Final Report

Digital Tool

Digital Tool for Assessment and Design of Integrated Wastewater Treatment & Resource Recovery

Project Code
2021-1142

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Date Submitted
26/07/2022

Published by
AMPC

Date Published
26/07/2022

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1 Executive Summary

Red meat processors are required to use significant amounts of potable water in their operations due to their commitment to Australia's high standards in meat safety and the industry's long-held internationally recognised disease-free status in red meat. It's estimated that during 2020 the red meat processor sector consumed 27.65 GL in water intake which created 22.75 GL of wastewater.

The meat industry is often regarded as being more water intensive than other food groups. However, recent research found in the Australian context that fresh meats contributed less than 8% of the total dietary water footprint when regional Australian data on water scarcity was used[1].

In fact, Australian red meat processors achieved good reductions in both water intake intensity and water discharge intensity of 8% and 23% (respectively) between 2015-2020. However, this improvement came with a 10% increase in energy intensity. Similarly, improved processor water management and increased efforts in treating higher volumes of wastewater on-site don't seem to have been accompanied by more sophisticated bio-resource recovery outcomes, with a smaller than 1% increase in biogas and an increase in solid waste to landfill intensity occurring during this period[2].

Aligned with the United Nations Sustainable Development Goals (SGD30) and Australia's National Climate Resilience and Adaptation Strategy (Australia, 2021), the Australian red meat and livestock industry has set the ambitious target to be Carbon Neutral by 2030 (CN30). This target means that by 2030, Australian beef, lamb and goat production will make no net release of greenhouse gas (GHG) emissions into the atmosphere (AMPC, 2021).

Concurrently, the environmental regulators across Australian states are requiring red meat processors to comply with stricter standards for water usage, wastewater treatment and waste management practices. A significant step-change on many fronts of the production chain is required in a short period to achieve simultaneously robust environmental compliance and dramatically reduce carbon emissions.

Most of the current wastewater infrastructure, which was designed and implemented over past decades, is now based on outdated nutrient removal targets and has limited energy efficiency (Warnecke, 2008). Therefore, nationwide access to a tool that helps to illustrate targeted refurbishment options for wastewater and waste management systems is urgently required. Wastewater treatment plants need to align with the widespread movement away from effluent disposal, toward one of "resource recovery" (Tessele *et. al.*, 2020).

To achieve this paradigm shift, the existing pond systems need to be replaced by appropriately engineered processes, where higher levels of process control are possible, leading to higher efficiency. The proposed new way to manage wastewater and organic wastes brings the added benefits of generating income and significantly reducing carbon footprint. While this approach is considered new in Australia, it is commonly used and well-proven in Europe and other developed countries (Vellacott, 2016, McCabe, 2012).

The red meat processing sector, including its associated research centres, consultants, and suppliers, generally lack expertise in designing, building, and operating such systems, and the pace required to respond to demanded changes needs to be fast so that red meat processors can remain compliant and productive in the coming years while achieving net-zero goals.

By adopting this digital tool, red meat processing plants can benefit from having the initial assessment easily done, allowing for a faster-informed decision-making process.

[1] Ridoutt B. Baird D. Anastasiou K. and Hendrie G. 2019, Diet Quality and Water Scarcity: Evidence from a Large Australian Population Health Survey, Nutrients

[2] 2020 AMPC Environmental Performance Review.

Developing a tailor-made concept design for different scales promotes inclusive participation, helping smaller operators to undergo the required upgrades with lower levels of investment, and potential side-stream revenues. This integrated approach can generate impacts beyond the processing facility, being integrated with the community as a training centre, events venue, and part of the local attractions for visitors. This will contribute to the development of higher awareness of the value of what was previously considered waste and normalise the recovery of valuable resources.

By implementing the proposed integrated Bio-resource recovery concept developed for the digital tool, the average Australian red meat processor can become financially attractive. Non-financial outcomes include:

- Development of a digital tool that informs small, medium, and large-scale processing plants on their decision-making process on managing waste/wastewater streams from a different lens
- Increased environmental compliance via reduction of the adverse effects of nutrient emissions to the environment
- Reduction of wastewater discharged to the environment and of waste diverted to landfills
- Reduction of overall carbon footprint via bio-energy production using organic waste streams
- Provide a tool for decision-makers to identify and select the most appropriate technical pathway according to the scale of their operations
- Contribute towards a change in paradigm on how waste streams are managed in Australia

Figure 1 shows the schematic diagram of the integrated Bio-Resource Recovery Facility, the blueprint for the digital tool development. The diagram shows the Anaerobic Digestion process as a central pillar for achieving bio-resource recovery via adopting a circular economy approach, as described by Tessele and van Lier, 2020.

