Crystal Clearwater Resources (CCR)
Low Temperature Distillation LTDis®

Technology Overview and NMPWRC Pilot Results, May 11, 2022

Innovative | Clean-Tech | A New Approach

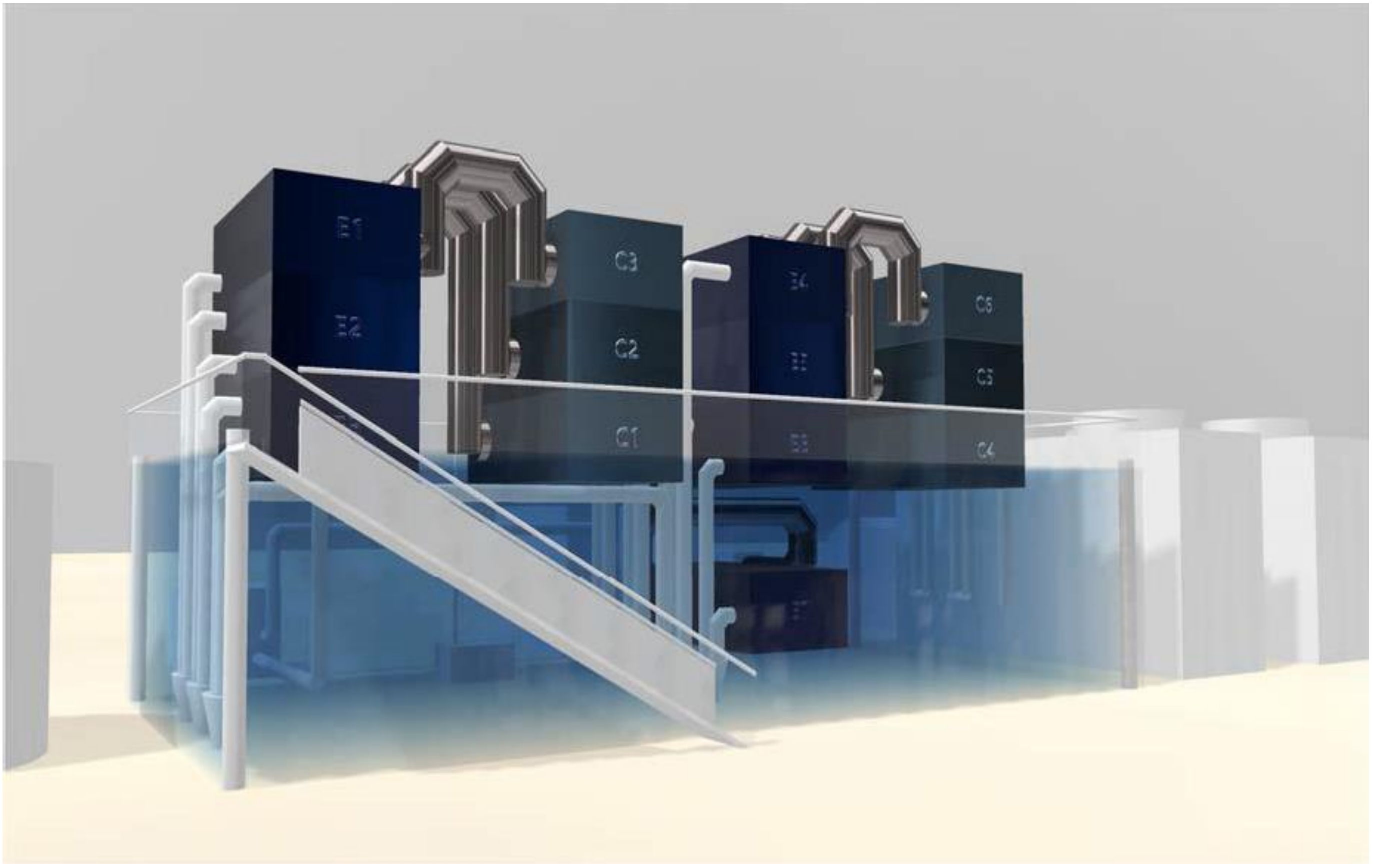
NM STATE NEW MEXICO PRODUCED WATER RESEARCH CONSORTIUM

Crystal Clearwater Resources (CCR)

Innovative Clean Technology

Crystal Clearwater Resources develops innovative, **clean-tech** solutions to address challenging wastewater streams associated with industrial applications.

- Environmental, Social, and Governance (ESG) focused
- Veteran managed and operated
- Leading-edge technology creating optimal solutions



Chevron

Winner of the 2019 Chevron Technology Challenge

CCR Management Team

Derek Pedersen

Co-Founder & CEO

- Experienced building and leading teams
- Retired Navy SEAL
- Worked on the most sensitive programs in the SEAL community.
- Received his MBA from SMU in Dallas Texas.

Kris Odland

VP of Cyber Security

- 18 years experience in Cyber & Technical security at the NSA.
- Received his MS of Computer Science & Networking at John Hopkins University.

Casey McKinne

VP of Operations

- Over 15-years of experience in the Oil & Gas industry.
- Former Navy SEAL and intelligence community.
- Experienced leading, managing multifaceted programs

Apoorva Sharma

COO

- 24 years leading in the energy sector.
- Multi-disciplinary background in petroleum, environmental engineering, and clean-tech applications.
- Received his M.Eng in Civil Engineering and MBA from University of Calgary.

Robert Noakes

VP of Technology

- Started at Shell's TechWorks.
- Developed predictive corrosion software and prototypes for fiber-optic measurement systems.
- Received a bachelor's degree in Mechanical Engineering from Queen's University.

Scott Carson

VP of BD & Marketing

- 25+ years of experience in Sales & Marketing for leading CPG companies..
- Former Marine Corps Sniper.
- Received his MBA from SMU in Dallas Texas.

Ambrose Lessard

VP of Innovation

- 14 years experience as a chemical engineer
- Integrated novel heat sources in to LTDis
- Drives the modifications to the existing technology
- Works cross functionally to improve reliability, thermal efficiency, and cost to build.

Marina Foster, PMP

Special Projects Mgr.

- Responsible for all aspects of sourcing, applying for and executing DOD/DOE challenges and grants
- Serves as the point of contact for relationships with National Labs.

CCR
Crystal Clearwater Resources

Awards and Grants

DOE’s Chevron Technology Challenge

2019 DOE’s Chevron Tech Challenge Finalist for purposing our LTDis® technology to decrease produced water management costs while reducing waste streams.

DOE’s American Made Solar Desalination Challenge

Quarterfinalists of the DOE's American Made Solar Desalination Challenge for our proposal to utilize solar thermal as the energy source for our LTDis® technology

DOE’s American Made Water Resource Recovery Facility Challenge

Semifinalists of the DOE's American Made WRRF challenge for proposing to partner with Ramona’s San Vicente Wastewater Treatment Plant to increase their water recovery and decrease their brine disposal costs.

