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NATIONAL CENTRE FOR ENGINEERING IN AGRICULTURE

Improving energy efficiency on irrigated Australian cotton farms

EEIG1401 Final Report

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Part 1 - Summary Details

Please use your TAB key to complete Parts 1 & 2.

CRDC Project Number: **EEIG1401**

Project Title: Improving the Energy Efficiency on Irrigated Australian Cotton Farms

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Preface

This report, prepared for the Cotton Research and Development Corporation by the National Centre of Engineering in Agriculture, directly address the milestones contained in the project EEIG 1401, “Improving the Energy Efficiency on Irrigated Australian Cotton Farms”. The numbered headings of this report are structured so as to exactly align the Milestones of the project (which are repeated in Table 1).

Executive Summary

This project clearly highlights that there are opportunities for growers to identify practices where energy consumption is high, and modify to reduce direct energy use on farm.

The Australian Cotton Industry is one of the most highly mechanised sectors of the Australian broad-acre agricultural industries, and in particular, the irrigated component of this industry is subject to high levels of direct energy consumption in the form of diesel fuel and electricity. Improving energy efficiency therefore offers significant cost savings as well as environmental benefits.

This research was funded by the Cotton Research and Development Corporation (CRDC) with funding from the Department of Resources, Energy and Tourism's Energy Efficiency Information Grants. This program aims to empower Small and Medium Enterprises and community organisations to make informed decisions about energy efficiency.

Information materials, assessment protocols, fact sheets and myBMP information were updated:

- 'Energy report card' templates, which report an individual grower's position against industry benchmark energy use, were developed.
- Nine energy fact sheets (6 required) covering key activities were developed.
- Training packages were developed and delivered to the CottonInfo RDOs to perform level one and level two energy assessments. This included a site visit to assist with their first assessment.
- In response to requests from the RDOs, significant changes were made to the *EnergyCalc* web-based software tool, which collects, stores and reports energy use. Sundry resources, including cotton-specific assessment protocols, were also provided in response from the RDOs.
- Training to improve the energy efficiency of cotton industry pumps was provided to farm consultants in Moree, NSW, during October 2014.
- The *myBMP Energy Module* was updated.

A work plan was developed for the NCEA to provide support to the RDOs in undertaking level one and level two assessments, who were to provide audit results to the NCEA. However, there were no level one or level two energy assessments were received during the milestone period. The following feedback was received from cotton growers:

- Cotton growers are finding the Level 1 assessment of limited value as they offer no guidance about how they can change their operations to improve their energy efficiency.
- Level 2 assessments are time consuming (taking up to 6 hours) and require specialised knowledge to provide practical energy efficiency feedback back to the growers. The current database interface slows the process down.

The NCEA undertook significant additional work to identify, collect and analyse level one data. Energy, area and yield were totalled for each level two, irrigated cotton energy assessment held by the NCEA. This produced 39 level one assessments.

The CRDC sub-contracted Boyce Charted Accountants to supply de-identified summary data from their client records, which was received 23 March 2015. The data represented 190,000 Ha of cotton production from 53 different farms from 2011 through to 2014. These data are cotton specific and the grower participating in the benchmarking would decide how much diesel would be apportioned to cotton and how much would be apportioned to other enterprises. This is consistent with level one assessment methodology.

Fuel and electricity each needed to be converted from a dollar cost into units of energy and this information was not available from Boyce. Thus, assumptions of the unit cost of diesel and electricity had to be made to convert costs into units of energy. This introduced an unknown error into the calculations. An additional 117 level one assessments were derived from this method.

Three of the required 30 level 2 assessments were received during the milestone period. The CRDC employed various independent consultants to collect energy benchmarking data during April and May 2015. The lateness of this data caused significant issues. Consultants simultaneously required more than normal assistance; the training provided to RDOs (section 1.4.2) was effectively re-delivered. This occurred in a compact period of time.

Fifteen level three energy assessments were completed; 13 on pumps and 2 on tractors. RDOs were to organise the level 3 assessment sites and that the NCEA would conduct the assessment. In addition, a further 11 pump inspections were conducted where general advice was given to the grower. The RDOs organised three of the fifteen level three assessment site and the NCEA, in conjunction with others, organised 12 of the fifteen level three assessment sites. The following feedback was received from cotton growers:

- The Level 3 assessments are more valuable as they provide specific feedback to growers about how energy efficiency of specific operations can be improved.

Categorising the 24 level three assessments of large mixed flow pumps undertaken by the NCEA (including the 13 assessments conducted under this project) according to the potential level of efficiency gain shows that of the pumps tested, approximately:

- one-third of pumps are operating efficiently, or reasonably so.
- One-third have gains (10 to <15%) that may be worthy of capital investment and,
- one third of pumps have large gains in efficiency available.

How well this trend represents the Australian cotton industry generally depends on how representative these 24 pumps are of the rest of the industry. It would be reasonable to conclude that pump efficiency warrants further investigation because it is likely significant gains are available to the cotton industry.

Industry communications were an important part of this project and the following activities were undertaken and/or supported by the NCEA:

- Eight industry workshops (six required).
- Eight media articles (six required).
- Six grower case studies.
- Participate in the planning for and make presentation at the ‘Big Day Out’.

The report, "*Improving Energy Efficiency on Irrigated Australian Cotton Farms: Farm level benchmarking report of direct energy consumption in Australian irrigated cotton production*." was produced. The report is a significant analysis of all level one, two and three energy assessment data. The looks across all levels of energy assessment and data set to make overall, data-based conclusions from the energy assessments. The outcomes from this benchmarking exercise clearly highlights that there are opportunities for growers to identify practices where energy consumption is high, and modify to reduce direct energy use on farm. This report is attached in Appendix 2.5.2 Final benchmarking report. Key recommendations of this report are that:

- Whole of farm energy use benchmarks are generated and incorporated into myBMP to allow individualised on-farm per year benchmarks characterised according to: region / locality; amount of irrigation water used; irrigation system type (surface, CP&LM); water sources / pump type (i.e. scheme, water harvesting, bore etc); cropping practices.
- A significant improvement in the application and use of simple energy measurement equipment is required across the industry, especially for large energy consuming equipment such as pump stations with water flowrate, pump shaft speed, pump pressures, and diesel fuel metering.
- Education on the fundamentals of irrigation pump station design and installation of appropriate monitoring points for routine evaluation of pump performance is required. Measurements could not be undertaken at a number of sites due to inaccessibility of measurement points for water flowrate and pressure
- Explore in more detail the large variation in direct energy expenditure experienced across the farm and the contributing factors (i.e. $90 to $740 per hectare).
- Identify the features of low energy farms and farming practices.
- As potential water savings in surface irrigated cotton fields can be 10 to 20%, and 20 to 40% in on-farm storages, every effort should be made to always conserve irrigation water at the field level, in distribution systems, and in water storages, as any water lost that has already been pumped is simply lost energy expenditure.
- While generally the focus has been on irrigation, it is apparent that tractor operations can be a significant component of direct energy use, and in some instances were up to 50%; greater analysis of tractor operations, farmer practice and appropriateness of machinery setup is required.
- Education on the fundamentals of tractor setup and performance (incorporating on-board tractor performance technologies i.e. IVT) is required once a more detailed assessment of tractor operations identifies particular issues experienced in industry.
- Incorporate the Level 1 analysis from this work into standard industry reporting such as Boyce & Co. Cotton Comparative Analysis reports.
- More awareness of, and support for the application of, the energy assessment methodology is required; some difficulties were encountered by industry service providers in undertaking these assessments, and the insights from Level 2 assessments conducted by industry service providers were limited.

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Objectives

This project, “Improving the Energy Efficiency on Irrigated Australian Cotton Farms” is funded by the Cotton Research and Development Corporation (CRDC) under their ‘1. Farmers’ program and theme and strategy ‘1.2.2 Developing and providing practices that deliver optimal resource efficiencies on cotton farms’. The CRDC received funding from the Department of Resources, Energy and Tourism’s Energy Efficiency Information Grants. This program aims to empower Small and Medium Enterprises and community organisations to make informed decisions about energy efficiency.

The specific objectives and milestones of this project are contained in the EEIG1401 project agreement, which are repeated below in table 1. The main body of the report details have each objective was met. The numbering of in the main body is congruent with the objectives of the project (table 1).

Table 1. EEIG 1401Objectives and Milestones.

Obj No.	Objective Description		Milestone Description		*Performance Indicator*	*Start Date*	*Finish Date*
1	Updating of information materials, energy assessment protocols and myBMP modules	1.1	Cotton farm 'energy report card' template	1.1.1	*Template for cotton farm 'energy report card' developed and provided to CRDC*	*1/9/2013*	*15/11/2013*
		1.2	Support for level 1 and level 2 assessments	1.2.1	*Any additional resources or support required to facilitate the conduct of level 1 and level 2 assessments by industry Regional Development Officers and farm consultants identified and provided to CRDC*	*1/9/2013*	*15/11/2013*
		1.3	Energy Factsheets	1.3.1	*6 Energy Factsheets for fallow, planting, in-crop operations, harvest and post-harvest operations developed and provided to CRDC in a format suitable for publishing by both print and on the web*	*1/9/2013*	*15/11/2013*
		1.4	Training Package	1.4.1	*Training materials and resources for training of industry Regional Development Officers and farm consultants developed and provided to CRDC*	*1/9/2013*	*30/10/2013*
				1.4.2	*Training provided to 7 industry Regional Development Officers*	*1/9/2013*	*15/11/2013*
				1.4.3	*Training provided to at least 20 farm consultants*	*1/9/2013*	*20/11/2014*
		1.5	Record keeping protocols	1.5.1	*Record keeping protocols to support the use of EnergyCalc and EnergyCalc Lite developed and provided to CRDC*	*1/9/2013*	*15/11/2013*
		1.6	myBMP module	1.6.1	*Updated energy module for myBMP provided to CRDC/ myBMP Manager*	*1/9/2013*	*1/8/2014*

2	**Undertaking of on-farm energy assessments**	**2.1**	**Workplan developed for the undertaking of on-farm energy assessments**	**2.1.1**	***Workplan for the undertaking of on-farm energy assessments developed in collaboration with D&D Manager***	***1/9/2013***	***30/9/2013***
		2.2	**Level 1 assessments**	**2.2.1**	***Industry Regional Development Officers are supported in the undertaking of level 1 assessments, and the details of the assessments provided to CRDC, including number of assessments, feedback from farmers and lessons learned***	***1/10/2013***	***21/2/2014***
				2.2.2	***Industry Regional Development Officers are supported in the undertaking of at least 50 level 1 assessments, and the details of the assessments provided to CRDC, including number of assessments, feedback from farmers and lessons learned***	***1/10/2013***	***4/7/2014***
				2.2.3	***On-going support provided to Regional Development Officers for the undertaking of level 1 assessments in accordance with workplan developed with D&D Manage, and details of support provided***	***1/10/2013***	***20/11/2014***
				2.2.4	***On-going support provided to Regional Development Officers for the undertaking of level 1 assessments in accordance with workplan developed with D&D Manage, and details of support provided***	***20/11/2014***	***27/2/2015***
		2.3	**Level 2 assessments**	**2.3.1**	***Industry Regional Development Officers are supported in the undertaking of level 2 assessments, and the details of the assessments provided to CRDC, including number of assessments, feedback from farmers and lessons learned***	***1/10/2013***	***21/2/2014***

