# Hazer Process

# Commercial Demonstration Plant

ARENA Lessons learnt report #3

| Rev | Date | Details | Prepared | Checked | Approved |
|---|---|---|---|---|---|
| A | 21/11/2023 | Draft | ME | AW | |
| B | 30/11/2023 | Draft | NB | ME | |
| C | 06/12/2023 | Issued for Approval | AW | ME/NB | NB |
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HazerGroup

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# PROJECT DETAILS

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| **Reporting Period** | 1st May 2021 – 30th November 2023 |

This Project received funding from ARENA as part of ARENA's Advancing Renewables Program.

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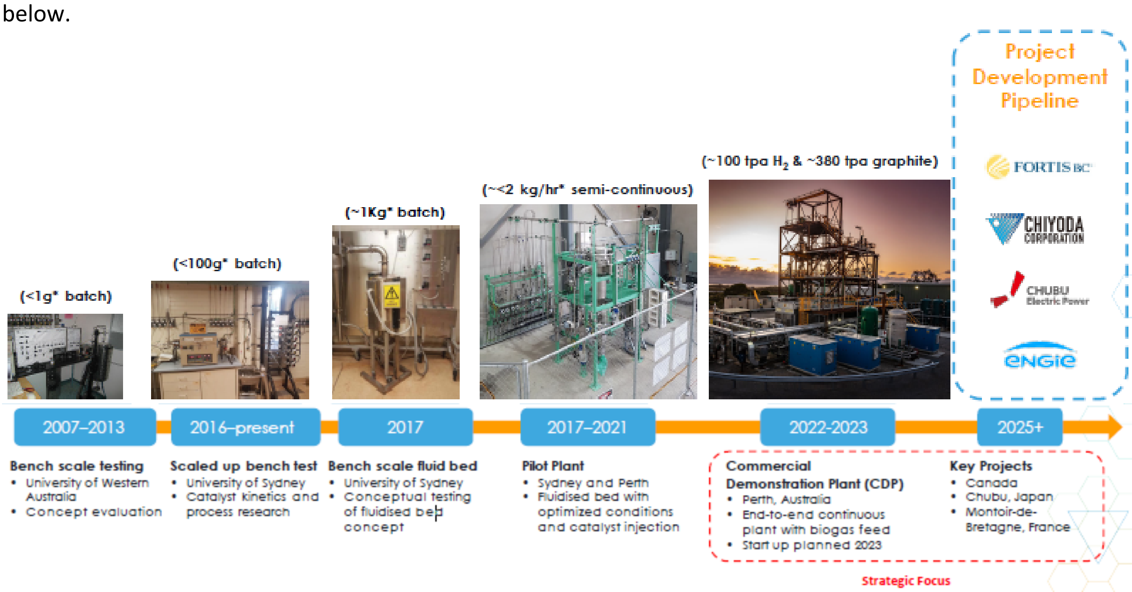
# PROJECT OVERVIEW

Hazer Group was founded in 2010 to commercialise technology originally developed at the University of Western Australia. The Company listed on the ASX in December 2015. Prior to listing, more than eight years was spent developing the underlying Hazer Process.

The Hazer Process is a novel method to produce low emissions hydrogen from any form of methane. The process utilises methane as a feedstock to produce hydrogen – without producing $CO_2$ in the reaction process – instead capturing the carbon in the feedstock as solid graphitic carbon.

In early 2016, Hazer developed a partnership with the University of Sydney, and established its core development operations within the School of Chemical and Biomolecular Engineering at the University: including development of the first pilot plants. Hazer has been successively scaling up to technology since 2007 as shown in the diagram below.




In 2023, Hazer completed construction of the Commercial Demonstration Plant (CDP). The CDP is the first scaled-up, fully integrated deployment of the Hazer Process. The CDP will use biogas from the Woodman Point Water Resource Recovery Facility (WRRF) as feedstock to create hydrogen and solid graphitic carbon. The Hazer technology is unique in that when processing biogas, it provides a nett carbon negative process. The CDP project will also take biogas that is otherwise flared, resulting in a local reduction in carbon emissions.

