The Repowering of Lightning Dock Plant in New Mexico

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ABSTRACT

The paper presents the repowering of the Lightning Dock plant in New Mexico, USA.

The Lightning Dock geothermal resource area is located on the east side of Animas Valley in Hidalgo County, New Mexico. The area was identified as a Known Geothermal Resource Area in 1974. Lightning Dock area was previously home to one of the biggest greenhouse complexes in the U.S. In 2013, a 4 MW plant was realized by Cyrq, with plans to further enhance it to 10 MW. However, the second phase of the development with the original equipment supplier was never realized. The site is at 4236 ft above mean sea level, with an average ambient temperature of 60 °F.

Turboden was selected together with Industrial Builders to perform a complete revamp of the power plant at Lightning Dock. The contractor offered to provide a brand new power plant producing 11.2 MW net (14 MW gross) electric power with a single ORC turbine.

Cyrq ordered the new plant in 2017, which is currently in commercial operation since December 2018. The client secured a PPA for a period of 25 years.

The plant is designed to exploit geothermal brine from existing geothermal wells. Isobutane is the design working fluid selected in its approach to efficiently harness the geothermal fluid readily available in the area. The choice of the working fluid was made after other alternatives were carefully studied. Other fluids such as pentane have been put onto test but they have failed to deliver results as efficient as isobutane.

The power plant is composed by heat exchangers, a single turbine directly coupled with a generator, a recuperator, a condenser, and feed pumps. The plant will be fed by 5000 gal/min of geothermal brine at 310 °F. After cooling in the plant heat exchangers, the brine will be returned to the reinjection wells at about 170 °F.

The project is an interesting example on how an improved design and technologies can be utilized for revamping older plants and create a positive business case, due to the expected higher plant availability and increased efficiency.

1. Cyrq

Cyrq Energy holds the fourth largest geothermal operating portfolio in the U.S., and is a privately-owned renewable energy company primarily focused on geothermal power ownership, operations and development. The senior management team has a combined 100+ years of power project development and operations experience, having completed over 35 utility scale power plants. Cyrq's current operating portfolio is comprised of five facilities located in the southwest U.S. totaling 131 MW of gross generating capacity (including 10 MW of solar primarily utilized to provide for parasitic loads). Cyrq also has a development pipeline of 110 MW across four projects with established geothermal resource and secured land rights, 50 MW of which are located at an existing operating site.

2. Experience of Turboden and Industrial Builders in Geothermal Applications

Turboden stands among the pioneers of Organic Rankine Cycle Technology (ORC), being at the same time the European Leader for Geothermal application. Currently there are more than 350 Turboden ORC plants in operation in 40 countries worldwide, featuring in-house designed turbines.

Turboden completed its first geothermal plants in Italy and Africa in the early Nineties.

Turboden is present in Europe with six geothermal binary plants in operation, and three under construction. The plants are located in Germany, France, Turkey, and Croatia, supplying base-load power and heat for the local communities.

In the last years, Turboden has successfully implemented 4 geothermal plants in the Molasse basin (Bavaria, south of Munich). One 5 MW geothermal power plant (in Sauerlach), two other 5,6 MW plants in the same region (in Dürrnhaar and Kirchstockach), and a 4,1 MW cogenerative geothermal plant in the city of Traunreut, designed to deliver also up to 12 MW thermal power to the local heating grid.

A further 5 MW geothermal plant is commissioned in the Oita prefecture in Japan, Kyushu Island. This plant uses a geothermal source with about 15% steam quality at 140 °C.

In August 2017, Turboden has won a European tender for a 3,4 MWel plant to be realized in Holzkirchen. This order confirms Turboden's leadership in the German market.

Turboden successful experience continues in France, for the Soultz-sous-Forêts plant in operation. Currently Turboden is in the construction phase for another geothermal plant in the Upper Rhyne Valley.

The first geothermal power plant of Turboden in Turkey is in operation since 2017. A tailor made Turboden solution was designed and put into operation in the city of Afyon. In addition to electricity production, AFJET also provides heating for homes in the area and water for the greenhouses.

In Croatia, Turboden has constructed one of the largest single ORC turbines for the 16 MW Velika Ciglena project.

