FINAL REPORT 2017/011

Productivity improvements through energy innovation in the Australian Sugar industry

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Sugar Research Australia

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ABSTRACT

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 % 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. This project examined various technology components available to reduce the cost of pumping in a micro grid situation: solar PV, diesel gensets, grid energy, wind turbine and lithium-ion batteries. The results found that economic feasibility of incorporating components to lower pumping costs was heavily influenced by Ergon grid connection policies and retail pricing, i.e. export limitations of solar PV, feed-in-tariff rate and the high cost of undertaking 'user pays' studies for systems above 39 kW acted as a deterrent. Putting aside grid policy barriers, the study found solar PV to be the most cost-effective technology for this purpose when tested among a range of components. For smaller, grid connected irrigation plant (under 40 kWp), incorporating solar PV systems achieved high investment returns.

Renewable energy also offsets fossil fuel-based energy resulting in reduced greenhouse gases in each scenario. Farmers have many options when it comes to financing renewable energy projects. A power purchase agreement is a novel approach offering nil-upfront cost with immediate energy savings. Leasing and traditional debt financing models are also available to increase irrigator uptake. Adoption of renewable energy into irrigation pumps has been slow. This study found carbon and energy policy settings have room for improvement to accelerate uptake: increased STC threshold from 100 kW to 200kW, greater incentives for users connecting to the grid and a targeted approach from both water and energy policy to investigate innovative ways to incentivise a shift to renewables.

EXECUTIVE SUMMARY

Issues and objectives

Ag Econ project mission statement:

"lower pumping $/ML energy cost using optimal combinations of available energy technologies"

The initial phase commenced with project planning, understanding issues and quantifying energy fits into the cane gross margin budget. A targeted industry survey was undertaken focusing on energy literacy, attitudes to sustainability and current cost of irrigation. Following, a gross margin analysis found different variable cost regimes for a number of application methods; comparative irrigation costs were ranked with Big gun water cannons as the highest cost per applied megalitre (ML)/ha followed by low pressure overhead, drip lateral move and furrow irrigation showing the least-cost energy consumption per ML. The findings from this analysis and survey data provided valuable information on research method design and choice of case study sites for maximum savings and highest investment returns. Survey data from 115 farm advisors, irrigators and industry personnel also offered insights that would help structure communications and disseminating results to industry. A vast network of family and corporate cane irrigators, farm advisors, industry personnel was established during the survey period and a Southern region site visit in 2017.

Project method

A careful examination of industry pumping data by region and application was undertaken in collaboration with SRA to identify the most relevant case study sites. Within the chosen criteria, a short list of potential irrigators was drafted and subsequent interviews followed to firm up case study participation. Once established, site visits and data collection were tabled. In-depth analysis on energy technology component retail pricing and availability would serve as practical numbers underpinning equipment optimisation for each case study site. Energy pump demand was modelled in detail with hourly usage through a calendar year, using before/after scenarios to test economic metrics such as payback period and Internal Rates of Return (IRR). HOMER (Hybrid Optimisation of Multiple Energy Resources) software was then used to rank technology options, taking into account grid policy for connection costs, feed-in-tariff criteria, a range of Ergon consumption tariffs and Levelised Cost of Energy. Displaced fossil fuels from renewable sources enabled emissions abatement calculations using tonnes of CO_2e over the assumed 25-year life of the installation.

Results and extension

First year case studies in Ayr (flood irrigation), Mackay (overhead) and Bundaberg (bore – big gun) were published in a top ranking global journal[1], *Journal of Cleaner Production* in collaboration with the University of Western Australia. The first major extension activity (other than ASSCT presentations) occurred during this period with a well-attended industry webinar on key findings. A presentation to SRA extension staff also took place, to help industry extension officers understand the main success factors of renewable energy pump site integration. Other communications outputs featured in CaneConnection and the Australian Canegrower magazine. New case studies for phase two of the project began with analysis on drip irrigation (Tablelands) and a 22 kW grid connected transfer pump (Burdekin).

[1] https://www.journals.elsevier.com/journal-of-cleaner-production/news/top-publication-in-google-scholars-sustainable-development

Finance for energy efficiency and renewable energy projects is also a driver of adoption of renewable energy technology. Various sources of finance can influence a decision to invest in renewable energy. Options include cash, bank loan, rental or leasing and Power Purchase Agreement. Each have their own unique characteristics that transfer financial and operating risk between the consumer, financier and equipment supplier. The financing models offering the highest returns over the life of the project (Net Present Value) were a cash purchase or direct loan financing. A Power Purchase Agreement provides electricity at a discount with no up-front capital payment required. This option was the least risky, however, it provides the lowest cumulative cash flow over the comparable investment period. A further two new case study sites were evaluated and run through alternative financing models to show risk/returns scenarios. Raw feasibility results of each site enabled more data and higher confidence in application of alternative energy. These results have been communicated to each grower who offered their site information and a detailed report is available on the SRA website.

