

Pact Renewables' Technology-Based Solution for Sustainable Management of Produced Water from Australian CSG Production Fields

Overview of the Technologies and Proposed Approach

by

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Introduction

Coal seam gas (CSG), presently produced in the Surat and Bowen Basins of Queensland, is an important energy source and increasingly recognised as an essential part of Australia's energy mix, considering the expected tripling of gas demand in Eastern Australia.

Gas production also generates a co-product, known as produced water, the bulk of which after volume reduction by desalination processes has been stored in 36 brine dams, awaiting a viable long-term disposal solution. It is estimated that over the life of current CSG projects, around 5 million tonnes of waste salts (CSG brine with mixed salts precipitated in the dams containing heavy metals and organic compounds) will be produced, which will need safe disposal. The need for identifying, evaluating and implementing a permanent solution for sustainable management of produced water is expected to grow significantly with the recent commencement of Arrow Energy's Phase 2 of Surat Gas Project in Western Downs, and the planned development of Santos Limited's Narrabri Gas Field project in NSW in the next few years.

The aim of this presentation is to provide an overview of Pact Renewables' technology-based solutions and its technical expertise in the field of produced water management. It also includes a brief outline of an integrated approach to the challenge of CSG brine disposal by selective recovery of minerals from CSG brine followed by encapsulation for safe landfilling of the residuals, for consideration by the Australian CSG industry.

The multi-faceted challenge of permanent disposal of CSG produced water

The key technical barrier

Whether a selective mineral recovery step is applied upfront or not, because of its very nature, the residual material (CSG brine and hygroscopic salt accumulated in the dams through time) cannot be satisfactorily encapsulated by conventional technologies for safe landfilling.

Engagement of capable technology delivery teams

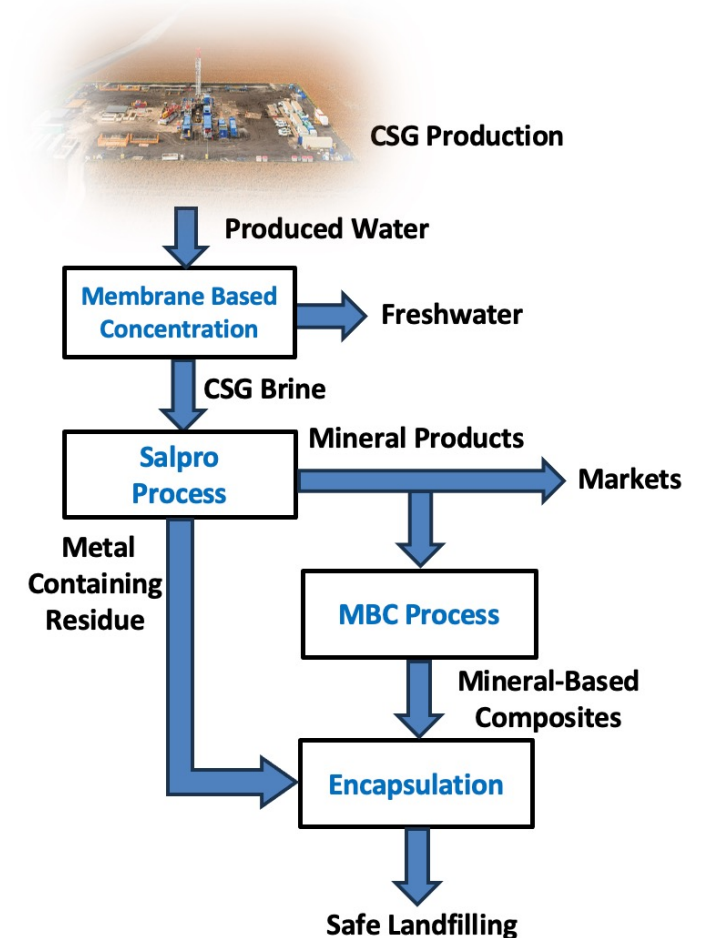
Technology-based solution for the permanent disposal of CSG waste can be only optimised and delivered by experts in the field, having established technological and reputational standing with the regulators and technology community. Accordingly, the notion of grass root R&D for reinventing new technologies in a timely manner, and the expectations for disruptive solutions do not apply in this highly specialised technology field.

The need for regulatory framework

The development of regulatory mechanisms by the States for residual risk management (as related to managing future salt encapsulation facilities) should be pursued by CSG industry at the earnest. This will enable timely decisions by current CSG/LNG companies on the most appropriate pathways to sustainable removal of CSG waste residues from the landscape, whilst avoiding potential risks to timely deployment of new CSG projects by addressing the community concerns in a coordinated manner.

