Economic evaluation of farm energy audits and benchmarking of energy use on vegetable farms

John Cumming
Infotech Research

Project Number: VG13054

VG13054

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Level 8
1 Chifley Square
Sydney NSW 2000
Telephone: (02) 8295 2300
Fax: (02) 8295 2399

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Summary

Energy management is a key function of successful vegetable growing and processing. All growers have an opportunity to manage their processes more efficiently, save wastes and reduce energy demand. Energy audits are a suitable method for growers to gain an understanding of energy costs and opportunities for practical energy savings.

Infotech Research conducted 22 energy audits of vegetable growers around Australia, as part of project VG13054***- Economic evaluation of farms energy audits and benchmarking of energy use on vegetable farms***. Through this project we found that these audits best assisted medium sized growers with farms and packing sheds in improving their business profitability through energy saving measures. The best returns on investment are achieved through prevention of energy losses (waste losses) followed by energy efficiency improvements.

Small and large growers need a different emphasis on energy management. The former require practical guidance while the latter need more detailed investigations of processes to gain an understanding of the best actions for energy savings.

A focal point of this project was dissemination of information and cost saving opportunities revealed by the audits. Infotech Research produced five case studies and presented at seven grower forums to discuss the audit program, benchmarking results and key opportunities for energy efficiency improvement. We also produced a set of 74 energy saving opportunities for growers that will be distributed via the Ausveg Infoveg web pages. Of the 74 improvement opportunities, 69 were costed as being of interest to a majority of growers. Simple loss reduction measures were found for most growers and process efficiency measures yielded potential savings from 10% to 40% of current electrical energy demand.

Infotech Research produced a benchmarking report (Appendix 1) and options analysis to assist growers to evaluate their own energy consumption. Benchmarking of energy efficiency for growers was not directly comparable from one grower to another due to the wide variety of circumstances of individual growers. The benchmarking can be best put into use by individual growers benchmarking their own performance and being able to measure improvement with time.

It was also possible to measure technology or process efficiency, for instance chiller efficiency and then put this against best practice to be able to gauge improvement opportunity. Theoretical energy use can also be used to measure improvement opportunity, as in the case of vegetable cooling, to see how much thermal loss is occurring. Pumping costs for irrigation was undertaken as a practically useful measure of efficiency that is comparable between growers.

In the context of increasing grower competition in an international market place, energy management is an element that can benefit from a measurement of energy efficiency and process modelling that an energy audit can provide. This study of 22 growers produced energy saving opportunities totalling 6,196 GJ per year with a value of approximately $400,000 p.a.

Keywords

kJ	Kilojoule (10^3 Joule)
MJ	Megajoule (10^6 Joule)
GJ	Gigajoule (10^9 Joule)
kW	Kilowatt (power)
kWh	Kilowatt hour (energy)
VSD	Variable speed drive
kL	Kilo Litre (10^3 Litre)
ML	Mega Litre (10^6 Litre)
GHG	Greenhouse gas
LPG	Liquified Petroleum Gas
COP	Coefficient of Performance (refrigeration systems)

Introduction

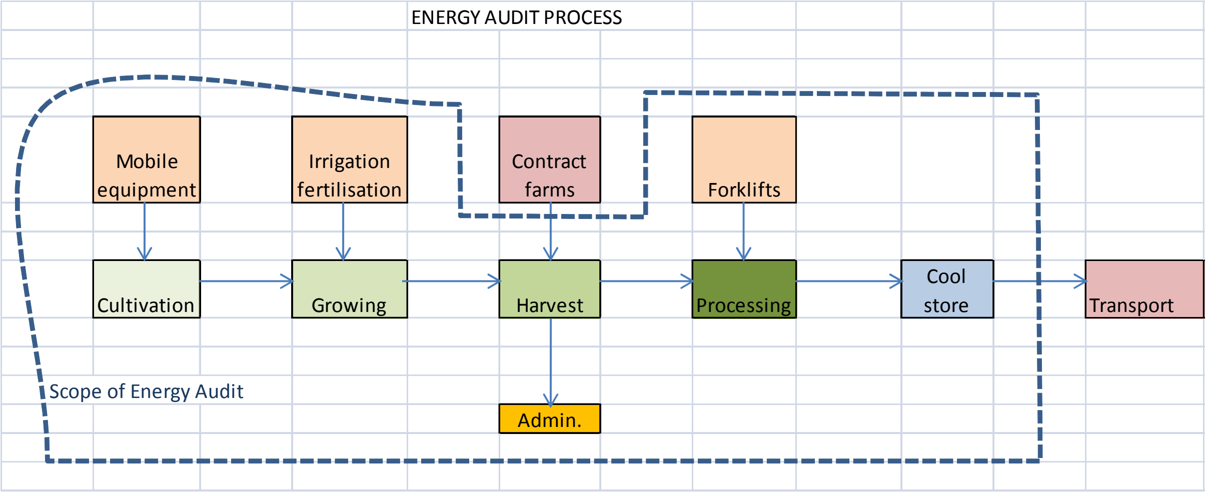
Infotech Research was engaged by Horticulture Innovation Australia (HIA) to complete project VG13054- ***Economic evaluation of on-farm energy audits and benchmarking of energy use on vegetable farms***. The aims of the project were to identify energy efficiency improvement opportunities for individual growers and the wider grower industry through the energy audits, as well as benchmark energy consumption of growers. The findings were then to be disseminated to growers through forums and published articles.

This project followed others that have looked at on-farm energy generation (VG13051) and biogas production from farm wastes (VG13049). It has complemented the environmental management initiatives of the vegetable growing industry.

Funding was gained for this project from the National Vegetable Growers Levy with matched funds from the Australian Government through Horticulture Innovation Australia Limited (HIA; previously Horticulture Australia Limited).

Methodology

The audits were limited to the activities performed on the farms and packing sheds and did not include transport from the farms or supply of vegetables from contract growers.



Twenty two representative growers were chosen from the industry of more than 8,000 growers with the objectives of covering the the major growing regions in Australia: Gin Gin, Myalup, Virginia, Melbourne, East Gippsland, Cowra, Bathurst, Sydney, Lockyer and Fassifern Valleys and Bundaberg. A preference was given to those who use larger amounts of energy. Of the 22 sampled only three had less than 100 Ha under cultivation (two of these had green house operations). Consequently the majority of small growers are not represented in this study, which is focussed on medium and large growers with processing plants.

Energy demand was modelled for the activities undertaken by growers using a survey of equipment and measurements of energy consumption when processes were active. Water flow measurement was undertaken to enable the estimation of irrigation efficiencies when irrigation systems were active.

For each audit a set of Key Performance Indicators was measured over the major sources of energy being diesel fuel, electricity and LPG. ULP was used by some growers in utes and quad bikes. There was no recorded use of natural gas by the growers audited.

Data has been compiled for the main energy consuming activities for each grower and this data has been used to show the variation of performance for the 22 growers audited.

Benchmarks were measured as energy consumption relative to outputs, or the size of the farm, cool store, or crop being irrigated.

Highlights of the consolidated data were compiled in the benchmarking report and opportunities for improvement were also consolidated in a reference list for use by the whole industry.

PROJECT OUTPUTS

1.Audits

Infotech Research has completed 22 energy audits for growers in Tasmania, Victoria, Queensland, New South Wales, Western Australia and South Australia.

The audits were conducted on site to the Australian Standard AS/NZS 3598:2000 for Level 2 energy audits. Those growers who participated were provided with reports detailing their significant on farm energy costs, energy consumption models and a list of costed opportunities to reduce energy consumption.

2.Case Studies

Five case studies (Appendix 2) have been developed that illustrate some of the major findings of the energy audits. These case studies cover topic such as efficient cool store systems, the use of electric forklifts, irrigation pumping, a combination of energy saving initiatives at Invankovich Farms in WA and a general article on the benefits of farm energy management.

These articles have been submitted to Ausveg for consideration of publication on its web pages with pointers from articles provided in *Vegetables Australia* magazine.

3.Benchmarking Report

The benchmarking report was submitted to HIA initially on August 8 and subsequently on September 15, 2014 after data from the full 22 energy audits was finalised. This report provides a set of energy metrics for growers in relative terms to production. Benchmarks were drawn from the key operations of irrigation pumping and cool stores.

4.Grower Forums

Infotech Research presented at two Ausveg EnviroVeg/Biosecurity Workshops on:

- Wednesday 27 August, Virginia, South Australia
- Tuesday 2 September, Cranbourne, Victoria

A further five grower forums were presented at in collaboration with Applied Horticultural Research, who were also undertaking an on-farm energy generation project for HIA. These forums occurred on:

- Thursday 25 September, Cranbourne, Victoria
- Tuesday 30 September, Bundaberg, Queensland
- Wednesday 1 October, Gatton, Queensland
- Thursday 9 October , Madeley, Western Australia
- Thursday 20 November, Devonport, Tasmania

The presentations included details of the audit program, benchmarking results and key opportunities for energy efficiency improvement.

Infotech Research has a video of its presentation at the Gatton forum. This is outside the requirements of the project but will be provided for consideration of inclusion on suitable grower associated websites. An enquiry has also been sent to the ABC Television program ***Landline*** regarding an opportunity to report on some of the grower energy saving outcomes.

5.Grower Energy Efficiency Opportunities Information System

Results of the energy audits included a list of energy saving opportunities for vegetable growers. This list was drawn from the audits and compiled in a standard format giving energy savings, dollar savings and simple payback period (or return on investment calculated from the capital expense divided by the net annual dollar savings).

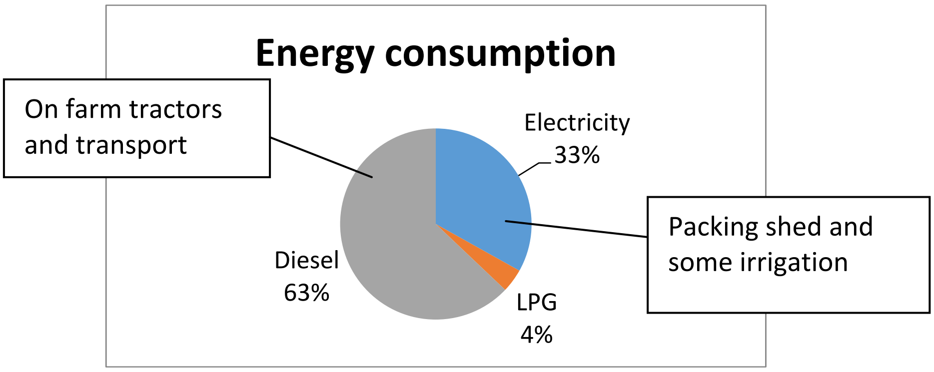
A total of 74 opportunities have been listed that may have application for a significant population of growers. 69 opportunities for energy savings have been costed with savings and payback periods calculated.

These opportunities have been established as a spreadsheet for growers with instructions for use. This has been split into processes for easier access and all of the sheets have a section for grower entry of their own energy costs. When growers enter this data the savings and payback periods are recalculated.

The opportunities spreadsheet for growers will be distributed via the Ausveg Infoveg web pages. A “Top Dozen” opportunities has also been compiled by Ausveg personnel into a fact sheet to be sent out to growers.

Outcomes

1. **Energy is of increasing importance as**
    - A cost centre (2-5% of overhead costs to a grower business)
    - The major contributor to Carbon emissions by the business
    - An important element of environmental management for growers



2. **Diesel and electricity are the major energy sources used**
3. **Renewable energy sources**
    - 3 of 22 growers (all in WA) had installed PV panel systems
    - 1 of 22 growers used energy storage (in WA)
4. **Electricity charges varied from 9 to 44c per kWh consumption**
    - Demand charges were additional in Eastern States
    - Average charge 25c/kWh ($69.40/GJ)

- Electricity costs have an uncertain future as renewable energy become cheaper and government subsidies vary for renewable energy installations

5. **Diesel and LPG charges were simpler (Diesel averaged $1.40/L, $36.30/GJ)**
6. **Energy audit outcomes**
    - Provided on average 15 opportunities for energy savings
    - Provided a total of 69 costed opportunities for grower energy savings and a further 5 uncosted opportunities
    - Generally opportunities added up to a reduction in energy demand of ~15% of consumption
    - Payback periods of <3 years were common in opportunities costed (internal rate of return ~ 30% +)
    - Expected commercial energy audit cost was expected to be in the range of $5,000 to $20,000 (dependent on the size and complexity of the business audited)

Grower Energy Saving opportunities

A. Reduce energy losses (and wastes carrying energy)

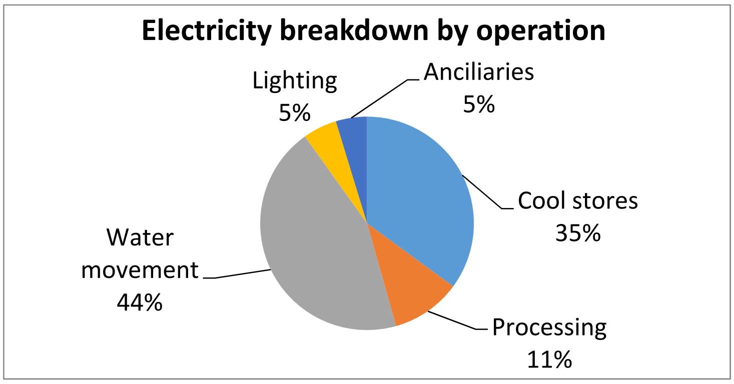
a) Better insulation of cool stores
b) Insulation of cooling systems (chillers, flumes, hydro-coolers...)
c) Reduce the effects of solar heating
d) Reduce evaporation of water from irrigation systems
e) Reduce run off from irrigation
f) Reduce idling plant and equipment (esp. during breaks)
g) Lights off when not needed
h) Stop cool room fans when doors opened
i) Reduce restrictions in irrigation mains (build-up of sand and algae)

B. Improve energy use efficiency

a) Chiller efficiencies (COP from 0.7 up to 4, VSD controls)
b) Pumps efficiency maximised
c) Pump diesel to electric conversion (plus the addition of VSDs to accommodate duty cycles)
d) Irrigation systems conversion to low pressure (guns >> fixed, boom>>pivot, spray>>drip)
e) Belt drives to direct drives
f) Forklifts to conveyors / flumes (diesel/LPG to electric forklifts)

C. Secure the cheapest reliable energy supplies

a) PV panels
b) Grid electricity
c) Wind
d) Batteries / Fuel cells / Gen sets
e) Fuel storage
f) Water storage
g) Pre-cooling over night (temperature cycling of cool stores)



   - h) Ice, brine and glycol cooling storage systems

D. Establish Energy Management Systems

   - a) Control and secure energy supplies
   - b) Establish targets for energy efficiency
   - c) Monitor cost and efficiency in major areas of consumption

Grower information needs

1. Evaluation of current technology efficiencies and the need to improve (particularly measurement of cooling systems and pumps)
2. Awareness of energy saving options
3. Best practice for grower operations
4. Energy supply options (with costs)

Grower communications

1. Q&A leading to decisions about the business case for system improvements
2. Examples of improvements in published articles (magazines and web)
3. Forums and interest groups
4. Video and audio / smart phone apps

Evaluation and Discussion

The primary observation from 22 grower energy audits was that a good potential for energy savings, through relatively simple measures, existed. Awareness of the costs of the various energy sources and the benefits of implementing specific improvements was critical to growers being able to evaluate opportunities in their individual operating situations. The energy efficiency performance of growers was found to vary widely but was dependent on the position and nature of the operations conducted, consequently direct comparison was of little value.