A further three case studies were undertaken on overhead irrigation (Isis), a bore pump (Maryborough) and an additional study focussed on the benefits of a pump audit prior to sizing up a solar PV array. Industry engagement of project outputs was a feature of 2019 - with workshops held at Mackay, Proserpine, Bundaberg, Ayr and Haughton. All were well-attended and audience feedback found an appetite for more demonstration sites as a prerequisite to more investment in alternative technologies. A lack of quality service providers and general competition was mentioned as a limiting factor of on-farm solar PV investment.

A newly designed SRA "energy portal" was developed to house all project resources for ease of access. These include detailed academic reports, webinars, podcasts, ASSCT presentations and energy YouTubes and final project summary webinars. A policy review was the final output, which found novel approaches to government policy are urgently needed to improve the uptake of renewables among sugar cane irrigators. Potential policy areas of interest include merging energy and water policy departments and incentives, increasing the Renewable Energy Target threshold from 100 kW to 200 kW, and support for adaptive transmission policy such as feed-in-tariff Time of Use rates and relaxing export limits.

Outcomes, implications and beneficiaries of this research

Over the duration of the project the main research findings are best summarised as follows:

- Viable options to reduce energy costs for irrigation exist for small grid-connected pumps under 40 kW by incorporating solar PV systems;
- Carbon emissions abatement occurs by incorporating solar PV systems into irrigation sites;
- Undertaking an energy audit prior to solar can have multiple benefits:
    - offer higher returns per dollar spent than solar in most cases;
    - reduce the PV array size and therefore capital requirements;
    - identify small changes in configurations that flow-on to large long-term savings
- Energy literacy and confidence to invest in energy technologies among irrigators remains low;
- Proactive policy settings and well-resourced industry extension are required to improve irrigator adoption;
- Service provision for renewable energy is scant, with monopoly behaviour or poor quality products / services deterring many would-be adopters of renewable technologies; and
- The cane industry as a whole would benefit through higher adoption of solar PV systems leading to improved sustainability (CO_2e/t cane) and lower per ML cost of pumping, flowing-on to higher water use and higher cane yields.

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1. BACKGROUND

1.1. Energy as an input for irrigation

Energy is a critical input and cost component for sugar irrigators and processors alike. Energy is also the focus of policy makers looking to reduce greenhouse gas emissions and encourage sustainable practices. A study commissioned by the CSIRO[2] predicts the wholesale price of electricity energy to grow by 5% per annum (net of transmission costs) to 2035, factoring an emissions reduction policy over that period. Retail electricity prices experienced an 82% increase from 2007-2014, outstripping inflation of 13% over the same period, and diesel prices have moved in a range of $1.02 to $1.90 per litre in the last 10 years. If no action is taken to investigate and adopt alternative, cost-effective means to increase productivity, energy will continue to erode industry gross margins and impact negatively on industry sustainability credentials.

1.1.1. Industry value of this research

Incorporating solar into irrigation can reduce reliance on fossil fuels and grid-supplied energy and significantly reduce greenhouse gas emissions. Upgrading pumping systems with solar energy can also increase productivity through remote water monitoring systems that reduce on-farm labour costs, measure inputs and streamline farm management. While localised studies have been undertaken on pumping energy efficiency, no other SRA industry projects have explicitly considered a cost-benefit analysis on new energy technologies to identify opportunities. Industry value will occur in three areas:

1. Reduced energy costs in the sugar gross margin budget from savings in technology adoption ($/t produced)
2. Reduced environmental footprint of sugar production (CO_2e / t produced)
3. Socially, through increased collaboration, interaction and networking among growers, farm advisors and technology providers.

2. PROJECT OBJECTIVES

2.1. Broad research aim and study areas

The research project aimed to understand the costs and benefits (both economic and environmental) of the application of renewable energy to supply energy to Australian sugarcane irrigation motors. Sugar producers will have increased capacity through knowledge and confidence to engage renewable energy engineers and suppliers to adopt/install the technology, knowing the key drivers of available alternatives and project economic returns.

The project was broken down into three key areas of study.

Area 1. Scoping study: The opportunities for energy innovation in Australian irrigated sugarcane

The objective was to gain an understanding of the most common irrigation systems used for Australian sugarcane and detail the energy requirements and the source of energy used. We also aimed to review alternative energy applications in irrigated agriculture globally, identify key Australian government policies and incentives for installing renewables, and understand the cost of energy in a typical irrigated cane gross margin.

Area 2. Investigation via Case studies

[2] https://publications.csiro.au/rpr/pub?pid=csiro:EP141067

The objective of using case study analysis was to understand the feasibility of renewable energy for sugarcane irrigation using real farm data. Case studies were selected in conjunction with SRA staff to cover key pumping scenarios across the major irrigated cane areas. Eight case studies were completed and a number of other sites analysed privately for interested irrigators to contribute to results. Results and sensitivity testing were published with the aim of covering the scenarios relevant to most irrigated sugarcane growers.

Area 3. Study to understand applicable policy mechanisms for renewable energy in Australian sugarcane

The purpose of this policy research paper was to review current policies applicable to sugarcane irrigators, consider their effectiveness in terms of adoption and identify potential opportunities.

