Chapter 6

Opportunities of adopting renewable energy for the nursery industry in Australia

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6.1 INTRODUCTION

In Australia, the nursery and garden industry provides significant economic, cultural, social and environmental benefits to the community (NGIA, 2014). The production nurseries support a diverse array of industries and end users, including retail outlets, landscapers, cut-flower growers, orchardists, vegetable growers, interiorscapers, sustainable forestry and revegetation enterprises. Overall, the gross value of production (GVP) of the broad “nursery, flower and turf” industry in Australia is A$1271 million, which is 17% of the total GVP of Australian horticultural industry (ABS, 2013).

Amenity horticulture is currently one of the fastest growing industries in Australia (NGIA, 2009). Energy use efficiency has also become increasingly important due to the increasing cost and scarcity of energy sources and also the associated greenhouse gas (GHG) emissions causing global warming (Bundschuh and Chen, 2014; Chen and Baillie, 2009a). The horticultural sector contributes about 6% of the total agricultural GHG emissions in Australia (Deuter, 2008). Nursery operators are thus under increasing pressure to reduce their energy and carbon footprint. By improving energy efficiency and using clean energy sources, the nursery industry can drive down their carbon footprint (Abeliotis et al., 2015; Beccaro et al., 2014; Lazzerini et al., 2014; Russo et al., 2008), and also simultaneously increase their bottom line.

6.2 ENERGY USE IN NURSERY

To save energy, the first step is to conduct an energy audit to identify where the major energy uses are occurring, and which of these can be practically and economically changed (Chen and Baillie, 2009a; Chen and Maraseni, 2012). Quite often, conducting an energy audit may be one of the fastest and the most effective ways to save money and reduce energy demand. Furthermore, reducing energy demand also makes significant reductions in GHG emissions. This is important in maintaining the ‘clean and green’ of relevant products.

6.2.1 Energy audits and assessments

Energy audits refer to the systematic examination of an entity, such as a firm, organization, facility or site, to determine whether, and to what extent, it has used energy efficiently (Chen and Baillie, 2009a; Chen and Maraseni, 2012). They may also assess opportunities of potential energy savings through fuel switching, tariff negotiation and demand-side management.

Typically, an energy audit may involve the following steps:

- Gather data.
- Evaluate energy use.
- Recommendations.
- Report.
- Review.

Overall, the nursery is often a high-value and an energy intensive industry (Lazzerini et al., 2014; Schmidt et al., 2010). Energy uses in the nursery industry may include heating/cooling, irrigation and various machinery operations such as tillage, potting, fertilizing, and crop maintenance, etc. These operations may also be implemented by specific practices such as potting machines and trans-planters.

Nursery production is often divided into a number of phases relating to the age or type of plant under cultivation. These may include (Cameron and Emmett, 2003):

- Stock plant management or seed production.
- Propagation.
- A weaning and growing-on stage often carried out under protection.
- A growing-on period after plants have either been potted-on into larger containers (container stage) or planted in a field to reach marketable size (field-grown stage).

With the rising energy costs and increasing concern over GHG emissions, on-farm energy efficiency is becoming an increasingly important issue for many nursery operators. In many ways, on-farm energy inputs represent a major and one of the fastest growing cost inputs to the growers. In New Zealand, it was found that average energy use of flower greenhouse nursery ranged between 57 and 3768 MJ m^{-2} per annum, with an average 880 MJ m^{-2} or 8800 GJ ha^{-1} (Barber, 2004). Energy use was also found to be strongly influenced by management practice, regional location, the type and age of greenhouse, and the type of crop being grown. Generally, smaller operations were less energy intensive, possibly due to capital constraints. In comparison, greenhouse cultivation of cut flowers in Greece was found to require 37,343 kWh ha^{-1} of electricity consumption for refrigeration and 7900 kWh ha^{-1} for water pumping, equivalent to a total electricity energy use of 45,243 kWh ha^{-1} or 1,628 GJ ha^{-1} (Abeliotis et al., 2015). Lazzerini et al. (2014) also reported electricity use of 6.5-18.2 MWh ha^{-1} plus 600-806 kg of diesel use for both field- and container-grown plants in Italy. Kipp and Snodgrass (2006) found that using modern mechanical and lighting systems, energy use could be cut by up to 80% in Idaho, USA.

