Opportunities for energy innovation in Australian irrigated sugarcane

December 2017 | JM Welsh and JW Powell
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Published in December 2017, by Ag Econ, Burren Junction, NSW, Australia

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This document should be cited as follows:


The authors acknowledge the funding contribution from the Queensland Department of Agriculture and Fisheries towards this research activity.
Executive Summary

Water pumping forms a significant portion of energy use in Australian irrigated agriculture. Water for Australia’s $2 billion annual sugarcane crop is from precipitation and irrigation. As an irrigated industry in a variable climate, energy is a critical input and significant cost component in the sugarcane gross margin. With approximately 90 per cent of irrigated sugarcane growers accessing the national electricity grid for their energy needs, exposure to some of the highest power prices in the world threatens operating margins and export competitiveness (Australian Energy Council, 2017). While efforts to increase irrigation application and water pumping efficiencies are ongoing, opportunities exist to integrate new energy technologies into pump sites. Improved use of energy storage equipment to overcome intermittency issues with renewable energy pumping applications has been identified as having high potential and high value to the Australian water sector (Beca, 2015).

This review of energy in irrigated sugarcane aims to better understand energy use, intensity and exposure to energy prices by examining energy demand characteristics at an enterprise, regional and industry level. This is achieved by collating industry research and recent survey data in a range of regional contexts; climatic variability and sensitivity to growing season rainfall (GSR); irrigable area; volume of water applied; static lift; and irrigation application method. Irrigation energy consumption and application costs are examined in detail via gross margin analysis. Those areas with highly variable, low GSR and high pumping heads were found to be more reliant on energy and therefore, more vulnerable to higher prices. Sugarcane farmers in the Maryborough region have the highest static lift and incidence of stage pumping, adding to overall energy demand. Irrigation methods vary between regions, although furrow and high pressure overhead remain the most common, each with different energy requirements. This study also considers sustainability via Life Cycle Assessment from energy used in raw sugar, where energy for irrigation accounts for almost one-quarter of the entire carbon footprint. In addition, the study identifies energy technologies suitable for irrigated sugarcane farming systems, price outlooks for liquid fuels and battery storage. Recent reports suggest energy storage costs for flow and lithium-ion batteries could be cut by up-to 60 per cent by 2030. In contrast, the outlook for liquid fuels suggests price increases well in-excess of inflation to 2040.

Innovative technology applications aim to reduce both per ML pumping costs and carbon footprint while improving farm productivity. Achieving these goals provides benefits for policy makers, the sugarcane industry, regional economies and sugarcane farmers collectively.
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Introduction

Energy is one of the fastest growing costs for irrigated sugarcane growers, with electricity and to a lesser extent, diesel accounting for a significant portion of total farm input costs. While diesel fuel is dependent on world oil markets and exchange rates, the price of electricity consists of transmission line rental and the wholesale power price. In the state of Queensland, the combined electricity costs (line rental plus wholesale prices) have increased by approximately 400 per cent since the year 2000. Inflation over the same period has been around 45–50 per cent (National Irrigators Council, 2014).

As national policy initiatives strive for more efficient use of water, studies have shown the connection between water and energy productivity has considerable room for improvement. A study by Eyre et al. (2014) found the more water efficient systems are generally the more energy intensive systems. For example, water transfer occurring in closed pipes rather than channels, or installing drip or pivots to replace flood irrigation requires more energy than the systems they would replace. Knowing the trade-off between water use and energy use efficiency in the current environment, this review of energy in Australian irrigated sugarcane has three objectives: i) to understand the energy demand characteristics of irrigated sugarcane at an industry, region and enterprise level, ii) to identify costs at the enterprise level for a range of irrigation applications and iii) to summarise future energy price outlooks and innovation opportunities for irrigators. A better understanding of energy use in irrigated sugarcane through a review of recent industry surveys, benchmarking, case studies and policy documents will enable a clear rationale for future in-depth analysis. Outcomes ultimately aim to reduce per ML extraction costs, improve productivity and industry sustainability credentials.
1. Irrigated sugarcane: an industry energy overview
1 Irrigated sugarcane: An industry energy overview

Irrigated sugarcane producers are located along the East coast of Australia from Mossman in far North QLD to Ballina in Northern NSW (see Figure 1).

Figure 1: Map of sugar growing regions. Image source: ABARES (2015)

1.1 Regional climate and irrigation demand

Water is critical to the sugarcane industry to maximise crop yields and sugar content. In most sugarcane growing regions during the production cycle, crop water demand exceeds rainfall supply. Although rain-fed sugarcane crops are successfully grown in some areas, irrigation enables high-yielding sugarcane to be grown in a wider range of regions. Data collected by the Australian Bureau of Statistics (2017) found in 2015-16, of the 423,479 ha of sugarcane harvested, 229,484 ha (54 per cent) was irrigated. The average volume of water applied across the irrigated area was 5.6 ML/ha.
Irrigation water transfers to field vary between gravity and scheme water, to deep wells pumping into storage. For simplicity, assuming an average 30 m total pumping head and an efficient pump consumption of 4.55 kilowatt hour (kWh)/ML/m of electricity (Foley, 2015), the industry would use around 175,418 megawatts (MW) of power per annum – if all irrigation pumps were grid-connected. If the water is moved once at $0.27/kWh the annual total cost to industry is just over $47.4 million. Further, applying an emissions factor of 0.94 kg of CO$_2$e/kWh (Department of the Environment and Energy, 2016), then approximately 165,000 tonnes of CO$_2$e p.a is generated from this practice. Therefore, adoption of industry-wide energy efficiency measures or capital installations aimed at improving water productivity has potential to make both economic and environmental gains.

A successful and profitable irrigation enterprise is one that manages precious water at both the crop root zone level (soil moisture monitoring and irrigation scheduling) and at the whole farm level (water access licenses, losses etc.). Reducing or optimising the amount of water pumped around the farm can substantially lower demand and energy costs. Equally, consideration of changes in evapotranspiration and how much water the crop is going to use by adjusting for the expected seasonal conditions can impact seasonal energy demand. This requires knowledge of the region’s growing season rainfall including the reliability and effectiveness of rainfall and when rainfall occurs (how rainfall timing will timing affect irrigation, dam supplies or extraction limits).
Examining climate, including historical rainfall distribution and current climatic patterns may help assess water and energy demand in a wider context. Such knowledge underpins farm management, which aims to ensure that crop water stress is minimized during critical growth phases, but not during ripening when stress is welcomed in order to maximise sucrose yields. Figure 2 shows the 20-year average sugarcane Growing Season rainfall (GSR) during the months of October to May for each irrigated region. Orange markers indicate the Co-efficient of Variation (CoV) of each regional rainfall sample from 1996-97 to 2016-17 (right hand axis). CoV is defined as a standardised measure of dispersion of a probability distribution or frequency distribution (Simpson and Kafta, 1977) and helps assess rainfall reliability – i.e. the degree of scatter from the mean. A low CoV shows a lower degree of scatter and higher reliability. Results of this analysis found that Ingham has both the highest average GSR (1,860 mm) and CoV (0.43) and therefore, less likely to require large volumes of irrigation to optimize production. In contrast, the Burdekin has less than half the average GSR (852 mm) of Ingham, whilst experiencing the same high degree of variability (0.42). The influence of fluctuating seasonal conditions underscores the dependence on irrigation and hence energy, to meet crop water requirements in certain regions. When comparing two areas with a similar GSR such as Burdekin and Bundaberg, Burdekin is more reliant on irrigation, experiencing a 56 per cent more variable GSR (reflected by the higher CoV) than Bundaberg with the latter more likely to achieve the mean GSR. Intra-seasonal rainfall variation has not been considered.