3. OUTPUTS, OUTCOMES AND IMPLICATIONS

3.1. Outputs

As the project consisted of research, development and communication, a range of outputs were developed and extended in the project. SRA created the Energy portal section on their website as a place to collate all the energy outputs. The hub was promoted in an Australian Canegrower article in December 2019.

A comprehensive reference list is provided in Section 9.

Scoping study: The opportunities for energy innovation in Australian irrigated sugarcane

The first output of the project was the report *Opportunities for energy innovation in Australian irrigated sugarcane.* This report was made available on the SRA website and printed by SRA. Findings of the report were also included in presentations made via a webinar and at SRA grower research updates in early 2019.

Investigation via Case studies

A number of case study outputs were created to extend the findings of the analysis. Interim results were presented via a conference software (Go-to-meeting) with SRA RD&A staff in June 2018 for feedback. Individual farm results were also presented to case study participants. Several participants indicated that they may purchase a solar installation.

A key output was the peer-reviewed journal paper, *Can applying renewable energy for Australian sugarcane irrigation reduce energy cost and environmental impacts? A case study approach*.

Several fact sheets and cane industry articles were also published, extending results to irrigated sugarcane growers. The factsheets are available on SRA's energy portal.

In March 2019, Ag Econ's Janine Powell conducted a radio interview with Kalle Buchanan from ABC Wide Bay, and the radio clips outlined how micro grids can potentially save cane irrigators money.

A webinar, *Reducing energy costs in irrigated cane – what stacks up when?*, was offered broadly to sugarcane growers.

In an effort to create a range of extension outputs, a podcast was recorded summarising the renewable energy options applicable to irrigators in the Australian sugarcane industry.

An energy Best Practice Module was drafted for Canegrowers' SmartCane BMP program. Canegrowers welcomed the module (in December 2019) as a potential future addition to Smartcane BMP.

The CaneClip *Renewable energy for sugarcane irrigation* has been well received.

A paper titled *Factors influencing Australian sugarcane irrigators adoption of solar photovoltaic systems for water pumping* developed with economists from the University of Western Australia (UWA) has been submitted to the Journal of Agricultural Systems.

A final summary of results was extended via a two-part webinar series. The webinars, *Renewable Energy Case Studies (#1 of 2 part series)* and *Finance options and barriers to adoption (#2 of 2 part series)*, had a strong live audience and were viewed many times afterwards. Both webinars are available on the Australian Cane Learning Centre.

There was much enquiry as to whether a simple decision-support tool could be developed to help cane growers quickly assess their situation. While it was outside the scope of this project, such a tool could be a possibility for development.

Australian renewable energy policy and impact on sugarcane irrigators

A journal paper, *Under Review: Australian renewable energy policy for sugarcane irrigators: challenges and opportunities*, is being developed with UWA economists. A related extension article, *Australian renewable energy policy for sugarcane irrigators* aimed at sugarcane farmers, will be published in CaneConnection.

3.2. Outcomes and Implications

Scoping study: The opportunities for energy innovation in Australian irrigated sugarcane

The initial investigation was to understand the opportunities for energy innovation in Australian irrigated sugarcane. The key factors contributing to the energy demands of an irrigated sugarcane farm were reported and included:

- Pumping scenario (efficiencies & heights)
- Energy source
- Water source
- Irrigation system
- Volume of irrigation water pumped
- In crop rainfall and evapotranspiration

Several factors that influence energy demand are out of a farmer's control. Climatic factors such as Growing season rainfall (GSR) and regional supply and availability of irrigation water influence the irrigation water source and volume applied. Regional topography and farm layout dictate suitable irrigation systems and heights that water needs to be pumped – in some cases requiring staged pumping.

A farmer can alter irrigation systems and fine-tune pump and motors but there is a point when efficiencies are maximised. The report '*Opportunities for energy innovation in Australian irrigated sugarcane*' outlined that further cost reductions can be potentially made through investments in energy infrastructure.

The report also compared the different energy requirements and variable costs of various irrigation systems and pumping scenarios. The key scenarios are analysed in the sugarcane gross margin. The energy intensive systems not only account for a higher proportion of variable costs and reduce gross margins, but also result in the enterprise being more exposed to price risk of energy inputs.

Investigation via Case studies

In Australian sugarcane production, 90% of irrigation pumps are connected to the national electricity grid. In regional Queensland, where irrigated sugarcane is grown, both the retailer and distribution network service providers are government-owned and highly regulated.

The study investigated options for on-farm embedded generation from a range of commercially available components to reduce energy costs of furrow, centre pivot, and Big Gun® irrigation.

The study confirmed that demand-side management crucially affects the economic feasibility of embedded generation. Connection rules, such as feed-in tariffs and export limits affecting renewable embedded generation, can also influence emissions abatement costs and investment returns. When export limits are allowed on larger sites (solar PV systems >40 kW), abatement costs fall from \$109/t CO_2e to \$18/t CO_2e and the present value of the investment improves substantially.

