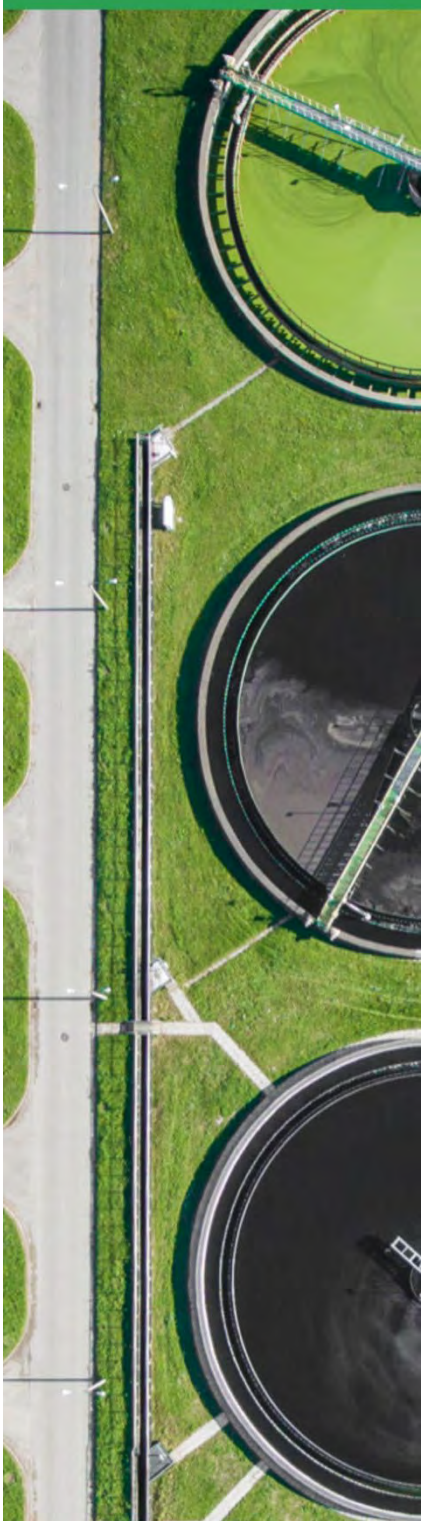

Transforming Biosolids

Biosolids Transformation Technology Assessment (BTTAS): A Systematic Approach Involving Selection Criteria and Benchmarking based Analysis

(Project 1B)

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About the Centre

The ARC Training Centre for the Transformation of Australia's Biosolids Resource has a primary goal of delivering world-class and innovative technological solutions and knowledge, to train the next generation of biosolids practitioners in cutting-edge, transformational approaches, and to guide best practice in the biosolids sector.

About the Project

A key project delivered by the Centre through Project 1B is the Biosolids Transformation Technology Assessment (BTTAS): A systematic approach involving selection criteria and benchmarking based analysis. Project 1B focuses on assessing and comparing processes such as pyrolysis, gasification, and hydrothermal liquefaction, with the objective of assisting water utilities in selecting suitable thermal technologies. The evaluation includes mass and energy balance analyses, comparison of different reactor designs, and high-level techno-economic assessments. A key innovation of the project is the development of the Biosolids Transformation Technology Assessment (BTTAS) tool.

For further information visit: www.transformingbiosolids.com.au

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Contents

1. Executive Summary

This report presents the progress and outcomes of the project titled "Enhancing Resource Recovery through Thermal/Hydrothermal Processing of Biosolids" under the ARC Training Centre. The project addresses critical gaps in biosolids management, focusing on sustainable and value-generating thermal and hydrothermal treatment technologies.

The central outcome is the development of the Biosolids Transformation Technology Assessment (BTTAS) tool. This tool integrates scientific, economic, and regulatory data into a user-friendly Excel/Visual Basic for Applications (VBA) platform. Its development was informed by two comprehensive literature review reports, original experimental data, correlation derivation from more than 200 scientific journals, and extensive stakeholder engagement. The BTTAS tool supports evidence-based decision-making in the selection and integration of biosolids transformation technologies.