**Growing season rainfall and CoV by region**

![Figure 2: 20-year GSR for irrigated sugarcane areas represented by the blue bars. Orange markers show the Co-efficient of Variation of each sample. Those CoV values closer to zero denote higher reliability and less degree of scatter from the sample mean. Source: Australian Bureau of Meteorology (2017)](image)

Consistent with climate and growing season rainfall analysis, industry estimates confirm regions with higher GSR have lower irrigation requirements. Table 1 shows each region with approximate area under fully irrigated and semi-irrigated sugarcane farming. Fully irrigated land area refers to those regions and fields where irrigation water is applied to completely meet crop water demand that is not supplied by rainfall or stored soil water, with the typical aim of maximizing yield. In contrast, the term semi-irrigated indicates less irrigation water is applied than that required to fully satisfy crop
evapotranspiration. The irrigation categories do not necessarily account for limitations of water applied due to infrastructure, energy use or intra-season allocation of water and are derived to illustrate quantities of energy used for irrigation. Annual variances of water applied may, in part, explain discrepancies between water application rates and irrigated areas referenced by ABS (2017) and estimates gathered in the current study. The approximate static lift was derived from a recent survey by Ag Econ (see Appendix 1, Qu. 5) and indicates Maryborough (50 m), Atherton Tableland (45 m) and Isis (35 m) have increased delivery (higher energy) costs to field relative to other regions. Hence these regions with their higher energy requirements appear more exposed to price increases.

**Table 1 Average values of irrigated sugarcane land area, static lift and water use.**

<table>
<thead>
<tr>
<th>Region</th>
<th>Fully irrigated ha(^1)</th>
<th>ML/ha(^{1,2,4})</th>
<th>Semi-irrigated ha(^3,5)</th>
<th>ML/ha(^{3,4,5})</th>
<th>Average static lift (m(^3))</th>
<th>Total ML transferred</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atherton Tableland</td>
<td>6,000</td>
<td>7.0</td>
<td>3,000</td>
<td>2.5</td>
<td>45</td>
<td>49,500</td>
</tr>
<tr>
<td>Ingham</td>
<td>5,000</td>
<td>20</td>
<td>2</td>
<td>20</td>
<td>7,500</td>
<td></td>
</tr>
<tr>
<td>Burdekin</td>
<td>70,000</td>
<td>13.5</td>
<td>21,000</td>
<td>2.8</td>
<td>20</td>
<td>945,000</td>
</tr>
<tr>
<td>Proserpine</td>
<td>21,000</td>
<td>2.8</td>
<td>35,000</td>
<td>3.0</td>
<td>25</td>
<td>105,000</td>
</tr>
<tr>
<td>Mackay</td>
<td>35,000</td>
<td>3.0</td>
<td>7,000</td>
<td>0.5</td>
<td>25</td>
<td>3,500</td>
</tr>
<tr>
<td>Plane Creek</td>
<td>26,000</td>
<td>4.5</td>
<td>7,000</td>
<td>0.5</td>
<td>25</td>
<td>117,000</td>
</tr>
<tr>
<td>Bundaberg</td>
<td>5000</td>
<td>7.0</td>
<td>7,000</td>
<td>3.5</td>
<td>35</td>
<td>59,500</td>
</tr>
<tr>
<td>Maryborough</td>
<td>6,000</td>
<td>2.2</td>
<td>6,000</td>
<td>2.2</td>
<td>50</td>
<td>13,200</td>
</tr>
</tbody>
</table>

1. Crane (2017) and regional Productivity Services
2. Down to Earth Research (2017)
3. AgEcon (2017)

Total Dynamic Head (TDH) is the term given to the pressure that needs to be supplied for a specific pumping task and is often expressed in metres, meaning the pressure at the bottom of an equivalent vertical column of water at sea level (Smith and Pendergast, 2012). TDH is made up of: static head, friction head, pressure head and velocity head. Assuming a conservative aggregate of friction head, pressure head and velocity head of 10 m is applied to regional static lift in each region (listed in Table 1), a demand profile based on water volume and energy expended is estimated. Figure 3 shows a graphical representation of estimated energy demand values for each region. Ingham, with the highest average GSR has one of the lowest amounts of irrigation water transferred, and therefore has a low regional energy consumption compared to the Burdekin which has the largest area of irrigated sugarcane. The data suggests 70 per cent of the industry’s irrigation water is transferred in the Burdekin, highlighting the importance of resourcing future energy productivity solutions in this area. This exercise suggests the highest energy use for irrigation is in the Burdekin, Mackay and Bundaberg regions. Other factors contributing to irrigation energy requirements are discussed throughout the report.
1.2 Regional energy characteristics

Variability between regions is expected when considering an industry with such a large geographic spread. As farmers in each region adapt their sugarcane systems taking into account varied climatic, topographic and other environmental conditions, each region develops unique production characteristics.

There are four common systems used to apply irrigation water. The most common irrigation application systems are high pressure overheads and furrow irrigation. The SRA 2017 Grower Survey (Down to Earth Research, 2017) displays the percentage of respondents that indicated they used one (or more) irrigation methods on their farm. The results (Figure 4) show that high pressure overhead systems are the most common irrigation application method closely followed by furrow.

High pressure overhead irrigation systems are water cannons (also known as; winch, travelling guns or big guns).

Low pressure overhead irrigation systems include both pivots and lateral moves.

These results are supported by the Ag Econ 2017 Irrigated sugarcane farm energy survey. When considering the percentage of respondents, the Ag Econ survey results were similar to the SRA survey.
However, when converted to hectares under each irrigation method, the results indicate that furrow irrigation (48 per cent of total hectares) is the most common, closely followed by water cannons (39 per cent) (see Appendix 1, Qu 7). Figure 5 shows the Ag Econ survey results by region, including the area sampled in each region. The Southern growing systems appear to have greater use of energy intensive, high pressure water cannons (big gun irrigators).

![Graph showing irrigation system by region](image)

**Figure 5: Irrigation system by region, Ag Econ 2017 Irrigated sugarcane farm energy survey (Appendix - Q7).**

Results from the same survey indicated that the primary source of energy used on sugarcane farms is electricity which covered 79 per cent of total hectares. Diesel was the next most utilised energy source at 11 per cent. Diesel use was proportionately higher in Proserpine, Plane Creek and Northern NSW. Despite the high energy costs faced by irrigated sugarcane growers, solar (and other renewables) are currently insignificant in the industry (see Appendix 1, Qu 4).

The number of times water is pumped to get from source to paddock and the elevation at which the water is applied are two key impacts on irrigation energy use. Sugarcane farmers in the Bundaberg, Isis and Maryborough regions noted the highest static lift (see Appendix 1, Qu 5). The highest incidence of stage pumping (see Appendix 1, Q6) was for the respondents in the Proserpine and Maryborough regions, followed by the Bundaberg and Mackay regions. For these reasons, per ML pumping costs are likely to be comparatively high in these regions.

