HARDWICK PROCESSORS PROPRIETARY LIMITED
HEAT PUMP PROJECT

Project Knowledge Sharing Report (Interim)

Recipients Name and website	Hardwick Processors Proprietary Limited (ABN 45 005 920 678) www.hardwicks.com.au
Primary Contact Name	Mark Hardwick
Contact Email	mthardwick@gmail.com
Reporting Period	28/02/2022 to 31/01/2023
Date of Submission	28/04/2023

This Project received funding from the Australian Renewable Energy Agency (ARENA) as part of ARENA's Advancing Renewables Program.

Table of Contents

EXECUTIVE SUMMARY

The Project involves the installation of a heat pump and high voltage upgrade and their integration with the site's solar and battery storage system.

This Interim Knowledge Sharing Report covers the Project from commencement until commissioning. A Final Knowledge Sharing Report will be completed following the 24-month post-commissioning review.

The Project has now been commissioned, with refinement and optimisation of the heat pump operations and performance continuing, while the necessary interface requirements for day-to-day production are further developed.

At this stage, due to the present high gas prices, the heat pump is achieving energy cost savings substantially above Business Case estimates (this was noted as a possibility in the Business Case).

The estimated payback period for the Project of approximately 5 years could therefore be reduced to 2 years or less if performance continues to be satisfactory, gas prices remain high, and operation and maintenance costs are reasonably in line with estimates (which is expected). This is contingent upon project disruptors not occurring too often, including ongoing maintenance, price of gas and other operational costs increasing due to inflationary pressures impacting the project to realise long term payback / value return later.

In summary, technical outcomes have been achieved although some optimisation is still to be undertaken, and operational interface factors remain to be finalized.

Key lessons learnt are detailed within the following sections below:

- Planning and Design Flexibility;
- Control Systems and Communication with Existing Systems;
- Heat and Thermal Store;
- Developing an Operational Interface

Implications for Industry are also further outlined.

OVERVIEW OF THE PROJECT

The Project's aim was to demonstrate the use of heat pump technology in managing industrial process heat demand. This will aid further uptake in the Australian Industry by:

- Reducing the perceived risk of retrofitting heat pumps for industrial process heating by, demonstrating the technical and economic feasibility of heat pumps as a retrofit solution;
- Demonstrating how the hot water demand of industrial processing can be managed with on-site renewable energy production, heat pumps, thermal storage and

complimentary gas-fired boilers (existing) in order to maximise the use of on-site renewable energy;

- Demonstrating how thermal storage can improve the economics of a heat pump solution by reducing the capex of heat pump and electrical system upgrade and increasing the heat pump utilisation;
- Quantifying the economic and environmental benefits of heat pump systems for industrial process heat applications; and
- Providing insights into the electrical supply infrastructure requirements associated with electrifying process heat for industry.

The total Project scope included:

- The installation and operation of approximately 1 MW (thermal) capacity heat pump and associated heat recovery infrastructure in order to deliver hot water at a planned 75°C to satisfy the majority of the heat demand for the 82°C hot water circuit. The heat pump and cooling oil heat recovery once fully optimised will displace approximately 33,000 GJ p.a. of natural gas which represents approximately 75% of the current gas consumption. The Project also makes use of existing thermal energy storage in the form of existing 150,000 litre (approximately) hot water storage tanks to enable the 1MW heat pump to build the base thermal requirements for the plant with final water temperatures provided by the existing gas hot water heaters.

- The Project included a significant upgrade to the electrical supply system. This upgrade resulted in Hardwick Meat Works becoming a High Voltage customer, taking supply at 22 kV from the Powercor network and also upgrading total supply capacity from 2 Mega Volt-Amp (MVA) to 4 MVA.

- An upgrade of the existing AZZO Microgrid system which allowed the heat pump and thermal storage tanks to be better integrated with the existing plant electrical systems. Once fully integrated, this system will allow the heat pump installation to leverage off the existing on-site renewable energy supply infrastructure of 2.5 MW solar PV and a 2 MWh battery energy storage system (BESS).

The Project has now been commissioned, with refinement and optimisation of the heat pump operations and performance continuing, while the necessary interface requirements for day-to-day production are further developed. The heat pump operation and associated systems are somewhat complex and require specialist skills to achieve ongoing performance objectives.

