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MHI's Carbon Capture Technology

Wyoming/JCOAL Workshop 2017
Gillette, Wyoming

September 21

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MITSUBISHI HEAVY INDUSTRIES AMERICA, INC.

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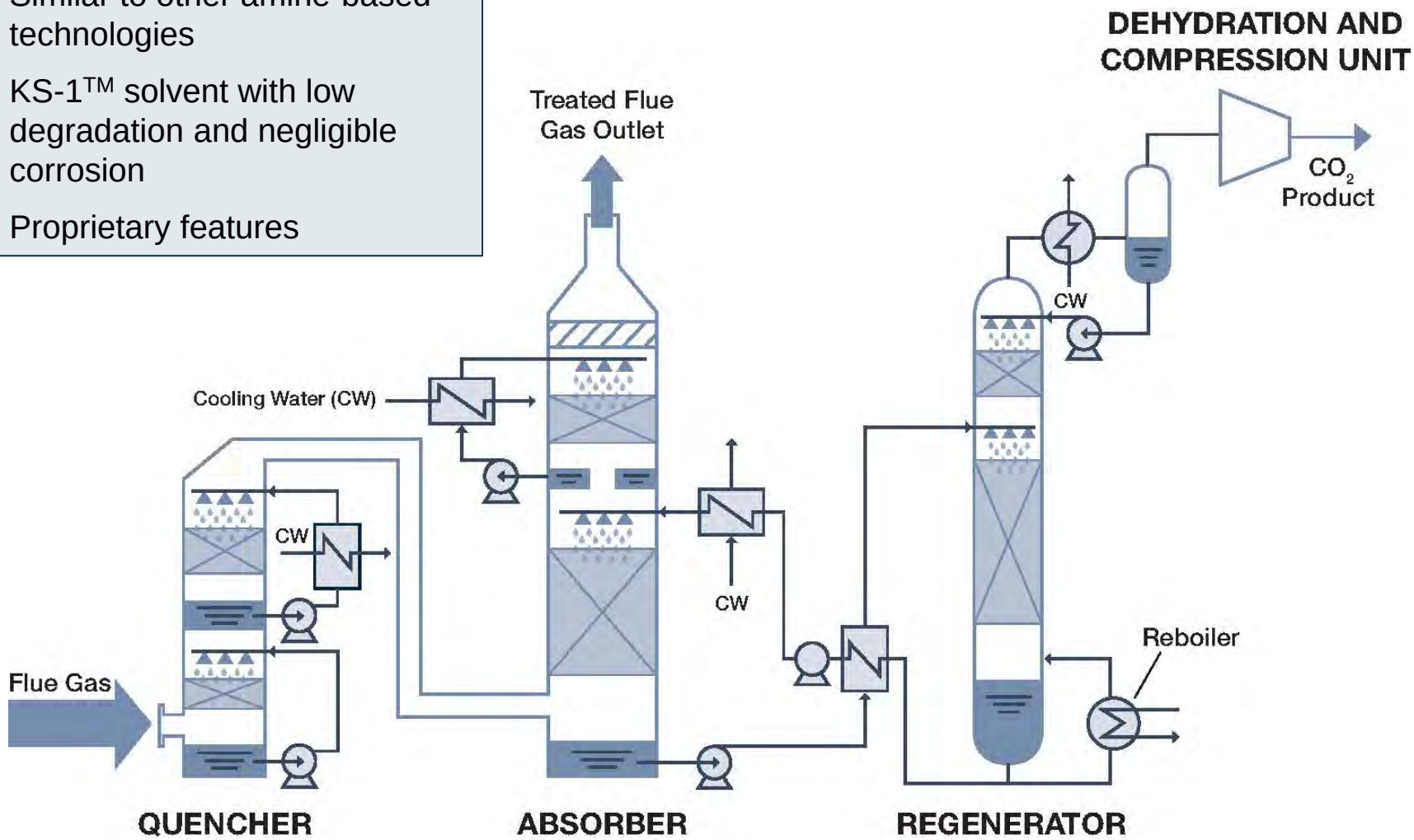
Background

KM CDR – Kansai Mitsubishi Carbon Dioxide Removal – Process®

- Similar to other amine-based technologies
- KS-1™ solvent with low degradation and negligible corrosion
- Proprietary features



KM CDR Process is a registered trademark of Mitsubishi Heavy Industries, Ltd., in Japan, the United States of America, European Union (CTM), Norway, Australia, and China.