Industrial Builders, Inc. (IB) has been responsible for installing eight (8) modular geothermal organic rankine cycle (ORC) power plants in the last twelve (12) years. Including binary conversion equipment and balance of plant equipment for; San Emido, Empire, NV (12.0 MW), Dixie Valley, Fallon, NV (46.5 MW), Neal Hot Springs, Vale, OR (33.0 MW), Patua 1, Hazen, NV (48.5 MW), Lightning Dock, Animas, NM (4.0 MW and a 14.0 MW repower), Raft River, Malta, ID (15.0 MW), and Blue Mountain Faulkner 1, Winnemucca, NV (49.5 MW).

IB's clients include; CYRQ Energy, Ormat, US Geothermal, Terra-Gen Power, Idaho Power, BASF, SAIC (Science Applications International Corporation, Leidos, Haskell), Tesoro, Chevron, Anhaueser-Busch, Transportation Security Administration, and US Bureau of Reclamation to name a few. From world leaders in geothermal power, chemicals and military contracts, to cities, counties, state and federal authorities, IB is a leader in geothermal, pipeline, civil, infrastructure, and industrial power and process.

With IB's history in geothermal, our resume and geothermal credentials, support and construction, qualify IB as having more experience and more exposure and analysis than any other independent binary power plant Engineering, Procurement and Construction (EPC) firm.

IB provided the EPC and balance of plant (BOP) including start-up and commissioning, for the Lightning Dock Geothermal (LDG) power plant, installing one (1) Turboden 14.0 MW ORC turbine and generator, heat exchangers pumps, storage, lubrication, air cooled condenser heat rejection, and related systems. This includes all; mechanical, structural, electrical, instrumentation and control auxiliaries and accessories necessary for safe, efficient, and reliable operation, modular building groups, with equipment arranged so all systems can be easily accessed for maintenance.

IB constructed the Turboden designed and provided plant layout with features to optimize maintenance work, minimize operator surveillance, complied with all OSHA requirements, and designed all equipment and piping support with adequate permanent connections to perform acceptance and performance testing, operable from the control room under all normal conditions, and designed for minimal local operator attention for startup and shutdown.

IB furnished a 100% Performance and Payment Bond, and guaranteed the IB supplied equipment conformed to the appropriate requirements, codes and standards, and warranted all IB supplied equipment, Turboden likewise provided all appropriate guarantees and warrantees, within their scope of supply and responsibility.

IB has assisted Turboden in supporting and performing the Reliability Testing after substantial completion and ready for commercial operation and deliver, operating the plant at full load for the required continuous period.

IB and Turboden were both mutually responsible for providing their respective scope of supply and work, an extremely common and cost effective approach that is often undertaken in these competitive projects.

3. The ORC technology

The well-known Rankine Cycle is a thermodynamic cycle that converts heat into work. The heat is supplied to a closed loop, which typically uses steam as working fluid to spin a turbine and generate power. The Rankine Cycle based on steam provides approximately 85% of worldwide electricity production.

The Organic Rankine Cycle's (ORC), instead of generating steam, it vaporizes an organic fluid characterized by a molecular mass higher than that of water and lower boiling point. In such way it is possible to exploit the heat of lower temperature resources. The ORC turbogenerator features slower rotation of the turbine, lower pressures and no erosion of the metal parts and blades.

The ORC turbogenerator uses low-to-high-temperature geothermal brine (heat source) to preheat and vaporize a suitable organic working fluid in the evaporator. The organic fluid vapor rotates the turbine, which is directly coupled to the electric generator, resulting in clean, reliable electric power.

The exhaust organic vapor flows through the recuperator, where it heats the organic liquid and is then condensed in the condenser and cooled by the cooling media. The organic working fluid is then pumped into the recuperator and evaporator, thus completing the closed-cycle operation.

4. US Geothermal industry

The first uses of geothermal energy occurred more than 10,000 years ago in North America by American Paleo-Indians, using water from hot springs for cooking, bathing and cleaning.

The first industrial use of geothermal energy began near Pisa, Italy in late 18th century. Steam was used to extract boric acid from the hot pools known today as the Larderello fields. In 1904, the first geothermal electric power plant used geothermal steam to generate electricity.

In 1922, the first geothermal plant in the U.S. was a 250 kW plant. Pacific Gas and Electric started the first large scale geothermal power plant outside San Francisco located at the Geysers, and began operating in 1960, producing 11.0 MWs. That plant operated for more than 30 years.

