UNIVERSITY OF SOUTHERN QUEENSLAND AUSTRALIA

Research

National Centre for Engineering in Agriculture

Feasibility of Solar PV Irrigation in Queensland

REPORT 3: Queensland Agribusiness Pumping Capacities, Irrigation and Water Requirement

Prepared for Queensland Government (Department of Natural Resource, Mines and Energy)

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Executive Summary

This document is the third report in a series of publications which discuss the feasibility of solar PV powered irrigation systems in Queensland.

These reports provide a useful resource to inform the feasibility of solar PV powered irrigation in Queensland by:

- Identifying and discussing the technology of solar power and pumping systems.
- Outlining incentive and funding opportunities for solar pumping systems.
- Reviewing Queensland agribusinesses' irrigation systems, efficiencies and crop and irrigation water requirements.

These reports do not provide a detailed address of grid connected solar PV rather focussing primarily on potential for standalone solar PV and diesel hybrid systems.

Solar irrigation must be considered in a holistic (whole of system) manner. Water demand should be seen as the critical starting point. Understanding irrigation demand is as important as understanding the technologies involved in the conversion of solar energy to electricity, to meet this demand.

When considering solar irrigation the starting point is an analysis of current energy usage. This is followed by an evaluation of energy conservation and efficiency opportunities of the current system, before finally looking at appropriate renewable energy technologies.

Report1 provides a technical summary of solar power and solar irrigation systems in Queensland.

Report 2 describes a number of incentives, funding opportunities and programs to support uptake of solar systems. These include Renewable Energy Certificates and Feed in Tariffs (for grid connected systems). There are a range of energy efficiency loans, energy services agreements and project specific funding from agencies such as the Queensland Rural and Industry Development Authority. Businesses can also apply for finance through the Clean Energy Finance Corporation and the banking sector with reduced rates and fees, due to the renewable nature of infrastructure.

Finally, **this report** outlines a number of factors that impact the scale of and potential market opportunities for solar irrigation systems in Queensland. These factors include:

- Crop water use and irrigation requirement for different industries.
- Typical capacity of irrigation pumps.
- Pumping costs and pumping efficiency.

There is significant variability in crop water requirement between crops and locations, as well as between and within years. These aspects need to be considered in design of solar-hybrid irrigation systems, which need to meet peak crop water demand.

Also important is the contribution rainfall will make to crop water needs, the irrigation system application efficiency, and the amount of time the pump is operating. Irrigation systems with low application efficiency and low pump utilisation ratio will require a larger pump which will increase the capital and operating cost. Improving irrigation system efficiency and pump utilisation ratio is a key step in irrigation operations.

A large number (525) of irrigation pump evaluations have been conducted across industries in Queensland as part of the Rural Water Use Efficiency initiative, using the Irrigation Pump Evaluation and Reporting Tool (IPERT). These tool was designed to assist in the evaluation and collation of on-farm irrigation pumping system performance data. The resulting dataset provides a representative assessment of irrigation pump type, capacity, efficiency and operating cost across industries. These are all important criteria when considering potential for solar irrigation.

In the sugar, dairy and horticulture industry electrical centrifugal pumps are dominant, and in the cotton industry diesel centrifugal systems are dominant. Bore irrigation is generally a smaller component with dairy having the largest percentage represented (25%).

The database provides useful information on the pump duty or Total Dynamic Head (TDH) and flow rate, which together give an indication of the power required to pump water (in kW) and the size of the pump and solar system that would be required to support irrigation.

Most Queensland cotton pumping scenarios require 100 – 200kW and operate using diesel powered pumps. Most Queensland sugarcane industry and dairy industry pumping scenarios require 10 – 30kW and are operated by mains powered electric powered pumps. While the horticulture industry is quite varied in their pumping requirement there are a large number of smaller (<10kW) electric pumps being used for irrigation. As a contrast most stock watering systems require a system of typically <2kW.

It is also possible to assess the cost of pumping and the overall efficiency (pump and motor) of systems. The overall efficiency of irrigation pumps ranges from 6% - 30% for diesel powered pump and 14% - >80 % for electric powered pumps. The cost of pumping ranges from less than $5/ML up to>$240/ML.

There are a significant number of pumps that are operating at low efficiencies (<60%). If solar energy is being considered then it will be critical to improve the efficiency of the pump and motor unit before beginning to size and design a solar power unit for the pumping systems.

A useful indicator of pumping efficiency is the energy required per ML of water pumped, per metre of total dynamic head. A target figure of 5 kWh/ML/m is often used as an achievable industry standard.

Analysis of the database shows that the majority of the cotton industry systems (despite being predominately diesel driven) are able to meet the 5 kWh/ML/m target. Approximately 33% of the sugarcane and industry assessments met the target. A larger number of horticulture and dairy industry pumps that were assessed using the IPERT tool were significantly above this target. It should be noted that there are a significantly higher number of pumps that have been assessed in these industries.

1. Introduction and Scope

On 30 November 2016, the Queensland Government, as part of its response to the Queensland Productivity Commission's Electricity Pricing Inquiry Final Report, announced the Regional Business Customer Support Package (RBSCP). As part of this package, the Government made a commitment to investigate opportunities to utilise solar PV for water pumping and irrigation.

The Department of Natural Resources, Mines and Energy (DNRME) subsequently engaged the University of Southern Queensland to undertake research into the potential for solar PV as a replacement or complementary system for diesel powered irrigation and water pumping.

USQ were commissioned to summarise existing information on and initiatives around solar pumping relevant to Queensland. A review of Queensland agribusinesses' irrigation systems, efficiencies and crop and irrigation water requirements was also to be provided.

Prior to this engagement, much work has been undertaken by others on this topic. The Queensland Governments Energy Savers Plus Program, which has now been extended under the Affordable Energy Plan (Business Energy Savers Program), has produced a number of high quality case studies and reports. The NSW Government and NSW Farmers Association have also published excellent user friendly manuals on solar PV for irrigation and separately for stock watering. These have been a key resource for the technical components of this report. NSW AgInnovators provides good resources and explains the technology and components in a solar PV system.

By agreement with the Department of Natural Resources, Mines and Energy, this project does not provide substantial detail on grid connected solar PV and has been limited to standalone and diesel hybrid systems, including battery storage.

Solar irrigation must be considered in a holistic (whole of system) manner. Water demand should be seen as the critical starting point, rather than the solar hardware perspective. Understanding irrigation demand is as important as understanding the technologies involved in the generation (or more correctly the conversion) of solar energy to electricity.

Figure 1 illustrates the flow of energy and water through an irrigated agricultural system. Consideration of water demand from crops (irrigation) and stock watering and the water source (surface or groundwater) is the starting point. The technical requirements of the solar PV system in terms of pressures and flow rates are determined by this, which will impact the hardware (panels, battery, inverter, motor and pump).