BTTAS is built in Excel/VBA to ensure accessibility and ease of use for end-users in the water industry. It integrates:

- **Mass and energy balance models** for pyrolysis, gasification, hydrothermal liquefaction, hydrothermal carbonisation and hydrothermal gasification.
- **Economic parameters** including capital and operational expenditure, and revenue from energy recovery.
- **Environmental considerations** such as greenhouse gas emissions (Part of project 3B).
- **EPA compliance benchmarks** for various treatment outcomes.

The tool includes two advanced modules:

- **BTTAS-SC (Selection Criteria)** module that allows users to filter technologies based on a customizable set of performance indicators.
- **BTTAS-BM (Benchmarking Module)** which performs high-level performance evaluation to assist in strategic planning.

2. Background and Industry Context

Biosolids, a byproduct of wastewater treatment, are rich in nutrients but often contain contaminants like heavy metals, PFAS, microplastics, and pathogens. Traditional disposal methods pose environmental and economic challenges. The Australian water industry is increasingly seeking advanced, sustainable options to manage and valorise biosolids.

Thermal and hydrothermal processes, including pyrolysis, gasification, hydrothermal liquefaction, hydrothermal carbonisation and hydrothermal gasification, offer promising pathways by reducing volume, transforming waste into value-added products (e.g., biochar, syngas), and minimizing environmental impact. Despite this, widespread implementation has been limited due to gaps in understanding of process integration, performance benchmarking, regulatory implications, and commercial viability.

3. Project Aim and Specific Objectives

Project Aim: To develop and benchmark a robust, adaptable, and scientifically grounded tool (BTTAS) for evaluating thermal/hydrothermal treatment technologies suitable for Australian biosolids.

Specific Objectives:

- Conduct literature reviews to understand the state-of-the-art in thermal and hydrothermal biosolids transformation.
- Derive mass and energy balance correlations from simulation, literature, and experimental data.
- Assess the effect of reactor designs and configurations on product yield and quality.
- Integrate techno-economic models to evaluate OPEX, CAPEX, and techno-economic feasibility.
- Engage with regulatory bodies to align tool outputs with EPA compliance requirements.
- Provide technical, scalable solutions for regional and urban water utilities.

4. Methodology: Development of BTTAS Tool

Literature Reviews

Two in-depth reviews were undertaken:

- **Review 1:** Thermal treatment technologies (pyrolysis, gasification) and their integration potential in wastewater systems.
- **Review 2:** Fate and behaviour of contaminants like PFAS, heavy metals, and microplastics during thermal treatment.

These reviews informed the tool structure, process modeling, and emissions estimation logic.

Development of Mass and Energy Balance Correlations

Correlations were derived using:

- Peer-reviewed studies and industrial case reports.
- In-house laboratory testing where data gaps existed.

Example correlations include:

- Energy required for drying biosolids as a function of moisture content.
- Calorific value estimation based on ash and volatile matter proportions.
- Ultimate data analysis (C, H, O, N, S and Ash) estimation for product based on literature data.
- Gas, liquid, and solid product yield as a function of temperature, pressure and retention time.

Process Technology Evaluation

Technologies evaluated:

- Pyrolysis
- Gasification
- Hydrothermal liquefaction, hydrothermal carbonisation and hydrothermal gasification

Design variables considered:

- Reactor type (fixed bed, fluidized bed, auger, multi-hearth and advanced technology)
- Operating temperature and pressure

Techno-Economic

- CAPEX and OPEX modelled from technology provider data and cost indices.

EPA Guidelines and CO_2 Estimation

Collaborations with EPA (VIC/NSW/QLD), and DWER WA have led to the development of practical guidelines for emissions, by-products, and end-use safety of biosolids-derived products.

Focus Areas:

- Heavy metal concentration limits
- PFAS and microplastics monitoring
- Gaseous emissions (NOx, SOx, CO_2)

A CO_2 estimator model is being refined in partnership with Project 3B, to offer site-specific GHG performance metrics for each thermal process.

5. Tool Structure: BTTAS Overview

BTTAS (Figure 1) is an Excel/VBA-based tool divided into:

- **End-User Input Module:** Biosolids characteristics, transformation goals, and product targets.
- **Developer Input Module:** Correlations for performance, cost, and environmental impact.
- **Output Module:** Technology ranking, benchmarking, EPA alignment, economic summaries.

