# Delivering the design for Australia's first biosolids gasification facility

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Project: Loganholme Wastewater Treatment Plant Gasification Facility Demonstration Project

## March 2022

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# Acknowledge and Disclaimer

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# 1. Abstract

The purpose of this report is to provide an overview of the design and delivery challenges in constructing the *Loganholme Wastewater Treatment Plant (WWTP) biosolids gasification facility*. The innovation in the gasification facility is using individually proven technologies and systems from different industries around the world and integrating it into a process that can be replicated by others water utilities.

A demonstration trial was undertaken in February 2021 that validated the concept and provided vital information to develop the design and interfaces. However, with innovation meant challenges such as process assumptions, performance requirements, compliance with various design codes, liaison with international and remote designers, and working in an environment of developing legislation and standards.

These design and delivery challenges are identified in this report to provide the knowledge in assisting future water utilities looking to incorporate Gasification into their biosolids management.

# 2. Introduction

## 2.1 Project Description

Logan City's largest wastewater treatment plant (WWTP) at Loganholme provides services to about 300,000 people. It produces 34,000 tonnes of biosolids each year, with six truckloads of biosolids transported 300km for disposal daily. This is a major operating cost for Logan Water; about $1.8 million per year or 30% of the total operating costs at Loganholme WWTP.

Biosolids treatment and disposal costs are increasing due to rising electricity prices, population growth and tightening of government regulations associated with the disposal of biosolids, carbon reduction and the management of persistent organic pollutants (POPs).

Following successful gasification trials at Loganholme Wastewater Treatment Plant in 2020, Logan Water has used the results and lessons learned to design and construct a full-scale gasification facility. The facility will be operational by April 2022.

The '*Loganholme Wastewater Treatment Plant Gasification Facility Demonstration Project*' will develop and build a gasification facility to treat biosolids at the Loganholme wastewater treatment plant (WWTP), located in Loganholme, Queensland. The gasification facility will process sludge dewatering, drying and gasification.

By developing and building a gasification facility, Logan Water will reduce the amount of biosolids requiring disposal by 90% and reduce the carbon footprint of the Loganholme WWTP. The gas produced by the facility will be utilised within the system as part of the biosolids drying process, and the biochar produced will be suitable for agricultural use and for easier disposal. Although the biochar will continue to be transported for land application, Logan Water is exploring opportunities to identify markets.

## 2.2 Project Objectives

The objective of the biosolids gasification plant is to transform sewage sludge (biosolids) into renewable energy and an environmentally friendly product called biochar.

A unique objective of this facility, which is vital to its success, was to utilise the heat energy from the gasification system to provide heat for the drying process. The cost to dry biosolids is currently a costly process and requires a significant amount of electrical energy or natural gas. So having a balanced heat energy system enables the production of biochar from biosolids without requiring fossil fuels like natural gas..

Producing a product from a substance that is currently a regulated waste is a significant step towards a circular economy. Logan is currently working with the Queensland environmental authority to develop an end of waste code for biochar that will further open the market for this sustainable product.

As the processing biosolids through gasification has not been undertaken in Australia and the performance and emission objectives were under development in parallel to the design being completed. Creating a balance between the design and understanding what will be used as the standard for best practice for other utilities to follow in implementing this design into their WWTP.

## 2.3 Biosolids in the wastewater industry

Biosolids or sewage sludge is mainly a mix of water and organic matter and may contain:

- macronutrients, such as nitrogen, phosphorus, potassium and sulfur
- micronutrients, such as copper, zinc, calcium, magnesium, iron, boron, molybdenum and manganese.

Biosolids may also contain traces of synthetic organic compounds and metals, including arsenic, cadmium, chromium, lead, mercury, nickel and selenium. These trace compounds can limit the uses for biosolids, with all potential uses regulated in Queensland by the *End of Waste Code for Biosolids* (DES, 2020).

The production of biochar from biosolids at Loganholme WWTP will need to comply with *End of Waste Code – Biosolids* which stipulates the quality of biosolids that can be applied to agricultural land. Provided that the biochar meets contaminant and pathogen reduction requirements specified in the code, it can be used as a resource and reused in agriculture.

The design of wastewater treatment processes and technologies varies throughout the water industry but largely depends on the wastewater catchment and population. A specific design challenge was integrating the design into the current location of the biosolids management facility within the Loganholme WWTP. The limited land available and being an operational plant supplied its own set of design challenges.

Biosolids handling is subject to the configuration of the upstream liquid stream treatment, and how the product will be utilised by end users. For Logan Water, biochar will be a new by-product of the wastewater treatment process, therefore introducing additional ‘unknowns’ as to how the product will be stored, transported, and how quality of the product can be assured.