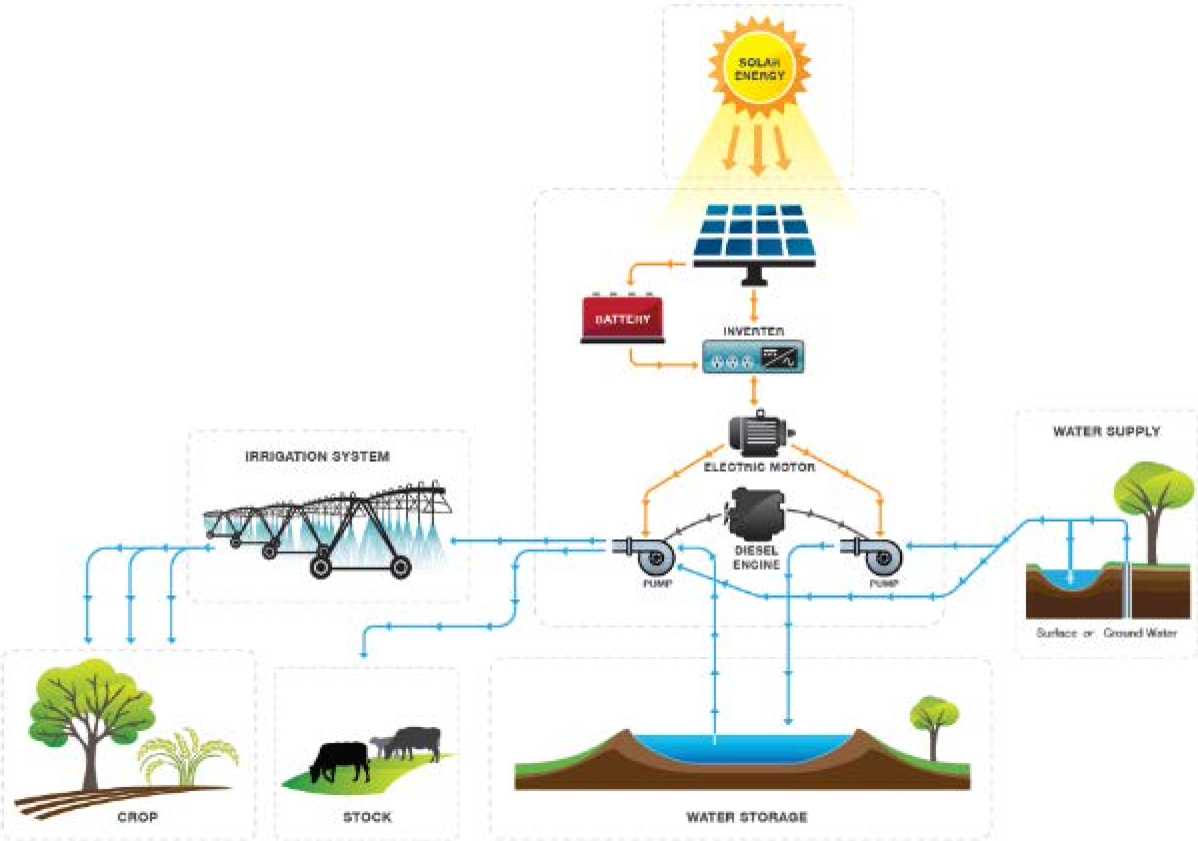

Figure 1 - Whole of system approach to solar PV water pumping

2. Methodology

The project methodology combined desktop assessment, and ground truthing through discussions with key stakeholders on both the supply and customer side of solar PV irrigation systems. This included:

1. Reviewing existing technical information on solar power and solar irrigation (Report 1)
2. Collating information on initiatives around solar pumping (Report2)
3. Assessing Queensland agribusiness' pumping capacities, and irrigation and water requirements (this report)

For this assessment typical pumping capacities and irrigation water requirements of Queensland irrigator's have been assessed based on datasets that have been collated by the NCEA through Rural Water Use Efficiency funding of Queensland Government (Department of Natural Resources and Mines and Energy). This information has been collected over the last 10 years using a range of online software tools that assist famers and advisors in the management of energy and water on farm. Only generalised non grower specific details have been reviewed.

Information included assessment of:

- Crop water requirements for irrigated production.
- Types of irrigation systems and their capacities across a range of industries and regions in Queensland.
- Size and configuration of diesel and electric powered (surface and bore) pumps in Queensland agricultural industries and key energy use parameters including the cost per ML pumped and overall efficiency.

3. Queensland Agribusiness Pumping Capacities, Irrigation, and Water Requirement

When considering opportunities for solar irrigation in Queensland it is important to assess:

- Variation in crop water use and irrigation required to meet crop demand.
- Typical capacity of irrigation pumps in Queensland.
- Pumping costs and pumping efficiency.

To assess the typical pumping capacities and irrigation water requirements of Queensland irrigators, datasets collated by the NCEA through Rural Water Use Efficiency funding of Queensland Government (Department of Natural Resources, Mines and Energy) were assessed and key trends are summarised below.

3.1 Crop Water Requirement

The majority of Queensland cotton, sugarcane, dairy pasture, fodder and horticultural crops are either under supplementary or full irrigation. The following section shows that the crop water requirement is dependent on the plant date, location and the crop type.

The following figures provide the daily crop water requirement based on modelled atmospheric demand data from 1900 – 2016 for specific crops in specific locations. The typical trend is low water requirement soon after the crop has been planted, followed by a rapid increase in daily water requirement as the plant is actively growing. This is then followed by a plateau and gradual decline as the plant reaches maturity. There is significant variability in crop water requirement between crops and locations as well as between and within years.

Crop water requirement is calculated based on climate potential evapotranspiration and a crop cover factor. It is estimated in the figures below based on the FAO56 method which uses the Penman Monteith equation to determine potential evapotranspiration (ETo) and a crop factor (Kc) to convert to crop evapotranspiration (ETc).

Figure 2 through Figure 8 show the daily crop water requirement (mm/day) for a range of crops and locations across Queensland. All graphs use the same calculation parameters with a varying ETo data set and crop specific Kc values. The blue dots are the daily crop water requirement for growing day from 1900 – 2016. The orange and red circles indicate the 25^{th} and 75^{th} percentiles. The median, 50% of all daily requirements lies between these two values.

Sugar Cane

Sugarcane is grown at a number of locations on the Queensland coastline. Figure 2 and Figure 3 indicate the crop water requirement for an autumn plant and a spring plant crop in the Burdekin and Bundaberg respectively.

These figures show different shaped curves as the autumn plant sugarcane uses less water immediately after planting as the crop enters winter. The Bundaberg spring plant cane curve rises sharply to peak crop water requirement in January each year.