Level 2 energy audits include a review of energy consumption across operations and modelling of energy demand by each process, leading to the ability to define the costs and benefits of energy saving opportunities. This level of audit is particularly well suited to medium sized vegetable growers who have the means to evaluate opportunities for improvement. A key aspect of improvement programs is to gain the maximum result for effort and this requires focussing on the big energy users. For electrical energy consumption it was clear that these were cooling and irrigation processes for most vegetable growers.

Smaller growers and the very large growers may not benefit as much from energy audits due to differing management needs. The smaller growers do not have the time to plan out improvements and need a quick guide to what is best practice at their size of business. Large growers are generally more complex and have large investment in operating technologies, so improvements need to be carefully examined with a more in-depth analysis.

The energy audits were better able to handle electrical energy use than the use of fuels in mobile equipment for which the outputs could not be so easily measured. Tractor and other mobile equipment efficiencies can be measured by logging fuel use over time with operations. This was beyond the capacity of the audits at level 2 and would be a possible function of a more detailed level 3 audit.

The systems of communication with growers that were undertaken could not be evaluated in the time frame of the project. Evaluation of the uptake of opportunities identified during the audits was also not possible as this may occur over years.

Recommendations and areas for further investigation

The promotion of energy audits and the development of energy efficiency targets for growers are beneficial for the industry. The level of technology applicable for growers varies and so a broad range of energy efficiency information is required.

Suggested energy information channels:

1. Embed energy management further into the EnviroVeg program
2. Develop industry technology benchmarking to enable individual growers to evaluate performance (look at using technology benchmarking as well as energy performance)
3. Establish case studies of specific energy efficiency improvements at growers
4. Provide a process for growers to use to measure pump and chiller efficiencies independent of technology suppliers
5. Provide growers with options for government assistance for energy efficiency improvement (such as the Direct Action Carbon Abatement program)

Financial assistance for the implementation of key grower technology improvements with outcomes monitored and reported may enable other growers to more carefully evaluate these improvements for their own businesses.

Opportunities identified that could be considered for implementation evaluation include:

- Solar powered bore pumps
- Low pressure irrigation systems
- VSD application to chillers, condenser fans and evaporator fans
- Cool store insulation improvements (floor insulation and doorway air curtains).

Publications arising

No scientific publications are expected to be written as the nature of this project was not research but rather the measurement of process energy consumption.

One article on the grower, 4 Ways Fresh, from Virginia, SA has appeared to date in ***Vegetables Australia*** (November / December 2014 pp34-35) on the outcomes of their energy audit.

IP / Commercialisation

Similarly no commercialisable outcomes have been produced by this project.

If you would like further information on the above or any other aspect of the project, please contact John Cumming, Director of Infotech Research, on 0418 125 688 or email John at john@infotechresearch.org

Appendix 1 – Energy Audit Benchmarking Report

Economic evaluation of farm energy audits and benchmarking of energy use on vegetable farms

Project VG13054

Benchmarking Report

Prepared by INFOTECH RESEARCH

Updated September 15, 2014

1. Summary

The benchmarking data has been gathered from a series of 22 energy audits conducted on vegetable grower farms between February and August 2014. The audits gathered energy consumption and energy demand data for grower operations and then modelled the energy use between various operations on farm and in the packing shed.

The data relates to only 22 grower operations that range from 10’s to 1,000’s of hectares in size and, as such, it cannot be extrapolated to represent the industry as a whole.

Key findings are that the growers are very conscious of the rising cost of energy and the impact this has on the bottom line of their businesses. The actual cost as a percentage of overall business costs was not canvassed, however, sales figures indicated that energy costs represented 1 to 4% of sales in most cases.

The cost of energy is split between electricity and diesel at a 1:2 ratio, with the carbon emissions weighted toward electricity. After mobile plant diesel use, the major energy consuming activities were found to be refrigeration and irrigation systems.

There was significant variation in key energy consumption benchmarks that related more to the crops processed than the size of the operations, although energy overheads are a higher percentage of the total for smaller growers.

Growers audited were investing in new and more efficient plant and equipment, which will save energy by reducing process wastes. Three growers of the 22 had, or were in the process of installing, industrial sized PV panel systems for solar energy production.

The growers have not as yet invested in energy management and, although aware of the cost of energy, most did not measure their energy consumption or have targets for energy efficiency and cost reduction.

New energy efficient technologies were being installed, such as LED lighting, but none of the growers produced an analysis of the outcomes for such investments.

There is large variation in energy efficiency across all aspects of grower operations and therefore opportunities for those with high energy consumption to reduce this and improve business viability.

Details are provided in this report as well as the raw data.

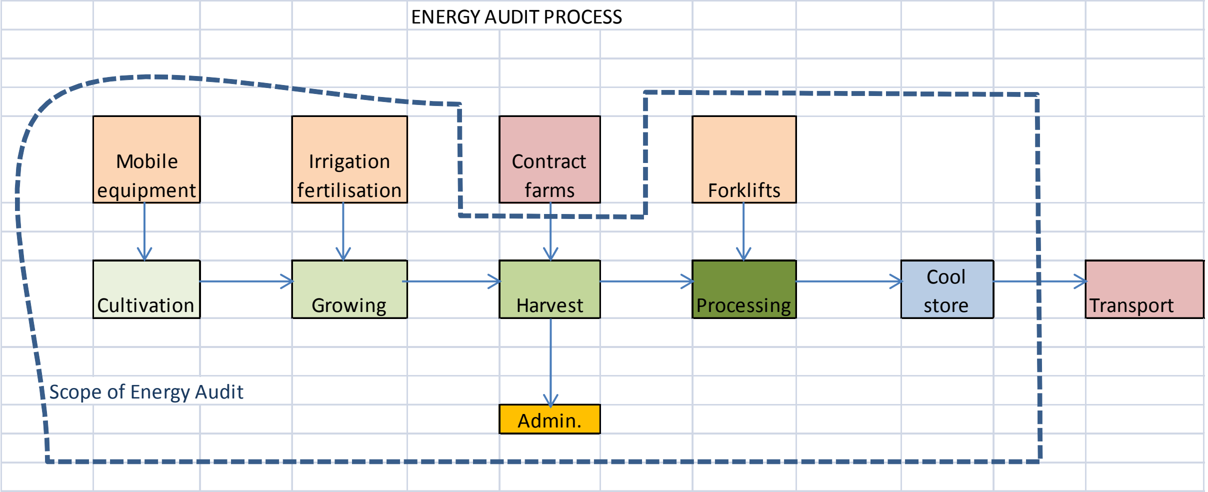
Contents

2. Introduction and method

Energy is a growing issue for the vegetable growers in Australia with energy costs practically doubling over the last decade in most areas. This has caused growers to look more closely at their energy consumption and energy audits are seen as a means of examining consumption and identifying areas of efficiency improvement.

This study, to conduct 20 Energy audits to Australian Standard AS/NZS 3598:2000, was funded by Horticulture Australia Limited (HAL) using the National Vegetable Levy and matched funds from the Australian Government. Audits were conducted for vegetable growers in nine of the major vegetable growing regions of Australia. It follows on from a number of initiatives in the environmental area supported by HAL.

The audits were limited to the activities performed on the farms and packing sheds and did not include transport from the farms or supply of vegetables from contract growers.



The energy demand was modelled for the activities undertaken by growers using a survey of equipment and measurements of energy consumption when processes were active. Water flow measurement was undertaken to enable the estimation of irrigation efficiencies when irrigation systems were active.

The results of these audits are presented in summary in this report without identifying individual growers or particular operations. As crops vary and the volume of growing and processing will affect energy consumption, the data has been put in relative terms. Energy consumption has been measured as a function of production, or land area.

For each audit a set of Key Performance Indicators was measured over the major sources of energy being diesel fuel, electricity and LPG. ULP was used by some growers in utes and quad bikes. There was no recorded use of natural gas by the growers audited.

Data has been compiled for the main energy consuming activities for each grower and this data has been used to show the variation of performance for the 22 growers audited.

Variables

The audit presents a snapshot of performance that is then checked against energy consumption data over a year or more. The activities change by season and estimates had to be used when activities were not in progress.

Estimates were enhanced by grower comments and their own estimates of the time of equipment use. However, high levels of uncertainty result from these estimates.

Key uncertainties:

- time of use of equipment (such as the percentage of time a refrigeration compressor is on),
- variation in the load on equipment (such as variations in soil conditions and tractor travel resistance),
- ambient temperature variation (leading to changes in produce cooling requirements),
- production process variation and
- product variation (a tonne of carrots is more readily harvested than a tonne of lettuce).

Typically the audit model was adjusted to be within 15% of the actual energy demand, but often multiple uses of an energy source, such as diesel used in pumps and generator sets as well as tractors, caused greater uncertainty in energy source allocation.

The sample

Twenty representative growers were chosen from the industry of more than 8,000 growers with the objectives of covering the nine major growing regions in Australia, with a preference to those who use larger amounts of energy. Of the 20 sampled only two had less than 100 Ha under cultivation. Consequently the majority of small growers are not represented in this study, which is focussed on medium and large growers with processing plants. There were two farm-only audits where the growers did not have processing facilities and there were two audits conducted exclusively on the processing facilities, due to seasonal restrictions.

Growers audited produced the following crops:

- Onions
- Carrots
- Broccoli
- Lettuces
- Sweet corn
- Pumpkins
- Beetroot
- Leeks
- Capsicum
- Eggplant
- Cabbage
- Silver beet and Spinach

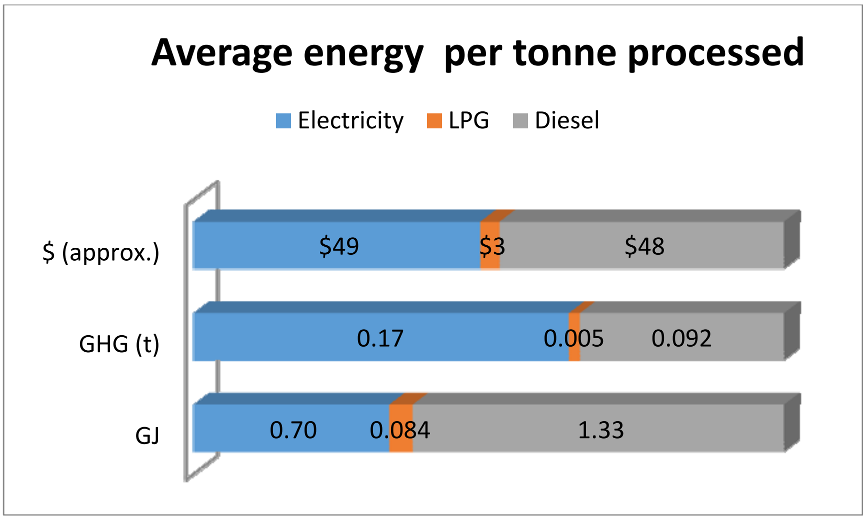
And a range of smaller volume vegetables.

3. Results

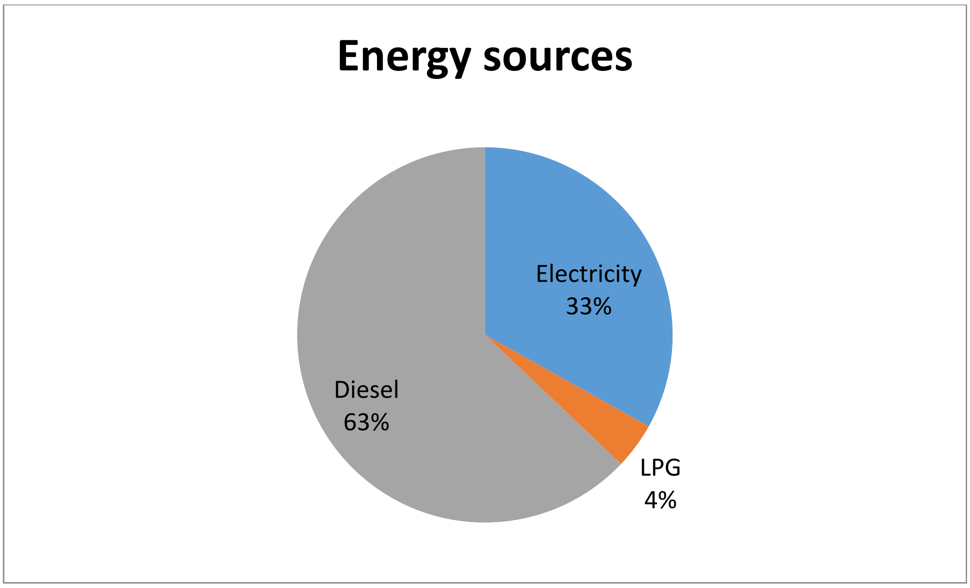
In order to compare energy consumption and benchmark performance relative measures needed to be used. In the proceeding analysis a variety of measures related to level of activities were used, from production in tonne and area under cultivation, to volume of cool rooms for refrigeration efficiency comparisons.

1.Total energy consumption

Energy consumption was averaged[1] over the audited growers, giving a mean energy consumption of 2.1 GJ at a cost of $100 per tonne of processed vegetables. Greenhouse (carbon) emissions averaged 270 kg from energy consumed per tonne of product.



Diesel was the highest energy source at 63% on average of the total energy demand. Electricity contributed 33% of energy demand, but was responsible for 63% of the Greenhouse emissions. LPG was used by most growers in forklifts and was a minor source of energy at 4%.