KM CDR Process® Development History

From 1991 –
2 TPD Nanko Pilot Plant on
Natural Gas Exhaust
(Kansai Electric Power Co.)

Engineering HQ
(Yokohama)

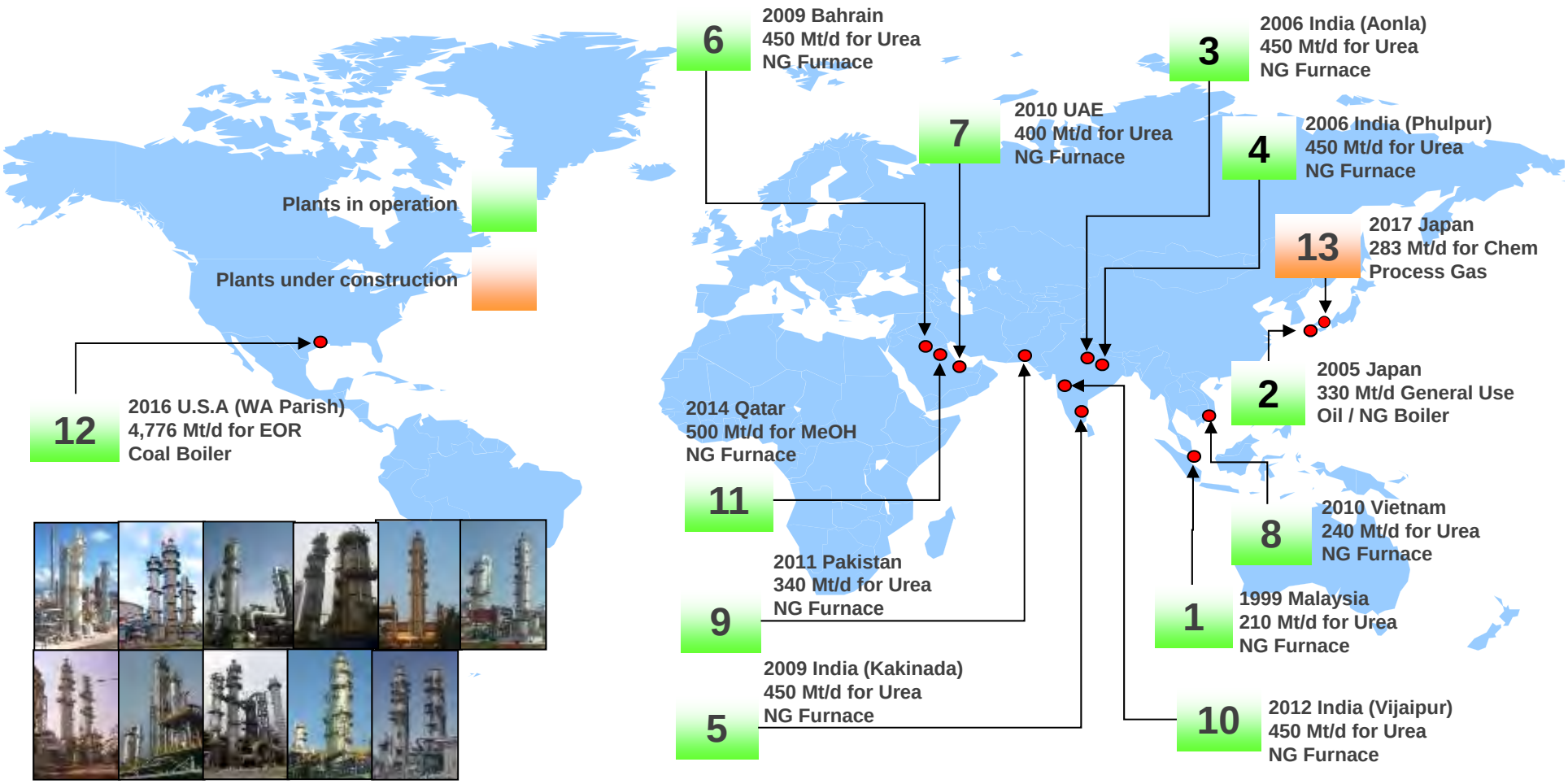
From 2002 -
1 TPD Hiroshima Pilot Plant on
Coal Exhaust
(MHI R&D Center)