New Mexico Produced Water Research Consortium Grant

Awarded a grant to partner with a national testing facility to demonstrate LTDis® cost effectiveness and energy-efficiency in treating both medium and high salinity produced water.

Technology Overview

Low-Temperature Distillation (LTDis®)

Our innovative approach overcomes challenges associated with wastewater treatment

Simple

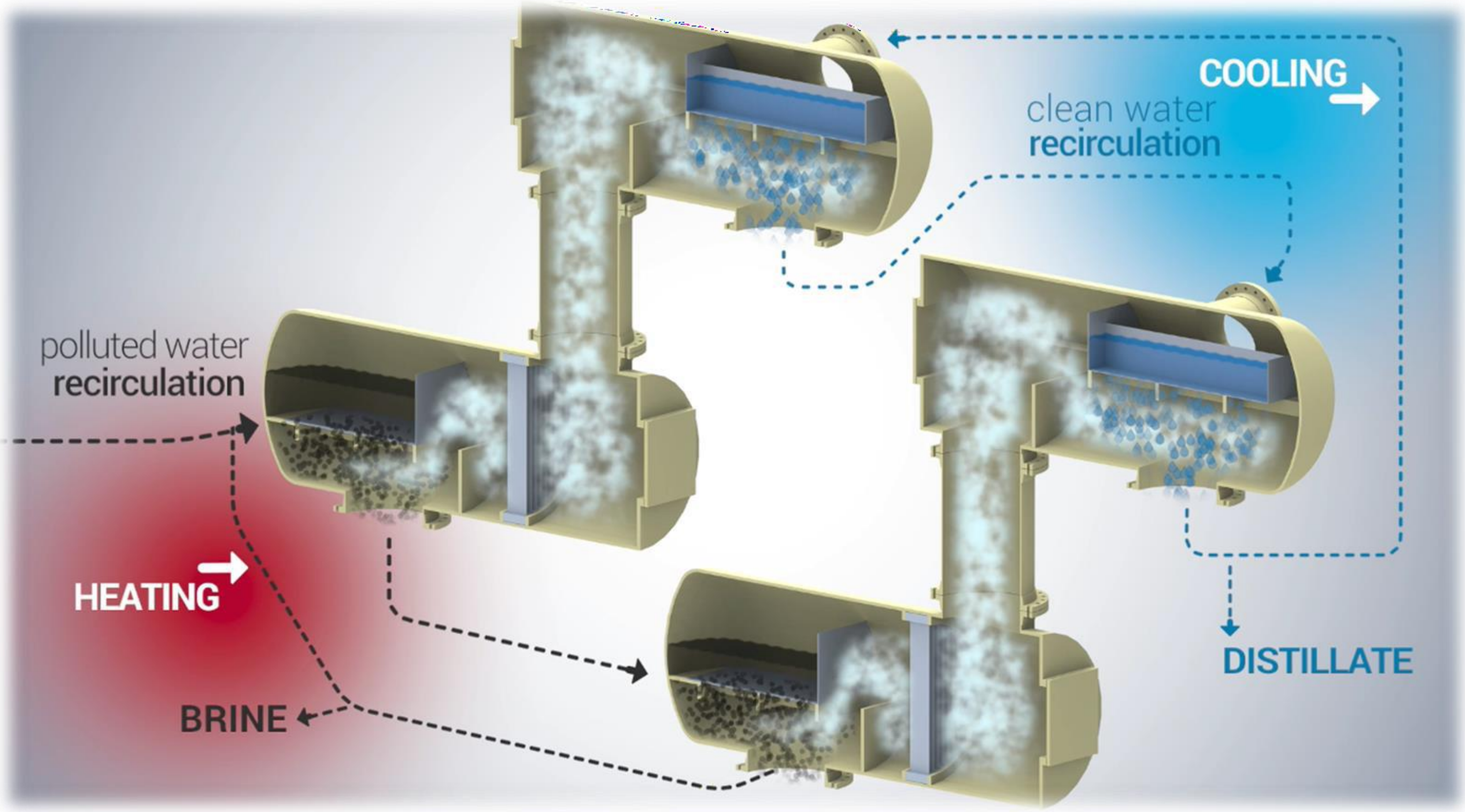
- Spontaneous evaporation/condensation
- Water droplets replace traditional heat exchange surfaces

Robust

- Concentrate up to 300,000 ppm
- Little to no scaling

Efficient

- High energy efficiency
- Operates under partial loads
- Capable of utilizing waste heat



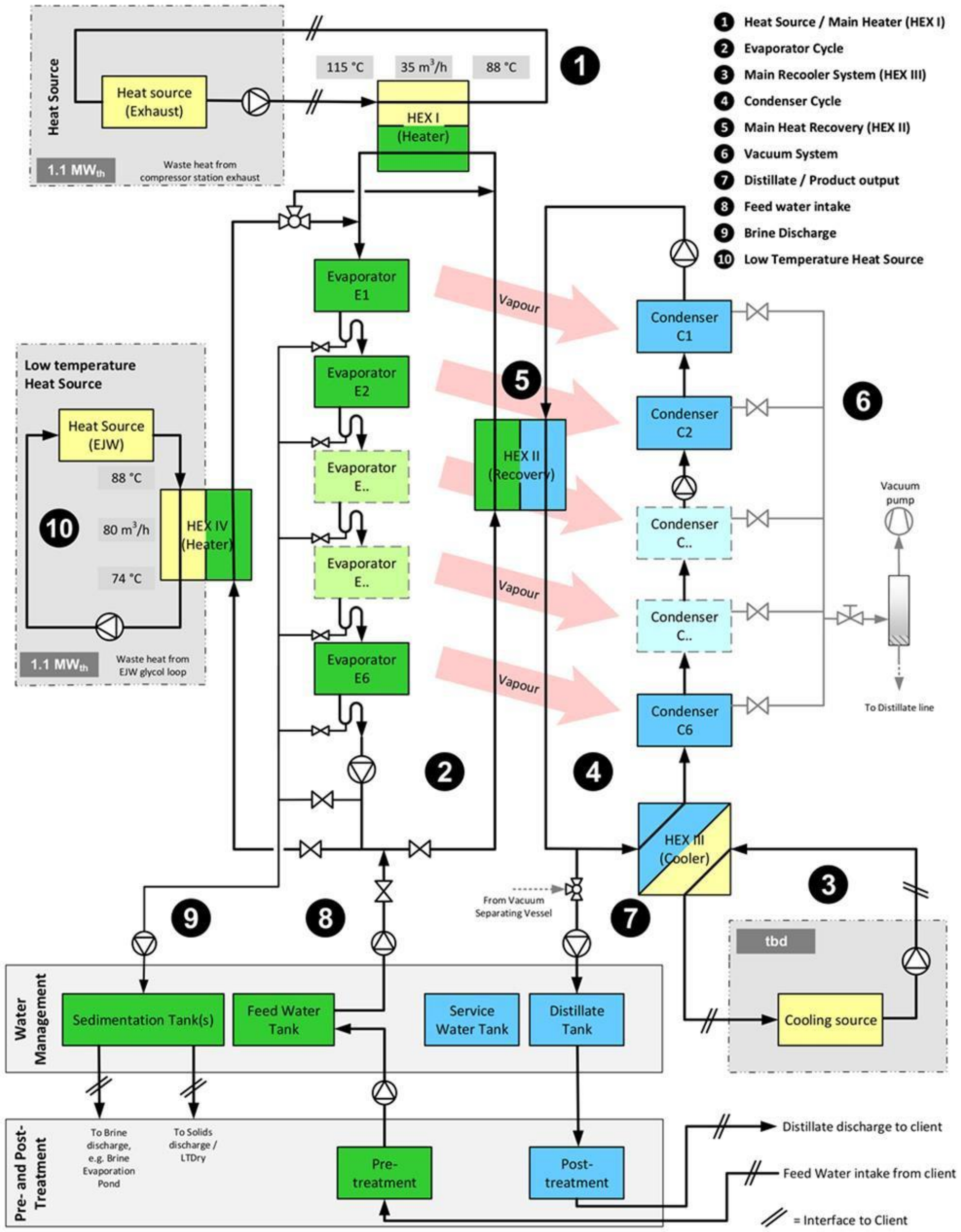
LDTis® Compared to Similar Desalination Technologies