Despite the significant effort by the nursery industry, a number of barriers or challenges to the improvements of energy efficiency might still exist. These include (OAN, 2011):

- Energy use is decentralized across a large number of large, medium and small operations.
- There might not be a single entity synthesizing all the resources to support energy savings efforts.
- Inconsistent or unavailable data identifying projects with high degree of success, evaluating technologies, and real energy savings.
- Nurseries have limited time and staff to research and implement programs.

- The large capital investment necessary to fund efficiency projects is non-existent for many operations, and the paperwork for incentive programs is consistently mentioned as burdensome.
- The nursery industry currently has no energy baseline from which to measure the effectiveness of energy reduction activities.
- Education and awareness of new practices, programs and technologies is not focused on rural, small businesses.

6.2.2 Case studies of nursery energy use in Australia

Currently, there appears to be little data available regarding the energy use in the horticultural sector. In Australia, there also seems a total lack of energy data for the nursery sector outside Queensland (Chen et al., 2015a).

There are evidences to suggest that most of the nurseries in Australia utilize greenhouse systems to maintain year-round production. In the following, very limited case studies of energy use of five small-to-medium nurseries around the Brisbane metropolitan area in Queensland will first be presented (Schmidt et al., 2010), noting that Brisbane is the state capital of Queensland, and it has a humid subtropical climate with hot, humid summers and dry, mild winters. The summer (December – February) average temperature is 20–28 °C, while the winter (June – August) average temperature is 11–21 °C (Guan and Bell, 2010).

In this study, the energy data was collected from these five farms over a period of one year (2010). For this purpose, the electricity consumption was obtained from the utility bills while the fuel (diesel, petrol and gas) consumption obtained from grower records. The machinery energy use data was based on either the figures provided by the growers or on-site observation. Diesel, electricity, petrol and LPG gas are used for various processes in these nurseries, such as preparation, establishment, in-season, irrigation, harvest, post-harvest, and general (Chen et al., 2011). Electricity is mostly used for heating, pumping, refrigerating, running potting mixture, bag filler mixers and fertilizer agitator, and for general office use. LPG gas is mainly used for hot water heating and hot air burners, whereas diesel is mostly used for tractors and other vehicles.

The energy use data was then entered into an online energy management calculator (EnergyCalc), which was a process-based software for calculating and storing energy use and GHG emission data for the whole site or individual processes (Chen and Baillie, 2009b; Schmidt et al., 2010). The software outputs are also grouped into four broad categories related to fuel use, electricity use, total on-farm energy use and carbon emissions. This software has been used for a systematic quantification of energy use across the nursery processes (e.g., potting machine, transferring/conveyor, trans-planter, lighting, irrigating, spraying and fertigation).

A summary of energy and production data for these five nurseries in Queensland is presented in Table 6.1, where the raw energy data from different sources has been converted into the standard energy unit [GJ].

Table 6.1. Summary of energy consumption in five different nurseries in Queensland.

Attributes	Nursery A	Nursery B	Nursery C	Nursery D	Nursery E
Used area for production [ha]	1.5	5	3.5	2.5	5
Annual turnover [million A$]	1.1	3	na	na	na
Energy consumed from electricity [GJ]	122.1	242.3	651.2	493.1	1,558.5
Energy consumed from diesel [GJ]	0	92.6	204.6	na	867.5
Energy consumed from LPG gas [GJ]	0	488.3	586.0	na	119.4
Energy consumed from petrol [GJ]	0	0	0	0	165.4
Total direct energy consumption [GJ]	122.1	823.2	1441.8	493.1	2710.8
Total direct energy intensity [GJ ha^{-1}]	81.4	164.6	411.9	197.2	542.2
Total direct energy cost [A$]	4500	24650	41550	22000	73500
Energy cost per ha [A$ ha^{-1}]	3000	4930	11871	8800	14700

It can be seen that in total, these five nurseries collectively used over 5591 GJ of energy. Out of them, 54.9% was consumed by electricity, 21.4% by LPG gas and 20.8% by diesel. Petrol used about 3% of the total energy.

From Table 6.1, it can also be seen that the overall energy consumption is generally not directly related to the production area. In Nursery A, energy consumption per hectare production area is 81.4 GJ, whereas in Nursery B it is 164.6 GJ, Nursery D 197.2 GJ, Nursery C 411.9 GJ and for Nursery E it is 542.2 GJ. Instead, energy consumption is more directly related to intensity of operations. These energy use figures may also be 20–1,000 times higher than those of broad-acre cereal crops (0.4-4.4 GJ ha^{-1}) for Australia (Chen et al., 2015a), but are still significantly lower than their New Zealand counterparts, which has a considerably cooler climate than subtropical Queensland.