**Figure 1: Loganholme WWTP biochar**

## 2.4 Design development

To be able to design a system that has not previously been implemented means there is risk and a balance to be found between design development and avoiding unwanted cost and other impacts of introducing additional project scope. These risks were reduced by undertaking dewatering trials on the Loganholme WWTP biosolids using a portable centrifuge and detailed trials on dried biosolids using a pilot gasification plant. The design phase utilised a detailed 3D model incorporating vendor designs, and this was shared with key subcontractors. The model was also used in discussions with various remotely located designers and delivery partners, including internationally based team members.

### 2.5 Key challenges

Ideally process trials and the selection of major equipment would be conducted early in the design process so that critical dimensions and layouts can be established and developed throughout the detailed design period. Due to the magnitude of ‘unknowns’ and project scheduling, many decisions had to be made early, without the design being fully ‘locked down’.

Key challenges faced on the design of the Loganholme WWTP biosolids gasification facility included:

- Solid’s loadings and materials composition, particularly at the interfaces with various vendor equipment to achieve desired process requirements
- Heat balance between the gasification process and required heat source for the drying process
- Requirements for biochar quality and related contaminants to meet project objectives and emissions for licencing requirements (which were in development while the design/construction of this project was progressing)
- Design of plant and equipment to meet the requirements of specific engineering codes and safety standards that are not usually related to the wastewater industry
- Design of conveyance systems, platforms, access, and maintainable items to meet process objectives and end users’ requirements despite limited inputs / information early in the process.

## 3. Biosolids gasification

### 3.1 Process overview

The biosolids gasification facility at Loganholme WWTP consists of three main processes:

1. **Dewatering** using a centrifuge (equipment commonly used in Australia)

The biosolids dewatering system upgrade involved two new centrifuges to meet the process objectives prior to the drying process, producing sludge cake % solids (21wt%) and capture rate (>95%). Refer to Figure 2 for a process flow diagram (PFD) showing the integration of biosolids gasification at Loganholme WWTP.

2. **Drying** using a belt dryer (proprietary equipment not commonly used in Australia)

Dewatered sludge is transported through two low temperature belt dryers where sludge is contacted with hot air. Water within the sludge cake is evaporated as it is dried from 21wt% to 90wt%. Heat is provided to the dryers via the hot water generator which, in turn, receives heat from the gasification process.

3. **Gasification** (newly developed system using “established” technology in other industries)

Gasification is a process that converts organic materials such as biomass and biosolids into carbon monoxide, hydrogen and carbon dioxide. The technology has been successful with other feed stocks including green waste, agricultural residues, forestry crops and residues, municipal solid waste and even construction waste. The process relies on the material reacting at high temperatures, without combustion, with a controlled amount of oxygen and/or steam. The resulting gas mixture is called biogas or syngas (synthesis gas) and is itself a fuel (this is where the heat is recovered for the Loganholme WWTP biosolids gasification facility).

The gasification process at Loganholme WWTP will produce biochar and provide advantages such as >88% reduction of water in dry solids compared to dewatered sludge cake. This requires fewer truck movements to transport biosolids, significantly reduced disposal costs and destruction of pathogens, micro-pollutants and nano-plastics.

