# NET Power


**Truly Clean, Cheaper Energy**

May 2016

# The size of the prize

**The only technology that will enable the world to meet the COP 21 climate targets *without* having to pay more for electricity.**

# NET Power is a truly novel approach

- **NET Power makes electricity from natural gas**
  - NET Power costs the **same as, or less than**, electricity from existing natural gas power plants
  - NET Power generates electricity at **high efficiency** (59% LHV)
- **NET Power will capture substantially all of the $CO_2$ and non-$CO_2$ atmospheric emissions without any additional cost**
  - The $CO_2$ is captured at **pipeline purity and pressure** ready for use in other industrial applications and EOR
  - NET Power **increases margins** per BOE extracted via EOR by reducing injectant, gas processing and re-injection energy costs.
- **NET Power does not need to use water (at a small reduction in efficiency)**

# NET Power readiness

*Every single item of equipment is commercially available, except the turbine*

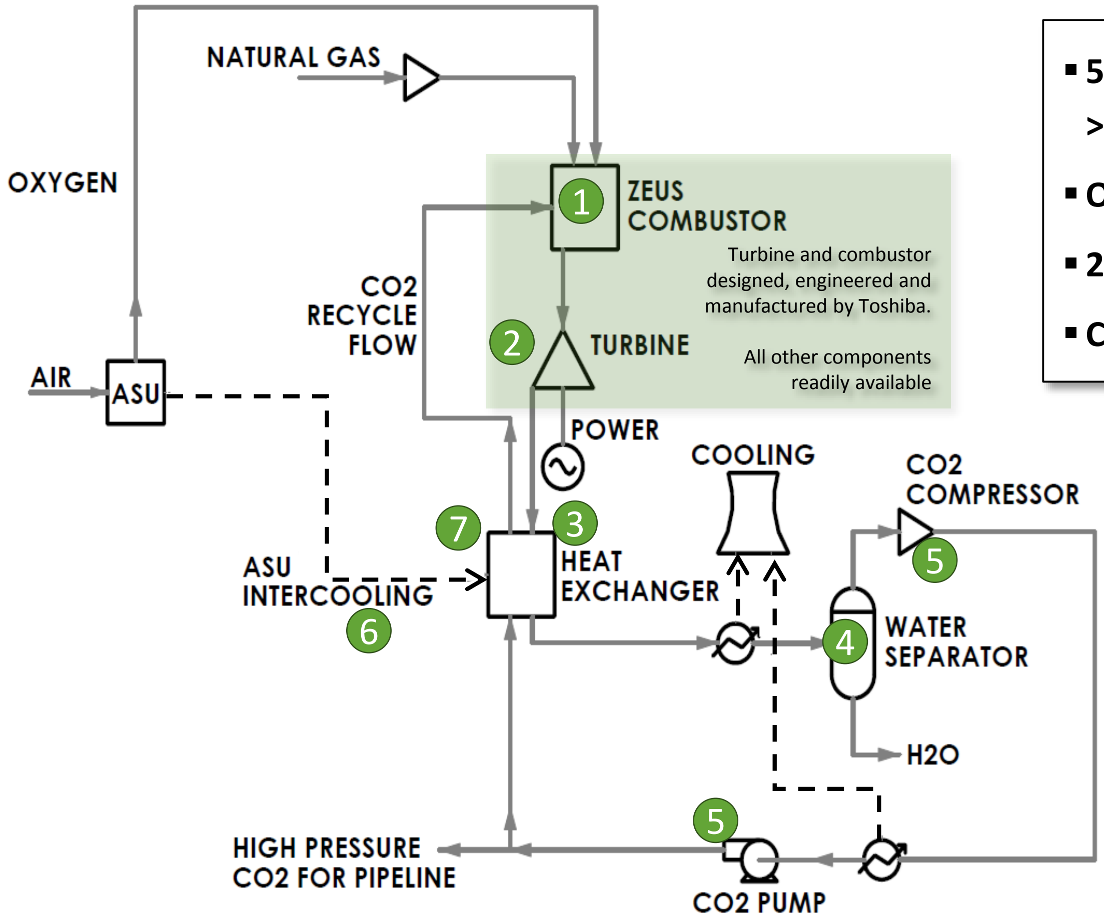
**The turbine is in an advanced state of readiness**