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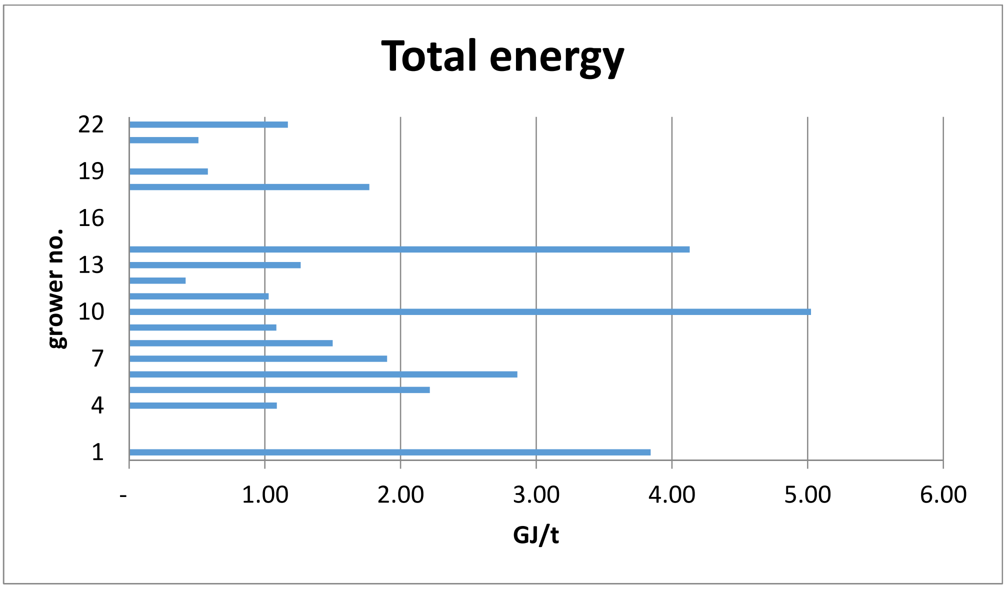
[1] Averages were calculated as the total divided by the number of samples

Total energy consumed per tonne of product was calculated for the growers where possible and showed a significant variation between individual growers. The lower figures may account for the processing of contractor produce being a significant percentage of the total processing, in which case the on-farm energy use was not counted.



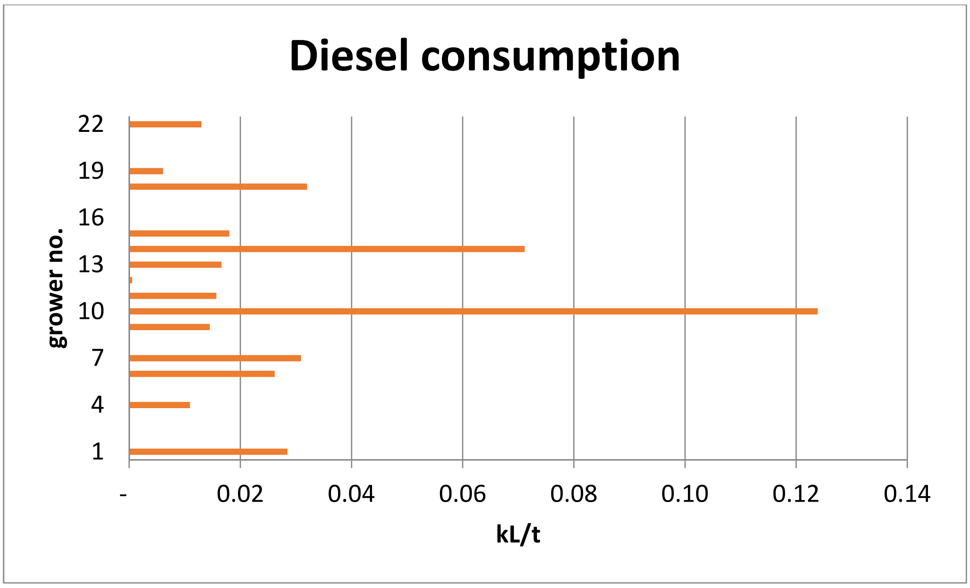
The split of energy between the farm and processing operations is skewed by the processing of contractor produce, which is undertaken by a majority of the growers audited. The other factor of concern in comparing total energy consumption per tonne is the amount of processing undertaken.

For these reasons there is no established benchmark for the growers to aim at, in terms of total energy in GJ per tonne, other than to use their own performance as a baseline for targeted improvement.

1a) Diesel fuel

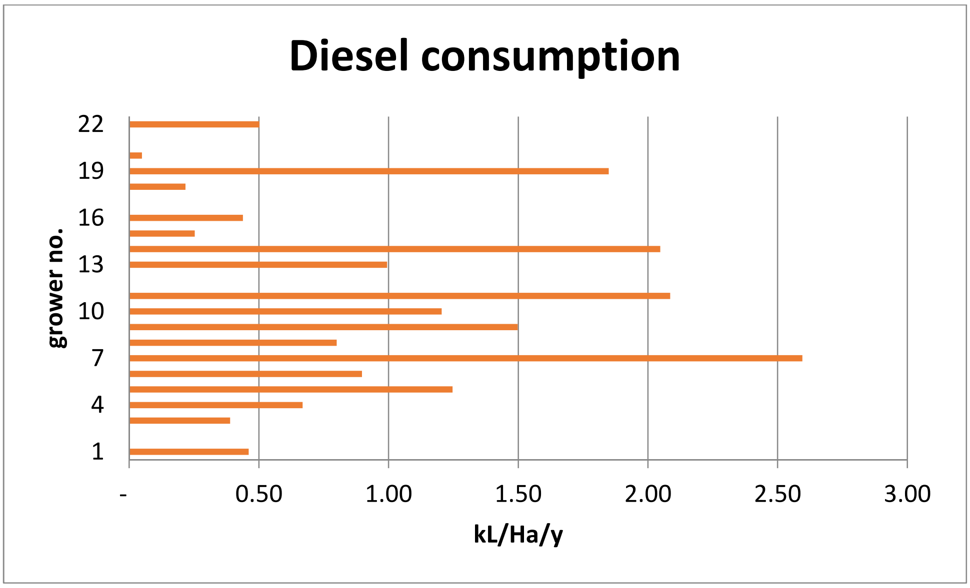
Diesel fuel was used in the main for on farm plant – tractors, harvesters, sprayers, graders etc. Most of the growers also run a fleet of trucks to take product to market. They may also use diesel to fuel irrigation pumps and to fuel generator sets.

Diesel consumption was determined per tonne of production. Diesel use averaged 34 L per tonne, but this was again skewed by two growers using 71 and 120 L/t.



The high diesel use growers were also using diesel for irrigation pumps, but the percentage could not be determined. If diesel use for irrigation is discounted the majority of growers used between 15 and 25 L/tonne.

Another measure of diesel use is consumption per unit area under cultivation. This was provided for the total farm area as the actual area under cultivation was not certain in most cases.



This may be a better measure of diesel usage efficiency as the outliers are less prominent. Good performance may be between 400 and 1000 L/Ha/y. Again the measure of diesel use may be skewed by a number of factors including the type of crops sewn and the condition of the soils.

Growers planning to use diesel consumption as an efficiency measure need to be able to segregate its uses and quantify them.

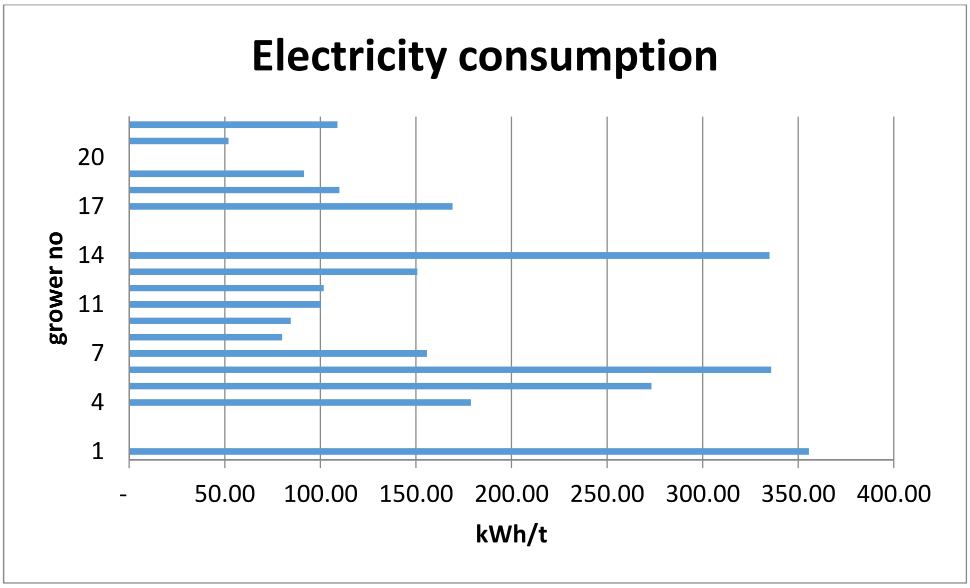
Due to an inability to measure fuel consumption rates for most of the diesel powered equipment it was not possible to establish process efficiencies for diesel powered pumps.

1b. Electricity

The uses for electrical energy are many and varied, but the predominant uses can be classified as processing and water movement (pumping). All of the growers audited used electrical energy for irrigation and most then used electricity as the major source of energy for processing. It could then be expected that production could prove a useful basis for efficiency measurement.

As some of the growers did not measure production in tonne, this comparison was not possible for them.

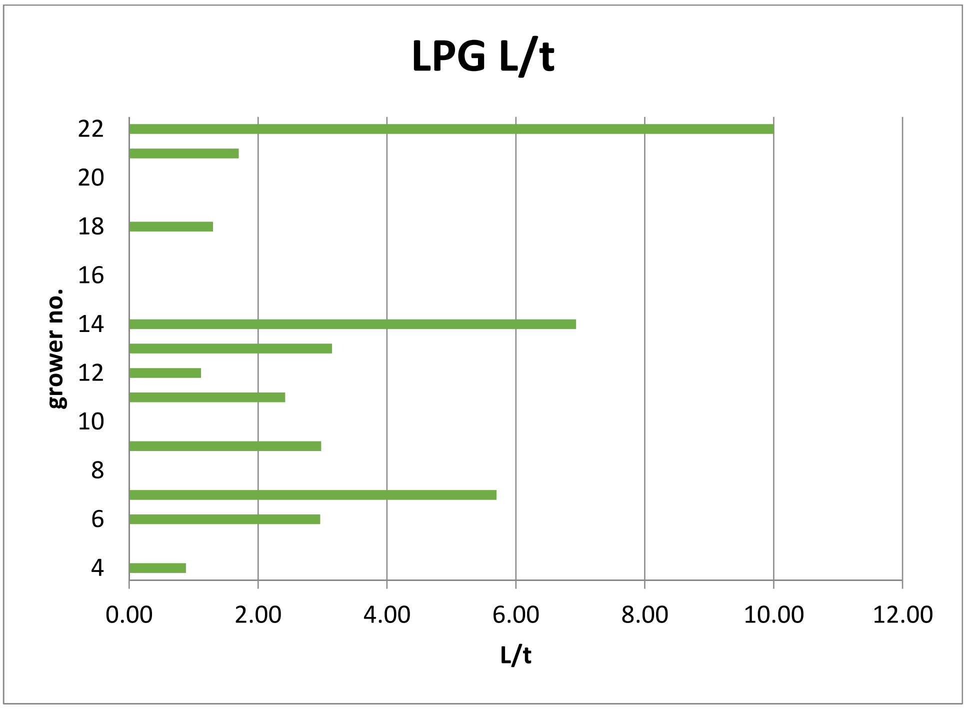
A high level of variability was observed for electrical energy consumption efficiency, with a band of growers using approximately 100 kWh/t of finished product; another band of growers at 150 kWh/t; and four growers from 270 to 350 kWh/t. Growers in the latter grouping have either more complex processing operations or smaller operations with a higher energy overhead.



With certain exceptions there is a reasonable efficiency target for growers with processing operations to target an electrical energy efficiency of 100 kWh/t or less.

1c. LPG

LPG (liquefied petroleum gas) is the most used fuel for forklift operations by growers and, with one exception, LPG was only used for on-site forklifts. Therefore, it is expected that LPG consumption should be proportional to production, as it is a measure of forklift travel distance.



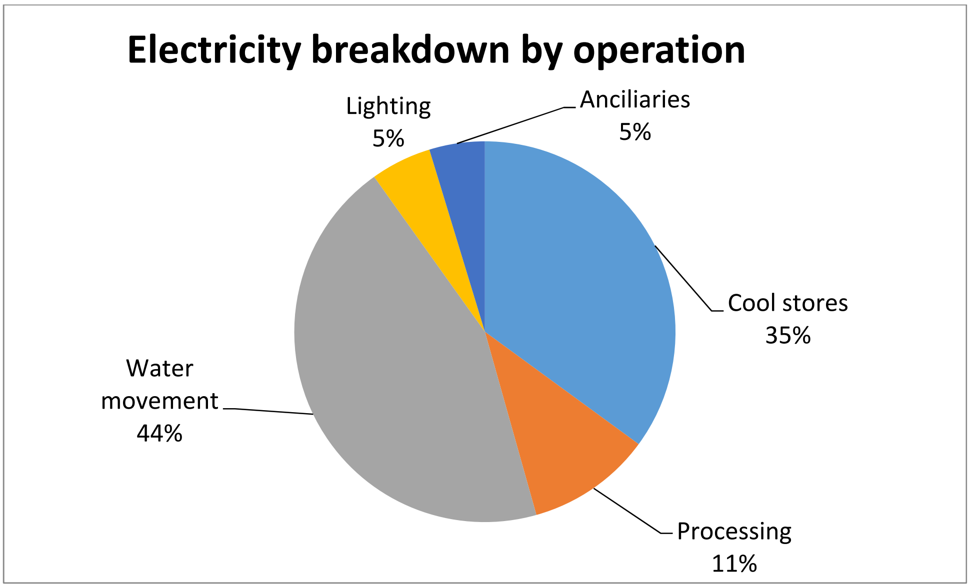
To some degree the use of forklifts can be reduced by conveying product rather than using a forklift. This effect is considered responsible for some of the variation observed. Another factor is the layout of the processing facility and the distance that product has to be transported to storages from the processing line.

In any case the good performers are using 1 to 2 L of LPG per tonne and the worst 6 to 7 L/t.

Some of the growers have moved to electric forklifts (and one was noted to use diesel forklifts) in which case this analysis does not apply.

4. 2. Consumption of energy by operation

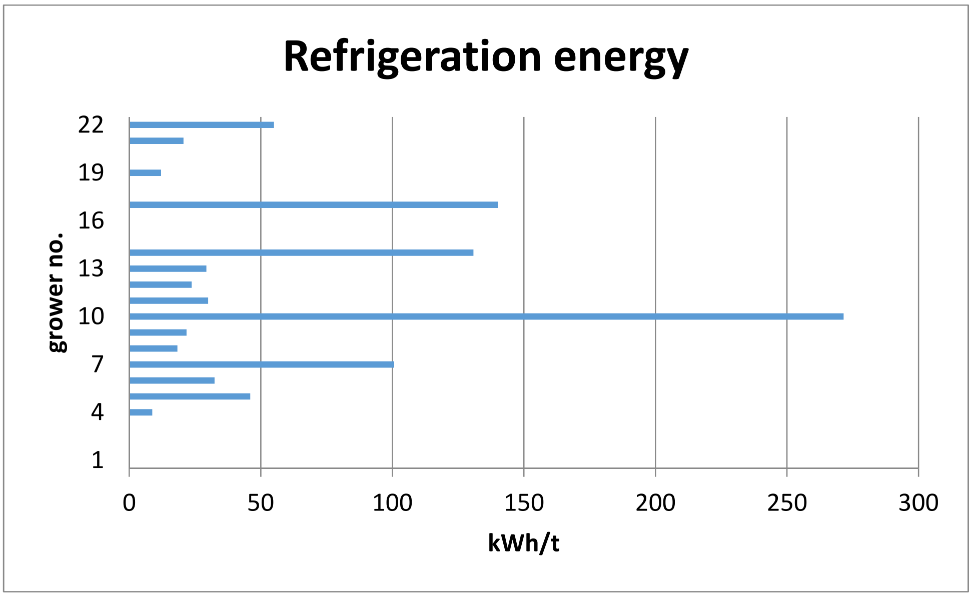
The electrical energy demand models produced indicated that there were two major operations using electrical energy that could be examined for efficiency: cool stores and irrigation pumps. An approximate breakdown of electrical energy demand was calculated.



