system over its lifetime.

HOMER models a particular system configuration by performing an hourly time-step simulation of its operation over 1 yr. The following fundamental calculations are performed during each time-step. Firstly, the available renewable supply is calculated and is compared to the required electrical load. If RES satisfies the demand, any excess electricity is spread to other secondary demands. If the demand is not satisfied, alternative supply, either by diesel generator or grid generation, is sought to fill the deficit. HOMER's 1-h time step is sufficiently small to capture most of the statistical variability of the load and the fluctuating renewable resources, but not so small as to slow computation excessively. Finally, after 1 yr of simulations, any constraints on the system imposed by the user are assessed; e.g. the fraction of the total electrical demand served or the proportion of power generated by renewable sources.

2.1.1. Load supply data

HOMER uses hourly data that are obtained by either of the following two methods:

1. A full year of hourly load data input as a text file.
2. Average 1-day load data. HOMER expands this 1-day data using randomisation functions and correlations to annual temperatures related to global latitude and longitude.

Option 1 was chosen as the source input as it was considered to produce the most representative results. Hourly load data for the case study hotel were retrieved from the energy management system installed on site. The data were measured in kWh and at half-hourly increments.

2.1.2. Net present cost (NPC)

HOMER uses total NPC to represent the life cycle cost of the system. This includes all costs and revenues that occur within the project lifetime, with future cash flows discounted to the present. The NPC includes the initial cost (IC) of the system components, the cost of any component replacements that occur within the project lifetime, the cost of maintenance and fuel. The NPC is calculated according to the following equation:

$$\mathrm{NPC}(\$) = \frac{\mathrm{TAC}}{\mathrm{CRF}}, \tag{1}$$

where TAC is the total annualised cost (which is the sum of the annualised costs of each system component). The capital recovery factor (CRF) is given by

$$\mathrm{CRF} = \frac{i(1+i)^N}{(1+i)^N - 1}, \tag{2}$$

where N is the number of years and 'i' is the annual real interest rate (%).

HOMER assumes that all prices escalate at the same rate, and uses 'annual real interest rate' rather than the 'nominal interest rate'. This method allows inflation to be factored out of the analysis. The overall annual (real) interest rate (i) in the simulations was taken to be 6% [64,65]. Project lifetime for this case study was taken as 20 years.

NPC also takes into account any salvage costs, which is the value remaining in a component of the power system at the end of the project lifetime. HOMER assumes a linear depreciation of components, meaning that the salvage value of a component is directly proportional to its remaining life. It also assumes that the salvage value is based on the replacement cost rather than the initial capital cost. The equation to calculate salvage value (S) is

$$S(\$) = C_{\mathrm{rep}} \frac{R_{\mathrm{rem}}}{R_{\mathrm{comp}}}, \tag{3}$$

where Crep is the replacement cost of the component, R_{rem} *is* the remaining life of the component (t) and R_{comp} is the lifetime of the component (t).

2.1.3. Battery dispatch

Ideally, the priority of battery charging should take into account future load and supply. HOMER incorporates the battery dispatch strategies of Barley and Winn [66], namely 'load following' and 'cycle charging', and are used as an alternative to the use of probabilistic logic. Under the load following strategy, a generator produces only enough power to serve the load, which does not charge the battery bank. Under the cycle charging strategy, whenever a generator operates it runs at its maximum rated capacity, charging the battery bank with any excess electricity produced. The generator will not stop charging the battery bank until it reaches the specified state of charge set by the user. Cycle charging was chosen as the case study dispatch strategy as it is the more suitable for large-scale systems, providing greater longevity both for the diesel generator and battery bank, due to less frequent stopping and starting, and battery bank and a reduced risk of over-discharge.

2.1.4. Renewable fraction (RF)

The RF is the portion of the system's total annual electrical production originating from renewable power sources. It is calculated by dividing the total renewable power production by the total energy production.

2.1.5. Constraints

2.1.5.1. Operating reserve. HOMER's operating reserve constraint (commonly called 'spinning reserve') is the additional reserve capacity which a system requires to account for sudden increases in the electric load or sudden decreases in the renewable power output. An hourly electrical load reserve of 10% was defined for the present case study, as recommended by Cotrell [53]. Higher reserves were defined when using the renewable output due to their inherent variability and were set at 25% for PV and 50% for WECS.

2.1.5.2. Capacity shortage fraction. The capacity shortage fraction (CSF) is the fraction of the total load plus operating reserve that the system fails to supply (i.e. allowable blackout). A CSF can be defined by the user as a constraint and is normally set up to a maximum of 2% of hourly load for most SPS RES simulations [67]. This 2% limit was chosen for this study.

2.2. HYBRIDS

HYBRIDS uses a series of interlinked spreadsheet equations for system power generation and economic assessment. Inappropriate configurations input by the user, are flagged by the software, indicating how best to reconfigure the system before the software continues the analysis. Features in HYBRIDS, such as transparency and internal checking, facilitate user understanding and good system design. The following outlines the main input requirements for HYBRIDS, and compares them to HOMER where appropriate.

2.2.1. Load supply data

HYBRIDS requires daily average energy loads for each month of the year. Load data can be determined by two different methods:

1. Energy load profile calculated from a manual energy audit. The power rating for all appliances are listed, together with the total number of operation, multiplying them together to obtain the average daily energy demand (kWh) for that day. Input of monthly average temperatures as well as monthly heating and cooling

hours, enables HYBRIDS to estimate daily average load for each month of the year.
2. Load collected from a data logger or energy management system. Unlike HOMER, which uses hourly inputs, HYBRIDS only accepts average daily energy consumption (kWh) per month.

Option 2 was used for this case study, as the hourly data obtained from the study site could be easily transformed to daily averages for each month.

2.2.2. NPC

HYBRIDS uses the following equation to deduce the NPC:

$$\mathrm{NPC}(\$) = \frac{\mathrm{TCO}(1+i)^N}{(1+\mathrm{MDR})^N}, \qquad (4)$$

where TCO is the total capital outlay and represents all ICs, replacements costs and operations/maintenance for that year, 'i' is the annual inflation rate, N is the cumulative number of years (t) and MDR is the market discount rate or the rate of return of the investment (ROI).