FINDINGS AND OUTCOMES

At this stage, due to the present high gas prices, the heat pump is achieving energy cost savings substantially above Business Case estimates (this was noted as a possibility in the Business Case). Future gas costs are very unpredictable, however at this stage the current gas contract price is presently approximately 3 times what it was when the Business Case was prepared. Power usage savings are generally in line with Project estimates. In addition to the gas savings there, as expected, has also been saving in a significant reduction in power usage of the main refrigeration compressor condensing fans. Currently this is estimated at 10KW average reduction in fan loading at current heat pump operating loads however this is very dependent on overall refrigeration loading and production and seasonal conditions. Currently as we have cooler seasonal conditions the fans run sparingly due in part to heat extracted by the heat pump as well as general lower loadings of the plant's refrigeration compressors.

In summary, technical outcomes have been achieved although some optimisation is still to be undertaken, and operational interface factors remain to be finalized. During the 24-month post-commissioning period, the operating and maintenance costs will also be further defined. It is expected that these costs may be slightly higher than the Business Case estimate of $60K per annum due to the complex nature of the equipment which will increase the payback period.

The Project is therefore considered successful at this stage and is achieving the Business Case objectives.

SUMMARY OF KEY LESSONS LEARNT AND IMPLICATIONS FOR INDUSTRY

The following are the key lessons learnt during the Project:

Planning and Design Flexibility

1. For complex integration works like this (which involve both enhanced communication and renewable integration into the grid) very detailed planning and implementation needs to be factored into the works program regardless of the experience of stakeholders. In addition, consideration needs to be given to increased stakeholder meetings. The power Upgrade caused delays in renewable assets coming back online. In the days leading up to the scheduled works the network provider established that they required a major communications device to remotely monitor and control the existing renewable assets of Battery and Solar. This involved the renewable assets being taken offline for approximately 2.5 months until the communications works could be executed. The incorporation of renewable assets and having many small generators is a new area for the network provider to manage. Hardwick's have existing renewable assets, but under this project Hardwick's wanted to re-configure existing renewables as part of the power upgrade. The renewable re-configuration works required is something which possibly the networks have not encountered many times in the past. Having a few more formal face-to-face meetings with all the parties involved may have flagged this issue at an earlier stage in the Project life.

2. Integration of Renewable assets into a HV upgrade should be included in the HV installation to allow more straightforward upgrades for future renewable upgrades, etc. In designing a system, it is very important to consider what flexibility is required to allow for operational variabilities of the processing facility. There was one scope change during the project to the overall electrical architecture. Prior to this project taking place the renewable assets, battery and solar, all fed back into the existing main LV switchboard. At project conception it was intended to leave this arrangement to reduce the complexity of the project and modifications to existing assets. A scope change was agreed on in order to

bring the existing renewable asset, battery and solar, onto the new HV board. This ensured that the renewable assets feed into the plant at the head of the system and ensured balanced systematic distribution of renewable assets across the entire plant including new electrical infrastructure and existing electrical assets.

3. For this project, natural gas continues to provide some of the final heating which has built greater flexibility into the project. The initial analysis for this Heat Pump Project was carried out over three years ago and was carried out largely due to the availability of funding to support the investigation. Meat Processing plants can be very dynamic with production levels changing dramatically due to seasonal changes, weather patterns and world markets. Plants can very rapidly change production levels over a short period from one shift (8-10 hours) to two shifts (16 to 20 hours)– typically most plants are continually driving to increase volume which delivers the highest economical outcome during prosperous times. From when the first analysis took place and completion of this phase of the project, the water usage across the site has increased by 20%. Due to the variable production levels as noted above, water usage can regularly vary in excess of +/- 20%. We are currently working through the early stages of balancing the Heat Pump Hot Water generation with the varying Hot Water demands of the processing plant. It is important to obtain existing usage data (for this Project water and ammonia usage). For example, accurate instantaneous water flows and a profile over a 7-day period. Although this is a big expense prior to the commitment of moving forward with the project it reduces the risk of incorrect equipment size selection. In designing a system, it is very important to consider what flexibility is required to allow for operational variabilities of the processing facility.

4. The heat pump chosen employs a variable speed drive in conjunction with a high-pressure multistage reciprocating compressor. This allows for high efficiency at part load demands as well as matching the thermal load more effectively. It can also be used to reduce site electrical peak demand during high demand periods. The selection of the variable speed drive on the heat pump as well as the water supply pump provides the system with very good flexibility and ensures good part load performance. This also reduces capital as it avoids multiple compressor costs and associated complexity in sequencing.