It should be noted that the largest consumers of electricity are not necessarily those with the highest instantaneous demand. Both cool stores and irrigation pumping use a relatively large amount of energy due to the long times of use. The cool stores run continuously and irrigation pumps run over long periods, while the processing plant may only run for 40 to 60 hours per week.

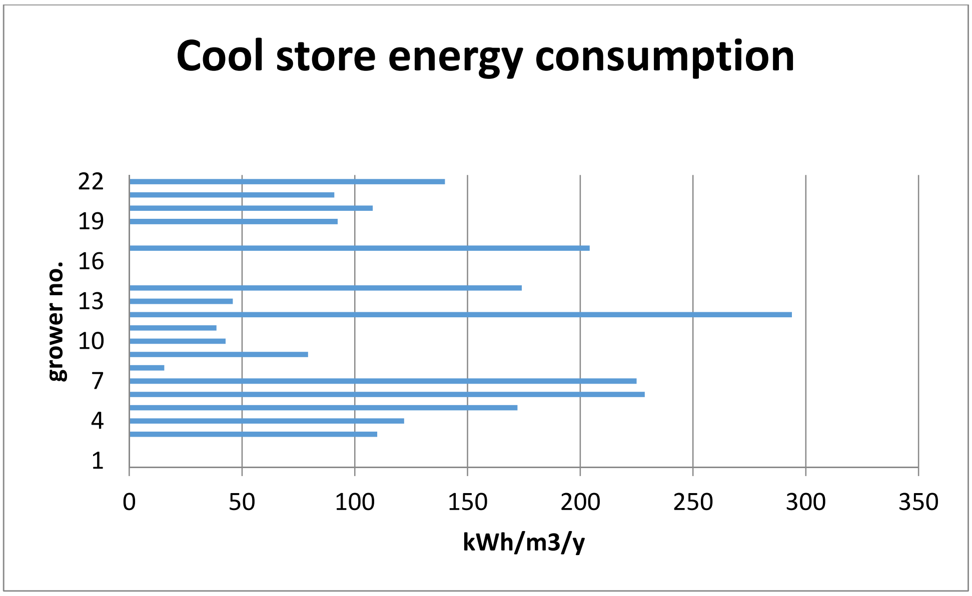
2a. Cool stores

The cool stores were analysed through the electrical energy demand model predictions of total energy used. This was then related to production through the processing facility for each grower.

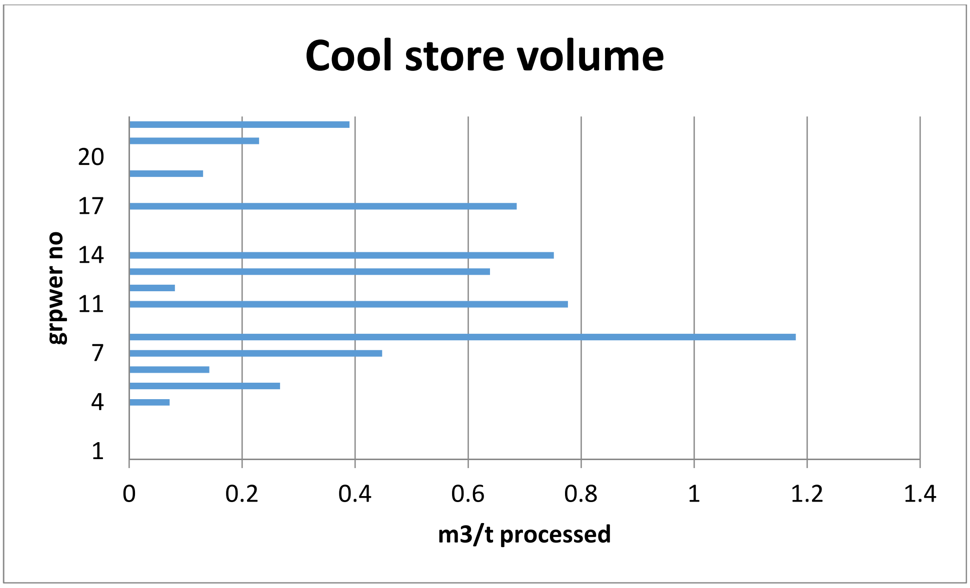


Refrigeration energy is dependent on the processing conditions and the high usage outlier had special processing conditions leading to a high value. The type of crop also has a large impact on the refrigeration requirement and should be considered in interpreting these results.

Good performance for most vegetables may be less than 50 kWh/t used in refrigeration, the average was 72 kWh/t, but this depends on the crop and processing requirements.



The efficiency of the cool stores themselves was measured as the energy used per m^3 of cool store space. Again this showed a wide variation from one grower to another, varying from 39 to 294 kWh/m^3 of space. This measure may be an indicator of cool store efficiency that is affected by the structure and refrigeration system efficiency. It may also be impacted by the volume of goods going through the cool store on a per m^3 basis. It was noted that the grower with the highest rating of cool store energy per m^3 had the lowest m^3 per tonne value.



It makes sense that the growers should aim to have the lowest cool room volume per tonne of product possible and this varied by a factor of ten from 0.072 to 0.78 m^3/t. Storage time is a critical factor in this measure and this needs to be balanced against production capacity and market demands.

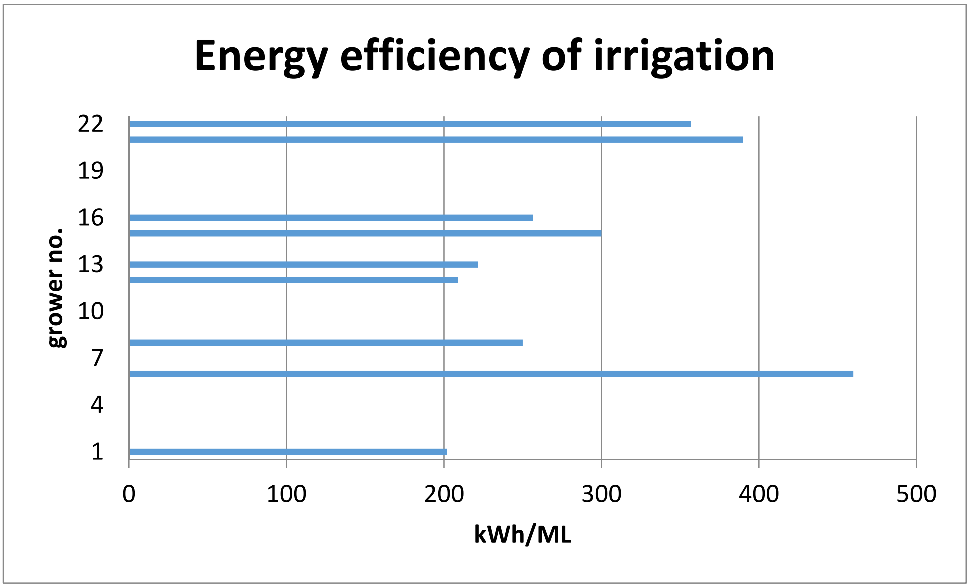
2b. Irrigation pumping

The energy needed to irrigate crops is dependent on factors that may be outside the grower's sphere of control, such as the head and distance required to be pumped between the water source and the field to be irrigated. Energy required also depends on the type of irrigation, from high pressure spray systems to low pressure drip and flood irrigation systems.

The grower also needs to balance the energy and cost of water delivery with the volume needed, which will also depend on a range of factors that include the crop type and climatic conditions.

This study measured flow rates where possible and matched energy demand to the flow to work out the energy per ML pumped. This was then converted to cost per ML and checked against metered data where possible. In some cases it was possible to measure pump efficiencies from flow and pressure measurements (or system dynamic head calculations). The method provided by the NSW Department of Agriculture (Smith, 2003) was used for pump efficiency calculations.

Energy consumption per ML of water pumped was measured only from dam or river to the field. There can be an additional cost to the grower of pumping either bore water or irrigation channel water to the dam concerned.

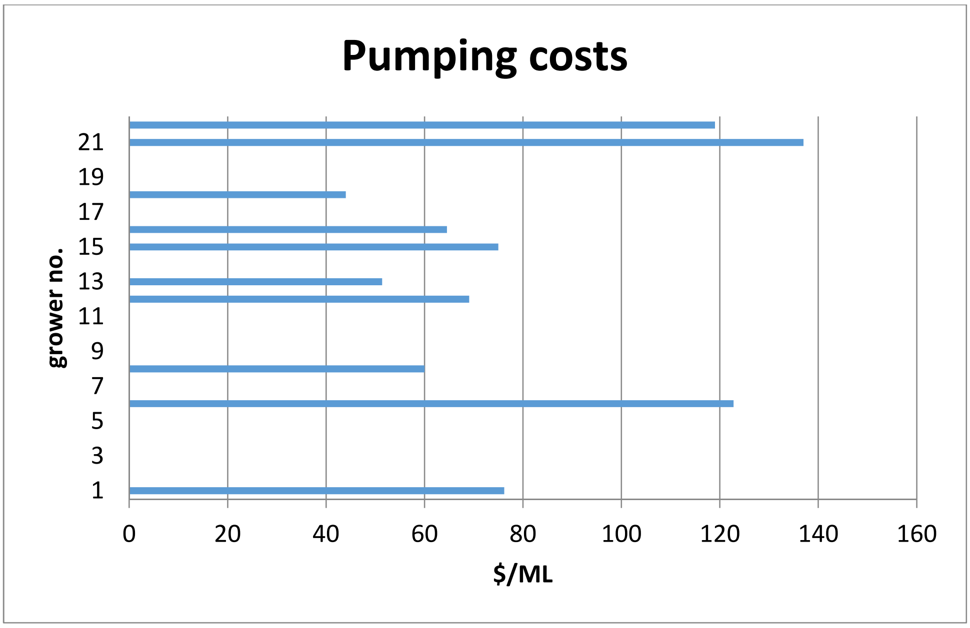


Irrigation from dam/river to field + one from bore to field

This measurement was only possible for growers who had pumps operating during the audit inspection. It also required the ultrasonic meter to function adequately.

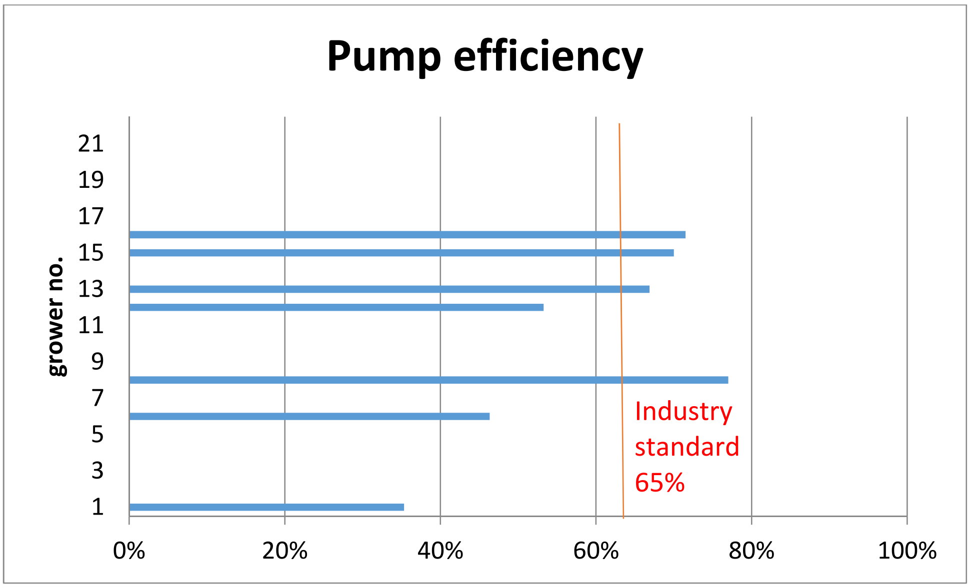
This data was averaged over a number of irrigation sets for the particular growers covered. It could be concluded from the individual grower's measurements that the type of irrigation system had a large impact on the energy required. Low pressure systems such as drip tape were less energy intensive per ML than the high pressure traveller irrigators, with booms and pivots in the middle of energy efficiency.

There is significant room for energy efficiency improvement over the results produced for the five growers. This can be achieved with a combination of improved pumping systems and choice of irrigation systems.



The pumping costs mirrored the energy usage with some modification due to the local cost of electricity. This cost needs to have the cost of bore pumps, or pumping to dams added to gain the full energy cost of water delivery.

Measurement of the actual efficiency of the pumps was undertaken where the pressure at the pump was metered. This value is the percentage of energy delivered to the pump that finds its way into the water outflow.



This set of measurements show a variation in pump efficiency averages for growers from 35 to 72%. At 35% twice the energy is required to pump the same amount of water as at 70% efficiency. The pump efficiency measurement can show growers where they can improve pumping. This may be a case of maintaining the pump itself or changing the settings so that it is running at an optimal point on its pump curve.

70% pump efficiency and above is an achievable goal for irrigation pump systems (Grundfoss, 2014).

2c. Lighting

Lighting used an average of 5% of the processing area electrical energy consumption. There were five growers (20%) who had adopted LED lighting for various task oriented operations, three growers had put in complete LED high bay replacement programs and one grower had installed an inductively coupled fluorescent high bay system.

None were using movement or lux activated light switching that is compatible with LED and inductive lighting systems.

5. 3. Efficient Technology adoption

3a. Cool stores

Most of the measurable efficiency measures that could be compared between grower operations related to refrigeration systems and cool store operations. A set of options for energy saving were identified and grower adoption was recorded.

Grower	Rapid rise curtains	VSDs	Air curtains	Temperature cycling	Energy recovery / storage	Floor insulation	Sun reflection	Delivery truck sealing
1							yes	
2							yes	
3								
4								
5					yes			
6								
7							yes	
8								
9								yes
10	yes			yes		yes		yes
11	yes	yes					yes	
12								yes
13								
14								
15								
16								
17	yes							yes
18								
19	yes							
20	yes	yes					yes	yes
21							yes	
22							yes	

Generally the adoption of cool room efficiency improvement systems is less than 20% for the growers audited. As the major source of energy consumption at the processing facility these opportunities for cool stores can be adopted to improve energy efficiency of operations.