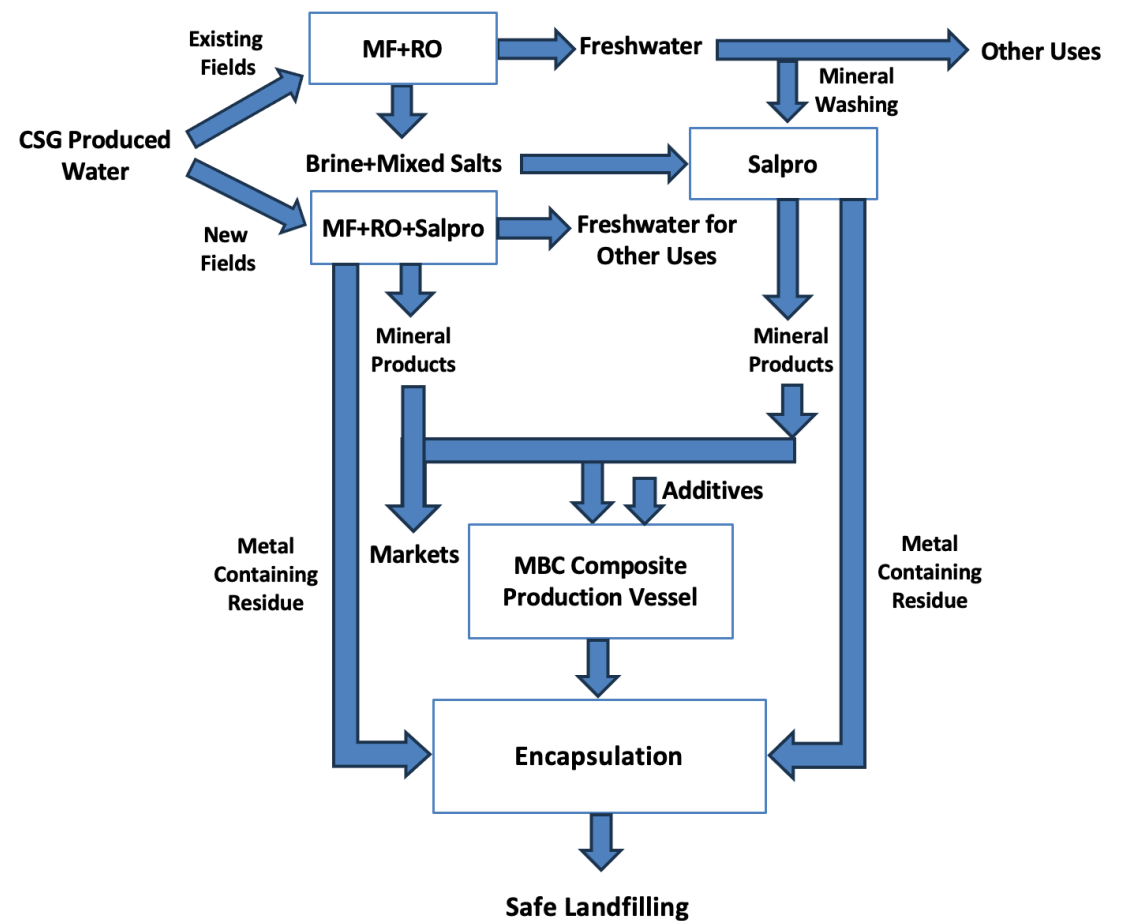
High-level presentation of an integrated approach, combining Salpro and MBC processes for safe disposal of CSG produced water

- The process components of this technology package have been tested at multiple sites, verified individually or collectively, and their detailed flow sheets and product specifications held by Pact Renewables. Regardless, as CSG produced water storage systems are site-specifically designed and operated, each will require own optimised technology applicability package.
- Projects based on our technology-based solutions draw from the expertise of Dr Aharon Arakel, the lead inventor of these technologies and his project delivery team, to ensure timely and on-budget delivery of the technology packages for commercial decisions.