The analysis revealed economically feasible opportunities exist for small-scale solar PV system installations (under 40 kW), reducing Net Present Cost of pumping from 12 to 25% and emission reductions ranging from 1245 t CO_2e to 1314 t CO_2e per installation over 25 years. Where a site is not eligible for a feed-in tariff, high renewable energy utilisation rates are required to make the site feasible. Batteries did not feature as an optimal component, even when battery storage and replacement values were discounted by 60%, indicating that seasonal load profiles under-use a battery investment. Therefore, batteries are inefficient and can be avoided in an irrigation microgrid.

Australian renewable energy policy and impact on sugarcane irrigators

Effective policy and regulatory frameworks incentivise the utilisation of renewable energy to achieve long term reductions in carbon emissions. While Australia's renewable energy policy has taken significant steps towards encouraging the deployment of lower-emission energy generation, adoption among sugarcane irrigators remains low.

A key policy mechanism incentivising renewable energy in Australia is the feed-in-tariff (FiT) paid by energy retailers for renewable generation sold back into the grid; however, connection policies in each state impact the effectiveness of this approach as a policy lever. In Regional QLD, the current FiT was reduced 17% to 7.8c/kWh for the 2019-2020 tariff year. The 2019 Ag Econ study *Can applying renewable energy for Australian sugarcane irrigation reduce energy cost and environmental impacts?* concluded that the two significant economic disincentives of renewable energy for sugarcane irrigation were the regional Queensland FiT policies around the maximum inverter capacity of 30 kW to qualify for the regional FiT, and uncertainty surrounding the long term value of the FiT.

Two federal levers currently incentivising renewable energy in Queensland include the Renewable Energy Target (RET) and the Emissions Reduction Fund (ERF). Under the ERF, projects earn Australian Carbon Credit Units (ACCUs) for every tonne of CO^2e abated using an approved method. Projects on sugarcane farms are unlikely to be suitable for the ERF due to the project scale required for minimum abatement and to recoup auditing and administration costs.

Under the RET, generators of renewable energy receive STCs and LGCs (small-scale technology certificates and large-scale generation certificates, respectively). STCs (for solar PV installations up to 99 kW) are administered upfront by the equipment supplier upon the purchase and installation of renewable energy. The rebate is deducted from the capital cost, reducing the upfront cost of the system. Accessing LGCs (for solar PV installations 100 kW plus) involves a more detailed set of criteria and administrative load, LGCs are sold on an open market. With increased investment in solar and wind farms nationally, the LGC price has trended steeply lower. If the threshold for STC rebates increased from 100 kW to 200 kW, it is plausible that small industrial loads such as irrigation pumps may attract new renewable energy investment from improved economic feasibility and administrative simplicity. This strategy is likely to involve a hybrid policy approach with changes also to connection policy (FiT and export limits) also required for success.

The Queensland Government also has a hydrogen policy strategy aimed at driving the development of an economically sustainable and competitive hydrogen industry. Innovative solar-hydrogen-storage co-operative models in cane growing regions may offer opportunities to achieve more price-certainty, reduce greenhouse gas emissions and access lower prices.

A collaboration among water and energy government departments could better target irrigators through financial incentives or rebates on water charges for those using renewable sources to accelerate uptake.

4. INDUSTRY COMMUNICATION AND ENGAGEMENT

4.1. Industry engagement during course of project

The outline of the many extension outputs and activities of the project in Section 3.1 indicates that industry engagement was a strong feature of the project.

In addition to the desktop component of the initial scoping study, industry stakeholders were also widely consulted. Meetings were held with SRA extension staff, Canegrowers staff, productivity services, millers, growers and agronomists across the cane growing regions. An online industry survey was also conducted to complete the understanding of the existing energy profile and the level of energy literacy within the cane industry.

Visits were made to many farm case study sites (both published and unpublished) to gain understanding of irrigation specifications and factors that may affect the adoption of renewable energy for different farms in different regions. The farmers welcomed the engagement and were pleased to be involved within the study. Each case study farmer received a personal explanation of results and tailored analysis.

A total of five industry workshops were conducted and each was well attended. An overview of renewable energy potential for irrigated sugarcane was presented with all sessions quite interactive in terms of farmer questions and discussion. Participant feedback from SRA post-workshop survey revealed energy as a high-scoring topic in the agenda. Across all workshops, a common theme emerged that there was very little independent advice and that generally farmers didn’t trust the traveling salesman style of solar retailer. Farmers welcomed any information they could obtain from an independent and trusted source such as SRA.

Three industry webinars were conducted over the course of the project. The first, *Reducing energy costs in irrigated cane – what stacks up when?,* only had 25 live participants, but there were further subsequent views of the recording. The more recent two-part series summarising the key messages of the project (see section 4.2) had over 60 live participants each and further views of the recording.

The CaneClip *Renewable energy for sugarcane irrigation* has been one of the more popular extension outputs with 565 views to date.

