Case Study: Al Reyadah CCUS Project

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Panel 2: Carbon Capture Process:
Lessons Learned in Project Start-Up
Al Reyadah - Abu Dhabi CCUS Project

Al Reyadah is a pioneering initiative and a Knowledge Hub for Abu Dhabi in CCUS Technology, and it is a working platform for future CCUS.
Al Reyadah Combating Global Warming & Abu Dhabi’s Sustainability

UAE has high per capita CO2 rates (Industries & Domestic)

UAE Hydrocarbon Industry requires Enhanced Oil Recovery (EOR)

Al Reyadah (Abu Dhabi Carbon Capture Company), Middle East’s first specialized company focused on exploring & developing commercial-scale CCUS (launched on Nov 2016)

Emirates Steel identified as an ideal choice for the 1st Project due to proximity of the CO2 to ADNOC oil fields
Al Reyadah - Abu Dhabi Carbon Capture Company
Phase-I: Emirates Steel

Al Reyadah: ME’s 1st Company mandated to develop Commercial Scale CCUS Projects

Enhance Oil/Gas Production with CO2-EOR
Liberate Natural Gas
Reducing UAE’s Carbon Emissions
Al Reyadah is a new ADNOC OPCO specialized in CO2 Supply

Mandate:

• Manage the CO2 supply to both ADNOC’s Onshore & Offshore assets for CO2-EOR requirements

• Create a CO2 Network & Hub in order to achieve flexibility between CO2 Supply and Injection requirements

• Share learning from a pool of strategic technical advisors: US DoE, Masdar Institute, PI, Khalifa University, GASCO R&D, ADNOC R&D, etc.

Vision: Maximize profitability by a robust CO2 Master Plan

Mission: Optimized new technologies and lowest CO2 price
### Project Timeline

- **Apr-2010**: FEED completed
- **Nov-2011**: Successfully completed CO2 pilot injection project at Rumaitha field
- **Jan-2012**: Abu Dhabi CCUS project announced

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<th>Year</th>
<th>Half</th>
<th>Event</th>
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<tr>
<td>2013</td>
<td>H1</td>
<td>EPC Award</td>
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<tr>
<td>2013</td>
<td>H2</td>
<td>Engineering &amp; Procurement</td>
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<td>2014</td>
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<td>Construction</td>
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<td>2014</td>
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<td>Commissioning</td>
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<td>2015</td>
<td>H1</td>
<td>Operation / Stabilization</td>
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<td>2015</td>
<td>H2</td>
<td>CO2 Injection begins</td>
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<td>2016</td>
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- **Nov-2013**: EPC Contract awarded to Dodsal Group to build the facilities & 43km pipeline to ADCO fields
- **Jul-2014**: Construction commenced in Mussafah, Abu Dhabi
- **Nov-2014**: Formally unveiled Al-Reyadah: Abu Dhabi Carbon Capture Company
- **Nov-2016**: Al Reyadah Launch - 1st CO2 at ADNOC fields
Al Reyadah Location

Dubai

YAS Island
CO2 Dehydration & Compression Facility

ESNAAD

CO2 Dehydration & Compression Facilities

ESI-1

ESI-2
Project Technical Overview

Al Reyadah Carbon Capture Usage and Storage (CCUS)

1. Up to 800,000 tons of CO₂ captured from Emirates Steel manufacturing complex

2. CO₂ transferred to Al Reyadah plant for compression & dehydration

3. Metered and exported through a 43km buried pipeline for Enhanced Oil Recovery to ADNOC’s NEB (Al Rumaitha) and Bab onshore oilfields

- World’s 1st fully commercial CO₂ Capture from Iron & Steel Industry. Middle East’s 1st Commercial Scale Carbon Capture Project
- A commercially self-sustaining project with No Governmental Subsidies
- Start-up of the project is completed and stabilization underway
- Working towards multiple industrial scale CCUS projects and CO₂ pipeline network aimed at reducing the carbon footprint in line with ADNOC’s 2030 Strategy and Abu Dhabi Vision 2030

#CO2EOR
Generic Steel Making

- **Raw material preparation**
- **Iron making**
- **Steel making**

**Primary steel production**
- Lump ore
- Fine ore
- Sinter
- Pellets
- Coke
- Coal

**Secondary steel production**
- Recycled steel

**Energy Intensity (GJ/t)**:
- BF: 26.4 – 41.6
- DR: 19.8 – 31.2
- DRI: 28.3 – 30.9
- OHF: 9.1 – 12.5

BF - Blast Furnace; DR - Direct Reduction; DRI - Direct Reduced Iron; EAF - Electric Arc Furnace; BOF - Basic Oxygen Furnace; OHF - Open Hearth Furnace
Iron Making – A CO2 Intensive Process