LTDis® is differentiated by:

- Versatility & efficiency
- Minimized scaling risk (evaporation in air)
- Tolerance of fluctuating or intermittent heat source (e.g. solar thermal, waste heat)
- Proprietary Distribution System
- Billions of water droplets
- No phase change on solid surfaces
- Robustness, made from standard equipment and not from exotic materials.

Parameter	LTDis®	Multiple-Effect Distillation (MED)	Evaporator
Heat (MMBtu/bbl.)	0.15	0.05	0.6
Electricity (kW-h/bbl.)	1	<1	4
Risk of Scaling	LOW	HIGH	HIGH
Heat Source Versatility	HIGH	POOR	MODERATE
Equipment	Standard kit Standard materials	Exotic metallurgy	Exotic metallurgy
Turndown Performance	3:1	Narrow	Varies

Treatment Process Overview



1 The heat source supplies the heat for the **Main Heater** (HEX 1) of the LTDis system by pumped heating media.

2 In the **Evaporative Cycle**, the hot water is sprayed and evaporated in pressure reduced evaporator vessels. The water flows by gravity from the one chamber to the next and its temperature decreases.

3 The **Main Re-cooler System** cools down the distillate before pumping it into the condenser cycle. The re-cooler cycle consists or a re-cooling devise using a cooling media and pumps for running circulation.

4 In the **Condenser Cycle,** cool water is pumped and then sprayed into the condenser vessels for absorbing heat and vapor from the evaporators. During this process temper increases from one stage to the next.

5 The **Main Heat Recovery Heat Exchanger** (HEX II) extracts the heat from the hottest condenser and transports it as a preheating into the cool evaporator flow.

6 A **Vacuum System** extracts the non-condensable gases in the condensers.

7 The **Distillate** is extracted before the re-cooling at the coolest temperature possible. A post-treatment system treats the produced distillate according customer requirements

8 The **Feed Water** enters the evaporator cycle after a pre-treatment.

9 The **Brine** is extracted from the evaporator cycle after the last evaporator stage.

10 Part of the evaporator flow is brought to the **Low Temperature Heat Source** (HEX IV) for preheating. Depending on temperature, this flow is mixed again with the main evaporator cycle flow before or after the main heat source.

Energy Sources

Heat Sources

LTDis® is heat-source **agnostic**

- 0.15 MMBtu thermal energy input per barrel of distillate output
  - E.g. 10 MMBtu/hr. (heat) = 1,600 bpd (distillate)
  - Distillate production is **constant**, regardless of feed salinity
- Tolerant of fluctuating and intermittent heat sources
- Operable with heat source as low as 75°C (167°F)

Conventional Sources	Non-Traditional Sources
Boiler (diesel)	Engine exhaust heat (Caterpillar 3608 = 2 MMBtu/hr.)
Boiler (field gas)	Thermal solar (7,000 ft^2 = 1 MMBtu/hr.)
	Engine jacket water heat (3600 = 2 MMBtu/hr.)
	Compressor inter-stage cooler (12.5 MMSCFD = 4 MMBtu/hr.)

Non-Traditional Heat Sources – Genset

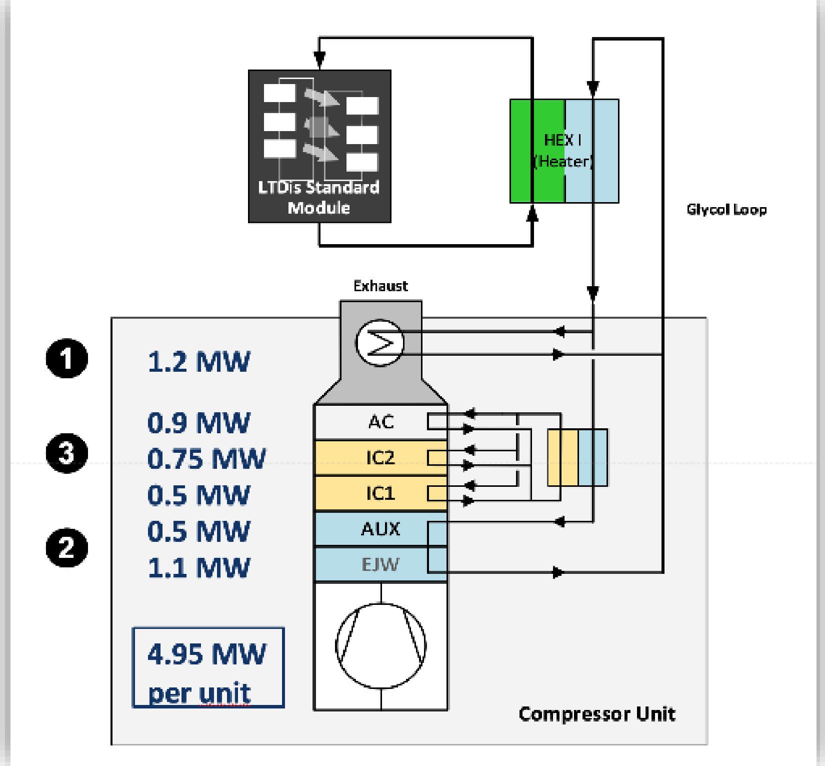
Why LTDis® with Combined Heat Power?