From 2008 -
400MWeq Absorber Flow Tests
(MHI Mihara)

From 2006 –
10 TPD Matsushima Pilot Plant
on Coal Exhaust
(J-Power)

KM CDR Process® Commercial Experience

MHI is the world's leading large scale post-combustion CO_2 capture technology licensor.



Testing and Scale-up for Coal-fired Flue Gas

2002 – Hiroshima R&D Facility (1 tpd)

2006 – Matsushima Pilot Plant (10 tpd)

MHI performed extensive testing to understand the impact of **flue gas impurities** and develop countermeasure technologies.

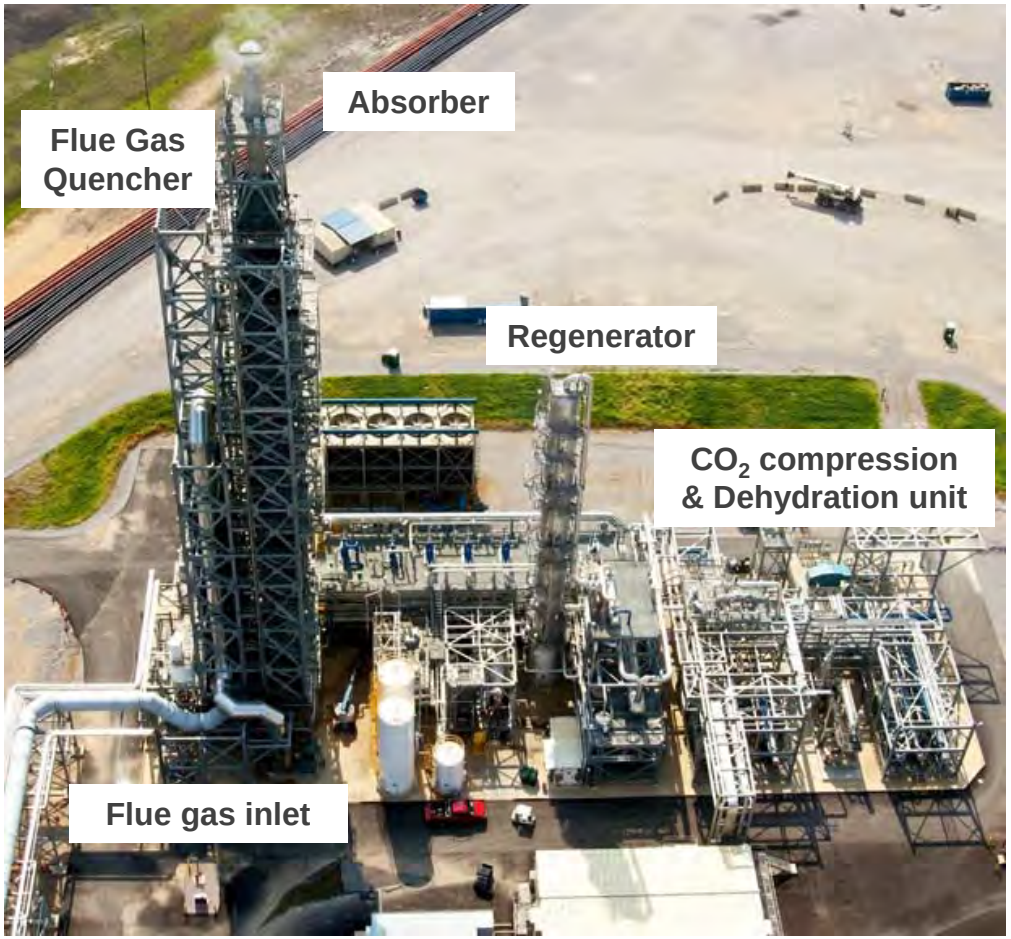
MHI performed liquid distribution tests for rectangular towers which **simplify scale-up and modularization efforts**.