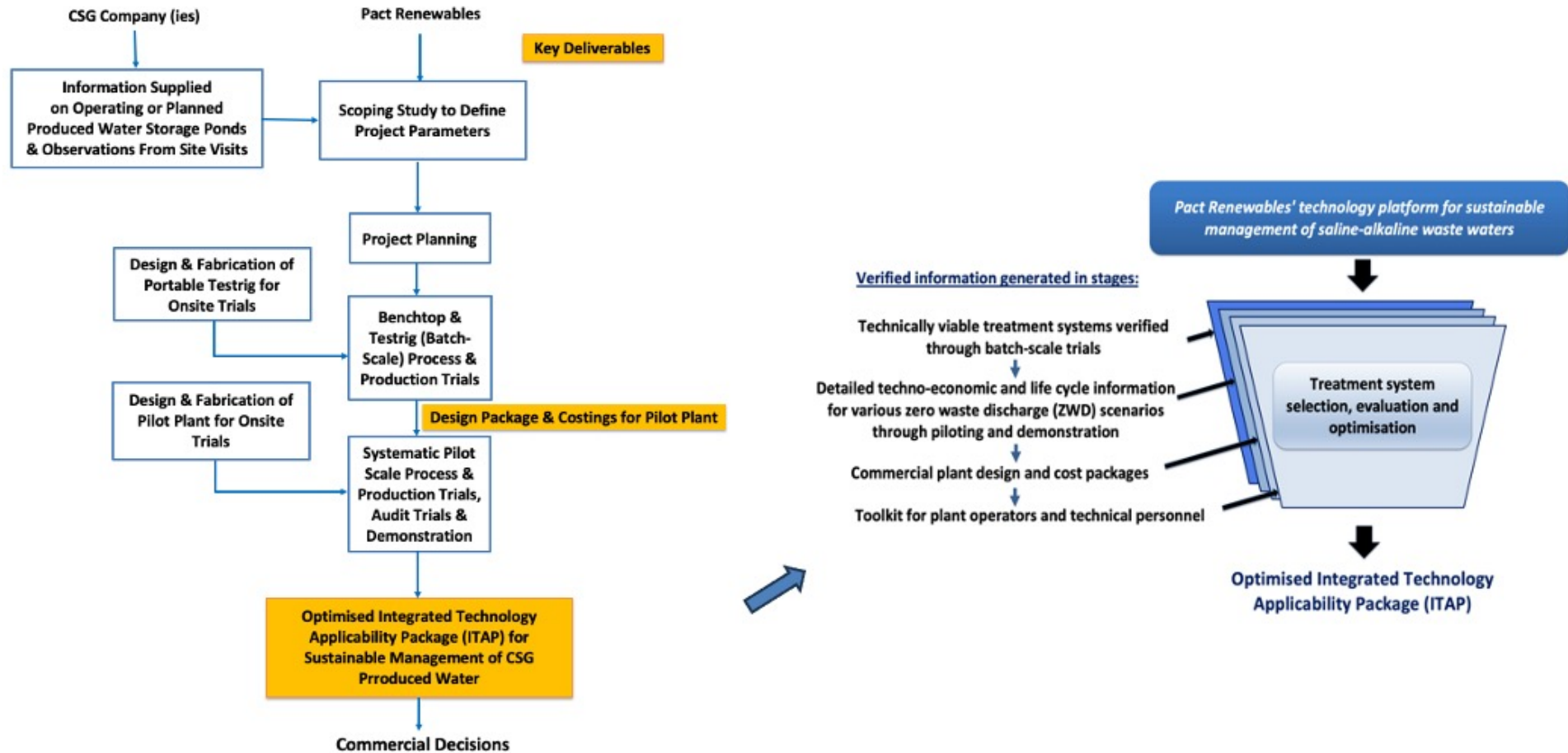


How Pact Renewables' integrated CSG produced water treatment system works

The integrated treatment system, shown in the opposite diagram, is the result of over 30 years of experience with developing appropriate technologies for the treatment of a wide range of industrial saline and alkaline waste streams. These saline processing technologies have been tested, their core IP patented and independently assessed by qualified organisations, dating back to 2006. However, we do not offer a Best Available Technology (BAT) claimed by some others, as our treatment systems incorporate two or more technologies that need site-specific optimisation, prior to undertaking detailed techno-economic and life cycle assessments, which are essential for commercial decisions. We offer best-fit saline waste minimisation solutions, after optimising the technology packages for site-specific application.