- **It is being engineered, designed and manufactured by Toshiba.**
- **The blades, stages and pressure shells are not new.**
- **Only the combustor is new.**
- **A 5MWt test combustor has been operating since January 2013.**

# Technology Overview

## The Supercritical $CO_2$ Allam Cycle

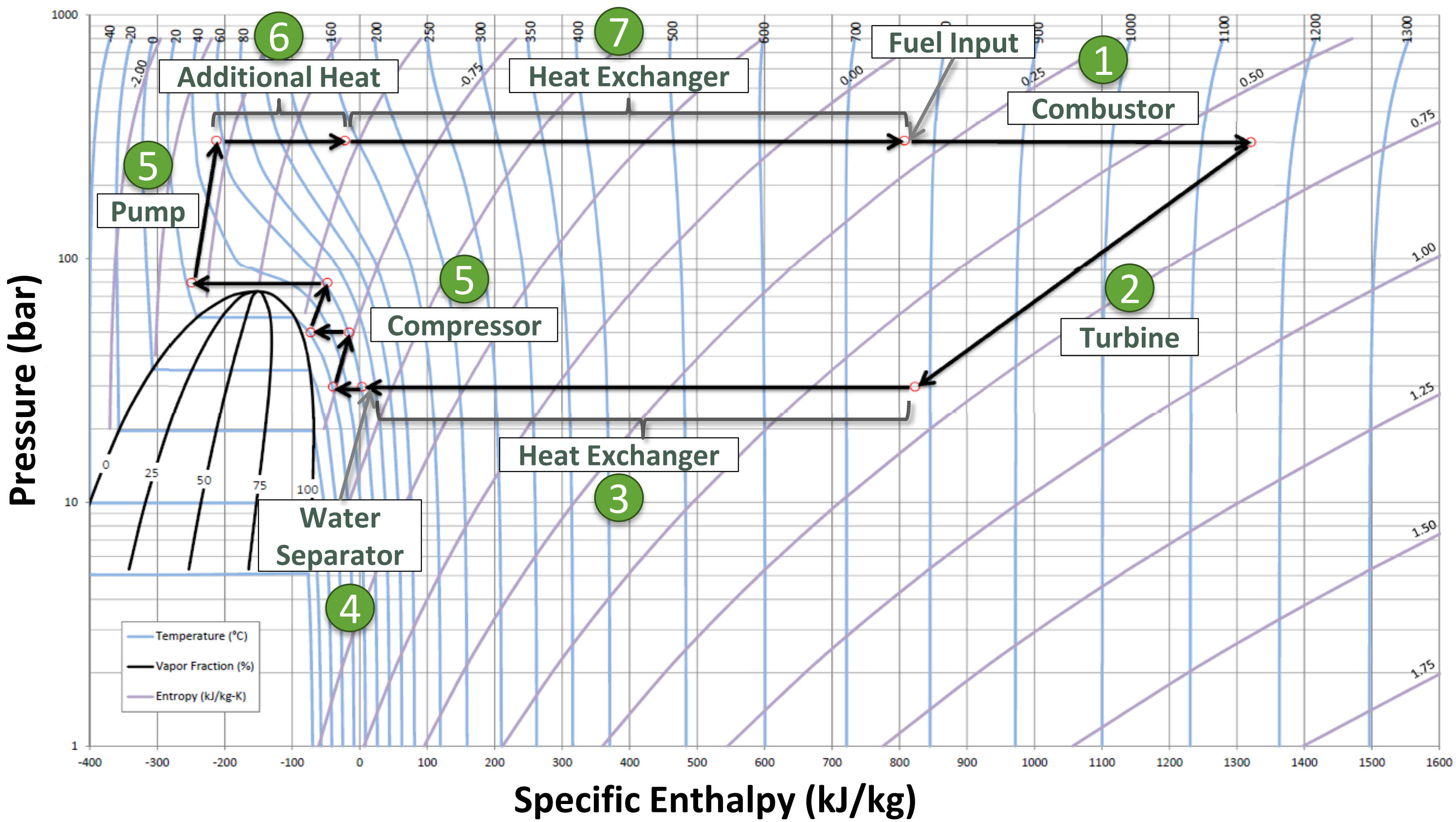
# NET Power is based on the Allam Cycle platform