(Scaling technique is similar to that used on more than 200 commercial FGD systems.)

2008 – Mihara Works (~35 ft x ~15 ft)

25MW$_{eq}$ CCS Demonstration Project at Plant Barry

Plant Barry CO_2 Demo Plant – helped prove commercial viability of carbon capture on coal fired flue gas



- Funding for capture facility from Southern Company, MHI, and others.
- Designed to capture 500 metric tons per day of CO_2 at 90% capture efficiency.
- From 2011-14: over 12,000 hours, over 250,000 tons captured, over 125,000 tons injected.
- Tested multiple technology improvements.

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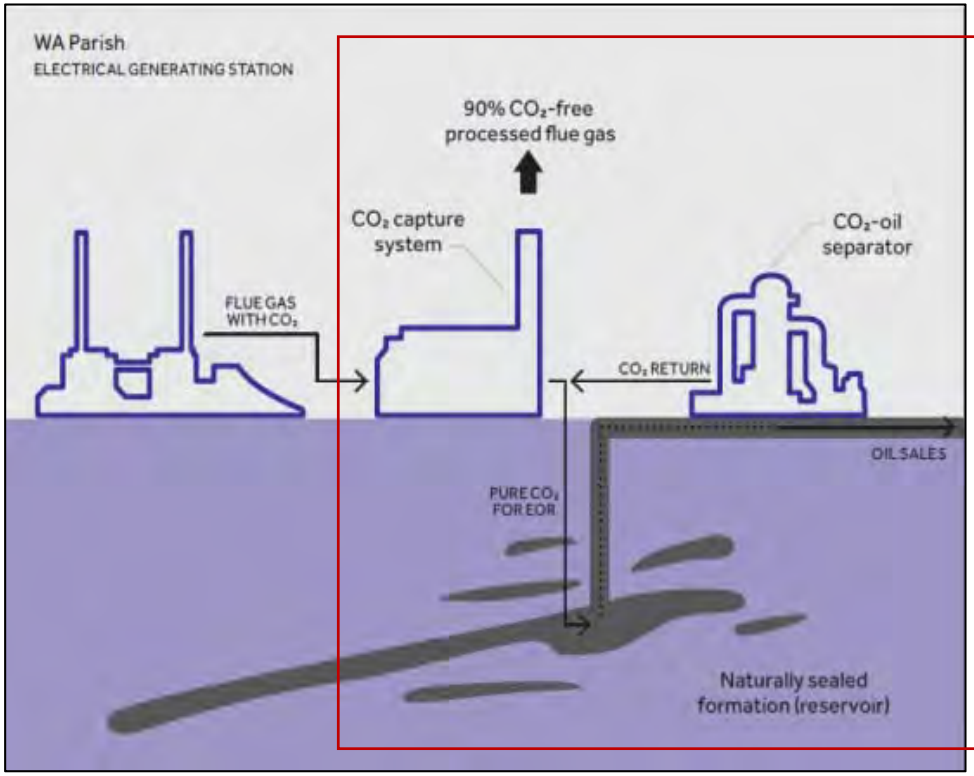
Petra Nova Project

Complete Petra Nova Project Overview

Oil revenues from CO_2 enhanced oil recovery can recover costs for the entire project without significant impact to the existing power plant.