				2.3.2	***Industry Regional Development Officers are supported in the undertaking of at least 10 level 2 assessments, and the details of the assessments provided to CRDC, including number of assessments, feedback from farmers and lessons learned***	***1/10/2013***	***4/7/2014***
				2.3.3	***On-going support provided to Regional Development Officers for the undertaking of level 2 assessments in accordance with workplan developed with D&D Manager***	***1/10/2013***	***20/11/2014***
				2.3.4	***On-going support provided to Regional Development Officers for the undertaking of level 2 assessments in accordance with workplan developed with D&D Manager***	***20/11/2014***	***27/2/2015***
		2.4	**Level 3 assessments**	**2.4.1**	***At least 5 potential sites / farmers for undertaking level 3 assessments are identified***	***1/10/2013***	***21/2/2014***
				2.4.2	***At least 5 level 3 assessments are undertaken, and the details of the assessments provided to CRDC, including number of assessments, feedback from farmers and lessons learned; further 5 potential sites identified***	***1/10/2013***	***4/7/2014***
				2.4.3	***At least a further 5 level 3 assessments undertaken, and the details of the assessments provided to CRDC, including number of assessments, feedback from farmers and lessons learned; further 5 potential sites identified***	***4/7/2014***	***20/11/2014***
				2.4.4	***At least a further 5 level 3 assessments undertaken, and the details of the assessments provided to CRDC, including number of assessments, feedback from farmers and lessons learned***	***20/11/2014***	***27/2/2015***

		2.5	**Benchmarking Report**	**2.5.1**	***In collaboration with industry Regional Development Officers, prepare an interim benchmarking report that collates the information from all energy assessments undertaken up to 31/10/2014; potential case studies for inclusion in the final report to be highlighted***	***1/10/2013***	***20/11/2014***
				2.5.2	***In collaboration with industry Regional Development Officers, prepare a final (updated) benchmarking report that 1) collates the information from all energy assessments undertaken during the course of the project and 2) highlights key energy efficiency best management practices***	***1/10/2013***	***31/3/2015***
3	**Communications**	**3.1**	**Awareness raising workshops**	**3.1.1**	***Energy Technical Specialist and Energy Project Officer support industry Regional Development Officers in the preparation for awareness workshops / information sessions, e.g. through preparation of information materials, agendas, presentations etc.***	***1/9/2013***	***20/11/2013***
				3.1.2	***Energy technical Specialist and Energy Project Officer participate in at least 3 awareness workshops / information sessions***	***20/11/2013***	***4/7/2014***
				3.1.3	***Energy Technical Specialist and Energy Project Officer participate in at least a further 3 awareness workshops / information sessions***	***4/7/2014***	***27/2/2015***
		3.2	**Spotlight / Australian Cotton Grower Articles**	**3.2.1**	***An agreed schedule for drafting of 6 articles for publication in industry magazines (e.g. Spotlight, Australian Cotton Grower) is developed with CRDC Communications Manager***	***1/9/2013***	***30/9/2013***
				3.2.2	***At least three articles published in industry magazines per agreed schedule***	***1/12/2013***	***31/7/2014***

				3.2.3	***At least three articles published in industry magazines per agreed schedule***	***1/8/2014***	***27/2/2015***
		3.3	**Big Day Out**	**3.3.1**	***Energy technical Specialist and Energy Project Officer participate in the planning and preparation for the Big Day Out***	***1/1/2014***	***20/11/2014***
				3.3.2	***Energy technical Specialist and Energy Project Officer participate in and make presentations to attendees at Big Day Out, as agreed with CRDC Communications Manager***	***20/11/2014***	***30/4/2015***
		3.4	**Case Studies**	**3.4.1**	***6 energy efficiency case studies are drafted and provided to CRDC (to be available to attendees at Big Day Out)***	***1/7/2014***	***27/2/2015***
4	**Reporting**	**4.1**	**Project Reports**	**4.1.1**	***Project Reports provided to CRDC with requisite information as required by the Grantor and detailed in Schedule 4 of the Funding Agreement***	***1/9/2013***	***30/4/2015***
		4.2	**Risk Management Plans**	**4.2.1**	***Details relevant to managing risks associated with activities undertaken by NCEA provided to CRDC to enable the completion of the risk management plan required by the Grantor***	***1/9/2013***	***30/9/2013***
				4.2.2	***Updated risk management details provided to CRDC***		***4/7/2014***

1. Updating of information materials, energy assessment protocols and myBMP modules.

1.1. Cotton farm 'energy report card' template developed

The following cotton farm 'energy report card' templates were developed and submitted to the CRDC for acceptance.

- *R 01 'Report Card L1*
- *R 02 'Report Card L2*
- *R 03 'Report Card L3-Pumping*

These items correspond to the EnergyCalc Level One, EnergyCalc Level Two and IPERT Level Three pump assessment reports respectively. Please refer to *Appendix 1.1* for the submitted reports. These report cards present the output information in terms of GJ, dollars, and CO2-e on both production and an area basis.

As discussed in section1.5, EnergyCalc houses the energy benchmarking database. Each level two report card produced compares the individual cotton farm energy use, per bale and per hectare, to the benchmark average of all cotton farms that have been involved in this project and in previous projects. The benchmark average is presented as a box and whisker plot and the individual is shown as a point within the box and whisker plot.

1.2. Additional support level1 and level2 assessments

The EnergyCalc tool has been revised to align with the requirements of the RDOs involved in the project. These changes were driven by the RDOs during consultation at the RDO training sessions (section 1.4.2) and on-going updates as requested by the RDOs.

A raft of refinements were made to the Level 2 interface of the software tool. These included: refinements to in the inbuilt calculators; improvements to how the software handled GST and rebate; changes in the functionality of the software and changes to the reporting; inclusion of more types of energy sources, and, rearrangement of dropdown lists so that cotton-specific activities appeared at the top of the list.

Significantly, a level one assessment interface was built in EnergyCalc for this project. This interface is shown below in figure 1. These changes were made to process, store and report level one assessments for the project. Expectations were that RDOs would be able to collect level one information quickly and easily. For example, the fuel billing calculator, shown in figure 2, increased ease of use by allowing entry of fuel costs on a GST and/or rebate inclusive or exclusive basis. The calculator also includes options for the entry of weekly, monthly or quarterly accounts. This reduced the workload of the user and reduced error by allowing entry of figures directly from account statements and by removing the need to calculate fuel costs exclusive of GST and rebate

Figure 1. The enhanced level one interface allowed for direct entry of total energy consumption.

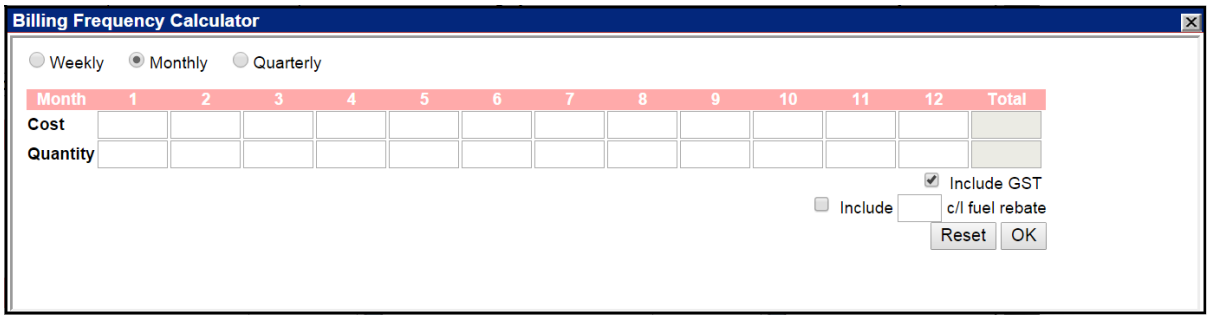


Figure 2. The fuel billing calculator increased ease of use by allowing entry directly from invoices on a GST and/or rebate inclusive or exclusive basis.

As listed in section 1.4.1 the following materials were provided to the RDOs during the relevant training session.

- *MW 02 EClite user manual*
- *MW 03 EnergyCalc User Manual Level 1*
- *MW 04 Energy Calc User Manual Level 2*

The following promotional items were developed in response to requests from the RDOs and were submitted to the CRDC for approval.

- G 04 - Guide to media articles
- G 06 - Energy Efficiency Promotional flyer

At the request of the RDOs, the following additional materials were developed and provided to the RDO's.

- *G 02 'L1 Energy Assessment Data Requirement'*
- *G 03 'EnergyCalc Level 2 data collection sheet'*
- *G 05 'L1 Report Explanations'*
- *G 07 'Audit summary guide'*

All other protocols have been included in the Audit Summary Guide (Document G07) which defines what an audit is and the steps involved in undertaking an audit. This document defines the protocols that are specific to energy auditing in the cotton industry as well as a step by step guide to using the EnergyCalc tool.

These items (G02 to G07) are attached in *Appendix 1.2*.

1.3. Six Energy Factsheets

The initial project agreement used the production phases "fallow, planting, in-crop, harvest and post-harvest" as an example of a likely structure for the factsheets. As the project progressed it became apparent that, because operations often overlapped, a slightly different structure was more appropriate. For example, tractors are used in fallow, planting, in-crop, and post-harvest operations with some use in harvest operations. The set-up and operation of the tractor itself is more significant because it is common across all production phases. That is, factsheets *FS07* and *FS08* refer to tractor set-up and operation and these two fact sheets apply across the previously mentioned producion phases.

Additionally, a need was identified for factsheets that presented energy use efficiency concepts in overview. Factsheets *FS01*, *FS02* and *FS03* refer to the need, opportunities and process of achieving more efficienct energy use. These fact sheets apply across all of the production phases.

Notwithstanding the above, there are some production phases that warrant specific attention. Sandell et al. (2013) show that irrigation of cotton typically accounts for 45% to 75% of all direct on-farm energy use. Acordingly, *FS04*, FS05 and FS06 refer specifically to the production phase of 'irrigation'. Sandell et al. (2013) show that picking typically accounts for 25% of all direct on-farm energy consumption. Similarly, *FS09* refers specifically to the production phase of 'harvest' (picking), which is also a distinctly different operation.

This approach allows for the total number of factsheets to continue to increase as the demand changes, by drafting factsheets that address the specific topics that RDOs and cotton farmers have expressed interest in. Table 2, below aligns the factsheets to the six processes detailed in the project specification.

Table 2. Project specifications and fact sheet matrix.

Factsheet Title	Production Phase					
	Ground Preparation	Establishment	In Crop	Irrigation	Harvest	Post Harvest
Energy assessment and Mgmt.	■	■	■	■	■	■
Reducing Farm Energy	■	■	■	■	■	■
Energy Use in Cotton	■	■	■	■	■	■
Pump Efficiency				■		
Pumps in the Aust. Cotton Industry				■		
Impact of Cavitation in pump				■		
Monitoring Tractor Fuel Use	■	■	■			■
Tractor Setup	■	■	■			■
Energy Use in Cotton Picking					■	

Seven factsheets, *FS03* through to *FS09*, inclusive, were developed under the project. Factsheets FS01 and FS02 existed prior to the start of the project and were modified to be cotton specific. Following correspondence with the CRDC, the final fact sheets were submitted to the CRDC 13 November 2014.The fact sheets are listed below and are attached in *Appendix 1.3 Six Energy* Factsheets.

- FS 01 Factsheet - Energy Assessment and Management
- FS 02 Factsheet - Reducing Farm Energy
- FS 03 Factsheet - Energy Benchmarking
- FS 04 Factsheet - Pump Efficiency
- FS 05 Factsheet - Pumps in the Australian Cotton Industry
- FS 06 Factsheet - Impact of Cavitation on Pump Efficiency
- FS 07 Factsheet - Monitoring Tractor Fuel Use
- FS 08 Factsheet - Tractor Setup
- FS 09 Factsheet - Energy Use in Cotton Picking

Factsheets were developed in the MS Publisher template provided by the CRDC, which is also provided in *Appendix 1.3 Six Energy* Factsheets. Energy fact sheets were distributed at relevant industry events such as the 2014 Cotton Conference, The Big Days Out, grower workshops and other events.

1.4. Training Package

1.4.1. Training materials and resources

The following training materials and resources were developed and submitted to The CRDC. These materials are included in *Appendix 1.4.1 Training materials and* resources.