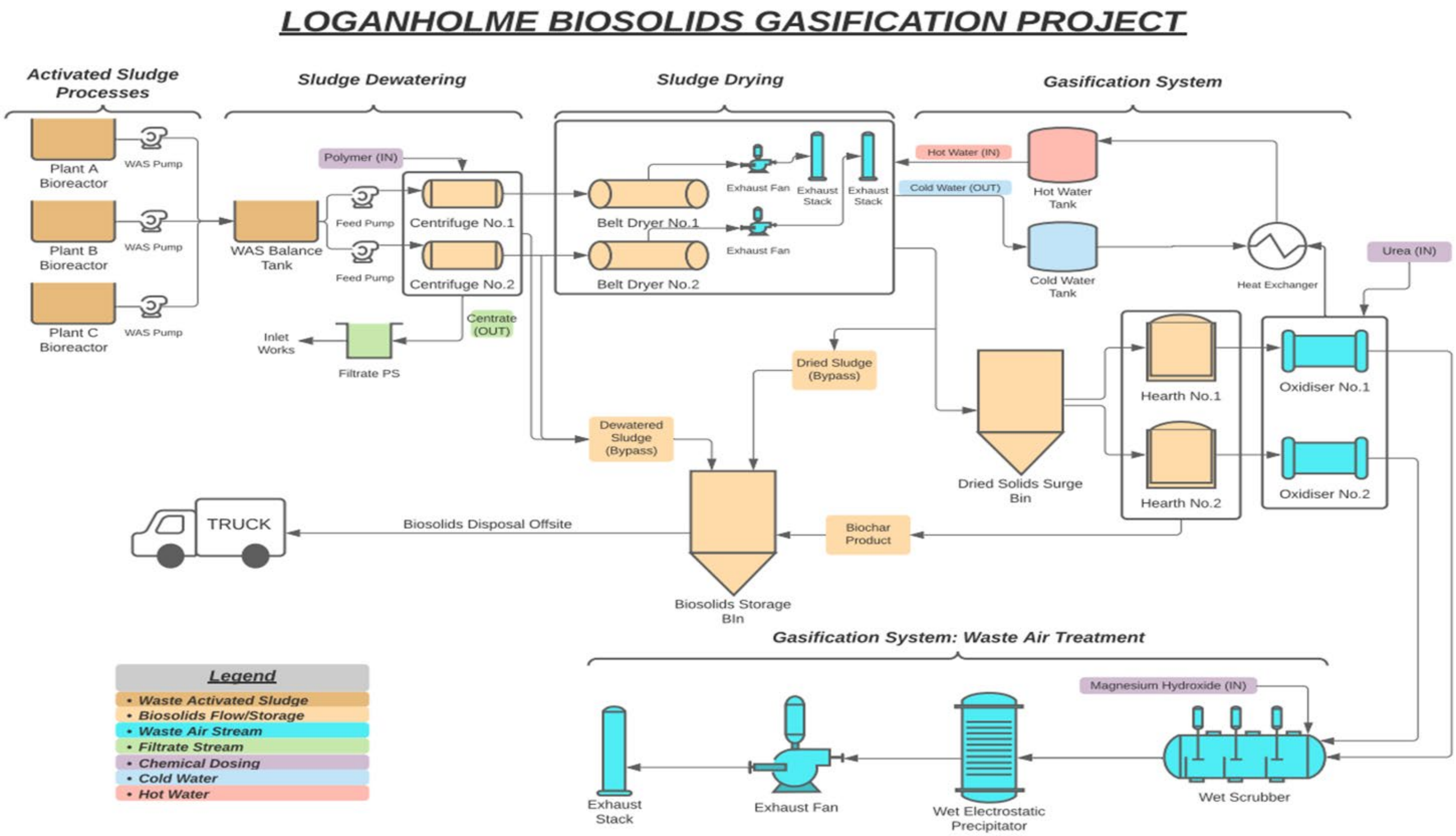



**Figure 2: Biosolids Gasification Flow Diagram**

# 4. Research and Development

## 4.1 Gasification Demonstration Plant

The gasification facility was designed following several months of research and development on the Loganholme WWTP site. This equipment was process focused and therefore had to be developed to a point where it was acceptable to be utilised as a permanent facility on a WWTP and comply with the relevant standards and legislation applicable to the newly developed equipment.

Although the Gasification technology was proven, there had to be a significant number of modifications required to allow for biosolids and provide suitable compliance for the emissions being released into the environment.

The demonstration plant (Figure 3) utilised biosolids from different treatment plants that could provide a suitably dry product of around 90% dry solids (It was unfeasible to dry the sludge at Loganholme to an equivalent standard). This demonstration plant was able to validate that production of biochar from biosolids was feasible and provided enough energy by recovering heat from the oxidisation and airstream processes, which would be utilised for the drying process.

**Figure 3: Gasification demonstration plant trials**

The demonstration plant allowed the team to focus on the use of chemicals in the process to manage Nitrogen oxides (NOx) and Sulphur oxides (SOx), along with requirements for elimination/reduction of particulates that would be released into the environment. This led to the adoption of using a wet scrubber and electrostatic precipitator for emissions control. The exact requirement for controls would not be fully appreciated until commissioning commenced, therefore the design team had the challenge of how to accommodate various operational scenarios.

## 4.2 Dryer Technology and Heat Balance

The drying process receives dewatered biosolids and provides dried product to the gasification process. The dryers were reliant on the dewatered sludge dryness, heat produced from the gasification facility, and appropriate conveyance interfaces to ensure the performance requirements could be met.

The belt driers we selected on a multi criteria basis with a focus on strict particle size distribution and dryness requirements for the gasification process to work effectively (and in turn provide a suitable energy source for the heat balance). Personnel from the stakeholder group undertook extensive research and attended operational sites in New Zealand and Europe to determine the most suitable equipment for the application.

The design and supply of the drying equipment was from Europe, as it was not able to be sourced in Australia. This design interaction was made easier through the utilisation of a fully integrated 3D model (Figure 2) and extensive discussion with the European Partners.