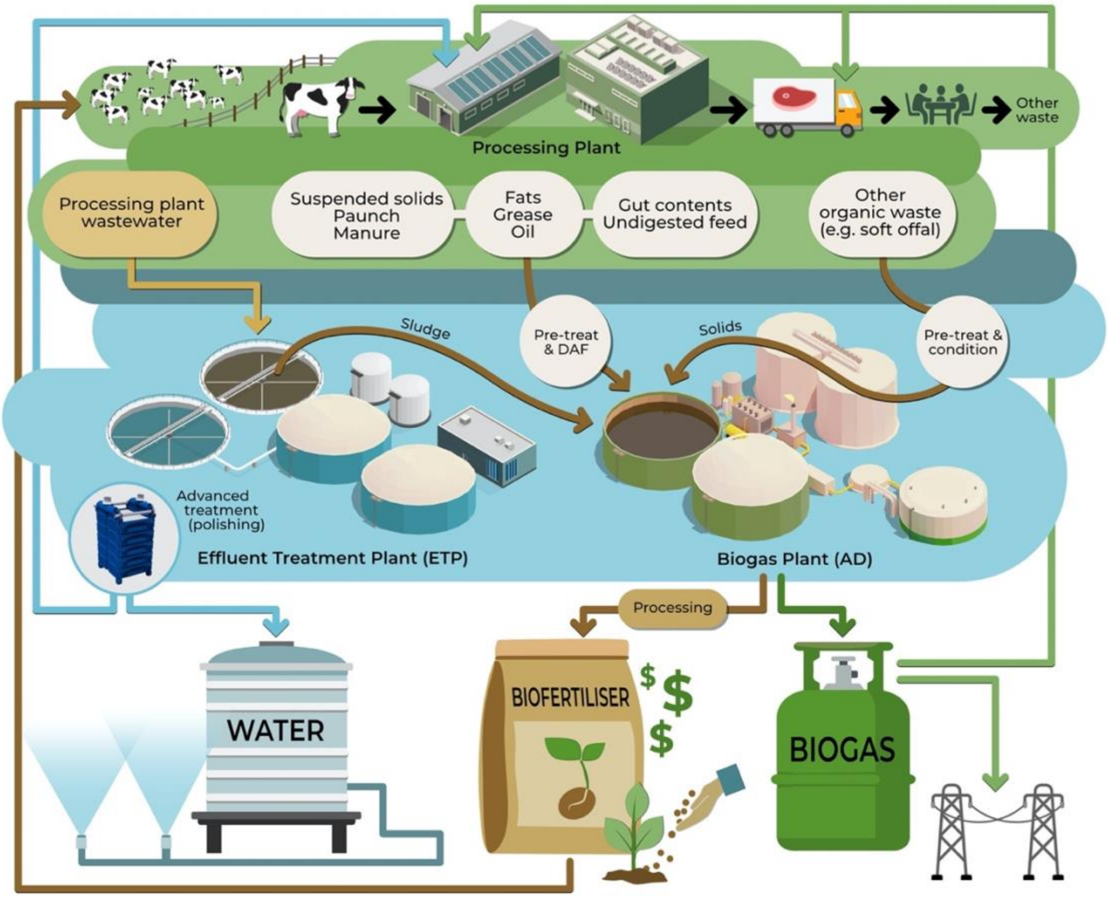

Figure 1. Schematic Diagram of the Integrated System, or Bio-resource Recovery Facility Used as a Basis for the Digital Tool Development, Based on Circular Economy Principles

The digital tool involved a comprehensive understanding of the unmet needs of the Australian red meat industry and involved an extensive collaborative effort between the processing plants, AMPC and the consultant. The integration of the wastewater treatment plant with a biogas plant, to process red meat wastewater and organic solid wastes, provides a unique opportunity to produce high-quality water with recycling potential and organic solid waste processing on-site, while producing energy in form of biogas (potential for conversion into electricity or heat) and fertiliser in form of digestate or even further improved high-value fertiliser products.

The developed digital tool for preliminary sizing and economic evaluation of an integrated resource management facility enables the easy assessment of best practices and possible outcomes for different scales of processing plants, provides adequate waste management practices and creates an innovative approach for recovering resources in the industry.

The model allows for different inputs as drivers depending on the operational requirements and focuses on the outputs in terms of costs, level of complexity, return on investment and carbon offsetting opportunities. The digital tool was validated using real case studies from operating plants and considered Australian conditions (climate, regulatory barriers, etc.).

The digital tool contributes to closing the gap in the red meat industry on the path to achieving net-zero carbon, as well as robust environmental compliance via a bio-resource recovery approach, underpinned by Circular Economy principles.

2 Introduction

The Australian red meat processing sector has traditionally operated under an environmental regulatory framework focused on controlling the emissions of organic matter and suspended solids to the environment. More recently, the increasing pressure on environmental conservation resulted in the review of legislation in many states. Most of the meat processing facilities in Australia are in the process of adapting their traditional environmental practices to comply with the new regulatory demands. The main concerns reside around the removal of nutrients (N and P), disposal of treated effluent during wet months and adequate management of organic solid wastes. The Digital Tool aims to serve as the initial step in the transition from the current linear wastewater management model into a more integrated and circular way of approaching it.

These changes impact production costs and result in the need for more technical, skilled labour to manage the waste streams. The old pond systems implemented in most of the facilities are no longer able to comply long-term with increasingly stricter standards. In this context, more efficient and well-engineered technologies will have to be adopted, replacing the traditional passive systems. The national and global trends in the industry point to water reuse, recovery of value from wastes (biogas, fertilisers) and a more circular way to manage liquid and solid streams. This approach has been standard in Europe for 3 decades and is a proven concept, and this digital tool consists of an effort to translate this to Australian reality and test its viability on small, medium, and large scales.

Red meat processing wastewater is a rich source of valuable nutrients, energy and water. When appropriately managed, and combined with selected streams of organic wastes, optimised anaerobic digestion and resource recovery can be achieved, along with robust environmental compliance. Implementing the integrated concept to wastewater and waste management will future-proof companies' operations in terms of environmental compliance, aligned with the concepts of circular economy and resource recovery. This is also contributing to the Australian red meat and livestock industry's ambitious target to be Carbon Neutral by 2030 (CN30), and will bring Australian red meat processing facilities to the forefront of the industry, as a model to be implemented globally.

The concept design proposed for this model has taken into consideration the production of recycled water compliant with medium and high exposure quality, and the production of biogas and fertiliser from mixed solid waste streams. The integration process, along with resource recovery and combining the treatment of both solid and liquid streams, is an innovative concept in the Australian red meat industry which will result in positive environmental, economic, and social outcomes.

Liquid streams will be processed in the modular wastewater treatment plant, aiming to remove oil & grease, solids and organic matter, nitrogen, phosphorous and pathogens. For the technology selection, recovery of recycled water was primarily considered. This is possible using a combination of secondary/tertiary and advanced water treatment technologies, allowing for alternative end-users for the treated water.

Selected solid waste streams, including paunch, save all screened solids, manure, sludge, and fat from the WWTP, will be processed in an anaerobic digester (AD), aiming to produce biogas and bio-fertiliser. The plant will allow for flexibility of solid and liquid waste received and pre-treatment (to achieve an adequate mixing ratio), consequently yielding higher methane and offsetting energy/gas consumption from the WWTP. The diagram in Figure 2 summarises the sustainability outcomes based on the 3 pillars: Environmental, Social and Economic.