- *G 01 Journal article on cotton energy use*
- *MW 01 A standardised practical methodology for benchmarking on -farm energy use and greenhouse gas emissions on cotton farms.*
- *RDO Training schedule*
- *WSM 02 RDO Training Slides L1*
- *WSM 03 RDO Training Exercise 1*
- *WSM 04 RDO Training Exercise 2*
- *WSM 05 RDO Training Exercise 3*
- *WSM 07 RDO Training Slides L2*
- *WSM 08 RDO Training Exercise 4*

Also presented were

- *MW 02 EClite user manual*
- *MW 03 EnergyCalc User Manual Level 1*
- *MW 04 Energy Calc User Manual Level 2*

which can be accessed in *Appendix 1.5*.

1.4.2. Provide training to RDOs

Training was provided in two separate training sessions, one focused on Level 1 assessments, the second on level 2 assessments

Training was provided to enable RDO's and others to perform a Level 1 energy assessent in Goondiwindi on 14 November 2014. There were eight attendees: 6 RDOs, an NSW DPI irrigation officer and the RDO manager. The 7th RDO was on maternity leave, and her temporary replacement had not been appointed at the time the training was held. An individual session was held at a later date to provide her with this training.

This training was provided according to *RDO training schedule* a background the EEIG project, why energy auditing is important in cotton, an overview of the auditing process and an overview of Level 3 energy audits (WSM 02). Practice sessions saw the RDOs undertake Level 1 energy audits using a worked example (WSM 03). Participants were provided with further training examples to gain some experience and confidence in the process before engaging with cotton farmers (WSM 04 and WSM 05). Other resources were disseminated to the RDOs including a journal article looking at energy auditing in the cotton industry (G 01) and a report on the development of an energy auditing methodology specifically for cotton farms (MW 01).

User manuals for EnergyCalc and EnergyCalc Lite (Documents MW 02, MW03 and MW04) were provided to participants at this session. (Refer to section 1.5 for further details.)

In response to feedback from participants at this session, shortcut guides G 05 and G 07 were developed and provided to participants. (Please refer to section 1.2 for further details.)

Additionally, at these training sessions the RDOs were able to provide significant feedback as to significant upgrades to the EnergyCalc interface. For further details please refer to section 1.5.

Level 2 energy audit training was undertaken in Moree on the 30 January 2014. The participants were the seven RDOs, a NSW DPI irrigation officer and the RDO's manager.

This training provided a short review of the overview topics from the first training session in Goondiwindi (WSM07). Given the fundamental knowledge and theoretical background had been provided, it was decided that the best way to learn the process was by a hands-on training exercise where the RDOs conducted a Level 2 audit.

NCEA researchers Gary Sandell and Phillip Szabo, with Mrs Janelle Montgomery from NSW DPI had previously conducted a Level 2 energy audit at a subject farm and have a good working knowledge of this farm. At the training session, the RDOs conducted a realistic Level 2 audit where Mrs Montgomery role played "the grower". RDOs then began the audit process with general questions regarding farming and record keeping practices to arrive at a methodology to complete a level 2 energy audit for this farm. All relevant records were provided to the participants (WSM 08). The RDOs then worked through the exercise and discussed the errors and issues that the auditors faced.

At both of these training events it was stressed that the NCEA were available to provide telephone and other support for energy audit activities. Additionally, it was stressed that an NCEA researcher would attend their first energy audit to assist with the process.

The attendance lists are attached in *Appendix 1.4.2 Provide training to RDOs.*

- *WSM 01 RDO L1Training attendance sheet*
- *WSM 06 RDO L2 Training attendance sheet*

Additional support was provided to the RDOs in two main forms: Personal attendance at their first real audit and continued telephone and email support. These sessions were:

- Kieren O'Keffe at "Huddersfield", 19 Feb 2014. Audit details discussed/
- Amanda Thomas with Jodi Browning, Narromine, 20 Feb 2014
- Geoff Hunter, Narrabri, 4 June 2014. No audit undertaken at the visit
- Kiralee Blomfield, no response received
- Alice Devlin, South Bunarba, 21 June 2014
- John Smith, no response received, although, other activities were undertaken.
- Sally Dickinson, Evolution Farming, 20 June 2014

All telephone and other support requests from RDOs have been met.

1.4.3. Training provided to at least 20 farm consultants.

A pumps workshop "Improving energy efficiency for low lift high volume irrigation pumps within the cotton industry" was held on Wednesday 29th October 2014 at Keytah, Moree NSW. The workshop

was conducted by The National Centre for Engineering in Agriculture (NCEA) and NSW DPI. The presenters were: Peter Smith (NSW DPI), Dr Joseph Foley (NCEA), Phil Szabo (NCEA), Gary Sandell (NCEA). The day was facilitated by Dr Janelle Montgomery (NSW DPI).

There were 18 participants including 5 irrigators, 9 irrigation consultants and 4 industry personnel (including 1 Cotton RDO and CottonInfo Manager).

The course covered the following topics:

- Demonstration of how a pump test is performed.
- Training on how to use EnergyCalc Lite
- Understanding pump duty
- Understanding pump curves
- Pump selection, efficiency and power requirements

The follow material was used in the course and is presented in *Appendix 1.4.3 Training provided to at least 20 farm consultants*.

- *Pump Training presentation.*
- *Energy Audits – short version.*
- *EnergyCalc Lite.*

Workshop evaluation

The majority of participants found the course met their expectations, topics useful and instruction was at a high standard. However, the content was at times quite technical and some participants found sections difficult to understand. Discussions with participants post workshop suggest that participants would have liked to have seen more emphasis on how to use the pump variables to determine their pump performance. While the workshop showed them how to collect the information needed to examine pump efficiency, it did not go into much detail about the calculations.

It was decided before the course to remove the content relating to calculations as previous experience showed that the calculations where difficult for participates to understand and caused confusion with the limited time available for the course.

There was very little interest from consultants prior to the course to undertake EC Lite training and incorporate it into their business. There was however a greater interest in learning the skills required to perform a pump assessment as the industry lacks the numbers of required trained consultants to perform pump assessments.

1.5. Record Keeping Protocols for EnergyCalc and EnergyCalc Lite

The web-based tool “EnergyCalc” is the primary tool that was used by the RDOs for undertaking Level 1 and Level 2 energy audits. EnergyCalc is not only used as a data collection tool but also generates the audit report card, and houses the benchmarking database.

As mentioned in section 1.2 the EnergyCalc tool has been revised and aligned with the requirements of the RDOs. A level 1 platform was developed under this project so that EnergyCalc accommodates both Level 1 and Level 2 energy audits. It provides the user with a data collection template which allows consistent methods for collection and compiling data. The tool has built in calculators for estimating energy consumption and that are relevant to cotton cropping systems. The tool also provides a consistent reporting feature for both Level 1 and Level 2 energy audits. All data is securely stored in NCEA databases for benchmarking.

Templates were developed for users to fill in the raw data required to use EnergyCalc and EnergyCalc Lite. A Level 1 Energy assessment data collection template was developed in response to RDO requests (G02). Similarly, a Level 2 Energy assessment data collection template was developed (G03). These documents are presented in section 1.2.

Please refer to the following documents in *Appendix 1.5.* These documents had been previously developed by the NCEA.

- MW 02 EClite user manual
- MW 03 EnergyCalc User Manual L1
- MW 04 Energy Calc User Manual L2

In addition to these comprehensive manuals the following documents were developed for the RDOs to be more 'cotton-specific' and thus simplified.

- Level 1 Energy assessment data collection protocols; document G 02 (refer to section 1.2).
- Level 2 Energy assessment data collection; document G 03 (refer to section 1.2).
- Additionally, the document G07 Audit Summary Guide (refer to section 1.2) provides a step by step guide to undertaking an audit. This document defines the protocols that are specific to energy auditing in the cotton industry and incorporates a step by step guide to using the EnergyCalc tool.

1.6. Update the myBMP energy module

Revisions to myBMP are typically undertaken annually during the winter / off-season each year so that they are made available to cotton growers in September, prior to the planting of the crop. Significant updates were provided to the *Energy and Input Efficiency* section of the myBMP site during September 2014. The text on this page is contained in *Appendix 1.6* , which also includes a list of the links available on the site.

Links on the site refer to Best Practice materials promoted under the project. This commonality better facilitates knowledge transfer through RDOs and other industry participants and supports the completion of online myBMP modules. Some of the documents previously supported by the site were also retained.

Another, more extensive review of the MyBMP site is now being undertaken by the NCEA and the CottonInfo team.

2. Undertaking on-farm assessments

The project proposal was based on Chen & Baillie (2009), which is congruent with the Australian Standard, "AS/NZS 3598:2000. Energy Audits." This standard (AS3598) is applicable to "a range of premises from complex industrial sites or commercial buildings to a small office building." Chen & Baillie (2009) use the essence of AS3598. However, their work applies energy audits to modern agricultural biosystems rather than the built environment. While further information is available in these two documents, figure 3 presents the key process of energy audits for the convenience of the reader.

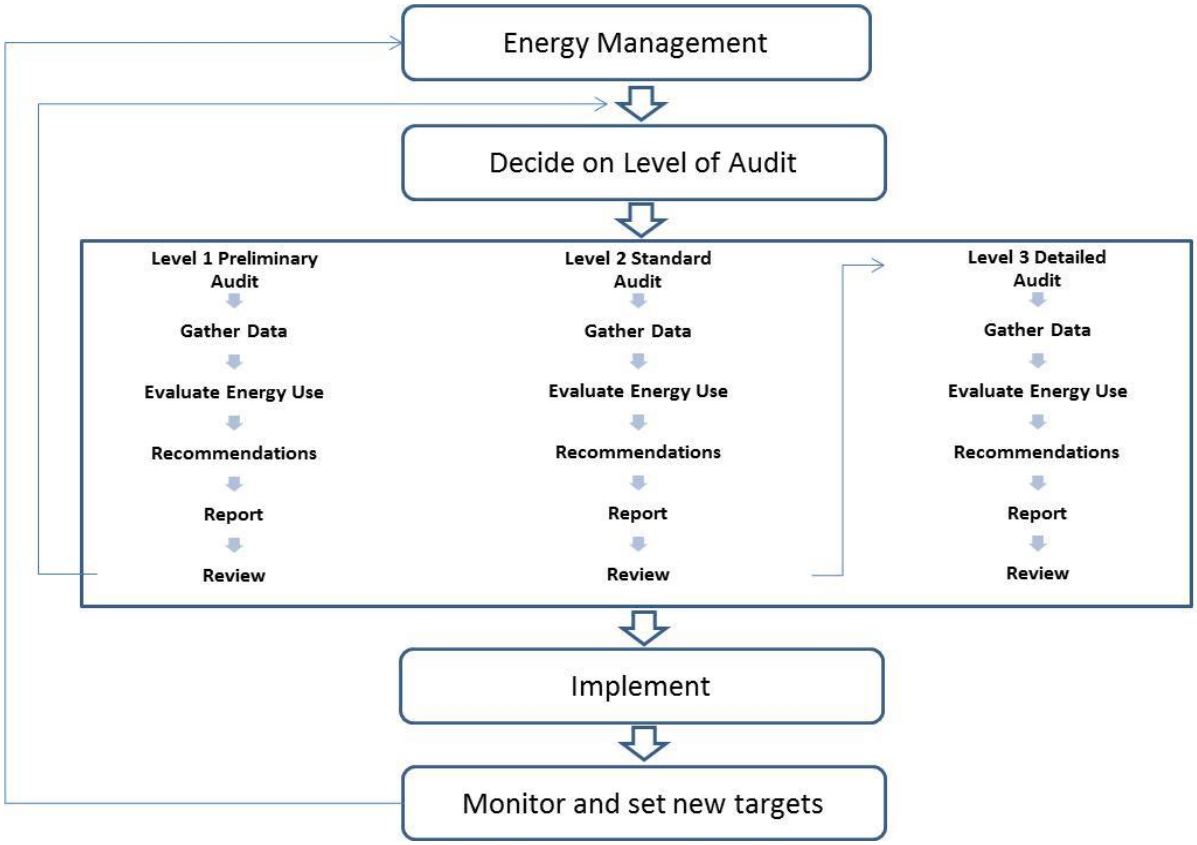


Figure 3. The energy audit process. Baillie & Chen (2012)

Generally a level one audit (total energy used per hectare and per bale) is conducted in the first instance. These results are compared to industry benchmarks to identify if the farm in question has a relatively high energy use. This quantifies the need for a level two audit. A subsequent level two audit quantifies energy use of each process within the operation and these are compared with industry benchmarks. In this way, a level 2 assessment then identifies any unusually high energy use activities. A level three audit is then used to closely examine these activities and resolve inefficiencies therein.