70% - 80% CO2
Al Reyadah CO2 Source

HYL / Energiron DRI Process

BF - Blast Furnace; DR - Direct Reduction; DRI - Direct Reduced Iron; EAF - Electric Arc Furnace; BOF - Basic Oxygen Furnace; OHF - Open Hearth Furnace
Direct Reduced Iron (DRI) Process

CO2 is generated by Process of Direct Reduced Iron (DRI)

- Methane Gas is reformed to a H₂ & CO Syn Gas
- Iron Ore (Fe₂O₃) is reduced to Iron (Fe) in reactor, producing CO₂ & H₂O waste
- CO₂ is removed via a traditional MEA Amine Absorption System
- CO₂ rich waste stream (>99% dry) is available for the CCS Project

Process Objective: Capture 800 KT/Y byproduct CO₂ emitted from ES DRI plants and deliver it to ADNOC Oil Fields for use in EOR
Conventional Amine Solvent based Absorption/Regeneration System remains the preferred Technology for CO2 Capture

CO2 rich gas is absorbed in an Ammine absorber (MDEA) (Methyl Di Ethanol Amine)

CO2 which is desorbed from the rich amine is cooled and sent for dehydration and compression

CO2 absorbed rich amine is regenerated in a Desorber at 110 Deg. C bottom temperature

CO2 Lean Gas

CO2 Rich Gas

CO2 for Utilization and Sequestration
Process Overview

Feed CO2
(0.5 bar)

Emirates Steel

LP Compressor
(Integrally geared 6-Stage Centrifugal (0 – 41barg))

Dehydration Package
(Reduce water content to 20lb/MMSCF)

HP Compressor
Reciprocating 2 Stage Compressor
(35 - 238barg)

Mass Flow Meter
(0.8 Million TPA or 41.5 MMSCFD)

Product CO2
(98% min purity)

Pig Launcher & Pipeline

8" X65 API5L Carbon Steel Buried Pipeline
CO2 Compression Facility - Layout

- Future Expansion and/or R&D Activities
- Control Room
- Electrical Sub-station
- Compression Shed
- Utilities
- Transfer Lines
CO2 Transmission Pipeline - Location

- 8” X65 API5L Carbon Steel buried pipeline designed for 245barg
- 2 Block Valve Stations for emergency venting of CO2 in case of pipeline leak
- Remote isolation and maintenance blowdown facilities
- Pipeline Safety: Telecoms, SCADA, CCTV and Leak Detection running over buried fibre optics
3D Model of the Facility
Al Reyadah – Abu Dhabi CCUS Project
Construction Highlights

- No Lost Time Incident (LTI) during the entire project. Nearly 5 Million Man-hours
- Approx. 80kms of piping at a weight of 270 Tonnes
- 800 Tonnes of Rebar and Structural Steel
- 7000 m3 of Concrete poured
- 260km of Electrical and Instrument Cable installed
- 42kms of Transmission Pipeline
- LP Compressor: An integral 6-Stage Centrifugal Compressor (one of the largest ever manufactured by Ingersoll Rand)
Al Reyadah – Future Potential Growth

- **Potential Market Demand**: 400 MScfd (MMscfd)
- **40 X Al Reyadah Phase I**: 1,600 MScfd

**Phase I: Emirates Steel CO2 Source**
- 40 MScfd

**Forecast Growth in CO2 Demand (15-20 years)**
- 800 MScfd

**Phase II: ADNOC OPCO CO2 Sources**
- 400 MScfd

**UAE Clean Energy CO2 Capture**
- Additional CO2 from other UAE Sources
Accuracy of FEED: Completion of pre-FEED/FEED phases at a level of detail suitable for the project is required which will increase the likelihood of project delivery within the approved budget and schedule. Ensure detailed design is sufficiently mature before moving in to construction.

FEED-Two train vs. EPC-Single Train: FEED was done with 2 trains (50%), however during EPC phase concept was change to Single train design, It is always difficult to maintain the full availability of plant with high maintenance prone single reciprocating compressor, It is recommended to opt for Two train approach to get higher plant availability.

Water in CO2: Diligently ensure no water / moisture in the carbon steel transfer pipeline during start-ups and process upsets to avoid rapid corrosion, hydrate formation and slug flow. Ensure 100% availability of moisture analyzer upstream of the transfer pipeline.

Molecular Sieves vs. Tri-Ethylene Glycol (TEG): Molecular Sieves dehydration system was chosen over TEG as it results in much lower water content in the dried CO2 and result no CO2 loss as witnessed in TEG regenerators.

Project Award - Delay in Finalizing the EPC Contract: Project was conceptualized in 2007/2008 and FEED was completed in 2009, however it took almost 4 years to award the EPC contract:
ESI Brown field work: CO2 feed is received from ES-1 & 2 plant, designing and construction work of new pipeline within existing congested plant was real challenge, as there was no space in existing pipe racks, it requires existing structures to be analyzed and modified to accommodate the additional 20” pipeline.