Overall, it was also found that (Chen et al., 2011; Schmidt et al., 2010):

- Due to historical, personal and geographical reasons, a wide variety of growing methods and systems are used in different nurseries in Queensland.
- Energy costs vary significantly between different operators (Fig. 6.1), with their intensities varying between A$3000 to A$14,700 per hectare of production area (not the total farm area) (Table 6.1). Overall, the energy cost may consist of less than 0.5–1% of production value in these sites.
- Heating often forms a very significant component of the energy cost, particularly when this is supplied by electricity energy (Fig. 6.2). In this case, alternative heat sources such as LPG may be used to reduce the energy costs.
- There are few diesel pumps used in the nursery industry. The most common pumps used for irrigation in the nursery appear to be electric centrifugal pumps (both single and multistage) and are often run in excess of 12 hours per day.
- Growers are generally well aware of the need to reduce their energy usage. This may be evidenced by the widespread uses of vari-speed pumps to save pumping energy.

- It is observed that some motors used at a number of sites are significantly more powerful than the tasks they are required to perform.

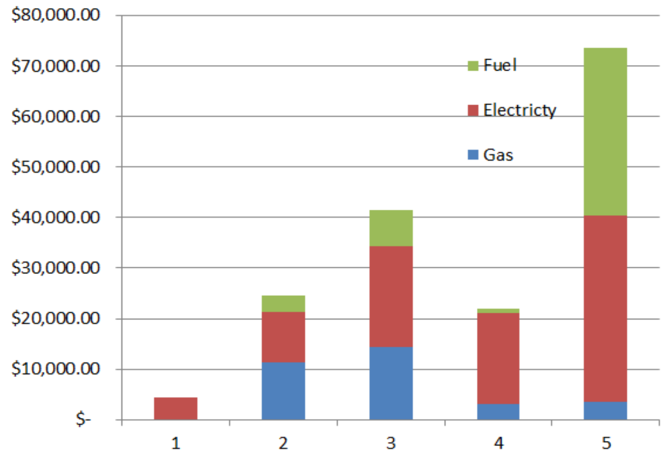

Figure 6.1. Total annual energy expenditures (A$) at the five nurseries in Queensland.

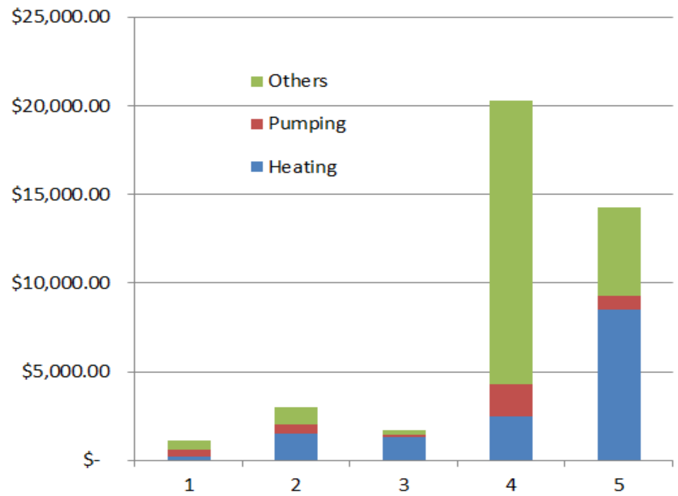

Figure 6.2. Annual heating energy costs (A$) per ha of total farm area at the five nurseries in Queensland.

In another extended study of irrigation energy use in nurseries, 16 further energy audits were carried out in South East Queensland (Eberhard et al., 2013). It is shown that in these farms, an average 30% of the total electricity used on-site was for pumping water and irrigation (Fig. 6.3). This ranged from 6% (at a site where the heating dominated the usage) to 59% (Fig. 6.4). Irrigation is the single largest electricity using process in 7 out of 16 audits conducted. This further demonstrates that irrigation could be a significant user of energy in the nursery industry in this area.