2.1. Work plan developed for the undertaking of on-farm energy assessments

A work plan was agreed between the CRDC and the NCEA. It is attached *in Appendix 2.1 Work plan developed for the undertaking of on-farm energy assessments.*

As the project progressed it became apparent that there were unexpected obstacles in completing the initial number of level 1 and level 2 assessments. Instruction was received from the CRDC to reduce the total required number of level one assessments from 200 down to 150 and to reduce the number of level two assessments from 40 down to 30.

2.2. Level 1 Assessments

This section deals with Performance Indicators 2.2.1 through to 2.2.4, concurrently.

The project agreement was that the RDOs would collect Level One Audit information. Initial expectations were that the RDOs would collect the required data through a 'quick chat' with the grower and that this would be a quick and simple process. Once the project progressed it quickly became apparent that this is not the case.

A cotton grower typically conducted multiple operations. For example, a break crop is usually grown and there may be several different crops in any given season. Often, a cotton farmer will also have other enterprises such as cattle or machinery contracting. Usually all enterprises are operated from one diesel tank with no account for what diesel is apportioned to each enterprise. Therefore, the simple question 'How much diesel did you use to grow your cotton?' requires a complex and time consuming level two audit to separate the cotton enterprise from these other enterprises.

The CRDC received feedback on the level 1 assessments:

- Cotton growers are finding the Level 1 assessment of limited value as they offer no guidance about how they can change their operations to improve their energy efficiency.

Thus, there were no level one audits completed during the milestone period. Alternate analyses were performed by the NCEA in lieu of RDO-supplied information. Please refer to section 5.1 for further details.

2.3. Level 2 Assessments

This section deals with Performance Indicators 2.3.1 through to 2.3.4 concurrently.

Level two audit training (section 1.4.2) and additional resources (section 1.2) were provided to the RDO team. During the milestone period (1/10/13 to 27/2/15) Alice Devlin completed one level 2 assessment and Sally Dickinson and Amanda Thomas largely completed a level 2 assessment each. Please refer to the end of section for 1.4.2 for details. No other enquiries for level 2 assessments were received.

The CRDC received feedback on the Level 2 assessments:

- The Level 3 assessments are more valuable as they provide specific feedback to growers about how energy efficiency of specific operations can be improved.

- Level 2 assessments are time consuming (taking up to 6 hours) and require specialised knowledge to provide practical energy efficiency feedback back to the growers. The current database interface slows the process down.

Alternative collection methods were employed after the milestone period and these are discussed in Section 5.2.

2.4. Level 3 Assessments

This section deals with Performance Indicators 2.4.1 through to 2.4.4 concurrently.

Discussions with growers has shown that the primary areas of grower interest are in water pumping systems with some interest in tractor operations. Thirteen level three assessments were conducted on pumps and two level three assessments were conducted on tractors. Level 3 assessments were conducted across the length of the Australian cotton industry from Emerald, Qld. to Southern NSW.

The NCEA have used a range of sophisticated electronic devices to measure the performance of each pumping system. This involves measuring the energy input and energy output and quantifying pump performance and suitability to the task.

Input energy is either measured from the electrical meter if electrical, or, by installing meters to measure diesel inflow and diesel outflow for diesel engines.

The energy output and pump performance is calculated by measuring the suction and discharge pressures of the pump, water flow rate and pump speed. It is necessary to install the pressure gauges via drilling and tapping a port as close as possible to the inlet and out let of the pump to account for all the energy. An ultrasonic flow meter is installed to measure water flow rate, a long section of pipe is required for a successful measurement.

The following section, *Level three assessment details,* lists the pump assessments that were completed for this project. For each of these a L3 report card, or IPERT report, (section 1.1) was developed asnd these can be found in *Appendix 2.4 Level 3 assessments*. The L3 report card was provided to each collaborator at the time of assessment and a detailed discussion held regarding the relative efficiency and performance of the pump station and the recommendations if any remedial action was required.

In addition to these fifteen level three assessments there were a number of pump inspections which were undertaken but not formally assessed. Thus, there is no IPERT report pertaining to these inspections. Generally a full test was not conducted because the grower had asked for general advice only. Sometimes this was because there was insufficient water to pump and in one case the pipes were badly rusted and a water flow measurement could not be attained. These pumps are listed in the next section, entitled *Pump inspection.*

Level three assessment details

1. Dirranbandi, 03/12/2013, Don Crothers, John Deere 6081AF001 diesel engine driving 26HBC-40 pump, tail water recirculation or storage. Janelle Montgomery was contacted by Don Crothers from an article written in Spotlight magazine relating to pump efficiency. Phil Szabo

and Janelle Montgomery performed a successful assessment. Results from the assessment include:

- Lower pump or raise water level in tail water channel by 0.5m.
- Increase suction side pipe diameter to 750mm.
- Operate engine at 1800 RPM 70% load with a pump speed of 570 RPM.
- Increase number of belts to 8 (C section) with a pulley ratio of 3.158.

2. Griffith, 18/02/2014, Gavin Del Broi (Ph: 0429 634 311), Hino K13C diesel engine driving Ingersol Rand Turbine 16NKL bore pump. Kieran O'Keeffe sourced the pump assessment. Phil Szabo and Gary Sandell performed a successful assessment. Results from the assessment include
    - The pump and engine combination are performing well. It is recommended that the engine operate at 1500 +/-50 RPM.
    - The engine is oversized for the pump. In the future, should the engine be replaced it is recommended to source an engine that operates at 70 to 80% load, as the current engine operates at less than 50% load.
    - The LPG injection system will simply over-fuel this engine as it is mechanically injected. An electronic engine should be sourced to allow the LPG system to be reconnected to further reduce running costs
3. Narromine, 20/02/2014, Jodi Browning (Ph: 0417 892 336), Newmans Industry 5042/DC4343BR electric motor driving Kelly & Lewis M18x2 axial pump for river harvest. Amanda Thomas sourced the pump assessment. Phil Szabo and Gary Sandell performed a successful assessment. Results from the assessment include:
    - The pump station is operating at peak efficiency in accordance with the performance curve supplied by the manufacturer. There are no further recommendations for pump station efficiency improvements.
    - It has been identified that network charges are significant and if the pump station is not in use for an extended period of time and it could be disconnected from the grid.
4. Goondiwindi (Macintyre Downs), 15/04/2014, Hamish Johnston (Ph: 0428 765 125), Volvo Penta TAD 1241 diesel engine driving 26HBC-40 pump for river harvest. NCEA and NSW DPI have been working closely with Macintyre Downs testing the Pump Efficiency Monitor. Phil Szabo and Janelle Montgomery performed a successful assessment. Results from the assessment include:
    - Assessments conducted at a pump speed of 480RPM and 570RPM produce operating point results that conform to the pump curve, and that the pump is operating efficiently. However, the third assessment at the [high] pump speed of 660RPM, indicates that the pump is most likely cavitating due to the high suction lift, the significantly reduced flow rate, and operating TDH. Therefore, it is recommended that the pump be operated at lower speeds or significantly increased suction supply water heights.
    - Assessment of the belt slip was completed by calculating the engine and pump shaft speeds ratios across the speeds tested, and there is no significant belt slip.
5. Dalby, Kim and Andrew Bremner (0429 639 136). This level 3 assessment is one of the two tractor tests. Ripping depth, ground speed and throttle position were compared in a 4.5

metre wide fixed-tyne ripper behind a 2010 model John Deere 8220 tractor. Please refer to the case study derived from this assessment (section 3.4) for more information.

6. Emerald, 01/12/2014, Cam Geddes (Ph: 0400 009 190), Weo L44 E2W21 TYCO electric motor driving Southern Cross 250x200-315 pump, tail water recirculation or storage. Lance Pendergast (QDAFF) sourced the pump assessment. Phil Szabo and Gary Sandell performed a successful assessment. Results from the assessment include:
    - Perform a shut off test to confirm the size of the impeller.
    - The pump station is operating at peak efficiency in accordance with the performance curve supplied by the manufacturer. There are no further recommendations for pump station efficiency improvements.
7. Emerald, 01/12/2014, Cam Geddes (Ph: 0400 009 190), Monarch 180L-6 electric motor driving 10HBC-30 pump for opportunity river harvest. Lance Pendergast (QDAFF) sourced the pump assessment. Phil Szabo and Gary Sandell performed a successful assessment. Results from the assessment include:
    - Investigate solar power options to operate the pump.
    - Investigate control systems to operate the pump station and maximise off-peak rates.
    - Investigate tariff options to ensure pump station is on the correct tariff.
    - The pump station is operating at peak efficiency in accordance with the performance curve supplied by the manufacturer. There are no further recommendations for pump station efficiency improvements.
8. Saint George, 05/12/2014, Hamish McIntyre (Ph: 07 4625 5600), John Deere 6081HF001 diesel engine driving 26HBC-40 pump for river harvest. Glen Lyons sourced the pump assessment. Phil Szabo and Gary Sandell performed a successful assessment. Results from the assessment include:
    - Explore the possibility of different suction inlets (bell mouth).
    - The pump station is running efficiently at 1350 RPM (measured engine speed, 1400 RPM according to engine tachometer) in accordance with the pump performance curve supplied by the manufacture. The most efficient cost ($/ML) of pumping with a TDH of 5.16m is $4.56/ML.
9. Saint George (Cubby North), 06/12/2014, Brent Brimblecombe (Ph: 07 4625 1100), Volvo Penta TWD1210V diesel engine driving 26HBC-40 pump, tail water recirculation (normal operation). Glen Lyons sourced the pump assessment. Phil Szabo and Gary Sandell performed a successful assessment. Results from the assessment include:
    - Reduce engine speed to give more economical pumping when lower required flow rates are possible. This will improve pump efficiency and reduce cost $/ML pumped, when possible.
    - Ensure that the trash screens are operating.
10. Saint George (Cubby North), 06/12/2014, Brent Brimblecombe (Ph: 07 4625 1100), Volvo Penta TWD1210V diesel engine driving 26HBC-40 pump, tail water recirculation (trash caught in pump centre). Glen Lyons sourced the pump assessment. Phil Szabo and Gary Sandell performed a successful assessment. Results from the assessment include:

- Reduce engine speed to give more economical pumping when lower required flow rates are possible. This will improve pump efficiency and reduce cost $/ML pumped, when possible.
- Ensure that the trash screens are operating.