Today there have been more than 60 geothermal power plants operating at sites across the country.

Since these early projects, geothermal energy in the United States has continued to expand, however, geothermal remained a minor contributor of energy until the ‘70s. The oil crises, which began in 1973, caused many utilities to start looking for alternative energy sources, which led to increased investment in alternative energy sources like geothermal.

As of 2017, geothermal power plants in the U.S. generated approximately 16 billion kilowatt-hours (kWh), which is less than1% of the total U.S. utility-scale electricity generation. California produces 73% of the country’s geothermal energy. Geothermal power is expected to supply upwards of 20% of world’s energy by 2050.

The Basin and Range geologic regions in Nevada, Oregon, Idaho, Arizona, New Mexico and Utah are now areas of rapid geothermal development.

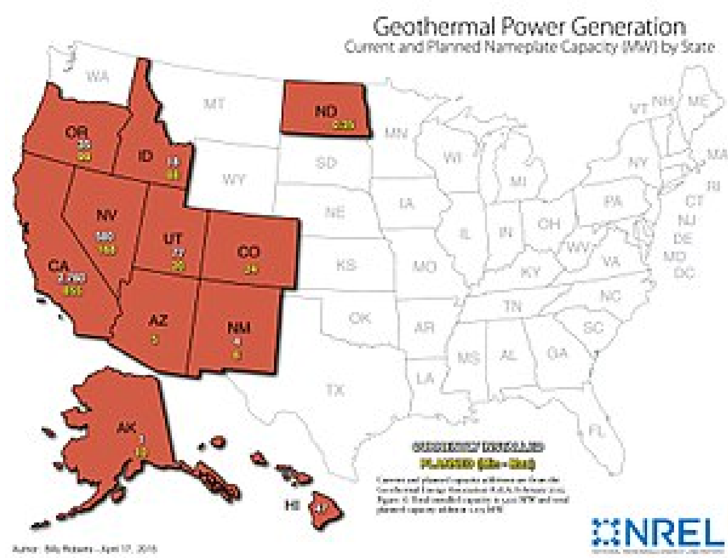

Figure 1: Current and planned nameplate capacity (MW) by state

The United States leads the world in the amount of electricity generated with geothermal energy. Geothermal electricity generation requires water or steam at high temperatures (275° to 700°F). Geothermal power plants are generally built where geothermal reservoirs are located, within a mile or two of the earth's surface.

In 2017, seven states had geothermal power plants.

Share of U.S. geothermal electricity produced by each state in 2017:

California	73%
Nevada	21%
Utah	3%
Hawaii	2%
Oregon	1%
Idaho	<1%
New Mexico	<1%

Figure 2: Share of U.S. geothermal electricity produced by each state in 2017

Production and development

Figure 3: US electricity generated from geothermal sources 1960-2008 (blue), and as a percentage of total US electricity (red).

With 3,591 MW of installed geothermal capacity, the United States remains the world leader with 25% of the online capacity total. The future outlook for expanded production from conventional and enhanced geothermal systems is positive as new technologies promise increased growth in locations previously not considered.

A geothermal resource requires fluid, heat, and permeability to generate electricity. Conventional hydrothermal resources contain all three components naturally. These geothermal systems can occur in widely diverse geologic settings. In 2008, the U.S. Geological Survey (USGS) estimated that 30 GWe of undiscovered geothermal resources exist in the western United States— ten times the current installed capacity.

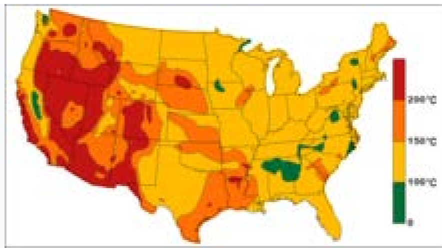

Figure 4: Estimated subterranean temperatures at a depth of 6 kilometers

Unlike some other renewable power sources such as wind and solar, geothermal energy is reliable and dispatchable, meaning that it is both available whenever needed, and can quickly adjust output to match demand.

According to the US Energy Information Administration (EIA), of all types of new electrical generation plants, geothermal generators have the highest capacity factor, a measure of how much power a facility actually generates as a percent of its maximum capacity. The EIA rates new geothermal plants as having a 92% capacity factor, comparable to those of nuclear (90%), and higher than gas (87%), or coal (85%), and much higher than those of intermittent sources such as onshore wind (34%) or solar photovoltaic (25%). While the carrier medium for geothermal electricity (water) must be properly managed, the source of geothermal energy, the Earth's heat, will be available, for most intent, indefinitely.