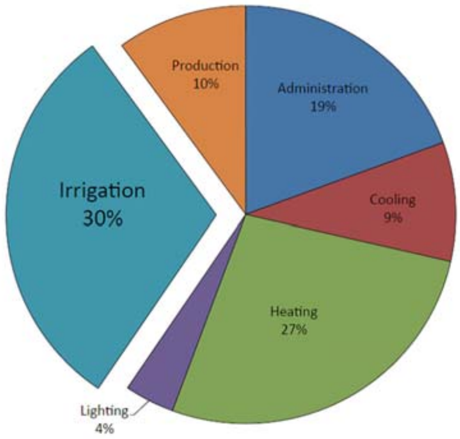

Figure 6.3. Average annual energy use at the 16 nurseries in South East Queensland.

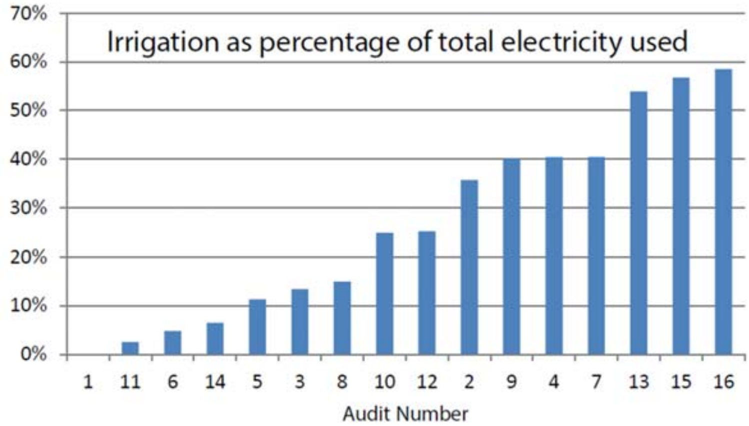

Figure 6.4. Average irrigation energy use as a percentage of total electricity used at the 16 nurseries in South East Queensland.

McHugh et al. (2010) also suggested that for horticultural operations with considerable cooling requirements, heating and refrigeration systems could consume a large amount of electricity and thereby contribute significantly to the running costs of businesses. This is consistent with the findings of Figure 6.3. Improvements to the design, controls and operations of these systems have thus also great potential to reduce energy consumption (Cumming, 2015).

6.3 OPPORTUNITIES OF ADOPTING ALTERNATIVE ENERGY SOURCES

Fossil fuels are a limited resource and can also create considerable environmental problems such as GHG emissions, so it is desirable that where the opportunities are appropriate, renewable energy such as solar, wind, and bio-energy may be integrated into the nursery operations to save energy costs, and to reduce GHG emissions (Chen et al., 2015b; Yusaf et al., 2011). Examples of specific applications of renewable energy in agriculture and horticulture may include solar space and water heating, and using biomass for heating purposes (Sonneveld et al., 2010). Other applications include lighting, irrigation, wastewater treatment pond aeration, communication and remote equipment operation, etc. (Gopal et al., 2013; Mekhilef et al., 2013; Vick and Almas, 2011). Biofuels may be used for tractors and road transport purposes (Basha, 2014).

6.3.1 Opportunities of adopting solar energy

Australia is a country which has a rich solar energy resource with the highest average solar radiation per square meter in the world (Geoscience Australia and ABARE, 2010; Yusaf et al., 2011). The average annual solar radiation gathered in Australia is approximately 58 million PetaJoules (PJ), which is nearly 10,000 times the nation's annual energy consumption (Bahadori and Nwaoha, 2013). Therefore, solar energy in many cases is considered to be an attractive substitution of conventional energy. For example, electricity generation and solar hot water production can be used to either offset or replace the electricity used within a nursery operation and offers the ability to significantly reduce or even eliminate electricity costs to the nursery business.

Currently, it appears that the greatest interest exists in the nursery industry in the use of solar energy for photovoltaic (PV) electricity generation and thermal collectors for hot water production. A number of nursery and horticultural enterprises in Australia have already implemented some of these measures, including the installation of a PV system and upgrading to more energy efficient lighting such as LED lighting.

6.3.2 Opportunities of adopting wind energy

The idea of using wind to produce work is not a recent concept with traditional windmills being used to pump water and grind flour for centuries. With the advent of more efficient generators, the wind turbine has been used to generate electricity from the wind and is a promising source of renewable energy (Yusaf et al., 2011).