11. Gunnedah, January 2015, Scott Morgan (0407 255 190). This level 3 assessment is one of the two tractor tests. A trial was conducted during a listering operation to measure and compare time performance and fuel use during turning and listering tasks in a JD8235R tractor.
12. Saint George, 27/01/2015, Ian Brimblecombe (Ph: 0428 253 807), Western Electric F250 MU04 001 motor driving 20HBC-40 Wuxi Hubei pump. Joe Foley sourced and performed a successful pump assessment. Results from the assessment include:
    - The energy consumption of this motor/pump combination could only be reduced by reducing sharpness of pipe bends, removing butterfly valves on both suction and discharge side of the system. There are potential reductions of around 1.0 meters of TDH, which corresponds to a16% overall in load on the electric motor.
    - At the current speed, motor was consuming <62 kW.h per hour, and the motor size is 75 kW. There will be some windage losses associated with this larger sized motor.
    - When the data is homologised using the pump affinity laws back to a speed of 580 rpm for comparison with the factory curve, the evidence suggests that there is some wear on the pump impeller and it may be underperforming by about 5%.
13. Saint George, 27/01/2015, Ian Brimblecombe (Ph: 0428 253 807), Western Electric 3AFP 315M-4 motor driving Wuxi Hubei 26HBC40 pump. Joe Foley sourced and performed a successful pump assessment. Results from the assessment include:
    - The pump was performing to curve.
    - Friction and minor head losses were too large a component of TDH.
    - The second 26HBC-40 should be brought into service to lower the flowrate at this pump speed, and improve the pump efficiency at the operating point, from 76% to 88%.
    - The pump inlet suction pressure of -50 kPa was considered excessive. Check for:
        i. high suction entry losses,
        ii. other local losses such as bends,
        iii. static height of pump above the water source and a declining level of the water source,
        iv. blockage of the inlet strainer.
14. Dalby, Test Date, Adam McVeigh: Phil Szabo and Gary Sandell inspect a pump station that operates a centre pivot. Joe Foley performed a successful assessment. See attached IPERT report.
    - Pumps are supplying additional head that is surplus to requirement.
    - Variable Frequency Drive (VFD) set point to be adjusted on seasonal basis from 58%. Invertech parameter P3-06 = 50% for Pivot 1 only. P3-06= 48% for Pivot 2 only.
    - Water check valve (150mm) on suction side has 10 kPa loss. Replace with ball check valve or swing check valve. Common suction manifold needs removal and replacement. Add 8" suction pipe where 6" exists. Existing suction side cavity needs

attention. Dam suction entry needs re-design to assist manual brush screen under-sizing.

- Cavitation noted when one pump only operating at 94 L/s - not recommended.
- Energy demand can be reduced by 14% overall.

15. Goondiwindi (Macintyre Downs), PEM 2013-2014 season, Hamish Johnston (Ph: 0428 765 125), Volvo Penta TD1211V diesel drives 26HBC-40 pump (lift pump 3), tail water recirculation or storage. NCEA and NSW DPI have been working closely with Macintyre Downs testing the Pump Efficiency Monitor. Phil Szabo and Janelle Montgomery performed a successful assessment. Results from the assessment include:
    - Under the current pump station setup reducing the engine speed to 1550 RPM will result in the engine operating in a more efficient range for the power required, thus reduce fuel consumption and cavitation with a minimal reduction in water flow.
    - The maximum load imposed by the pump is only 50% of the rated continuous power of the current Volvo engine. While the engine is operating in an efficient zone, the over-capacity means that the total energy consumption is larger than required. Source a smaller engine so that the maximum load imposed by the pump is 75% to 80% of the rated continuous power of this new engine.
    - Lower the pump to just above the flood level, which is approximately 1.5 meters below the current pump centre line. Lowering the pump will decrease the Net Positive Suction Head and eliminate cavitation, increasing the life of the impeller. By lowering the pump this will allow for higher operating pump speeds thus pumping a greater volume of water. The current pulley ratios will require a reduction to 2.344:1. This will allow the engine to operate at its most efficient point for maximum water (1500 RPM).
    - An axial flow discharge pump is suited to this situation due to the low total dynamic head and high flow rate required. The axial pump will have a higher efficiency than a mixed flow pump and further reduce energy costs.

Pump inspection details

16. Goondiwindi (Macintyre Downs), PEM 27/01/2013 till 07/02/2013, Hamish Johnston (Ph: 0428 765 125), Volvo Penta TD1211V diesel drives 26HBC-40 pump (lift pump 3), tail water recirculation or storage. Phil Szabo collected the data with the pump efficiency monitor during a flood event that allowed the storage dam to be filled.
17. Griffith, 17/02/2014, Huddersfield. Phil Szabo and Gary Sandell inspected a pump station during training for level 2 assessment with Kieran O'Keeffe. It was highlighted to the grower that extra unnecessary bends in the suction line at the pump inlet increases the operating cost of the pump. No further testing was conducted due to time constraints.
18. Narromine, 21/02/2014, Alex Belhausen. A suitable pump station was located by Amanda Thomas. An electrically driven Everflow 200FHM bore pump was on site. The pump station was equipped with a pressure sensor and water flow meter. While trying to determine the level of water above the pump it was discovered that the command line was split. This resulted in an incomplete measurement to assess the total dynamic head. The assessment could therefore not be completed successfully.

19. Goondiwindi Mulala, 11/06/2014. Phil Szabo met Will Coulton for a tour of the properties pump station to identify potential level 3 assessment. A 26HBC-40 was due for an overhaul which required a new pump centre and a new diesel engine. This was going to be used as a case study highlighting the efficiency gains when replace an old diesel engine with a modern engine. Unfortunately the project did not go ahead.
20. Dalby, 09/07/2014, Kim Bremner: Phil Szabo and Gary Sandell inspect a flood harvest pump as a potential level 3 assessment. The setup consisted of an electrically driven axial flow pump with a diesel engine driven HBC mixed flow pump attached as a backup. Due to the intricate maze of pipes it was not possible to install a water flow meter to complete a successful assessment. However, significant analyses were undertaken and a recommendation provided.
21. Keytah, 28/10/2014, Nathaniel Phillis (Ph: 0427 860 150), KHD Deutz F12L413F diesel engine driving 26HBC-40 pump, tail water recirculation or storage. Phil Szabo, Gary Sandell and Joseph Foley performed a level 3 assessment. Due to the large diameter of the pipe the velocity of the water was below the minimum required for the water flow meter. Therefore the accuracy of the water flow rate could not be relied upon and the assessment could not be completed successfully.
22. Emerald (Dennison), 02/12/2014, John Walter, (Ph: 0417 696 560). Phil Szabo and Gary Sandell inspected an 8HBC-35 pump driven by a Shanghai 495AG-6 diesel engine. An assessment could not be completed successfully.
23. Emerald, 03/12/2014, Nigel Burnett: Phil Szabo and Gary Sandell inspect pump stations. The grower has issues with the design of his river harvest pumps and seeking advice on option to rebuild the pump station. The grower was seeking advice on how to improve efficiency on two lift pumps. We were unable to perform an assessment due to safety concerns on the river pumps and insufficient water on farm for the lift pumps.

24. Emerald, 03/12/2014, Paul Yates: Phil Szabo and Gary Sandell inspected the pump stations. They consisted of river harvest electrically driven HBC mixed flow pumps, some of which were rebuilt after the 2011 floods. The grower wanted to confirm he was getting his water allocation, cost of pumping and pumping efficiency. Unfortunately it was not possible to perform a pump assessment due to lack of water.

25. Emerald, 04/12/2014, Rob Ingram. A suitable pump station was located by Lance Pendergast. At the arranged time for the assessment the grower was unable to switch the pump station off to allow us to install fuel flow meters and pressure gauges to perform the assessment. The complete assessment was cancelled due to time constraints.

26. Saint George, 08/12/2014, Glen Rogan: A suitable pump station was located by Glen Lyons. This was an old Perkins diesel engine driving an Everflow 400P axial pump. Fuel flow meters and pressure sensor where installed for the assessment but unfortunately due to the age and poor condition (corrosion) of the pipe it was not possible to establish an accurate reading from the water flow meter and the assessment could not be completed successfully.

Observations of level three pump assessments

Twenty-four level three assessments of large mixed flow pumps undertaken by the NCEA (including the 13 assessments conducted under this project) were categorised according to the potential level of efficiency gain. This is presented below as a frequency distribution in figure 4.

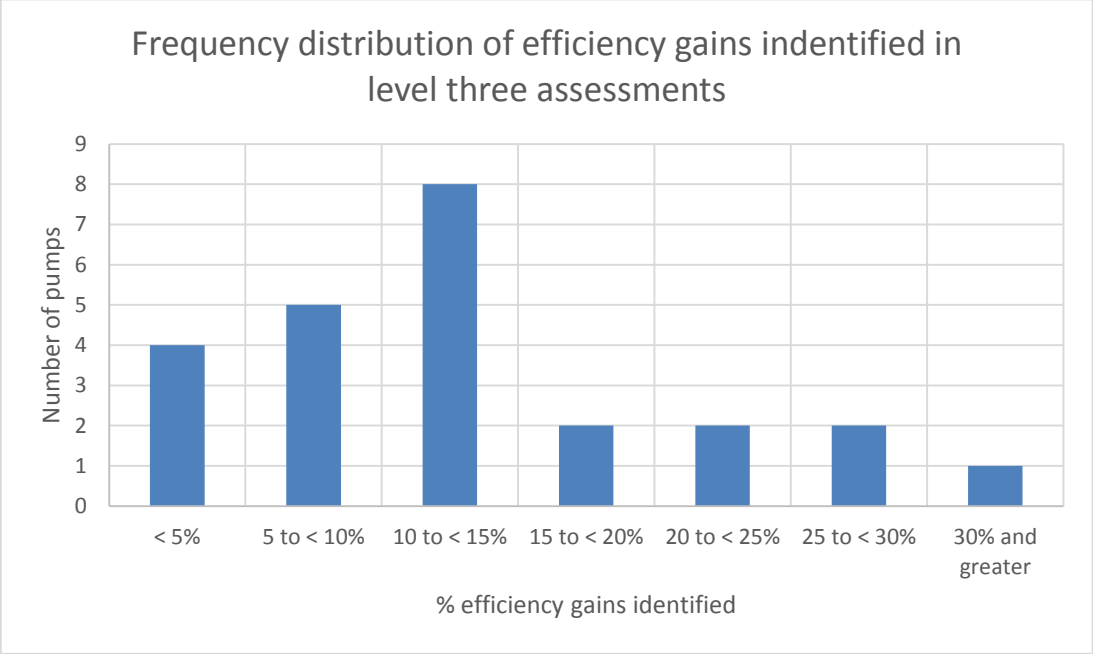


Figure 4. Frequency distribution of the potential gains identified in level three assessments.

Figure 4 shows that of the pumps tested, approximately one-third of pumps are operating efficiently, or reasonably so, one-third have gains (10 to <15%) that may be worthy of capital investment and one third of pumps have large gains in efficiency available. How well this trend represents the Australian cotton industry generally depends on how representative these 24 pumps are of the rest of the industry. It would be reasonable to conclude that pump efficiency warrants further investigation because it is likely significant gains are available to the cotton industry.

2.5. Benchmarking Report

2.5.1. Interim benchmarking report.

Interim results of the Benchmarking Report were presented by Dr Joseph Foley in Mascot, NSW, on the 22nd of April 2015. Please refer to Appendix *2.5.1 Interim Benchmarking report* for the following documents:

- *Energy Audit Workshop Agenda*
- *Energy Audit Attendance Register*
- *Energy Audit Workshop presentation*

2.5.2. Final (updated) benchmarking report.

A final benchmarking report "*Improving Energy Efficiency on Irrigated Australian Cotton Farms: Farm level benchmarking report of direct energy consumption in Australian irrigated cotton production*." was prepared and submitted to the CRDC for acceptance and is attached in *Appendix 2.5.2 Final benchmarking report*.

This benchmarking report is a significant analysis of all level one, two and three energy assessment data. The looks across all levels of energy assessment and data set to make overall, data-based conclusions from the energy assessments. The outcomes from this benchmarking exercise clearly highlights that there are opportunities for growers to identify practices where energy consumption is high, and modify to reduce direct energy use on farm. This report is attached in Appendix 2.5.2 Final benchmarking report.

Media and promotion has begun around this recently released report with the CottonInfo e-newsletter (June 2015) "Energy audits spark on-farm savings", also attached in Appendix 2.5 Benchmarking report.

The grower summary document "Benchmarking report of direct energy consumption in Australian irrigated cotton production." was also developed and a link included in the above media article. This document is attached in Appendix 2.5 Benchmarking report.

