New Energy Options for the Victorian Dairy Industry

Produced by Negotiaction in consultation with the United Dairyfarmers of Victoria (UDV), a division of the Victorian Farmers Federation (VFF)

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Industry Context

The Australian Dairy Industry

The dairy industry is a vital component of the Australian economy. Australian dairy is a $13 billion farm, manufacturing and export industry.

Australia's 6,128 dairy farms produce approximately 9.5 billion litres of milk a year. More than 100,000 Australians rely on dairy for their livelihoods, including veterinarians, scientists, mechanics, financial advisers and feed suppliers, while 39,000 Australians are directly employed on farms and in dairy processing. Approximately 98% of Australian dairy farms are family-owned businesses.

More than 125 Australian companies export dairy products. Around 65% of Australian dairy product is sold on the domestic market, with the remainder exported. Australia is the fourth largest dairy exporter in the world, accounting for 7% of global trade. Australian dairy exports go to more than 100 countries and are worth around $2.8 billion a year.

Australian export volumes to Greater China grew by 34%, from around 128,000 tonnes to 172,000 tonnes while the US$ value of Australian exports increased by almost 70% year-on-year, from US$314 million in 2014/15 to US$533 million in 2015/16.

Supermarket sales of cheese, milk, yoghurts/snacks, and dairy spreads in Australia in 2015/16 were $2.14 billion, $2.11 billion, $1.44 billion and $433 million respectively.

The Victorian Dairy Industry

Victoria is Australia's leading dairy producer. Our state's 4,284 dairy farms produce more than six billion litres of milk a year and provide work for 16,000 Victorians on farms and another 11,000 in milk processing facilities.

Victoria is export-oriented, accounting for 86% of Australia's dairy exports. Around $2.3 billion a year worth of Victorian dairy products passes through the Port of Melbourne, where dairy is the largest container exporter.

Average farm income in 2015/16 in Southwest Victoria was $1.138m (average of 378 cows per farm), $1.128m in Northern Victoria (average of 367 cows per farm) and $748k in Gippsland (average of 291 cows per farm).

A recent report on the economic impact of dairy found that 'for every $1 of dairy industry output in Victoria, $1.25 is created in flow-on economic activity, 99 cents is added to Gross State Product and 54 cents is created in household income in the state's economy'. The report also found that 'for every $1 million of dairy industry output, 7.61 full time equivalent (FTE) jobs are created in Victoria'. Furthermore, 'the dairy industry contributes 2.0 per cent to Victoria's Gross State Product and underpins 54,635 FTE jobs. This represents 2.2 per cent of the state's employment and creates 1.9 per cent of the state's household income.'

Over the past 30 years the average milk produced per year per farm has increased from 311,000 litres to 1,563,000 litres. This significant expansion is a result of increases in yields per cow and herd sizes that are two-and-a-half times larger on average.

While yields could be enhanced further and herd sizes could be expanded further, Victorian dairy participants are questioning the extent to which existing infrastructure is capable of supporting further growth.

The Stated Problem

The Victorian dairy industry was concerned that single wire earth return (SWER) lines are seriously constraining the operations of dairy farmers and milk processors in Victoria and, hence, limiting the growth of those operations and the Victorian dairy industry at large. The industry suspected that the constraints could be linked to the clustering of dairy farmers and milk processors around SWER lines.

The concern of the industry with SWER lines was not unreasonable and without basis. SWER lines are common in remote areas serviced by the Victorian power distributors Powercor Australia and AusNet Services, and while SWER lines are an effective method of economically electrifying remote areas, the inherent electrical properties of these lines make them highly susceptible to power quality problems, mostly around voltage. Due to the resistive nature of the lines, voltage falls significantly when load increases. This creates a need for higher power and additional SWER lines and/or alternative technologies to meet peak demand for remote areas.

This project was designed to consider the role that energy storage could play in cost-effectively overcoming residual power issues associated with SWER lines, specifically for cases where dairy farmers and milk processors could be competing with each other and other major power users to secure adequate power.

In consultation with the United Dairyfarmers of Victoria and the Department of Economic Development, Jobs, Transport & Resources, Negotiaction formed the view that developments in energy storage could play a valuable and cost-effective role in smoothing peak energy consumption in areas with clusters of dairy farms and milk processing facilities at peak milking and processing times.

We identified the PureWave® Storage Management Solution by S&C Electric as a credible offering principally based on its successful installation and commissioning across parts of the SWER network operated by the distributor Ergon Energy in Queensland.