The Ag Econ survey results suggested that a lack of knowledge around energy, renewables, investment feasibilities and a perceived lack of cashflow are the main limiting factors for investment into new energy technologies (see Appendix 1, Qu 9). The full results for the Ag Econ 2017 Irrigated sugarcane farm energy survey can be found in Appendix 1. Considering the small sub sample sizes in the survey, this information is best used to as a guide only.
2. Energy use in irrigated sugarcane
2 Energy use in irrigated sugarcane

A better understanding of the energy demand profile in irrigated cane can assist in finding alternative solutions to meet the challenges of seemingly divergent goals of water and energy use efficiency. Lifting and distributing irrigation water is energy intensive, particularly in water efficient, pressurised systems. While many irrigation systems are meticulously designed, others may have evolved incrementally and without systematic engineering analysis. Large gains can often be made to existing systems through pump and energy assessments. This section examines the impact of energy use in terms of carbon footprint from irrigation practices followed by listing the fundamentals of energy use efficiency.

2.1 Life Cycle Assessment (LCA) of energy for irrigated sugarcane

With an increasingly aware global consumer, energy used for irrigation can also be viewed in terms of environmental impact via detailed Life Cycle Assessments (LCA). LCA based greenhouse gas (GHG) methodology measures impact upstream in the supply chain to capture emissions from the manufacturing processes, as well as those occurring at farm level. This assessment enables industries to quantify their carbon footprints over time or against a base year. Research by Renouf and Wegener (2007) found electricity from irrigation contributes around 22 per cent of emissions of raw sugar cane, behind field emissions of nitrous oxide emissions from soils as the most dominant source across the study area. Figure 6 shows results of GHG analysis from various activities from two regions in Queensland (wet tropics and Burdekin) compared with the state average.

![Figure 6 The aspects of raw sugar production that contribute to greenhouse gas emissions. Image source: Renouf and Wegener (2007)](image-url)
These numbers remain in relative proportion to other Australian broad acre irrigated industries. Nitrous oxide and fertilizer production are also the dominant sources of emissions per bale of cotton, followed by diesel fuel used for irrigation (Visser et al., 2015). However, irrigated lucerne (a legume), unlike cotton or sugarcane, does not rely on synthetic fertilizer for high levels of production. Research conducted on the Darling Downs region of Queensland also found pressurised irrigation systems achieved the leading GHG emissions source ahead of farm machinery operations such as spraying, cutting and baling (Mushtaq et al., 2015). Consistent with energy intensive agricultural industries, adoption of energy efficiency techniques through modification, benchmarking and novel technologies can ultimately reduce GHGs and have a positive impact on sugarcane growing sustainability.

2.2 Energy efficiency and irrigation fundamentals

Simple equations can assist to ensure pumping equipment and control systems optimise return on energy inputs. A first step in evaluating irrigation energy costs is to quantify operating costs. Table 2 provides a summary of useful energy and irrigation pumping data. Based on an electricity retail price of $0.27 kWh (Ergon Energy, 2017) and a diesel retail price of $1.31/L (Australian Institute of Petroleum, 2017) the cost to lift 1 ML 1 m is $1.22 and $0.89 respectively. These energy costs do not account for differences in capital costs, maintenance, labour and depreciation.

Table 2 Irrigation pumps – summary of key energy facts

<table>
<thead>
<tr>
<th>Category</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 kWh of electricity contains (theoretical)</td>
<td>3.6 MJ of energy</td>
</tr>
<tr>
<td>1 L of diesel contains (theoretical)</td>
<td>38.4 MJ of energy</td>
</tr>
<tr>
<td>1 ML of water lifted 1 m (theoretical)</td>
<td>9.81 MJ of energy</td>
</tr>
<tr>
<td>Average irrigation pump efficiency(^1)</td>
<td>70-85%</td>
</tr>
<tr>
<td>Diesel genset efficiency(^2)</td>
<td>80-95%</td>
</tr>
<tr>
<td>Average electrical motor efficiency(^1)</td>
<td>82% (5kW) - 90% (100kW)</td>
</tr>
<tr>
<td>Average loss (in addition to above) from cables and submersibles(^1)</td>
<td>4%</td>
</tr>
<tr>
<td>Diesel motor efficiency(^3)</td>
<td>35%</td>
</tr>
<tr>
<td>Drive train efficiency (a) V-belt drive(^1)</td>
<td>90%</td>
</tr>
<tr>
<td>(b) Gear drive(^1)</td>
<td>95%</td>
</tr>
<tr>
<td>(c) Direct drive(^1)</td>
<td>100%</td>
</tr>
<tr>
<td>Electrical pump energy use (1ML lifted 1m)(^3)</td>
<td>4.55 kWh</td>
</tr>
<tr>
<td>Diesel pump energy use (1ML lifted 1m)(^3)</td>
<td>1.10 L diesel</td>
</tr>
</tbody>
</table>

2. FAO (2017)

Once energy data for a pump site is collected together with how much water is pumped, a cost per ML can be obtained. If these results are benchmarked against the theoretical energy/ML/m head cost, the pump’s performance or ‘efficiency’ should be checked against the manufacturer’s pump curve (by plotting the ‘duty point’ on the chart). Pump efficiency can vary from 20 per cent in poorly running pump sites to 90 per cent in optimised systems. 70 per cent is often quoted as being desirable. When considering that over 80 per cent of the cost of pump ownership is attributed to energy costs, the
importance of selecting a suitable, high efficiency pump and motor combination becomes evident (Jessen, 2011).

### 2.3 Energy use and costs by irrigation application and energy source

A range of suitable irrigated sugarcane water application methods has been identified in the Irrigation of Sugarcane Manual (Holden and McGuire, 2014). These methods, each with their own costs and benefits, fit a range of production systems depending on field type, terrain, water quality, energy and labour source availability. The energy consumption and resulting cost of irrigation will vary for every individual pumping situation depending not only on the pump and motor efficiencies (as discussed in section 2.2), but also the depth of the water source and the system used (farm layout, size of piping systems etc.). Table 3 provides an indication of energy use and cost of pumping for the common irrigation systems and pumping scenarios found in the Australian sugarcane industry.

The lowest energy use and cost are the furrow irrigation systems, as they do not require energy to pressurise the system. A typical furrow irrigation system pumping water from a river (or channel) using an electric motor, requires 4.55 kWh to lift 1 ML, equating to $11.90/ML (at an electricity cost of 27c/kWh).

The higher the pressure required for an irrigation system, the more energy used to pressurise it. Also, the greater the distance water needs to be moved or ‘lifted’ the higher the subsequent energy requirements. The highest energy use and cost examples in Table 3 are high pressure overhead water cannons. In a scenario where the water is pumped from a bore (deepest water source), a typical water cannon would require 375 kWh to lift 1 ML over a total pumping head of 85m, equating to $101.19/ML.