Key findings from the final benchmarking report for Australian irrigated cotton growers are:

- The median direct energy use per hectare from a total of 198 whole of farm energy assessments in this study is 11.2 GJ per hectare.
- The middle 50% of growers from the total dataset used between 7.4 and 16.4 GJ per hectare of direct energy in fully irrigated cotton production.
- These results, within the error bounds of the assessment processes applied in this study, are closely aligned with results from recent studies (Sandell et al., 2013) across seven farms where direct energy use was 10 GJ per hectare.
- With a median yield across 198 results of 10.7 bales per hectare, the median direct energy use is 1.1 GJ per bale.
- Generally, half of the direct energy consumed will be through irrigation, and about 25% will be used for high load tractor operations during the field prep and post-harvest phases of cotton production.
- A single pump make and model is used to pump up to 60% of the water volume in the industry, and uses up to 30% of the total direct energy of the industry.
- Significant tractor energy savings of up to 20% are possible with correction of tractor and implement setup.
- Diesel fuel provides at least 90% of the direct energy used on farm.
- Expenditure on diesel fuel is at least 85% of the total direct energy expenditure.
- The median direct energy expenditure across 198 farm results is $298 per hectare across the two separate data sets, and represents 8.5% of 2013 average cotton production costs reported in industry as $3627 per hectare.

- Median GHG emissions are 920 kg CO2-e per hectare and 91 kg CO2-e per bale across the total of 198 results, with the middle 50% of growers emitting between 575 and 1255 kg CO2-e per hectare.

Key recommendations from the final benchmarking report for Australian irrigated cotton growers are:

- Whole of farm energy use benchmarks are generated and incorporated into myBMP to allow individualised on-farm per year benchmarks characterised according to: region / locality; amount of irrigation water used; irrigation system type (surface, CP&LM); water sources / pump type (i.e. scheme, water harvesting, bore etc); cropping practices.
- A significant improvement in the application and use of simple energy measurement equipment is required across the industry, especially for large energy consuming equipment such as pump stations with water flowrate, pump shaft speed, pump pressures, and diesel fuel metering.
- Education on the fundamentals of irrigation pump station design and installation of appropriate monitoring points for routine evaluation of pump performance is required. Measurements could not be undertaken at a number of sites due to inaccessibility of measurement points for water flowrate and pressure
- Explore in more detail the large variation in direct energy expenditure experienced across the farm and the contributing factors (i.e. $90 to $740 per hectare).
- Identify the features of low energy farms and farming practices.
- As potential water savings in surface irrigated cotton fields can be 10 to 20%, and 20 to 40% in on-farm storages, every effort should be made to always conserve irrigation water at the field level, in distribution systems, and in water storages, as any water lost that has already been pumped is simply lost energy expenditure.
- While generally the focus has been on irrigation, it is apparent that tractor operations can be a significant component of direct energy use, and in some instances were up to 50%; greater analysis of tractor operations, farmer practice and appropriateness of machinery setup is required.
- Education on the fundamentals of tractor setup and performance (incorporating on-board tractor performance technologies i.e. IVT) is required once a more detailed assessment of tractor operations identifies particular issues experienced in industry.
- Incorporate the Level 1 analysis from this work into standard industry reporting such as Boyce & Co. Cotton Comparative Analysis reports.
- More awareness of, and support for the application of, the energy assessment methodology is required; some difficulties were encountered by industry service providers in undertaking these assessments, and the insights from Level 2 assessments conducted by industry service providers were limited.

3. Communications

3.1. Six Awareness Raising Workshops

This section deals with Performance Indicators 3.1.1 through to 3.1.3 concurrently.

Initial expectations were that RDOs, via contact with cotton farmers throughout the season, would plan, organise, promote and facilitate the workshops and that the NCEA would provide relevant technical expertise.

The focus in the first season for the project was on providing information about the grant, and the opportunity for growers to have someone help them undertake an energy assessment.

Result of earlier projects were presented to support this. During the second season known results from previous projects, as well as lessons from this project were synthesised into an A5 booklet. The *A5 booklet* is an important extension tools because it is a simple and easy to understand summary of all of the broad concepts encapsulated in the project. This booklet was presented at all workshops from August 2014 onwards. The booklet was distributed to participants and provided a quick 'glove-box' guide to energy efficiency. It acted as a prompt for discussions and questions.

Gwydir Valley Field day (26 February 2014)

NCEA provided a technical specialist at the Gwydir Valley Irrigators Association field day on 26 February 2014 to discuss the program and the Level 3 energy audits that have been undertaken in the cotton industry to date. This was extremely well received and many growers were interested to be involved in the project.

Macintyre Valley Field Day (12 March 2014)

Phillip Szabo (NCEA) presented a session at the Macintyre Valley field day to 150 growers to introduce the Level 3 (pumping) Energy Audits.

Energy Efficiency Farm Walk at Goondiwindi (22 July 2014)

Twenty-five people attended this activity. Evaluations showed all participants improved their understanding of pump efficiencies.

Energy Efficiency workshop at the Australian Cotton Conference (6 August 2014).

Approximately 1,800 people attended the 2014 Cotton Conference on the Gold Coast. The NCEA conducted a specialist energy workshop which was attended by between 45 to 50 people. Of these, from a show of hands, about 70% were growers and the remaining 30% were researchers, extension staff, etc.

The NCEA distributed full sets of nine fact sheets factsheets (*refer to Appendix 1.3 Six Energy* Factsheets). Sessions were presented on alternative energy, energy assessment, pump efficiency and monitoring and on tractor efficiency and monitoring. The NCEA prepared comprehensive material on all of these subject areas. A short presentation was made on each of these subject areas.

Importantly, the content of the workshop was participant-driven. Thus the following questions from the floor determined the content of the session.

- What effect does pump cavitation and increased RPM have on fuel consumption?
- What is optimum wheel slip for tractors?
- What is the value of ripping after round bale harvest?
- What are the warranty issues around using biodiesel?
- Can LNG be used in stationary engines?
- What is the relative efficiency of mixed flow compared to axial flow pumps?
- Will running an engine at low RPM damage it?

Water use Efficiency Field Day Wolonga, Merriot and Yattlewondi (17 September 2014)

Twenty-six people attended this field day. Growers were very responsive to the energy efficiency presentation. Many growers are interested in having a pump test performed on their farm and provided details for a follow up discussion.

Emerald pump workshop (3 Dec 2014)

Organised by Lance Pentergast (QDAFF) and the NCEA, this workshop was held at Cam Geddes property and was attended by approximately fifteen people. The NCEA presented the information on the EEIG project and energy efficiency generally via the A5 booklet. Cam's pump assessment details and how to perform pump assessments were also discussed. Additionally, Arwen Rickert presented for the BBIFMAC EEIG. There was a strong discussion that centred on pumping issues.

Saint George Workshop (11 December 2014)

The NCEA, with Sarah Rossiter (Healthy Headwaters extension officer) and Neil Lyons (independent consultant) organised this workshop, which attended by ten people. The workshop was held at "Moolabah", Saint George, pump site. At this workshop the A5 booklet and energy efficiency generally was presented with results from the "Moolabah" pump assessment and how to perform pump assessments. The discussion primarily focused by metering and measurement of water flow.

'Darling Downs Cotton Grower of the Year' awards, "Maclee", Dalby (4 Feb 2015).

This event, organised by the Dalby Grower Awards Field Day Committee, was held at Adam McVeigh's property and was attended by one-hundred and fifty people. The format of the day was several separate sessions with busses shifting people between sessions. The NCEA's Dr Joseph Foley and Mr Gary Sandell presented sessions on a pump case study and on pump efficiency respectively.

Joseph presented with John Fuelling and Adam McVeigh at the centre pivot site, addressing the results of the pump test and centre pivot analysis for the complex corner arm system. Dr Foley presented operating costs on the basis of his analysis where Adam is spending approximately $41/ML applied, including pumping and machine movement. Grower interest was significant around the total $200/ ML application costs for a typical irrigation season of 5ML/ha applied. A quick overview and Q&A session was run by Joseph as well at the VFD pump station pointing out the limitations in terms of the design of the suction manifold.

Mr Gary Sandell presented a session on energy and pump fundamentals. This session identified that nitrogen, other nutrients and chemicals accounted for 90% of on-farm energy use and the nitrogen use efficiency was particularly

3.2. Six Articles published in industry magazines

For the convenience of the reader Performance Indicators 3.2.1 through to 3.2.3 will be discussed concurrently in this section. The following articles were developed under the project. Please refer also to *Appendix 3.2 Articles published in industry magazines*.

Working to improve energy efficiency on irrigated cotton farms

'Working to improve energy efficiency on irrigated cotton farms', CRDC *Spotlight* magazine, Autumn 2014.

Trends in pumping efficiency

'Trends emerge in irrigation pump testing.' CRDC *Spotlight* on cotton R&D, Spring 2014. This article highlights the 'take home' messages from the level three pump assessments.

Putting performance first

'Putting performance first', CRDC *Spotlight* magazine, Summer 2014-15. This article encourages growers to evaluate their pump performance in light of rising energy costs.

Finding the sweet spot – maximum water using minimum fuel

"Finding the sweet spot – maximum water using minimum fuel", Australian Cotton Grower, Volume 54, No. 7, Dec 2013 – Jan 2014, pp32-34.

The Australian Cotton Production Manual, March 2015

NCEA (along with NSW DPI) have re-drafted the energy chapter was completed for *The Australian Cotton Production Manual, 2015*.

Improving tractor efficiency

'Improving tractor efficiency can save thousands of dollars.' *The Australian Cotton Grower'* April – May 2015 Volume 36, No.2. This article investigates the primary operational factors of tractor performance – gear selection and ballasting.

Ripping depth and ground speed

The Australian Cottongrower magazine has begun a series of six articles on energy use in cotton production. The first of these articles is: 'Ripping depth and ground speed.' *The Australian Cottongrower* magazine, April – May 2015 Volume 36, No.2. This article promotes the results of a case study that shows that the old adage of 'gear up and throttle back' still applies to modern tractors and farming operations.

Improving pump efficiency to save money and energy

"Improving pump efficiency to save money and energy" is the second in a series of six articles in the Australian Cottongrower magazine on energy use in cotton production. The article is due to be published in *The Australian Cottongrower* magazine, June – July 2015 Volume 36, No.3. This article quantifies the importance of irrigation and pump efficiency in energy use in Australian cotton production and list some of the most common issues seen at pump sites.

CottonInfo website "Energy Use efficiency

The NCEA assisted the CRDC (via Meg Strang) to develop the content for the CottonInfo website "Energy Use Efficiency" page in the 'Information for growers' section.

3.3. Big Day Out

3.3.1. Participate in the planning and preparation for the Big Day Out.

NCEA staff interacted with the CottonInfo team and the CRDC Project Leader, Jane Trindall, to develop the "Big Day Out" (BDO) generally and particularly by completing additional level three assessments at the BDO sites. Initial engagement with CottonInfo staff was centred around a site near Boggabilla, on the Qld/NSW border and significant effort was expended in preparing a level 3 assessment for this site. Subsequently, this site was discarded.

The final BDOs occurred at two sites, each with an accompanying level 3 assessment. The first was at Scott Morgan's "Kensal Green" property near Gunnedah, NSW, where Gary Sandell completed two visits to the site where tractor testing under heavy tillage occurred. This was then reported through various case studies around heavy tillage. The second site that was arranged for the BDO was at Ian and Anne Brimblecombe's property at "Burgorah", near Saint George, Queensland. This site was visited by Dr Joseph Foley for a series of three pump tests on very common pump makes and models used across the industry. Two case studies were developed from this series of tests. The interaction with the growers and the testing at each of these sites was valuable in providing topics for meaningful discussion at each of these sites on the Big Day Out."