The MDR is adjusted by the inflation rate so that all future costs are being discounted to represent the real discount rate. Real discount rate is the market discount rate minus the inflation rate. Use of the MDR in HYBRIDS allows the user to specify individual inflation rates for different commodities, such as fuel or lead in batteries. MDR is similar to HOMER's capital recovery factor (CRF).

High discount rates discriminate against RES as they have high upfront costs and low running costs. Values for Australian MDR have been quoted by Gavin [68]: 14% for commercial ventures, 7% government and 3% domestic. A more recent value for MDR of 10% was chosen for this paper, modified from Heaney [69] and a general inflation rate of 4% [70].

2.2.3. System voltage and load safety factors

HYBRIDS requires that the system voltage be specified, which is chosen on the basis of the maximum demand on the DC bus. Due to the large size of the power generating system, the maximum system voltage available was chosen, being 240 volts (V). (Other voltages available were 12, 24, 48 and 110). A 'load safety factor' (LSF) is specified for HYBRIDS (which is not the same as HOMER's load factor) and is an additional percentage load added onto the existing load to cover shortfalls. An average value of 5% is usually taken to cover this fluctuation in load demand. However due to the smooth daily load profile obtained from the site (see Fig. 2 below), a 2% LSF in HYBRIDS was used. Many of load settings and components in HYBRIDS are rated in kVA (kilovolt amps). This value incorporates a 'power factor', which describes the ratio of active power to apparent power [71], and was taken to be 0.8 for this case study. HYBRIDS has inputs for the maximum half-hourly daily demand and surge demand. This is similar to the operating reserve in HOMER. These were input as 1125 and 1500 kVA, respectively, the former value obtained from inspection of the hourly load profile.

2.2.4. System configuration

HYBRIDS requires the system configuration be defined by either of the three following options:

1. *Series*: DC configurations or AC under 1 kWh/day.
2. *Switched*: AC loads, but must be tolerant of short breaks in supply.
3. *Parallel*: requires an interactive converter that allows synchronous bi-directional power flow between battery bank and diesel generator, eliminating the risk of short power supply breaks [72]. Parallel configuration allows both the AC component (usually wind turbine) as well as the diesel generator to directly supply the load, rather than having to be routed through the converter and battery bank, producing greater efficiency.

The parallel configuration was chosen for this case study, as the possibility of multiple short power supply breaks would not be tolerated for a large-scale operation.

2.2.4.1. Fraction of diesel generator to load. This factor in HYBRIDS has an equivalent in HOMER, contained in the battery dispatch strategy section. 0% value is used in series configuration, where diesel generator charges battery 100% of the time. In systems where the diesel generator operates 24/7, and where there are no battery or inverter (and consequently no battery charging), a 100% value is used. In this study, the diesel generator runs in parallel with the RES system and requires a certain percentage of the diesel generator time to charge the batteries. A value of 40% was chosen, as recommended by Berrill [38].

2.2.4.2. Component efficiency values. HYBRIDS requires the user to specify values for many efficiency factors which are either not accounted for in HOMER, or are assumed in the underlying algorithms. Final results from HYBRIDS can be sensitive to these values. Table 1 lists system component losses recommended for SPS.

2.3. Summary

Both HOMER and HYBRIDS produce results based on NPC and RF. HOMER uses an hourly time-step method, whereas HYBRIDS uses simple spreadsheet algorithms requiring only monthly average values. HOMER will produce results with a greater degree of detail and enable analysis of the RES system performance over the entire 12-month period. However for the purpose of this paper, only the final NPC result is required, enabling HOMER to be compared with HYBRIDS.

Table 1
HYBRIDS efficiency factors for SPS[a]

	Value (%)
Transmission efficiency, battery to load	90
Transmission efficiency, WECS to battery	95
Transmission efficiency, PV to battery	95
WECS voltage regulator efficiency	95
Battery energy efficiency	80
Battery charger efficiency	80
Invertor efficiency	90
Maximum power point tracker (MPPT) efficiency	96
PV temperature coefficient of power	(Usually 0.5)
Average diesel generator loading for expected operating regime	75–85

[a] Efficiency values obtained from the Australian Standard AS4509 [81].

The NPC estimation for the two programs should produce similar results, as comparable forms of the discount rate method are used for both, although different variables are used in their estimation. HOMER requires comprehensive diesel generator schedules, which are not available in HYBRIDS. Consequently HOMER results should reflect improved diesel generator performance, reduced fuel consumption and reduced NPC in comparison to HYBRDS for similar configurations. HYBRIDS has more system input requirements, which assists in good system design, but can increase the possibility of result variation due to the substantial sensitivity to some these input variables e.g. the efficiency factors. It is anticipated that NPC may also vary due an increased chance of data input error.

3. Data inputs and component specifications

3.1. Site details

Data for this paper was accessed from the energy management systems of a large-scale resort situated in the subtropical Gold Coast area of south-eastern Queensland, Australia. The resort is of a tower block style, 28 stories high with a small footprint of approximately 36,000 m^2, 378 bedrooms, and can accommodate a guest capacity of approximately 1000 guests.

Fig. 1 shows the annual load profile of the case study hotel derived from hourly load data obtained from the hotel's energy management system. Peak energy consumption is in the summer months from December to February, and minimum in the winter months, August to September. The annual energy consumption for the hotel was 5.5 GWh, with an average energy consumption of 15,000 kWh/day. Peak load for the year was 966 kW.

Fig. 2 illustrates that the hotel's energy management system succeeds in producing a smooth daily energy load profile, without any significant peaks or fluctuations. It achieves this through load shedding.

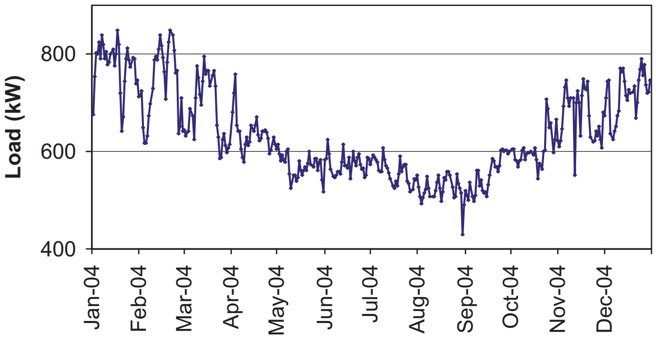

Fig. 1. Hourly energy load profile for the year 2004, Gold Coast hotel resort.