Throughout the project, SRA extension staff have assisted with output development and extension, in particular Veronica Chapman facilitated a number of meetings with Southern growers and experts to ensure a suitable and relevant case study site was chosen and that information was gained in a timely manner.

Jon Welsh and Janine Powell presented posters and papers at the ASSCT conferences in 2018 and 2019 and submitted papers for 2020 (prior to COVID postponement). These industry conferences were an effective way to engage with a broad range of industry stakeholders.

A presentation had been accepted for the National CRSPI Conference 2020: *Factors influencing Australian sugarcane irrigators adoption of solar photovoltaic systems for water pumping.* The presentation is pending a postponement.

4.2. Industry communication messages

Over the duration of the project, the main research findings are best summarised as follows;

- Viable options to reduce energy costs for irrigation exists for small grid-connected pumps under 40 kW by incorporating solar PV systems;
- Carbon emissions abatement occurs by incorporating solar PV systems into irrigation sites;
- Undertaking an energy audit prior to solar can have multiple benefits:
    - Offer higher returns per dollar spent than solar in most cases;
    - Can reduce the PV array size and therefore capital requirements;
    - Can identify small changes in configurations that flow-on to large long-term savings
- Proactive policy settings and well-resourced industry extension is required to improve irrigator adoption; and
- The cane industry as a whole would benefit through higher adoption of solar PV systems and improved sustainability (CO_2e/t cane), lower per ML cost of pumping, higher water use and higher cane yields.

5. METHODOLOGY

The research project aimed to understand the benefits (both economic and environmental) of the application of renewable energy to supply energy to Australian sugarcane irrigation motors. The project was broken down into three key areas of study; the methodologies undertaken for each study area are outlined below.

Scoping study: The opportunities for energy innovation in Australian irrigated sugarcane

A desktop review was conducted (using available published information, SRA industry surveys and advice from the SRA adoption team) of energy use in irrigated sugar production to identify the most common systems, inefficiencies and fuel source.

Due to the lack of published information on energy in the sugarcane industry, Ag Econ ran an online grower survey. The survey was designed to get an indication of industry energy statistics, knowledge and attitudes. It ran from August to October 2017 and received 115 responses. At a confidence level of 95%, a sample of this size results in a 9% 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. The full results for the Ag Econ 2017 Irrigated sugarcane farm energy survey can be found in

Appendix 1 of the report '*Opportunities for energy innovation in Australian sugarcane*'. Considering the small sub sample sizes in the survey, this information is best used to as a guide only.

Additionally, analysis was conducted to get an understanding of comparable energy and cost /ML for various irrigation systems and pumping scenarios. This information was presented in Table 3 of the report *Opportunities for energy innovation in Australian sugarcane* and is a key report output. The developed cost information was used to conduct a partial budget analysis and comparison of key irrigation and pumping scenarios.

Investigation via Case studies

A range of economic methods were used to conduct a cost benefit analysis of renewable energy applied to sugarcane irrigation. Using discounted cash flow investment analysis, partial budgeting and energy decision-support tools, a range of irrigation plant scenarios (on-grid or off-grid) incorporating renewable energy and battery storage were evaluated:

- The feasibility of renewable energy for sugarcane irrigation (three case studies)
- The funding opportunities for renewable energy in Australian sugarcane (three case studies)
- Additional feasibility case study scenarios (three case studies)

Study to understand applicable policy mechanisms for renewable energy in Australian sugarcane

The purpose of this policy research paper was to review current policies applicable to sugarcane irrigators, consider their effectiveness in terms of adoption, and identify potential opportunities. A desktop review methodology was used and the structure of this study was as follows:

1. Global energy policy landscape - mechanisms used to increase adoption of renewable energy
2. Current policy in QLD, Australia review: regulatory frameworks and incentives
3. Opportunities for policy change
4. Conclusion

6. RESULTS AND DISCUSSION

Scoping study: The opportunities for energy innovation in Australian irrigated sugarcane

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 % 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 growing season rainfall (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, each 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 % 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, Total Dynamic Head (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.

Investigation via Case studies

The farm energy study has shown the cost of energy can be reduced, using microgrids in small-scale, seasonal irrigation (< 100 MW per annum) in the highly regulated electricity market in regional Queensland. Energy cost reductions of up to 26% and avoided emissions of 1,303 t/CO_2e over a 25-year investment period indicate the potential industry wide gains if the technology were to be widely adopted. The optimal component selected by the HOMER software for integration into the grid-connected sugarcane irrigation scenarios was solar PV. With solar PV, the cost of energy for all sites was reduced. To achieve maximum cost reductions, two sites needed to undersize the microgrid to remain within DNSP (Distribution Network Service Provider) eligibility criteria for export and FiT. When larger systems above 55 kW, such as those analysed at Mackay and Bundaberg (sites B and C) exceeded embedded generation limits of a 30 kW inverter, and were ineligible for export, the microgrid was not economically feasible, as only minor reductions in the cost per kWh occurred compared to business as usual scenarios. Sites with a sporadic seasonal load could not use enough renewable energy to warrant the microgrid installation, unless some unused energy could be exported and a FiT received.