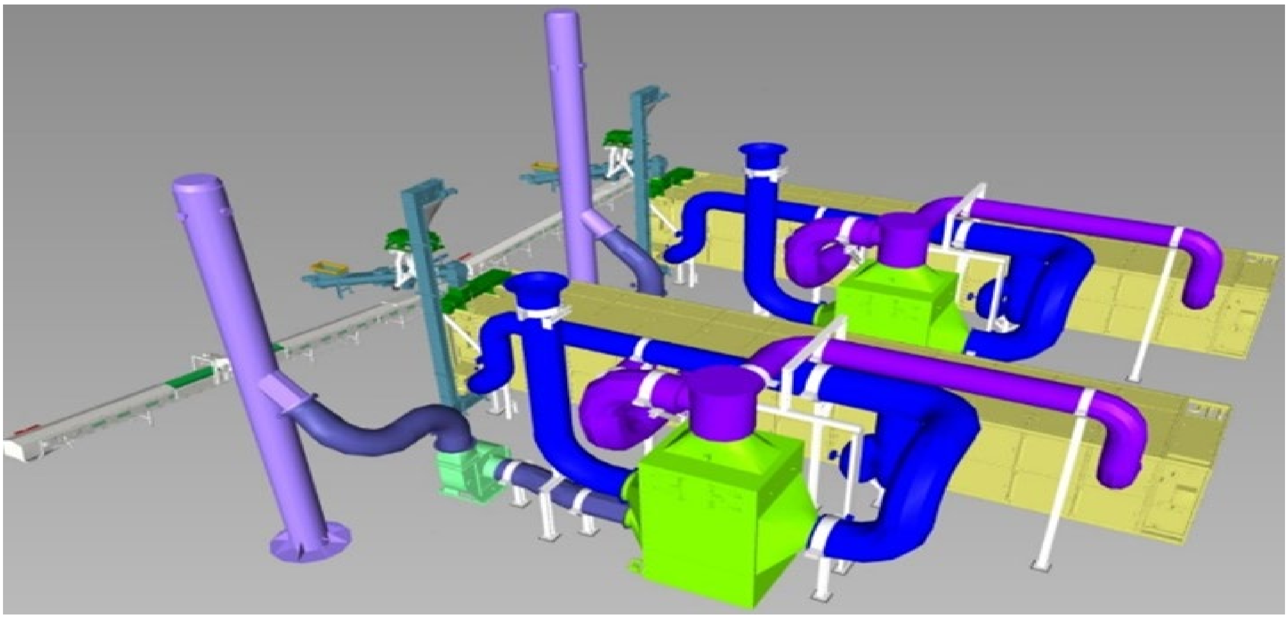


**Figure 4: Dryers 3D model**

## 4.3 Centrifuge Trials

The dewatering process included proprietary centrifuge decanters; however, the challenge was that the effective dryness produced would have a significant impact on the heat balance of the system. The designers had to rely on site testing and provide a contingency plan to ensure performance could be met for the systems reliability moving into commissioning and operations.

**Figure 5: Portable centrifuge trials on Loganholme biosolids**

Utilising an onsite portable centrifuge trial (Figure 3), with the same type of centrifuge and site-based waste activated sludge, allowed the team to gain an appreciation of flowrates, polymers, any sludge pre-thickening requirements to achieve continuous and reliable performance.

# 5. Challenges & Lessons Learnt

The various objectives and "unknowns" provided challenges for the design phase. The team was faced with designs and interfaces that had not been done before, as discussed in section 2.3. A fully integrated 3D model was established and utilised between vendors and for specific discipline designs and reviews throughout the project delivery (Refer to Appendix A for screenshots of the model verses construction progress) These challenges, including lessons learnt are further addressed in the following sections:

### 5.1.1 Technical

- **Heat Balance:** Was critical to the facility functioning in its entirety. The biosolids had to provide appropriate calorific value to permit the gasification facility to operate without being supplemented with diesel fuel. Gasification of the biosolids allowed for the production of a high-quality, stable and beneficial biochar product, while also facilitating the destruction of harmful pollutants in the air stream. Heat energy within the air stream is captured in the hot water generator and is used as the heat energy source for operation and performance of the belt dryers.
- **Conveyance:** The drying and gasification processes were delivered under separate subcontracts, with the particle size distribution produced from the dryers having to meet strict requirements to assist the performance of the gasification process. The conveyance systems played a big factor in this integration with the products integrity being protected throughout the process, utilising 3D designs from vendors to enable an integrated 3D model (Figure 4).