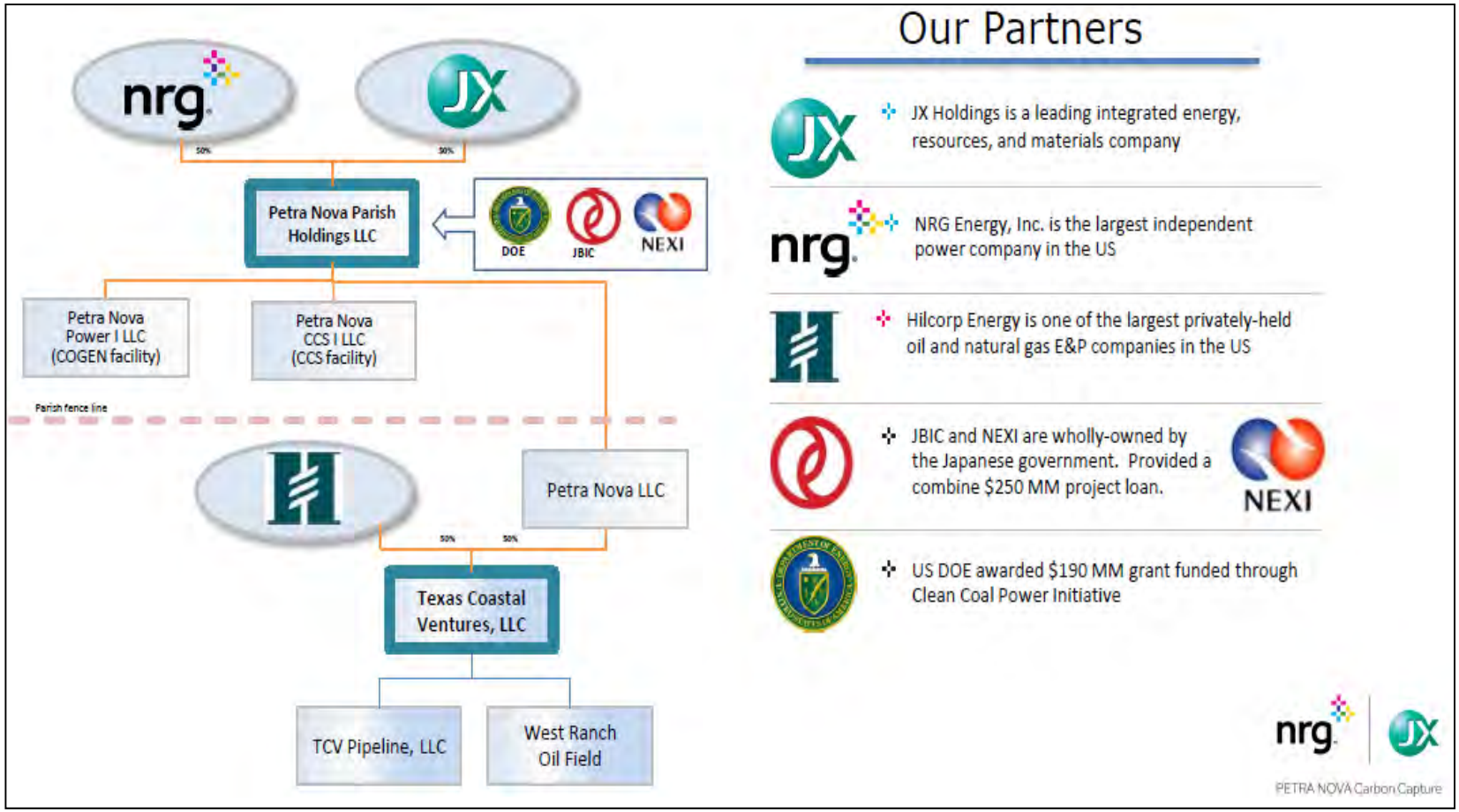


- **CO_2 Capture System** (MHI technology)
- **Cogeneration Plant**
- **CO_2 Transport / Pipeline**
- **Oil Field & Processing Facilities**

NRG Fact Sheet: Carbon capture and enhanced oil recovery: http://www.nrg.com/documents/business/generation/581409-factsheet-petra-nova-carbon-capture-final.pdf

Petra Nova Commercial Structure

NRG Energy and JX Oil and Gas formed the Joint Venture, Petra Nova Parish Holdings. They own the CCS facility and 50% of the CO_2 pipeline and oil field.