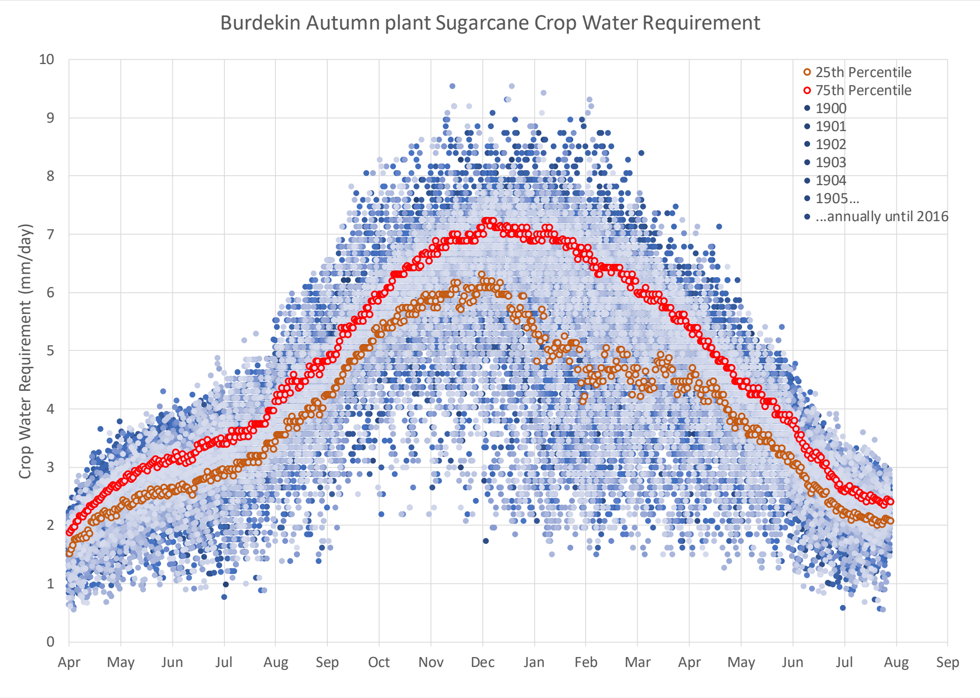

Figure 2 - Burdekin Autumn Plant Sugarcane Crop Water Requirement

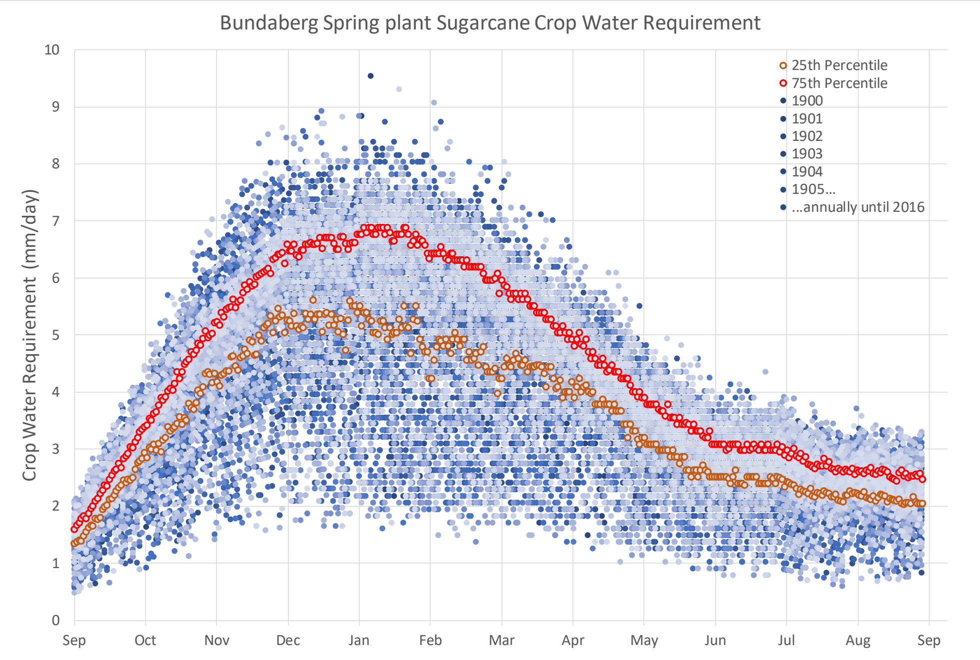

Figure 3 -Bundaberg Spring Plant Sugarcane Crop Water Requirement

Cotton

Cotton is grown on the Darling Downs, Border Rivers, St George, Dirranbandi and in Central Queensland. While plant and harvest dates will vary slightly depending on the location the shape of the curves in Figure 4 and Figure 5 are very similar. Both locations begin the season with a low crop water requirement 1.5 – 2.0 mm/day. The differences are apparent in the peak irrigation season. In St George the cotton crop will have a peak crop water requirement of 9 mm/day whereas in Dalby is it approximately 8 mm/day in January. The slightly cooler temperatures generally leads to a slightly longer growing season.