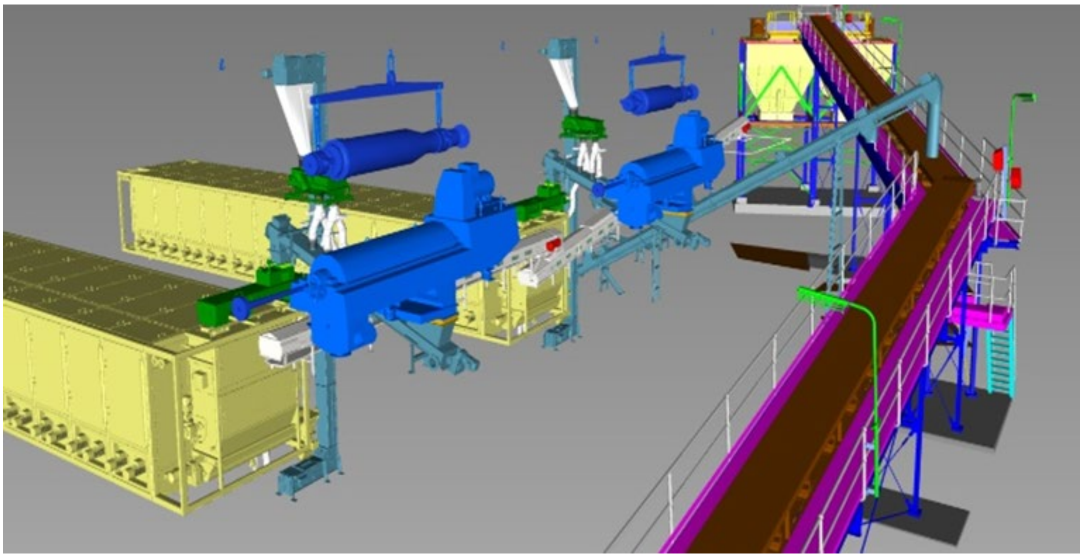


**Figure 6: Conveyance 3D model**

  A combination of inclined and horizontal screws, belts and bucket lift elevators were used for the conveyance of various biosolids phases. The conveyance system had to allow for different operating conditions and material properties, as well as being "future proof" for the installation of the future third dryer.

- **Platforms and Access:** The common access platform in the dryer building presented many challenges for the design team. It formed the central walkway to access all the conveyance, was utilised for the piping corridor and provided structural elements for equipment (including the bucket elevator, screeners and the common belt conveyor). The structural design was integral to the construction, however, was reliant of all the equipment details in order to progress. An interactive 3D model was used to coordinate between vendors and in the structural model to assess effects from vibration and fatigue (Figure 5).

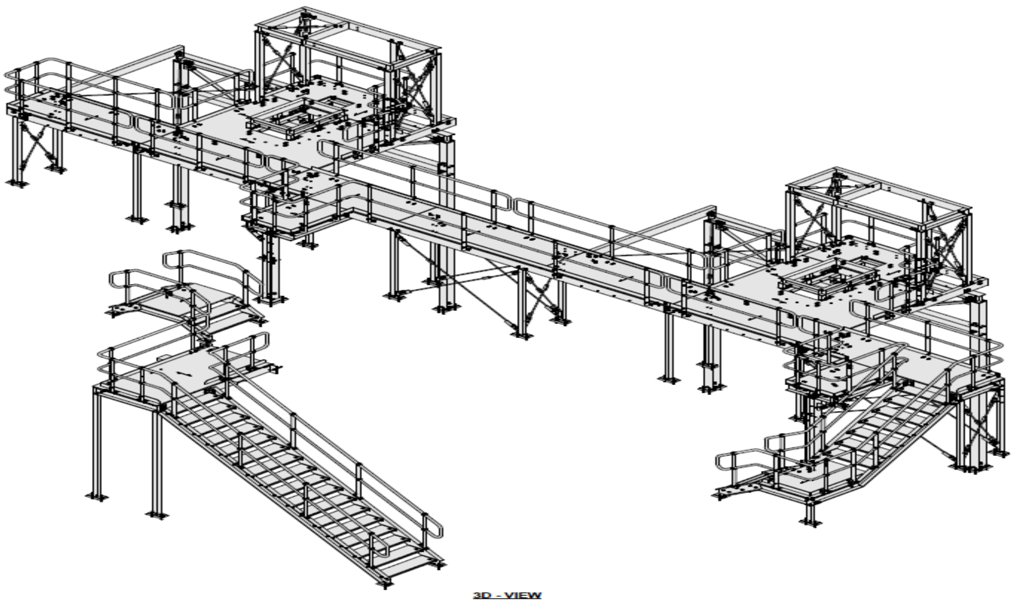



Figure 7: Platform 3D model

#### 5.1.2 Operations and costs

- **Chemical usage:** During the demonstration trials, lime and liquid Urea were used for the control of SOx and NOx. Early on in the trials, the use of lime was substituted with MgOH2, with positive results. The dosing rates were optimised and used as a basis to size the chemical storage and dosing requirement on the permanent facility, however there were risks due to the trial biosolids being from a different plant and could have some different characteristics.
- **Control systems:** One major challenge for the design team was with the control system and system integration. The Gasification Facility in its entirety relies on a complex control system, integrated into a drying control system that included an imbedded controller for the dryer, and several interfaces with various conveyance systems to provide for process interlocks. The team was required to cater for a domino effect for equipment interlocks, faults, sludge diversions and safety protocols.