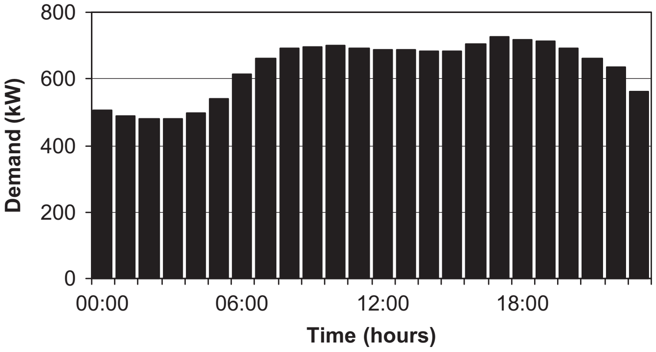

Fig. 2. Energy load profile for 24-h period, 2004, Gold Coast hotel resort.

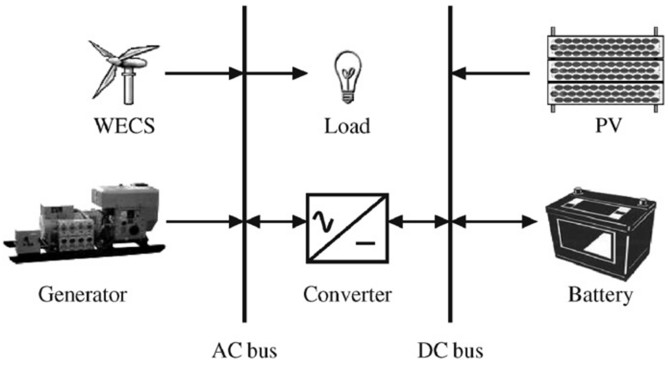

Fig. 3. Energy flow diagram for alternating current/direct current (AC/DC) buses.

3.2. System configuration

A hybrid energy system generally consists of RES sources working in conjunction with a standby non-renewable SPS and storage modules.

Fig. 3 illustrates a large-scale hybrid configuration that will be used as the basis of the case study simulations. Wind turbines over 10 kW usually produce AC, requiring connection to the AC bus. The advantage of this configuration is that the power can directly supply the load without having to be diverted through the DC bus and storage components, thus saving on energy efficiency. PV

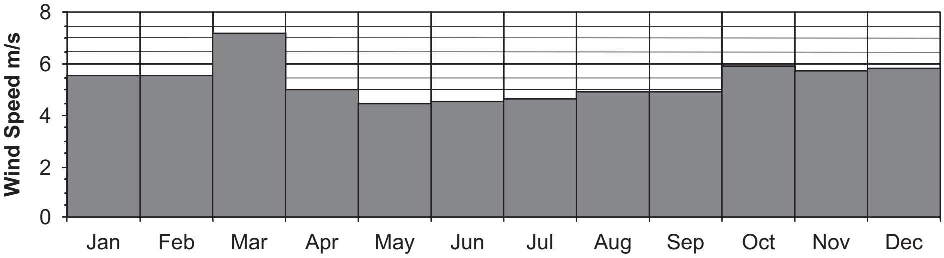

Fig. 4. Average monthly wind speed in m/s, at Gold Coast Seaway, 2004 (supplied by the Bureau of Meteorology, station 40764).

and battery modules exit from the DC bus, and a converter links both AC and DC buses.

3.3. Environmental data

3.3.1. Wind resource data

The closest anemometer location was the Bureau of Meteorology (BOM) facility in the Gold Coast Seaway, latitude 29° south, and longitude 153° east, 4 km from the hotel case study location. The anemometer is on top of a 10 m mast, and situated on the foreshore. The average wind speed for 2004 was 5.85 m/s with a small variation in monthly average wind speed between 4 and 6 m/s (Fig. 4). The summer months had higher wind speeds, peaking in March at 15.5 m/s. The Weibull K factor (a measure of the distribution of wind speed over a year) was 2.04[2] and an auto correlation factor (randomness in wind speed from hour to hour) of 0.839.[3] These data are extrapolated to the hub height of the WECS used in the modelling.

3.3.1.1. HOMER. Average hourly wind speed data in m/s for the year 2004 were input as a text file. Only a general surface roughness (SR) (as measured by roughness length) is specified, with no factoring of wind direction or time of year. An average SR value of 0.04 m was chosen, corresponding to crop fields, which is representative of the terrain around the site. HOMER does not account for varying prevailing wind directions throughout the year.

3.3.1.2. HYBRIDS. Instead of direct hourly input of wind speed data, HYBRIDS requires a frequency histogram of wind speed for each month. HYBRIDS requires input of SR for each month with the value varying according to the direction of the prevailing wind. From September to June, the average prevailing wind direction is a southeast (SE) sea-breeze and a low surface roughness of 0.04 m was used. During the winter months of June to August, the average prevailing wind changes to a west/southwest (W/SW) direction, traversing a rougher topography, and a higher SR selected value of 0.28 m was selected.

3.3.2. Solar resource data

Hourly solar data were not available from the Gold Coast Seaway weather station (only monthly averages were available). The closest station was at the University of Queensland (UQ) in Brisbane. The two locations are around 100 km apart and have similar weather patterns [75].

3.3.2.1. HOMER. Hourly data are used for the solar irradiance input. Fig. 5 illustrates a summer monthly average peak of 6 kWh/m^2/day, and a winter low of 3.4 kWh/m^2/day, with an annual average of 4.9 kWh/m^2/day. The average clearness index is 0.53.

3.3.2.2. HYBRIDS. A frequency histogram of the hourly irradiance values for each month is required and is then converted to monthly average irradiance (kWh/m^2/day). The ambient monthly mean daytime temperature is also input. HYBRIDS includes the irradiance data and temperatures for Brisbane as the default, and this option was used here. HYBRIDS also requires the user to specify 'shading'. The solar panels are considered to be 'located' on the roof of the hotel (which has minimal shading) for the purposes of the case study.