Interface Management: Managing interfaces with 4 operating companies (Emirates Steel, ESNAAD, GASCO (Pipeline Corridor) and ADCO with differing objectives and priorities of work, was a huge challenge.

Inexperience: For delivering a CCUS project with new/unfamiliar contractors/vendors, will require to build in sufficient cost/schedule contingencies at project approval stage.

CO2 Expertise: Limited Industry CO2 operating knowledge in the region required projects and operating team to take a more proactive guidance role to ensure developing Code of Practices especially for HSE and Process Integrity. The operating standards used for CO2 need be different from natural gas pipeline as it is different in terms of the physical properties.

Avoid Irrelevance: Challenge established protocols where benefits are unclear. Opted for low-cost Carbon Steel material for pipeline by properly managing the risk, instead of opting for stainless steel pipeline material!

Oil & Gas Industry Bias: Contractors biased towards using material compatibility reference to that used in hydrocarbon industry and not focusing on specific to CO2. Al Reyadah fully engaged with contractors to ensure proper material compatibility.
Project Execution - Lessons Learnt & Challenges (3 of 3)

- **NO Objection Certificates:** Over 60 No Objection Certificates (NOC), were obtained from various organizations and from community prior to startup of the project, as 12 km length of the pipeline falls within a densely populated area. Target achieved due to continuous engagement and pre-agreement with all parties.

- **Security Access:** Part of the pipeline is within high security Government-controlled area which requires access authorization for every individual, many days ahead. Managing personnel access during unplanned and urgent maintenance works was a challenge.

- **Delivery Timeline:** Integrated projects completion with different EPC contractors resulted in differing project completion timelines against the plan. Contracts and agreements shall address the risk associated with the misalignment in delivery of projects.

- **Quality Assurance:** Contractor and vendor quality commitments cannot be relied upon and hence requires significant company involvement and intervention for assurance.

- **Personnel:** Continuity of key staff helps in project start-up and operation. Recruited critical personnel from EPC contractor as employees of Al Reyadah.

- **HSE:** Aligning multiple subcontractor teams with varying levels of HSE competencies was a significant challenge, which was managed through continual engagement and rewards, which resulted in 5 Million MHRs without LTI during the entire project phase.
Al Reyadah - Abu Dhabi Carbon Carbon Capture Company
Phase-I: Emirates Steel - Highlights & Summary

• World’s 1st fully Commercial CO2 Capture Project from Steel Industry (Emirates Steel)

• Captures 800,000 T of CO2 at Emirate Steel, compresses & dehydrates and Transports through a 43 km Pipeline for injection into ADNOC oil wells for CO2-EOR

• Operates Highest Pressure (240 bar) CO2 Pipeline in the World

• Combats Climate Change by eliminating CO2 equivalent to 170,000 cars’ emission

• Commercially Self-Sustaining project with no Governmental Subsidies

• Working towards Multiple Industrial scale CCUS Projects & CO2 Pipeline Network/Hub aimed at reducing the carbon footprint in line with Abu Dhabi vision 2030

• Driven by the requirement to Capture CO2 from Multiple Industries & the high potential availability of CO2 storage

• Current CO2 Supply Potential: 1.6 Bscfd (ADNOC group & industrial sources in Abu Dhabi which is expected to increase due to the expected increase in sour gas production and the new expected power plants)
CCUS Challenges Middle East!

- CCUS is one of the potential option to tackle climate change especially for ME (CO2-EOR)
- CCUS projects number needed to be increased to meet global average temperature to well below 2°C
- Financial & Policy support from governments is necessary to encourage large scale CCUS projects
- CCUS has struggled to expand and meet expectations, often for economic reasons
- Different CO2 emission sources with different concentrations are available specifically in industry, hence will require site specific solution
- Capture ready guidelines for industry CO2 capture need to be developed
- Retrofitting CO2 Capture Facilities may require extensive shutdown of a part of the industry combined with modification to existing technology and limitation in land availability
- Accessible CO2 storage sites are crucial in order to lower the cost and technical barriers for many potential CCS projects, particularly in industrial sector
- Development of feasible 2nd & 3rd generation CO2 capture technologies are required to lower the current CO2 capture cost
Al Reyadah - Abu Dhabi Carbon Capture Company

Site Visit
Site Walk down Route Map
CO2 Compression Facility - Layout

- Future Expansion
- LP & HP Compressors
- Utilities
- Air Coolers
- Metering Skid & Launcher
- Product Pipeline to Rumaitha
- Feed lines from ES-1/2
- Dehydration Package
- Warehouse and W/shop
- Control Room
- Electrical Sub-station
Overall Plant (South side)
Overall Plant (East side)
Admin & Control Building
Sub Station Building Outside
Sub-Station Building Inside
Feed lines from ES-1&2
Metering Skid and Launcher
Air Coolers
Utilities – Air Compressor package
LP Compressor
HP Compressor
Dehydration Package
Thank You