#### 5.1.3 Regulatory

- **Hazardous Areas:** Due to the potential to create dust from the conveyance of dried biosolids, the Hazardous Area (HA) assessment ventured into areas outside of the general experiences documented in wastewater treatment.

  In some cases, equipment from Europe complied with different standards to what was being procured in Australia, and in isolation was deemed as a hazardous environment when interfacing between equipment with conflicting hazardous area compliance ratings. In addition, the gasification process creates hazardous gas zones which were managed through the vessel designs by including blasting panels. Instrumentation located within the HA zone of influence had to be selected to comply with the required HA ratings.
- **Environmental regulations:** The Loganholme gasification facility is a first in Australia and as such did not have any specific environmental requirements in place. The team had a collaborative relationship with the Department of Environment and Science, (DES), the environmental regulator in Queensland, however there were risks and challenges of not having emissions and biochar performance criteria locked in from the start. The team looked at what requirements and performance parameters were being looked at internationally and in other industries to form appropriate performance targets. These targets were used in design and performance requirements for the various process units.

#### 5.1.4 Environmental

- **Contaminants:** The demonstration plant trial data proved that Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) destruction efficiencies were between >91% and >99% (with a mean of >94%). To cater for fine particulates being released into the atmosphere, an electrostatic precipitator, in addition to a venturi and wet scrubber, was utilised, however not included in the initial design. Similarly, the addition of lime $CaCO3$ for SOX control was established during the demonstration trial and included in the initial design, however, was replaced with $Mg(OH)2$ based on a number of operational issues experienced with the product during the demonstration plant trials
- **Air Emissions:** With a product that is not being produced in Australia at this scale and the feed source completely dependent on the dried biosolids produced by the Loganholme WWTP, the air emissions and plant performance requirements had to be determined and agreed based on the demonstration plant trial data, which used 90% dried biosolids supplied from different treatment plants.

#### 5.1.5 Market

- **Storage and beneficial reuse:** The Gasification Facility had the ability to produce various products, including dewatered biosolids or biochar (or a mix). Due to the contracts in place for material export and reuse, and also potential risks related to the biochar that would be produced, the material storage and safety interfaces became acutely important. The risks relating to biochar from biosolids remain fairly uncharted, therefore great attention and detail was included in the design for the different scenarios.
- **Future use of Gasification:** The gasification technology could be utilised in many markets (refer to section 2.1). By addressing the above challenges for the production of biochar, many of the technological advancements and lessons learnt can be used for the future design and development of the technology. The Gasification Facility (Figure 6) has been developed in the 3D model and would be interchangeable to many other marks.