Sensitivity testing of microgrids exceeding the 30 kW export and FiT eligibility found embedded generation connection rules were the largest driver of economic and environmental rewards. A small export limit at current FiT rates showed a marked improvement in economic feasibility, with improvements in internal rate of return and payback period, with similar gains in avoided emissions and cost of abatement. The model was more sensitive to changes in export limits compared to changes in the FiT.

Batteries did not feature as an optimal component, even when battery storage and replacement values were discounted by 60%, indicating that seasonal load profiles under-use a battery investment. Therefore, batteries are inefficient and can be avoided in an irrigation microgrid. Sensitivity analysis also showed an additional abatement and cost saving if net metering policies were implemented.

The RET's ability to encourage small-scale renewable investment for irrigators with seasonal energy demand is contingent on state-based distribution network service provider policies. At present, the policy discourages medium-scale renewables (30–99 kW) with the absence of a FiT for those systems. This study found lowest cost abatement from STCs is achieved when medium-sized grid-connected pumping systems can maximise exports with a FiT. Avenues for future research include flow-on effects of increased irrigation from the reduced cost of energy, sustainability calculations per tonne of cane produced under the investment scenarios and the inclusion of Life Cycle Assessment costs relating to the manufacture and disposal of solar PV systems at the end of life.

Study to understand applicable policy mechanisms for renewable energy in Australian sugarcane

Countries around the world have successfully managed the integration of variable renewable energy into their power systems. Notably, some countries have managed 100% for short periods (International Renewable Energy Agency, 2017). The same report mentions increases in electricity storage, digital technologies, new grids and dispatchable generation and innovative market design as solutions to smoothing the intermittent supply of wind and solar energy. Using a combination of incentives, Government policies can have a substantial impact on delivering practice change through the adoption of new technologies. This policy review has identified that while Australia boasts high penetration of domestic rooftop PV, policy reform is required to increase uptake among the 'small industrial' category.

Queensland's 50% renewable energy target is a state-based objective to enhance the uptake of energy technologies from renewable sources to reduce emissions. This policy intersects others in a renewed focus to improve current rates of adoption. The SRA strategic plan, the Queensland hydrogen initiative and various sub-policies within the RET and the ERF aim to incentivise commitment and acceptance of renewable technologies. Grid policy settings through export limits and feed-in-tariff pricing can assist in improving the feasibility of combining solar PV into grid-connected seasonal loads. Collaboration between water and energy Government Departments also offers a more niche and tailored approach to incentives available to sugarcane irrigators by, for example, offering rebates for water pumping from micro grids with a renewable component. Finally, the ease at which the STC rebates can be administered and the success of the Small-scale Renewable Energy Scheme since inception would suggest greater irrigator participation in renewables if the future policy could modify SRES thresholds from 100 kW to 200 kW. Under this scenario, those pumps 55 kW and above would be relieved of current administrative and risk exposure required under the Large Renewable Energy Scheme. Refining current policies to carefully targeted incentive programs that offer opportunities for irrigated cane growers can improve practice change and, in doing so, lower production costs, improve productivity and reduce emissions.

6.1.1.Project delivery reflections

This project overall progressed smoothly. Initial stages were difficult for Ag Econ as new providers in the sugar industry to gain trust and credibility among productivity resvice organisations, Canegrower representatives, growers and farm advisors. Unfortunately, by the time our project eventually made meaningful connections in 2019, the project was almost complete and extension output milestones met. The extension proportion of the project was resourced well-below demand levels, with irrigators very keen to understand in greater detail technical and commercial nuances regarding the solar PV system integration leading to lower pumping costs.

In terms of measuring impact of this project, a study on irrigator adoption of solar PV was undertaken with UWA (ancillary to project milestones) to help understand limitations and project impact. The ADOPT framework (CSIRO, 2019) assumes that adoption of a new technology will proceed over time according to a sigmoidal response. Adoption would be slow at the start, gaining momentum and then slow at the end (**Error! Reference source not found.**). Solar PV is a mature technology, with minimal adoption by sugarcane farmers, so the ADOPT questions were answered relative to the current situation – which would be considered year 0. By year 5, the adoption level predicted by ADOPT for solar PV is around 25% of irrigated sugarcane farmers, and by year 10 adoption on 50% of farms is predicted. A step up in extension resources would improve adoption by 20% to 70% after year 10. Considering the current minimal adoption of the technology to date, there are many factors at play which influence industry RD&E. Some of these points are discussed in the project conclusion.