We planned to undertake a feasibility study of incremental sizes of the technology across a cohort of Victorian dairy farms and milk processing facilities that are constrained by SWER lines. The feasibility study aimed to identify the technical requirements and operational allowances required for this technology in regional Victoria, and the financial viability of the solution.

Our Approach

We outline below the original methodology for the project and provide comments on each process step. We note that the shift in project direction required us to invest more resources in the completed steps than originally anticipated.

1. Prepare document to request data from farmers in the context of confidentiality provisions. In consultation with UDV and Powercor, Negotiaction created a form that enabled farmers on an individual basis to supply site-specific information and authorise UDV and Negotiaction to access commercially-sensitive energy data from Powercor. **COMPLETE**

2. Collate meter data from all dairy farms on the end of the SWER line in Tyrendarra. Each participating dairy operator located in or around Tyrendarra received a blank copy of the authorisation form via UDV, completed and signed the form and furnished us with a copy, again via UDV. We collated the nine forms and created a list of the 17 National Meter Identifiers (NMIs) located across the nine dairy properties and forwarded this information to Powercor for processing. **COMPLETE**

3. Request and receive relevant network and transformer data from Powercor. Given the relatively small number of dairy properties and NMIs involved in this project we were able to work directly with technical officers within Powercor to access and store the relevant data on a portable hard disc for analysis. **COMPLETE**

4. Tour LC Anderson and collate insights regarding on-farm energy consumption. We visited the dairy property of LC Anderson located in Athlone and were led on an extensive tour of the operations. The tour focused heavily on energy consumption but also included detailed presentations of the energy generation and energy storage technologies in-use across the property. The energy consumption elements of the tour concentrated on water heating, milk harvesting and milk refrigeration. **COMPLETE**

5. Model all end-user load data and aggregated consumption to evaluate full electricity consumption requirements. Notwithstanding the shift in focus of this project (refer to next Sections) we were able to successfully model all end-user load data. However, given we discovered that dairy operators were not competing with each other or other major power users to secure adequate power as a result of residual power issues associated with SWER lines, we were not able to meaningfully model aggregated consumption. **COMPLETE** – **NOT POSSIBLE**

6. Determine all alternate storage solutions by location, effect upon aggregated consumption, and storage size. Given we discovered that dairy operators were not competing with each other or other major power users to secure adequate power as a result of residual power issues associated with SWER lines, we were not able to meaningfully consider storage solutions. **NOT POSSIBLE**

7. Collate quoted prices of S&C Electric solutions. Given we were not able to meaningfully consider storage solutions, we were not able to collate quoted prices of S&C Electric solutions. **NOT POSSIBLE**

8. Visit Tyrendarra dairy farms to determine farm capability to offset peak consumption, and refine energy efficiency list from practical experience. We visited all the properties of the participating Tyrendarra dairies. In the context of the tour of LC Anderson and the research we conducted prior to and following that tour we paid particular attention to the energy requirements associated with heating, milking and refrigeration. **COMPLETE**

9. Build list of factors contributing to dairy farm peak energy consumption, and steps farmers can take to lower this load distribution. We built a list of factors contributing to dairy farm peak energy consumption across heating, milking and refrigeration activities, and steps farmers could take to even out this load distribution. **COMPLETE**

10. Produce individual farm assessments. With the advantage of direct observation and access to the data accessed from Powercor we were able to produce individual farm assessments. **COMPLETE**

11. Complete full cost versus benefit analysis. Given we were not able to consider storage solutions for this project we were not able to meaningfully conduct a full cost versus benefit analysis. **NOT POSSIBLE**

12. Identify public grants and co-financing opportunities relevant for farmers to offset their prospective investment costs. Given we were not able to consider storage solutions and were not able to meaningfully conduct a full cost versus benefit analysis we were not able to identify public grants and co-financing opportunities relevant for farmers. **NOT POSSIBLE**

13. Complete final report. This document represents the final report. **COMPLETE**

14. Present to UDV (and more broadly VFF), Tyrendarra dairy farmers, DELWP and DEDJTR, and gain exposure via *Vic Farmer* magazine and *Tyrendarra Energy Forum*. **PENDING** (linked to completion of this final report).

What We Discovered

The stated problem doesn't exist to the extent we thought it would

By visiting the dairy operators in and around Tyrendarra and undertaking critical technical and operational inspections of their respective properties, we discovered that with the exception of one limited case involving a dairy operator located in close proximity to an engineering workshop, the dairy operators are being serviced by entirely different SWER lines or no SWER lines at all. In other words, we discovered that dairy operators were not competing with each other or other major power users to secure adequate power as a result of residual power issues associated with SWER lines.