3.4. Micro-generation renewable energy components

3.4.1. Introduction

Micro-generation RES are defined as energy generation technologies that are installed in individual premises [76]. Although the size of these RES components can range in supply from 1 kW up to 1 MW, micro-generation pertains to supplying a particular source demand rather than a broad network, with direct financial connection to that source. RES technologies available for micro-generation are in general limited to PV and micro-wind.[4] Micro-hydro applications are confined to a few site-specific locations in Australia, due to the limited availability of water and appropriate terrain. Other RES types such as wave, tidal and geothermal are still at the research stage and are not

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[2] Typical values range from 1.5 to 2.5. Higher k values, which correspond to narrower wind speed distributions, are advantageous for wind power extraction due to the better possibility of choosing the appropriate WECS to match environmental conditions. The k value for the present study indicates wind speeds are within normal range. [73]

[3] Typical values range from 0.8 to 0.95 [74].

[4] In contrast to WECS in wind farms.

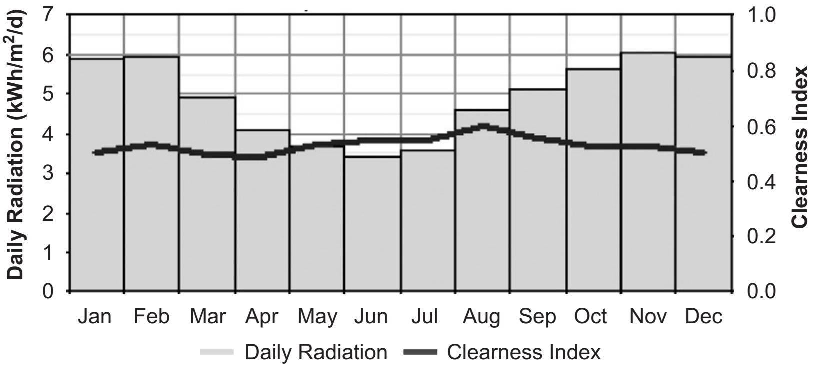

Fig. 5. Average monthly solar irradiance kWh/m^2/day, at the University of Queensland, 2004.

considered in this paper. Hydrogen fuel cells and storage are another interesting development area in RES technology, but are beyond the scope of this paper.

3.4.2. *Wind energy conversion systems (WECS)*

The case study has a considerable load and would need large-scale wind turbines to make a significant contribution to supply. The location of these turbines would be on the roof of the complex if small turbines are chosen. Adjacent private land would be used for large-scale turbines, with power transported to the hotel by dedicated cable. Surface area requirements for WECS are assessed for this paper using the NREL WECS calculator [77], which assumes that any one turbine will require 1500 m^2 surface area for accommodation, regardless of size. This includes service roads and power distribution facilities. Elhadidy [78] conducted a study of the optimal number of wind turbines appropriate for a 200 home residential project. He concluded that a large number of small WECS was more efficient than a small number of large WECS.[5] Two different sized WECS were chosen to test Elhadidy's conclusions in this study:

1. 1.8 megawatt (MW) Vesta V90 turbine [79] with a hub height of 80 m (Table 2). The power curve is efficient for low wind situations (Fig. 6). The IC is $3.5 million including installation, with a 2% annual operational/maintenance (O/M) cost. The lifetime expectancy is 25 years.
2. AOC 15/50 turbine [80] with a 50 kW capacity and hub height of 25 m (Table 2). The power curve is again suitable for low wind situations (Fig. 7). IC is $147,000 and O/M is $4400/yr with a life expectancy of 20 years.

HYBRIDS requires the user to specify the cable size and transmission voltage of the power from the WECS. These factors can be critical in large-scale system design, as high

Table 2
Vesta[a] and AOC[b] wind turbine specifications

	Vesta V90 1.8 MW	AOC 15/50 50 kW
Hub height (m)	80	25
Blade diameter (m)	90	15
Rotor area (m^2)	6361	176.7
Cut-in speed (V_c)(m/s)	3.5	4.9
Nominal speed (V_r)(m/s)	12	12
Stop speed (V_f)(m/s)	25	22.3

[a] Specifications sourced from Vesta product information website [79].
[b] Specifications sourced from AOC product information website [80].

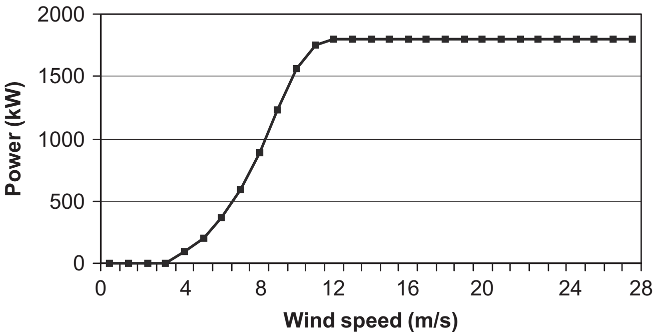

Fig. 6. Vesta 1.8 MW wind power curve (c/o Vesta publications [79]).

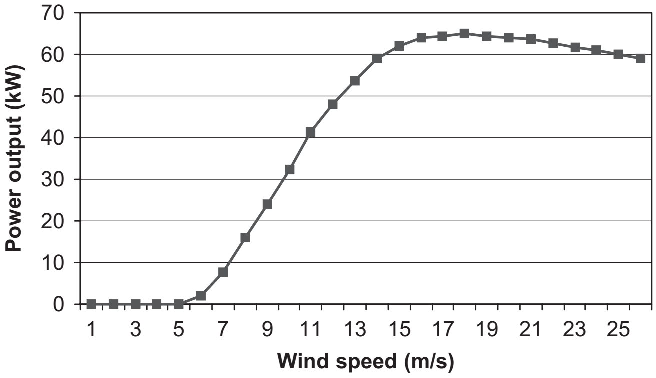

Fig. 7. AOC 15/50–50 kW wind power curve (c/o AOC publications [80]).

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[5] The study used a uniform WECS height of 50 m for all brands. This may have led to a bias in results toward the small WECS, as larger WECS, which are typically 100 m tall or more, would under-perform at this lower height.