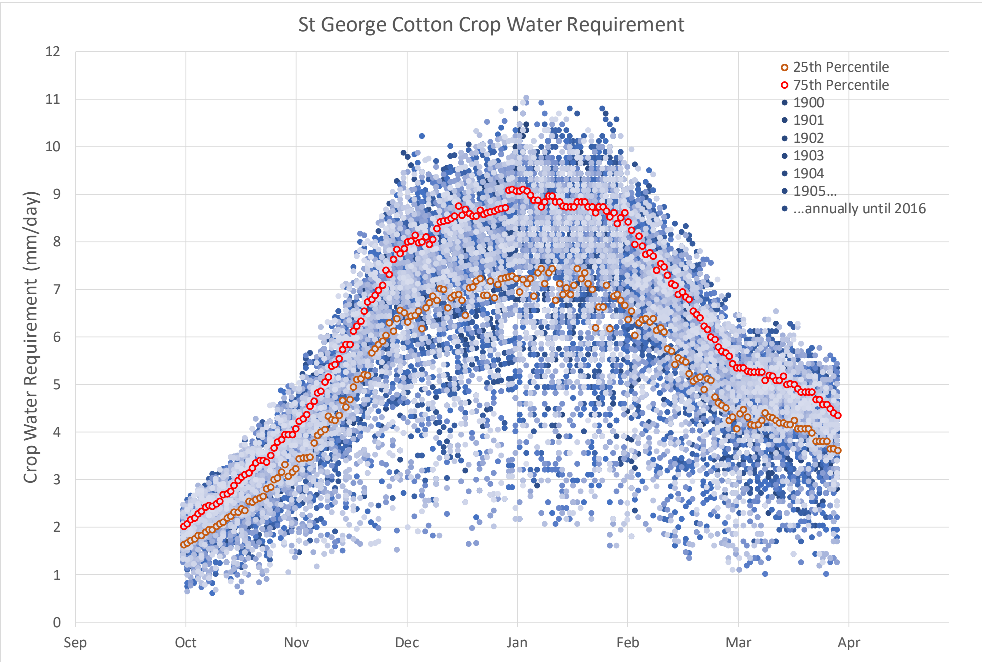

Figure 4 - St George Cotton Crop Water Requirement

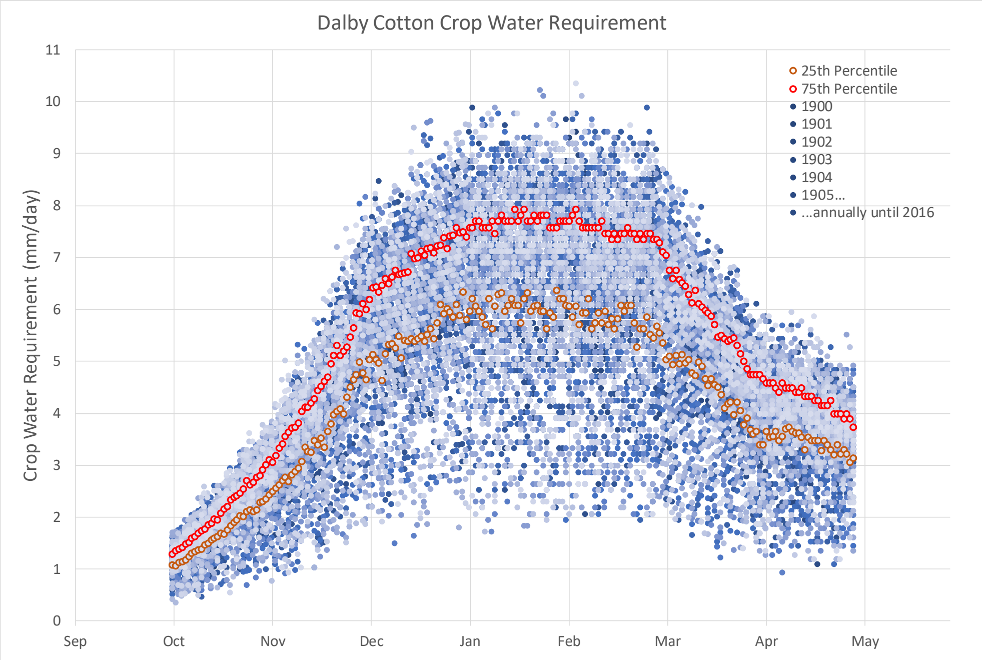

Figure 5 - Dalby Cotton Crop Water Requirement

Horticulture

A wide variety of horticultural crops are grown across almost all irrigation regions in Queensland and it is not possible to present all crops in this report. Figure 6 and Figure 7 show the crop water requirement for tomatoes grown in Bundaberg and Bowen. The curves are very different to one another due to both the growing window, and the location. The Bundaberg crop planted in July has an initial daily water use of approximately 2 mm/day as it comes out of winter and reaches a peak crop water requirement of approximately 5.4 mm/day in September. By contrast the Bowen tomato crop planted in February requires approximately 3 mm/day from planting and crop water use decreases rapidly once the crop has reached maturity and enter the cooler winter months.

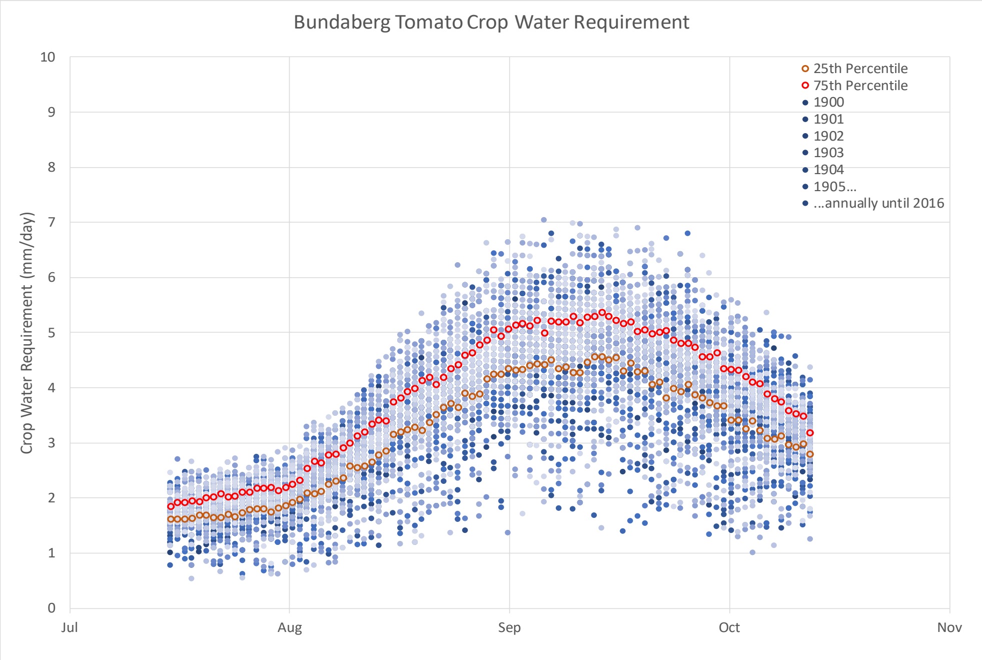

Figure 6 - Bundaberg Tomato Crop Water Requirement

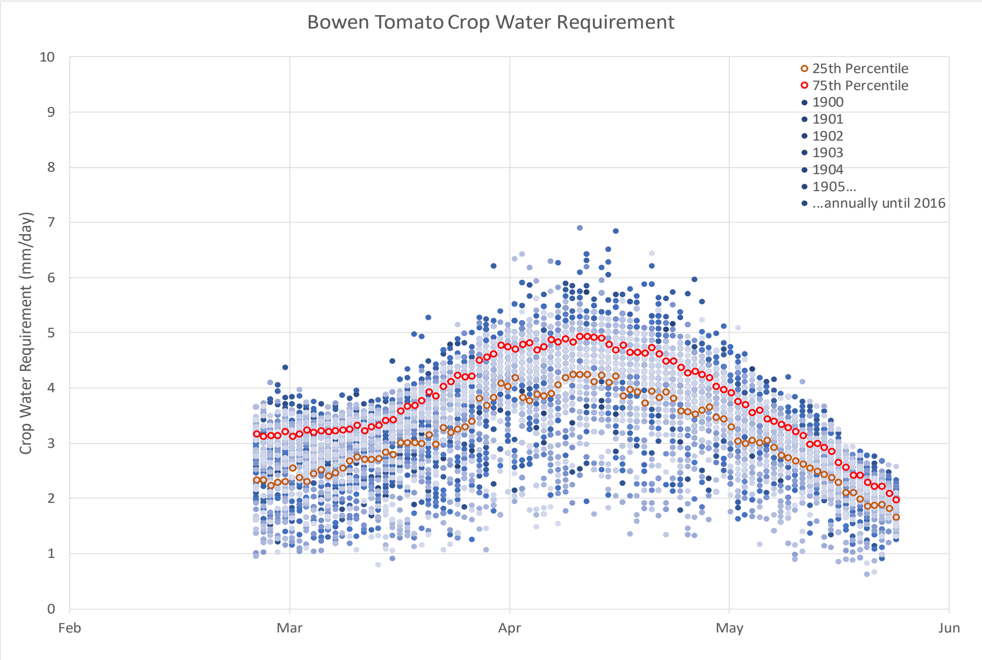

Figure 7 - Bowen Tomato Crop Water Requirement

Figure 8 shows the crop water requirement for a broccoli crop in Stanthorpe and demonstrates a rather unique crop water requirement curve. As the crop is maturing and requiring more water, the season is also cooling and there is less atmospheric demand. The crop water requirement does not change significantly (3.5mm/day at planting to 2 mm/day at harvest) throughout the growing season.