Following our site visits we worked closely with UDV and some of its prominent members to invite dairy operators across Victoria (serviced either by Powercor or AusNet) to report instances of SWER lines constraining clusters of dairy operators. We did not receive a single report. While this does not necessarily imply that SWER lines are not constraining clusters of dairy operators it adds weight to our discovery in and around Tyrendarra.

To place our observations in the correct context and in another attempt to uncover cases of the SWER line constraints we were interested in, we worked closely with Powercor to better understand the SWER network across its jurisdiction; approximately 145,650 square kilometres extending across the western half of the state. We confirmed from an assessment of Powercor's current and subsequent five-year network upgrade plan that no significant SWER line upgrades are scheduled. While this does not categorically confirm that SWER lines are not significantly constraining clusters of dairy operators and, indeed, Powercor customers in general, it is consistent with our direct observations.

Most importantly, while we discovered that the stated problem doesn't exist at least to the extent we thought it would, our site visits uncovered a disturbing pattern and one that could have more serious and far reaching implications for the Victorian dairy industry.

The problem we discovered could be more serious and have greater implications

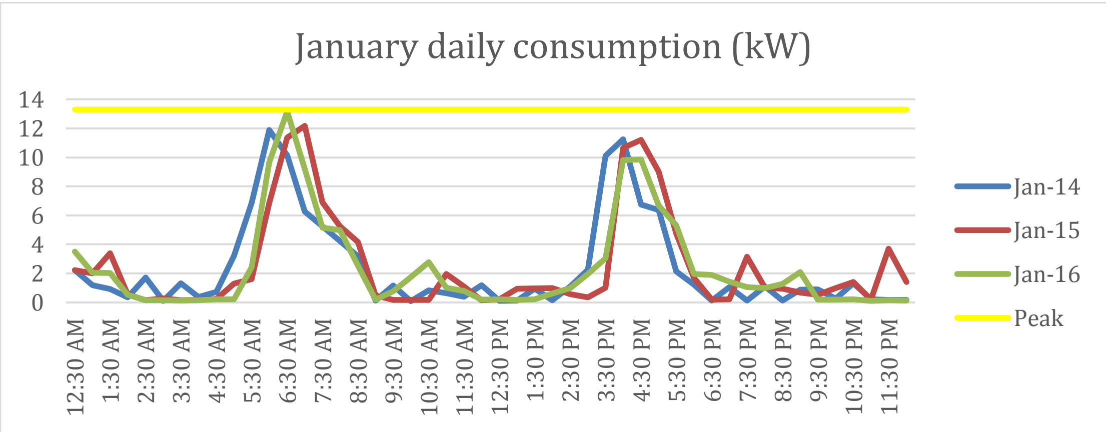
We found that all dairy operators being serviced by SWER lines in or around Tyrendarra are constrained to some extent, even though they are not competing with other operations for power along their respective SWER lines.

We strongly suspect that the limitation we observed could be due to the pattern of electricity load that is typical of dairy operations, and its inconsistencies with the power supply nature of SWER lines.

Dairy operators milk their herds of cows early in the morning and late in the afternoon every day. Accordingly, dairies typically use very little energy during long stretches of a typical day and a typical night, but have relatively large spikes in power demand immediately before, during and directly after milking activities. Understandably, these spikes can place great strain on a dairy operator's power network and the SWER line associated with the network.

The graph below illustrates the hourly load across a 24 hour period for one of the dairy farms we visited and analysed. We note that the farm under consideration is a good representative of the pattern of power consumption, the month in question (January) is typical of monthly power consumption, and the years in question (2014 – blue line, 2015 – red line and 2016 – green line) are very likely to be typical of annual power consumption.

The farm under consideration consumes up to 4kW of power for long periods of time but requires almost 14kW of power to support early-morning milking and milking-related activities and almost 12kW of power to support late-afternoon milking and milking-related activities. These spikes in power represent respectively a 250% increase and a 200% increase on the base power requirement. The yellow line on the graph represents the peak load.



The hourly load (kW) across 24 hours for a representative dairy farm we visited and analysed.