Table 3
Three PV configurations considered, describing power output, panel number and area required

Power output (kW)	Panel number (n) (at 150W per panel)	Area required (m^2) (10 m^2 per kW [94])	Area required (m^2) (16 m^2 per kW [87])[a]
500	3360[b]	5000	8000
1000	6720[b]	10,000	16,000
8000	53,040[b]	80,000	128,000

[a] Area specification requires 20% of the PV to be installed on the roof of the building.
[b] Refers to values rounded up to comply with system voltage for HYBRIDS.

voltages, requiring appropriate transformers and large transmission cable diameters, are necessary to minimise transmission losses, and add substantially to IC. An ideal cable size should result in a maximum cable transmission loss of approximately 5% [81]. In order to achieve this, HYBRIDS requires that the transmission voltage of the Vesta be increased to 11,000 V, with a cable diameter of 10 mm^2. For the AOC, 1000 V and 25 mm^2 cable diameter were used, respectively. Using the manufacturers power curves (Figs. 6 and 7), HYBRIDS returns an average output power coefficient[6] of 0.35 for the Vesta, and 0.26 for the AOC.

3.4.3. PV array

3.4.3.1. HOMER. HOMER does not require information on PV type or area, but considers PV sizing in terms of required output in kW. It also assumes that output is linearly proportional to incident radiation. A standard cost of $10,000 per kW of PV power produced was used, with an operational and maintenance bill of $10/yr/kW (as recommended by Gilver [67]). Three PV panel configurations were considered, specifications of which are described in Table 3. The derating factor to compensate for reduction in efficiency due to temperature, dust and wiring losses is 0.9. Lifetime of the panels is 20 yr. Maximum power point tracking (MPPT) is taken as a standard installation.

3.4.3.2. HYBRIDS. HYBRIDS allows some specification of PV details. BP Solar 2150S 150W modules [83] were chosen. Average current is 4.5 A and voltage approximately 33.3 V (Table 4), giving an approximate power rating of 150 W per module, depending on whether it is operating under (a) short circuit, (b) MPPT or (c) max operating temperature. Normal operating cell temperature (NOCT) is 47 °C.

HYBRIDS requires the number of PV modules to be specified. This is estimated by dividing the total required PV kW rating by the power rating of the PV module selected. In order to obtain a power output equal to 500 kW, 3360 PV modules are required (Table 3). HYBRIDS also requires specification of the number of panels in series and parallel. For the 3360 PV panels, 60 panels were placed in series and 56 in parallel[7] (rounded up). PV regulator size is another required input. An 18 A current rating is chosen, necessitating 7 regulators as determined from the following formula [84]:

Table 4
PV specifications required by HYBRIDS

BP Solar 2150 S module	Current (A)	Voltage (V)	Power (W)
Short circuit	4.8	42.8	
MPPT	4.5	34.0	151.3
Max at operating temperature	4.4	32.0	140.8

$$N(\mathrm{reg}) = \frac{NI(\mathrm{pv})1.25}{I(\mathrm{reg})}, \tag{5}$$

where $N(\mathrm{reg})$ is PV regulator number, N is the number of panels in parallel, $I(\mathrm{PV})$ is the PV module current (A) and $I(\mathrm{reg})$ is the regulator current (A).

3.4.4. Diesel generator

Optimisation requires that all possible scenarios from 0% to 100% diesel generator contribution be examined. As peak demand was 950 kW, diesel generator sizes up to 1000 kW were considered. Larger diesel generators have longer lifetimes and are more fuel-efficient. Table 5 lists the specifications and fuel curve efficiencies used in this case study. Simulation of multiple diesel generator of different sizes in HOMER were performed using separate generators and individual fuel curves, as opposed to different sizes all using the same fuel curve. This involves much longer simulation times in HOMER, but ensures greater accuracy in results, enabling more accurate comparisons to HYBRIDS. Designated diesel generator IC for the paper was $750/kW, and a fuel price of $1/l, which was the approximate price in 2004 [85].

3.4.5. Conventional lead acid storage

3.4.5.1. HOMER. Due to the size of the system, the largest battery cell/block capacity was chosen from batteries

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[6] The maximum coefficient of power for a wind turbine was determined by Betz to be is 16/27 (0.59 Betz limit) [82].

[7] HYBRIDS uses the series number as the prime determinant, and the number in parallel is dependant on the total panel number rounded up to comply with the overall system voltage and module voltages.

Table 5
Diesel generator fuel consumptions and fuel curve settings

Diesel generator (kV)	Lifetime	Fuel consumption (l/h)	Intercept (l/h/kW rated)	Slope (l/h/kW output)
400	20,000	(a) 80 (b) 62 (c) 46	0.03	0.17
600	30,000	(a) 160 (b) 121 (c) 85	0.0158	0.25
800	40,000	(a) 239 (b) 184 (c) 121	0.005	0.295
1000	50,000	(a) 270 (b) 207 (c) 146		

(a) 100%, (b) 75%, (c) 50% capacity.
Obtained from Caterpillar diesel generator specification sheets [95].
l—litre.

specified in HOMER. This was the Surrette 4KS25KP [86], with a nominal capacity of 1900 ampere-hours (Ah), cell voltage 4 V, efficiency of 80% and a maximum depth of discharge (DOD) of 60–80%. A costing of $1100 per battery block was chosen, and O/M of $11/yr [86].

3.4.5.2. HYBRIDS. Extra data required by HYBRIDS for the Surrette battery modules was obtained from HOMER's information files. A 10 h capacity rate of 1107 Ah was derived from the current capacity curve. Cycles to failure at 60% DOD was taken as 2500. HYBRIDS requires specification of the battery layout, split into series and parallel configurations. For simplicity, 60 modules were kept in series, while the number in parallel was used as the variable for configuration sizing. HYBRIDS calculates the battery number to produce the optimum DOD by the following equation [84]:

$$\mathrm{DOD}(\%) = \frac{\mathrm{AE} \times 1000}{\mathrm{SV} \times \mathrm{BA} \times \mathrm{NBP}}, \tag{6}$$

where AE is the annual average daily load (k Wh), SV is the system voltage (V), BA is the battery capacity (Ah) and NBP is the number of batteries in parallel (n).