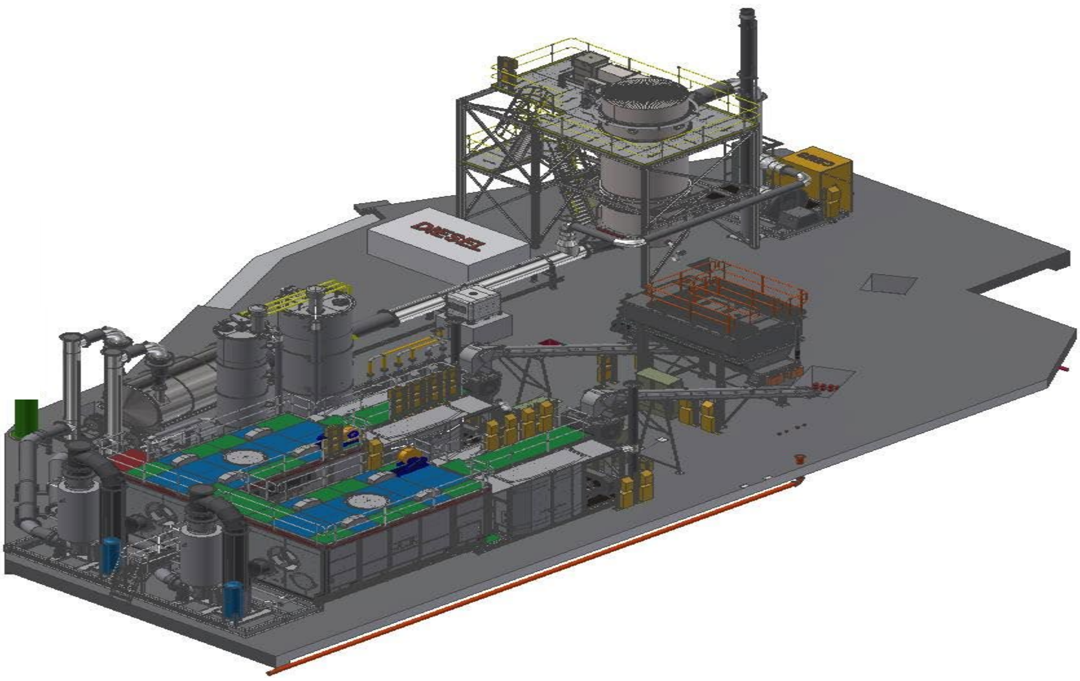


**Figure 8: Gasification facility 3D model**

# 6. Conclusion

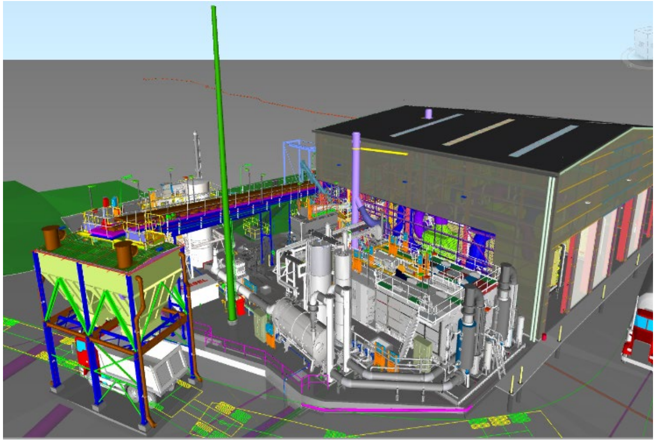
Delivering a multidisciplinary design for the "first of its kind" integrated Loganholme gasification facility, although challenging, was executed by being proactive with the knowledge gained from both demonstration trial testing and industry expertise. With detailed communication, 3D models and collaboration with key partners and stakeholders relating to the materials composition, emissions, interfaces and specific fields of interest, the key performance indicators were established early, and the design adapted to meet the requirements.

The char that will be produced from the Loganholme WWTP will contain many valuable components and will be an extremely valuable benefit for the use in soil enhancement by applying the char as a fertiliser supplement to agricultural soils. The char includes the following constituents

- Phosphorus and Potassium (P & K)
- Fixed Carbonised Carbon
- Minor nutrients and trace elements (such as sulphur, Boron, Iron, Molybdenum, Zink, Cobalt and Copper)
- Energy

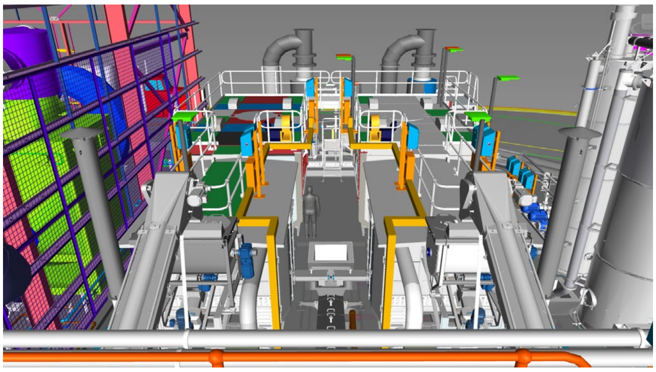
Feedstock examples for the gasification system when utilised for processes outside of wastewater treatment, include green waste, agricultural residues, forestry crops and residues, municipal solid waste, construction, and demolition waste. The biochar could be used for soil amendment (as per the biosolids biochar, amenity horticulture, water filtration, landfill capping, metal smelting and refining as some examples. These could be considered for future ideals when progressing with the technology.

# Appendix A – 3D Model Vs Construction



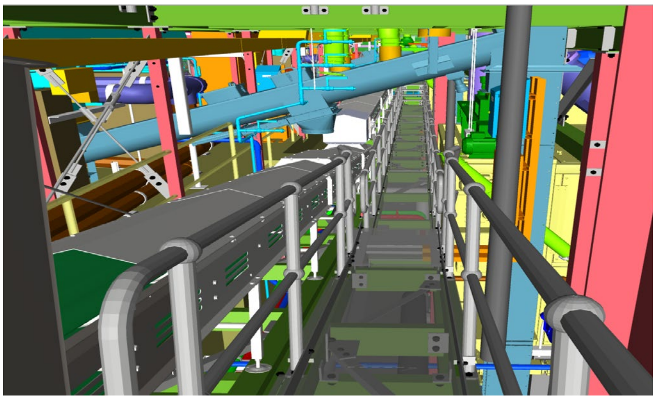
Aerial view of Gasification Facility (model)

Aerial view of Gasification Facility (photo)

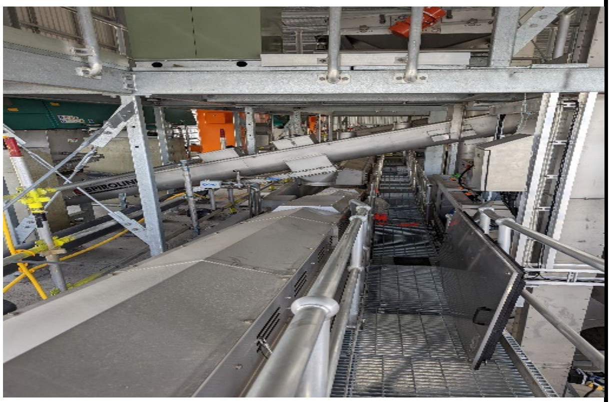


Gasification air stream (model)