The restrictive nature of the SWER network means these peaks are using the full electric potential available to the dairy operator. We confirmed that every single operator we visited that operated on a SWER line was constrained during peak consumption. Once farmers cross the limit effectively imposed by the SWER line, heating units, milking machines, refrigeration units or pumps cease operating (typically a fuse is tripped), signifying network failure. It is reasonable to conclude that network failure could be exacerbated during periods of daylight saving given that the broader community in which dairies operate would draw power one hour earlier than during standard periods and, hence, add load during dairies' peak times.

While some dairy operators were able to confidently engage in meaningful discussions about the power and energy characteristics of their properties and demonstrate an intimate understanding of their heating, harvesting and refrigeration equipment and the specifications of that equipment, we note that all operators confirmed that they rely on their local commercial electricians and other electrical contractors to inform their power and energy decisions. Not surprisingly, the electricians and contractors undertake all electrical work on their properties.

We appreciate that dairy operators are very keen to minimise downtime and keep their dairies operating while milking and milking-related activities are underway. System failures and related breakdowns are problematic and could lead to serious issues across herds and operations. Understandably, failure recovery (mechanics) typically takes precedence over designing better solutions (engineering).

In any case, we are concerned that the electricians and contractors engaged by the dairy operators may not be fully abreast of good case practice for the dairy industry and, hence, may not be informing decisions appropriately. For example, while it may make sense *prima facie* for a larger electrical motor to be installed on a milk storage vat of a nominated capacity, a smaller motor with a variable speed drive may be a better option; it could be cheaper to purchase (lower capital expenditure) and cheaper to run (lower operating expenditure), and its lower start-up load profile renders its performance in the context of peak loads superior. Another option to consider is an unloader attached to a refrigeration unit compressor that could automatically purge the load on the compressor and enable the refrigeration unit motor to start unloaded.

We note that the head of LC Anderson is an exceptional case of a dairy operation run by an operator who is extremely knowledgeable and very confident in matters relating to power and energy.

It is important to consider relative development. SWER lines are common in Victoria and other parts of Australia, and are part of the remote network infrastructure that has been in place for several decades. The average dairy has increased milk production from 311,000 litres to 1,563,000 litres per year over the same period; this represents over 400% growth. As dairy operations increase in terms of their herds and milk output, the peak loads will almost certainly increase and, hence, place greater strain upon the network. The serious implication is that as the dairy industry attempts to expand, operators that rely on SWER lines could be restricted from expanding, regardless of whether they are competing with other operators on the same SWER lines or not.

During our site visits we didn't find an example of a dairy that had more than 200 cows and was well-serviced by a SWER line. Of course, this does not necessarily mean that all SWER line serviced dairies across the state are limited to 200 cows. However, we considered that our observations could indicate that those operators (and perhaps others like them across Victoria) are already struggling to grow and keep up with industry expansion. We confirmed during further investigation that while power constraints are not the only factor at play, they are negatively impacting the dairy operators' expansion decisions to a significant degree.

It is worth noting that the largest dairy we discovered serviced by a SWER line in Tyrendarra depended heavily on a bank of large diesel generators over extended periods (including those pertaining to milking and milking-related activities) and could not rely on the SWER network to any significant degree.

When we originally scoped this project and agreed to explore the role energy storage (specifically, battery storage) could play in alleviating the power constraints being experienced by dairy operators in Victoria, it was on the basis of considering storage for one or more clusters of dairy operators. In this way, the modelling we expected to undertake would consider the costs of storage borne by one or more operator cluster (presumably across each cluster). Given the nature of the power constraint we discovered (specifically, the power constraints experienced by dairy operators in and around Tyrendarra independent of other dairy operators and non-dairy operators) it is not feasible to consider energy storage as a power constraint relieving option. This technology would certainly be too cost-prohibitive at present for any individual dairy operator serviced by a SWER line we investigated. However, we note that battery storage technologies are developing rapidly and could become feasible for individual dairy operations in the future.

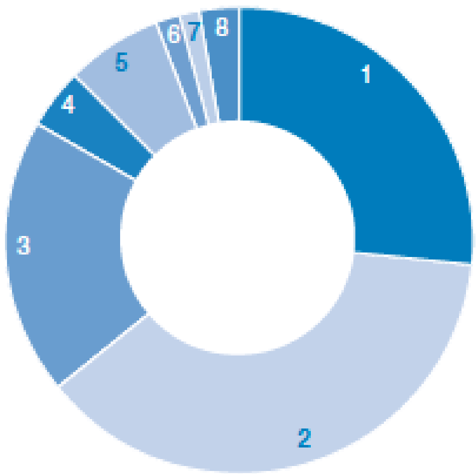
This project effectively builds upon the *Smarter Energy use on Australian Dairy Farms* program administered by Dairy Australia with support from the Australian Department of Industry and Science. Importantly, our project presents new knowledge by specifically analysing the energy consumption peaks, rather than the energy costs to dairy farms. The findings from this project could direct actions that can be taken by dairy operators serviced by SWER lines to support expansion.