- 58.9% (LHV) net efficiency, with capture of >97% of carbon
- Oxy-fuel, closed-loop, $CO_2$ working fluid
- 200-400 bar; 6-12 pressure ratio
- $CO_2$ and water are the only byproducts

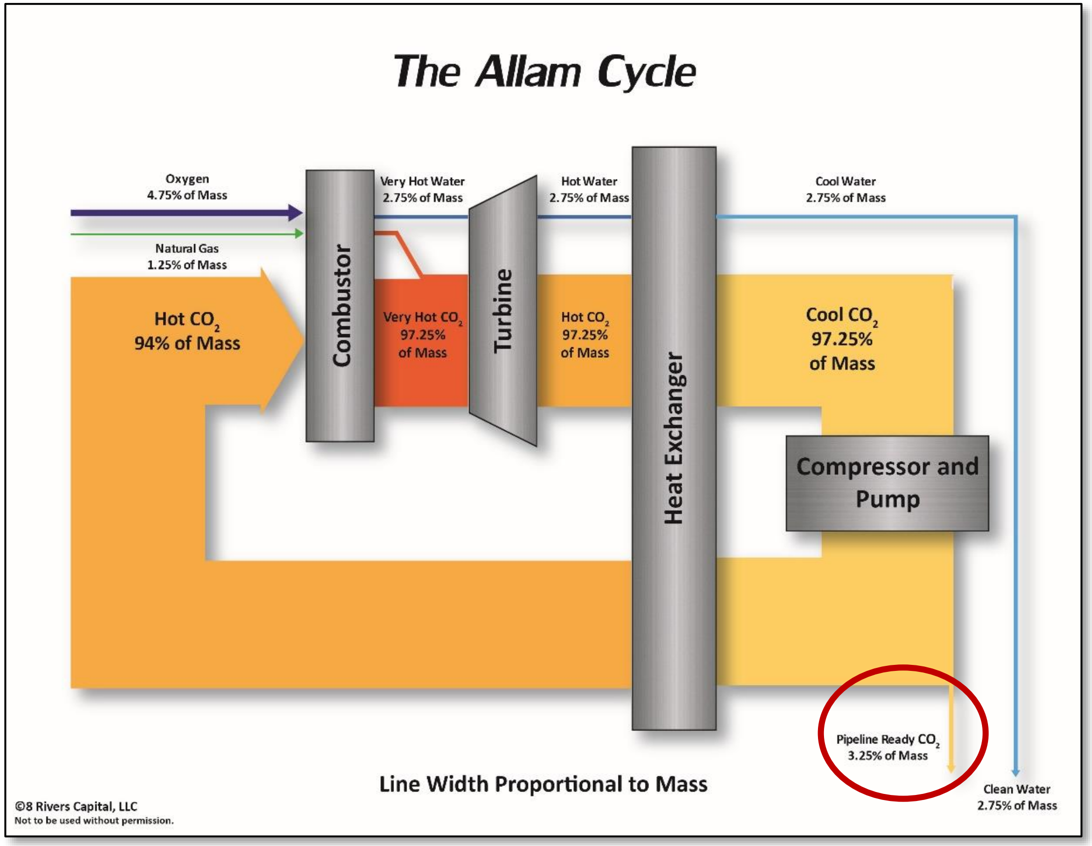
1. Fuel Combustion
2. $CO_2$ Turbine
3. Heat Rejection
4. Water Separation
5. Compression and Pumping
6. Additional Heat Input
7. Heat Recuperation