Reference: Petra Nova Parish Holdings

Petra Nova Carbon Capture Facility Project Overview

"NRG Energy, JX Nippon complete world's largest post-combustion carbon capture facility on-budget and on-schedule[1]"

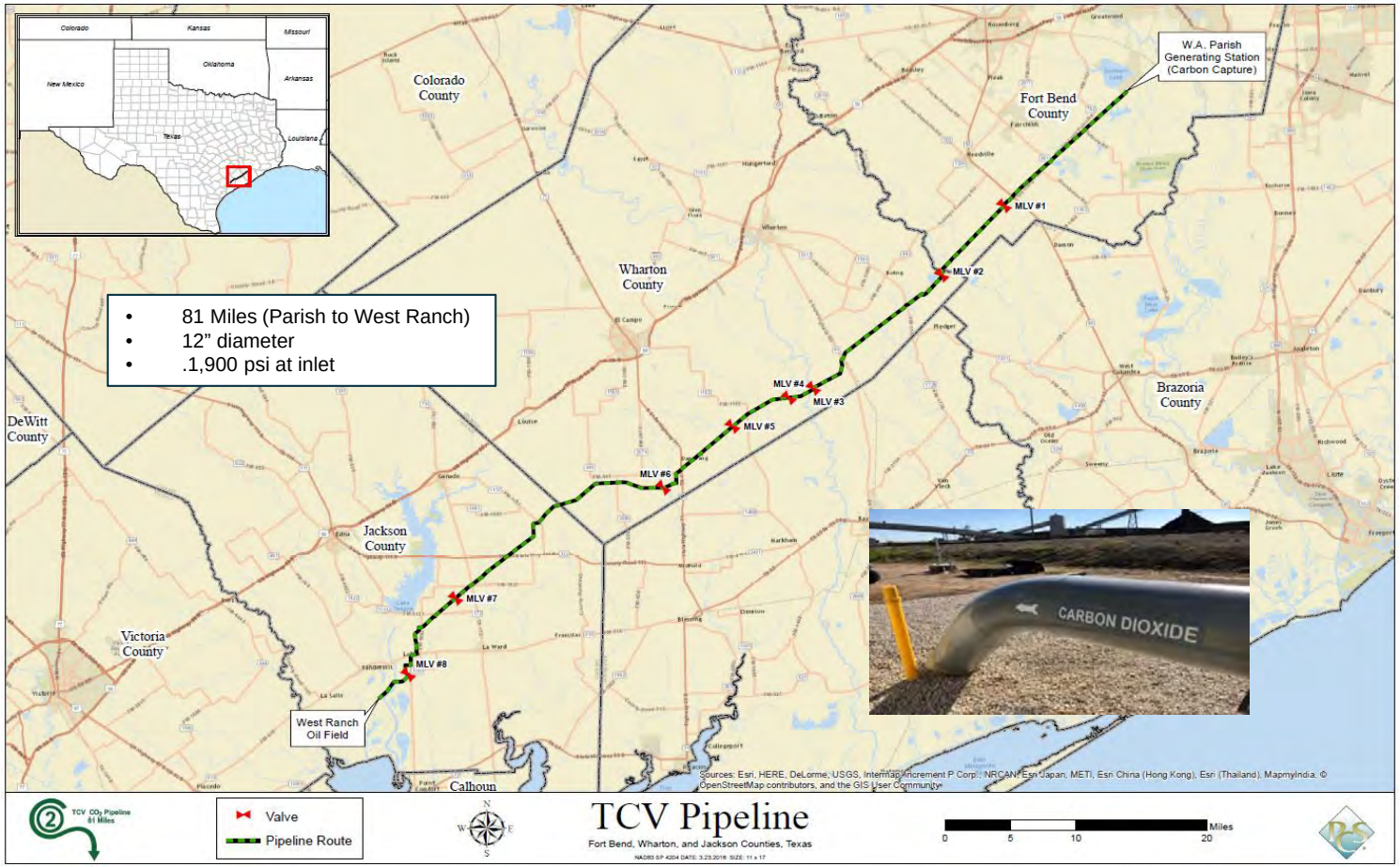
- Takes a partial "slip" stream from host unit - NRG's Parish Plant Unit 8
- Captures 5,200 tons of CO_2 per day
- Achieved COD on December 29, 2016.
- 2017 – Power Magazine "***Plant of the Year***"

[1]NRG press release: http://investors.nrg.com/phoenix.zhtml?c=121544&p=irol-newsArticle&ID=2236424

Petra Nova Project CCS Facility Layout

Petra Nova Pipeline

Captured CO_2 is compressed by Mitsubishi's compressor and transported 81 miles by pipeline to the West Ranch Oil field for EOR.