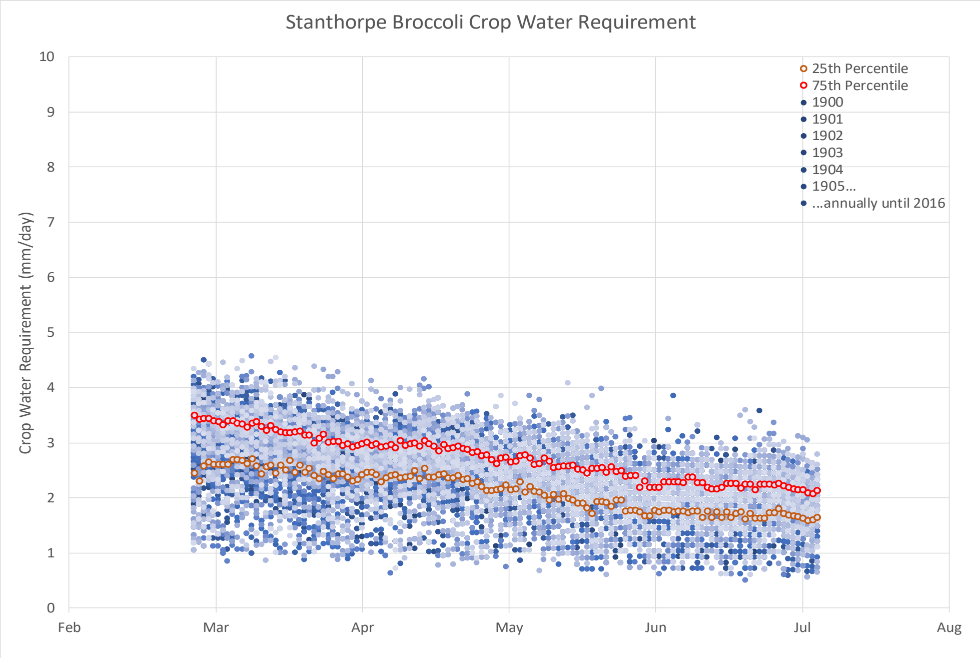

Figure 8 - Stanthorpe Broccoli Crop Water Requirement

3.2 Irrigation Water Requirement

Crop water requirement is met by a combination of rainfall and irrigation. The proportion to be supplied by irrigation will vary substantially between and within years. The irrigation system capacity needs to be designed to meet peak crop water requirement.

Rainfall and effective rainfall

The amount of rainfall that can be infiltrated and stored in the plant root zone is called 'effective rainfall', and is a function of rainfall intensity, soil moisture, land slope, soil type and land cover and management.

In Queensland rainfall is often received as high intensity, short duration storms when rainfall intensity exceeds infiltration rate, resulting in surface runoff. Additionally if a soil profile is wet a substantial amount of rainfall will be lost beneath the root zone as drainage.

Nett and gross irrigation

Only a proportion of water that is pumped is stored in the root zone and is available for the plant. There are losses in the storage, distribution and application systems, the latter referred to as the Application Efficiency.

These losses are generally in the form of seepage and evaporation or through over irrigation where runoff or deep drainage occurs in the field.

Even modern mechanised irrigation systems have losses. When designing solar irrigation systems, consideration must be given to losses and the system application efficiency. Improving irrigation system efficiency should be seen as a key step in any solar irrigation investigation.

Irrigation System Capacity

System capacity is one of the most important design parameters. If the system capacity is too low and can't meet peak crop water demand, the crop will not be fully irrigated, resulting in yield loss.

The system capacity refers to the maximum flow rate that can be applied to the field or block. This capacity is reduced when the pump is not running 24 hours per day 7 days per week. This is known as the "managed" system capacity. The amount of time that the pump is running is called the pumping utilisation ratio (PUR) expressed as the number of running hours per day divided by 24 hours/day. In standalone solar systems PUR will be less than 33% (8/24). Hybrid systems allow PUR of up to 100%.

Irrigation systems with low application efficiency and low pump utilisation ratio will require a larger pump to meet a design peak crop water requirement. This impacts the capital and operating cost. Improving irrigation system efficiency and PUR is a key step in planning solar irrigation.

3.3 Irrigation Pumping Capacities

A large number of irrigation pump tests have been conducted across industries in Queensland using the Irrigation Pump Evaluation and Reporting Tool (IPERT), which was designed to assist in the evaluation and collation of on farm irrigation pumping system performance data. The table below summarises the number of system tests across each industry and for different pump types.

The large number of tests (525) give a realistic assessment of the situation in each industry. In the sugar, dairy and horticulture industry electrical centrifugal pumps are dominant and in the cotton industry diesel centrifugal systems are dominant. Bore irrigation is generally a smaller component with dairy having the largest percentage represented (27%).

Table 1 - Number of IPERT assessments in each of the main irrigation industries in Queensland

Pump Type	Cotton Industry (n=61)	Sugar Industry (n=121)	Dairy Industry (n=185)	Horticulture industry (n=158)	All Evaluations in IPERT (n=525)
Diesel **Centrifugal**	**43 (70%)**	1 (1%)	8 (4%)	17 (11%)	69 (13%)
Diesel **Bore**	4 (7%)	0 (0%)	3 (2%)	0 (0%)	7 (%)
Electric **Centrifugal**	13 (21%)	**117 (97%)**	**127 (69%)**	**120 (76%)**	**377 (72%)**
Electric **Bore**	1 (2%)	3 (2%)	47 (25%)	21 (13%)	72 (14%)

The database provides a representative coverage of irrigation pumping in Queensland, and gives a good insight into the pump duty (Total Dynamic Head (TDH) and Flow Rate (Q)) and the costs and efficiencies of irrigation pumps.

The total dynamic head (TDH in m) and water flow rate (Q in l/s) when combined (TDH x Q) gives an indication of the power required to pump the water (kW). This gives an indication of the size of the pump and the size of solar system that would be required to support irrigation.

Figure 9 shows the duty point (TDH and Q) of all 525 IPERT evaluations in the database separated into their respective industry types. Assuming an average overall efficiency of 60%, the lines show the power of the pumping system required. From this figure it can be seen that the evaluations range from >200m TDH and >1,700L/s flowrate (Q). It can be seen that a number of cotton industry evaluations are at low TDH but are in excess of 1,000 L/s. These are obviously surface irrigation or flood lifting pumps. There are some cotton industry pumps below 300L/s operating at higher heads (20m – 50m) which are likely centre pivot or lateral move irrigation pumps.

There is a substantial concentration of evaluations in other industries that operate below 200 l/s and up to 200m TDH, therefore Figure 10 shows a zoomed in version of Figure 9.