3b. Irrigation pumping systems

Technology options for pump system efficiency improvement are less clear cut than for other processes. Variable speed drives (VSDs) are often put forward as energy saving devices for electric motors driving pumps. Three growers were recorded as having VSDs on irrigation pump motors. The benefit of these VSDs is clear in slowing motor speeds, but this comes at a potential loss of pump efficiency as the pump curve alters and pump efficiency can be reduced.

A common practice in irrigation is to choke the outflow of a pump to increase the pressure at the pump outlet. A gate valve half closed will potentially add several meters of head to the pumping system as well as significant turbulence to the water. This increases the energy required to pump the water and is a sign of a pumping system that has been over specified for the irrigation task.

There is a 60-70% energy saving in electric motor driven pumps to diesel powered pumps, mainly due to the thermal efficiency of the diesel motor at 30-40% while the electric motor has a 90% efficiency. The costs of running a diesel engine are also significantly higher than for an electric motor.

Eight of the audited growers (44%) used diesel pumps as well as electric pumps. This was thought to be due to the high cost of electrical connections to some remote locations on rivers and dams.

3c. Forklifts (LPG / diesel / electric)

A similar argument applies to the choice of energy source for forklifts. Electric forklifts are three times more energy efficient than those that are diesel or LPG fuelled (Warehouse IQ, 2014). Two growers (10%) were identified as using electric forklifts at processing operations. One grower used diesel and the rest (15 growers) used LPG forklifts.

6. Conclusions

It is clear that growers have implemented measures to improve energy efficiency of their operations. A key influence on energy efficiency is process efficiency, which was not within the scope of this report. There was evidence in operations of wastes that had been processed, chilled and then discarded. A reduction in this processed waste is a major opportunity for some of the growers to pursue.

The key areas of potential industry improvement include:

1. Diesel plant efficiency
2. Refrigeration efficiency
3. Cool room energy loss reduction
4. Irrigation pump efficiency
5. Irrigation system design

These areas have the greatest potential for the industry to reduce energy demand, save energy costs and improve the business bottom line.

Care should be taken with the interpretation of the data given in this report as many factors affect the energy efficiency of grower operations and the specific areas of their operations.

7. Appendix – Raw data

	Benchmarks for Grower Energy Efficiencies				**Technology uptake**	
	Activity	Measure	units		Technology	Measure
1	Cultivation	Diesel usage	kL/Ha/year		Fuel management systems	
			kL/Tonne unprocessed		Electric tractors	
		Equipment utilisation	% available hours			
2	Irrigation	Electricity	kWh/ML		Low pressure systems	drip tape
			$/ML		High efficiency pumps	?
		Pump efficiency	%		Evaporation prevention	plastics
		Mains head loss	m/km		VSD technology	
3	Processing	Electricity	kWh/Tonne		Insulation	tank insulation
			kWh/$		Water treatment and recycling	
		Energy overhead	% of costs		Energy demand management	
		Demand utilisation	%		Power factor correction	
		LPG consumption	GJ/tonne		On-farm power generation	
			GJ/m2 (factory)		VSD technology	
4	Cool stores	Electricity	kWh/Tonne		Insulation	Slab, roof, structural
			kWh/m3 of cool stores		Hybrid heating/cooling	
			m3/Tonne		CO2/NH3 systems	
					Refrigerants R??	
					Centralised cooling systems	
					VSD technology	

	Total energy	Electricity	LPG	Diesel usage	
	GJ/t	kWh/t	L/t	kL/Ha/y	kL/t processed
1	3.84	355.58	-	0.46	0.03
2					
3				0.39	
4	1.09	179	0.88	0.67	0.01
5	2.22	273		1.25	
6	2.86	336	2.96	0.90	0.026
7	2.04	156	5.7	2.60	0.031
8	1.5	80		0.8	
9	1.08	85	3.0	1.50	0.014
10	5.03	1226		1.20	0.12
11	1.03	100	2.42	2.1	0.016
12	0.42	102	1.12		0.00053
13	1.26	151	3.15	0.99	0.017
14	4.13	335	6.93	2.0	0.071
15				0.253	0.018
16				0.44	
17		169			
18	1.77	110	1.3	0.217	0.032
19	0.58	91	0	1.85	0.0061
20				0.049	
21	0.51	52	1.7		
22	1.17	109	10	0.502	0.013

	Water /Tonne	Energy efficiency	Pumping costs	Pumping efficiency
	kL/t processed	kWh/ML	$/ML	%
1	137	202	$76	35%
2				
3				
4				
5	0			
6	318	460	$123	46%
7				
8		250	$60	77%
9	0			
10	0			
11	0			
12	21	209	$69	53%
13	0	222	$51	67%
14	0			
15		300	$75	70%
16	0	257	$65	72%
17				
18	386		$44	
19	0			
20				
21	76	390	137	
22	126	357	119	

	Refrigeration energy		
	Product refrigeration energy kWh/t	Cool room consumption kWh/m3/y	Cool room capacity m3/t
1	0		
2			
3		110	
4	8.7	122	0.072
5	46	172	0.27
6	32	229	0.14
7	101	225	0.45
8	18.3	15.5	1.18
9	22	79	
10	272	43	6.35
11	30	39	0.78
12	24	294	0.081
13	29	46	0.64
14	131	174	0.75
15			
16			
17	233	204	1.14
18			
19	12	92	0.13
20		108	
21	20.6	91	0.23
22	55	140	0.39

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Grundfoss. (2014). *Grundfoss pumps irrigation handbook.* Grundfoss.

Smith, A. R. (2003). *How efficient is your pump.* AGFACTS NSW Agriculture.

Warehouse IQ. (2014). *Comparing costs of propane forklifts to electric forklifts.* http://www.warehouseiq.com/electric-forklifts-vs-lp-forklifts-reduce-operating-costs/.

Appendix 2 – Case studies

Case Study 1. Energy is a hot topic

Infotech Research is running a program of energy audits for vegetable growers, funded through Horticulture Australia Limited (HAL) using vegetable levy funds.

The program aims to provide opportunities for growers to check their energy consumption against industry benchmarks and to access opportunities for energy cost savings. If you know where you stand with energy efficiency you can act on the biggest areas for the best savings.

To date the audits indicate that energy has grown in cost to between 2 and 5% of turnover. So a cost saving of 20% in energy will add 4 – 10% to profits (at a 10% profit margin). In other words it is worth looking at!

Where is the energy dollar going? This depends on the grower’s operations, but in general terms 50% goes to diesel for farm use and about 50% of the rest into cool store refrigeration systems. Lighting is generally less than 5% of the electricity demand.

Irrigation can be a big energy drain. It makes sense to maintain pumping systems and ensure that they are suited to the irrigation or water movement application.

Where are the savings? They are usually in a combination of things from the simple to the technical, including:

- setting up switches to turn off everything during production breaks
- insulating cold or hot processes
- looking for natural sources of energy - from skylights, solar heating etc. to PV panels.

Then the more technical:

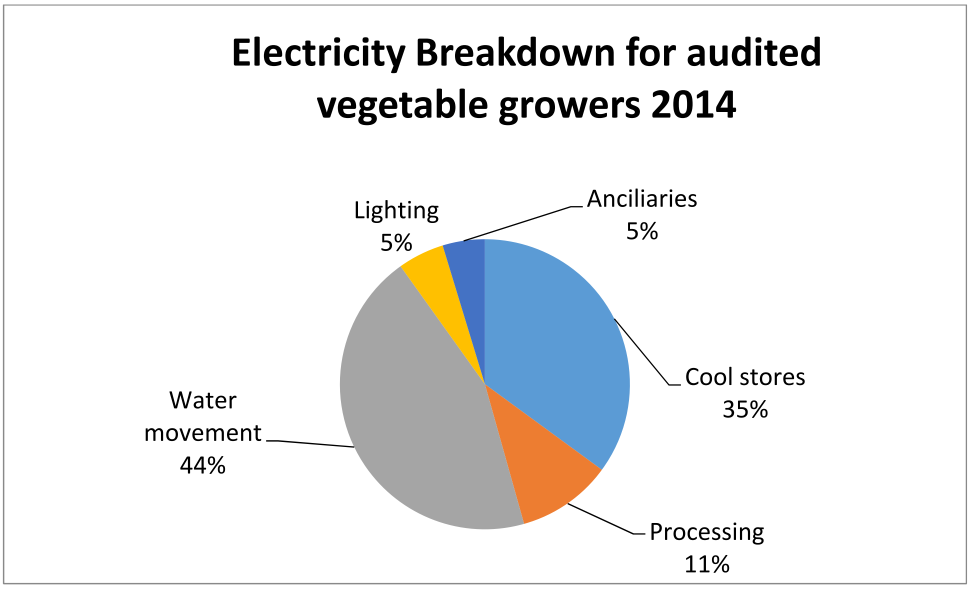
- compressor efficiencies
- air movement within cool stores
- temperature cycling controls
- pump efficiencies etc.

The bottom line on energy is know your efficiency factors, then you can improve them and lower your costs. An energy audit is a good starting point!

If you are interested in audits or energy benchmarking please contact your local Ausveg representative or John Cumming at Infotech Research directly on 03) 9867 7446 or john@infotechresearch.org

Case Study 2: Energy efficient cool stores

Vegetable growers spend an increasing amount of money on energy and electricity is the major energy source in vegetable processing. Energy audits conducted for a group of 20 growers across Australia yielded a picture of where this energy is spent.



Cool stores accounted for 35% of the total electrical energy consumed and around 60% of the electrical energy used in the processing facilities themselves. These figures vary considerably from one grower to another, but very few are unaffected by cool stores and their energy consumption.

The next question that needs to be answered is what is the cause of this energy consumption? It is clear to all that the refrigeration unit out the back of these stores is humming through the power almost continually, as the cool store temperatures have to be maintained to preserve vegetable freshness, but is it the cat or the mouse?

There are two ways of considering the refrigeration issue: how do you make the refrigeration system more efficient and how do you actually use less energy in cooling and keeping the product cold through to market? Both are important but here we look at cooling demand and how this may be reduced by improving cool rooms.

Site the cool store well

A key improvement is the position of the cool store. To make best use of the cooling, have doors open internally so that cool air is not lost from doorways. This also saves the cool store from direct sun and hot air from blowing into the cool room when the doorway is open.

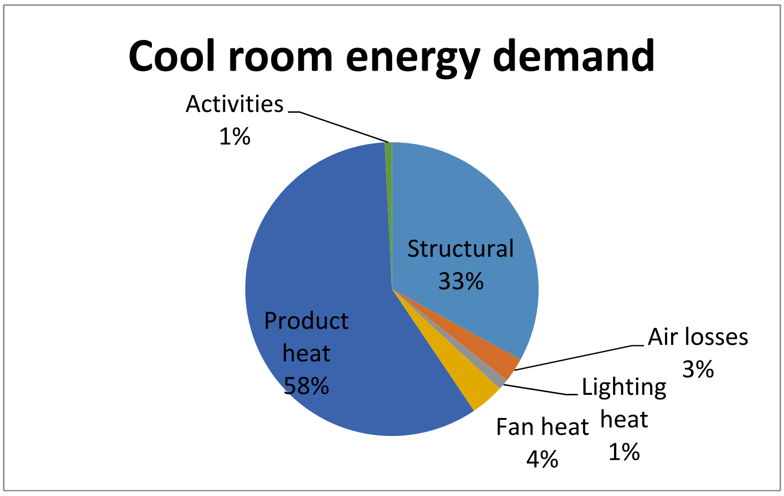
Internal cool store with an opening into the processing shed

Cooling power is needed to reduce the temperature of the vegetables from the field and keep them cool. This is “sensible heat” taken from the vegetables and, along with a smaller amount for plant respiration, is unavoidable and necessary. The rest of the cooling power required is incidental to the cool store design and ambient conditions.

Where is the cooling demand?

Taking an example of a typical cool store with dimensions 12 m x 13m x 4.5 height, built on an existing concrete slab in a shed. By adding the storage of 30 tonne of vegetables from the field at an ambient temperature of 25°C we can work out the energy demand on the refrigeration system.

Thirty tonne of product has a demand of 2,622 MJ of energy to reduce its temperature from 25°C to 2°C (the sensible heat), plus another 140 MJ for respiration over 24 hours in the cool store. Using the Australian Refrigeration and Air Conditioning Vol 2[2] to calculate the energy demand of the cool room structure, a further 1,950 MJ/day is required continuously by the cool store structure and activities assuming an ambient temperature of 25°C. A full analysis showed this to be split in a number of energy loss avenues.



The cool room structure, itself, losses heat through the walls, ceiling and floor. This is compounded by heat producing activities within the cool room and cold air losses when the door is open.

Break up of energy demand by a cool room established on an uninsulated concrete slab

So approximately 42% of the energy consumed in cooling is wasted in this case. Where?

The activities of moving products in and out of the store contribute little. Cold air losses when the doorway is open contribute more, as does the energy used by lighting and fans. However, most of the losses are through the structure itself. Which elements?

The components of walls, floor, ceiling and doorway were examined by estimating heat transfer through them and temperature gradients between the cool room interior and the external environment.

Cool room structure

The structural elements most often used in cool store construction are polyurethane foam sandwich panels for floor and ceiling construction. These insulate well, but the concrete floor may be left untouched so that forklift movements are unimpeded.

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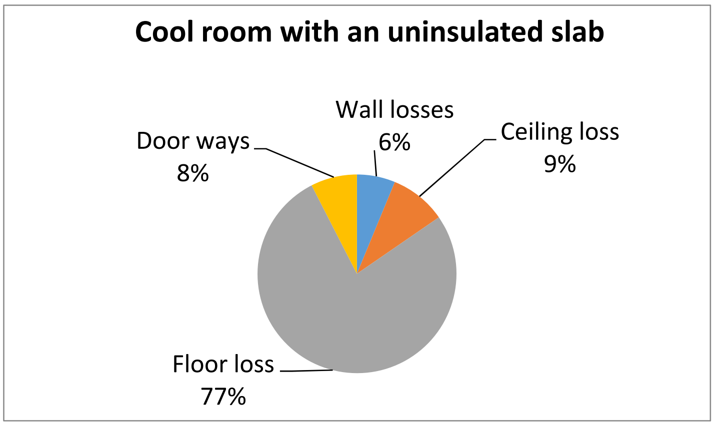
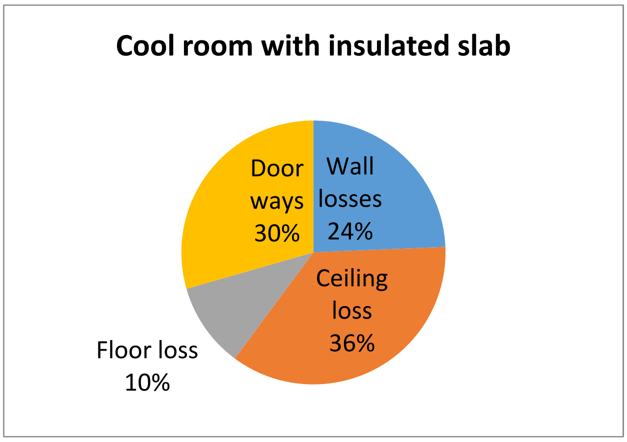
[2] Graham Boyle – Australian Refrigeration and Air Conditioning Volume 2 Fourth Edition 2004



If the ground temperature under the slab is set at 12°C, the thermal conductivity of concrete allows large energy losses through it. Wall and ceiling losses are only 20% of the energy loss through the floor.

