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# Sizing a Hybrid Renewable Energy System to Reduce Energy Costs at Various Levels of Robustness for an Industrial Site.

Ashley Thornton[a]*, Seung-Jin Kim[b], Sami Kara[a]

[a]*Sustainability in Manufacturing and Life Cycle Engineering Research Group, UNSW, Sydney, Australia*
[b]*Suez, Sydney, Australia*

* Corresponding author; *E-mail address:* ashley.thornton@unsw.edu.au

## Abstract

The rising cost of energy in Australia is causing industry to look for energy sources other than the conventional grid. Industry has been slow to adopt non-dispatchable renewable sources partly because of their inherent variability, however their inclusion can reduce greenhouse gas emissions and energy costs. By using an alternative fuel production facility as a case study an installation of a hybrid renewable energy system is explored. This paper studies the effects of varying the robustness of the design with respect to load and renewable variability separately. Lithium ion battery packs are also included to act as a buffer in the system. The installation is modelled using a robust Mixed Integer Linear Programming (MILP) framework and the potential cost savings are quantified at various levels of robustness. Broad sizing guidelines are drawn from the results for the case study that should result in a robust energy supply.

*Keywords:* Hybrid Renewable Energy System, Industrial Microgrid, Renewable Energy, Robust

## 1. Introduction

Electricity generation accounts for around a third of Australia's total energy consumption [1]. Due to Australia's heavy reliance on fossil fuels for electricity generation this means that there is a huge potential for greenhouse gas (GHG) emission reduction if alternative generation means were used instead. Energy payback periods for solar installations are now 4 years or less with expected service lives of 30 years [2]. Wind systems also have a seemingly high energy return, needing only 6 months to pay back their energy investment with an expected life of 20 years [3] thus making them both viable primary energy producers. Furthermore both wind and solar technologies are on parity, or in many cases cheaper, than conventional fossil fuel generation with regards to Levelised Cost of Energy (LCoE). [4]

However total renewable sources only account for a disappointingly low 17% of Australia's total electricity generation [5]. One of the main barriers hindering widespread adoption is the reliability and non-dispatchable nature of renewables. In this paper a grid linked Hybrid Renewable Energy System (HRES) will be explored to supply a waste processing and alternative fuel generation plant in Adelaide

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South Australia. The focus will be to observe the effects on sizing the HRES when minimizing energy cost under various risk profiles.

## 2. Literature Review

Sizing Hybrid Renewable Energy Systems is a developing field. As renewable prices have fallen their area of applicability has grown.

Most HRES sizing techniques focus on ensuring the Loss of Power Probability (LPSP) of the system is below a certain level [6–10]. This is partly because the first application area of renewable energy was to supply isolated sites where fuel and centralised energy was not available. This focus on the reliability of the system has dominated analysis for many years and as a result energy cost is only minimised after the reliability constraints have been met.

Multiple studies [11–13] aim to size HRES systems with grid linkages to minimizing the cost of energy. [11] and [12] are actually best described as approaches to cost-effectively minimize grid dependence. Atia et.al. [13] developed a detailed framework for sizing HRES systems in residential microgrids with the aim of reducing the entire system cost.

Many studies included Energy Storage Systems (ESS) [6–11,13,14] within their HRES, but only some [6,7,11] included the size of storage as a variable that the system could optimize. In most cases the ESS control strategy aimed to provide a supply buffer to absorb any energy surplus or deficit. Only a few studies included the potential economic advantages of load shifting [13,14].

Many studies used simplistic models for their load curves. [7] and [14] utilized certain load profiles, giving no space for variability. [6] represented load with a uniform distribution between the maximum and minimum levels. [8] used seasonal worst case analysis, as their main focus was on achieving a LPSP of 0%, but such analyses generally lead to overly expensive systems, as explored by [12]. [13] allowed Demand Side Management (DSM) so the system itself could manipulate the load curve, they also did include a few scenarios to capture some of the variability in their non-controllable loads.

Therefore, there is a gap in the literature to optimally size of an industrial HRES system, with the option of ESS with non-trivial control strategies, for grid linked sites with the aim of lowering energy costs at various levels of robustness.

## 3. Methodology

The proposed HRES model has wind, solar, a battery, and a grid connection. The battery can charge and discharge into the site or into the grid. This was formulated within a linear programming framework. The variables within the model are shown in Table 1 and the objective function and constraints shown in equations 1-5.

Table 1. Variables in the model

| Variable | Description |
|---|---|
| $t$ | Time period |
| d | Day of the week |
| $p$ | Robustness factor for Renewable supply |
| $b$ | Robustness factor for Load |
| $D(b,t,d)$ | Demand estimate based on time period ($t$), Load Robustness factor ($b$), and the day of the week ($d$) |
| $Apv(p,t)$ | Generation factor of Solar based on the time period ($t$) and Robustness factor ($p$) |
| $Aw(p,t)$ | Generation factor of Wind based on the time period ($t$) and Robustness factor ($p$) |
| $Cgrid_t$ | Cost of Grid energy at time $t$ (\$/kWh) |
| $Sgrid_t$ | Selling price of energy to the Grid at time $t$ (\$/kWh) |
| $Grid\_in_t$ | Energy bought from the Grid at time $t$ (kWh) |
| $Grid\_out_t$ | Energy sold to the Grid at time $t$ (kWh) |
| $Grid_{max}$ | Maximum draw from the Grid (kVA) |
| $CgridCap$ | Cost of Grid kVA Capacity (\$/kVA) |
| $PF$ | Power Factor |
| $PV_{cap}$ | Solar Capacity (kW) |
| $W_{cap}$ | Wind Capacity (kW) |
| $Bat_{cap}$ | Battery Capacity (kWh) |
| $Cpv$ | Cost of Solar Capacity (\$/kW/week) |
| $Cw$ | Cost of Wind Capacity (\$/kW/week) |
| $C_{bat}$ | Cost of Battery Capacity (\$/kWh/Week) |
| $Bat_t$ | Battery fill level at time $t$ (kWh) |

$$Obj = \sum_0^T \Big( (Cgrid_t * Grid\_in_t) - (Sgrid_t * Grid\_out_t) \Big) + (Grid_{max} * CgridCap) + (PV_{cap} * Cpv) + (W_{cap} * Cw) + \big(Bat_{cap} * C_{bat}\big) \quad (1)$$

$$D_{t,d}(p,t,d) = \big(PV_{cap} * Apv(p,t)\big) + \big(W_{cap} * Aw(p,t)\big) + (Grid\_in_t - Grid\_out_t) + (Bat_{t-1} - Bat_t) \quad \forall t \quad (2)$$

$$Grid_{max} * PF \geq Grid_t \quad \forall t \quad (3)$$

$$Bat_{cap} \geq Bat_t \quad \forall t \quad (4)$$

$$Bat_{t=0} \leq Bat_{t=last} \quad (5)$$

Expression (1) is the objective function to be minimized. It includes the cost of purchasing solar and wind systems based on their capacities. It also includes grid energy purchase costs and the cost of the grid connection's flow capacity (in kVA). Furthermore, it incorporates the money gained by selling energy to the grid. Both purchasing and selling prices can vary with Time Of Use (TOU) schemes. The constraint (2) ensures that the demand from the plant is always met by the supply options. (3) ensures that $Grid_{max}$ is always at least the maximum kVA draw and (4) ensures that $Bat_{cap}$ is at least the