Overall, wind power is seen as an effective alternative and renewable electrical energy source suitable to many areas of Australia, particularly along the coastline. Wind turbines can often have a shorter payback period and higher return on investment than solar power in areas with high average winds speeds and low wind turbulence. However, there is currently less interest in the wind energy in the nursery sector in Australia, owing to relatively few regions having average wind velocities which warrant wind power and also the potential issues for visual and noise pollution (Hall et al., 2013).

6.3.3 Opportunities of adopting bio-energy

Biogas is a combustible gas produced as a result of anaerobic digestion (AD), a process in which organic matter is broken down by microbial activity in the absence of oxygen. Biogas normally consists of 50 to 60% methane. It is currently captured from landfill sites, sewage treatment plants, livestock feedlots and agricultural wastes. The typical conditions required are biomass combined with water in a lagoon or containment vessel, with the combined solution being maintained at between 16 and 60 °C.

Overall, it appears that biogas production is a less suitable energy source for the nursery industry because nurseries generally do not produce enough suitable organic waste on-site to run an anaerobic digester. Biogas technology has not been tested in the nursery environment in Australia, and could pose a financial risk unless complete or major financial subsidization from external sources is provided. However, biogas could play a part in reducing energy and fertilizer costs of nurseries in the future, but at the moment other turnkey alternative energy sources exist that place themselves in a more suitable position for use.

6.4 DEVELOPMENT OF ONLINE CALCULATOR FOR ALTERNATIVE ENERGY SOURCES

Commissioned by Nursery & Garden Industry Australia (NGIA), an online calculator for renewable energy has recently been developed for the nursery industry by the National Centre for Engineering in Agriculture (NCEA), University of Southern Queensland. The overall framework for the calculator is shown in Figure 6.5. To run the program, the user will first need to capture energy demand information based on a utility statement of electricity usage or using calculations undertaken using EnergyCalc (Chen and Baillie, 2009b). A pre-determined percentage of energy demand to be met using wind or solar power is selected as is an appropriate local weather station for downloading of meteorological data (Fig. 6.5). The calculator is then able to size the appropriate solar or wind turbine system and provides a simple cost benefit based on energy demand, renewable energy generated, electricity costs, system capital and operating costs (Fig. 6.6).

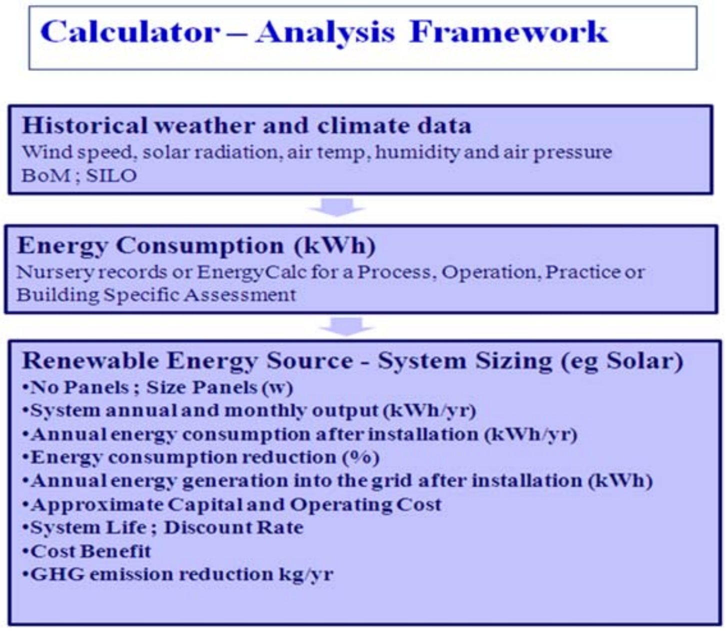

Figure 6.5. The framework for the NGIA/NCEA online renewable energy calculator.

Items	Details
System Type	Solar
Rated Power	9.44 kW
System Lifetime	25 year
Capital Cost	$36969
Operating Cost	$739 per year
Electricity Sale Price*	$0.44 per kWh
Electricity Purchase Price	$0.22 per kWh
Panel Area	66.3 m²
Energy Demand	18600 kWh per year
Energy Generated	18600 kWh per year
Greenhouse Gas Emissions Reduced**	19456 kg per year

Figure 6.6. An example of NGIA/NCEA online renewable energy calculator output sheets.

6.5 CASE STUDIES

In the following, the above renewable energy calculator will be used to model and examine the generation and cost-effectiveness of solar and wind energy at a relatively large (25 ha) hypothetical nursery farm, noting the limitation of these case studies because both the assumed generation efficiency and costs of renewable energy could change significantly as the technology advances and government policy changes. The conclusion derived here is thus only applicable for the given energy tariff and also the particular location.