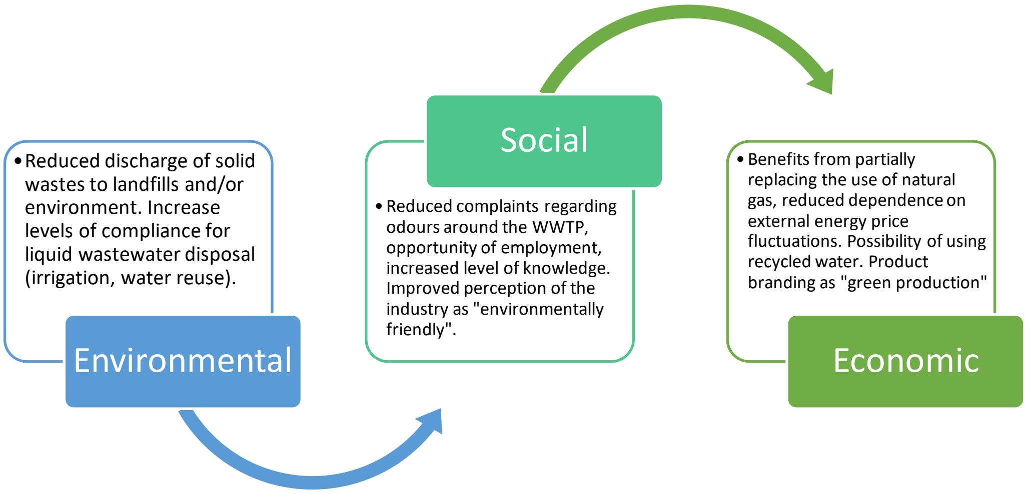

Figure 2. Sustainability Outcomes are Based on the 3 Pillars: Environmental, Social and Economic.

In this context, the digital tool involved a comprehensive understanding of the unmet needs of the Australian red meat industry and involved an extensive collaborative effort between the processing plants, AMPC and the consultant. The integration of the wastewater treatment plant with a biogas plant, to process red meat wastewater and organic solid wastes, provides a unique opportunity to produce high-quality water with recycling potential and organic solid waste processing on-site, while producing energy in the form of biogas (potential for conversion into electricity or heat) and fertiliser in form of digestate or even further improved high-value fertiliser products.

The developed digital tool for preliminary sizing and economic evaluation of an integrated resource management facility enables the easy assessment of best practices and possible outcomes for different scales of red meat processors, provides adequate waste management practices and creates an innovative approach for recovering resources in the industry. The model allows for different inputs as drivers depending on the operational requirements and focuses on the outputs in terms of costs, level of complexity, return on investment and carbon offsetting opportunities. The digital tool was validated using real case studies from operating red meat processors and considered Australian conditions.

3 Project Objectives

The key objective of the project is to develop a digital tool for the design of an integrated wastewater treatment & biogas plant for managing red meat processing plants' wastewater and organic solid waste, considering three different scales: small, medium and large. The desired long-term outcomes include:

- Development of a digital application for AMPC membership use, with 135 red meat processing plants. A total of seven cases were selected, increasing the sampling representativeness
- Wastewater treatment selection in an EOI process for demonstration and testing
- Increased environmental compliance via reduction of the adverse effects of nutrient emissions on the environment, reduction of wastewater discharge to the environment and of waste delivered to landfills
- Reduction of the overall carbon footprint via bio-energy production using organic wastes
- Provision of a tool for decision-makers to identify and select the most appropriate technical pathway according to the scale of their operations

4 Methodology

This project focused on the development of a digital tool for preliminary sizing and economic evaluation of an integrated bio-resource recovery facility, based on the concept of turning wastewater treatment facilities for red meat processing plants into resource recovery plants. The Digital Tool focused on increased environmental compliance and reduction of overall carbon footprint, achieved via reduction of nutrient emissions, wastewater recycling, minimisation of waste diverted to landfill and biogas energy production. The framework for the development of the digital tool considered aspects such as the scale and urgency of Environmental Protection Authority (EPA) and Department of Water and Environmental Regulation (DWER) wastewater issues for Australian red meat processors and adaptability for various sizes of red meat processing plants.

The initial phase of the Digital Tool development, from Milestones 1 to 4, includes assessments of literature and legislation, preparation of an “expression of interest” (EOI) and submission for interested participants, evaluation and selection phases, and data collection from selected participant industries. A total of seven participants were selected, and, during the data collection stages (Milestone 4) these participants provided the necessary information for the Digital Tool development, such as:

- Water consumption and type of uses
- Raw wastewater characteristics and production as well as current issues
- Energy consumption and source
- Solid wastes production, and
- Expansion plans

The data was cross-checked and validated with relevant literature (AMPC, 2021, Ware and Power, 2016). In the subsequent stages of the project, the data collected from seven real-case studies of red meat processing plants (red meat processors) across Australia, was used for the development of the Digital Tool.

Milestones 5 to 7 have been carried out using excel spreadsheets and requirements for the Biological Nutrient Removal (BNR) process were the main criteria used for equipment sizing (Metcalf & Eddy, 2013). Calculations were also developed for ancillary equipment during the development of the concept design of small to large-scale facilities. The selection of the technology/system planned for the treatment of liquid and solid organic streams from the processing plants was driven by (i) maximising recovery of high-quality treated water (in compliance with environmental discharge targets); (ii) recovering energy from carbon-rich organic streams and (iii) producing commercial bio-based fertilisers.

In Milestone 8, the previously developed concept design was built into Envirosim’s BioWin 6.2 environment and was used to validate the process design. The BioWin model was also used to perform sensitivity analysis (evaluation of the plant performance with varying effluent flow rates vs loads). The simulations were first run for five of the selected cases and subsequently run for five facilities of varying sizes. In order to check the robustness of the system, three effluent strengths have also been tested.

Concept level cost estimates, within +/-30% accuracy, were developed for each case in the Milestone 9 report. Besides the cost estimate, economic analysis was performed using the Net Present Value method, in which capital expenditure (CAPEX), operating costs (OPEX), and potential sources of revenue including recycled water, energy (from biogas), biofertiliser (biochar, from processed digestate), savings on waste disposal, and carbon credit offsets were considered to estimate the Return on Investment and Payback Period.

