

NRG Petra Nova Success Story

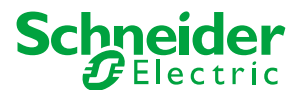
Mike Bradberry, NRG Petra Nova

Scott Barnhill, Tennergy

Ganesh Venkataraman, Simsci Esscor, Schneider Electric Software

#SESIinnovate

Life Is On



What is the Petra Nova Project?

- World's largest post-combustion carbon capture facility
- 50/50 joint venture between NRG and JX Nippon Oil & Gas Exploration
- Captures 90+ % CO₂ from a 240 MW slipstream of flue gas from coal power plant
- High-performance solvent for CO₂ absorption and desorption
- CO₂ is increasing oil production at the receiving oil field
- Process came online in late 2016
- POWER Magazine 2017 Plant of the Year
- Mitsubishi Heavy Industries proprietary amine process
- PN management desired hi-fidelity training simulator for new and complex process

Overall Petra Nova Process Schematic

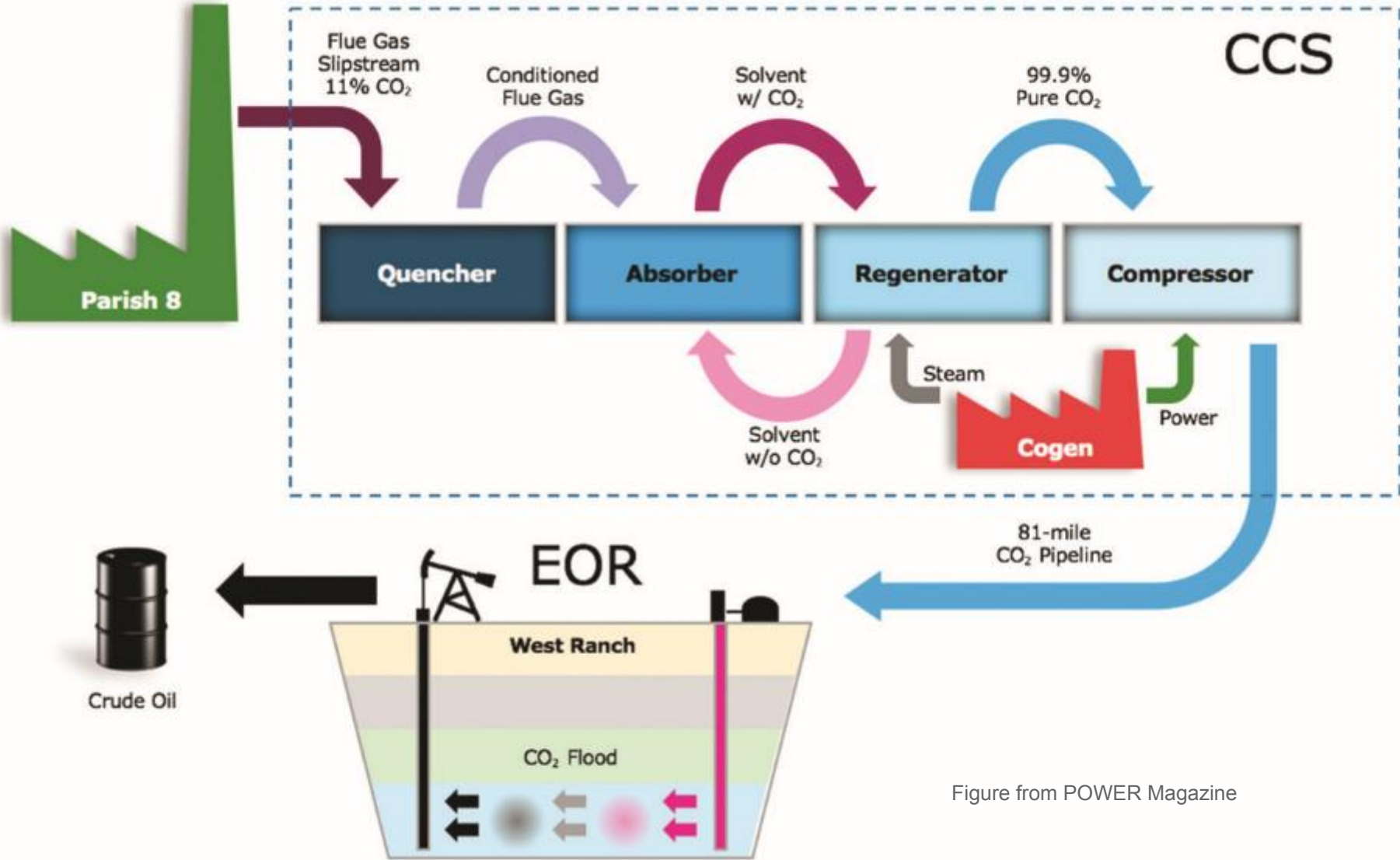
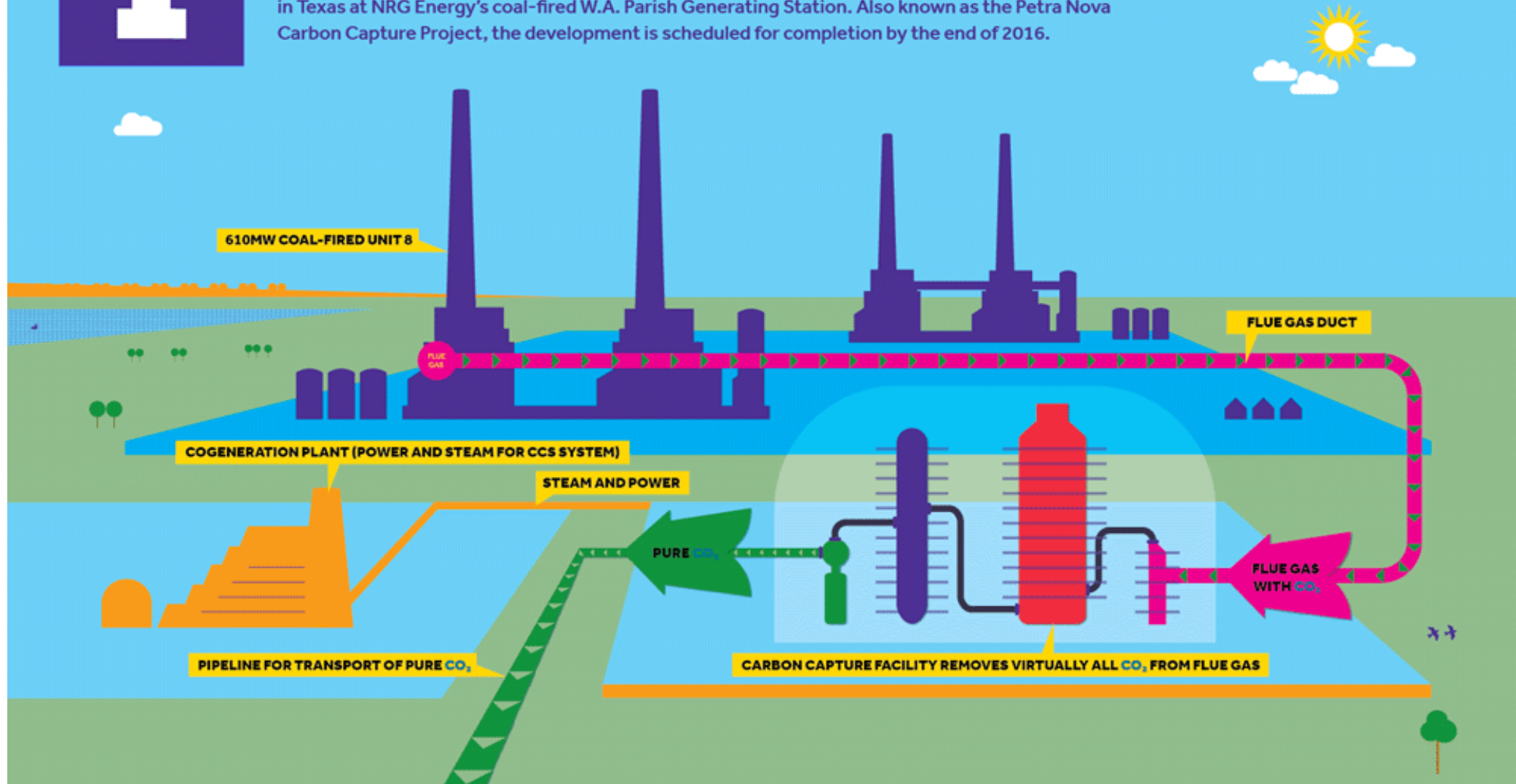