# The NET Power advantage - the Allam Cycle

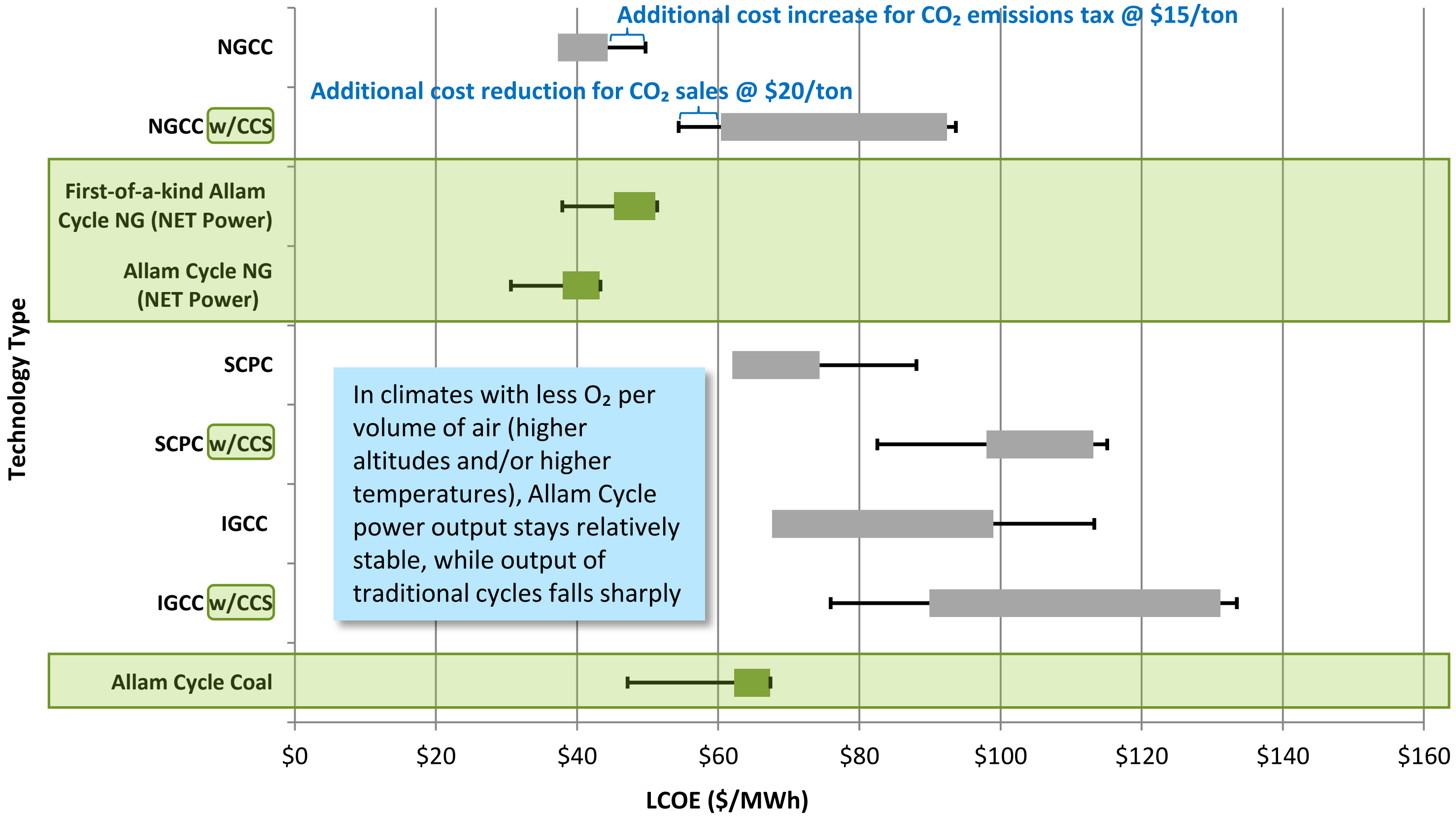


# The supercritical $CO_2$ Allam Cycle is simple

- **Historically, $CO_2$ capture has been expensive, whether using air to combust or oxy-combustion**
  - Air combustion
    - $\underbrace{8N_2 + 2O_2}_{air} + CH_4 \rightarrow \underbrace{8N_2 + CO_2}_{expensive\ to\ separate} + 2H_2O$
  - Oxy-combustion
    - $\underbrace{2O_2}_{expensive\ to\ produce} + CH_4 \rightarrow CO_2 + 2H_2O$
- **The Allam Cycle makes oxy-combustion economic by:**
  - Relying on a more efficient core power cycle
  - Recycling heat within the system to reduce $O_2$ and $CH_4$ consumption, and associated costs of the ASU



# NET Power is competitive without $CO_2$ sales




- **LCOE calculated using EPRI methodology**
- **Assumes natural gas at $2.85/MMBTU and coal at $1.73/MMBTU**
- **Every move of $1 in natural gas moves LCOE $6**
- **Cost ranges represent range of data combined from: EIA (2013), Parsons Brinkerhoff (2013); Black & Veatch (2012); DOE NETL (2012)**

# NET Power's Development Program

## Performance and Economics Overview

# Development pathway

- Thermodynamic modelling
- Costing
- Program development

- 295MWe commercial plant pre-FEED
- 50MWth demonstration plant FEED
- 5MWth combustor testing