- Recovered Waste heat improves total system efficiency from 33% to 80-90%
- Generating electricity onsite reduces transmission and distribution losses which average 4.5% nationally
- Compared to conventional electricity generation, on average CHP systems use 32% less fuel and have 50% less annual carbon emissions
- Improve business competitiveness by increasing energy efficiency and managing costs

Non-Traditional Heat Sources – Waste Heat

Why LTDis® with Waste Heat?

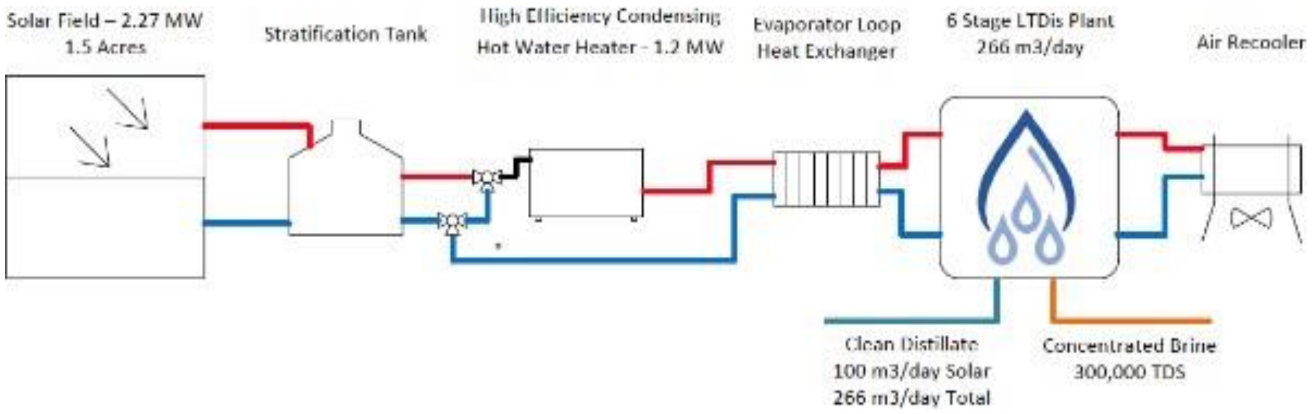
- 4.95 MW (16.9 MMBtu/hr.) compressor heat = 2,700 bpd (distillate)
- Carbon-neutrality for existing infrastructure
- LTDis® operates through unexpected fluctuations and outages in heat source



Non-Traditional Heat Sources – Solar Thermal

Why LTDis® with Solar?

- We can operate well under 100°C (212°F), which makes solar thermal more efficient
- The flexibility of LTDis® enables it to use the transient nature of solar heat
- Potential access to carbon credits
- Lower operational expenses