3.3.2. Make presentations to attendees at Big Day Out.

Dr Joseph Foley presented at the BDO at Saint George, and Mr Gary Sandell presented at the BDO event at Gunnedah

Saint George

The presentation in Saint George (provided in Appendix 3.3 Big Day Out) concentrated on delivering an understanding of pump fundamentals in relation to energy consumption and specifically in relation to the large mixed flow pump performance test results from the level 3 testing completed to that date. An analysis technique for determining the appropriate nature of the test results was developed and applied so that it could be determined if the pump test results were valid and whether or not the test results conformed to the factory curve. The 25 minute presentation by Dr Foley provided the audience of about 40 growers and other attendees with an opportunity to understand the full implications of shifting large quantities of water, and specifically the energy cost of pumping. Two pump site visits on the day at Saint George rounded out the discussions with two twenty minute presentations at each of the pump sites. Case study sheets handed out at the sites. At each site the presentation focussed on the potential energy savings and the alterations required to achieve them. A particular focus was on the reduction of energy losses due to 'local' and 'minor' losses. That is the energy losses due to pipe friction (local) and due to bends, valves, screening, pipe entry et cetera.

Gunnedah

NCEA Energy specialist, Mr Gary Sandell presented at the Gunnedah BDO and focused on tractor efficiency. In particular, Mr Sandell discussed utilising the existing in-cab tractor technology to best advantage. This covered the basics of 'gear up, throttle back', ballasting and field efficiency. This was covered in the media article "Improving tractor efficiency can save thousands of dollars", (see *Appendix 3.2 Articles published in industry magazines*).

3.4. Six Case Studies

Please refer to *Appendix 3.4 Case Studies* for copies of the case studies.

Energy efficiency audit delivers savings
Published on the CottonInfo website, this case study highlights the ability of energy audits to deliver cost savings.

Energy efficiency plan pays off for Gunnedah irrigator
Published on the CottonInfo website, this case study discusses the use of solar energy on a cotton property near Gunnedah, NSW.

Solar
Published on the CottonInfo website, this case study discusses the use of solar energy on a cotton property near Saint George, Qld.

Ripping depth
Submitted to the CRDC, this case study quantifies the effects of reducing engine speed on the cost of ripping as well as how costs increase as ripping depth increases.

Pump evaluation pays off
Published on the CottonInfo website, this case study highlights how measurement of the pump site has saved this grower significant money.

Diesel Gas
Published on the CottonInfo website, this case study highlights the advantages of LPG injection into diesel engines.

4. Reporting

4.1. Project Reports provided to the CRDC

Projects reports were provided to the CRDC according to Schedule 4 of the Funding Agreement.

4.2. Risk Management Plans

Risk Management Plans were provided to the CRDC according to Schedule 4 of the Funding Agreement.

5. Non-contracted work

5.1. Complete Level 1 assessments.

The Contract agreement specified that level one assessment data would be supplied to the NCEA. As agreed, a level one interface was developed in EnergyCalc under the project to ease data collection and to store the data set (refer to section 1.2). This approach would provide a very 'flat' and 'streamlined' data set to enabled rapid analysis and benchmarking. However, as outlined in section 2.2, no level one assessments were supplied to the NCEA.

While level one audits offered less than anticipated results to growers, the value in level one audits was perceived in understanding industry-wide energy consumption of Australian cotton production. In response the NCEA undertook the following additional work to meet milestones. This was a very significant additional workload on the NCEA. Specifically, the NCEA were required to:

1. Identify sources of level one assessment data.
2. Collect level one assessment data.
3. Analyse level one assessment data.

The initial step was to take all irrigated cotton level two assessments existing in EnergyCalc and total energy, area and production for each record to obtain a level one assessment for irrigated cotton. This method is further described in section 5.1.1 and yielded 39 of the required 200 level one assessments.

The CRDC successfully negotiated with the Federal Government to reduce the total number of level one assessments with the head funding body to a total of 150 level one assessments. Additionally it was negotiated to achieve these 150 assessments by using the 39 EnergyCalc records and a combination of the following approaches:

1. Collaborate with Roth Regional & Rural Pty Ltd to obtain on-farm energy data as part of the annual Cotton Grower Survey.
2. Collaborate with Boyce Chartered Accountants (Boyce) to provide on-farm energy data, derived from their financial clients as part of the Cotton Comparative Analysis.

5.1.1. EnergyCalc benchmark data

The NCEA has completed hundreds of level two energy assessments for a range of industries and crops. For each of these, the end-user, (the grower) received a report and personalised feedback. Of these, the subset that contained irrigated cotton was extracted. From these data, level 1 assessments were derived by taking the totalling all energy used for all activities in the assessment with total area and production. This gave 39 level one assessments.

5.1.2. Boyce results

The CRDC sub-contracted Boyce Charted Accountants to supply de-identified summary data from their client records, which was received 23 March 2015. The data contained 120 records and represented 190,000 Ha of cotton production from 53 different farms. The data set was obtained from 2011 through to 2014. These data are collected by Boyce as part of their benchmarking

activities. These data are cotton specific and the grower participating in the benchmarking would decide how much diesel would be apportioned to cotton and how much would be apportioned to other enterprises. This is consistent with level one assessment methodology.

Of these records, three were discarded as outliers and the remaining 117 records were processed. The data consisted of the following fields (headings):

- Production year
- Valley
- Production area [Hectares]
- Production [Bales]
- Electricity cost [$]
- Fuel and oil cost, net of GST and rebate [$]

Fuel and electricity each needed to be converted from a dollar cost into units of energy and this information was not available from Boyce. Thus, assumptions of the unit cost of diesel and electricity had to be made to convert costs into units of energy. This introduced an unknown error into the calculations. The following steps were taken to mitigate the errors.

For each year, diesel price was derived from the Brisbane Terminal Gate Price (TGP) as published by the Australian Institute of Petroleum. Comparison between Brisbane and Sydney TGPs showed differences in price were insignificant compared to the likely differences in farm gate prices. Brisbane TGP was used in all analyses. Finally, GST and rebate were subtracted from the TGP and 5¢/L was added to account for delivery charges.

Electricity forms a much smaller portion of total energy use, typically around 10% or less. As such final results are much less sensitive to electricity prices than for diesel prices. Gazetted electricity prices were used for the Boyce analysis.

In addition to the errors associated with energy cost assumptions, the field 'Fuel and oil cost, net of GST and rebate [$]' was taken to be the cost of diesel alone. To quantify errors associated with oil consumption the following assumptions and analysis was made: that the diesel is consumed by an engine at a rate of 35 litres of diesel per hour; diesel costs $1.00 per litre; the engine also consumes 20 litres of engine oil every 100 hours; engine oil costs $5.00 per litre. Over 100 hours of operation the engine would consume $3,500 of diesel and $100 of oil; a total of $3,600. Based on these assumptions, the cost of oil represents $100 in $3,600, or around 3% of the total. This error was considered small compared to other errors and was ignored.

5.1.3. Roth Rural survey data

Roth Rural (2013) conducted a substantial industry survey of the Australian cotton industry. The survey quantified respondent demographics and investigated areas such as nutrition, soils and harvesting, for example. As part of this survey, growers were asked to '*estimate the energy usage for your 2012-13 cotton crop.* These results were analysed by Sandell et al. (2014) and further analyses under this project. Figure 5 shows three box and whisker plots: Roth Rural (2013) survey data; Sandell et al. (2013) industry benchmark data; and, Boyce financial benchmark data. For each plot, the upper and lower whiskers of the plot show maximum and minimum values in the data set,

respectively. The bottom and top of the box show the 25th and 75th percentiles, respectively, while the middle line shows the median value of the data set.

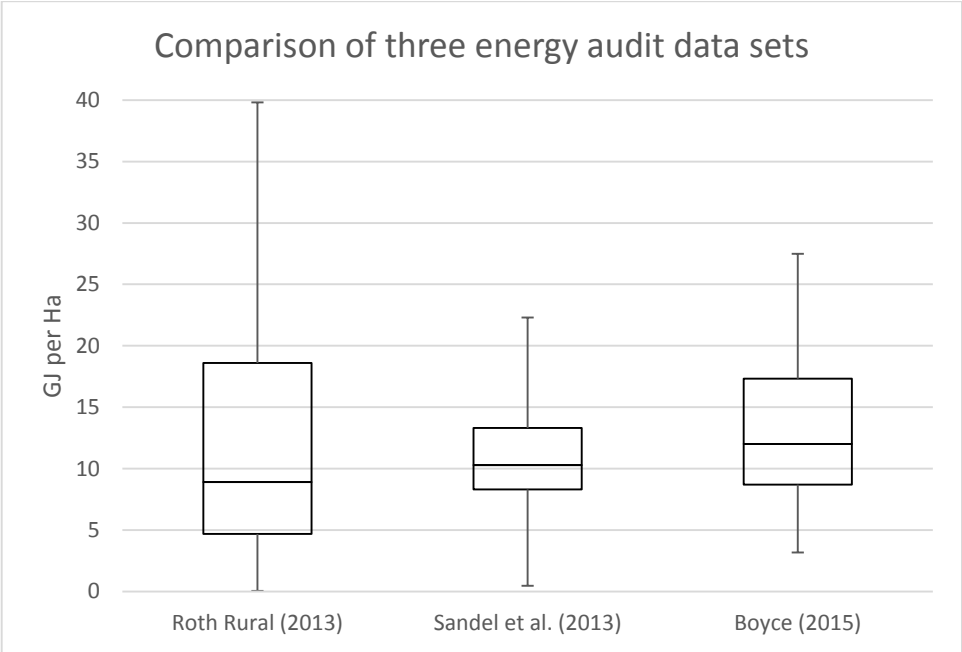


Figure 5. Box and whisker plots of energy survey data, Roth Rural (2013), and energy benchmark data, Sandell et al. (2013).

Figure 5 shows good correlation between Sandell et al. (2013) and Boyce (2015) within the bounds of assumption and experimental error. Roth Rural (2013) has a very data spread. Two of the primary issues with this data set are: 1) that it is not known if GST is included or excluded in the figures, which introduces a 10% error into the cost of diesel. And, 2) that it is not known if fuel rebate is included or excluded in the figures, which introduces a further error in the order of 30% into the cost of diesel. Sandell et al. (2013) conclude that, while the energy section of the survey has provided valuable insights into energy use and perceptions, a telephone survey is an unreliable method to establish energy benchmarks. For this reason, Roth Rural (2013) survey data was not included in the analysis.

5.2. Level 2 assessments

Three of the required 30 level 2 assessments were received during the milestone period as described in section 2.3. The CRDC employed various independent consultants to collect energy benchmarking data during April and May 2015. The lateness of this data caused significant issues. Consultants simultaneously required more than normal assistance; the training provided to RDOs (section 1.4.2) was effectively re-delivered. This occurred in a compact period of time. Subsequently, more analysis was required to 'clean' and error check the data than would normally be required as it was intended that the RDO provide a complete and accurate data set. This was required to be completed before the benchmarking report analyses could begin.

5.3. Level 3 assessments

The project assumed that the RDOs would organise the level 3 assessment sites and that the NCEA would conduct the assessment. The RDOs organised three of the fifteen level three assessment site and the NCEA, in conjunction with others, organised 12 of the fifteen level three assessment sites.

5.4. Fact Sheets

Fact sheets were accepted, printed and distributed by the CRDC during November 2014 in the format supplied by the CRDC. During April 2015 the CRDC requested that the fact sheets were re-provided in a different format to cover a broader range of topics.

5.5. Awareness raising workshops

In most cases, the NCEA worked with other parties to organise the awareness raising workshops. Less than expected assistance was received from the RDOs. In many cases, the RDO provided no assistance.

5.6. Benchmarking report

The benchmarking report is the culmination of all work in the projects and, as such, requires all other activities to be complete before preparation of the report can commence. While there was no additional, non-Contracted work in the benchmarking report itself, the lateness and complexities, outlined below, compounded to cause undue time pressure on preparation of the benchmarking report. Most significantly was the fact that Level 2 assessments were not complete until early June 2015, which was due a matter of days later. Compounding this time pressure was additional work from fact sheets, received in late Aril 2015. These came on top of delays caused by other additional work outlined in sections 5.1, 5.3 and 5.5.