Figure from POWER Magazine

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The Carbon Capture and Enhanced Oil Recovery Project

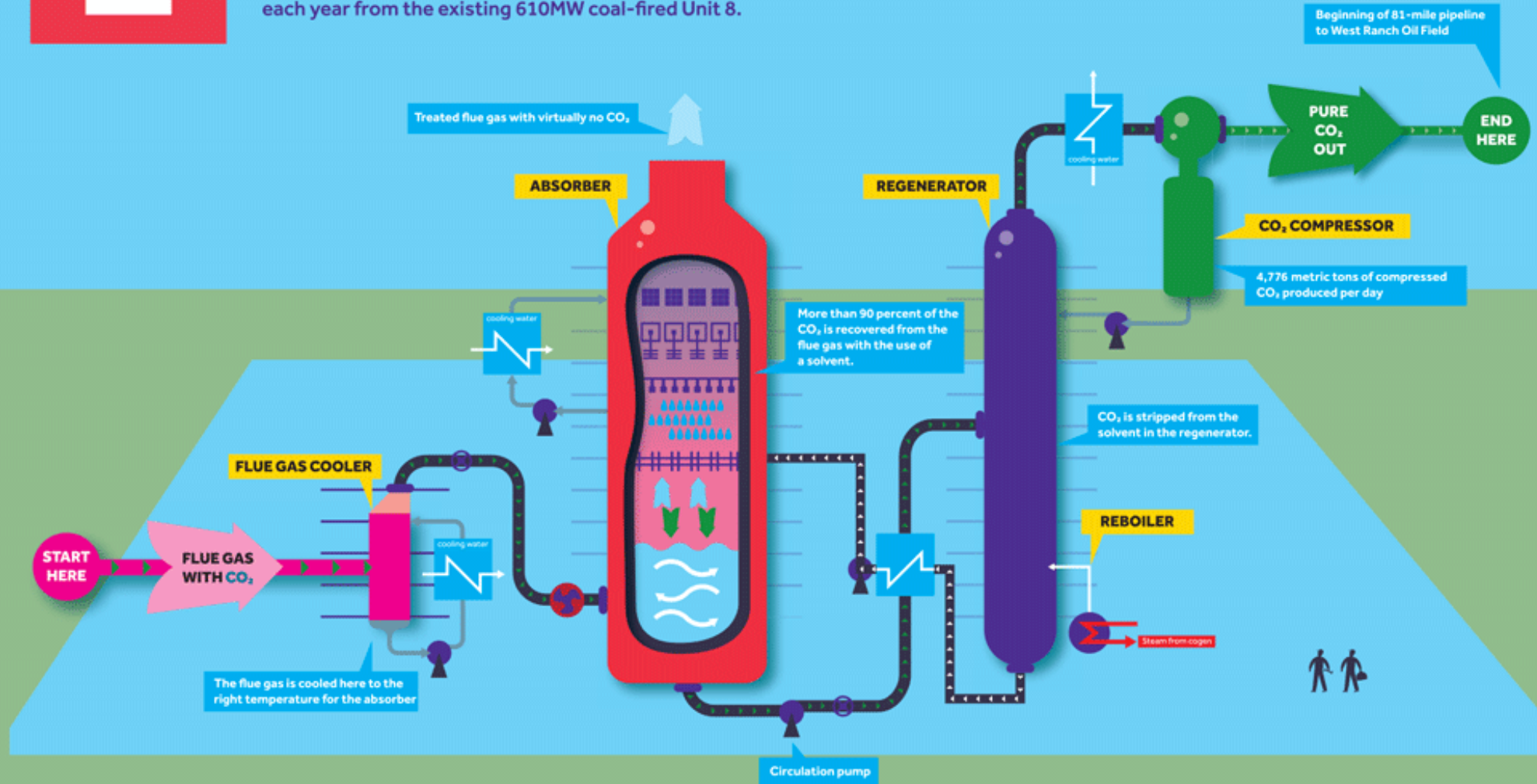
The world's largest post-combustion carbon capture and enhanced oil recovery project is located in Texas at NRG Energy's coal-fired W.A. Parish Generating Station. Also known as the Petra Nova Carbon Capture Project, the development is scheduled for completion by the end of 2016.