5. Lightning Dock geothermal field

The Lightning Dock Geothermal (LDG) project is located in the Animas Valley (Hidalgo County) in the southwest corner of New Mexico, approximately 15 miles east of the border between Arizona and New Mexico. The LDG system is a “blind” geothermal resource (without any surface manifestations) that was discovered during drilling for crop irrigation in 1948. In 1974, the resource was designated by the Federal government as a Known Geothermal Resource Area (KGRA) encompassing 23,552 acres. Exploration and development of the resource was undertaken by several entities over the years, including Amax Exploration, Inc., who were the first geothermal lease holders from 1979 to ~1984; Steam Reserve Corporation, who drilled well 55 7 and operated the lease from ~1984 to 1987; Lightning Dock Geothermal, Inc. (not related to Cyrq) run by Roy Cuniff and Roger Bowers, who operated the field from 1987 to 2008; and Lightning Dock Geothermal HI 01, LLC, current operator of the field since 2008 (owned first by Raser Technologies and now by its successor Cyrq). The Animas Valley is within the Mexican Highland part of the Basin and Range physiographic province, a large region characterized by steep, well dissected mountains separated by flat floored desert valleys. NS trending, range bounding faults define the Animas Valley on the west and east; thus, the valley is both a topographic low and a structural graben, bounded on the west by the Peloncillo Mountains and on the east by the Pyramid Mountains. As discussed in Witcher (2008), the geothermal anomaly in the Animas Valley is likely the result high regional heat flow and the intersection of several geologic structural features, including the margin of a Tertiary age volcanic caldera (the Muir Cauldron) that is believed to be the source of geothermal heat; and one or more large offset Basin and Range normal faults that likely serve as conduits for heated water to rise to shallow depths, resulting in a natural geothermal outflow plume at the site.

6. Revamp of the Lightning Dock geothermal plant

Turboden was selected to perform a complete revamp of the power plant of Lightning Dock geothermal. Turboden offered to provide a power plant producing 11.2 MW net (14 MW gross) electric power with a single ORC turbine.

The plant commenced delivery of electricity to the grid in December 2018, and passed initial performance testing in January 2019.

The plant is designed to exploit geothermal brine from existing geothermal wells. Isobutane is the design working fluid selected by Turboden in its approach to efficiently harness the geothermal fluid readily available in the area. The choice of the working fluid was made after other alternatives were carefully studied. Other fluids such as pentane have been put onto test but they have failed to deliver results as efficient as isobutane.

The plant has been configured to utilize a single turbine. A diagram to illustrate the configuration of the plant is included below. The power plant is composed by heat exchangers, a single turbine directly coupled with a generator, a recuperator, a condenser, and feed pumps. The plant will be fed by 5000 gal/min of geothermal brine at 310 °F. After cooling in the plant heat exchangers, the brine will be returned to the reinjection wells at about 170 °F.

• Taking into consideration the low corrosivity potential of the geothermal water observed in the previous installation, the material adopted for the parts in contact with geothermal water is the carbon steel (e.g. tube sheet, distributor channel, partition plate and heat exchanger tubes). Likewise, on the ORC working fluid side, carbon steel has been employed. The plant operator suggested the minimum reinjection temperature to be considered in the plant design, in order to avoid any risk of deposition of silica or other solids.

• The single turbine designed and manufactured by Turboden is axial, multistage and runs at 1800 rpm. The Turbine is directly coupled to the electric generator. The turbine design inlet pressure is about 400 psi. The expected turbine isentropic efficiency is about 90% (total to static, including all the stage losses). The axial geometry is the most suitable to achieve high efficiency in the widest range of operation; it is expected in fact a derating of the efficiency of only -1% during summer operation, and -4% during winter operation. The turbine is designed to maximize the energy production according to the Lightning Dock site ambient conditions.