Conclusion and extension opportunities

Key recommendations are that:

- Whole of farm energy use benchmarks are generated and incorporated into myBMP to allow individualised on-farm per year benchmarks characterised according to: region / locality; amount of irrigation water used; irrigation system type (surface, CP&LM); water sources / pump type (i.e. scheme, water harvesting, bore etc); cropping practices.
- A significant improvement in the application and use of simple energy measurement equipment is required across the industry, especially for large energy consuming equipment such as pump stations with water flowrate, pump shaft speed, pump pressures, and diesel fuel metering.
- Education on the fundamentals of irrigation pump station design and installation of appropriate monitoring points for routine evaluation of pump performance is required. Measurements could not be undertaken at a number of sites due to inaccessibility of measurement points for water flowrate and pressure
- Explore in more detail the large variation in direct energy expenditure experienced across the farm and the contributing factors (i.e. $90 to $740 per hectare).
- Identify the features of low energy farms and farming practices.
- As potential water savings in surface irrigated cotton fields can be 10 to 20%, and 20 to 40% in on-farm storages, every effort should be made to always conserve irrigation water at the field level, in distribution systems, and in water storages, as any water lost that has already been pumped is simply lost energy expenditure.
- While generally the focus has been on irrigation, it is apparent that tractor operations can be a significant component of direct energy use, and in some instances were up to 50%; greater analysis of tractor operations, farmer practice and appropriateness of machinery setup is required.
- Education on the fundamentals of tractor setup and performance (incorporating on-board tractor performance technologies i.e. IVT) is required once a more detailed assessment of tractor operations identifies particular issues experienced in industry.
- Incorporate the Level 1 analysis from this work into standard industry reporting such as Boyce & Co. Cotton Comparative Analysis reports.
- More awareness of, and support for the application of, the energy assessment methodology is required; some difficulties were encountered by industry service providers in undertaking these assessments, and the insights from Level 2 assessments conducted by industry service providers were limited.

Appendix 1.1 Cotton farm ‘energy report card’ template developed

- *R 01 ‘Report Card L1’*

- *R 02 'Report Card L2'*

- *R 03 'Report Card L3-Pumping'*

Appendix 1.2 Additional support level1 and level2 assessments

- *G 02 'L1 Energy Assessment Data Requirement'*

- *G 03 'EnergyCalc Level 2 data collection sheet'*

- *G 04 - Guide to media articles*

- *G 05 'L1 Report Explanations'*

- *G 06 - Energy Efficiency Promotional flyer*

- *G 07 'Audit summary guide'*

Appendix 1.3 Six Energy Factsheets

- CRDC EEIG Factsheet Template

- FS 01 Factsheet - Energy Assessment and Management

- FS 02 Factsheet - Reducing Farm Energy

- FS 03 Factsheet - Energy Benchmarking

- FS 04 Factsheet - Pump Efficiency

- FS 05 Factsheet - Pumps in the Australian Cotton Industry

- FS 06 Factsheet - Impact of Cavitation on Pump Efficiency

- FS 07 Factsheet - Monitoring Tractor Fuel Use

- FS 08 Factsheet - Tractor Setup

- FS 09 Factsheet - Energy Use in Cotton Picking

Appendix 1.4.1 Training materials and resources

- *G 01 Journal article on cotton energy use*

- *MW 01 A standardised practical methodology for benchmarking on -farm energy use and greenhouse gas emissions on cotton farms.*

- *RDO Training schedule*

- *WSM 02 RDO Training Slides L1*

- *WSM 03 RDO Training Exercise 1*

- *WSM 04 RDO Training Exercise 2*

- *WSM 05 RDO Training Exercise 3*

- *WSM 07 RDO Training Slides L2*

- *WSM 08 RDO Training Exercise 4*

Appendix 1.4.2 Provide training to RDOs

- *WSM 01 RDO L1Training attendance sheet*

- *WSM 06 RDO L2 Training attendance sheet*

Appendix 1.4.3 Training provided to at least 20 farm consultants.

- Pump Training presentation.

- Energy Audits – short version.

- EnergyCalc Lite.

Appendix 1.5 Record Keeping Protocols for EnergyCalc and EnergyCalc Lite

- MW 02 EClite user manual

- MW 03 EnergyCalc Users' Manual L1

- MW 04 Energy Calc Users' Manual L2

Appendix 1.6 Update the myBMP energy module.

Appendix 2.1 Work plan developed for the undertaking of on-farm energy assessments.

Appendix 2.4 Level 3 assessments

1. Dirranbandi, 03/12/2013, Don Crothers, John Deere 6081AF001 diesel engine driving 26HBC-40 pump, tail water recirculation or storage.

2. Griffith, 18/02/2014, Gavin Del Broi (Ph: 0429 634 311), Hino K13C diesel engine driving Ingersol Rand Turbine 16NKL bore pump

3. Narromine, 20/02/2014, Jodi Browning (Ph: 0417 892 336), Newmans Industry 5042/DC4343BR electric motor driving Kelly & Lewis M18x2 axial pump for river harvest.

4. Goondiwindi (Macintyre Downs), 15/04/2014, Hamish Johnston (Ph: 0428 765 125), Volvo Penta TAD 1241 diesel engine driving 26HBC-40 pump for river harvest.

5. Dalby, Kim and Andrew Bremner, (0429 639 136). Ripping depth, ground speed and throttle position were compared in a 4.5 metre wide fixed-tyne ripper behind a 2010 model John Deere 8220 tractor.

6. Emerald, 01/12/2014, Cam Geddes (Ph: 0400 009 190), Weo L44 E2W21 TYCO electric motor driving Southern Cross 250x200-315 pump, tail water recirculation or storage.

7. Emerald, 01/12/2014, Cam Geddes (Ph: 0400 009 190), Monarch 180L-6 electric motor driving 10HBC-30 pump for opportunity river harvest.

8. Saint George, 05/12/2014, Hamish McIntyre (Ph: 07 4625 5600), John Deere 6081HF001 diesel engine driving 26HBC-40 pump for river harvest.

9. Saint George (Cubby North), 06/12/2014, Brent Brimblecombe (Ph: 07 4625 1100), Volvo Penta TWD1210V diesel engine driving 26HBC-40 pump, tail water recirculation (normal operation).

10. Saint George (Cubby North), 06/12/2014, Brent Brimblecombe (Ph: 07 4625 1100), Volvo Penta TWD1210V diesel engine driving 26HBC-40 pump, tail water recirculation (trash caught in pump centre).

11. Gunnedah, January 2015, Scott Morgan (0407 255 190). A trial was conducted during a listering operation to measure and compare time performance and fuel use during turning and listering tasks in a JD8235R tractor.

12. Saint George, 27/01/2015, Ian Brimblecombe (Ph: 0428 253 807), Western Electric F250 MU04 001 motor driving 20HBC-40 Wuxi Hubei pump.

13. Saint George, 27/01/2015, Ian Brimblecombe (Ph: 0428 253 807), Western Electric 3AFP 315M-4 motor driving Wuxi Hubei 26HBC40 pump.

14. Dalby, Test Date, Adam McVeigh: Phil Szabo and Gary Sandell inspect a pump station that operates a centre pivot.

15. Goondiwindi (Macintyre Downs), PEM 2013-2014 season, Hamish Johnston (Ph: 0428 765 125), Volvo Penta TD1211V diesel drives 26HBC-40 pump (lift pump 3), tail water recirculation or storage.

Appendix 2.5.1 Interim Benchmarking report

- *Energy Audit Workshop Agenda*

- *Energy Audit Attendance Register*

- *Energy Audit Workshop presentation*

Appendix 2.5.2 Final benchmarking report.

- *Energy Audit sparks on-farm savings.*

- *Grower summary*

- *Farm level benchmarking report of direct energy consumption in Australian irrigated cotton production.*

Appendix 3.1 Awareness raising workshops

- *A5 booklet*

Appendix 3.2 Articles published in industry magazines

- Working to improve energy efficiency on irrigated cotton farms

- Trends in pumping efficiency

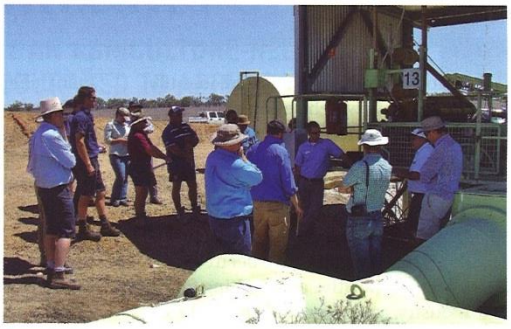
- Putting Performance first

PUTTING PERFORMANCE FIRST

PUMP PERFORMANCE EVALUATION IS A HOT TOPIC IN THE COTTON INDUSTRY AS RISING ENERGY COSTS ENCOURAGE IRRIGATORS TO LOOK EVEN MORE CLOSELY AT THE EFFICIENCY OF THEIR IRRIGATION PUMPING EQUIPMENT.

To reduce emissions and avoid the increased costs of burning excess diesel or electricity, pumps need to be running at peak efficiency.

An irrigation pumps workshop at "Keytah" near Moree in the Gwydir Valley in late October was aimed at irrigation consultants, to demonstrate the tools and necessary theory to improve their knowledge and understanding of pump evaluation. Participants heard from experts in this field including Peter Smith from NSW DPI and Joseph Foley, Gary Sandell and Phil Szabo from the National Centre for Engineering in Agriculture (NCEA).



NCEA's Gary Sandell discussing fuel flow measurement at the irrigation pump workshop held at "Keytah".

NCEA has been conducting irrigation pump evaluations across the industry and have found various issues affecting pump performance, from oversized diesel engines to undersized suction pipes. Often pumps are run at maximum RPM thinking they are achieving maximum flow, but this is not always the case. Like all things, measurement is the key. A pump evaluation will measure different variables needed to assess pump efficiency and to find the "sweet spot" - the maximum water for best fuel consumption.

CottonInfo Water Use Efficiency Technical Specialist (NSW) Janelle Montgomery said there is currently a shortage of irrigation consultants who have the skills to evaluate pump performance and the cotton industry would like to see more consultants take up pump evaluation as a service for their clients. However workshops at like that held at "Keytah" are helping the process of alleviating the shortage.

The workshop was funded by the Department of Industry as part of the Energy Efficiency Information Grants Program and Sustainable Rural Water Use and Infrastructure Program.

Need a pump evaluation? Contact Phil Szabo at NCEA Phillip.szabo@usq.edu.au

email us

Want more info on energy use efficiency? Visit the cottoninfo website www.cottoninfo.net.au

see our website

- Finding the sweet spot – maximum water using minimum fuel

- The Australian Cotton Production Manual, March 2015

- Improving Tractor efficiency

- Ripping depth and ground speed

- Improving pump efficiency to save money and energy

Appendix 3.3 Big Day Out

Appendix 3.4 Case Studies

- Energy efficiency audit delivers savings

- Energy efficiency plan pays off for Gunnedah irrigator

- Solar

- Ripping depth

- Pump evaluation pays off

- Diesel Gas

Glossary

BBIFMAC	Burdekin Bowen Integrated Floodplain Management Advisory Committee.
BDO	Big Day Out
Boyce	Boyce Chartered Accountants
CottonInfo	Australian cotton industry's joint extension team/program.
CRDC	The Cotton Research and Development Corporation
EEIG	Energy Efficiency Information Grants
Local losses	Energy losses in water pumping due to friction in pipe entry, bends, valves and other fittings.
Minor losses	Energy losses in water pumping due to friction against pipe walls.
NCEA	The National Centre for Engineering in Agriculture
NSW DPI	New South Wales Department of Primary Industries
QDAFF	Queensland Department of Agriculture, Forestry and Fisheries
RDOs	Regional Development Officers (who are part of the CottonInfo team).
SMEs	Small and medium enterprises
TGP	Terminal Gate Price [of diesel, from the Brisbane terminal]

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