2

The CO₂ Capture Process

The proprietary KM-CDR Process[®], jointly developed by Mitsubishi Heavy Industries, Ltd. and the Kansai Electric Power Co., Inc., will capture approximately 1.6 million tons of CO₂ each year from the existing 610MW coal-fired Unit 8.



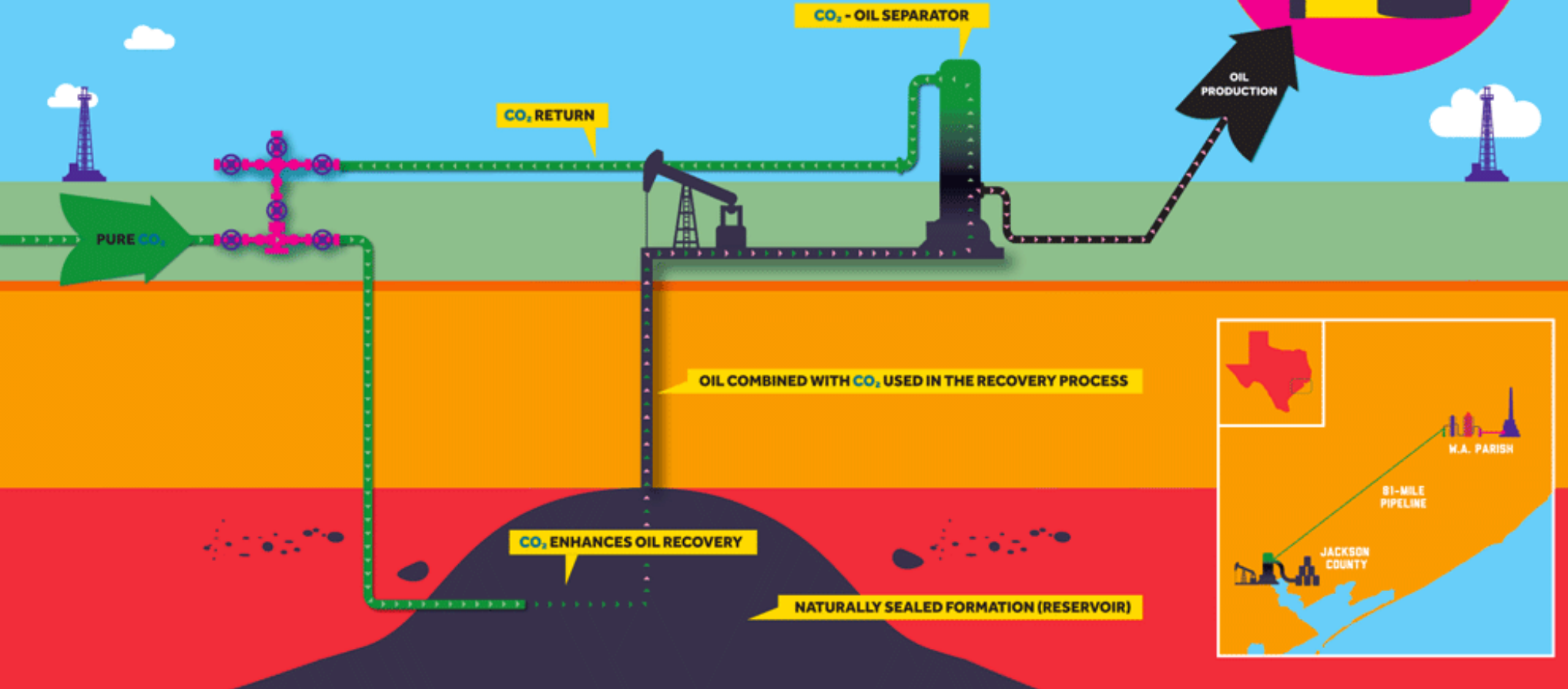
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Beneficial use of the captured CO2