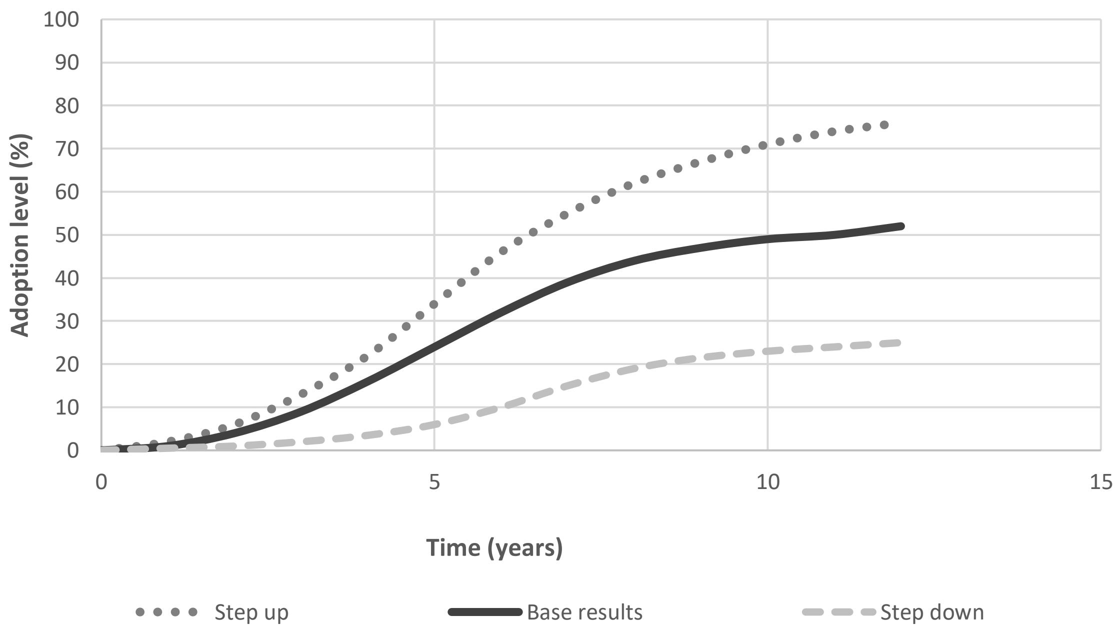

Figure 1. Curve sensitivity analysis (ADOPT) under the original level (solid line), a step up in resourcing (dotted line) or a step down in resourcing (dashed line).

7. CONCLUSIONS

Decisions about adopting energy technology, such as incorporating solar PV systems into irrigation pump sites, are influenced by a complex set of factors.

Factors influencing the level of adoption are focused around the relative advantage of the technology. In this study the greatest influence was how the technology affects farm profit, particularly grid and connection policies that affect profitability. Also influencing the level of adoption was the number of farms that could benefit, how the technology impacted farm business risk, its ease of use and environmental benefit.

According to our study using the ADOPT framework, the immediate economic benefits generated by the PV systems was the main rationale for their adoption. All factors that contribute to increasing revenue and reducing costs have an impact on profitability and therefore the level of adoption. The up-front capital cost of the systems and the ongoing revenue they generate from energy export via a FiT were major drivers of the financial model, as most sugarcane irrigation pumps were connected to grid power. Government incentives such as rebates provided by the RET and interest subsidies through the CEFC to lower the cost of renewable technology. Connection policies influencing FiT eligibility, both increased the profitability of the technology and can potentially increase the number of sites that could benefit. Together these incentives could potentially shift the level of adoption from a predicted 50% after 10-years to 90%.

The factors influencing the rate of adoption were focused on the ability for a population to learn about the relative advantage of the technology and the current financial conditions of the population. The most sensitive factors around the learnability of the technology were the requirement for new skills by the population. While farmers did not require new skills to operate a solar PV installation, the lack of knowledge around the technology was likely to influence adoption. Increased industry communication around instances where and when the technology was most profitable, and demonstration of improved profitability, could reduce the time to peak adoption by 1.5 years. The study's results indicate a larger change could potentially be in made than the mid-range projection.

Existing adoption of solar PV technology for irrigation has been slow, and this is likely to be influenced by the changing relative advantage of the technology compared with business as usual. Some farmers who previously assessed the technology may be unaware the advantage has improved and those that understood the improving relative advantage may be waiting to invest when they feel the relative advantage has peaked. Both factors affect the rate and level of adoption.

The findings from this project can aid future extension strategies in irrigated industries, and potentially influence Australian government energy and industry policy design to ensure industry economic and sustainability goals are achieved. Increased adoption of solar energy directly improves farm productivity, lowers emissions and may indirectly improve on farm water use efficiency through increased investment in the more energy intensive technologies that increase cane production. The co-benefit of improved sustainability metrics (CO_2e per unit output) also has flow-on effects for irrigators seeking to meet expectations of more environmentally aware consumers and gain access to premium agricultural export markets.

8. RECOMMENDATIONS FOR FURTHER RD&A

Recommendations for future investment at the conclusion of this project are summarised below:

- Further adoption research would be useful around the uncertainty in the factors influencing the relative advantage of solar PV and investment in an uncertain environment;
- Bring SRA research farms up to "energy best management practice" to provide demonstration sites for growers to visualise what they can achieve;
- Industry advisors undertake energy literacy training to aid in conversations with growers and build capacity for increased confidence around renewable investment;
- More extension and industry resources on investigating the potential of solar PV integration (e.g. decision support portal or tool); and
- A demonstration solar-hydrogen fuel cell powered pump site (potentially on an SRA farm) to show this futuristic novel technology in use as an alternative to grid and diesel-powered pumps, emissions free.