Articulating the Problem in Greater Detail

Central loads that contribute toward peak consumption

The *Smarter Energy use on Australian Dairy Farms* program identified the major power consumption components of dairy farms.

Figure 2 Breakdown of energy costs average for herringbone sheds – Western Victoria



1	Hot water	26.7%
2	Milk cooling	37.6%
3	Milk harvesting	19.2%
4	Cleaning and effluent	4.0%
5	Stock and dairy water	6.8%
6	Feed	1.7%
7	Shed, office, workshop, misc.	1.3%
8	Lights	2.7%

Breakdown of energy costs average for herringbone sheds – Western Victoria

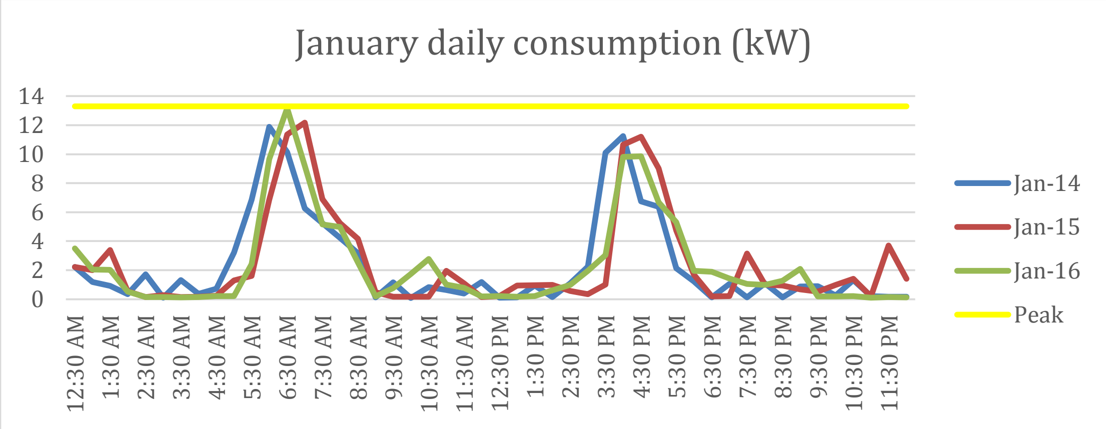
Based on this information and our focused interviews with dairy farmers in and around Tyrendarra, we identify the three central loads that contribute toward peak consumption as:

1. Milk refrigeration systems (vats)
2. Water heating systems
3. Milk harvesting systems (including pumps)

The *Smarter Energy use on Australian Dairy Farms* program only considered in-shed loads and therefore provided a limited view of dairy farm loads by excluding irrigation, which it recognised as 'typically the biggest part of the power bill for irrigated farms, depending on the season'.

We recognise that farmers in Northern Victoria typically irrigate their properties, and we witnessed some examples of irrigated properties in South Western Victoria. However, given the distribution of power consumption of irrigation systems over a typical day, we note that irrigation system load is not a major contributor to peak load. The operators with irrigation systems we visited confirmed that in the worst case scenario (i.e. they suffer from critical power constraints) they would operate their irrigation systems only when they are not milking or undertaking milking-related activities.

We now reconsider our sample daily consumption graph:



The hourly load (kW) across 24 hours for a representative dairy farm we visited and analysed.

The timing of the peak loads and the shape of the curves are affected by:

- **Milking start time**: Peaks will appear at different times of the day, and are dependent on when the farmer chooses to start milking. Here we see our sample farm has kept a reasonably consistent schedule over the course of three years.
- **Time taken to milk**: Each dairy allows for a different throughput of cows per hour. A dairy operator with a relatively small system and a relatively large herd of cows will have a much wider peak than one with a relatively large system and a relatively small herd, because the operator will take much longer to complete milking and milking-related activities every day.