Reference: Petra Nova Parish Holdings

Petra Nova Oilfield Facilities – EOR Operation

CO_2 captured from Parish Unit 8 will boost oil production from 300 bbls/day to up to 15,000 bbls/day.

West Ranch Field Central Facilities

- 200 new wells to be drilled (over 100 now complete)
- 2 central processing facilities to separate oil-CO_2-water
- All produced CO_2 and water is reinjected into the formation

nrg | JX

PETRA NOVA Carbon Capture

Reference: Petra Nova Parish Holdings

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Economics & Opportunities

Economics for CCS

CCUS may provide a real value proposition to the owners. It worked in Texas !

Costs	$ / ton-CO_2
Capture / Compression	$50 - $70

- Cost can vary depending on project and financing.

Potential Drivers	$ / ton-CO_2
EOR (today's value)	$20+
Tax Credit (12 years) ?	$35
Carbon Tax ??	$40

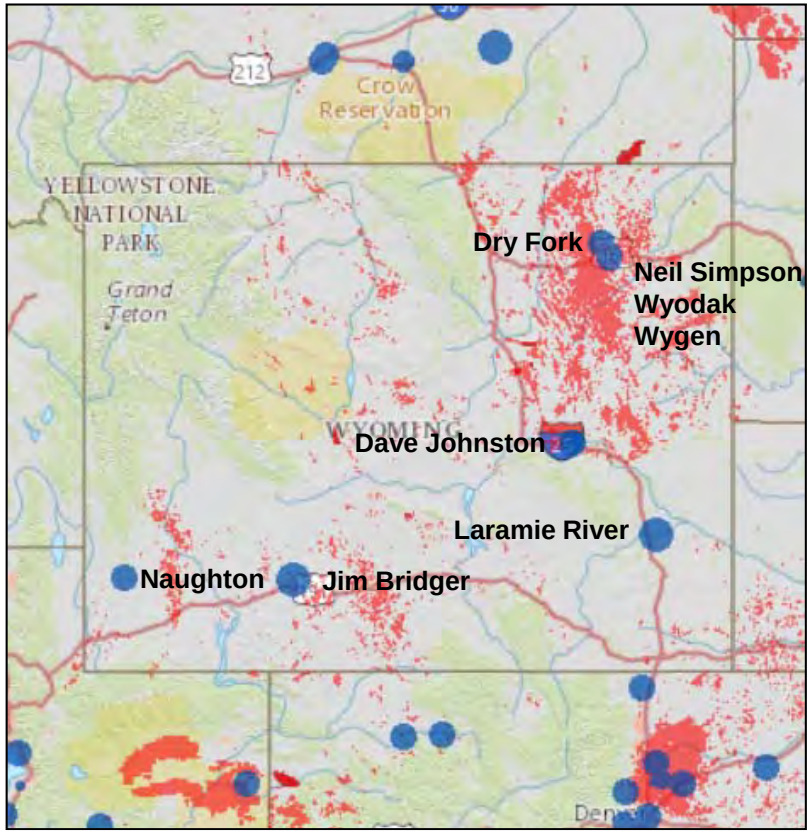
- CO_2 price for EOR will increase with higher oil prices and with motivated CO_2 purchasers.
- Revised 45Q could provide $35/ton tax credit for CO_2 used for EOR or $50/ton for CO_2 stored.
- Carbon Tax: industry support developing for $40/ton

Pressure on climate change growing !

National Carbon Sequestration Database and Interactive Viewer (NATCARB). http://www.natcarbviewer.com/

Wyoming Opportunities for CCS

Wyoming may be a great candidate for the next large scale CO_2-EOR project based on its supply of CO_2 sources and EOR potential



Electric Generating Units Oil and Gas Fields

- Wyoming's coal fired power plants have required emissions controls and are located close by to oil and gas fields.