Structural energy demand split for a cool room on an uninsulated concrete slab



If the concrete slab is insulated the floor losses are reduced by over 95% and the other structural elements become relatively important. And the total cool room structure's contribution to refrigeration demand reduces from 33% to 11%.

Structural energy demand split for a cool room on an insulated concrete slab (R = 3 Km^2/W)

The practicalities of retro fitting insulation into a concrete slab are significant, so a potential compromise approach is laying a tough rubber mat onto the cool room floor. It is estimated that a 10mm rubber matting will save 40% of the energy losses through the floor. This relates to an energy cost saving of $17,000 per year for the cool room running all year at 2°C. Savings from an insulated slab are in the vicinity of $30,000.

The Figures

700 m3 cool room with 75 mm PU insulated panels	uninsulated concrete slab (R= 0.10 Km2/W)	Rubber mat 10 mm (R= 0.11 Km2/W)	Insulated concrete slab (R= 3 Km2/W)
Wall losses (MJ/day)	29.0	29	29
Ceiling loss (MJ/day)	42.7	42.7	42.7
Floor loss (MJ/day)	359.4	174.1	12.4
Doorways (MJ/day)	35.1	35.1	35.1
Total structural heat load (MJ/day)	466.2	280.9	119.2
Savings*	base case	40%	74%

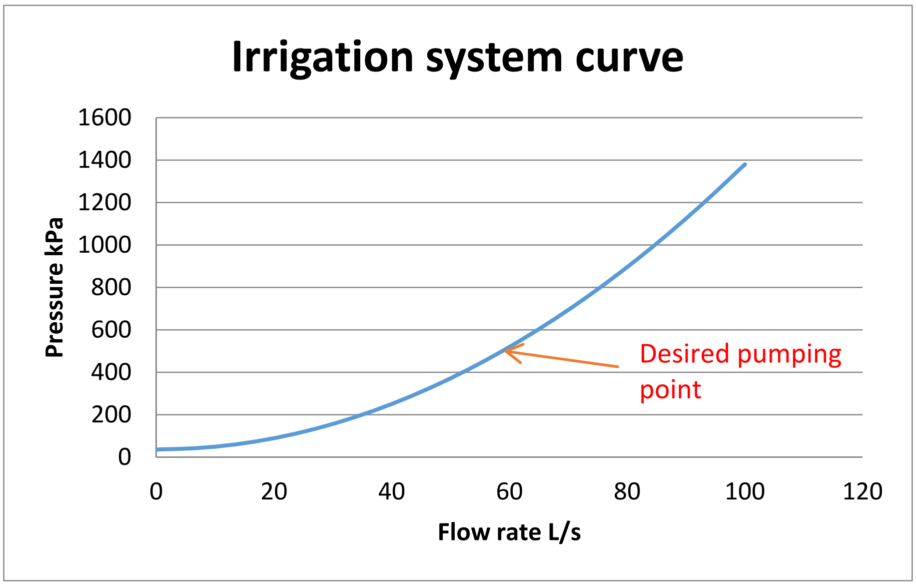
- Estimates only – figures will vary from case to case

Avoiding energy losses through insulation make sense as refrigeration systems do not have to be sized upward and their energy goes into cooling the product rather than surroundings. There are also good energy savings by attending to wall, ceiling, doorway and other incidental losses associated with cool store operations.

This article was prepared by Infotech Research as a part of a HAL project investigating energy audits for vegetable growers. The project has been funded by HAL using the national vegetable levy and matched funds from the Australian Government

For efficient irrigation follow the curve

Setting up a pumping system for irrigation is a technical task that requires some knowledge of the pumping system curve. For the mathematically minded, the system curve is always a square relation between the flow rate and the pressure (or pumping head). So if you need a flow rate of 60 litres per second at a pressure of 520 kPa (75 PSI) at the pump the curve is defined.



Possible system curve for irrigation layout

Then it is a question of matching a pumping system to the particular curve if you have one! If you do not it can be calculated from the irrigation system construction details – height to the point of irrigation (static head), length and diameter and main feeding the irrigator and the pressure demand of the irrigator. Unless you are on top this detail leave it to the engineers.

Things to consider:

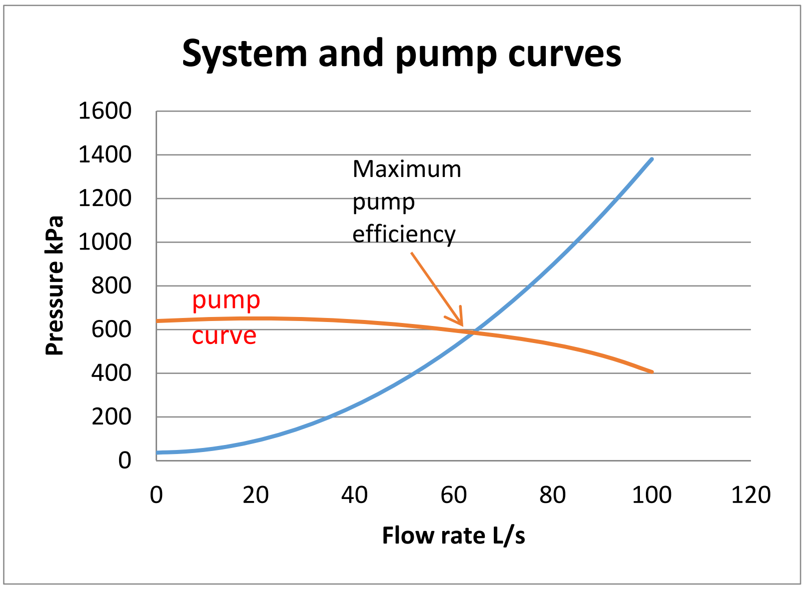
1. You can lose a lot of pressure down a low diameter main as the head loss depends on the diameter of the main to the power 5. That is right – double the main pipe width and you lower the pressure loss by 2^5 or x 32.
2. Valves, elbows and other restrictions add to the pressure and turbulence in the pipe.
3. Water does not go up hill easily so the height to the irrigator from the pump is important.
4. Suction of water from a dam or channel is limited and this varies in a square proportion to the flow rate as well. The suction side can cause problems if the delivery is not adequate.

One of the common issues we have come across in looking at pumping systems is valves partially closed to raise the pressure at the pump. This may be necessary if the pumping system is over specified for the irrigation task.

Partially closed gate valve raising the pressure at the pump

Choose the right pump

A pump can be chosen to meet a certain point on the system curve. The pump should be chosen so that its maximum efficiency is at the chosen flow rate and pressure requirement.



The problem arises when there is a variation in the system curve, or a different flow rate is required. Commonly this is achieved by adding a gate valve and chocking off the flow. This usually takes you into a less efficient position on the pump curve.

System curve matched with a pump at its maximum performance point

Variable demand systems

A pressure and flow rate reduction can be achieved by attaching a VSD to the pump motor, which will reduce the AC frequency and drop the revs of the pump. A new pump curve is then generated and, more often than not, the point of coincidence of the two curves is not at the maximum pump efficiency. So energy is saved at the VSD in current draw, but the pumping efficiency in kWh/kL pumped increases. A careful analysis of the pump curve needs to be undertaken before installing a VSD, as the use of a valve is much cheaper.

If more flow is required another pump may be the best answer. This can be added to boost flow in parallel or to boost pressure in series.

Pumps added in parallel to boost flow into the irrigation main

Suction is important

If water is to be sucked up from a dam or an irrigation channel, the suction head should be minimised to provide adequate water to the pumps. There are various ways of reducing the suction head to the pumps.

Growers have used multiple pipes from their dam and boosted the pressure with submersible pumps in the dam. This effectively lowers the system curve along the pressure axis, so less pressure is required for a set flow rate.

Dam extraction using submersible pumps to provide adequate flow for irrigation

This grower has a pump station situated below the dam to reduce the suction pressure

Bore pumps and transfer systems

Filling storage dams involves the use of bore pumps, or transfer pumps usually running at low pressure and high flow rates. These can transfer water over large distances, in which case the pressure required increases due to resistance in the pipe works.

A clear strategy for efficient water transfer is to use as low a flow rate as possible due to the relationship between pressure and flow rate ($P \alpha Vel^2$), so halving the flow rate reduces the pressure by a factor of four.

In essence if the pump duty can be well defined then a pumping system can be purchased that matches the system requirements. If, however, there is a variable demand the system has to be capable of meeting the highest level of flow demand and then controls put in place to meet the lower duty. Choking the pipe with a valve is the highest cost in terms of energy use.

If all else fails – ask an hydraulic engineer!

This article was prepared by Infotech Research as a part of a HAL project investigating energy audits for vegetable growers. The project has been funded by HAL using the national vegetable levy and matched funds from the Australian Government.

Case Study 3: The Quiet Achiever

Saves energy and cost

Whatever battery technology is used, electric forklifts have some special advantages for vegetable growers. Electric motors are potentially some three times more efficient than internal combustion engines, so your energy goes a lot further.

This is one of the reasons that electric forklifts are becoming more common in the vegetable growing industry.

Costs

The cost of LPG may be around $1.00 per litre and when compared with electricity at an average price of $0.25 per kWh, the cost per MJ of energy is then in favour of LPG[3] (3.9c/MJ for LPG and 7.2c/MJ for electricity). The energy conversion to useful power by an electric motor is conservatively 90%, while the internal combustion engine may be around 30%, so the useful energy swings back in favour of electric forklifts (and any other equipment that can use electrical energy or fossil fuels).

Useful energy cost	**electric forklifts = 8.0 c/MJ**	**LPG forklifts 13 c/MJ**
8 Hour shift energy	**41 kWh**	**17 L**
Annual fuel cost	**$2,560**	**$4,250**
Purchase cost ~	**$40,000**	**$20,000**
ROI (relative to LPG)	**8.45 years**	

If servicing costs at approximately $1/h for the LPG forklift is added the ROI is reduced to 5.4 years and if off-peak power is used to recharge the battery at 18c/kWh the ROI comes down to 4.5 years.

Indoor air

Another advantage particularly important for the food industry is the clean operation of the electric forklifts. LPG and other fossil fuels will produce exhaust gases that are odorous and may have a damaging effect on food products.

Exhaust gases from internal combustion engines include: Carbon Dioxide, Carbon Monoxide, Water vapour, Sulphur Dioxide, Oxides of Nitrogen, unburnt fuel and trace Volatile Organic Compounds of various types.

This is of concern to growers who are cooling fresh, un-packaged products in a cool store.

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[3] Using the energy intensities 25.7 MJ/L for LPG and 3.6 MJ/kWh for electricity

Recharging

One of the important concerns of growers has been the lack of certainty about electric forklift capacity to last the day, commonly called *range anxiety.* New battery technology and fast charging systems have put an end to this problem. Electric forklifts have the capacity to run for the full day and can be recharged overnight.

There is still the need to ensure an adequately ventilated area is available for commonly 40V recharging stations.

Operation

Electric forklifts are simple in operation having no clutch or gears and do not idle when stopped, the motor simply stops.

They are very quiet in operation.

This all adds up to a movement that is seeing electric forklifts moving into grower processing operations steadily replacing the older LPG and diesel forklifts.

LPG and diesel powered forklifts still have a place where power and distance is needed.

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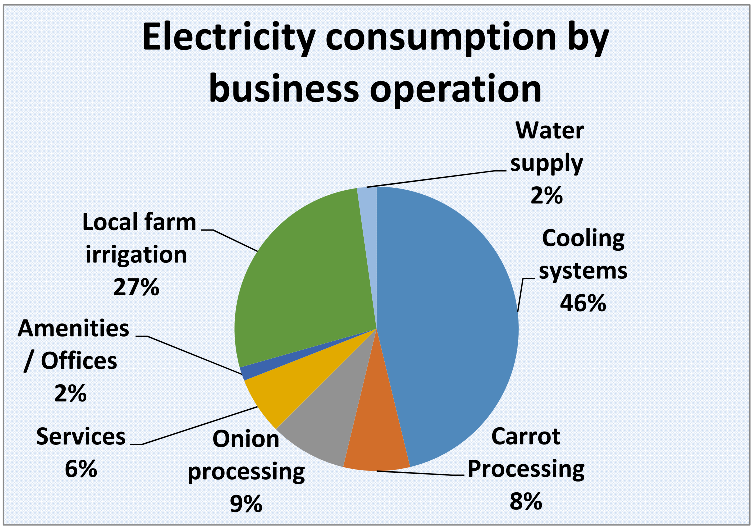
Case Study 4: Ivankovich Farms saving energy - father and son partnership

Ivankovich Farms is situated in the sandy coastal plains south of Perth at Myalup. Peter and his son Anthony have been busy recently upgrading their carrot processing operations to meet expanding export markets. Growing vegetables in this environment uses a lot of energy as the sand drains water through it almost instantly and the WA climate can be hot and harsh over the Summer months.

Energy efficiency is a key target according to Anthony as it is a high cost to the business. Electrical energy in particular is responsible for about 50% of the energy costs and this in turn is dominated by the cooling systems and irrigation at Myalup.

Their plan for energy saving is to make the processes as efficient as possible, to waste as little as possible and use technology to meet their requirements. Starting with carrot delivery and washing, Peter and Anthony have applied process efficiency considerations throughout the new carrot processing line. This utilises a combination of conveyors and flumes to move the carrots.



The flume channel shown below takes carrots from polishing to the hydro-cooler. VSDs are used on all electric motors, the polisher and the hydro-cooler to control flow rates while saving energy. The entire plant is remotely controlled allowing the hydro-cooler to do the bulk of its work during off-peak times. So it is ready and down to temperature by 6.00am.

(Note the LED high bays in place – they are very satisfied with the light output of these luminaires.)

Chillers and cool rooms have not been neglected with the installation of a large finished goods cool store fitted with a rapid closing roller door. This is serviced by a Neosys air cooled liquid chiller with a scroll type compressor. This unit claims a coefficient of performance[4] (COP) of 1.77 (2.5 times the efficiency of the industry average chiller). Condenser fans are mounted horizontally to maximize the cooling by directing air vertically away from the unit. An air tight loading dock (as shown) minimises cooling loss when loading out going goods.