The three central loads affect the peak separately:

- **Water heating system**: Largely through our farm visits we found that hot water systems servicing dairy farms require 4.8-7.2 kVA for a herd size of up to 200. While this is significant, we also found that every operation we visited principally runs its hot water system off-peak (between 11:00 PM and 7:00 AM) to take advantage of cheaper electricity rates that are available during off-peak periods. Therefore, we note that a dairy operation's hot water system does not contribute to its peak load to any significant degree.
- **Milk harvesting system**: We confirmed that the standard vacuum pump installed within a herringbone milking system supporting an operation of up to 200 cows is 7.5 kVA. This vacuum pump, by definition, runs during peak periods.
- **Milk refrigeration system**: We found that a milk vat should be powered by at least a 7.5 kVA motor for the aforementioned milk harvesting system. We note that farmers retain milk in their vats overnight to accelerate the rate of cooling the subsequently harvested milk and enhancing energy efficiency. Milk refrigeration systems run at their highest level and consume most power during peak periods, and reach a lower consumption rate once the milk reaches the legislated storage temperature (4°C).

Key steps required for energy-related expansion

To illustrate the peak energy requirements associated with dairy farm expansion we create a base case and three separate growth cases for farmers serviced by SWER lines (again, in the absence of farm clustering). We then proceed to illustrate how each growth case could be supported and how the existing SWER line infrastructure is likely to be inadequate for two of the cases.

The base case dairy operation is serviced by a SWER line within Victoria and has the following key elements:

- 150-240 cows
- 14-20 units per-side for a herringbone dairy
- 5-10 kL milk storage vat
- 7.5-10 kVA milk refrigeration system
- 7.2 kVA water heating system
- 7.5 kVA milk harvesting system (including vacuum pumps)
- Milk collected once per day

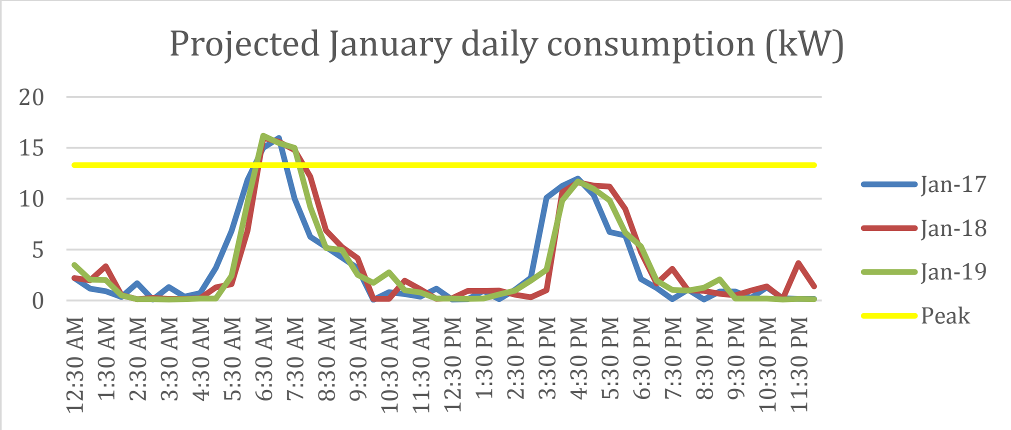
Five of the seven (71%) dairy operations we visited align with this base case.

Now we define three growth cases that represent expansionary options for dairy farmers that operate within the base case, and note that we are adopting the standard industry assumption that each cow produces 25L per day:

1. **Small growth**: Herd size reaches up to 400 cows
2. **Medium growth**: Herd size reaches 400-550 cows
3. **Large growth**: Herd size exceeds 550 cows

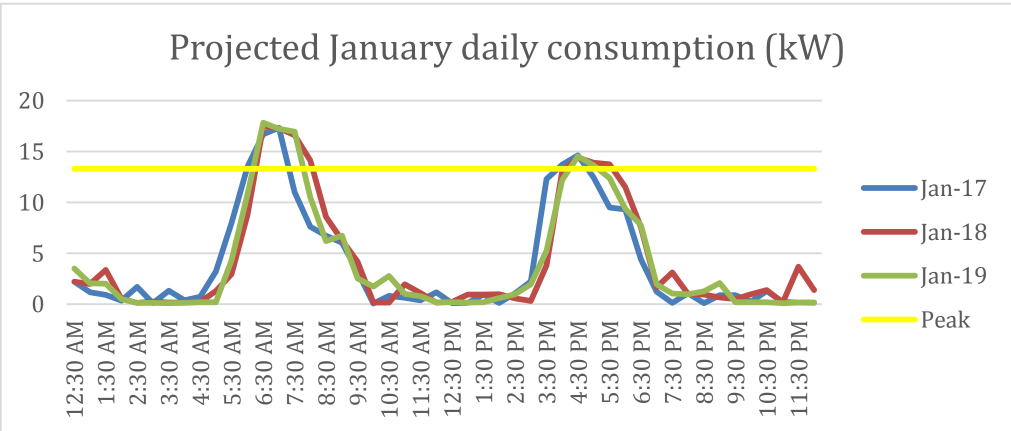
We recognise that a myriad of factors needs to be taken into account when considering the expansion of a dairy operation. However, for each growth case, we analyse the impacts on peak load to identify whether growth is being constrained by the power limit at peak load. As discussed, the water heating system is run off-peak and, therefore, we only consider two factors in our assessments: milk harvesting and milk refrigeration.