With historically low liquid fuel prices (Bureau of Infrastructure Transport and Regional Economics, 2016), diesel is cheaper than electricity as an energy source; however careful consideration would need to be given to the energy outlook for both energy sources if an irrigator was considering converting from one to other, as this conversion would not remove exposure to energy pricing risk.
Table 3: Comparative irrigation costs. Source: Smith (2017)

<table>
<thead>
<tr>
<th>Irrigation system</th>
<th>Irrigation application efficiency % (approx)</th>
<th>Labour requirement</th>
<th>Water source</th>
<th>Total pumping head (metres)</th>
<th>Power required to pump 1ML² (kWh)</th>
<th>Pumping costs ($ per ML)</th>
<th>Electricity cost @ 27c/kWh² = $/ML</th>
<th>Diesel cost @ 78.8/L² = $/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furrow</td>
<td>70</td>
<td>High</td>
<td>River/ channel</td>
<td>10</td>
<td>44</td>
<td>11.90</td>
<td>9.30</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bore</td>
<td>30</td>
<td>132</td>
<td>35.71</td>
<td>27.90</td>
<td></td>
</tr>
<tr>
<td>Low pressure overhead lateral move¹</td>
<td>80</td>
<td>Low (1/3 furrow)</td>
<td>River/ channel</td>
<td>30</td>
<td>132</td>
<td>35.71</td>
<td>27.90</td>
<td></td>
</tr>
<tr>
<td>Low pressure overhead Centre pivot²</td>
<td>70-80</td>
<td>Low (1/4 furrow)</td>
<td>River/ channel</td>
<td>60</td>
<td>265</td>
<td>71.43</td>
<td>55.79</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Piped scheme</td>
<td>5</td>
<td>22</td>
<td>5.95</td>
<td>4.65</td>
<td></td>
</tr>
<tr>
<td>Drip</td>
<td>80-90</td>
<td>Medium</td>
<td>River/ channel</td>
<td>50</td>
<td>221</td>
<td>59.52</td>
<td>46.49</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Piped scheme</td>
<td>10</td>
<td>44</td>
<td>11.90</td>
<td>9.30</td>
<td></td>
</tr>
<tr>
<td>High pressure overhead Water cannon</td>
<td>65</td>
<td>Medium</td>
<td>River/ channel</td>
<td>70</td>
<td>309</td>
<td>83.33</td>
<td>65.09</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bore</td>
<td>85</td>
<td>375</td>
<td>101.19</td>
<td>79.04</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Piped scheme</td>
<td>45</td>
<td>199</td>
<td>53.57</td>
<td>41.84</td>
<td></td>
</tr>
</tbody>
</table>

1. Gravity fed channel ~ 1.5 times the length of LM run
2. With pump, motor and main ~ 1.5 times CP length
3. Total pumping head equals static lift + pipe / hose friction + operating pressure. Static lift (or water depth) is assumed to be 15m.
4. Assuming a pump efficiency of 70% and electric motor efficiency of 90%
6. Assuming a pump efficiency of 70%, specific fuel consumption of 0.26 L/kWh, elevation 0.9, drive factor 0.95. Price calculated using the 12 month regional QLD average, less GST and rebates (Australian Institute of Petroleum, 2017).
3. Energy in the sugarcane gross margin
3 Energy in the sugarcane gross margin

A gross margin is the difference between crop income and the variable costs (expenses directly associated with growing the crop such as seed, chemicals, irrigation and harvest). Gross margins do not represent farm profit because the overhead costs (i.e. administrative, permanent labour and rates) and the operating costs (i.e. interest payments and machinery depreciation) are not considered. A gross margin is generally expressed as $/ha or $/ML. An understanding of the differences in gross margins between growing regions and irrigation practices can assist to identify the irrigation scenarios with greater exposure to energy prices.

3.1 Gross margins: regional differences

The ABARES (2015) report assessing the financial performance of sugarcane farm businesses in 2013-14 found an average electricity cost of $103/ha ranging from a low of $14/ha in the Ingham region to a high of $239/ha in the Burdekin region. The fuel costs averaged $274/ha with a range between $209/ha in the Ingham region and $313/ha in the Mackay region. The total costs for the average farm were $2,490/ha (excluding finance). Using this information, the average farm fuel and electricity accounts for 15 per cent of growing costs.

Industry research has found electricity is the primary energy source used for irrigation and the range of costs between regions is a combination of irrigation factors including the amount of irrigation water applied, in-crop rainfall and irrigation system used. The highest regional average of $239/ha is in the Burdekin where irrigation application is significantly higher than other regions. Across the industry a small portion of sugarcane is irrigated using diesel as the energy source; however, the ABARES (2015) survey found fuel consumption has less variation between regions. The key consumption of this energy source is through mechanized farming operations such as tractor passes and harvest, which is standard among all sugarcane crops.

Whilst energy costs varied between regions in 2013-14, it should be noted that analysis in that period for applicable tariffs by Australian Sugar Industry Alliance (2014) found prices were 23 cents per kWh as opposed to 27 cents per kWh in 2017-18 – an increase of 17 per cent. Consequently, recent price increase will have resulted in energy becoming a higher proportion of costs in the current growing system.

3.2 Gross margins: irrigation systems

Section 2 and Table 3 examined differences in the energy required to irrigate 1 ML of water, concluding the cost varies depending on application method. The effect the suite of irrigation systems has on a gross margin are indicated in Table 4.

A sugarcane gross margin published online by QDAF (2017) was expanded for the Burdekin region and a furrow irrigation system. By keeping all other income and costs equal, the irrigation costs are varied to consider other irrigation systems and pumping scenarios (based on the costs in Table 3).

Table 4 indicates that the energy intensive irrigation scenarios account for a higher proportion of variable costs and result in reduced crop gross margins. The most energy intensive irrigation scenario was a high pressure overhead pumped from a groundwater source. In this scenario, irrigation accounts
for 33 per cent of variable costs rather than 10 per cent in the furrow irrigation, river water scenario. The gross margin was $1,719/ha, 34 per cent lower than the furrow irrigation, river water scenario.

**Table 4: Gross margin analysis by irrigation system**

<table>
<thead>
<tr>
<th>Irrigation System</th>
<th>Furrow</th>
<th>Furrow</th>
<th>Centre</th>
<th>High</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water source</td>
<td>River</td>
<td>River</td>
<td>Bore</td>
<td>River</td>
<td>Bore</td>
</tr>
<tr>
<td>Pumping costs ($/ML)</td>
<td>$11.90</td>
<td>$35.71</td>
<td>$71.43</td>
<td>$83.33</td>
<td>$101.19</td>
</tr>
<tr>
<td>INCOME ($/ha)</td>
<td>122t @ $41.95/t</td>
<td>5118</td>
<td>5118</td>
<td>5118</td>
<td>5118</td>
</tr>
<tr>
<td><strong>VARIABLE COSTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Irrigation (10 ML)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water access charge ($12.10/ML)</td>
<td>121</td>
<td>121</td>
<td>121</td>
<td>121</td>
<td>121</td>
</tr>
<tr>
<td>Pumping energy costs</td>
<td>119</td>
<td>357</td>
<td>714</td>
<td>833</td>
<td>1012</td>
</tr>
<tr>
<td>Total irrigation cost</td>
<td>200</td>
<td>240</td>
<td>478</td>
<td>835</td>
<td>954</td>
</tr>
<tr>
<td>Other variable costs (Nutrition, planting, crop protection &amp; harvest)</td>
<td>2266</td>
<td>2266</td>
<td>2266</td>
<td>2266</td>
<td>2266</td>
</tr>
<tr>
<td>Total variable costs</td>
<td>2466</td>
<td>2506</td>
<td>2744</td>
<td>3101</td>
<td>3220</td>
</tr>
<tr>
<td>Gross margin ($/ha)</td>
<td>2652</td>
<td>2612</td>
<td>2374</td>
<td>2017</td>
<td>1898</td>
</tr>
<tr>
<td>Irrigation cost (% of variable costs)</td>
<td>8%</td>
<td>10%</td>
<td>17%</td>
<td>27%</td>
<td>30%</td>
</tr>
</tbody>
</table>