• The air-cooled condenser is composed by a large number of bundles interconnected to each other in parallel. To limit the influences of different condensing pressure of the bundles (e.g. fans of one bay out of order), the pipeline, where the liquid phase is collected, foresees a routing with the presence of a syphon/vapor trap. The design of the air-cooled condenser is made by Turboden. Considering the favorable properties of the working fluid, which is never under vacuum, it is expected to operate the condenser at constant volumetric flow (air-side) to maximize the energy production. This implies no variable speed drivers for the fans.

• The ORC working fluid feed pumps are centrifugal multi-stage, driven by 3-phase motors connected to a frequency converter in order to achieve optimal control and to minimize the power consumption. This solution is required particularly considering the operating pressure of the working fluid; in fact, the traditional solution of pump regulation by means of valves would significantly decrease the net energy production.

The operation of the ORC turbogenerator is automatic, continuous monitoring by personnel during operation will not be required. The ORC turbogenerator can operate at partial load, the process and the generated electric power vary self-adapting automatically to the available thermal power.

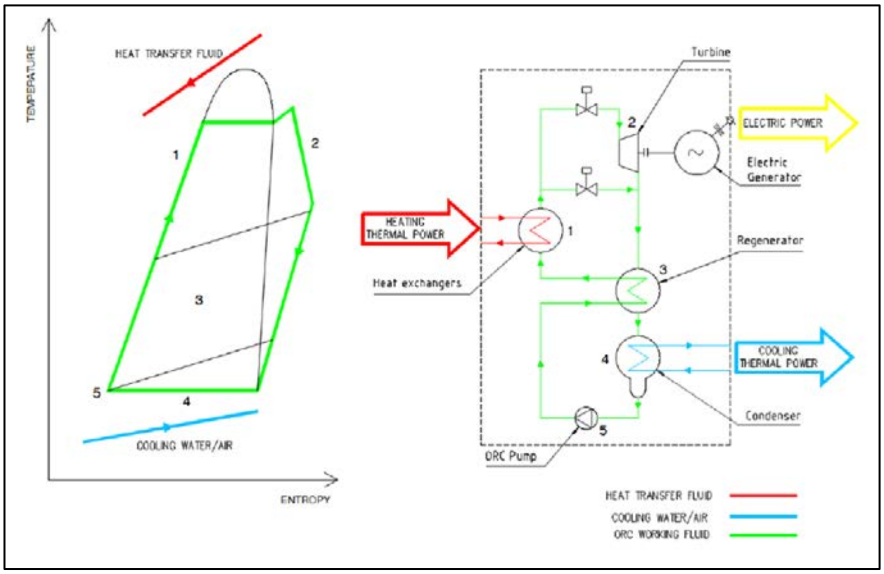

Figure 5: Organic Rankine Cycle Diagram

7. Site Erection Activities

Traditionally, the average construction time from order release to Commercial Operating Date (COD) for geothermal power plants ranges on average between 20 to 24 months in duration.

The Lightning Dock Geothermal (LDG) repower project was completed ~ 6 months earlier than average, due to a unique partnership between all parties, based on collaboration; being closely aligned, partnered cooperation, superior project communication and planning, parallel path schedule management, and advanced collaborative development of all project facets; “previous geothermal experience and incorporation of lessons learned”, value engineering, and close vendor coordination.

THE TEAM; CYRQ Energy - Owner/Developer, TURBODEN/MHI – ORC Manufacturer, and Industrial Builders, Inc. – Engineering, Procurement and Constructor (EPC):

• CYRQ - a leader in renewable energy with geothermal energy generation in California New Mexico, Utah, Oregon, Nevada, Washington, and Africa - with more than a decade of experience in utility scale power plants and renewable energy production.

• TURBODEN (MHI) – World Leader ORC Technology Provider - engineered, manufactured, delivered 377 plants in 42 countries and 607 MW's of high efficiency ORC power generation.

• IB - EPC constructor of eight (8) modular ORC power plants over the past 12 years, along with numerous industrial power and process plants.

The TEAM strategy for moving forward and constructing this project was to finalize together the "value engineered design", specific to; the LDG site, project parameters, specific equipment, integrating and fabricating as much of the equipment as possible in the shop for rapid deployment and smooth installation and execution; ORC plant, electrical, Power Distribution Center, and controls, etc.