The concept drawings developed during the design stages were 3D modelled, using CAD software, and a full model (wastewater treatment, biogas and biofertiliser plants) for the Integrated *Bio-resource Recovery Facility* was created for use in the digital tool. This was the subject of the Milestone 10 report.

For Milestone 11, an excel spreadsheet of the full concept design was prepared and used as the basis for the Digital Tool, including calculations of individual cases. Using this spreadsheet, several cases were tested and inputs and outputs of modelled cases, ranging from 6,000 to 210,000 t.HSCW per year (for different effluent strengths), were compiled into a single excel spreadsheet, where a Macro tool was developed. The macro contains three worksheets: (i) input screen; (ii) reference table, and (iii) results. The input screen contains the parameters required to calculate lifecycle costs. These include income, capital revenue, and other financial parameters, such as tax and nominal discount rates. The reference table contains information for each combination of 'Maximum Annual Weight' and 'Strength'. The parameters in use currently are Recycled Water; Biogas; Biochar; Landfill Disposal; Carbon Credits; Capex WWTP; Capex Biogas; and Capex Biochar. After executing the macro (pressing the button "Generate Results" in the 'Input Screen'), the results are displayed in the 'Results' sheet. The order of the columns is as follows: Inputs; Outputs; Income Results; Financial Variables; Capex; Opex; and Cash Flow.

4.1 BioWin Sensitivity Analysis

A total of 15 BioWin simulations were performed for the medium and large-scale systems (five cases), aiming to test the robustness of the designed system when facing loading changes. The sizing was performed based on the "Moderate" strength, with subsequent validation of the system via BioWin modelling. Then, for each case, two additional scenarios changing the effluent to Low and High strengths, were tested on BioWin, while keeping the initial wastewater treatment plant sizing.

The steps adopted in the simulations were:

- Design flow rates, based on wastewater currently produced at the facility
- Preliminary sizing, design of the system using excel spreadsheet and moderate effluent strength
- The input of preliminary sizing to Biowin for validation of the WWTP design
- Additional validation of the model for low and high effluent strength

The highest water quality (high-risk water reuse scenario) was considered as the target parameter for the model evaluation. After simulation, the model was validated for all cases using current flow rates and testing different flow strengths. To validate the designed wastewater treatment plant, the result was compared to target parameters. All the simulations have presented results inside the targeted treated effluent parameters.

4.2 Online Platform

In Milestone 12, the Macro excel spreadsheet was used for conversion and codification of the results into a digital online format (webpage with a functional calculator). The code includes the base/background information for the digital tool calculator. The digital tool calculator (the subject of this milestone) was developed in a website format with a user-friendly interface. The Digital Tool allows the user to input specific information from their processing plant and performs a rapid assessment of inputs and outputs. The Digital Tool includes the following pages:

- Dashboard
- Company details
- Wastewater Quality
- Sources of Revenue
    - Output Screen 1 - System Classification
    - Output Screen 2 - Resource Recovery
    - Output Screen 3 - Cost
    - Output Screen 4 - Economic Analysis

- Generate Report

Individualised plant assessments, using the Digital Tool and supported by wastewater characterisation and plant situational conditions (i.e. throughput), were performed for each of the seven participants. These assessments aimed to demonstrate how the tool can be used to support an accelerated design outcome.

5 Project Outcomes

5.1 Case Studies Assessment

The Digital Tool was developed based on data collected from seven anonymous real-case studies of red meat processing plants across Australia (Table 1) and validated with literature data (AMPC, 2021, Ware and Power, 2016).

Table 1. Case Studies Used as a Basis for the Digital Tool Development

Case	Animal Type	Capacity (tHSCW/year)
1	Cattle	88,490
2	Sheep/Cattle	25,500
3	Cattle	58,708
4	Lamb/Sheep	16,200
5	Lamb/Sheep	77,740
6	Lamb/Sheep	47,000
7	Lamb/Sheep + Cattle	47,000

[1] *tHSCW = tonne of hot standard carcase weight*

The technology selection was driven by (i) maximising recovery of high-quality treated water (in compliance with environmental discharge targets); (ii) recovering energy from carbon-rich organic streams and (iii) production of commercial bio-based fertiliser.

The concept design was developed using excel spreadsheets and Biological Nutrient Removal (BNR) process calculations (Metcalf & Eddy, 2013) for equipment sizing and ancillary calculations. Envirosim's BioWin 6.2 was used to validate process design and perform sensitivity analysis (evaluation of the plant performance varying effluent flow rates vs loads), represented in Figure 3.

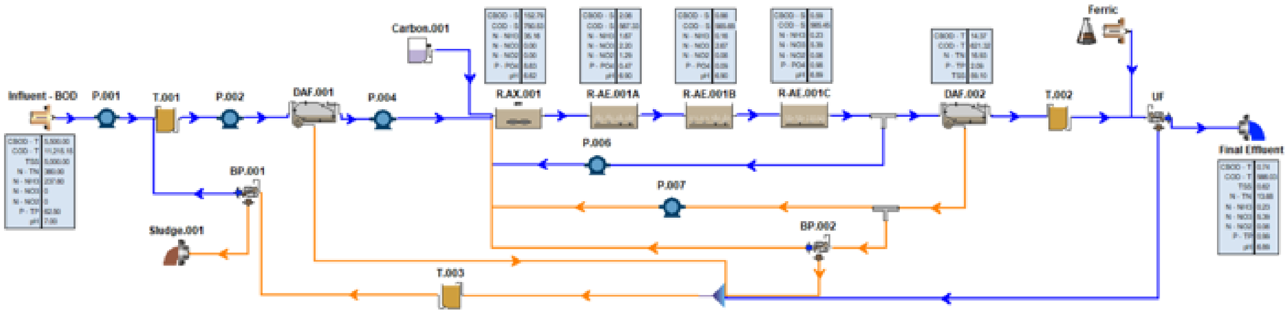

Figure 3. Biowin Model Schematic and Outputs, Red Meat Industry Wastewater

Concept level cost estimates were developed for each case. The economic analysis, using the Net Present Value method, considered the +/-30% capital expenditure (CAPEX) and operating costs (OPEX). The incomes considered in the analysis included recycled water, energy (from biogas), biofertiliser (biochar, from processed digestate), savings on waste disposal, and carbon credits offset (Figure 4).