Ivankovich Farms use fixed sprinkler systems serviced from a main excavation ditch by a series of 55 kW pumps. A diesel pump is also in service as a backup. Pump efficiency[5] was measured by the WA Department of Agriculture at 74% compared with an industry standard of 65%.

The ditch is fed by three bore pumps positioned across the farm. These are each 7.5 kW pumps running at about 60% of their maximum. This provides a good opportunity for Ivankovich Farms to switch over to solar bore pumps, or to add VSD drives to reduce the power draw of these pumps and save energy.

Perhaps the highlight of Ivankovich Farms' energy management initiatives is their purchase of 100 kW of solar photovoltaic panels. This bank of PV panels will handle a significant percentage of their power demand, estimated to be a maximum of 400 kW. Return on investment for the PV panels is expected to be less than five years and the panels themselves have a life expectancy of over twenty years.

Attention to energy efficiency and reducing process wastes are reasons why Ivankovich Farms was found to be one of the best performing vegetable growers in a 2014 energy study of 22 vegetable growers. Details of the energy benchmarking results and a costed list of energy saving opportunities can be sought from Infotech Research, who performed this work as a part of a Horticulture Innovation Australia project investigating key energy efficiencies for vegetable growers. The project was funded by HIA using the national vegetable levy and matched funds from the Australian Government.

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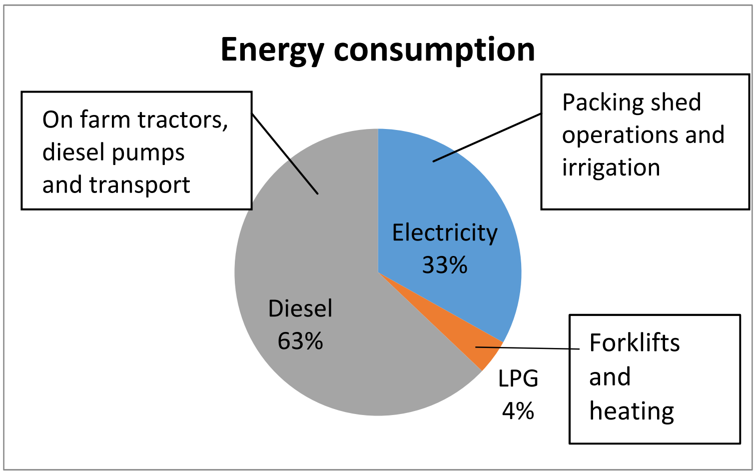
[4] Coefficient of performance is the ratio of sensible cooling achieved in energy and the electrical energy input. The industry average is believed to be about COP=0.7.

[5] Pump efficiency is the percentage of energy input to the pump that is transferred to water flow.

Case Study 5: Energy audits point to potential savings on vegetable farms

Energy is of increasing importance as a cost centre in vegetable operations. Saving energy can improve the bottom line; it's a matter of finding where the best and most economic energy savings are hidden.

Infotech Research conducted a series of 22 energy audits of levy paying vegetable growers in 2014, as part of a project with Horticulture Australia Limited. We found that while individual operations vary, most of the energy used on a farm is as diesel fuel for cultivation, planting, irrigation and harvesting. Electrical energy consumption is less but costs about the same as diesel, while LPG is the predominant fuel used by forklifts.



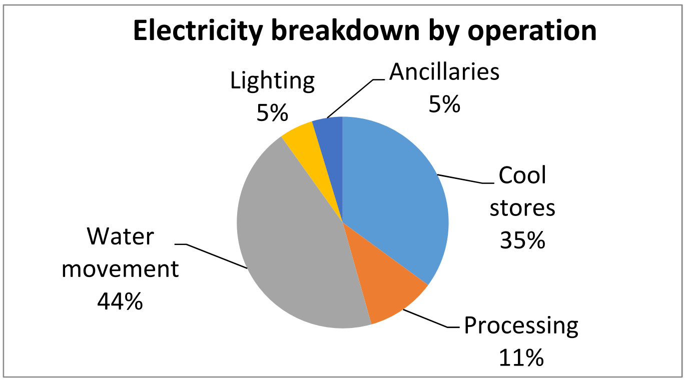
Diesel is an efficient fuel compared to petrol and LPG. Diesel engines average about 35% fuel energy conversion to work. When put through the tractor drive train, this drops to about 25%, so three quarters of the energy in the diesel is converted to heat rather than work.

This efficiency varied in a recent tractor study with efficiencies of 75kW tractors fluctuating between an efficiency of 23% to 31%. At the better efficiency end of the tractor range there is a potential saving in fuel of 25%, so it pays to buy a fuel efficient tractor.

Electric motors are more efficient than diesel engines, usually by about 90%, and simple direct drive chains give a total conversion of electrical energy to work of about 80%. So electrical motors are approximately three times more efficient than diesel engines.

Conversion of diesel fuelled systems to electric systems makes good economic sense where the option exists, such as for irrigation pumps.

Electrical energy consumption



The audits indicated that the majority of electrical energy consumption was split between irrigation pumps and the cooling systems, which take up 80% of the total electrical energy of most grower operations. Processing of vegetables is relatively minor as is lighting and ancillaries such as compressed air. A focus on the big users gives bigger rewards.

Cooling produce

The average energy used to run cool stores totalled 62 kWh per tonne across the 22 growers audited. This was compared to the sensible heat required to be extracted from a tonne of vegetables, starting at 30°C and cooling them to 2°C requires 111MJ/tonne (30.8 kWh/tonne including an allowance for respiration). This is almost 50% of the average energy used, so the losses are also about 50%.

Reducing losses is the cheapest way to save. In cool rooms this comes down to better insulation (particularly the floor – if not already insulated), protecting the cool store from the sun's heat, reducing heat from fans, forklift exhausts and cooling losses through doorways.

Improving chiller system efficiency is the next step in saving energy. This costs real money as chillers are not cheap. Before investing in a new chiller it may be worth considering the servicing regime of the chiller and fan systems employed. Chiller efficiencies were measured across a group of potato growers in the UK at a COP[6] of 0.7 (ave.) while new systems are available with a COP of 4. This will save 82% of the energy used by an old inefficient chiller.

Efficient water movement

Delivering water to crops and moving it between dams requires energy. Electric systems were compared, where possible, during the audits arriving at an average energy per ML moved to crops of 260 kWh/ML. The variation recorded between growers was from 200 to 460 kWh/ML and pump efficiencies measured varied from 20% to 75%.

Design of the irrigation system is critical to pumping efficiency with low pressure irrigation systems being more efficient. Irrigation mains can contribute to pumping pressure and energy costs with the pressure varying in inverse proportion to the pipe diameter to the power 5. So doubling the main diameter reduces the pressure loss by a factor of 32. Pressure also varies as the square of the flow rate so low pressure slow irrigation systems such as trickle irrigation can save pumping energy by large factors.

Restrictions in water flow using "T"s and elbows add to pressure, designing the pipe work to reduce turbulence and smooth water flow improves energy efficiency.

The pump itself needs to be able to supply pressure at the highest duty requirement and, if this varies, most irrigation systems encountered used a chocking valve to reduce the flow rate. Varying the flow rate electronically with a VSD is more energy efficient than using a valve and can save 30 or 40% of the pump energy if duty cycles vary a lot.

Growers can measure pump efficiencies and energy costs of pumping to determine where the opportunities lie for efficiency improvement.

Setting targets is necessary

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[6] COP stands for Coefficient of Performance for cooling systems the COP= sensible heat removed / energy input and can be from 2 to 4 for new chiller systems.

"Fail to plan and plan to fail" is an old adage that may be better stated as fail to have a target and then you don't know whether you are efficient or not and whether you are improving or going backward.

You can do your own energy audit and set your own plans for improvement.

Possible Grower Actions

A. Reduce energy losses (wastes)

a) Better insulation of cool stores
b) Insulation of cooling systems (chillers, flumes, hydro-coolers...)
c) Reduce the effects of solar heating
d) Reduce evaporation of water from irrigation systems
e) Reduce run off from irrigation
f) Reduce idling plant and equipment (esp. during breaks)
g) Lights off when not needed
h) Stop cool room fans when doors opened
i) Reduce restrictions in irrigation mains (build-up of sand and algae)

B. Improve energy use efficiency

a) Chiller efficiencies (COP from 0.7 to 4, VSD control)
b) Pumps efficiency maximised
c) Pump diesel to electric conversion (plus the addition of VSDs to accommodate duty cycles)
d) Irrigation systems conversion to low pressure (guns >> fixed, boom>>pivot, spray>>drip)
e) Belt drives to direct drives
f) Forklifts to conveyors / flumes (diesel/LPG to electric)

Secure the cheapest reliable energy supplies

a) PV panels
b) Grid electricity
c) Wind
d) Batteries / Fuel cells / Gen sets
e) Fuel storage
f) Water storage

C. Establish Energy Management Systems

a) Control and secure energy supplies
b) Establish targets for energy efficiency
c) Monitor cost and efficiency in major areas of consumption

Details of these suggested opportunities, including costings and payback periods can be found at Infoveg www.ausveg.com.au/infoveg and search for project VG13054.

Prepared by Infotech Research contact John Cumming on 0418 125688, email john@infotechresearch.org The project was funded by HIA using the national vegetable levy and matched funds from the Australian Government.

Appendix 3 – Opportunity Analyses

This is an options spreadsheet into which growers can insert energy costs to compute their own savings payback periods

The spreadsheet is split into the key grower operations and provides a calculation method, comments, assumptions and references that are not shown in this report.

Vegetable Growers - Energy Saving Opportunities

These opportunities have been identified in a series of energy audits of vegetable growers and are not meant to be comprehensive or accurate for individual growers.

Use these as a guide and then determine the costs and benefits for your own circumstance if it is considered worth pursuing.

STEPS:

1. Determine your own costs of energy (electricity, diesel and LPG)
2. Enter these costs at the head of the sheet concerned in the yellow cells
3. Review the costs (CAPEX = capital expenditure and OPEX = operational costs per year) which can be changed to suit your own circumstances
4. Review the calculations and if not sure contact the originator for details of the calculation method
5. Determine the suitability of the opportunities
6. If an opportunity is considered worth pursuing we strongly recommend a new analysis of costs and benefits is undertaken before deciding whether to implement the opportunity

The sheets have been split into key operations for ease of use of the sheet concerned.

Use the tabs at the bottom to source a particular operation, or use the "full calculations" list

Further information is available from:
Infotech Research - contact John Cumming on 03) 98677446 / 0418 125688
or email - john@infotechresearch.org

Chiller opportunities

PLEASE ENTER THE COST TO YOUR BUSINESS (or operational area) OF EACH ENERGY SOURCE			$/L or kWh	0.25	1.4	0.95			
Description	**Project Type**	**Project Cost ($) CAPEX**	**Project cost ($) OPEX**	**Electricity Savings (GJ/y)**	**Diesel Savings (GJ/y)**	**LPG Savings (GJ/y)**	**Other Savings ($)**	**Savings ($)**	**payback years**
Set up a fan cycling system or VSDs on all fans so that they even out the demand and maintain heat exchange	Cooling efficiency	$ 527		7.39		0		$ 513	1.03
VSDs can be added to the compressors and condenser fans to enable a variable refrigeration supply to the cool rooms	Cooling efficiency	$ 1,940		13.7		0		$ 950	2.04
If the site generates waste heat this can be combined with solar heating systems to drive a absorption chiller system	Energy efficiency	$ 150,000		180		0		$ 12,501	12.00
Replace R22 with less polluting alternatives	Greenhouse emissions							$ -	N/A
Installation of a solar absorption chiller could be considered to reduce cooling energy use	Energy sources	$ 60,000	0	43.2		0		$ 3,000	20
Install a roof over chillers to reduce the heat load on them by reflecting the sun's energy away from the chiller.	Cooling efficiency	$ 250		1.1		0		$ 74	3.4
Replace a group of small chillers with one larger unit that is more efficient	Energy efficiency	$ 21,600		90.7		0		$ 6,299	3.4
Any chiller system over 15 years old can be economically replaced with a new more efficient unit	Energy efficiency	$ 4,500		21.6		0		$ 1,500	3.0
Use time of low electrical tariff and periods when solar electricity cannot be used, to store cooling in the form of a glycol or salt block	Energy efficiency and cost efficiency	$ 9,500		0		0		$ -	N/D
Use solar power otherwise wasted to run chillers and generate cool storage in the form of glycol/water ice. Run this back through a heat exchanger to lower the load on chillers	Energy storage	$ 40,000		145		0		$ 10,070	4.0

Hydro-cooler opportunities

		PLEASE ENTER THE COST TO YOUR BUSINESS (or operational area) OF EACH ENERGY SOURCE			$/L or kWh	0.25	1.4	0.95			
Opportunity Name	**Plant Area**	**Description**	**Project Type**	**Project Cost ($) CAPEX**	**Project cost ($) OPEX**	**Electricity Savings (GJ/y)**	**Diesel Savings (GJ/y)**	**LPG Savings (GJ/y)**	**Other Savings ($)**	**Savings ($)**	**payback years**
Hydro cooler plastic blinds	Hydro cooler	Replace plastic strips with pull down plastic blinds to contain the cold water and reduce loss	Energy loss reduction	$ 500		40		0		$ 2,778	0.2
Hydro cooler thermal insulation	Hydro cooler	Reduce conductive and radiant losses from steel vessels and pipe work with spray on insulation (PU) and spacer isolation from the floor	Insulation	$ 12,000		130.464		0		$ 9,061	1.3
Insulation of cooling water pipe work	Hydro cooler	Insulation of exposed cooling water pipes	Insulation	$ 2,400		30		0		$ 2,084	1.2
Thermal insulation of cold water buffer vessels	Hydro cooler	Insulation of exposed surfaces and stands for cooling vessels	Insulation	$ 5,500		79		0		$ 5,520	1.0
Hydro cooler plastic blinds	Hydro cooler	Replace plastic strips with pull down plastic blinds to contain the cold water and reduce loss	Energy loss reduction	$ 500		40		0		$ 2,778	0.2
Energy recovery from cold waste	Hydro cooler	Heat exchange waste cold water discharged from the hydro cooler with incoming water into a cold water storage tank	Energy and resource efficiency	$ 27,500		38		0		$ 2,639	10.4
Cold water heat exchange	Hydro cooler	When chilled water is dumped a heat exchanger can be used to cool feed water into a cold water tank for use across the site	energy recovery	$ 27,500		335		0		$ 23,252	1.2
Insulation of cooling water pipe work	Hydro vac cooler	Insulation of exposed cooling water pipes	Insulation	$ 250		0.65		0		$ 45	5.6