This TEAM effort facilitated a project that capitalized on all of our previous geothermal ORC and plant experience in design and manufacture, modularization and prefabrication - by packaging as much of the plant as possible, pulling man hours out of the field and into a controlled shop fabrication environment. This allowed the team expect to mitigate virtually all risk, greatly improving project simplicity and speed to COD, minimizing costs to the Owner and meeting all financing requirements:

• EPC installed the power plant equipment – power plant manufacturer guaranteed and backstopped equipment delivery, with a 100% Performance and Payment Bond

• EPC guaranteed/backstopped construction schedule / cost – Technology Provider guaranteed / backstopped overall ORC performance / schedule / cost.

• The project was completed "ahead of time" and "on budget" by performing all work and services as smoothly as possible, relative to; design, permitting support, engineering, procurement, quality assurance, inspection, construction, start-up, performance testing, and system optimization.

• EPC performed all necessary site layouts and other engineering for permitting, including preliminary engineering, purchase specifications necessary to maintain schedule, installation of ORC power plant equipment, as well as obtain all construction-related permits, including; logistics and transportation, building, etc.

• ALL TEAM member schedule collaboration; long lead procurements needed to maintain schedule, including expedited completion schedule and continuous review, and preparation for construction of necessary electric and heat exchange interconnections, providing and performing EPC; testing and startup, including utility interconnection and permitting, achieving Commercial Operation and Delivery on or before the Scheduled Completion Date.

• ALL TEAM members cooperating together in prosecuting any guarantee or warranty claims.

With the proper TEAM coordination with Turboden, IB completed site work with all foundations, underground Electrical, Sub-station and completed Fire Water System, before any ORC equipment arrived at site. Once the ORC equipment arrived, it was off-loaded, set into place quickly and in a single pick as often as possible to avoid doubling of crane lifts, and all "pre-fabricated" Piping and Electrical integration could then immediately take place.

While waiting for long lead items from Turboden, IB was able to build the "prefabricated modules" for the "Power Distribution Center", "Equipment Center" housing all Variable Frequency Drives, "Control Room and Office", as well as the "Compressor Module" for the plant air system. All Equipment Modules were delivered, set-in-place, installed and field connected, before any long lead items arrived from Turboden, saving significant time and costs, minimizing lifts / downtime.

Equipment deliveries from Turboden were staged, so that the work could be completed in an optimized and orderly manner, without the crew stacking, adding labor inefficiencies and costs.

All Structural Steel was set-in-place, and the Air Cooled Condenser were erected before the large heat exchanger vessels; pre-heaters and evaporators, and Turbine and Generator - arrived at site. Large equipment piece delivery was well coordinated and "set-as-they arrived". Piping and electrical crews could start without interference with the erection crews.

With IB, as EPC, designing and coordinating the Balance of Plant work and the Owner furnished production well system, along with the coordination with the local Utility for interconnection and power distribution, all potential problems and schedule interruptions were mitigated during construction and start up. The project "struck first power" nearly two weeks ahead of schedule, and IB began to demobilize early.

The Lightning Dock Geothermal (LDG) repower was a very successful project because CYRQ, TURBODEN, and IB, all worked together from initial stage, through design and final installation, as a TEAM. The end result; the CYRQ received a quality project exactly as envisioned, planned, and contracted, ahead of schedule and on budget, in a smooth well executed project.

8. The start-up activities

The start-up activities for the Lightning Dock geothermal plant were performed very timely and effectively. The installation and commissioning processes were completed in 5 and 2 months respectively. The first start-up was performed on 21st of December 2018 with a net power of 4 MW due to the limitation on the grid. On 7th of January, the power provided to the grid increased to 11.2 MW.

During the performance test on 24th of January, a production of gross 15.29 and net 13.09 was achieved. Later on, a capacity test, a reliability test and a capability demonstration test personalized according to the client's requests were performed. The duration of the reliability test was 14 days. The start-up activities were finalized with success with the effort and collaboration of all parties involved.

Figure 6: Lightning Dock geothermal power plant

9. Conclusion

The repowering of the Lightning Dock geothermal project has been a resounding success, and the plant is well poised to deliver geothermal energy to the grid for the next 25 years. All of the required components, including a confirmed geothermal resource, transmission access for delivery of the electricity, and a long term PPA with a solid offtaker are in place, allowing the development team to execute in the design, installation and operation of this binary plant. The commitment and teamwork demonstrated by Turboden, Industrial Builders and Cyrq has proven binary projects can be installed on schedule and generate efficiently, even in the remote region of the desert SW of the US.

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