The Project is situated within the boundaries of the Woodman Point WRRF, located in the suburb of Munster in the City of Cockburn, Western Australia. Woodman Point WRRF is owned and operated by the Water Corporation – Western Australia's public water utility responsible for potable water supply and the collection, treatment, and disposal of sewerage and wastewater amongst other things. The treatment plant is the largest facility of its kind in Western Australia, it currently treats wastewater for a population of about 750,000 (approximately 160 Megalitre per day) living in the south metropolitan area of Perth.

# KEY LEARNINGS

## Lesson learnt No. 1: Exotic Material Technical Challenges

**Category:** Technical/Logistical/ Risk

**Objective:**

To source a suitable material for the CDP reactor that would provide sufficient life for the CDP test program.

**Detail:**

The CDP base case design utilises a hot wall reactor to hold the main process reaction at ~900 °C and 800kPag pressure. This was chosen as Hazer's previous lab testing and pilot plants had successfully operated with hot walled reactors of similar exotic materials.

During the design development, material selection was conducted through company research, and engaging external specialist consultants using mechanical properties (strength, corrosion resistance, chemical attack resistance) as the primary considerations, with material availability and manufacturer credentials as secondary considerations.

The project team selected an Incoloy 617 material known for its high temperature and corrosion resistive properties at high temperature, however, having limited use in Australia, it needed to be procured from overseas. Hazer internally hired an experienced Procurement Manager, a senior mechanical engineer dedicated to the materials specification, and used various external consultants. Significant effort was spent collating procurement options and developing suitable materials specifications and fabrication requirements to ensure quality requirements were met.

The tendering process over approx. 6 months found relatively limited options for supply which was complicated with supply chain interruptions due to covid-19. Suppliers' interest was also limited due to low contract value. Hazer hired an Australian company that specialises in procuring exotic materials from overseas and accepted their recommendation of a fabricator located in China. This Chinese supplier had undergone a recent QA due diligence, had Lloyds certification, and Chinese defence contracts, all of which provided confidence in their capability. They were also the only single supplier that offered all materials required for the CDP hot equipment.

In late 2021, during fabrication of the reactor, an unrecoverable flaw was detected in the shell after forging and fabrication had to be restarted. These events occurred during China's surge of covid-19 and ongoing power restrictions, making progress slow, communications difficult, and prevented Hazer personnel from conducting on-ground QA inspections. Hazer was therefore reliant on the agent and their independent TUV 3.2 Certification process. Even though some quality control issues and anomalies were detected, which can be typical, the materials passed their specified quality tests.

In July 2022, the heat exchanger manufactured in Australia with the exotic materials supplied by the Chinese supplier failed final heat treatment. An extensive investigation involving 3 specialist metallurgists concluded the original material supplied was defective despite having passed all the tests, having undetected inherent flaws at a metallurgical level. The fabricator was deemed to have made an error in the heat treatment or temperature control during fabrication. This raised concerns on the second reactor shell and a re-review of previous quality anomalies and TUV reports was completed. In October 2022, after reviewing the information and performing new tests on the raw materials, it was deemed that all materials from this supplier and its subsidiaries were not compliant, and materials needed to be re-ordered from a different supplier.

Previous supplier assessments were re-evaluated, and materials orders broken into 3 different components (reactor components, piping, and fittings) to suit the specialties of each fabricator. Tier 1 European and North American suppliers were chosen and were closely monitored by key Hazer personnel for a further 13 months as equipment was remade and fabricated. While successful, this was time and labour intensive, and caused significant delay to the full start-up of the CDP.