Proposed staged approach to developing an optimised technology package for commercial decision making



Expected benefits from application of our technology-based solutions

- Technologies have been tested at multiple sites faced with different sets of salinity management challenges.
- The integrated treatment system offers significant flexibility to adapt with changing mineral products market demand, site-specific environmental conditions and regulatory requirements.
- The proposed technology package potentially offers a unique opportunity for achieving significant operational cost saving via sale of mineral products generated by Salpro treatment of CSG produced water and residuals (brines and mixed salts) in the dams.
- The continued access to deep technical know-how vested with Pact Renewables, its worldwide experience with addressing diverse saline water disposal challenges and technology reputation established over the decades collectively point to Pact Renewables' proven project delivery capabilities.
- The generated IP (related to the optimised ITAP and operational know-how) is vested with the project funder for application at multiple sites/projects.
- We expect that our proposed solutions for permanent removal of CSG produced water and residuals will support project approvals (where needed), whilst satisfying community expectations.

About Pact Renewables' technologies

Salpro is an enabling technology for selective or sequential recovery of commercial-grade mineral products from inorganic saline waters and wastewaters by a combination of chemical reaction, evaporation, and separation process steps, using conventional mineral processing equipment. The technology is highly scalable and capable of achieving zero liquid discharge, by converting the bulk of impactful waste into saleable mineral products for sale and/or downstream value adding.

The technology has been evaluated on a wide range of saline-alkaline waters including CSG produced water from the Bowen Basin and has been independently evaluated and recognised as an enabling technology for mineral recovery from saline waters. Included is a CSIRO report (GISERA, 2024) identifying it as an economically and operationally attractive option for selective salt recovery for the beneficial reuse or end-use of produced water from the Narrabri Gas Project in NSW.



Skid-mounted Salpro test rig



Inside a shipping containerised Salpro unit



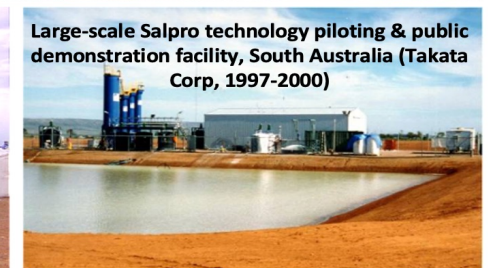
Trailer-mounted Salpro test rig



Small-scale Salpro pilot plant



Bagged Salpro product destined for overseas magnesium metal production trials, South Australia (1999)



Large-scale Salpro technology piloting & public demonstration facility, South Australia (Takata Corp, 1997-2000)



Field process/production trials in Bowen Basin, Queensland (Oil Company of Australia, 2003)



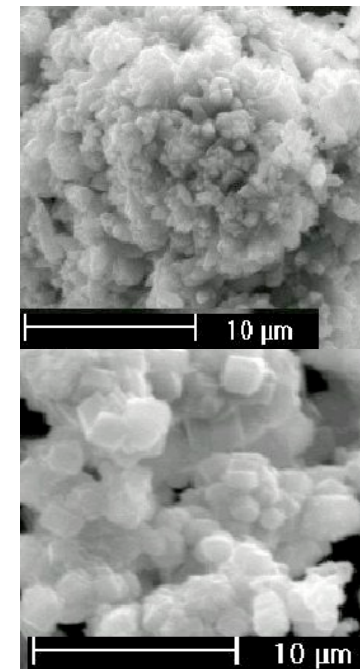
Field process & production trials on oil field brines (Petroleum Development Oman, 2002)



Field process/production trials on saline groundwater using a trailer-mounted testrig, NSW (2006)

Commercial-grade products obtainable from saline-alkaline waters, using Salpro-based selective mineral recovery processes

Product Group	Application Areas
Magnesium-based mineral products (various)	<ul style="list-style-type: none"> • Manufacture of magnesium metal; a critical metal primarily used in producing light-weight metal alloys for automotive and aerospace industries • Multiple uses in pharmaceutical industry, including antiacid preparation and laxatives, and production of cosmetics, toothpaste and ointments • Waste water treatment with neutralising properties, anti-caking, colour retaining and clarifying agents in the food and beverage industries • Feed supplement for animals/livestock, and magnesium source in fertilisers • Manufacture of inks, paints, plastics, rubbers, glass, ceramics, and specialty insulation material
Precipitated Calcium Carbonate (PCC)	<ul style="list-style-type: none"> • Very fine pure calcium carbonate used as a filler in plastics and specialty papers • Neutraliser of acidic soils for attaining optimal soil conditions for crop growth • Removal of sulphur dioxide produced from burning of coal in power stations
Sodium Chloride	<ul style="list-style-type: none"> • Diverse food and dietary related uses including food preservation • High purity molten salt for concentrated solar power systems • Preparation of sodium-ion battery electrolytes
Weighed Brines <small>(polished brine produced from the spent brine of Salpro process for site specific/opportunistic applications)</small>	<ul style="list-style-type: none"> • Carbon capture and sequestration • Deep-well injection • Selective extraction of critical materials (i.e., rare earth elements) or contaminants from mother liquors



Examples of targeted high-value, high market-demand mineral products recovered from CSG produced waters, using the Salpro technology. (Top view) Magnesium Carbonate Light (MCL). (Bottom view) Precipitated Calcium Carbonate (PCC).