**Scenarios with the electricity price increased by 15%**

| Gross margin ($/ha) | 2594 | 2320 | 1910 | 1773 | 1567 |
| Irrigation cost (% of variable costs) | 10% | 19% | 29% | 32% | 36% |
| Reduction in gross margin (% change) | 1% | 2% | 5% | 7% | 9% |

1. Published gross margin QDAF (2017)
2. Using $/ML costs from Table 3

Simple sensitivity modeling also indicated that the energy intensive irrigation scenarios are more vulnerable to energy price rises. In Table 4, results show that with a 15 per cent electricity price increase, the gross margin of the high pressure overhead bore scenario were reduced by 9 per cent compared to the 1 per cent gross margin reduction of the furrow/river water scenario. The feasibility of a change in power source depends on how exposed the business is to changes in energy prices with consideration given to future energy pricing.

### 3.3 Uncertainty in future energy pricing

In recent years grid-connected irrigators in eastern Australia have often contemplated the cost of alternative energy sources available to power this energy intensive practice. Those irrigators experiencing power price increases have been reluctant to change to labour-intensive, diesel generators or direct-drive diesel fuel pumps. Conversely, off-grid irrigators endure routine labour, oil and filter waste, depreciation and maintenance costs of diesel fired pumps, although benefiting from
cheaper running costs. However, when regional diesel prices peaked at $1.90/L in 2008-10, affected sugarcane growers were reminded of Australia’s sole dependence on imported refined oil products and the exposure of per hectare and ML gross margins. This section examines the pricing outlook for both electricity and liquid fuels.

3.3.1 Electricity price outlook
Electricity prices consist of line rental costs, set by the regulator, and the wholesale cost of generating the electricity from raw materials. In the past decade QLD farmers have experienced electricity price increases of at least 130 per cent, some up to 300 per cent (QFF, 2017). On top of these significant price increases, irrigation specific tariffs that were offered, considering the flat demand profile of irrigators are being phased out for generic business tariffs. These changes, planned for implementation in 2020 will place further price pressure on irrigators, exacerbating already diminishing returns.

Research by Graham et al. (2015) suggests government carbon and energy policy is likely to have a large impact on the wholesale electricity price in the next 30 years. An emissions reductions policy mechanism is expected to result in wholesale prices of $100–$140/MWh by 2035; a 5 per cent per annum increase from $40/MWh in 2015. Under a ‘no carbon price’ or emissions policy scenario, wholesale electricity prices could be in the range of $40–$80 MWh based on increased generation from renewable sources under the Renewable Energy Target (RET), pressuring price growth.

The growing peak demand and stable or declining requirement of total energy usage is a common feature in electricity markets. There is growing interest in strategies to reduce peak demand for electricity by reducing consumption at critical times or shifting it to non-peak times. For demand side management, battery storage and photo-voltaic (PV) systems has been proposed to reduce peak demand. For electricity supply side management, time-of-use electricity rate schemes have been introduced to absorb peak demand (Ren et al., 2016).

Although line-rental is determined by the Australian Energy Regulator (AER), studies into the likely impact of roof top PV found a continuing need for strengthening of the grid to underpin network demands. Analysis of renewable energy penetration and load profiles in Queensland by Jarrett et al. (2016) found that, with the likely uptake of energy technologies in the future, peak demand shifting was most likely to occur with a continued requirement for a strengthened grid. Similar studies by Green and Newman (2017) examined the impact of renewables on the grid in Western Australia. Implementation of power storage and renewables will likely mean the need to upgrade transmission to a more flexible and bi-directional system, ultimately funded by the consumer.

3.3.2 Liquid fuels price outlook
Rapid changes are currently occurring in energy markets and predicted penetration of electric passenger vehicles (EVs) is almost certain to displace a portion of traditional hydrocarbon based fuels in the future. The rate at which fossil fuels are displaced and the predicted growth rate in demand from growing, populous economies (such as China and India) are being carefully monitored by reporting agencies. Although predictions do not account for domestic exchange rate variation, Australia remains highly dependent on imported petroleum products. Globally, imports have grown
considerably, amounting to 11 per cent per year over the last decade (Department of the Environment and Energy, 2017). All reporting agencies surveyed suggest three underlying factors underpin the future price direction of oil to 2040:

- Global economic growth and consumer demand;
- The rate of urbanisation in non-OECD countries (particularly China and India) affecting energy demand and energy innovation (nuclear and renewables);
- Government carbon policies that influence the adoption of innovative technologies.

A summary of the real global oil price indexation to 2040 from each source is shown in Table 5. Although unity of climate and energy policy has a significant impact – rising demand in Asia is likely to ensure upward price pressure (over and above inflation) on refined oil products in the next 25-year period.

Table 5 Inflation-adjusted per annum indexed price forecasts for oil to the year 2040.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Assumption</th>
<th>Per annum oil price: real indexation to 2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>International Energy Agency (2016)</td>
<td>Business as usual</td>
<td>2.55%</td>
</tr>
<tr>
<td>International Energy Agency (2016)</td>
<td>Decarbonisation policies implemented globally</td>
<td>2.00%</td>
</tr>
<tr>
<td>Organisation of the Petroleum Exporting Countries (2016)</td>
<td>Decarbonisation policies implemented globally</td>
<td>2.80%</td>
</tr>
<tr>
<td>US Energy Information Administration (2017)</td>
<td>Business as usual</td>
<td>3.80%</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>2.79%</td>
</tr>
</tbody>
</table>
4. What are the potential solutions?
4 What are the potential solutions?

4.1 Renewable energy in irrigation – the story so far

The application of renewable energy in Australian irrigated agriculture at an industrial scale is relatively under examined. A feasibility study into alternative energy sources for irrigated cotton production by Chen et al. (2013) found solar resources to be unsuitable for irrigation, but useful in offsetting domestic electricity consumption. The study found wind resources were regarded as unreliable and expensive. Eyre et al. (2014) concluded that renewable energy infrastructure is not cost effective and unable to meet peak irrigation demands. Similar studies undertaken abroad concur with these findings eg. Irrigated rice in Qinghai Province in China by Campana et al. (2013); irrigated cotton, corn and wheat in the United States by Vick and Clark (2009), Vick and Almas (2011), Vick and Neal (2012); and vineyard drip-irrigation in the Mediterranean area (Carroquino et al., 2015).