- 50MWth demonstration construction and testing
- 295MWe commercial development

- 295MWe commercial construction and operation

**Current Stage**

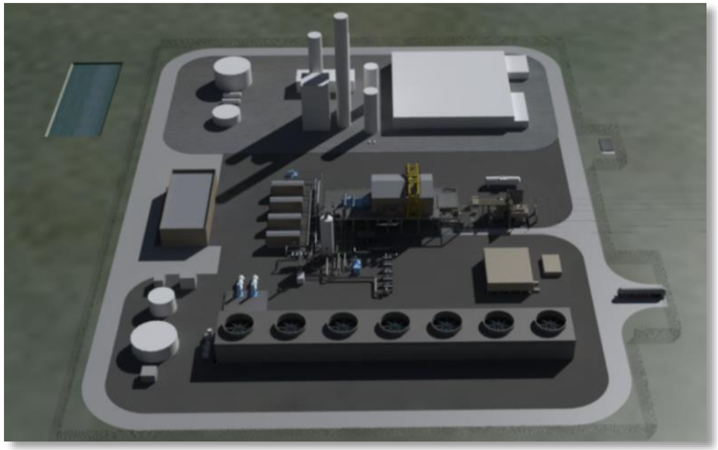
# Construction is underway on NET Power's 50MW demonstration plant

- **50MWth natural gas demonstration plant**
  - Plant design scaled down from 500MWth pre-FEED design to ensure scalability
  - Site is in La Porte, TX
- **Plant includes all core components of the Allam Cycle**
  - Combustor/turbine, heat exchangers, pumps and compressors, control system, and ancillary equipment
  - Plant will undergo full performance evaluation (startup, shutdown, ramping, hot/warm/cold starts, emergency operations)
  - Oxygen will be pulled from a pipeline as opposed to a dedicated ASU
  - CO2 will be generated at high pressure and quality
- **$140 million program**
  - Includes first of a kind engineering, all construction, and testing period


# Commercial plant characteristics

- **Large amount of operational flexibility**
  - Electrical turndown **not limited by air permit** constraints
  - Enables **rapid responsiveness** to load requirements
  - **Ramp-rate**
    - Cold (after being down for 36 hours): 3 to 4 hours
    - Warm/hot (being down less than 12 hours): 2-5% per minute from warm/hot start