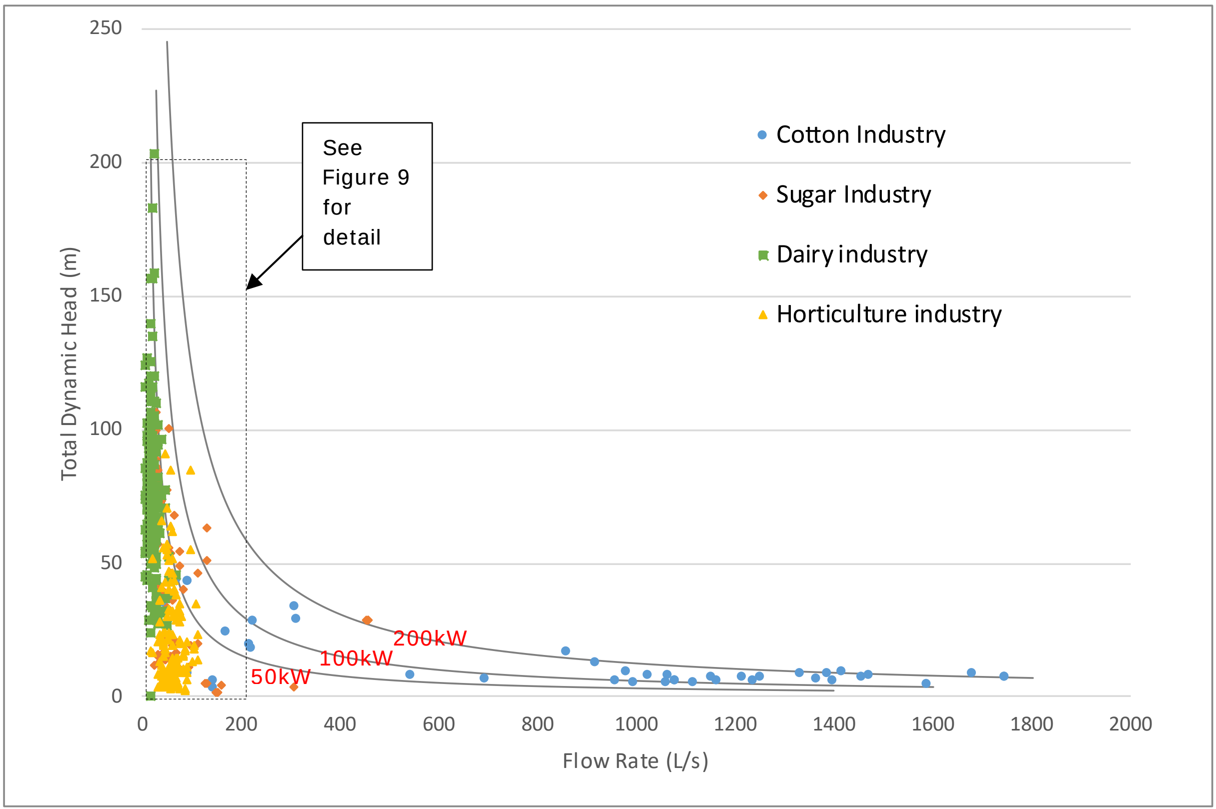

Figure 9 - Duty point and power requirement (assuming 60% overall efficiency)

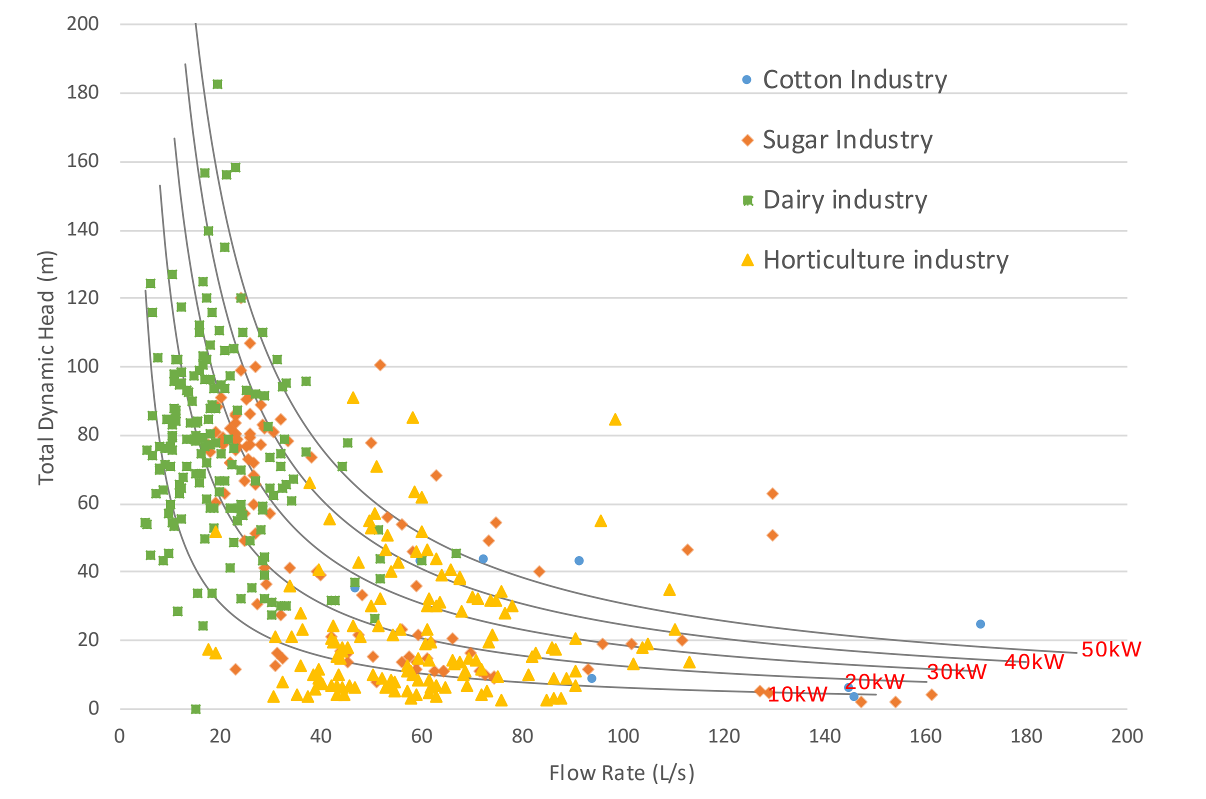

Figure 10 - Zoomed in version of figure above showing 0-20m TDH and 0 - 200L/s flow rate

Figure 10 shows that the majority of IPERT evaluations undertaken are in the range of 10 to 50 kW. The orange diamond shapes in Figure 10 represent evaluations undertaken in the sugarcane industry. There is a cluster of these at 20 -30 L/s, and 60 – 100 m TDH. This is characteristic of the water winch irrigator that is common in the sugarcane industry.

The majority of green squares representing the dairy industry in Figure 10 are located mostly below 40 l/s, with many less than 25L/s. the TDH range for dairy industry evaluations was approximately 50 – 120m. Some of these are pumping from deep bores but there are a number of high pressure irrigators operating in the dairy industry in Queensland.

The irrigation duty points in the horticulture industry are highly varied due to the highly varied nature of horticultural cropping and irrigation needs, but typically using flow rates of less than 100L/s.

Table 2 has been generated to tabulate the data in Figure 10. It shows a count of the number of assessments that fall into each of the input power brackets (assuming an average of 60% overall efficiency).