6.5.1 Solar energy generation

Sunlight can be converted into electricity using PV technologies. This can be used to replace existing electricity purchases and to sell power to the grid. The case study below illustrates generation of solar energy at the hypothetical nursery farm located in the inland township of Gatton, 90 km west of Brisbane.

Key technical inputs for the solar energy calculator include the location and intensity of solar radiation at that location. This information can be sourced from Bureau of Meteorology data. Others include the rated power of the system and peak power that can be generated during maximum solar irradiance. The cost of the solar system is determined from quotes to be A$4000.00 m^{-2} after subsidies and Renewable Energy Certificate (REC) discounts administrated by the Australian government. The system is to be depreciated over twenty years and the discount rate is 5% with an annual operating and maintenance cost of 2% of capital cost.

In this case study, it is assumed that solar energy is required to match electricity demand from one of the operational areas where annual electricity is 10,000 kWh per annum. It is assumed that electricity is purchased at 18 c kWh^{-1} and can be sold into the grid at 40 c kWh^{-1}. It is also assumed that electricity usage is 20% in quarter 1 and 4 and 30% in quarter 2 and 3.

Solar radiation data for the site is indicated below in Table 6.2 together with solar power generation capacity for 1 m^2 panel based on a 13% system efficiency.

Table 6.2. Solar radiation for the modeled site and solar energy generation potential.

Solar Radiation Gatton MJ/m2												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
24.3	21.3	20.2	17.1	13.8	12.2	13.4	16.3	20	22.2	24.1	25.1	19.2
Solar Radiation Gatton kWh/m2/m												
202.5	177.5	168.3	142.5	115	101.7	111.7	135.8	166.7	185	200.8	209.2	1917
Energy Generated kWh/mth 1square metre panel												
21.82	19.12	18.13	15.35	12.39	10.95	12.03	14.63	17.96	19.93	21.64	22.53	206.5

Figure 6.7 compares electricity demand for the production area (10,000 kWh) and generated electricity based on 40 m^2 of panels which is required to generate an equivalent annual power.

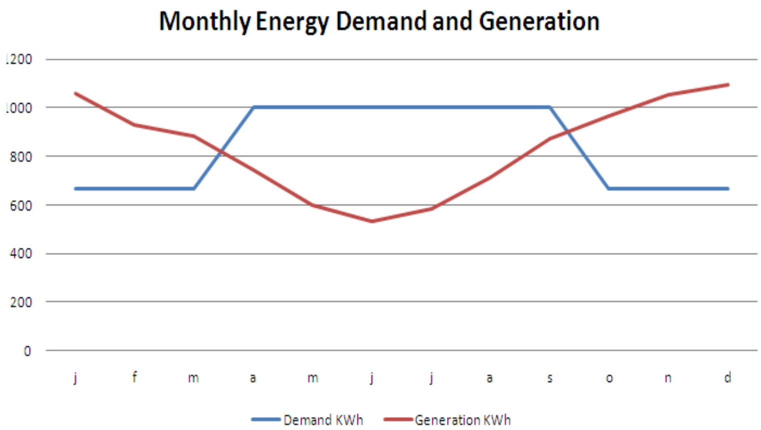

Figure 6.7. Monthly energy demand and generation based on 40 m^2 solar panels.

It can be found that the annual energy generation is equal to energy consumption and the energy generation efficiency of the system is 100%. 1983 kWh of surplus power is generated in the summer months of October to March which can be sold into the grid at 40 c kWh^{-1} generating A$793 of revenue. 1953 kWh of electricity has to be purchased during the winter months of April to September at 18 c kWh^{-1} costing A$352. This is substantially less than the pre-solar annual cost of electricity (A$1800).

Based on a discounted cash flow analysis over the 20-year life of the solar system, the annualized equivalent cost of purchasing and operating the solar system is A$1162. The annualized equivalent cost of the current system is the cost of electricity purchased

(A$1800). The overall benefit-cost ratio is 1.55 and the payback period is 8.3 years.

6.4.2 Wind energy generation

Because of the inland location, the assumption for wind generation at the particular site of the hypothetical nursery farm is that the installed system would be designed to supplement current power demand and not to be a power plant. Thus, small-scale (less than 10 kW) wind turbines are chosen and installation would be on towers at 10 to 30 m high rather than 60 to 70 m for typical wind farms employing large turbines.