The battery charger size is determined, using the following equation [84]:

$$\mathrm{size(A)} = \frac{\mathrm{genset\ power(W)}}{\mathrm{system\ voltage(V)}}. \tag{7}$$

3.4.6. Converter

The IC for the converter was chosen at $1000/kW, with O/M of $0/kW, a lifetime of 15 years and efficiency of 90%, as recommended by Gilver [67]. Converter sizing is roughly in proportion to the size of the diesel generator it serves. Sizing for the case study converters therefore ranged from 400 to 1000 kW.

3.4.7. RES location and footprint

Positioning of a RES, either on rooftop, building integrated or standalone, is not a design variable of either program, and therefore this factor does not affect the NPC result of a RES for this study.

Footprint is also not a variable that impacts on NPC. Final feasibility results are evaluated on the basis of practicality, and hence some configurations were deemed as impractical if their surface area footprint was too large.

4. Results

4.1. RES-only

The predicted system optimisations and specifications for HOMER and their comparison to HYBRIDS for RES-only systems are shown in Tables 6 and 8, respectively.

Both models show that a RES-only configuration is technically feasible. HOMER predicts that a 3 Vesta WECS (1.8 MW), 800 kW converter and 3500 battery configuration provides the lowest NPC of $19.1 M[8] within a 20-year project time scale (Table 6). The footprint required is 4500 m^2 [77]. The addition of 500 kW of PV enables a 2-Vesta-only configuration and increases the NPC by approximately 10%. However, a PV-only configuration requires 8000 kW of PV, with a NPC of $98 M, which is four times the cost of a WECS-only option and a surface area totalling 128,000 m^2 [87].

Simulations for HYBRIDS used the optimal RES-only configuration predicted by HOMER, which was 3 Vestas

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[8] M refers to millions of dollars.

Table 6
Optimised RES-only, comparing HOMER and HYBRIDS

Software	Vesta number	PV (kW)	Converter (kW)	Battery number	IC ($ M)	NPC ($ M)
HOMER	3	0	800	3500	15.1	19.1
	2	500	1000	4000	17.4	21.3
HYBRIDS	3	0	800	3500	14.5	24
	2	0	800	2500	10.8	18
HOMER	0	8000	1000	5000	86.5	98.5

WECS considered is a Vesta 1.9 MW. Diesel generator is excluded and hence RF equals 1 in all cases.

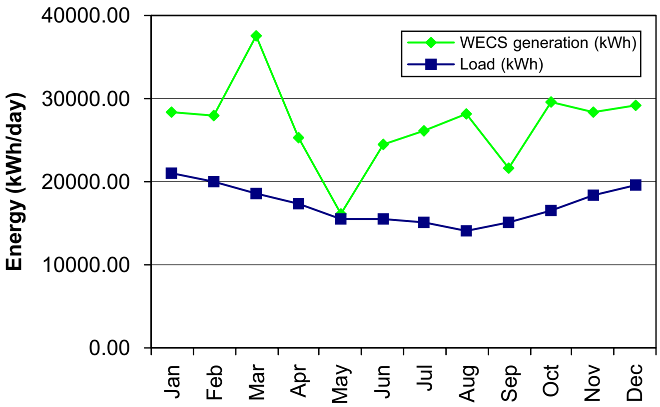

Fig. 8. HYBRIDS result, simulating 2 Vestas, 3000 batteries and 800 kW converter.

and 3500 batteries was used as input. NPC derived by HYBRIDS was 25% higher than for HOMER (Table 6) and excess electricity[9] was almost double.

HYBRIDS will allow a 2-Vesta configuration supplying sufficient power for all months of the year, including the month of May which has the lowest average wind speed, as is shown in Fig. 8. The 2-Vesta configuration results in a considerable saving in IC and resultant NPC. HOMERS's hourly time-scale requires more RES power (i.e. 3 Vestas) for that period in May with low wind speed. Thus, the lack of detailed data input for HYBRIDS can lead to undersizing in design.

The results of modelling for different WECS show that a RES-only option is feasible for both Vesta and AOC WECS (Table 7). However the NPC result is vastly different. As previously mentioned, HOMER simulations for RES-only require a minimum of 3 Vestas, totalling 5.4 MW. In order to attain full autonomous renewable supply using AOCs, the most economic NPC configuration consists of 150 AOC turbines, which is the equivalent of 7.5MW. Moreover, HOMER estimates that 10,000 batteries are necessary to provide the required supply. The IC and NPC are approximately twice that using Vestas. The area required to accommodate 150 turbines according to the NREL calculator is 225,000 m^2. Differences in NPC using AOC WECS, between HOMER and HYBRIDS, is approximately $10 M (22%)(Table 7).

4.2. *Diesel generator-only*

The optimised diesel generator-only size and configuration derived from HOMER simulations is a 1000 kW diesel generator, with no batteries or converters (Table 8). The IC of purchasing the 1000 kW diesel generator is $750,000. At the set cost of diesel for the project of $1/l, the NPC of the system after 20 yr is $20 M. Annual diesel fuel required is 1.6 million l, and CO_2 GHG emissions would be 4121 ton/yr.

HYBRIDS uses an algorithm which specifies that operating time for a diesel generator must not exceed the maximum number of run-time hours per day. In order to meet this criterion, the minimum diesel generator size that HYBRIDS allows is a 1200 kW generator. Using this generator size and corresponding fuel efficiency curves, the IC for both HOMER and HYBRIDS is $0.9 M approximately (Table 8), and NPC is approximately 7% less in HYBRIDS than HOMER.

4.3. *Hybrid RES configuration*

The predicted system optimisations and specifications hybrid RES systems (i.e. diesel generator and RES) are shown in Tables 9 and 10, respectively. The models show that hybrid RES configurations comprising either WECS and/or PV are technically feasible. HOMER optimisation predicts that one 1.8 MW Vesta, 600 kW back-up diesel generator, 400 kW converter and 500 battery configuration produces the lowest NPC of $13.1 M within a 20 years project time span (Table 9), which is 31% less than the RES-only option and 35% less than the diesel generator-only system. The RF is 76%. The optimal hybrid set-up produces 26% less excess electricity than the RES-only configuration. CO_2 GHG emissions were 1480 ton/yr, which represents a 65% reduction in emissions in comparison to the diesel generator-only option. The optimal PV/WECS hybrid configuration consisted of 500 kW of PV and one Vesta WECS. However, the resultant NPC increased by approximately 34% over the

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[9] Excess electricity is defined as surplus electrical energy (either by a renewable source or by the generator when its minimum output exceeds the load) that must be dumped because it cannot be used to serve a load or charge the batteries.