Table 2 - Number of IPERT evaluations in each industry in each input power bracket

Input power required (@60% efficiency)	Cotton Industry (n=61)	Sugar Industry (n=121)	Dairy Industry (n=185)	Horticulture industry (n=158)	All Evaluations in IPERT (n=525)
<10 kW	1 (2%)	10 (8%)	22 (12%)	**54 (34%)**	87 (17%)
10.1 – 20 kW	2 (3%)	**31 (26%)**	**56 (30%)**	39 (25%)	128 (24%)
20.1 – 30 kW	1 (2%)	30 (25%)	54 (29%)	15 (9%)	100 (19%)
30.1 – 40kW	0 (0%)	23 (19%)	24 (13%)	17 (11%)	64 (12%)
40.1 – 50 kW	1 (2%)	15 (12%)	13 (7%)	16 (10%)	45 (9%)
50.1 – 100kW	13 (21%)	7 (6%)	12 (6%)	13 (8%)	45 (9%)
100.1 – 200 kW	**34 (56%)**	2 (2%)	3 (2%)	4 (3%)	43 (8%)
>200 kW	9 (15%)	3 (2%)	1 (1%)	0 (0%)	13 (2%)

From Table 2 it can be seen that most Queensland cotton pumping scenarios require 100 – 200kW and these are generally operated using diesel powered pumps. Conversely most Queensland sugarcane industry and dairy industry pumping scenarios require 10 – 30kW and are operated by mains powered electric powered pumps. While the horticulture industry is quite varied in their pumping requirement there are a large number of smaller (<10kW) electric pumps being used for irrigation.

As a contrast typical solar solutions for stock watering comprise a stand-alone system of typically <2kW with a storage tank acting as a buffer.

3.4 Pumping Cost and Efficiency

Through the Australian Government’s Energy Efficiency Information Grants program it has been shown that pumping water is one of, if not the single highest variable cost, in irrigated agricultural production.

Utilising the IPERT databases, it is possible to assess the cost of pumping and the overall efficiency of a range of pumps across the main irrigated agricultural sectors. The overall efficiency refers to the combined efficiency of the pump, motor and any transmission. It represents how efficiently diesel or electricity is converted into water power (TDH and Q).

Figure 11 shows that the overall efficiency of irrigation pumps ranges from 6% - 30% for diesel pump and 14% - >80 % for electric pumps. The cost of pumping ranges from less than $5/ML up to>$240/ML.

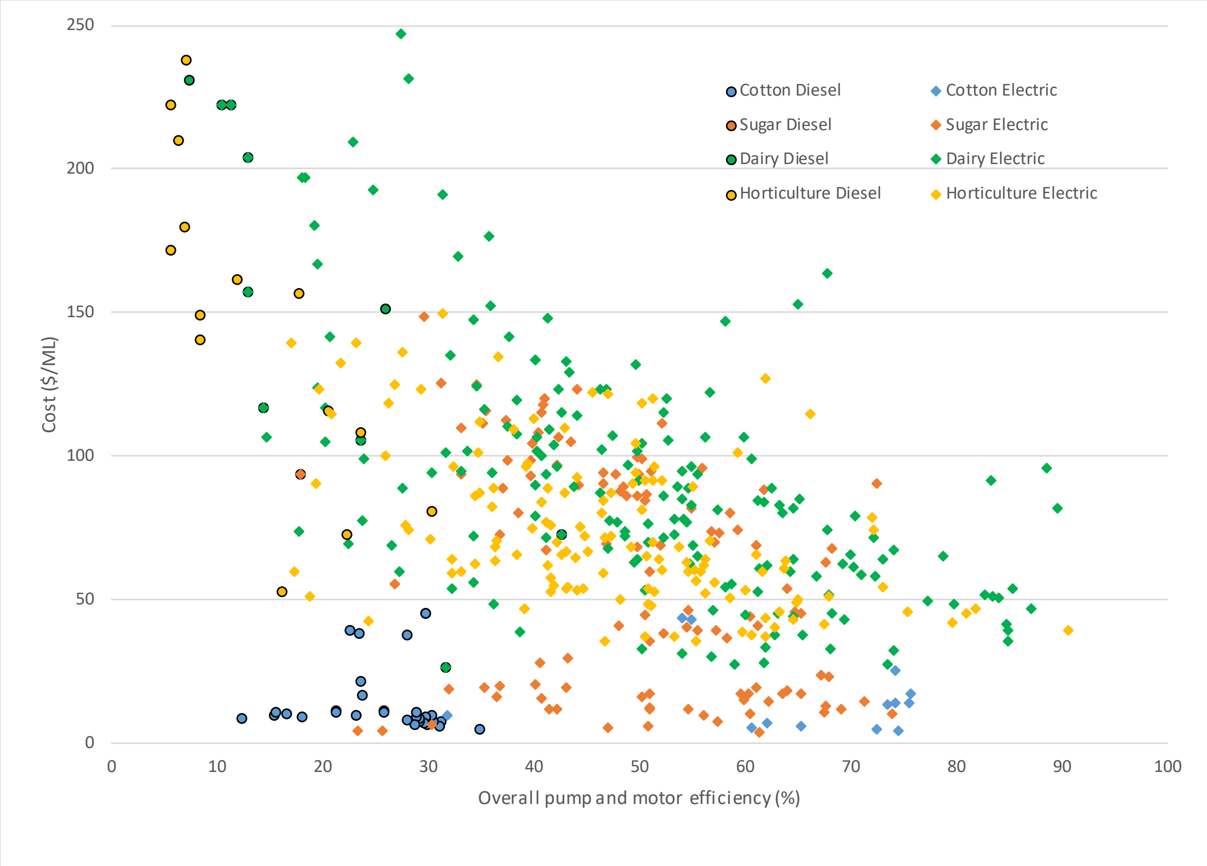

Figure 11 - Cost of pumping and the overall efficiency of irrigation pumps

A key point of interest in the figure above is that there are a significant number of pumps that are operating at low overall efficiencies (<60%). If solar energy is being considered then it will be critical to improve the efficiency of the pump and motor unit before beginning to size and design a solar power unit for the pumping systems.

Table 3 summarises the data in Figure 11, providing the number of assessments that fall into each of the ”cost per ML pumped brackets”. It shows that the majority of the cotton and sugarcane industry pumps are costing <$50/ML, while the majority of the dairy and horticulture industry pumps are costing between $50 and $100/ML to operate.

Table 3 - Number of IPERT evaluation in each industry in each cost price bracket

Cost per ML pumped	**Cotton Industry (n=61)**	**Sugar Industry (n=121)**	**Dairy Industry (n=185)**	**Horticulture industry (n=158)**	**All Evaluations in IPERT (n=525)**
<$50	**59**	**62**	34	26	181
$50.01 – $100	2	43	**93**	**97**	**235**
$100.01 - $150.00	nil	16	41	28	85
$150.01 – $200	nil	nil	12	4	16
>$200	nil	nil	5	3	8

Table 4 shows a breakdown of the minimum, maximum and median cost of pumping across the industries based on whether the pump is powered by a diesel or an electric motor. Diesel pumping is significantly less expensive in the cotton industry when compared with the dairy and horticulture industries, as the main irrigation system used in the cotton industry (surface furrow irrigation) requires quite low delivery pressure. It should be noted that there was only one diesel pump assessment in the sugarcane industry and therefore it is not appropriate for comparison.

The dairy and horticulture industries are paying the highest price per ML pumped. This is due to a combination of a number of low efficiency pumps combined with some high pressure requirements.