More recent studies related to irrigated cotton (Powell and Welsh, 2016a, Powell and Welsh, 2016b) found that unless renewable energy generation closely matches the timings of irrigation energy demand, or the water can be pumped and stored in reservoirs, the economics become marginal at best. Utilisation of surplus renewable energy generation was identified as a potential area to improving project economics when incorporating renewable sources into existing loads. However, recent advances in PV and pumping technology has reduced the capital cost of installation. These advances in conjunction with substantial increases in power prices and storage capabilities becoming more affordable, have changed the economic equation considerably. Figure 8 shows the fall in cost of solar PV per watt in the period between 2013 and 2017, with a real price reduction of approximately $1.01 per watt (39 per cent).

![REAL PV SYSTEM COST 2013-2017](image)

*Figure 8: Real PV system cost: 2013-2017. Source: Solar Choice Pty Ltd (2017)*

4.2 Energy storage – irrigation applications and pricing outlook

4.2.1 Micro grids: a mix of power sources

Diesel direct drive and diesel generators are widely used in irrigated agriculture throughout the world. It is not always viable to build electricity grid extensions long distances to pump sites – even prior to considering ongoing running costs. Advances in inverter, drive and control systems have supported mixing sources of Alternating Current (AC) and Direct Current (DC) to maintain a constant power source to a load such as a pump. The term ‘micro grid’ is often used to describe electricity generation...
encompassing a mix of traditional (such as grid and diesel) and renewable power source technologies. Micro grids can be defined as clusters of generators which are operated as single controllable entities (Gamarra and Guerrero, 2015).

Micro grid optimisation can be a complex process due to existing energy alternatives, as well as government policy incentives, constraints and uncertainties. Incorporating an intermittent renewable fuel source into a micro grid is challenging due to the intense seasonal demand behaviour required for irrigation plant. Despite these constraints in the design phase, the addition of cost-competitive energy storage systems has increased the utilization of renewable sources. Energy storage will play a crucial role in renewable power penetration in the future, enabling electricity systems greater supply-side flexibility. Behind-the-meter applications allow grid connected consumers to manage their energy bills, reduce peak demand charges and increase ‘self consumption’ from adopting micro grids. In 2015, an off-grid New South Wales irrigator displaced over one million litres of diesel and halved extraction costs over the modelled project life through micro grid technology (Welsh, 2016). An example of a possible micro grid is shown in Figure 9.

Figure 9: An example of a micro grid schematic, with many power sources feeding into one load source such as an irrigation pump. Image source: Ag Econ

Storage systems applicable for irrigators are reviewed in the following section.

4.2.2 Battery Energy Storage
The main-use case for battery storage to 2030 is likely to be influenced by the economic opportunities to provide electricity time-shift services to increase self-consumption or avoid peak demand charges in the irrigation sector. There may also be emerging demand driven by incentives from commercial distribution or generators to manage grid feed-in. Australia has been identified in a recent report by the International Renewable Energy Agency (2017) as having significant growth potential due to current high electricity prices, excellent solar resources and relatively low grid feed-in remuneration.

Battery energy storage has many combinations of chemistry. Suitability differs between application scenario, including space restrictions, temperature, and the frequency, duration and load of power requirements. Round-trip efficiency – energy on discharge and energy used to charge – is expected to
improve substantially in the period to 2030. In broad terms, battery storage can be separated into traditional Lead-Acid, High Temperature, Flow and Lithium-ion:

- **Traditional lead-acid batteries** are, typically the cheapest and are likely to fall 50 per cent by the year 2030 to around US$50 kWh installed.
- **High temperature batteries** may well have potential suitability for the irrigation sector. Corrosion and annual operating costs offer some challenges, although these batteries are used extensively in Japan on a commercial scale.
- **Flow batteries** are different from standard batteries with electro-active materials stored in the cells. Flow batteries have electrolyte solutions stored in tanks separated from the regenerative stack, which are then transferred during charging/recharging. Their long-term life and electrolyte stability is their advantage over other batteries. Flow technology is likely to experience some of the largest cost-reductions to 2030.
- **Lithium-ion batteries** are best known for their use in electric vehicles. These are more expensive as a stationary alternative due to management system and hardware requirements. Economies of scale and technology improvements are likely to lead to the largest cost-savings of all battery types by 2030.

The forecast 2030 installed price and 2016–2030 price reduction for battery energy is shown in Figure 10. The largest expected gains in price are predicted to occur with flow and lithium-ion batteries.

### BATTERY ENERGY STORAGE PRICE ANALYSIS 2016-2030

![Figure 10: Battery future energy storage installed price denoted by the blue bars ($US/kWh) price reduction to 2030 (orange dots) for a range of battery chemistries. Source: International Renewable Energy Agency (2017)](image-url)
4.2.3 Mechanical energy storage solutions

Mechanical systems suitable to irrigation scenarios where abundant renewable energy exists include Compressed Air Energy Storage and Flywheel Energy Storage.

- **In the Compressed Air Energy Storage (CAES) systems**, the energy is stored in the form of pressure energy, by means of a compression of a gas (usually air) into a reservoir. When energy is required, the gas is expanded in a turbine and the energy stored in the gas is converted in mechanical energy available at the turbine shaft. The round-turn efficiency varies between 70 per cent and 89 per cent since it is correlated to the compressor and turbine efficiencies and it is decreased by low self-discharge ability that is typical of this system. CAES can provide bulk power management and can discharge for tens of hours economically. CAES is suitable for daily through to long-term energy storage and is attractive due to its low costs.

- **Flywheel Energy Storage (FES) systems** store excess energy by means of conversion into a kinetic energy of a spinning mass. The FES is matched up with an electrical motor or generator for charge and discharge phases. These systems can be compared with electrochemical batteries, since they show high efficiency (90–95 per cent), long lifetime (20 years) with low maintenance, no depth-of-discharge effects, no environmental issues deriving from no use of toxic materials, fast response time and short recharge time. FES are suited to micro grid application with solar/wind/generator to bridge intermittent gaps in voltage loss, improve power quality and enhance equipment longevity. An example of a flywheel energy storage system with specifications is shown in Figure 11.

![Figure 11: Mechanical energy storage: Flywheels have proven to be economically viable in micro grids to supply short-duration power and smooth intermittent voltages. Source: ABB (2014)
5. Conclusion
5 Conclusion

The irrigated agriculture sector faces major challenges in a water and energy constrained future. Energy is a critical component in irrigated sugarcane production in an increasingly variable climate. There is significant potential in irrigated sugarcane for water savings through the adoption of water use efficient technologies; however, these can lead to increased energy consumption. Energy from irrigation can account for around one third of the total cost of growing sugarcane and 22 per cent of carbon emissions in raw sugarcane production. With the majority of irrigation pumps connected to the national electricity grid, recent sustained price increases have prompted research into productivity solutions to reduce per ML extraction costs and subsequent carbon emissions.

This review presents energy demand characteristics for irrigation at an industry, regional and farm level. Typically, the more water that is transferred in a region, the more growers depend on energy to meet crop water demands. Those regions with less-reliable average growing season rainfall are likely to have a more critical need to irrigate than those regions with higher GSR (relative to reliability). The Burdekin region has a similar GSR to Bundaberg, but a higher degree of variability year-to-year. This results in intermittent and intense periods of high energy consumption. Maryborough and the Atherton Tableland regions have a higher cost of irrigating, owing to higher static lifts from source to field. Although ML/ha rates are comparatively smaller than other areas, a higher energy requirement flows through to reduce farm gross margins. Irrigation application method is primarily high pressure overhead (water cannon) and furrow irrigation, both with contrasting energy requirements and water application efficiencies. Whilst energy productivity solutions may be available, ongoing assessments of water use and pump efficiencies on farms are required to ensure energy demand is reduced.