Cool store opportunities

		PLEASE ENTER THE COST TO YOUR BUSINESS (or operational area) OF EACH ENERGY SOURCE			**$/L or kWh**	**0.25**	**1.4**	**0.95**			
Opportunity Name	**Plant Area**	**Description**	**Project Type**	**Project Cost ($) CAPEX**	**Project cost ($) OPEX**	**Electricity Savings (GJ/y)**	**Diesel Savings (GJ/y)**	**LPG Savings (GJ/y)**	**Other Savings ($)**	**Savings ($)**	**payback years**
Cool room floor insulation	Cool stores	Cooling loss can be reduced with floor insulation using a 10mm rubber roll stuck to the concrete base	Energy efficiency	$ 3,900	$ -	280.8		0		$ 19,502	0.2
Cold water recycling	Cold flumes	Cold water used for hydro coolers and fluming can be filtered and recycled to reduce refrigeration loads	Recycling	$ 35,000	$ 12,000	912		0		$ 51,338	0.7
Paint roof white over the cool room and the chillers	Cool stores	White paint will reflect the sun light and lower the temperature gradient between outside and inside	Insulation	$ 388		9.6		0		$ 667	0.6
Reduce the number of evaporator fans	Cool rooms	Fan heat can be reduced by using less fans with a larger capacity	Energy efficiency	$ 1,700		3.0		0		$ 205	8.3
Replace room fans with external barrel fans and ducts	Cool stores	Barrel fans external to the cool store reduces heat input to the cool store and enables ducting of air for optimal circulation	Energy efficiency	$ 1,500		1.4		0		$ 95	15.9
Variable speed drive applied to the cool room evaporator fans	Cool stores	The air circulation can be reduced using a VSD on the fans which will reduce cold air loss in the cool room and save energy at the chillers	Energy efficiency	$ 900		8.4		0		$ 582	1.5
Rapid closing doors on the cool store	Cool stores	Cold air lost when the cool room doors are open during forklift movements in and out can be reduced with rapid closing roller doors	Reduce energy loss	$ 18,000	$ 150	19				$ 1,168	15.4
Link evaporator fan operation to door opening	Cool stores	Evaporator fans do not run when the doorway is open as they assist in circulating the air out through the doorway	Reduce energy loss	$ 400		8		0		$ 542	0.7
Apply VSD to AHU fans	Cool stores	Use VSDs to reduce AHU fans velocities after cooling and at night	Cooling efficiency	$ 1,178	$ -	9.5				$ 662	1.8
Cycle cool room temperature settings	Cool stores	Increase cooling during the night time and allow cool rooms to rise in temperature during the day to save energy and move consumption to off-peak	Cool room efficiency	$ 5,000		375			$ 3,128	$ 29,171	0.2
Use of air curtains at cool store openings	Cool stores	Air curtain directed vertically down at entrance to minimise air movement out of the cool store	Cool room efficiency	$ 4,000	$ 200	6.1		0		$ 225	17.7
Plastic curtains	Cool stores	Use of plastic strips to prevent air movement when cool room doors are open	Cool room efficiency	$ 500	$ 50	4.4		0		$ 256	2.0
Off-peak and week-end energy storage	Cool stores	An additional thermal store, in the form of frozen glycol or salt, can be established to store solar power when not used by operations. This can be bled back into the cooling system during operations	Energy efficiency and cost efficiency	$ 9,500		0				$ -	N/D
Set up forklift movement controls	Cool stores	Prevent forklifts inadvertently tripping sensors and opening cool room doors by protecting the sensor area or placing signage on the ground	Loss prevention	$ 500		4.8				$ 333	1.5
Old cool store upgrades to improve insulation	Cool stores	Converted cool stores can show high temperature variation on the external cladding. Construction of inner foam walls and ceiling will save energy	Energy efficiency	$ 5,000		7.2		0		$ 500	10.0
Truck seal during loading	Dispatch - cool stores	Air leakage during truck loading can be minimised with a flexible sealing system	Energy efficiency	$ 3,500		4.5		0		$ 313	11.2
Demand management system	Electricity supply	Demand management systems are used to shift energy loads from periods of high cost to periods of lower cost. This can be achieved by production planning, peak load shedding and additional sources of energy from solar, wind or batteries	Peak load reduction							$ -	N/D

Irrigation opportunities

		PLEASE ENTER THE COST TO YOUR BUSINESS (or operational area) OF EACH ENERGY SOURCE			**$/L or kWh**	**0.25**	**1.4**	**0.95**			
Opportunity Name	**Plant Area**	**Description**	**Project Type**	**Project Cost ($) CAPEX**	**Project cost ($) OPEX**	**Electricity Savings (GJ/y)**	**Diesel Savings (GJ/y)**	**LPG Savings (GJ/y)**	**Other Savings ($)**	**Savings ($)**	**payback years**
Solar bore pumps	Irrigation	Solar bore pumps can be added to the existing dam supply with the saving of bore pump energy and cost	Energy source	$ 12,500		24.192		0		$ 1,680	7.4
Replace belt drive pump couplings with direct drives	Irrigation	Redesign the pump coupling to direct through a gearbox for belt drives	Energy efficiency	$ 2,000		16.2				$ 1,125	1.8
Irrigation booster pumps	Irrigation	Install submersible pumps in storages with the pressure pumps on the banks to increase the flow rates	Energy efficiency	$ 3,540		5.4				$ 375	9.4
Reduce irrigation dam evaporation	Irrigation	Water loss from dams due to evaporation is likely to be > 1m per year	Loss reduction							$ -	N/A
Reduce dynamic head at the pumps	Irrigation	Rebuild the pump pipe work to be straight flow through with minimum corners and maximum pipe width	Energy efficiency	$ 2,800		8.6		0		$ 597	4.7
Reduce power demand on irrigation pumps with VSDs	Irrigation	Place VSDs on the major irrigation pumps to reduce power demand and avoid the use of choking valves for variable duty requirements	Energy efficiency	$ 7,700		43				$ 2,984	2.6
New EC motor for irrigation pump system	Irrigation	Old motors replaced with new efficient EC motors can save up to 5% of the energy consumed	Energy efficiency	$ 28,000		22				$ 1,500	18.7
Solar array to reduce energy consumption and peak demand	Irrigation	Employ solar energy collection with an array on the south bank of the dam	Demand reduction	$ 75,000		216				$ 15,001	5.0
Use electric pumps over diesel where possible	Irrigation	Savings of about 50% of energy and 40% of the cost of pumping are possible in using electric over diesel pumps.	Replace a diesel with an electric pump	$ 26,400		-133	448		$ 550	$ 7,554	3.5
Solar system for a pump station	Irrigation	Set up a solar array on the dam wall to gain reflected sunlight from the water as well as direct sunlight. Use this to feed into the pumps used at low pressure for water transfer operations	Renewable energy source	$ 8,000		8.64				$ 600	13.3
Use low pressure irrigation systems	Irrigation	Replace highpressure traveller irrigators with hard set or fixed sprinklers systems toreduce pumping pressure	Energy efficiency	$75,000		65			0	$ 4,514	16.6
Reduce dynamic head at the pumps	Irrigation	Rebuild the pump pipework to be straight flow through with minimum corners and maximum pipe width	Energy efficiency	$ 2,800		8.6	0		$ -	$ 597	4.7
Clean out main pipe works	Irrigation	Improve flow and reduce frictional losses in main pipe work with maintenance systems (regular disinfection and cleaning)	Energy efficiency								N/D
Diesel pump cooling efficiency	Irrigation	Diesel pump engines can use the irrigation water for engine cooling rather than a radiator and fan		200			2.2			$ 78	2.6
Rain water collection	Irrigation use	Collection and storage of storm water in a dam reduces the requirement for bore water pumping	Pumping reduction	$ 5,000						$ -	N/D

Other opportunities

		PLEASE ENTER THE COST TO YOUR BUSINESS (or operational area) OF EACH ENERGY SOURCE			$/L or kWh	0.25	1.4	0.95			
Opportunity Name	**Plant Area**	**Description**	**Project Type**	**Project Cost ($) CAPEX**	**Project cost ($) OPEX**	**Electricity Savings (GJ/y)**	**Diesel Savings (GJ/y)**	**LPG Savings (GJ/y)**	**Other Savings ($)**	**Savings ($)**	**payback years**
Electric forklifts	Alternative energy sources	Electric forklifts can be charged on weekends and evenings for day operations with the aid of battery system and PV back-up	Energy storage	$ 20,000	$ 250	-36.9		109	$ 1,500	$ 2,724	7.3
Solar panels on roof	Alternative energy sources	Reduce peak electricity demand with solar generation	Demand reduction	$ 40,000	$ -	129.6				$ 9,001	4.4
Wind power source	Alternative energy sources	Reduce peak electricity demand with wind generation	Demand reduction	$ 390,000	$ 20,000	1420				$ 78,619	5.0
Batteries for energy storage	Alternative energy sources	Spread the electricity demand using Lithium Ion batteries 100 kWh system installed	Demand reduction	$ 100,000	$ 1,000	108				$ 6,501	15.4
Blowdown heat recovery	Boiler	Install a flash vessel to recover waste heat from boiler blow down	Energy Efficiency	$ 8,500				85.32		$ 3,153	2.7
Boiler Management system	Boiler	Install a Boiler Management system that controls the air to fuel mixture to ensure complete consumption of fuel	Energy Efficiency	$ 10,500				142.2		$ 5,255	2.0
Economisers	Boiler	Install an Economiser is to the boiler flue, to recover waste heat. The waste heat could be used to pre heat boiler make up water	Energy efficiency	$ 12,200				142.2		$ 5,255	2.3
Pre heat combustion air	Boiler	Use waste heat to pre heat combustion air before feeding in to the boiler	Energy efficiency	$ 4,500				56.88		$ 2,102	2.1
Total dissolved solids (TDS) control, and boiler blowdown	Boiler	Install automated TDS control system, to reduce the amout of blow down required. Saving both energy, and boiler treatment chemicals	Energy and water efficiency	$ 3,560				56.88		$ 2,102	1.7
Demand management system	Electricity supply	Demand management systems are used to shift energy loads from periods of high cost to periods of lower cost. This can be achieved by production planning, peak load shedding and additional sources of energy from solar, wind or batteries	Peak load reduction							$ -	N/D
Power Factor correction	Electricity supply	Peak demand can be reduced by applying capacitors to compensate for reactive load	Peak load reduction	$ 25,000		0		0	$ 45,625	$ 45,625	0.5
Heat exchange cold water with incoming fresh water	Flumes	Use chilled water wastes to cool incoming town water and reduce the load on chillers cooling incoming water	Energy usage efficiency	$ 7,500		25.6		0		$ 1,778	4.2
Movement detector switches in cool stores	Lighting	Replace slow start high bays withrapid start luminaires Link cool store lights to a movement detector	Lighting controls	$ 2,040		8.46				$ 588	3.5
LED or Inductive high bays linked with sensors	Lighting	Metal halide high bays can be replaced with inductive fluoros to enable fast switch on and sensor controls. The same can be achieved with LED tubes replacing fluoro T8s	Energy efficiency	$ 600		8				$ 556	1.1
Replace 400W metal halide high bays with 200W inductively coupled H/Bs	Lighting	Metal halide high bays can be replaced with inductive fluoros and then lux controls can be applied to reduce lighting energy	Energy efficiency + reduction of losses	$ 360		2.02				$ 140	2.6
Fluoro T8 tube replacement with T5s or LEDs	Lighting	Replace T8s with LED tubes for purpose lighting	Energy efficiency	$ 1,200		1.38				$ 96	12.5
Cleaning of electric motors	Maintenance	Clean the air intakes and fins on electric motors	Energy efficiency								N/D
Preventative maintenance program	Maintenance	Pump efficiency measurement and target setting for efficiencies	Energy efficiency	$ 200		3.13				$ 217	0.9
Tractor fuel efficiency monitoring program	Maintenance	Establish efficiency benchmarks for tractor fleet and monitor progress toward efficiency goals	Energy efficiency	$ 2,000			77.2			$ 2,799	0.7
Cold water tank insulation	Processing	Energy savings come from insulation of the tank, the delivery flumes, pipe work and the sides of the elevators	Energy efficiency	$ 1,200		23				$ 1,620	0.7
Equipment switch off at breaks	Processing	One central switch linked to all equipment running on the lines will enable switching off all equipment during breaks	Energy control	$ 400		4.5				$ 313	1.3
Addition of skylights	Sheds	Improve dark production areas by installing skylights and a linked light switching system to the room lights	Energy efficiency	$ 11,000		21.6				$ 1,500	7.3
Awnings on north facing buildings	Sheds	Install awnings to reduce the heat onto the building and air conditioning loads	Demand reduction								N/D
Solar hot water	Boiler / hot water	Install Solar hot water units on the roof of the factory to supply hot water at 60-90 C to hot water operations.	Alternative energy source	$ 50,000		281				$ 19,515	2.6

Top Ten Quick energy saving opportunities

Opportunity Name	Plant Area	Description	Project Type	Project Cost ($) CAPEX	Project cost ($) OPEX	Electricity Savings (GJ/y)	Other Savings ($)	Savings ($)	payback years
Cool room floor insulation	Cool stores	Insulation and cooling loss can be reduced with floor insulation using a 10mm rubber roll stuck to the concrete base	Energy efficiency	$ 3,900		280.8	$ -	$ 19,488	0.2
Paint roof white over the cool room and the chillers	Cool stores	White paint will reflect the sun light and lower the temperature gradient between outside and inside	Insulation	$ 388		9.6	$ -	$ 666	0.6
Link evaporator fan operation to door opening	Cool stores	Evaporator fans are stopped when the doorway is open to reduce cold air losses	Reduce energy loss	$ 400		8	$ -	$ 541	0.7
Cycle cool room temperature settings	Cool stores	Increase cooling during the night time and allow cool rooms to rise in temperature during the day to save energy and move consumption to off-peak.	Cool room efficiency	$ 5,000		375	$ 3,128	$ 26,025	0.2
Thermal insulation of cold water buffer vessels	Hydro cooler	Insulation of exposed surfaces and stands for cooling vessels	Insulation	$ 5,500		79	$ -	$ 5,516	1.0
Improve pump couplings	Irrigation	Efficiency improvement by redesigning the pump coupling to direct through a gearbox	Energy efficiency	$ 2,000		16.2		$ 1,124	1.8
Reduce power demand on irrigation pumps with VSDs	Irrigation	Place VSDs on the major irrigation pumps to reduce power demand and avoid the use of choking valves	Energy Efficiency	$ 7,700		43	0	$ 2,982	2.6
Movement detector switches in cool stores	Lighting	Establish a movement detector switch and lamp replacement to instantaneous ON type.	Lighting controls	$ 2,040		8.46		$ 587	3.5
LED or Inductive high bays linked with sensors	Lighting	Metal halide high bays can be replaced with inductive fluoros to enable fast switch on and sensor controls. The same can be achieved with LED tubes replacing fluoro T8s.	Energy efficiency	$ 360		1.80		$ 125	2.9
Equipment switch off at breaks	Processing	A central switch to all equipment running on the lines will enable savings of equipment running during breaks	Energy control	$ 400		4.5	$ -	$ 312	1.3

End