- **Large amount of siting flexibility**
  - Ability to cool with hybrid or air cooling configurations, **eliminating water needs** (no make-up water required), with minimal (2-3%) efficiency impact
  - Simplified configuration capable of using **alternative water resources** (non-potable and/or brackish)
  - Elimination of air emissions enables siting in **non-attainment zones** without requiring purchase of offsets
  - **Maintains performance** (no major de-rating) in low air density locations (hot ambient temps/high altitudes)
  - Flexible with small contaminants in **fuel gas chemistry**

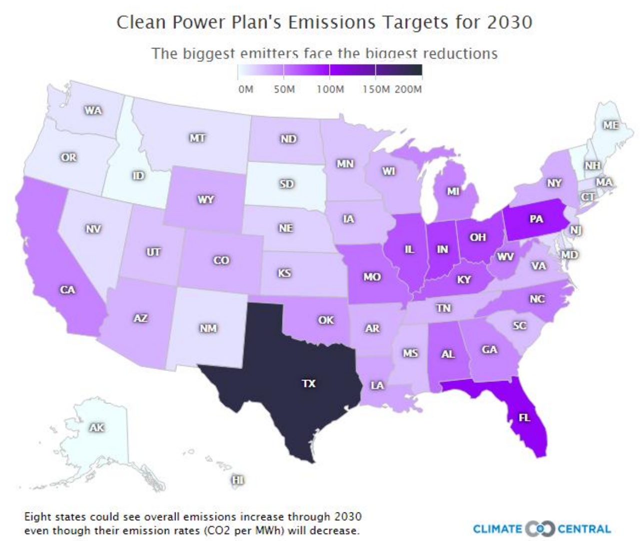


| NET Power Commercial Natural Gas Plant | |
|---|---|
| Electric Output | 295MW |
| $CO_2$ Output | 804,000 ton/year at 120 bar pressure |
| $N_2$ Output | 4.2 MM ton/year |
| ASU Output Demand | 3,500 ton/day |
| Site Area | 13 acres |

# Commercial marketing

- **Commercial power customers are already engaged**
  - In commercial discussions with many of the largest power generators in US an internationally.
  - Planned natural gas capacity additions by this group of customers is equal to, conservatively, 50 NET Power 2-train power stations.
- **Commercial-scale pre-FEED completed**
  - Moving into plant FEED stage.
- **Major and minor oil and gas EOR companies interested in $CO_2$ off-take**
  - NET Power enhances their economics and provides much needed $CO_2$ supply.

- **Potential regulatory opportunity in US**
  - New $CO_2$ regulations enhance NET Power's market position.
  - NET Power provides customers with certainty in the face of changing and increasingly stringent regulations.



# NET Power’s Benefits

## Performance and Economics Overview

# NET Power plants are highly efficient

- **Competes with or exceeds combined cycle efficiency, while eliminating air emissions.**

**NET Power and Combined Cycle: Efficiency Comparison**

| | HHV | | LHV | |
|---|---|---|---|---|
| **Energy Components** | **F-Class US NGCC Plant (0% CC)*** | **NET Power NG Plant (100% CC)** | **F-Class US NGCC Plant (0% CC)*** | **NET Power NG Plant (100% CC)** |
| **Gross Turbine Output** | 51.06% (Compressors mechanically coupled) | 74.65% | 58.7% (Compressors mechanically coupled) | 82.7% |
| **$CO_2$ Compressor Power** | | -10.47% | | -11.6% |
| **Plant Parasitic Auxiliary Power** | -0.86% | -11.01% | -1.2% | -12.2% |
| **Net Efficiency** | **50.20%** | **53.17%** | **57.5%** | **58.9%** |