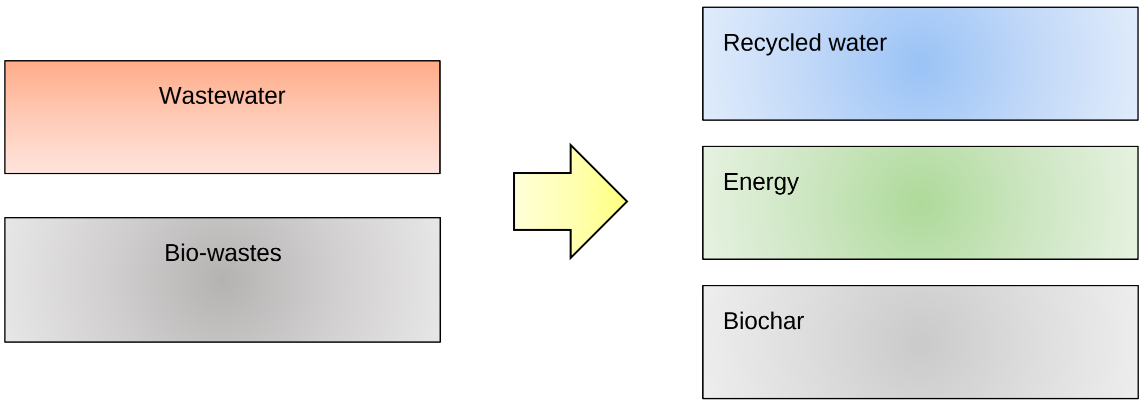

Figure 4. Inputs and Outputs of the Bio-resource Recovery Facility, Red Meat Industry

Individualised plant assessments, using the Digital Tool and supported by wastewater characterisation and plant situational conditions (i.e., species, throughput, climatic), were performed for each of the seven participants. These assessments aimed to demonstrate how the tool can be used to support an accelerated design outcome.

There is an option built into the digital tool allowing for calculating the outputs either based on the default wastewater characteristics established for the industry (organic and nutrient loadings), volume flows and situational data or allowing the user to enter their values. The default wastewater quality was based on average values for the case studies and Australian industry averages (AMPC, 2021), divided into three different strengths: Low, Moderate, and High. The outputs of the modelling served as inputs for creating an online digital tool, that will be made available online for members of the Australian Meat Processing Corporation (AMPC).

The assessed processing facilities were classified into Small, Medium and Large based on their production capacity, wastewater production, and their wastewater strength into “Low, Moderate and High” strength, as summarised in Table 2.

Table 2. Processing Plants Classification According to Size (S, M, L) and Strength (L, M, H)

	SMALL	MEDIUM	LARGE
LOW	-	CASE 7	-
MODERATE	CASE 4	CASE 5	CASE 3
HIGH	CASE 2	CASE 6	CASE 1

Based on the selected case studies, the volume of wastewater produced by the processing facilities varied from 143 to 2,000 kL/ day, as shown in Table 3.

Table 3. Average WWTP Flows Resulting from the Assessment of the Case

Case	Daily Flow	Annual Flow kL/year	Intensity kL/tHSCW
1	1,680	613,200	10.5
2	249	91,000	6.5
3	2,000	730,000	14.4
4	143	52,195	2.6
5	366	133,590	2.4
6	531	193,640	7.9
7	906	330,690	8.1

The collected data allowed the classification of the facilities in terms of flow (Small, Medium and Large), and its distribution is presented in Table 4:

Table 4. Classification of Scale Based on Wastewater Production Ranges

SMALL	MEDIUM	LARGE
< 750 kL/d	750 – 1,500 kL/d	>1,500 kL/d

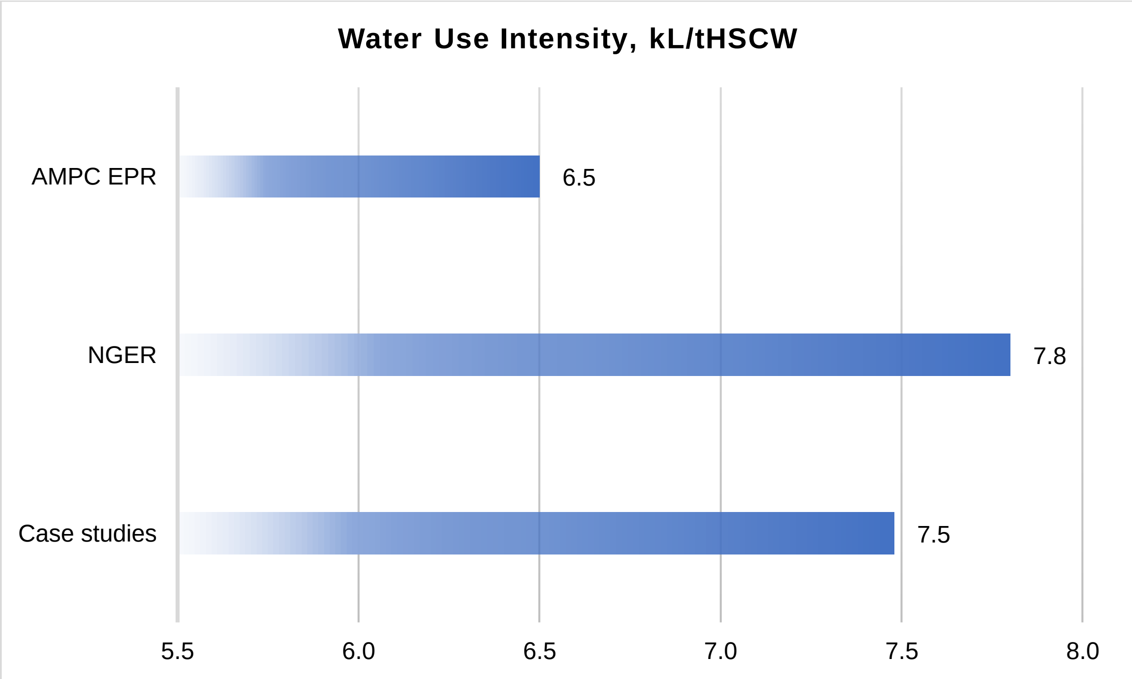

Figure 5. Wastewater Production Per Tonne of Hot Standard Carcase Weight (kL/tHSCW), Compared to the Industry. NGER (2021); AMPC (2021)