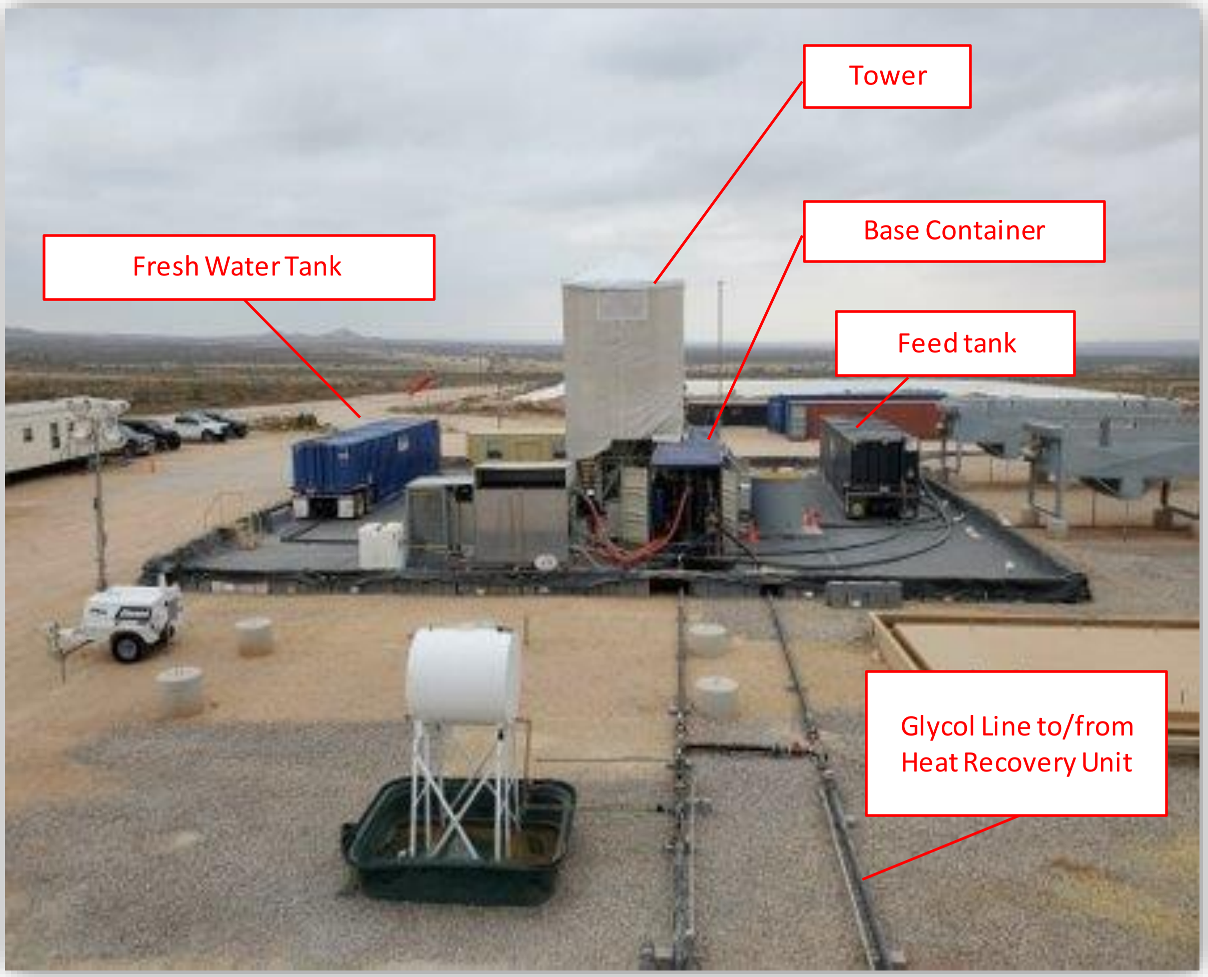


Crystal Clearwater Resources

NMPWRC Pilot – Produced Water/Waste Heat

NMPWRC Pilot Site Location

Pilot located at Customer Compressor Station



CCR
Crystal Clearwater Resources

Operating Time

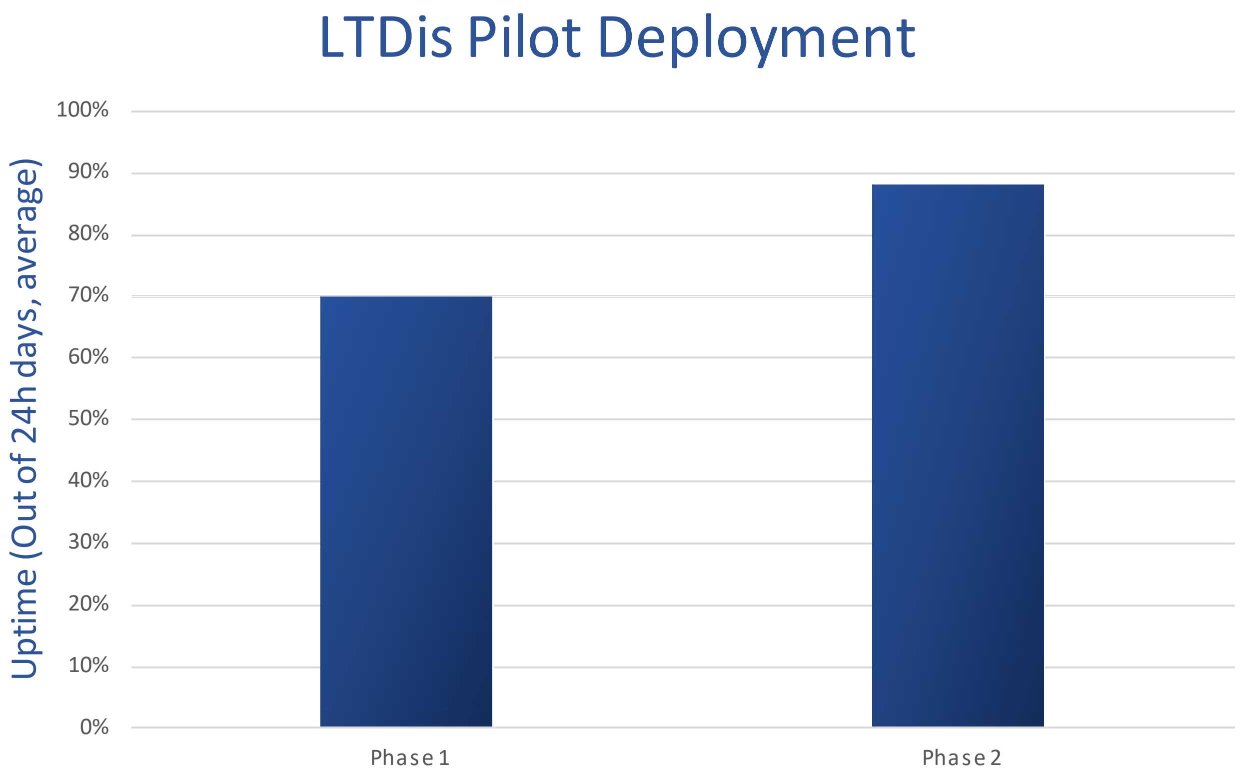
Phase 1 & 2

Phase 1: 70% uptime

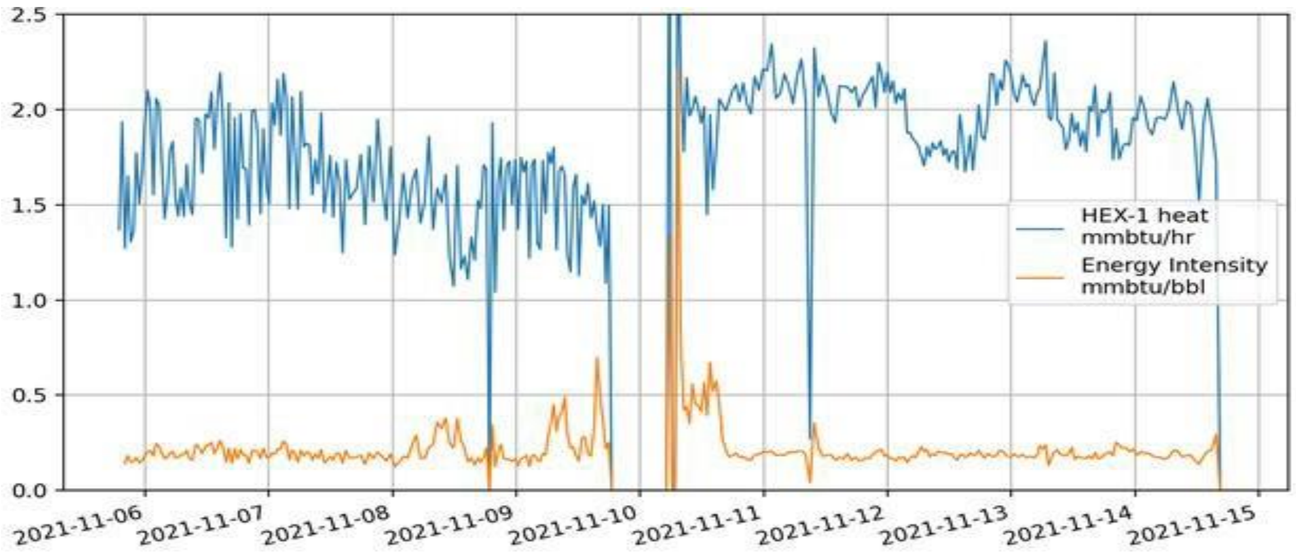
- Added insulation to the heat source
- Shut down for heating-loop maintenance

Phase 2: 88% uptime

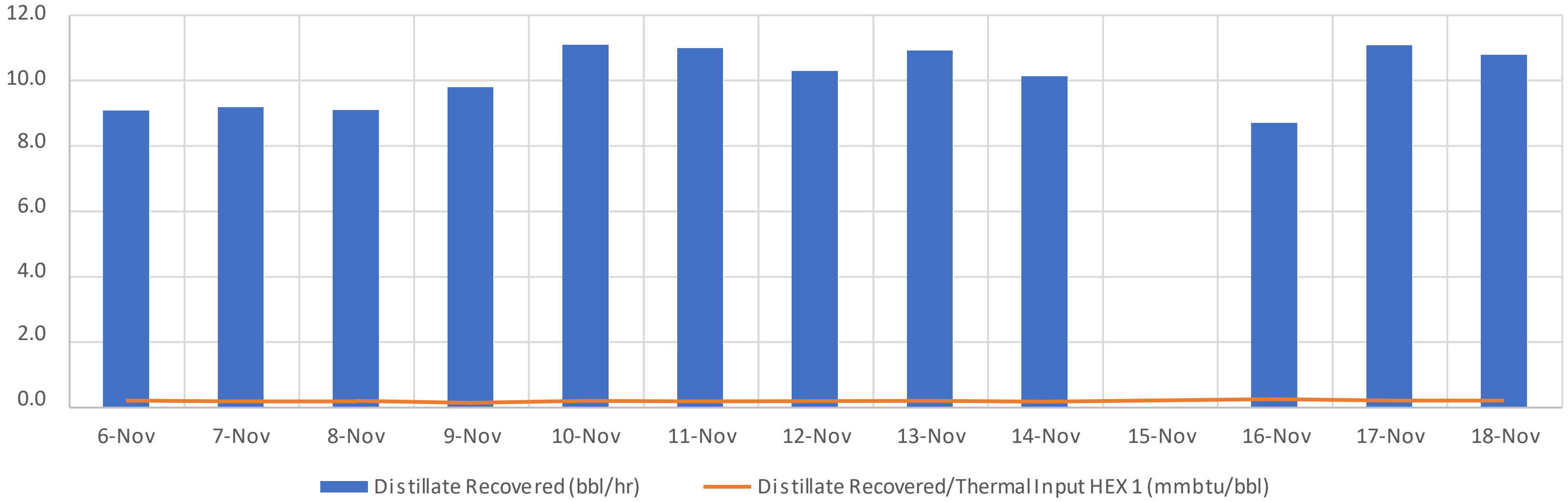
- Software modifications between Phase 1 and Phase 2 resulted in improved operating stability.
- Switched cooling loop to internal distillate recycle