About Pact Renewables' technologies (cont'd)

MBC is a unique technology for the manufacture and application of a suite of proprietary formulated mineral-based composites for effective encapsulation of hard-to-abate waste streams, including CSG residuals (brine and mixed salts) for safe landfilling. Manufactured from widely available precursor industrial minerals, this award winning technology is particularly suited for solidification of hygroscopic salt compounds via a recrystallisation step (which freezes free water molecules), considered essential for preserving the structural integrity of the encapsulated material and reducing risks commonly associated with internal dissolution of salts (due to the exerted hydrostatic head) leading to leakage of hazardous solutions to the surrounding environs.

Encapsulation of the solidified mass is achieved via aggregation, granulation or a combination of the two.

MBC composites were first evaluated in 2001 through large-scale field trials in Victoria and confirmed as a sustainable alternative to geotextile for lining dams for landfilling of nutrient-contaminated mixed salts, generated by large-scale irrigation projects. Considering the challenge with safe disposal of other hazardous waste streams Pact Renewables has since 2015 undertaken a systematic evaluation of various MBC formulations for encapsulation of a variety of intractable and toxic residuals for safe land filling. Against this background, MBC technology has emerged as currently the only proven technology offering zero waste discharge solutions for effective disposal of saline waste streams containing metal and organic contaminants.



About Pact Renewables

- A private cleantech company, established in 2011, that has developed and commercialised sustainable environmental technologies, and continues to develop new integrated technology-based hazardous waste discharge solutions
- The company also provides expert consulting services on salinity control, water reclamation, sustainable waste disposal and greenhouse gas abatement
- Owner of the IP for selective and sequential recovery of mineral products from saline effluents
- Led by Dr Aharon Arakel, the founder and lead inventor who has over 40 years of experience in advising industry, governments and communities concerned with all aspects of saline waste minimisation
- Engages highly qualified engineers and scientists, draws from complimentary skills and experience of collaborators around the world, and maintains close links with the government agencies, reputed EPCM providers and product off takers
- Operates specialised in-house material testing facilities and maintains field demonstration capabilities for its technology optimisation efforts.



Relevant Achievements

- (1993) Grant of first Salpro patent to Dr Aharon Arakel
- (1997-2000) First large-scale piloting of Salpro technology at Port Augusta, South Australia for treatment of seawater-sourced cooling effluent of a power station for recovery of high-grade magnesium metal feedstock and by-products. The project successfully achieved its zero liquid discharge (ZLD) objective leading to grant of a technology license to Takata Corporation of Japan in 2001
- (2002-03) Field trials of Salpro process for selective salt recovery from RO brine of a CSG production field operated by Oil Company of Australia in the Bowen Basin, Queensland, confirming the applicability of the technology for selective production of a suite of commercial-grade mineral products from CSG produced water
- (2006) Report by the U.S. Bureau of Reclamation providing a detailed comparative evaluation of several concentrate management technologies, and ranking Salpro as the best-fit ZLD brine solution in terms of its technical and operational feasibility, environmental acceptability and economic viability
- (2017) Grant of Patent for treatment of saline-alkaline waters including CSG produced water, brines and fracking water
- (2023): Recognition of the MBC technology at the World Economic Forum's annual meeting held in January 2023 at Davos and nomination of Pact Renewables as a "Top Innovator Company"
- (2023) Commencement of the +EU\$50m "Ash2Salt" plant by Ragn-Sells AB in Sweden, producing potassium and other chloride salt products from saline effluents generated by fly ash washing using an optimised saline processing technology package developed based on Pact Renewables' Salpro technology
- (2024) Completion of detailed evaluations of the MBC technology, which commenced in 2015, confirming its suitability for encapsulation of hazardous substances, including heavy metal residuals, asbestos waste and covid-infected masks and garment.

Technology demonstration

As part of its technology delivery process Pact Renewables has through time become well-versed with public demonstration of its technology-based salinity solutions to a wide audience ranging from communities and governments to companies seeking sustainable salinity solutions and sophisticated technology investors.