9. PUBLICATIONS

Welsh J.M and Powell J.W (2017), "Opportunities for energy innovation in Australian irrigated sugarcane." Sugar Research Australia report. Ag Econ, Burren Junction, NSW, Australia

Welsh J.M (2018), "Electric vs Diesel pumps: is there a clear winner?", *CaneConnection.* Spring 2018, Sugar Research Australia Limited, Brisbane, QLD, p. 24

"Micro grids: Powering the future of irrigated sugarcane", *Australian Canegrower,* April 2018, CANEGROWERS, Brisbane, QLD, pp. 10-11

Welsh, J.M and Powell, J.W. ASSCT poster (April 2018) Opportunities for energy innovation in irrigated sugarcane.

Welsh. J.M and Powell J.W (Aug 2018), *Reducing energy costs in irrigated cane – what stacks up when?,* Webinar [video file]. Available in SRA Australian Cane Learning Centre

Welsh, J. M & Powell, J. W (June 2018), *Integrating alternative energy solutions: Irrigated cane* , Ag Econ fact sheet. Available: SRA irrigation and energy portal

Powell J.W, Welsh J.M, Pannell, D. and Kingwell, R. (2019) "Can applying renewable energy for Australian sugarcane irrigation reduce energy cost and environmental impacts? A case study approach." *Journal of Cleaner Production,* 240, 118177.

Welsh J.M (2018), "Irrigators move towards profit and sustainability", *CaneConnection.* Winter 2019, Sugar Research Australia Limited, Brisbane, QLD, pp. 18-19

"Study helps irrigators assess options", *Australian Canegrower,* May 2019, CANEGROWERS, Brisbane, QLD, pp. 10-11

Welsh J.M and Powell J.W (2019), "The funding options for energy innovation in sugarcane irrigation." Sugar Research Australia report. Ag Econ, Burren Junction, NSW, Australia

SRA (2019), *Renewable energy for sugarcane irrigation,* CaneClips [video file]. Available in SRA Australian Cane Learning Centre

Welsh. J.M and Powell J.W (Dec 2019), *Renewable energy options in the Australian sugarcane industry,* Podcast [audio file]. Available in SRA irrigation and energy portal

Powell, J. W and Welsh, J.M (Dec 2019), *Energy efficiency case study - ISIS*, Ag Econ fact sheet. Available in SRA irrigation and energy portal

Welsh, J. M & Powell, J. W (Dec 2019), *Thinking solar? A pump audit beforehand can improve return on investment*, Ag Econ fact sheet. Available in SRA irrigation and energy portal

Welsh, J. M & Powell, J. W (Dec 2019), *Thinking solar and irrigation? A checklist for prospective purchasers*, Ag Econ fact sheet. Available in SRA irrigation and energy portal

Powell, J. W and Welsh, J.M (Dec 2019), *Borehole maintenance – Bundaberg case study analysis*, Ag Econ fact sheet. Available in SRA irrigation and energy portal

Powell, J. W and Welsh, J.M (Dec 2019), *Avoiding cheap solar companies*, Ag Econ fact sheet. Available in SRA irrigation and energy portal

Welsh, J. M & Powell, J. W (Dec 2019), *Grid connected pumps: improving performance*, Ag Econ fact sheet. Available in SRA irrigation and energy portal

Powell, J. W and Welsh, J.M (Dec 2019), *Pump and energy fast facts for irrigators*, Ag Econ fact sheet. Available in SRA irrigation and energy portal

"New SRA energy website portal released", *Australian Canegrower,* Dec 2020, CANEGROWERS, Brisbane, QLD, pp. 10-11

Welsh. J.M and Powell J.W (Apr 2020), *Renewable Energy Case Studies (#1 of 2 part series),* Webinar [video file]. Available in SRA Australian Cane Learning Centre

Welsh. J.M and Powell J.W (Apr 2020), *Finance options and barriers to adoption (#2 of 2 part series),* Webinar [video file]. Available in SRA Australian Cane Learning Centre

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11. REFERENCES

CSIRO. 2019. *ADOPT: Adoption Diffusion Outcome Prediction Tool,* [Online]. Available: https://www.csiro.au/en/Research/Farming-food/Innovation-and-technology-for-the-future/ADOPT [Accessed 7 October 2019].

INTERNATIONAL RENEWABLE ENERGY AGENCY 2017. Electricity Storage and Renewables: Costs and markets to 2030. website.

12. APPENDIX

12.1. Appendix 1 METADATA DISCLOSURE

Table 1 Metadata disclosure 1

Data	2017 energy survey data. HOMER energy working files
Stored Location	Ag Econ SRA project files
Access	Private access.
Contact	Jon Welsh or Janine Powell

Table 2 Metadata disclosure 2

Data	(Description)
Stored Location	(I.e. organisation and server)
Access	(I.e. publically accessible or restricted? Please provide details.)
Contact	(I.e. Details of person/position with access)