Analysis of the Bureau of Meteorology's wind data for the selected site provides an annual mean wind speed of only 1.96 m s^{-1}. This is quite low and results in an estimated annual production of only 343 kWh (Fig. 6.8).

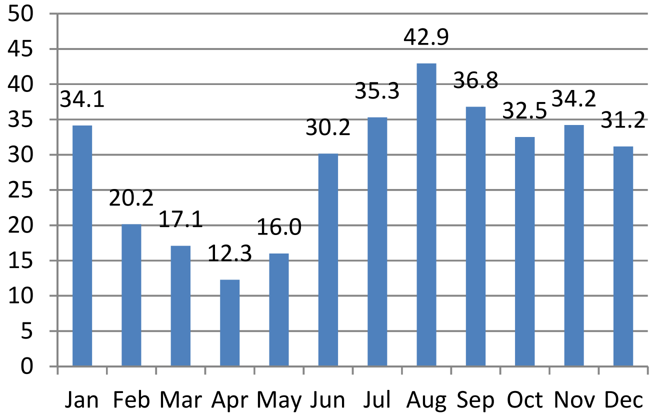

Figure 6.8. Monthly estimated electricity production [kWh] for a wind turbine at the modeled site.

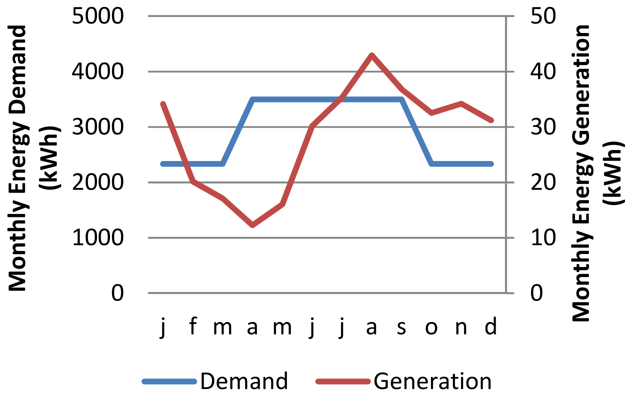

Figure 6.9. Monthly energy demand vs. energy production for a single wind turbine at the modeled site.

Figure 6.9 provides a comparison of the monthly energy demand for the site versus the estimated energy production from a single small-scale wind turbine. Energy demand is read from the left-hand y-axis while energy production is read from the right-hand y-axis. The ratio of demand to production is approximately 100:1. Therefore, energy generation from a single wind turbine can only produce 1% of the total energy demand for this particular site. No energy is able to be generated for sale to the grid, thus grid connection would not be feasible. 34,657 kWh of electricity also has to be purchased each year at 18 c kWh^{-1} costing A$6238. The cost of a 6 kW wind turbine and installation is estimated to be approximately A$55,000 after subsidies and REC discounts. The system is to be depreciated over 20 years and the discount rate is 5% with an annual operating and maintenance cost of 5% of capital cost. The benefit:cost ratio is 0.47 and the system is not viable at this location of very low wind speed.

6.5 CONCLUSION

Energy is increasingly becoming a key factor for the nursery industry to understand and manage in relation to sustainability and cost performance. Through case studies, this chapter has examined energy usage patterns in the nursery industry in Queensland, Australia. It has also identified potential renewable energy sources that could be utilized in the industry.

It has been shown that energy uses in nurseries vary significantly between different operators. Energy use is strongly influenced by management practice, regional location, the type and age of greenhouse, and the type of crop being grown. The energy cost typically consists of 0.5-1% of production value. Irrigation and heating and cooling could be the major sources of energy use, each contributing to some 30% of total energy use.

The opportunity of adopting renewable energy in nursery operations has also been evaluated. An online renewable energy calculator has been used to provide an indication of potential for solar and wind systems to replace purchased electricity and feed electricity into the grid.

Future work should focus on developing a better understanding of energy usage patterns in the nursery industry across a representative range of nursery operations and sub-operations, regions, and scales. Opportunities of utilizing other potential renewable energy sources should also be explored. With the new technologies currently under development, renewable energy costs are falling rapidly. By improving energy efficiency and using clean energy sources, the nursery industry can not only drive down their carbon footprint but also simultaneously increase their production and profits.

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