Advanced modules include:

Selection Criteria (BTTAS-SC): Prioritizes technologies based on performance, costs, emissions, and scalability (See Figures 2 & 3).

Benchmarking Module (BTTAS-BM): Assesses high-level performance indicators across scenarios (See Figures 4, 5 & 6).

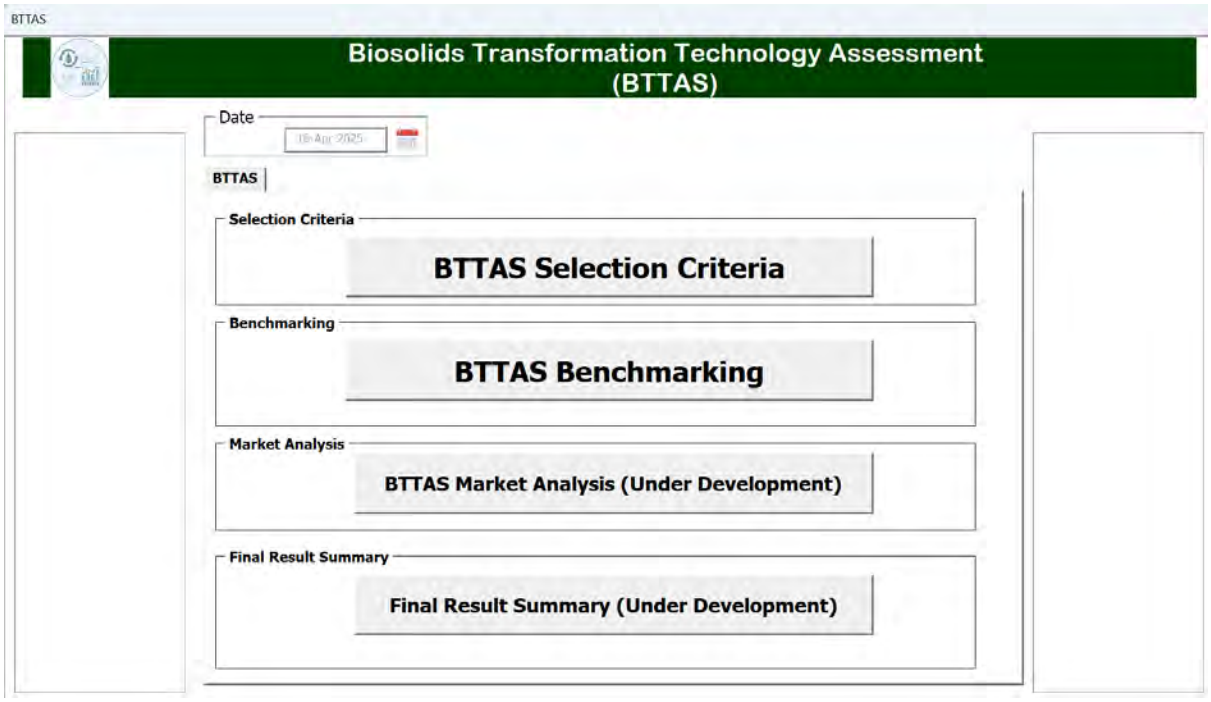

Figure 1. Skeleton of BTTAS tool

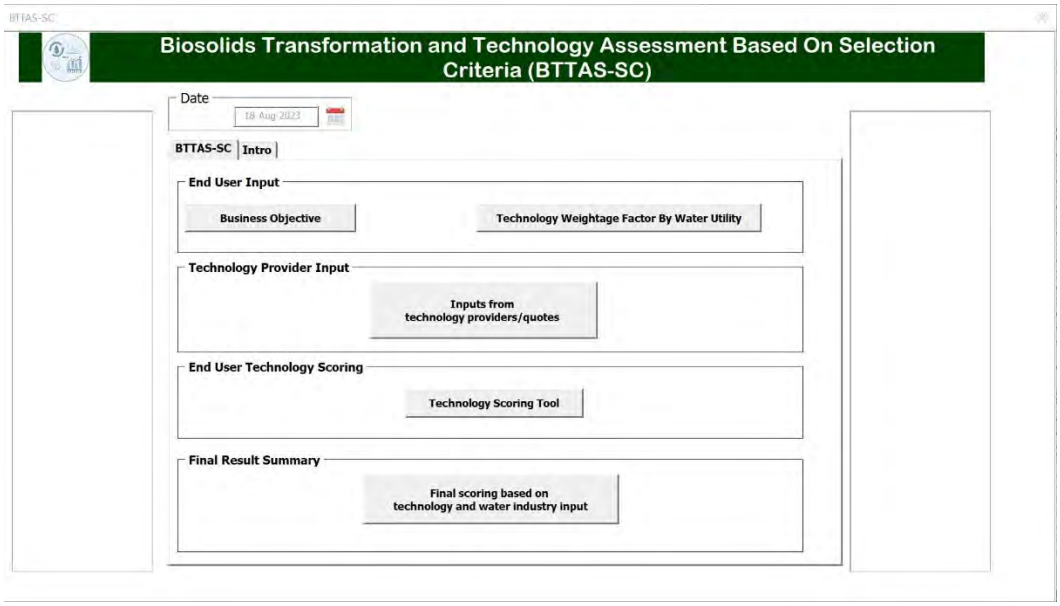

Figure 2. Skeleton of BTTAS SC tool

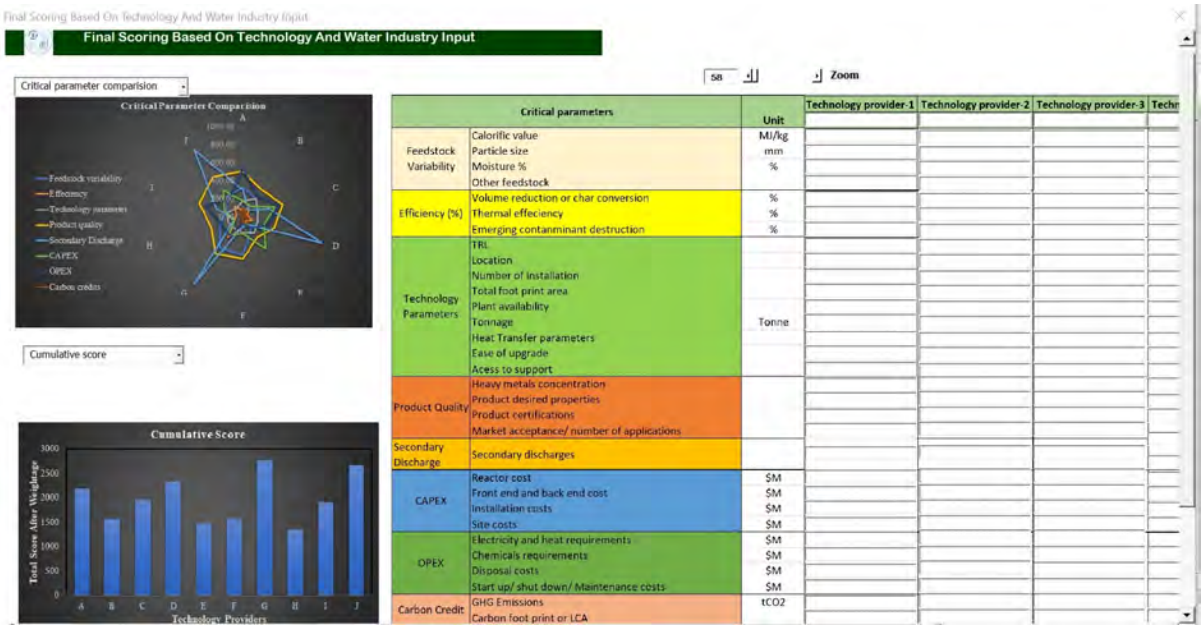

Figure 3. BTTAS-SC Tool Results as Qualitative Charts

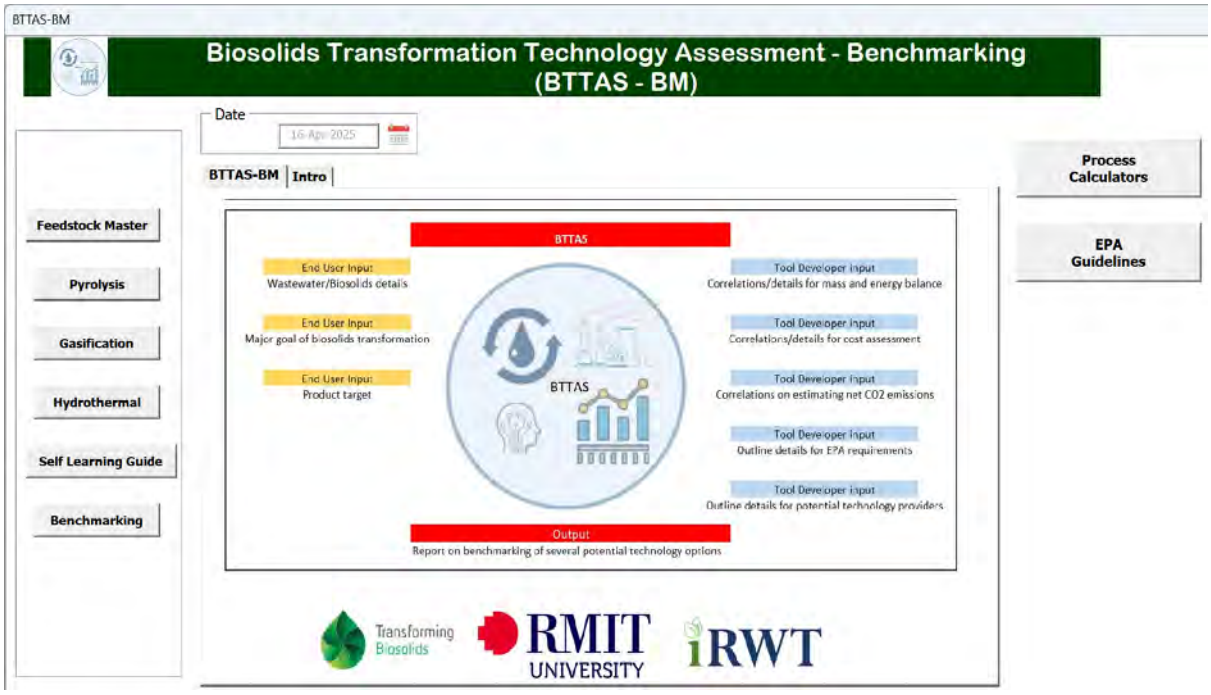

Figure 4. Skeleton of BTTAS BM tool

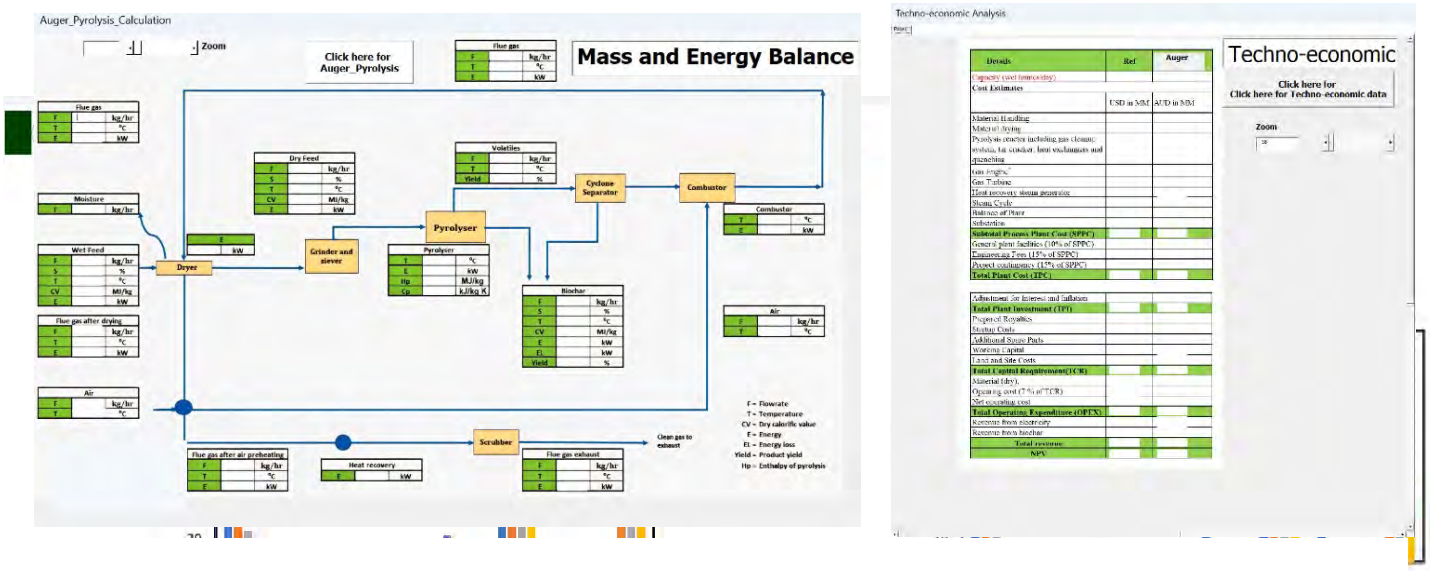

Figure 5. BTTAS-BM Tool Results as mass and energy balance and techno-economic

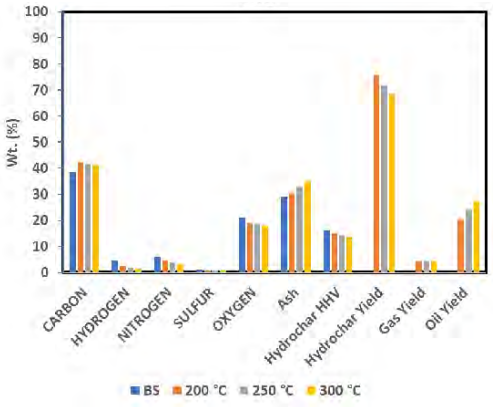

Figure 6. BTTAS-BM Tool Results as comparison of ultimate analysis, calorific value and product yield.

5. Benchmarking and Technology Evaluation