**Implications for future projects:**

The key learnings on this aspect for this phase of the project are as follows:

- There is significant inherent risk when fabricating with new material for the first time. While the fabricator had previously worked with similar exotic materials (not specifically 617) and despite assurances to the contrary, it was found the fabricator lacked the capability to adapt and manufacture 617 materials. Only suppliers who have specific experience successfully manufacturing 617 to specification should be considered.
- Engagement of specialists and external consultants to address internal company knowledge gaps was very useful and valuable to create clarity on material requirements and manage the risk associated with fabrication. This ensured the successful re-make of reactor and heat exchanger materials.
- The COVID-19 pandemic created an environment where normal risk mitigations were unable to be implemented effectively. This required adaptability of project managers to determine how to react to changing constraints and recognise when the existing plans were insufficient to achieve the desired quality assurance outcomes.
- Having adequate expertise and robust plans does not always guarantee success. Being the first to do something is difficult and failures should be expected and planned for. This requires resilience and flexibility in project management and engineering, to quickly learn why a process failed and find a solution.
- Firsthand engagement with suppliers and physical inspections provides valuable insights into behind-the-scenes, less visible quality management practices. For difficult and highly technical equipment, it is essential to have direct company representation to ensure the company’s needs are met as third-party inspections may not necessarily protect the company from quality issues.
- More caution has been embedded within the team on the selection process for any future exotic materials and specialty equipment., with a desire to eliminate wherever possible the use of exotic materials in future plants. This was expected to be part of future plant mandates due to the cost, however the quality control requirements to ensure integrity has been recognised as an extensive effort and will be considered with more weight when reviewing material options in the future plant designs.

## Lesson learnt No. 2: Fuel Cell Standards

**Category:** Regulatory

**Objective:**

To include a stationary power fuel cell as an ancillary equipment item in the CDP to demonstrate hydrogen quality achieved in the plant operations on a continuous basis and as an application for hydrogen use.

**Detail:**

As part of providing a means to demonstrate hydrogen production quality is achieved, the project design includes a fuel cell that will take a partial flow of the hydrogen produced at the CDP and produce some power to offset existing operating power consumption.

At the time the fuel cell was ordered in Q3 2020 no fuel cell standard was available yet in Australia. Hazer made enquiries within the industry and the approving regulator Department of Mines, Industry Regulation and Safety (DMIRS) standards committee to understand the likely requirements and understood that the Australian Standards adoption of IEC 62282-3 and associated standards were likely and engaged with the fuel cell supplier in anticipation of these standards coming into effect in the near future.

During the fuel cell fabrication, it was determined that the inverter design was not compliant to Australian Standards [which were available] thus re-design was required. During the re-design period, different AS 62282-3 and associated standards were released for fuel cells (August 2021) and further engagement with DMIRS resulted in direction that the fuel cell already delivered now had to be retrospectively made compliant. The compliance process was unclear with no precedence for defining inspector qualifications, and no clear direction on who could assess compliance approval. Further, at the time of order, there was no known fuel cell in Western Australia that had successfully gone through a full approval process with DMIRS.

The supplier went through a rigorous gap analysis identifying differences in the GB standards (Guobiao Chinese National Standards) and AS standards (Australian Standards) to test what changes might be required for the fuel cell to be made compliant. Ongoing discussions with DMIRS and the inspectors continued, at considerable cost, to try and clarify what specific changes could arise, and how more difficult areas to retrospectively change could be achieved. In Q3 2023 these analyses led to the decision that the process to achieve approval to operate the fuel cell from DMIRS was significant and likely unachievable, and that the existing fuel cell would need to be replaced.

As a back-up option, 12 months earlier Hazer had engaged another fuel cell supplier that had invested significant effort and resources over the prior 5-7 years developing a fuel cell that had since been designed and was deemed compliant with Australian standards as an "off-the-shelf" item. When re-engaged, the new supplier advised an earlier version had now successfully been through the approval process in WA. It was apparent that the time and cost invested to work through the approvals was extensive, more than could have been anticipated at project commencement.