Although the average obtained for all cases is inside the national water consumption range if considering the individual scenarios, the perspective is different. Most of the individual results of water consumption intensity (shown in Table 3) have a relatively elevated water consumption intensity compared to recent national averages. Consequently, there are opportunities to further reduce water consumption (NRMMC, 2006), and therefore the design has included modular flexibility to adapt to future wastewater production. In case future expansion of the facility is made necessary, the increase of the treatment capacity of the plant and easy integration with the system in operation becomes feasible. Additionally, having parallel treatment trains also allows operational and maintenance flexibility.

5.1.1 Wastewater Quality

Wastewater originated from red meat processing is typically a rich source of energy, carbon, and nutrients (Jensen and Batstone 2012). The results showed that small facilities producing sheep/lamb tend to produce more concentrated wastewater streams compared to medium and large facilities with combined cattle and sheep/lamb production. A possible cause for this result is the efficiency of oil and grease separation at the source and lower water used during the process resulting in less dilution of the final effluent. Table 5 presents the average results of wastewater concentrations identified in the seven case studies.

Table 5. Wastewater Quality at the Assessed Red Meat Processing Plants (all results in mg/L)

Case	TSS, mg/L	BOD, mgO_2/L	COD, mgO_2/L	TN, mg/L	TP, mg/L
1	3,799	5,042	10,074	39.8	18.1
2	1,450	2,567	5,600	423.3	22.7
3	1,853	2,363	5,933	117.3	35.0

Case	TSS, mg/L	BOD, mgO_2/L	COD, mgO_2/L	TN, mg/L	TP, mg/L
4	2,310	4,931	10,113	325.0	48.0
5	7,278	4,990	12,941	550.3	64.6
6	4,656	4,844	15,744	356.7	60.3
7	713	1,733	4,300	313.3	48.3

Based on the collected data, the resulting classification (Low, Medium, Large) in terms of loads are distributed as presented in Table 6:

Table 6. Wastewater Quality at the Assessed Red Meat Processing Plants

Parameter	Unit	Low strength	Moderate Strength	High Strength
TSS	mg/L	< 1,350	1,350 – 5,000	> 5,000
BOD	mg/L	< 1,500	1,500 – 5,500	> 5,500
COD	mg/L	< 3,064	3,064 – 11,215	> 11,215
TN	mg/L	< 180	180 – 360	> 360
TP	mg/L	< 35	35 – 62.5	> 62.5

5.1.2 Solid Waste Quantity and Characteristics

The solid stream of organic waste was estimated based on the Biomethane Potential (BMP) results from a previous project, PIP 2020-1030, and compared to literature data. For the sludge originating from the WWTP, it was considered the biological excess sludge from a BNR type of plant, and the sludge production originated from design calculations and BioWin modelling. Table 7 shows the organic solid streams considered for the Digital Tool.

Table 7. Organic Solid Streams Type and Quantities.

Parameter	kg/t.HSCW	Total Solids (TS%)	Proportion (%)
Combined Save-all	12	29	1.4
Sheep Paunch	23	18	2.7
Beef Paunch	32	19	3.7
Sheep Manure	9	75	1.0
Sludge from WWTP	791	7	91.2
Total	867	9	100

5.2 Concept Design Development

The concept design was developed based on an integrated facility for liquid and solid stream management (Appendix 1). In this concept, the liquid streams will be processed in the modular wastewater treatment plant (WWTP), aiming for the recovery of oil & grease, solids and organic matter, nitrogen, phosphorous and pathogens. The technology selection was based on maximising the recovery of recycled water, combined with optimised biogas production. This is possible using a sequence of secondary/tertiary and advanced water treatment technologies, allowing for unrestricted irrigation and other non-potable uses.

The core concepts of the WWTP process design include:

- High-efficiency pre-treatment, aiming to recover organic material for the biodigester and simultaneously offload the wastewater treatment process (hence requiring less energy for aeration)
- High efficiency modular biological nutrient removal (BNR), targeting high efficiency of Nitrogen removal
- No biogas recovery from liquid streams, preserving the Carbon for the denitrification step (eliminating the need for added carbon source)
- Chemical phosphorous precipitation, enabling very low TP concentrations, and effluent suitable for disposal on water bodies, if that is required
- High-efficiency ceramic membranes as a post-treatment after BNR system, producing clarified water
- Multi-barrier disinfection system to achieve log removals compatible with Class A water for recycling
- Management of all biodegradable solid streams using a Co-Digestion AD Plant, including sludge from saving all/primary DAF, manure, paunch, and waste sludge from the BNR process

In parallel, carbon-rich solid waste streams, including paunch, save all screened solids, manure, sludge, and fat from WWTP are diverted to an anaerobic digester (AD), aiming to produce biogas and bio-based fertiliser. This prevents the WWTP from being overloaded by BOD/COD, which could increase the aeration requirements, whilst still preserving sufficient carbon for the denitrification process to take place efficiently. This brings along opportunities to reduce costs by reducing aeration and external carbon requirements, and where possible, redirect carbon to energy-generating processes. The concept plant will allow for flexibility of solid and liquid waste receival and pre-treatment to achieve an adequate mixing ratio, consequently higher methane yield offsetting energy consumption by the WWTP.

From the process design and hydraulic calculations, an integrated Bio-resource recovery facility layout was developed. The process flow diagrams, and a General Arrangement and Plant Layout were created. Refer to Appendix 2, Concept Drawings:

- 2021-1142-MS15-DM-L-DW-001 for General Arrangement and Plant Layout
- 2021-1142-MS15-DM-L-DW-002 for Process Flow Diagram – WWTP
- 2021-1142-MS15-DM-L-DW-003 for Process Flow Diagram – Biogas & Biofertiliser

5.3 3D-Model Representations

The concept drawings of the Bio-resource Recovery Facility were converted into a 3D model and images were rendered into a high resolution for using in the Digital Tool. Refer to an example in Figure 6, and a full set of images in Appendix 3.