The captured CO2 will be transported via an 81-mile pipeline to the West Ranch Oil Field in Jackson County, Texas, where it will be used in an enhanced oil recovery process to produce an estimated 60 million barrels of oil.

OIL YIELD INCREASES FROM 500 BARRELS A DAY TO **15,000** BARRELS A DAY.

UP BY X30



Full Scope Operator Training System (OTS)

- Detailed Dynsim process models
 - Carbon Capture System (CCS)
 - CO₂ compression, dehydration, and pipeline
 - Integrated steam, cooling water, and water treatment utilities
 - Cogeneration (gas turbine generator + single pressure HRSG) supplying power and steam for the CCS
 - Integrated Cogen and CCS electrical grid
- Emerson Ovation DCS
- 5 Rockwell PLCs with separate HMIs
- Training Services (procedure development and training exercises)

Dynamic Simulation Process Benefits

- CO₂ Pipeline Dynamic Profiles
 - Pressure and temperature profiles below super critical phase
 - Pressure and temperature profiles above super critical phase
 - Transition from CO₂ compressor venting operation to pipeline delivery operation
- Dump Condenser Operating Profiles
 - Steam/Thermal model validation
 - Sensitivity testing of various possible operating profiles
 - Validation of potential design modifications (e.g., addition of a pump)
- Engineering Tool
 - Sensitivity testing of equipment operating profiles
 - Testing and validation of potential equipment design upgrades
 - Testing and validation of equipment degradation and impact on the overall CCS process

Dynamic Simulation Controls Benefits

- Cogen Burner Management PLC
 - Testing of logic revealed embedded errors prior to commissioning
 - Logic vetted in simulation runs prior to commissioning
- CCS DCS Sequence Logic
 - Filter logic issues identified in simulation runs prior to commissioning
 - Testing and validation for potential logic changes and problem solving ideas
 - Simulator identified opportunities for improving and fine tuning plant operation procedures
- CO2 Compressor PLC
 - Logic vetted in simulation runs prior to commissioning
 - Testing and problem solving on trip logic
- Simulator DCS Database Updates
 - Developed method for quickly updating DCS database from live unit
 - Documented update process and provided to Petra Nova for system maintenance

Simulator Project Challenges

- **Serial Number One Simulator**
 - First simulator to be developed for the Mitsubishi CCS Process
 - Controls modifications during and after the commissioning phase of the project made simulator DCS and PLC design completion moving targets
 - Punch-list management and system upgrades became a critical process
- **Proprietary Equipment Internals & Amine Solvent**
 - Key equipment in the process had proprietary internal configurations
 - The molecular composition of the amine solvent used in the CCS Process was not disclosed
 - The amine solvent thermodynamic model for the CCS Process had to be designed using a “best fit” amine from Schneider’s amine industry experience
 - The amine solvent thermodynamic model had to be tuned using actual CCS operating data
- **Automatic Load Adjustment Control System (ALACS)**
 - The ALACS serves as the central automatic control center for the CCS Process
 - ALACS implements hard coded relationships with many of the process variables
 - ALACS demanded a very accurate (zero degrees of freedom) model throughout operating region

Simulator Project Summary

- The simulator for Petra Nova's CCS plant has completed site checkout activities
- The amine solvent thermodynamic model has been successfully developed, validated, and proven to replicate the operation of the actual plant very closely
- The simulator virtualized DCS and PLC platforms have been successfully developed, validated, and proven to replicate the actual plant HMI interfaces and control actions very closely
- An operator training program has also been developed and delivered with the simulator to train operators on startup, shutdown, and upset operating conditions



Figure from Petra Nova Website

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