**Implications for future projects:**

Key learnings:

- The approvals process, particularly in Queensland and Western Australia, are rigorous with little flexibility, and difficult to achieve certainty of outcome. Understanding this will help with decision making to assign the appropriate time and effort needed for such approvals.
- New technologies are known to be difficult and will have higher risk profiles and unknowns than standard project work. There were various other equipment items, as well as this fuel cell, where the overseas supplier had underestimated that what is acceptable in other jurisdictions may not be acceptable according to Australian Standards.

- For equipment requiring regulatory approvals, more weight should be given to selecting a supplier/brand that has previously achieved approval compliance in the same jurisdiction to reduce project risk. This certainty can be expected to be reflected in potentially significantly higher pricing of the equipment, however, is likely to lead to a better long-term project outcome.
- Consistent with lesson learning no.1, being the first to do something is difficult and changes can be expected. A new technology company needs to be adaptable enough to make hard decisions and replace or abandon key plant components. This should not be viewed as failure, rather be anticipated as part of the learning and new technology deployment process on the path to success.

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## Lesson learnt No. 3: Equipment Quality Control

**Category:** Quality Assurance

**Objective:**

To ensure sufficient quality in materials procurement and equipment fabrication is achieved to ensure the CDP operations can operate as per design and specification.

**Detail:**

One of the learnings applied from the exotic material failures described previously was the importance of having firsthand company involvement overseeing critical or technically difficult equipment procurement and fabrication. For example, during re-make of the exotic materials, a procurement criterion was Hazer project staff being allowed direct inspection of the suppliers' facilities, and regular quality checks whenever requested.

For materials manufacturers, visits were made to the overseas suppliers' plants, and in-person technical discussions and facility inspections conducted to confirm firsthand what had been presented. While this added time in developing agreed scope, it ultimately contributed to the materials being fabricated correctly and to specification.

For example, for manufacture of the replacement reactor, Hazer identified a local specialist in welding exotic materials and, after significant due diligence, awarded the contract over other overseas and eastern state alternatives where direct in-person involvement would have been compromised. Hazer formed a close working relationship and created an integrated team with the fabricator. Being local, Hazer staff could be on site regularly to review progress and fabrication quality through the entire process. Close integration resulted in being able to influence production schedule, as Hazer engineers were able to identify and ensure decisions, for example regarding delays or changes, were prioritised to meet Hazer requirements. This engagement led to confidence in the expertise and capabilities of the fabricator, and subsequently led to them being awarded the CDP site piping fabrication and installation [in addition to reactor fabrication] providing further construction efficiencies.

**Implications for future projects:**

Key Learnings from introducing higher quality assurance control procedures:

- Embedding Hazer personnel directly into various parts of the critical orders and fabrication processes gave higher visibility over progress and allowed nuances in technical misunderstandings or requirements to be identified and easily rectified. The higher investment was worthwhile as it mitigated larger cost implications, ensured key decisions on changes or compromises were made with Hazer's input, and helped suppliers deliver the intended contract work scopes.
- There were tangible learnings from first hand engagement and site visits to the suppliers' facilities that not only gave confidence but led to adjustments in scope and specifications. This was not achieved

during the original ordering process where communications were limited, and reliance on third-party assessment and inspections proved to be inadequate.
- Critical and technically high-risk equipment requires direct company representation for future projects to mitigate the larger risks of receiving equipment/materials that are not compliant or to specification. The Hazer procurement procedure was refined to add further rigor and emphasise Quality Assurance.

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## Lesson learnt No. 4: Maintaining High Safety Standards

**Category:** Safety

**Objective:**

To develop a culture of safety and systems of safety that self-sustains the company in future to prevent any harm or injury throughout the organisation leading to improved business performance and value.