Figure 6. 3D Model of the Bio-Resource Recovery Facility, Including the Wastewater, Biogas and Biofertiliser Plants

5.4 BioWin Model Validation

The main purpose of the BioWin was to validate the robustness of the system to treat red meat processing plant effluent. The highest water quality (high-risk water reuse scenario) was considered the target parameter for the model evaluation. After simulation, the model was validated for all cases using current flow rates and testing different flow strengths Table 8.

Table 8. Final Treated Effluent Characteristics in Response to the 15 BioWin Scenarios Considering Low (L), Moderate (M), and High (H) Effluent Strengths

Outputs		Target	Case 1			Case 3			Case 5			Case 6			Case 7		
			L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
BOD	mgO_2/L	<10	0.7	0.7	0.8	0.7	0.7	0.8	0.7	0.8	0.8	0.7	0.7	0.8	0.7	0.7	0.8
TSS	mg/L	<10	0.2	0.6	1.1	0.2	0.6	1.0	0.2	0.6	1.0	0.2	0.6	1.0	0.2	0.6	1.0
TN	mg/L	<20	17.5	13.7	14.9	17.5	13.7	19.3	15.8	13.2	18.6	17.5	13.6	19.2	17.5	13.7	19.3
TP	mg/L	<1.5	5.0	1.0	1.0	5.0	1.0	0.2	6.3	0.6	0.1	5.0	1.0	0.2	5.0	1.0	0.2
pH	pH units	6 - 8	6.3	6.9	7.2	6.3	6.9	7.2	6.3	6.9	7.2	6.3	6.9	7.2	6.3	6.9	7.2

The process showed robustness coping with variation in the effluent loads. The conclusion is that the designed system can cope with temporary variations of load. In practicality, the use of equalisation tanks can help to homogenise effluent load variations. Additionally, the process configuration allows for operational flexibility to change recirculation flow rates, aeration settings, chemical dosing (when necessary), excess sludge purge; optimising the process based on the incoming wastewater to achieve the required recycled water quality target parameters.

Assumptions:

- External Carbon source might be necessary to achieve effluent quality target parameters, especially for TN, depending on flow variations and characteristics of the real wastewater
- Adopted input parameters for low, moderate and high strength effluents, present adequate ratios C:N ratios
- Ferric dosing might be necessary, in some cases, to achieve the TP removal required

5.5 Economic Analysis

The economic analysis outcomes show a net positive over 25 years' total project life. The payback time is estimated to be from 5 - 10 years, with an annual ROI of 2 – 5% depending on the scale and location of the facility. Cost estimate curves were calibrated with literature data (Guo et. al., 2014; Jalab et. al., 2019). The financial inputs will be updated in the model on a regular basis going forward.

Results show that as the production scale increases, the present value of total expenditure (TOTEX), composed of CAPEX + OPEX, gets more efficient. It is important to highlight these curves are based on a combination of five points of cost estimates done in 2021 and adjusted to scale up and down by modelling based on literature data.

5.6 Digital Tool

A compilation of the results of the design and cost estimates has been used as a background for the digital tool. An excel spreadsheet developed with Macro was used to vary several inputs, including throughput capacity, years selected for the plant implementation, current costs of revenues, economic factors affecting the NPV calculation, and others. The Macro excel spreadsheet has been codified in Java and a user-friendly webpage was created for online use of the digital tool. Figure 7 shows the first page of the Digital Tool (Ready Reckoner Dashboard), where the user can obtain a quick assessment of the feasibility of the system implementation by dragging the arrow (changing the annual throughput of the system).