Gasification air stream (photo)

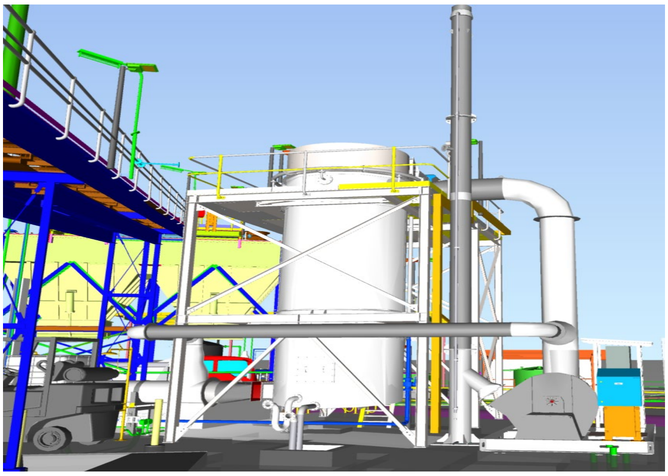


Middle platform conveyance corridor (model)



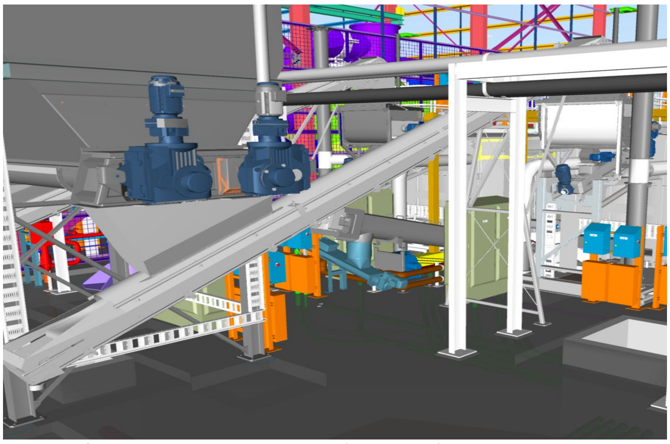
Middle platform conveyance corridor (photo)

**Figure 9: 3D model and construction snapshots**



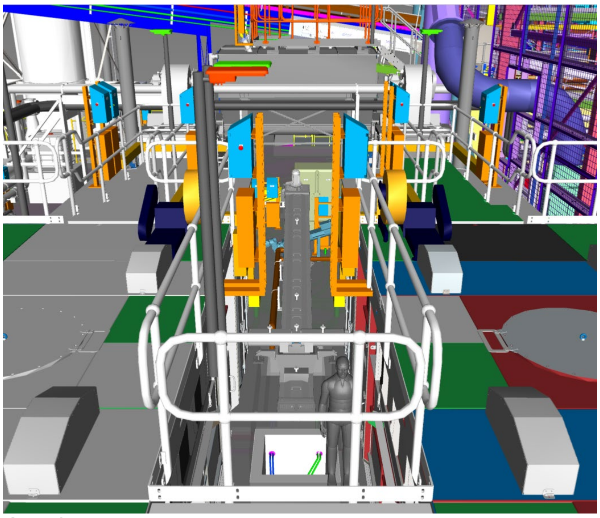
ESP (model)

ESP (photo)

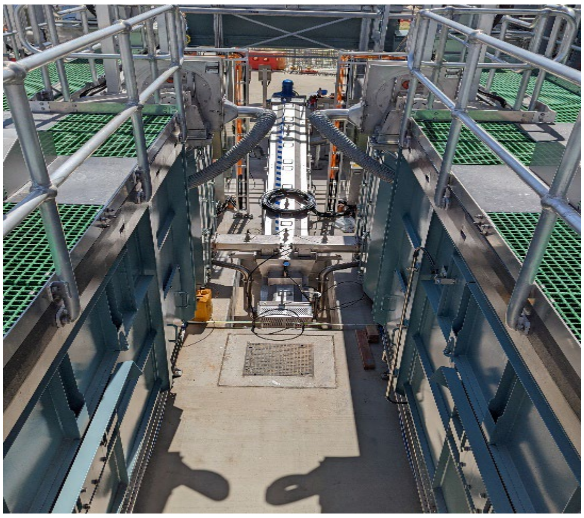


Surge hopper and gasification feed (model)

Surge hopper and gasification feed (photo)



Gasification central corridor (model)



Gasification central corridor (picture)

**Figure 10: 3D model and construction snapshots**