Vesta-only hybrid option with an increase in RF of only 9%.

HOMER's optimal configuration of one Vesta, no PV, 600 kW diesel generator and 500 battery bank is used as the input configuration in the comparison HYBRIDS simulation. With an IC similar to that of HOMER, the NPC derived by HYBRIDS is 23% higher for the same configuration (Table 9). HYBRIDS registers battery DOD problems using the 500 battery configuration. This will be discussed later.

The results of modelling for different WECS in a hybrid RES configuration also show that both Vesta and AOC WECS options are technically viable. As noted above, the HOMER optimal configuration for hybrid RES is one 1.8 MW Vesta. The most economic NPC configuration using AOCs consists of 40 AOCs, equal to 2 MW (Table 10). The configuration comprises two diesel generators in parallel, a 400 and 600 kW, combining together to give a total output of 1000 kW. The NPC for the AOC configuration is 36% more than the Vesta configuration. The NPC increase is mainly due to the fact that the resultant RF has decreased by 12% and requires more diesel generator input with a corresponding increase in fuel costs. The optimal PV/AOC WECS hybrid configuration increases the NPC by a further 23% with a RF increase of only 7%. Comparison of HOMER and HYBRIDS NPC results for AOCS WECS show that the NPC predicted by HYBRIDS is almost double that of HOMER (Table 10). A simulation using a smaller 800 kW diesel generator did not complete due to the diesel generator 24-h a day limitation being exceeded.

Table 7
Optimised NPC of AOC WECS for RES-only, no PV, comparing HOMER and HYBRIDS

Software	AOC (number)	Converter (kW)	Battery number	IC ($M)	NPC ($M)
HOMER	150	2000	10000	35	46
HYBRIDS	150	2000	10000	33	55

Diesel generator is excluded and hence RF equals 1 in all cases.

Table 8
NPC optimisation of diesel generator-only SPS, comparing HOMER and HYBRIDS

Software	Diesel generator (kW)	IC ($M)	NPC ($M)
HOMER	1000	0.75	20.3
HOMER	1200	0.9	20.6
HYBRIDS	1200	0.96	19.2

RF = 0.

5. Discussion

5.1. Payback time

Fig. 9 demonstrates the savings/or loss that the hybrid RES system (1 Vesta WECS, 600 kW diesel generator, 400 kW converter and 500 batteries) would have in comparison to a diesel generator-only system (1000 kW diesel generator) over a 20-yr project span. Estimation of payback time requires the collection of annualised costs for both diesel generator-only and hybrid RES systems, which are calculated summing the fuel, O/M and replacement costs for each year. Annualised costs are then subtracted from each other for each consecutive year, giving the savings or loss for each year. Year 0 will have a negative figure as the IC of the hybrid RES exceeds that of the diesel generator-only IC. Finally, the annual savings are cumulatively summed to provide the cumulative cash-flow for the duration of the project. The result is a positive cash flow

Table 9
NPC of Hybrid RES system using 1 Vesta WECS, comparing HOMER and HYBRIDS

Software	PV (kW)	Diesel generator (kW)	Converter (kW)	Battery number	IC ($ M)	NPC ($ M)	RF
HOMER	500	600	400	500	4.9	13.1	0.76
		600	800	1500	11.2	17.6	0.85
HYBRIDS	0	600	400	500[a]	5.2	16.1	.076

[a] HYBRIDS registers a DOD > 100% for this battery size. Explained in the discussion section.

Table 10
NPC of Hybrid RES system using 40 AOC WECS, comparing HOMER and HYBRIDS

Software	PV (kW)	Diesel generator (kW)	Converter (kW)	Battery number	IC ($ M)	NPC ($ M)	RF
HOMER	0	600 + 400	400	500	7.9	17.9	0.64
HYBRIDS	500	600 + 400	600	500	12.2	22.2	0.71
	0	1000	400	500	8.2	34	0.4

after 4.3 years. This result has a similar payback time to that obtained in both Kaldelsis's [88] study of a WECS/hydro scheme for a Greek island, where he reported a payback time of 5.7 years for a 20-year project, and Migliore's [89] report of a 5-year payback for a North West WECS in the US. The payback time for this system is shorter than that found in studies investigating grid-connected small-scale systems, which quote payback times of a minimum of 7 years (IC aided by large rebates) [90], 11.2 years [91], 15 years [92] and as high as 30 years [93].

5.2. *Component sizing and battery number*

This section examines the impact of battery/component choice on NPC for WECS-only hybrid configuration. The results are displayed in Table 11 and further discussed below.

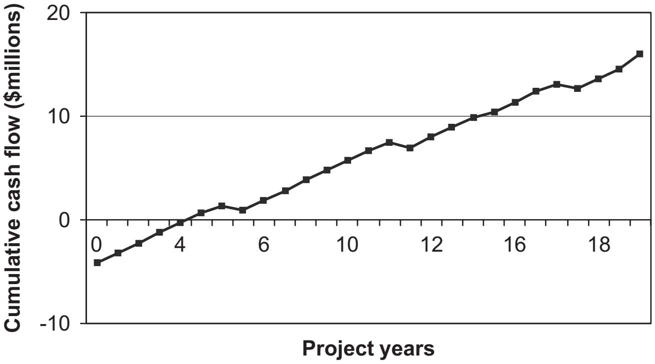

Fig. 9. Graph of cumulative flow for the optimised RES hybrid system (1 Vesta, 600 kW diesel generator, 400 kW converter, 500 batteries).

5.2.1. *Battery number*

An increase in the battery number from 500 to 2000 had the following impact on the NPC:

(a) Using HOMER, the NPC remained almost constant, and fuel consumption was reduced.
(b) Using HYBRIDS, the NPC increased by approximately 30%, but fuel consumption remained constant.

HOMER links the diesel generator dispatch with battery capacity, whereas HYBRIDS does not. As such, any reduction in the fuel consumption (and subsequent reduction in the NPC) due to increased battery numbers is not reflected in the NPC of HYBRIDS. Consequently, HYBRIDS produces an increase in NPC over that of HOMER as battery numbers are increased.