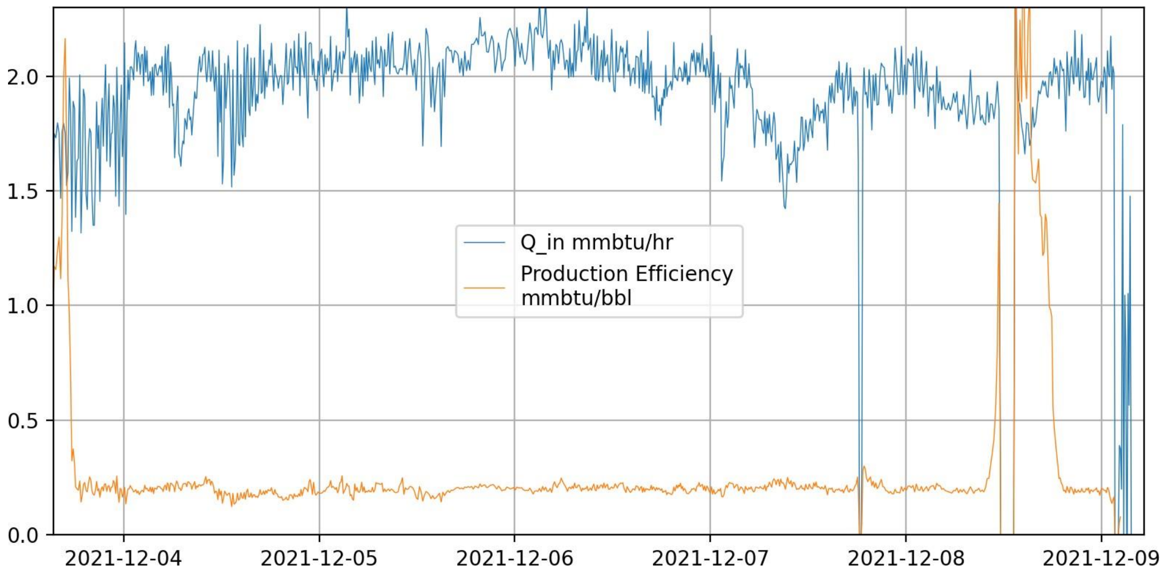
Distillate Production – Phase 1



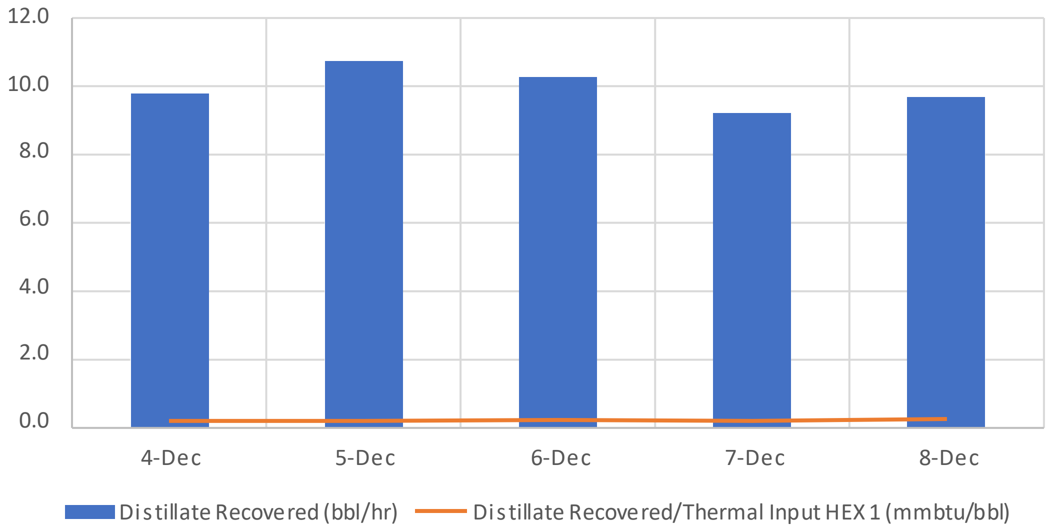
- Average thermal intensity was 0.20 MMBtu/bbl.
- Thermal efficiency 1.5 – 2.5, similar to shop testing
- Stable thermal intensity, even with variable heat input
- Simple re-start following heat source loss
- High turn-down capacity, but implications for scaling at lower flowrates



Distillate Production – Phase 2



- The average thermal energy per unit of distillate produced was 0.20 MMBtu/bbl.
- Production efficiency consistent and similar to Phase 1
- Average thermal intensity was 0.20 MMBtu/bbl.
- Stable thermal intensity, even with variable heat input



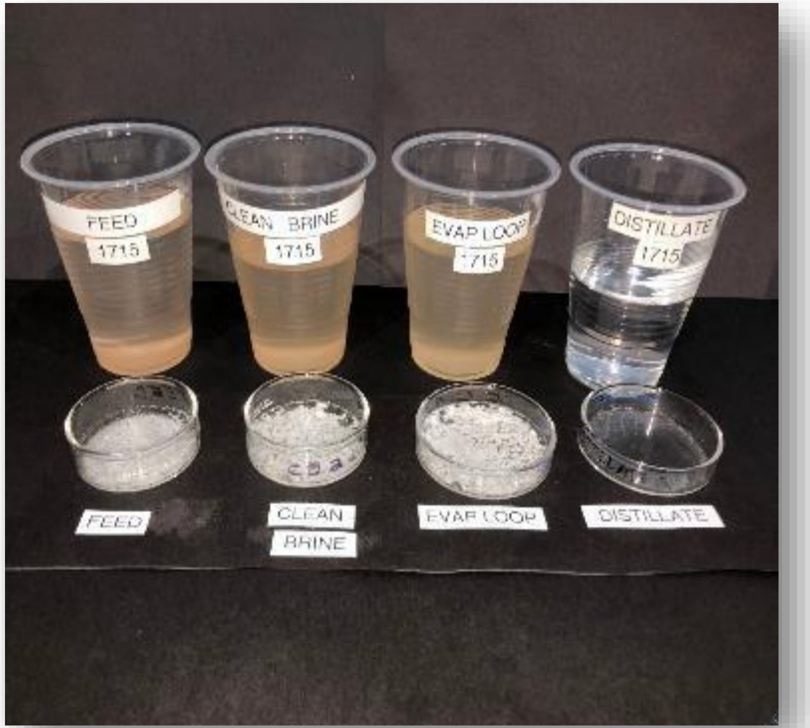
Distillate Water Quality – Laboratory Results