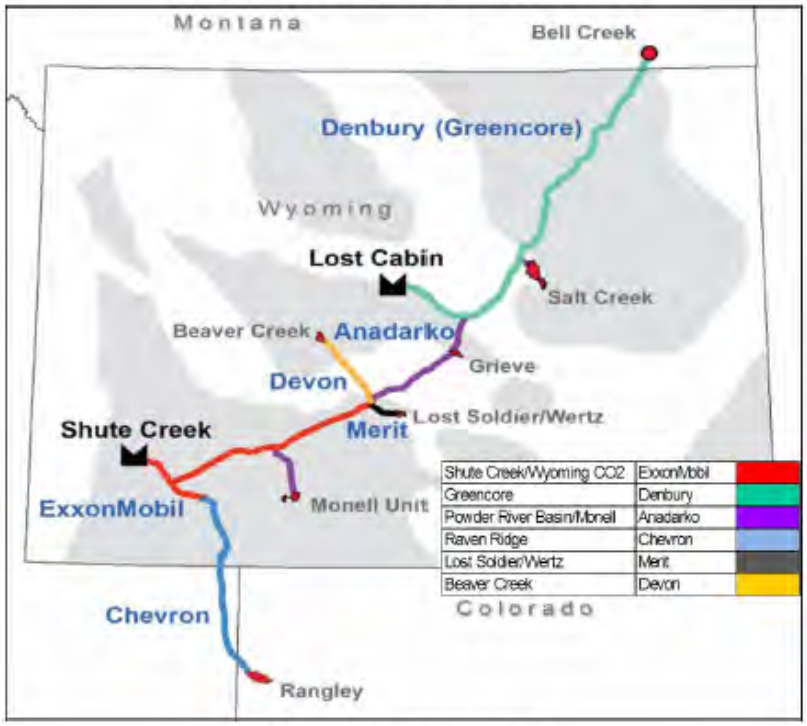
Plant Name	Capacity (MW)	SO_2 Control
Jim Bridger	2,300	Yes
Laramie River	1,700	Yes
Dave Johnston	810	Some
Naughton	700	Yes
Dry Fork	390	Yes
Wyodak	360	Yes
Wygen	300	Yes
Neil Simpson	100	Some

National Carbon Sequestration Database and Interactive Viewer (NATCARB). http://www.natcarbviewer.com/

Wyoming Opportunities for CCS

Wyoming oil fields could potentially support several large scale CO_2 Capture and EOR projects.

Exhibit 7 Rocky Mountain CO_2 pipeline infrastructure



Source: Denbury Onshore LLC (1)

- Currently, Shute Creek Gas Processing Plant and Lost Cabin Gas Plant produce CO_2 for the nearby oilfields.
- In 2014, an ARI study assumed an additional 400 MMcfd (~20,000 mtpd) of CO_2 would be captured from new projects by 2020, mostly coal gasification.
- Oil produced from CO_2-EOR would have increased from 39,000 bbl/d in 2014 to 103,000 bbl/d in 2020.

Kuuskraa, Vello and Wallace, Matt (2014). "CO2-EOR set for growth as new CO2 supplies emerge". https://www.adv-res.com/pdf/CO2-EOR-set-for-growth-as-new-CO2-supplies-emerge.pdf

NETL (2015). "A Review of the CO_2 Pipeline Infrastructure in the U.S". https://energy.gov/sites/prod/files/2015/04/f22/QER%20Analysis%20-%20A%20Review%20of%20the%20CO2%20Pipeline%20Infrastructure%20in%20the%20U.S_0.pdf

MHI's Technology Experience Summary

Technology Development

- Tested — MHI proved viability at multiple R&D facilities.
- Delivered — MHI delivered **eleven (11) operating commercial CO_2 capture plants** prior to the Petra Nova Project.
- Scaled-up — MHI successfully scaled-up and demonstrated long-term operation at Alabama Power's Plant Barry.

Commercial Delivery – Petra Nova Project

- **December 2016** – the world's largest post-combustion CO_2 capture project on coal-fired flue gas (4,776 mtpd) – completes performance testing.

Wyoming Opportunities

- Wyoming's abundance of CO_2 sources, EOR fields, and existing infrastructure provide a strong case for the next large-scale CO_2-EOR project.

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