Technologies Benchmarked:

- Pyrolysis
- Gasification
- Hydrothermal liquefaction, hydrothermal carbonisation and hydrothermal gasification

Parameters Evaluated:

- Mass and Energy balance
- Product yield, Heating values and Ultimate analysis data (CHONS and Ash)
- Techno-economic (CAPEX,OPEX, Payback period etc…)
- Emissions and regulatory compliance

6. Research Progress and Achievements

BTTAS Tool Development:

The BTTAS tool has evolved to offer assistance in technology selection through a set of criteria termed BTTAS-SC (Selection criteria). Following the technology selection process, BTTAS-BM (Benchmarking) aids in benchmarking by evaluating high-level mass and energy balances alongside techno-economic assessments for pyrolysis, gasification and hydrothermal process.

Publications:

1. Current understanding on the transformation and fate of per- and polyfluoroalkyl substances before, during, and after thermal treatment of biosolids: A critical review.
   https://www.sciencedirect.com/science/article/pii/S1385894724040245
2. Thermal treatment options for biosolids management and potential for integration with anaerobic digestors: A critical review.
   Received final comments from UQ team as well as from Prof Kalpit Shah and currently working on comments.

7. Industry Engagement and Stakeholder Involvement

Key Partners:

- Melbourne Water, South East Water, Veolia, Water Corp, Urban Utilities, Water RA, EPA (VIC/VIC/QLD) Imperial College London

Engagement Activities:

- Site visits (e.g., Barwon Water, Greater Western Water)
- Demonstrations of BTTAS tool to FNQROC, TAS Water, Queensland Water Directorate
- Tool was presented to all Industry Partners during the 4th Annual Symposium for the ARC Transforming Biosolids Training Centre, Perth, September 2024.

8. Industry Impact and Benefits

Strategic Decision-Making:

Water utilities can use BTTAS to:

- Choose the best-fit transformation technology
- Evaluate cost and energy trade-offs
- Assess environmental and emissions impacts

Operational Efficiency:

- Process flowcharts and benchmarks enable seamless technology integration
- Utilities gain visibility into expected product yields, emissions, and return on investment
- Develop web-based version of BTTAS

9. Conclusion and Recommendations

Project 1B provides a robust platform for accelerating the transformation of biosolids management in Australia. The BTTAS tool enables data-driven technology selection and investment planning. As the tool evolves, continued collaboration between researchers, utilities, and regulators will ensure it meets industry needs and supports sustainable, circular outcomes in the biosolids sector.

Recommendations:

- Pilot the BTTAS tool with industry
- Extend tool for biological and hybrid processes