5. As the heat pump uses a flammable refrigerant (ammonia), the safety monitoring systems needed to be incorporated into the new compressor room. For future applications where the heat pump systems are co located into existing refrigeration rooms which already have refrigerant safety systems, the extra costs for the safety system can then be avoided.

6. The coeffecient of performance (COP) of this compressor - like other heat pumps - can be reduced at high delivery temperatures, however we have found that the 74 to 75C current target temperature for the process water preheat is a good compromise for current hot water demands (i.e. higher water flows and lower delta T for the heat exchangers). With further tuning and equipment reconfiguration the temperature and flow rates may be further refined.

7. The lubrication of the heat pump is also a consideration in final selection of operating temperatures and consequent process water flows through the heat pumps heat exchanger. As operating temperatures increase, normally available lubricating oils can become too viscous at source temperatures or too thin at sink temperatures which can diminish its chemical stability. Lubrication oil condition is being closely monitored by Hoctors as the operating parameters (e.g. head pressures, temperature lift and water flows) are varied.

8. As the heat energy supplied from the heat pump is more expensive than the heat recovered from the refrigeration oil cooling heat exchangers as well as the existing desuperheater the sequencing has been introduced to ensure these other sources of heat are recovered prior to the heat pump. In this case there is normally sufficient heat load required to utilise the heat available from all of these.

9. The design of the supply water system in combination with the thermal store (preheat tank) ensures the maximum temperature lift over the heat pump heat exchanger is achieved (temperature of pre-heat water minus temperature of incoming cold water)
10. As existing hot water tanks were used in the pre-heating system, they were not designed specifically to exploit stratification effects. We were however able to place the inlets and outlets in both the pre heat and final heat tanks to exploit heat stratification but still allow flexibility in fill rates and water inventory held. Also, as this is a once through system, it guarantees the maximum water temperature lift thus reducing the requirement to finely balance water temperature stratification over the height of the tank as would be the case if we returned warm water back through the heat pump heat exchanger.

Control Systems and Communication with Existing Systems

1. When retrofitting a Heat Pump to an existing plant there is a large amount of work and analysis required on the programmable logic controller (PLC) communications side to ensure that all the systems can talk and operate together. The project went fairly smoothly as the project was run internally and the programmers used had been integral in the development of all existing PLC's and had a very strong knowledge of the entire plant operation including the refrigeration system. If the project had been run by an external contractor with little pre-history of the plant, extensive time and additional resources would likely be required in developing the integration and communications plan for such a project. The Heat Pump and HV upgrade required the new PLCs installed as part of the project to communicate and integrate with existing refrigeration PLC's, Hot Water Plant Room PLC's, Renewable Energy PLC's and external communications for the Electrical Network Provider. In-depth understanding of the existing controls was required to integrate the Heat Pump. To add complexity to the Project, during the construction period, there was a parallel project taking place updating all data cables on the site to optic fibre and putting in new computer servers.

2. The heat pump and associated hot water delivery systems are controlled by a network of dedicated PLC's which allow more precise control for the heat pump. In retrofitting heat pumps to existing plants, the approach used in ensuring communication between different dedicated controls is important to optimise systems. At Hardwicks control of the systems is achieved using individual controllers that are linked via the sites SCADA system.

Heat and Thermal Store:

1. As this heat pump uses condenser water (from main site ammonia system) as its heat source its thermal performance is not substantially impacted by ambient conditions. The heat pump will however operate more effectively during the summer months due to warmer supply water temperatures as well as higher loading on condenser systems. The actual performance will be compared over the forward monitoring and reporting period.
2. We have found if the heat pump operates in a stable mode, it is more reliable and a bit more efficient. This is the normal operating mode as the unit was originally conceived as a preheating system which constantly provides heated water to the large preheat water tank (thermal store).
3. The thermal storage component of this project has been crucial in delivery of a viable heat pump system in a meat processing plant. Whilst this was expected, the project has demonstrated that this can be practically delivered in this type of complex plant.
4. Peak heating demand for the hot water circuits is > 2MWT so the installation of a 1 MWT heat pump (< 50% of peak requirement) has resulted in a significant reduction in high temperature heat pump (HTHP) capital;
5. Heating demand has been effectively smoothed to simplify HTHP control and improve efficiency;
6. Potential for future electrical load shifting to minimise exposure to high tariffs or to defer installation costs;
7. Potential to participate in future demand response programs.