1. **Small growth**: In the small growth case, an operator can avoid investing in a larger herringbone dairy or a rotary dairy by extending the time taken to milk. This will require additional labour hours and costs, and have the effect of widening the curve. However, at 25 litres per cow, a herd size in excess of 300 will produce over 7,500L per day and allowing for the increase in milk volume produced per cow in spring an operator would require at least a 10kL vat. An upgrade of the storage vat, would require larger energy input and breach the capacity provided by the SWER line. Unless the operator migrates to a relatively expensive twice-daily milk collection schedule, with one pickup occurring after 7pm or overnight, the storage vat will effectively curtail the operation's ability to expand.



Small growth case

2. **Medium growth**: In the small growth case, the dairy operator avoided increasing their physical milk harvesting capacity by increasing the time devoted to milk harvesting. However, in the medium growth case it is not feasible for the operator to milk such a large herd twice a day using the base equipment. Therefore, the operator must expand the harvesting system to either a larger herringbone dairy or a rotary dairy (greater than 60 units in total in either case). Either expansion option requires much greater power, and directly pushes the peak consumption over the limit provided by the SWER line. Furthermore, the milk storage vat must also expand to cater for higher milk volumes, therefore pushing peak consumption even higher. Base case operators are therefore unable to grow their operations to a medium level.



Medium growth case

3. **Large growth**: The large growth case requires a rotary dairy (a herringbone dairy cannot easily cope with the large herd size unless equipment and workflow adjustments, such as rapid exits, are introduced to a dairy) and considerable operational capacity. The equipment associated with the milk harvesting and the milk refrigeration is well above the SWER capacity. Exacerbating the problem are other types of equipment such as roller mills (a feed system designed for livestock including large herds of dairy cows) that would be required to take advantage of economies of scale. The large growth scenario cannot be considered in the context of SWER network supply.

In summary, we have considered three cases for growth, and demonstrated that despite the admirable efforts of dairy operators to operationally shift energy consumption (e.g. switching off irrigation systems when milking or undertaking milking-related activities), farms on a SWER line cannot readily expand herd size beyond the milk storage capabilities of their vats. In other words, a dairy's ability to expand is constrained by its milk storage capacity and this capacity cannot be increased beyond the energy constraints imposed by SWER lines without intervention. Two of the farmers we interviewed have already reached this constraint and are unable to expand their operations.

Overview of Solutions

We will now review the current solutions available to dairy operators in each of the three growth cases, from both an industry perspective and a policy perspective. Each of the three cases faces different challenges that must be overcome, and therefore they require different solutions.

We acknowledge that the role of industry is to provide commercial solutions, while the role of the government is to provide policy support and associated mechanisms that enable dairies in each growth case to overcome the limits imposed by infrastructure, and increase gainful employment and output.

We begin by providing some context to the solutions offered for all three cases:

- **Battery storage**: We found through our analysis that implementing battery storage was not cost-effective for any of the three cases. Therefore, battery storage will not be considered further. We reiterate, however, that battery storage technologies are developing rapidly and could become feasible for individual dairy operations in the future.
- **Renewables**: Due to the pronounced twin-peak power distribution of the dairy daily load curve, we consider renewables (such as solar panels and wind turbines) alone not well-suited to providing a solution to the core problem. However, we are of the view that renewables could be worthwhile for smaller, flatter loads such as bore pumps that are often installed across dairy operations.
- **Generators**: Diesel generators are often used as a backup power source by dairy operators. We are of the view that this solution is inappropriate if they must be used frequently to augment power provided by SWER lines.