Table 4 - Summary of cost of pumping from 525 IPERT evaluations

Cost per ML pumped	**Cotton Industry (n=61)**	**Sugar Industry (n=121)**	**Dairy Industry (n=185)**	**Horticulture industry (n=158)**
Diesel Minimum	$4.61	Insufficient data	$26.35	$39.04
Diesel Median	**$9.36**	Insufficient data	**$116.78**	**$144.82**
Diesel Maximum	$45.40	Insufficient data	$231.02	$238.1
Electric Minimum	$4.39	$3.48	$27.36	$35.52
Electric Median	**$13.50**	**$46.36**	**$78.19**	**$66.94**
Electric Maximum	$53.43	$148.81	$246.91	$246.23

Using only the cost per ML pumped makes it difficult to compare across regions or systems. Therefore an energy use standardised term has been developed to incorporate the total dynamic head as well as the pump flow rate. The energy required per ML per m of TDH is often used as a comparison and a target figure of 5 kWh/ML/m is often used as an achievable industry standard.

Figure 12 shows the number of kWh/ML/m of TDH for each of the IPERT assessments for each of the major irrigation industries. This figure shows that the majority of the cotton industry evaluations (despite being predominately diesel driven) are able to meet the 5 kWh/ML/m benchmark. Approximately 30% of the sugarcane and 50% of the dairy industry assessments met the target. A large number of horticulture industry pumps were significantly above this target.

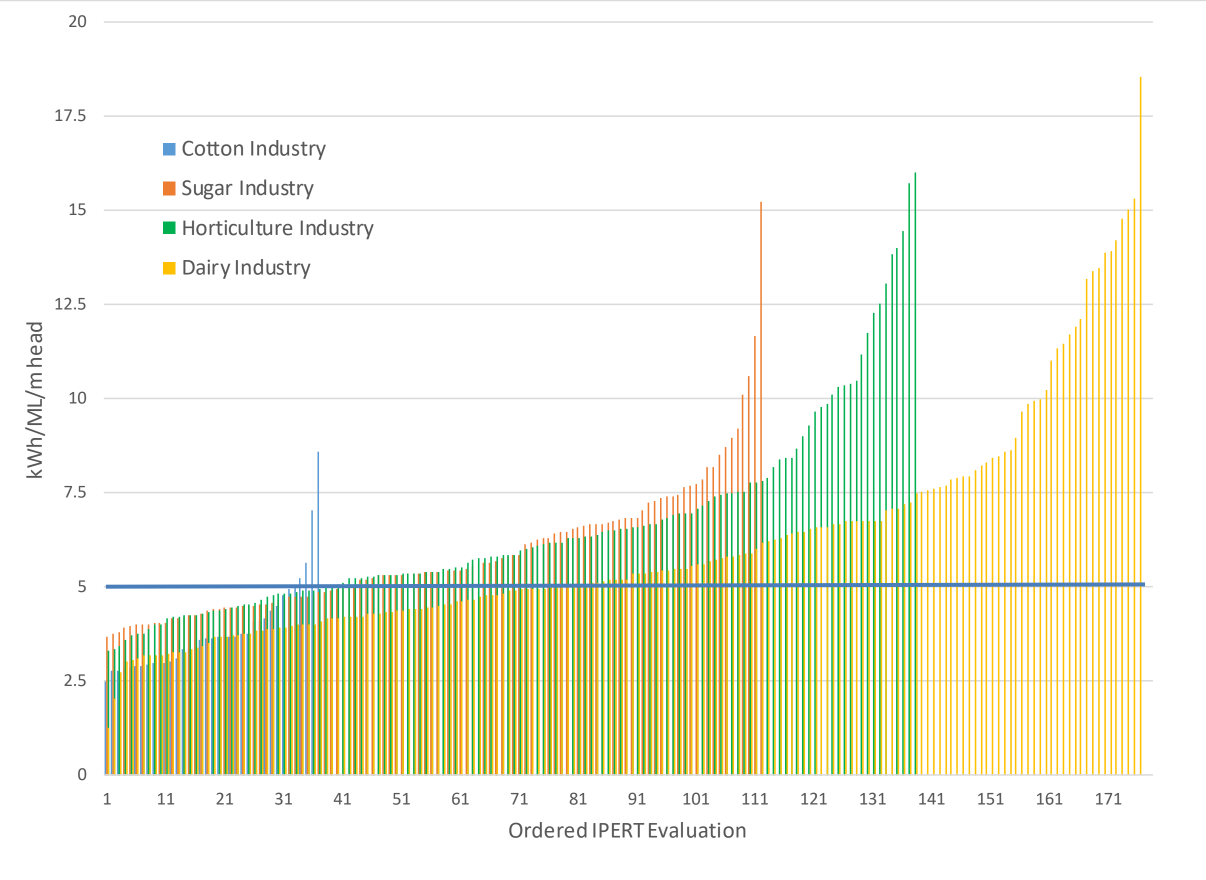

Figure 12 – A count of kWh/ML/m of TDH for each of the IPERT assessments

4. Conclusions

There is significant variability in crop water requirement between crops and locations, as well as between and within years. These aspects need to be considered in design of solar-hybrid irrigation systems, which need to meet peak crop water demand.

Also important is the contribution rainfall will make to crop water needs, the irrigation system application efficiency and the amount of time the pump is operating. Irrigation systems with low application efficiency and low pump utilisation ratio will require a larger pump which will increase the capital and operating cost. Improving irrigation system efficiency and pump utilisation ratio is a key step in irrigation operations.

A large number (525) of irrigation pump tests have been conducted across industries in Queensland as part of the Rural Water Use Efficiency initiative, using the Irrigation Pump Evaluation and Reporting Tool (IPERT). The resulting dataset provides a representative assessment of irrigation pump type, capacity, efficiency and operating cost across industries. These are all important criteria when considering potential for solar irrigation.

In the sugar, dairy and horticulture industry electrical centrifugal pumps are dominant and in the cotton industry diesel centrifugal systems are dominant. Bore irrigation is generally a smaller component with dairy having the largest percentage represented (27%).

The database provides useful information on the pump duty or Total Dynamic Head (TDH) and flow rate, which together give an indication of the power required to pump water (in kW) and the size of the pump and solar system that would be required to support irrigation.

The dataset shows that most Queensland cotton pumping scenarios require 100 – 200kW and operate using diesel powered pumps. Conversely most Queensland sugarcane industry and dairy industry pumping scenarios require 10 – 30kW and are operated by mains powered electric powered pumps. While the horticulture industry is quite varied in their pumping requirement there are a large number of smaller (<10kW) electric pumps being used for irrigation. As a contrast most stock watering systems require a system of typically <2kW.

It is also possible to assess the cost of pumping and the overall efficiency of systems. The overall efficiency of irrigation pumps ranges from 6% - 30% for diesel pump and 14% - >80 % for electric pumps. The cost of pumping ranges from less than $5/ML up to>$240/ML.

There are a significant number of pumps that are operating at low overall efficiencies (<60%). If solar energy is being considered then it will be critical to improve the efficiency of the pump and motor unit before beginning to size and design a solar power unit for the pumping systems.

A useful indicator of pumping efficiency is the energy require per ML of water pumped, per metre of total dynamic head. A benchmark figure of 5 kWh/ML/m is often used as an achievable industry standard.

Analysis of the database shows that the majority of the cotton industry systems (despite being predominately diesel driven) are able to meet the 5 kWh/ML/m benchmark. Approximately 33% of the sugarcane and industry assessments met the benchmark. A large number of horticulture and dairy industry pumps were significantly above this benchmark.