The ammonia-based heat pump used here has no direct emissions such as products of combustion which include CO2, NOX and SOX. It is also effective in upgrading heat from the condenser circuit up to more useful temperatures. Currently in operation it is lifting process hot water temperatures by typically 55C.

Developing an Operational Interface:

1. Using internal tradesmen during the installation and ensuring that maintenance staff have a very strong understanding of the operating system, assists with long term operation, and that the company staff can improve the design for better integration. Working with the existing refrigeration contractor helped to ensure the

Heat Pump was integrated optimally into the existing plant. Creating long-term relationships with specialist contractors who can continue deliver ongoing value for money assists to de-risk projects, and was critical in this Project. A large amount of plumbing and electrical works was carried out or supervised by Hardwick's internal tradesmen. All the refrigeration / Heat Pump works were carried out by the company's main refrigeration contractor who has carried out all works on the site for the last 25 years.

2. Tracking of trends and optimisation of the system should be given management focus on an ongoing basis. An appropriate maintenance schedule and management reporting system is required. During commissioning, a strategy was developed to ensure the Heat Pump system is reviewed daily, and monitored and calibrated on an ongoing basis after the Project is handed over. The Heat Pump involves both the refrigeration and heating water circuits for the plant, and operational staff will need to track trends and optimise the system on a weekly basis from the site SCADA system and do a full walkthrough of the system on a regular basis. A maintenance schedule and management reporting system is also being developed.

CONCLUSION AND IMPLICATIONS FOR FUTURE PROJECTS:

There is substantial potential to integrate HTHP operation with renewable electricity as alternative to gas fired hot water units. Since this project is in an operational meat works plant, there is still potential to fine tune this by using the new communication systems in conjunction with the HV upgrade and existing PV interface. These systems and protocols can be incorporated into other applications that either have on site PV, or purchase renewable power from the grid. They will need to be customised to some extent for each application.

The financial benefits and associated lifecycle costs for the heat pump installed appears to be better than expected due to higher projected natural gas costs than originally assumed. The future trends of gas prices are somewhat unpredictable but we would expect the financial viability of heat pump projects to continue to improve.

Although the heat pump's power demand is reasonably high, the inverter drive has helped in minimising peak demand the system sees on start-up. For this site, the power upgrade was required to facilitate the load and improve the PV system interface. At other sites there may be potential to avoid power upgrades through site supply reconfiguration as well as controlled start-ups to avoid excessive load demands.

There should be consideration given to undertaking prefeasibility for heat pump integration prior to developing business cases. Normally pre-feasibility work does need to be covered in order to correctly size the heat pump and allow it to be integrated into the existing and future plant operations. Whilst standard models can be used for commercial applications integration into ammonia refrigeration systems are more complex and do require more detailed design work (they are definitely not plug and play). This will vary significantly from site to site depending on assets at site. Typically, these assets include thermal storage capacity available/ required, power infrastructure and options to seamlessly integrate control logic into the existing refrigeration and hot water delivery systems.

Installation of new technologies into an existing operational plant will take time so it is important to provide a comprehensive business case including all likely benefits. In addition to the energy cost and carbon savings, it should also include all co-benefits associated with the project. In the case of high temperature heat pumps these co benefits could include reduced water consumption, lower condenser fan power, reduced head pressure due to higher condenser capacity available as well as avoided incremental capital for condenser capacity and boilers.

The involvement of specialist refrigeration suppliers at the commencement of the project is important as they provide a sounding board on the practicality of retrofitting with the existing assets.

NEXT STEPS

There is now a basis for considering additional renewables for the site, such as additional solar, wind or biogas. Additional renewables could support the installation of a second heat pump and substantially further reduce (or potentially eliminate) gas usage. Additional thermal storage would further maximise heat recovery from existing equipment and enable load shifting.

Other actions to further develop the existing heat pump would be additional heat recovery from Compressor 3 (oil cooling) and other sources not yet considered, such as boiler flue economiser and air compressor, and controls and modifications to further control and stage ammonia condensing across heat pumps and cooling towers.