Modelling energy price outlooks for both liquid fuels and electricity is challenging in a rapidly changing global energy market. The penetration of electric vehicles displacing petroleum-based products and government carbon and energy policies are set to drive the rate of future price increase to 2040. Similarly, with electricity prices, a wide range of future prices stem from national carbon and energy policy decisions that impact energy supply and consumer demand. Advanced battery storage systems will help the integration of renewable power generation through their ability to manage frequency variations and handle peak loads. In this scenario, studies have shown the network will still be relied upon and expenditure required, flowing onto consumers.

Those energy technologies most applicable to sugarcane irrigators will likely occur in the form of pump-site micro grids. These systems can include combinations of renewable energy generation and battery and/or mechanical storage controlled by drive systems to ensure voltages are stabilized at the load source. With prices of flow and lithium-ion batteries set to be reduced by almost 60 per cent in the next 13 years, cost effective solutions can provide a hedge of current energy sources used on-farm. These solutions have the potential to both reduce per ML pumping costs and lower carbon emissions, thereby increasing industry competitiveness and improving sustainability metrics.

Avenues for further research include a meta-analysis of industry pump benchmarking data, potentially identifying regional values for pump efficiency, TDH and irrigation application methods. The survey data used in this study, while useful at a high level, requires ground truthing. A detailed, larger data set would enable targeted use of specific energy productivity solutions and wider industry benefits.
6 References


AGECON 2017. SRA Energy in irrigated cane practices - survey. N/A.


CANEGROWERS BUNDABERG. 13 November 2017. RE: Irrigated cane estimates. Type to WELSH, J.


CRANE, J. 21 August 2017 2017. RE: Cane growing areas and irrigation quantities by region. Type to WELSH, J.


Hussey, B. 2014. Irrigation: one of the keys to reaching yield potential Canegrower.


Organisation of the Petroleum Exporting Countries 2016. Oil supply and demand outlook to 2040. website.


Appendix:
Irrigated sugarcane, farm energy survey results
Appendix 1- Irrigated sugarcane, farm energy survey results

Ag Econ conducted a small survey to get an indication of industry energy statistics, knowledge and attitudes. The survey ran from August to October 2017 and received 115 responses. At a confidence level of 95 per cent, a sample this size results in a 9 per cent margin of error.

With under 10 respondents in some regions, the small sub samples mean the regional results may not be indicative of the region as a whole.

Q1: In which region is your cane farm?
Answered: 115    Skipped: 0

Q2: Approximately how many hectares of irrigated sugarcane do you grow annually (total ha’s in each valley shown)?
Answered: 113    Skipped: 2
Q3: Approximately how much irrigation water would you budget on per year (considering the last 5 years)?

Answered: 115 Skipped: 0

Whole of industry Irrigation budgets (% ha)

‘Other’ responses were general over 12ML/ha

Irrigation budget by region (% ha)

Key Findings:
* Industry wide, sugarcane is generally supplementary irrigated (36% of respondents apply 3 ML/ha), due to sufficient rainfall received in the growing regions. Regional irrigation needs vary depending on GSR (see section 2.2)
* ‘Other’ responses were generally in excess of 12 ML/ha
* The highest noted application was over 30 ML/ha in the Burdekin region. This region applies considerably more than the industry average. A combination of several factors including low GSR and availability of irrigation water
* The 9% of respondents applying 12 ML/ha were all located in the Burdekin
* Plane Creek and Mackay had the lowest average regional application rates
**Q4: Which energy sources drive your pumps? Please show percentages of each source (all=100)**  
Answered: 114  
Skipped: 1

**Whole of industry Irrigation energy source (% ha)**

![Graph showing electricity, diesel, solar, pressurised scheme water, and gravity fed onto farm/fields.]

**Key Findings:**
*On farm irrigation is predominantly powered by electricity, accounting for 79% of respondent's hectares*
*Despite electricity price rises, solar and other renewable energy sources are insignificant suppliers at an industry level*

**Irrigation energy sources by region (% ha)**

<table>
<thead>
<tr>
<th>REGION</th>
<th>Electricity</th>
<th>Diesel</th>
<th>Solar</th>
<th>Pressurised scheme water</th>
<th>Gravity fed onto farm/fields</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atherton Tablelands (2177 ha)</td>
<td>59%</td>
<td>10%</td>
<td>0%</td>
<td>30%</td>
<td>13%</td>
</tr>
<tr>
<td>Burdekin (9843 ha)</td>
<td>78%</td>
<td>12%</td>
<td>0%</td>
<td>3%</td>
<td>9%</td>
</tr>
<tr>
<td>Proserpine (1036 ha)</td>
<td>53%</td>
<td>35%</td>
<td>7%</td>
<td>0%</td>
<td>5%</td>
</tr>
<tr>
<td>Mackay (4952 ha)</td>
<td>74%</td>
<td>19%</td>
<td>0%</td>
<td>13%</td>
<td>4%</td>
</tr>
<tr>
<td>Plane Creek (128 ha)</td>
<td>84%</td>
<td>16%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Bundaberg (9716 ha)</td>
<td>90%</td>
<td>7%</td>
<td>0%</td>
<td>2%</td>
<td>1%</td>
</tr>
<tr>
<td>Isis (1789 ha)</td>
<td>96%</td>
<td>2%</td>
<td>0%</td>
<td>1%</td>
<td>0%</td>
</tr>
<tr>
<td>Maryborough (935 ha)</td>
<td>82%</td>
<td>7%</td>
<td>0%</td>
<td>11%</td>
<td>0%</td>
</tr>
<tr>
<td>Northern NSW (40 ha)</td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>
Q5: What would be the average total lift to pump the water from source to field?
Answered: 114  Skipped: 1

Average water lift, whole of industry (% respondents)

Key Findings:
*60% of respondents lifted water less than 20 m from source to field
*91% of respondents indicated they lifted the water less than 50 m to get to the field
*The Bundaberg, Isis and Maryborough regions have the highest static lift

Average water lift by region (% respondents)

<table>
<thead>
<tr>
<th>REGION</th>
<th>AVERAGE LIFT TO PUMP WATER - % RESPONDENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>less than 20m</td>
</tr>
<tr>
<td>Atherton Tablelands (2177 ha)</td>
<td>40%</td>
</tr>
<tr>
<td>Burdekin (9843 ha)</td>
<td>83%</td>
</tr>
<tr>
<td>Proserpine (1036 ha)</td>
<td>67%</td>
</tr>
<tr>
<td>Mackay (4952 ha)</td>
<td>47%</td>
</tr>
<tr>
<td>Plane Creek (128 ha)</td>
<td>67%</td>
</tr>
<tr>
<td>Bundaberg (9716 ha)</td>
<td>75%</td>
</tr>
<tr>
<td>Isis (1789 ha)</td>
<td>46%</td>
</tr>
<tr>
<td>Maryborough (935 ha)</td>
<td>50%</td>
</tr>
<tr>
<td>Northern NSW (40 ha)</td>
<td>100%</td>
</tr>
</tbody>
</table>
Q6: How many stages is the water pumped to reach the field?
Answered: 112    Skipped: 3

Stages of water pumping, whole of industry (% respondents)

![Pie chart showing stages of water pumping]

Key Findings:
* 86% of the respondents’ pump water directly from source to field
* The staged pumping of 14% of respondents would result in increased energy requirements.
* The Proserpine and Maryborough regions had the highest incidence of staged pumping, followed by Bundaberg and Mackay.