Laboratory Water Quality	Average (mg/L)	Min (mg/L)	Max (mg/L)
Phase 1			
Feed	105,000	90,000	120,000
Distillate	388	152	929
Phase 2			
Feed	130,000	110,000	170,000
Distillate	303	223	372

TDS calculated using TDS Calculation Method 1030E for Factored Summation: Outliers Removed

- 6 inline instantaneous conductivity outliers (order of magnitude delta)
- 1 laboratory outlier (ion balance)
- Distillate quality uncorrelated with feed quality
- Feed upsets (increases in salinity) did not result in any observable change in distillate quality

Activated Carbon Filter – Polishing of Distillate Stream



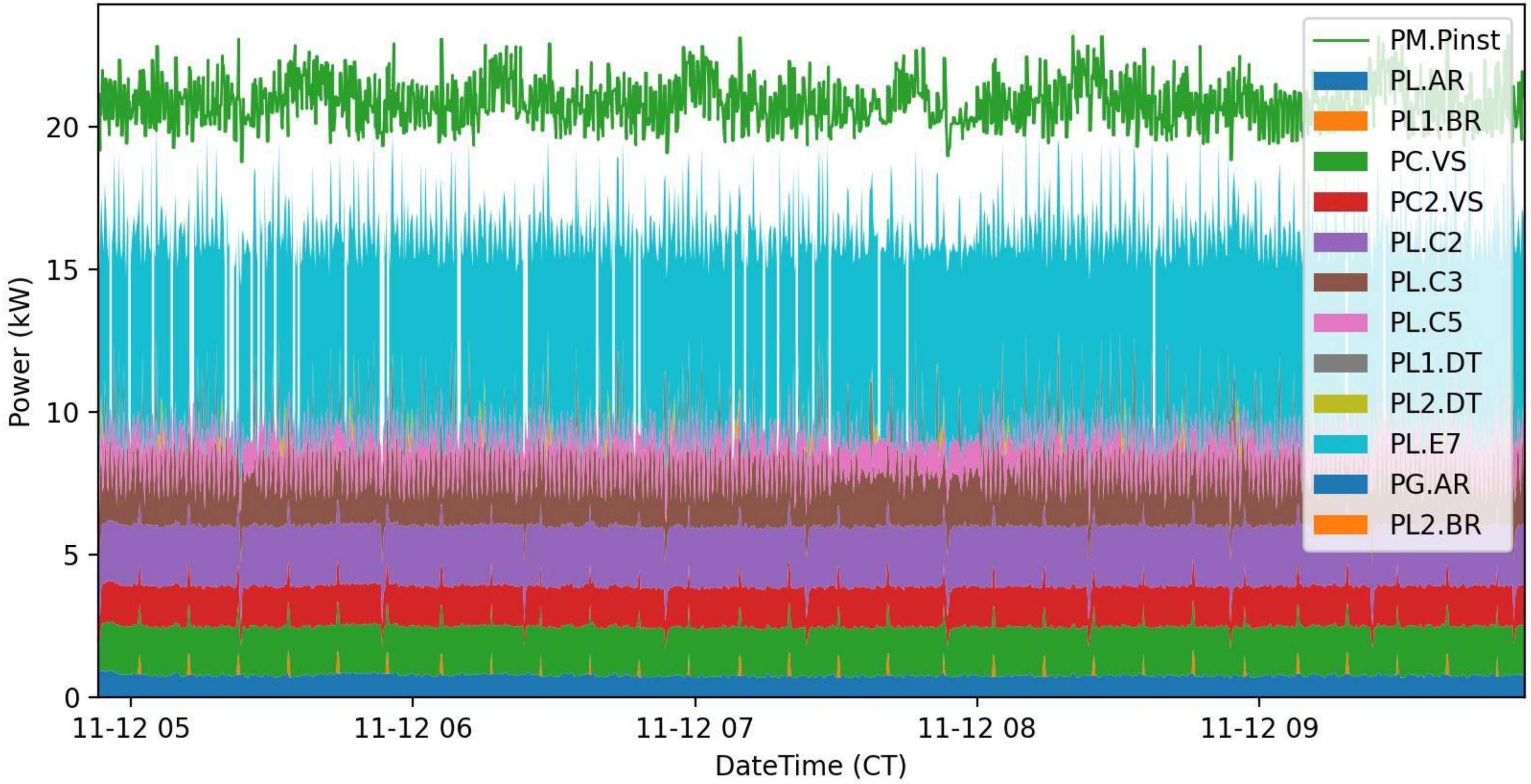
Distillate Sample	Pre-carbon Treatment	Post Carbon Treatment
Parameters (ppm)	**Distillate pre-carbon filter**	**Distillate post-carbon filter**
Benzene	0.501	<0.000214
Toluene	0.548	<0.000500
Ethylbenzene	0.0214	<0.000515
Xylenes	0.377	<0.000330

Thermal & Electrical Requirements

Performance Metric	Phase 1 Nov 7 - 10	Phase 1 Nov 11 - 18	Phase 2 Dec 3 - 8	Projected Commercial Plant
Distillate Production (bbl./d)	226	250	238	TBD
Thermal Req. (MMBtu/bbl.)	0.21	0.19	0.20	0.15
Electrical Req. (kWh/bbl.)	2.13	2.48	2.19	1.07

1.1 kWh/bbl. Electrical requirement demonstrated already with prototype using natural gas boiler

Continuous Operation – Electrical Demand



- Plant operating at turndown at lower heat input (9 bbl/hour vs. 30 bbl/hour)
- Two electrical data sets - VFD loggers,
  Onboard power logger
- Why discrepancy between two datasets? VFDs consume 4 – 6 kW.
- Power factor of 0.7 was low due to operation at **reduced capacity**.
- Estimate apparent power consumed was
  30kVa with 0.7 Power Factor
- Future opportunities to reduce consumption:
  - ✓Optimize PF to 0.8 (27kVA)
  - ✓Increase VFD utilization (constant loss)
  - ✓Evaporator pump re-selection
  - ✓Optimal vacuum pump selection