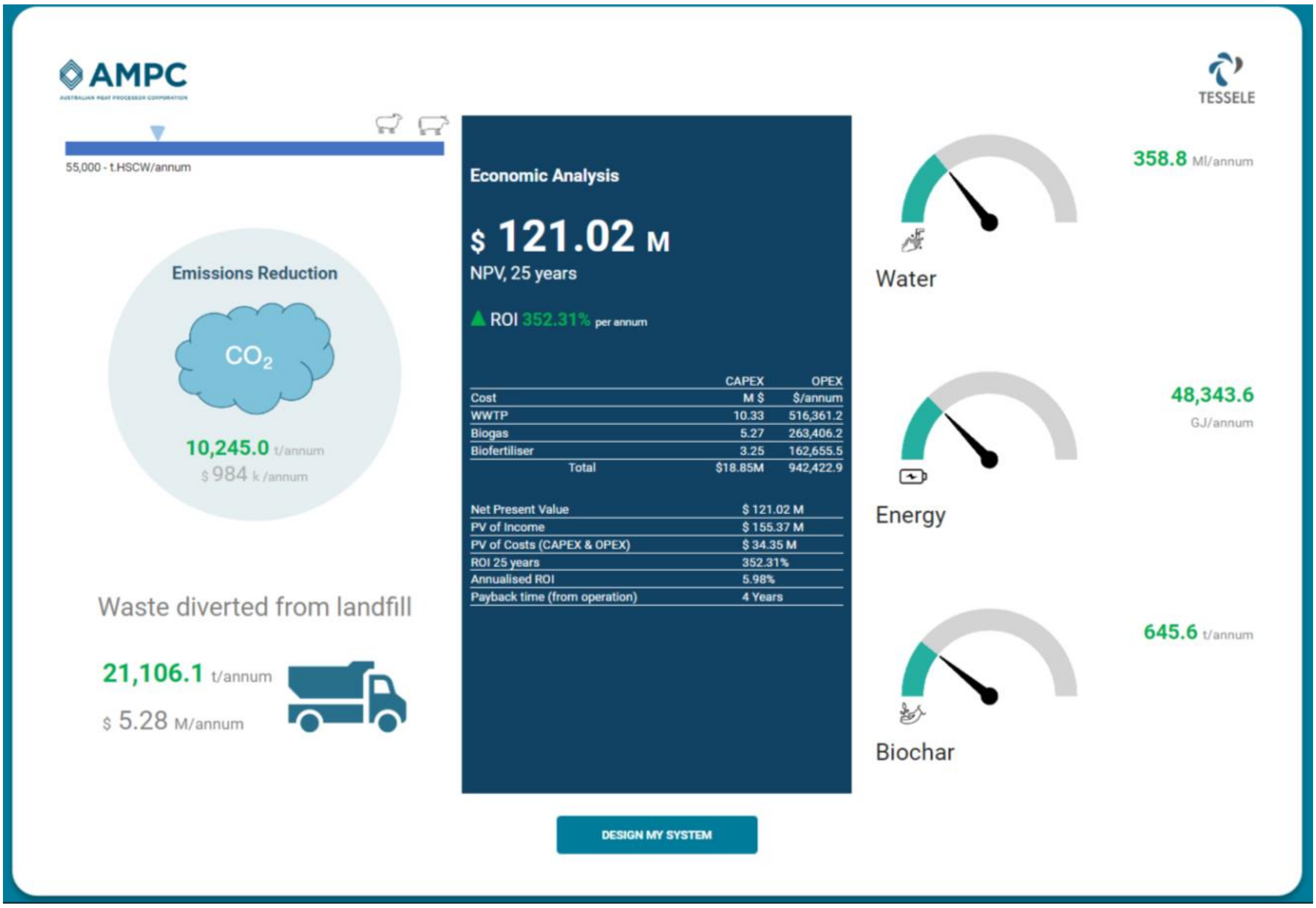

Figure 7. Dashboard Page of the Digital Tool

The link to the digital tool is:

https://vm7.uat01.oneit.com.au/tessele/ng/#/bio-resource-planner

5.6.1 User Guidelines

A Manual including the step-by-step guidelines to use of the Digital Tool was developed. Refer to Appendix 4.

5.7 Webinar

The Webinar was presented online and was divided into two parts: (i) background information about the Digital Tool's purpose and development; (ii) live use of the tool for the users.

6 Discussion

The Digital Tool was developed on an online platform and is user-friendly. Based on the throughput, wastewater quality and sources of revenue (values), the tool can produce a report with outputs with the type of system that is adequate for managing wastewater and solid waste from red meat processing facilities. It also provides the economic outputs of the system. A useful feature is that by providing information on the type of system to be implemented, it also becomes an educative resource for the whole sector - presenting an alternative solution for adequate wastewater and solid waste management, compliant with existing and stricter environmental regulations.

Since the tool is used as an indicative assessment of the type of system for processing wastewater and solid waste (considered resources), the information modelled and presented in the summary report is not a definitive answer. For example, equipment prices and implementation costs are based on standard cases without inferences from a brownfield site. For an accurate and definitive answer, each individual facility must progress with an individual assessment with specialised professionals.

One of its features, from the administrator's perspective, is the possibility of updating background parameters periodically; making sure the tool is always updated and will operate according to current market conditions.

In the decision-making process, regarding the implementation/upgrade (or not), of water and wastewater management systems, the Digital Tool is shown to be a way of producing a rapid assessment of the economic feasibility of the project, accelerating the internal decision-making process.

Currently, with stricter regulations in terms of wastewater disposal and increased costs associated with solid waste disposal, the optimisation of any existing resource is crucial for the sustainable growth of the red meat industry. The Digital Tool assists with accelerated decision-making for process implementation. The sooner the integrated bio-resource recovery facilities are implemented, the sooner the income generated from the by-products will be received, making the system net positive. Additionally, the impact on the carbon chain and reduction of carbon emissions will contribute to the Australian red meat industry’s ability to achieve the existing goal of Carbon Neutrality by 2030.

7 Conclusions / Recommendations

The Digital Tool involved a comprehensive understanding of the unmet needs of the Australian red meat industry and involved an extensive collaborative effort between the processing plants, AMPC and the consultant. The integration of the wastewater treatment plant with a biogas plant, to process red meat wastewater and organic solid wastes, provides a unique opportunity to produce high-quality water with recycling potential and organic solid waste processing on-site, while producing energy in the form of biogas (potential for conversion into electricity or heat) and fertiliser in form of digestate or even further improved high-value fertiliser products.

The developed Digital Tool for preliminary sizing and economic evaluation of an integrated resource management facility enables the easy assessment of best practices and possible outcomes for different scales of red meat processors, provides adequate waste management practices and creates an innovative approach for recovering resources in the industry.

The model allows for different inputs as drivers depending on the operational requirements and focuses on the outputs in terms of costs, level of complexity, return on investment and carbon offsetting opportunities. The Digital Tool was validated using real case studies from operating processing plants and considered Australian conditions (climate, regulation barriers, etc.).

The digital tool contributes to closing the gap in the red meat industry on the path to achieving net-zero carbon, as well as robust environmental compliance via a bio-resource recovery approach, underpinned by Circular Economy principles.

The Digital Tool went live in July 2022. In parallel, the first full-scale model of a bio-resource recovery centre is going through engineering design stages and will provide more accurate information to feed back into the model, once operational. The implementation will include a rigorous peer-review process and detailed market analysis on the offtake of products and revenue streams (water, biochar, energy).

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9 Appendices

9.1 Appendix 1 - Wastewater facility concept

Please see attached files:

- A1a Tessele_AMPC.jpg
- A1b Tessele_AMPC.pdf
- A1c Tessele_AMPC.tiff

9.2 Appendix 2 - Drawings

Please see attached files:

- A2c 2021-1142-MS15-DM-L-DW-003 for Process Flow Diagram – Biogas.pdf
- A2b 2021-1142-MS15-DM-L-DW-002 for Process Flow Diagram – WWTP.pdf
- A2a 2021-1142-MS15-DM-L-DW-001 for General Arrangement and Plant Layout.pdf

9.3 Appendix 3 – 3D Model

Please see attached files:

- A3a System Classification-.png
- A3b Resource Recovery.png
- A3c Cost.png
- A3d Economic Analysis.png

9.4 Appendix 4 – Digital Tool Manual

- A4 2021-1142 MS15 Final Report | Digital Tool User Guidelines.pdf