Stages of pumping, % respondents by region

<table>
<thead>
<tr>
<th>REGION</th>
<th>Stages of Water Pumped to Reach the Field</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>My irrigation system pumps direct from water source to field</td>
</tr>
<tr>
<td>Atherton Tablelands (2177 ha)</td>
<td>90%</td>
</tr>
<tr>
<td>Burdekin (9843 ha)</td>
<td>92%</td>
</tr>
<tr>
<td>Proserpine (1036 ha)</td>
<td>67%</td>
</tr>
<tr>
<td>Mackay (4952 ha)</td>
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<tr>
<td>Isis (1789 ha)</td>
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</tr>
<tr>
<td>Maryborough (935 ha)</td>
<td>75%</td>
</tr>
<tr>
<td>Northern NSW (40 ha)</td>
<td>100%</td>
</tr>
</tbody>
</table>
Q7: Which application method is used most on your farm (assign % used for each source)?
Answered: 114  Skipped: 1

Irrigation application method, whole of industry (% ha)

- Big gun irrigators: 39%
- Overhead irrigation: 11%
- Furrow irrigation: 48%
- Drip irrigation: 2%

Irrigation application method, by region (% ha)

- Atherton Tablelands (2177 ha)
- Burdekin (9843 ha)
- Proserpine (1036 ha)
- Plane Creek (128 ha)
- Northern NSW (40 ha)
- Maryborough (935 ha)
- Mackay (4952 ha)
- Isis (1789 ha)
- Burdekin (9843 ha)
- Bundaberg (9716 ha)
- Plane Creek (128 ha)
- Proserpine (1036 ha)
- Atherton Tablelands (2177 ha)

Key Findings:
* % of respondents’ results reflect SRA survey
* Furrow irrigation which has the lowest energy requirements represented 48% of ha
* Big gun irrigators (high pressure overheads) which are the most energy intensive irrigation systems accounted for 39% of respondents’ hectares
* Low pressure overheads including pivots and laterals accounted for 11% of respondents’ hectares
* 2% of respondents ha’s were irrigated using a drip system
Q8: Have increases in energy costs prevented you from irrigating during dry periods, in spite of having access to water?
Answered: 113         Skipped: 2

Do increased energy costs affect irrigation, whole of industry (% respondents)

Key Findings:
*19% of respondents indicated that increased energy costs had prevented them from irrigating during dry periods despite having access to irrigation water. The regions where high energy costs have reduced irrigations include Atherton Tablelands, Bundaberg and Maryborough

Do increased energy costs affect irrigation, % respondents by region

<table>
<thead>
<tr>
<th>REGION</th>
<th>No</th>
<th>Maybe</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atherton Tablelands (2177 ha)</td>
<td>30%</td>
<td>30%</td>
<td>40%</td>
</tr>
<tr>
<td>Burdekin (9843 ha)</td>
<td>67%</td>
<td>29%</td>
<td>4%</td>
</tr>
<tr>
<td>Proserpine (1036 ha)</td>
<td>50%</td>
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<td>0%</td>
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<tr>
<td>Mackay (4952 ha)</td>
<td>32%</td>
<td>48%</td>
<td>19%</td>
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<td>Plane Creek (128 ha)</td>
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<td>0%</td>
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<tr>
<td>Bundaberg (9716 ha)</td>
<td>38%</td>
<td>25%</td>
<td>38%</td>
</tr>
<tr>
<td>Isis (1789 ha)</td>
<td>54%</td>
<td>38%</td>
<td>8%</td>
</tr>
<tr>
<td>Maryborough (935 ha)</td>
<td>13%</td>
<td>50%</td>
<td>38%</td>
</tr>
<tr>
<td>Northern NSW (40 ha)</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

INCREASE IN ENERGY COST AFFECTS IRRIGATION DURING DRY PERIODS - % RESPONDENTS
**Q9: Improvements in renewable energy and storage technology have created opportunities for long-term on farm investments, reducing the cost of irrigating. What would be the limiting factors in investing in these potential solutions on your farm? (please tick as many as applicable).**

Answered: 115  
Skipped: 0

**Factors limiting energy investment, whole industry (% respondents)**

- **1%** I don’t understand RECs/KVA/Kwhrs/any of that lingo
- **12%** There isn’t enough competition around here from reliable engineers & solar suppliers
- **7%** I don’t know if it is a good investment
- **19%** Lack of cash flow to pay for the installation
- **24%** Energy policy change will occur eventually lowering power prices so no real need for concern
- **37%** Other

**Key Findings:**

- Lack of cash flow was the most frequently selected response, however respondents generally felt that a low knowledge of energy, renewables and investment feasibilities would be limiting factors in making an investment in new energy technologies.

- Other limiting factors that were noted included: lack of area suitable or large enough for solar installations, policy uncertainty, “technology is improving so fast – we should wait”.

**Factors limiting energy investment, % respondents by region**

- Proserpine (1036 ha)
- Plane Creek (128 ha)
- Northern NSW (40 ha)
- Maryborough (935 ha)
- Mackay (4952 ha)
- Isis (1789 ha)
- Burdekin (9843 ha)
- Bundaberg (9716 ha)
- Atherton Tablelands (2177 ha)

- I don’t understand RECs/KVA/Kwhrs/any of that lingo
- There isn’t enough competition around here from reliable engineers and solar suppliers
- I don’t know if it is a good investment
- Lack of cash flow to pay for the installation
- Energy policy change will occur eventually lowering power prices so no real need for concern
- Other
Q10: Rate your knowledge of renewable energy and innovative storage technologies applicable to irrigation?
Answered: 115  Skipped: 0

Average grower knowledge rating of renewable energy technologies

Key Findings:
* Atherton Tablelands respondents rated their knowledge the highest at 5.8
* With a range of regional average range of 2.2 – 5.8 out of 10, respondents generally felt their knowledge was low in relation to renewable energy and innovative storage technologies

Average grower knowledge rating of renewable energy technologies by region

<table>
<thead>
<tr>
<th>REGION</th>
<th>Average response</th>
</tr>
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<tbody>
<tr>
<td>Atherton Tablelands (2177 ha)</td>
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<tr>
<td>Burdekin (9843 ha)</td>
<td>5.1</td>
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<tr>
<td>Proserpine (1036 ha)</td>
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<tr>
<td>Mackay (4952 ha)</td>
<td>4.0</td>
</tr>
<tr>
<td>Plane Creek (128 ha)</td>
<td>2.9</td>
</tr>
<tr>
<td>Bundaberg (9716 ha)</td>
<td>5.2</td>
</tr>
<tr>
<td>Isis (1789 ha)</td>
<td>4.9</td>
</tr>
<tr>
<td>Maryborough (935 ha)</td>
<td>5.2</td>
</tr>
<tr>
<td>Northern NSW (40 ha)</td>
<td>2.2</td>
</tr>
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</table>