5.2.2. *Diesel generator and converter sizing*

An increase in diesel generator capacity results in an increase in the NPC under both the HOMER and HYBRIDS simulations (Table 11). Where battery numbers are low, an increase in converter sizing increases the NPC using both programs. When examining a high battery number accompanied by an increase in converter sizing, HOMER predicts a decrease in NPC. This result is expected due to the greater efficiency of battery capacity usage with larger converter sizing. However, the same configuration simulation using HYBRIDS shows an increase in the NPC, thus further demonstrating HOMER's better battery/diesel generator dispatch over HYBRIDS.

Table 11
Simulation of hybrid WECS-only (1 Vesta) configuration examining NPC effect due to variation in battery number, diesel generator size and converter size (no PV considered)

Battery number	Diesel generator (kV)	Converter (kV)	HOMER		HYBRIDS	
			NPC ($M)	Diesel (1000 l/yr)	NPC ($M)	Diesel (1000 l/yr)
500	600	400	**13.3**	562	**15.9**[a]	646
		800	**13.7**	563	**16.4**[a]	646
	800	400	**14**	635	**17.1**[a]	727
		800	**14.2**	621	**17.6**[a]	727
2000	600	400	**14.6**	479	**23.2**	646
		800	**13.7**	379	**23.8**	646

[a] Refers to an error message that HYBRIDS registers for that simulation, where battery DOD result is >100%.

Table 12
NPC sensitivity analysis on battery efficiency for hybrid RES: 1 Vesta, no PV, 600 kW diesel generator, 600 kW converter and 500 batteries

Hybrid WECS/RES	HOMER battery efficiency		HYBRIDS battery efficiency	
	80%	90%	80%	90%
NPC	$13.3 M	$13.2 M	$16.2 M	$13.1 M

5.2.3. Battery DOD

HOMER's dynamic programming and battery dispatch strategy optimises diesel fuel consumption and avoids exceeding battery DOD limits. As such HOMER more accurately refects diesel generator real run-time. The HOMER simulation of large-scale hybrid systems with diesel generator backup supports smaller battery banks. The simpler assessment process of HYBRIDS results in larger battery banks and a subsequent increase in NPC. Smaller battery bank sizing, whilst acceptable in HOMER, will incur a DOD error in HYBRIDS (refer to simulations of 500 batteries by HYBRIDS in Table 11). Aside from increasing the battery number, the only correction adjustment available under HYBRIDS to decrease battery DOD requires reduction of the "fraction of diesel generator output direct to load" setting. This would force more energy to go through the battery charger and batteries, before going to the load.

5.3. Battery efficiency

An increase in battery efficiency, within HOMER, from 80% to 90% decreases NPC by approximately \$0.1 M (Table 12). In HYBRIDS, the NPC decrease is much larger. This is because battery efficiency is an important element in the calculation for WECS output supply by HYBRIDS, as shown below:

$$\text{Wind output} = \text{wind output/day} \times \text{WECS subsystem efficiency factor}, \quad (8)$$

where the WECS subsystem efficiency factor is the product of the transmission efficiency from WECS to battery and battery to load, WECS voltage regulator efficiency and, most significantly, battery efficiency. An increase in battery efficiency for HYBRIDS increases overall WECS power output, thus resulting in a NPC reduction.

6. Summary and conclusion

A feasibility analysis for a large-scale stand-alone power supply (SPS) tourist accommodation operation has been presented. The analysis used real load data from a large hotel (>100 beds) located in a subtropical coastal location in Australia. RES assessment software programs, HOMER [37] and HYBRIDS [38], were used for the analysis and viability was determined on the basis of NPC, renewable factor (RF) and payback time. The study was based on a comprehensive hourly dataset obtained from the hotel's energy management system, over a period of one year's duration. RES-only, diesel generator-only and hybrid RES/diesel configurations were assessed. An examination of the most economically viable RES component (PV or WECS) for large-scale accommodations was also assessed. HOMER was the primary software used for optimisation analysis and optimal configurations were used as input for the HYBRIDS software program, the results then compared between the two.

The simulations demonstrate that stand-alone RES, in principle, could adequately and reliably meet demand of a large-scale resort hotel. Optimisation modelling demonstrates that a 100% RES-only configuration was viable, comprising of either three Vesta WECS (total 5.4 MW) or 150 AOCs WECS (total 7.5 MW), plus the appropriate number of batteries and converter. Large-scale Vesta WECS proved to be more economical in terms of NPC and more efficient in terms of surface area than multiple smaller AOC WECS. The use of PV to provide the majority of power supply was not viable due to its high ICs compared to large-scale WECS, and the large surface area necessary to accommodate the PV arrays.

Optimisation analyses comparing RES-only, diesel generator-only and hybrid diesel/ RES systems on the basis of NPC showed that a WECS-only hybrid/diesel resulted in the lowest NPC. The diesel generator-only configuration resulted in 50% extra NPC over the hybrid RES system. The optimum hybrid configuration consisted of a Vesta WECS (1.8 MW), 500 batteries and a 600 kW diesel generator back-up, potentially returning a RF of 76%. Greenhouse (GHG) gas reduction for this configuration was close to 65% compared to the diesel generator-only configuration and the configuration requires approximately 4.3 years to achieve.

Results from the two software packages were relatively consistent for small RES component numbers. For larger RES component numbers, HYBRIDS produced a larger NPC. The inability of HYBRIDS to represent hourly fluctuations in supply and demand results in configurations with an increased battery number which impacts on final NPC estimate. Overall, the modelling suggest that RES initiatives, specifically hybrid WECS, have significant potential for use in large-scale tourist resorts and hotels requiring stand-alone power supplies.

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A text file of the 2004 load data is available for further modelling by emailing the author. However, the source hotel will remain anonymous.

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Glossary

Small-scale resort: <10 beds
Medium-scale resort: 10–50 beds
Medium- large scale resort: 50–100 beds
Large-scale resort: >100 beds
Small-scale WECS: 0.1–100 kW
Medium-scale WECS: 100–1000 kW
Large-scale WECS: >1000 kW