Potential solutions for large growth cases

Government programs that offer a 50% rebate to upgrade power supply infrastructure to three-phase from either SWER or single-phase lines is worthy of consideration. This type of program has been implemented twice before, on a total of 384 farms:

- *Dairy Power Infrastructure Upgrade Program* (2000-2004)
- *On Farm Energy Grants Program* (2008-2012)

We are of the view that this type of program is well-suited to dairy operations under the large growth case. Our review of the implemented programs suggests that significant benefits have been introduced to the Victorian dairy industry including improved property values, removed impediments to expansion and growth, additional investment in technology and equipment, and job creation. This type of program could enable large farms to enhance profitability and expand further. Application of this type of program could be of particular benefit to the largest operation we discovered on a SWER line in Tyrendarra, given that this operation depended heavily on diesel generators over extended periods.

Potential solutions for small growth and medium growth cases

Because of the relative sizes of these cases, we are of the view that it is likely to be unprofitable for dairy operators that fall within these groups to upgrade to three-phase power, even with the government rebate. Battery storage is also currently too expensive for these cases, as discussed. Therefore, for these cases we are of the view that:

- All industry solutions explored are presently too expensive or inadequate. These cases include battery storage, renewables, and three-phase upgrades.
- While we applaud the three-phase rebate program and acknowledge its significance and success in Victoria, we are of the view that the program was particularly well-suited to larger operators or those operators that could grow. A parallel program that works to provide solutions specifically for medium and small growth cases is warranted. In particular, a program that focuses on supporting dairy operations on SWER networks to upgrade milk harvesting systems and milk storage vat sizes would be worthy of consideration.

Summary and Possible Next Steps

This project was designed to consider the role that energy storage could play in cost-effectively overcoming residual power issues associated with SWER lines, specifically for cases where dairy farmers and milk processors could be competing with each other and other major power users to secure adequate power. However, we discovered that dairy operators were not competing with each other or other major power users to secure adequate power as a result of residual power issues associated with SWER lines. Accordingly, we were not able to meaningfully consider storage solutions within the context of the original project scope.

Importantly, we found that all dairy operators being serviced by SWER lines in or around Tyrendarra are constrained to some extent, even though they are not competing with other operations for power along their respective SWER lines. We strongly suspect that the limitation we observed could be due to the pattern of electricity load that is typical of dairy operations, and its inconsistencies with the power supply nature of SWER lines.

We recognise that a myriad of factors needs to be taken into account when considering the expansion of a dairy operation. However, for each growth case considered (small, medium and large), we analysed the impacts of milk harvesting and milk refrigeration on peak load to identify whether growth is being constrained by the power limit at peak load. We contend that farms on a SWER line cannot readily expand herd size beyond the milk storage capabilities of their vats. In other words, a dairy's ability to expand is constrained by its milk storage capacity and this capacity cannot be increased beyond the energy constraints imposed by SWER lines without intervention. Two of the farmers we interviewed have already reached this constraint and are unable to expand their operations.

Government programs that offer a rebate to upgrade power supply infrastructure to three-phase from either SWER or single-phase lines is worthy of consideration in the case of large growth. A parallel program that works to provide solutions specifically for medium and small growth cases is warranted. In particular, a program that focuses on supporting dairy operations on SWER networks to upgrade milk harvesting systems and milk storage vat sizes would be worthy of consideration.

It's important to note that we were not able to identify from our primary or secondary investigations a contemporary suite of upgrade options that are available to Victorian dairies and what these upgrades could achieve on-farm in real and quantitative terms. A practical program that meaningfully educates dairy operators, electricians and electrical contractors, and supports on-farm assessments and upgrades directed at reducing peak demand and enhancing power quality and supply could yield valuable outcomes for Victorian dairies and the state of Victoria.

Technical Note

In this report we express power in both kilo volt amperes (kVA) and kilowatts (kW). The former refers to the apparent power of an electrical system while the latter refers to the system's real power.

In direct current (DC) circuits the current and the voltage do not move out of phase and, hence, the apparent power (expressed in kVA) is equal to the real power (expressed in kW). However, in alternating current (AC) circuits the current and the voltage can move out of phase (e.g. three-phase power circuits) and, hence, apparent power and real power will differ.

The relationship between kilo volt amperes (kVA) and kilowatts (kW) is expressed in terms of a power factor. In mathematical terms, the equations are kW = kVA x power factor; kVa = kW/power factor; and power factor = kW/kVA.

We note that three-phase motors are more efficient than single-phase motors (and, hence, less likely to compromise a network) principally because their power factors are considerably higher. For example, the power factors of a comparable three-phase motor and a single-phase motor could be 0.99 and 0.75 respectively.

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