CCR
Crystal Clearwater Resources

Operating Expenses

Heating Cost (US$ per MMBtu)

Electricity Cost (US$ per kW-h)

$/BBL	$ -	$ 0.50	$ 1.00	$ 1.50	$ 2.00	$ 2.50	$ 3.00	$ 3.50	$ 4.00	$ 4.50	$ 5.00	$ 5.50	$ 6.00
$ -	$ -	$ 0.08	$ 0.15	$ 0.23	$ 0.30	$ 0.38	$ 0.45	$ 0.53	$ 0.60	$ 0.68	$ 0.75	$ 0.83	$ 0.90
$ 0.02	$ 0.02	$ 0.10	$ 0.17	$ 0.25	$ 0.32	$ 0.40	$ 0.47	$ 0.55	$ 0.62	$ 0.70	$ 0.77	$ 0.85	$ 0.92
$ 0.04	$ 0.04	$ 0.12	$ 0.19	$ 0.27	$ 0.34	$ 0.42	$ 0.49	$ 0.57	$ 0.64	$ 0.72	$ 0.79	$ 0.87	$ 0.94
$ 0.06	$ 0.06	$ 0.14	$ 0.21	$ 0.29	$ 0.36	$ 0.44	$ 0.51	$ 0.59	$ 0.66	$ 0.74	$ 0.81	$ 0.89	$ 0.96
$ 0.08	$ 0.09	$ 0.16	$ 0.24	$ 0.31	$ 0.39	$ 0.46	$ 0.54	$ 0.61	$ 0.69	$ 0.76	$ 0.84	$ 0.91	$ 0.99
$ 0.10	$ 0.11	$ 0.18	$ 0.26	$ 0.33	$ 0.41	$ 0.48	$ 0.56	$ 0.63	$ 0.71	$ 0.78	$ 0.86	$ 0.93	$ 1.01
$ 0.12	$ 0.13	$ 0.20	$ 0.28	$ 0.35	$ 0.43	$ 0.50	$ 0.58	$ 0.65	$ 0.73	$ 0.80	$ 0.88	$ 0.95	$ 1.03
$ 0.14	$ 0.15	$ 0.22	$ 0.30	$ 0.37	$ 0.45	$ 0.52	$ 0.60	$ 0.67	$ 0.75	$ 0.82	$ 0.90	$ 0.97	$ 1.05
$ 0.16	$ 0.17	$ 0.25	$ 0.32	$ 0.40	$ 0.47	$ 0.55	$ 0.62	$ 0.70	$ 0.77	$ 0.85	$ 0.92	$ 1.00	$ 1.07
$ 0.18	$ 0.19	$ 0.27	$ 0.34	$ 0.42	$ 0.49	$ 0.57	$ 0.64	$ 0.72	$ 0.79	$ 0.87	$ 0.94	$ 1.02	$ 1.09
$ 0.20	$ 0.21	$ 0.29	$ 0.36	$ 0.44	$ 0.51	$ 0.59	$ 0.66	$ 0.74	$ 0.81	$ 0.89	$ 0.96	$ 1.04	$ 1.11

OPEX Matrix ($US per barrel distillate)

$0 Waste Heat: $0.07/kW-h Electricity $0.07
$4.00/MMBtu gas: $0.10/kW-h Electricity $0.71
$4.00/gallon diesel: $0.15/kW-h Electricity$4.54

CCR
Crystal Clearwater Resources

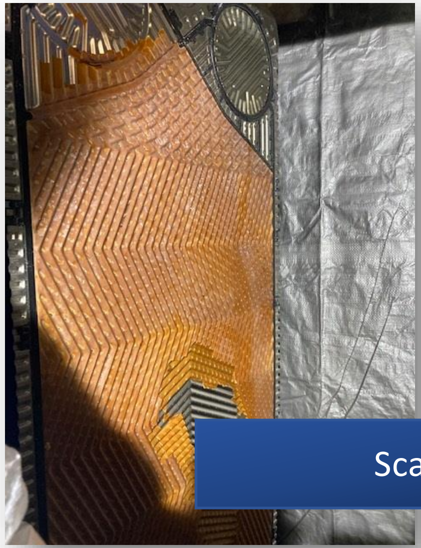
Pilot Summary

1. Utilized waste-heat
2. Desalinated produced water 120,000 – 170,000 ppm
3. Created distillate < 500 mg/l
4. Demonstrated a 3:1 turndown ratio
5. Uptime 88% (Phase 2)
6. Fluctuating feed and heat input
7. Brine concentrate 280,000 – 300,000 ppm

10 / Next Steps – Learnings for Commercial Design

Learnings for Commercial Design

Vacuum System Design



Scaling

Maximize Thermal Efficiency

Conductivity Spikes

WQ Management

Maximize Electrical Efficiency

Conclusion

Demonstrated the capability of the LTDis® and ***exceeded*** requirements for pilot operation.

- Successful desalination of produced water (120,000 ppm-170,000 ppm) to consistently below 500 ppm
- Utilized available ***waste heat*** on site even with a turndown ratio of 60%
- Produced high-quality distillate throughout steady state operations
- Energy OPEX requirements is **significantly lower** compared to other thermal technologies on market
  - ✓ The technology can be a significant driver for lowering carbon emissions in oil & gas operations
  - ✓ Combined with solar thermal and solar pv can be a driver for the "net zero journey"
- Can produce significant lower cost source of "freshwater production" in areas with water scarcity
  - ✓ Cost of "fresh water " in the Permian and Delaware basin can be > $1.00/bbl for sourcing and trucking costs
  - ✓ Beneficial water use/surface discharge possible with water polishing steps

A real solution for reducing volumes of produced water being injected into SWDs by up to 50% in the Delaware basin

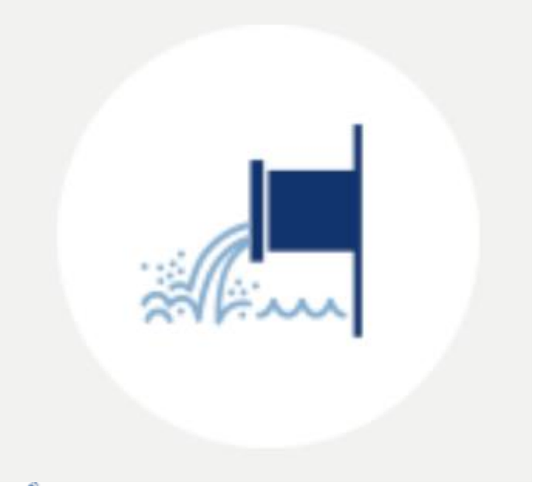
CCR
Crystal Clearwater Resources

Questions and Discussion

Applications

Oil & Gas Water Management

Industrial Wastewater



Brine Discharge

*From existing desalination plants

Seawater & Solution Mining