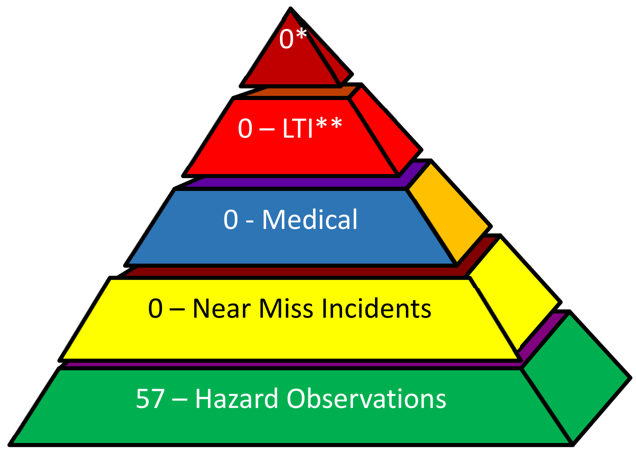
**Detail:**

During the development of the CDP project, Hazer engaged an external consultant to develop a company set of safety procedures and strategies to govern the safety practices for the organisation with the CDP specifically in mind. This involved a process of determining what Hazer needed as a company, developing procedures to cover all essential safety management processes, and then adjusting from internal reviews to specifically address safety in the context of the company and future CDP operations. This resulted in:

- A set of company safety strategies.
- A set of safety and risk management procedures.
- A set of essential safety procedures for high-risk operations specific to the CDP
- A set of supporting procedures and strategies for managing safety as part of an Integrated Management System.
- A set of golden safety rules.
- Setting up visible safety leadership in meetings, safety shares and site visits.

As the CDP started to move from construction to operations, the company risk profile changed and a full time HSE Manager was recruited to help further develop the next stage of safety management processes. This included:

- Reviewing all safety documentations and conducting a gap analysis to add procedures or update existing ones in consideration of impending CDP operational status and the new WHS Act 2020.
- Implementing a rigorous auditing process.
- Updating the risk management processes.
- Updating a more rigorous contractor management process
- Developing and implementing a more structured safety reporting process.
- Implementing a safety software package to allow more automated reporting and statistical analysis to feed into reports to management, and for proactively tracking safety trends.
- Providing more visible safety notices and flyers.
- Formalising regular safety shares on site with rotation of executives and management to attend to provide visible safety leadership.
- Developing quality management procedures, which indirectly impact on safety.
- Updating procedures to be generic where appropriate, and not CDP specific.




* Top item,- zero notifiable incidents

** LTI = Lost Time Injury is an injury sustained on the job by an employee that results in the loss of productive work time

**Figure 1 : HSE Highlights as of October 2023 (Since CDP Start up, ~101,500 manhours worked)**

The activities described above were complemented with ongoing safety discussions at the start of every meeting, in reports, and on-site daily toolbox and pre-start meetings. These were noticeably effective and supported by staff as this second wave of safety management was implemented.

Hazer management worked to engage staff and operations team consistently to drive a safety culture that would ensure the right decisions and behaviours were maintained not only on site, but also in other parts of the company's business. At the end of October 2023, Hazer had recorded approximately 101,500hrs on site at the CDP with zero injuries of any kind, and no known injuries at the workplace at Hazer since the company set up in 2015.

**Implications for future projects:**

Key learnings:

- Managing safety is a continuous and repetitive process that requires ongoing engagement to drive the right behaviours and attitudes.
- The level of safety management required changes depending on the circumstances and risk profile.
- Attitudes towards safety strongly affects the behaviours in practice.
- There was tangible change in safety awareness and consideration from staff and operations when the company shifted from more reliance on procedures and processes, to active engagement and education supported by all the different means and tools of managing safety.
- This strategy involves more resources and cost; however, it has resulted in zero injuries to date.
- Safety comes from visible safety leadership, good systems and procedures, constant repetition of safety practices and reinforcement of expectations. Hazer will continue to target the human aspect of achieving good safety outcomes for future projects.