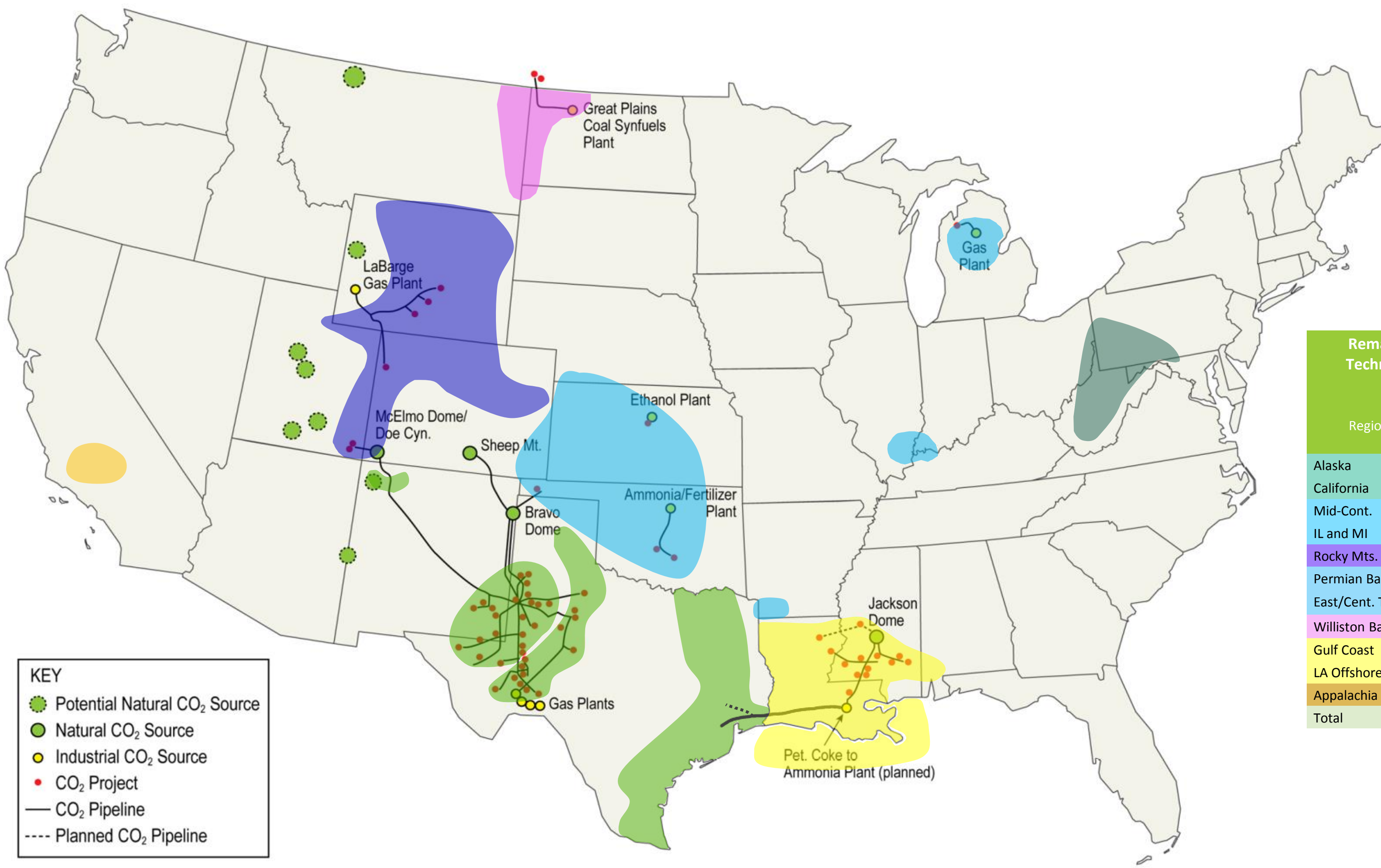
*Performance data from NETL Cost and Performance Baseline Report, 2013.

| Parasitic Load Provides Opportunity for Efficiency Improvement | |
|---|---|
| **ASU** | 91.8% |
| **NG Compressor** | 8.2% |

# NET Power's low cost-of-capture solves the $CO_2$ utilization and storage problem

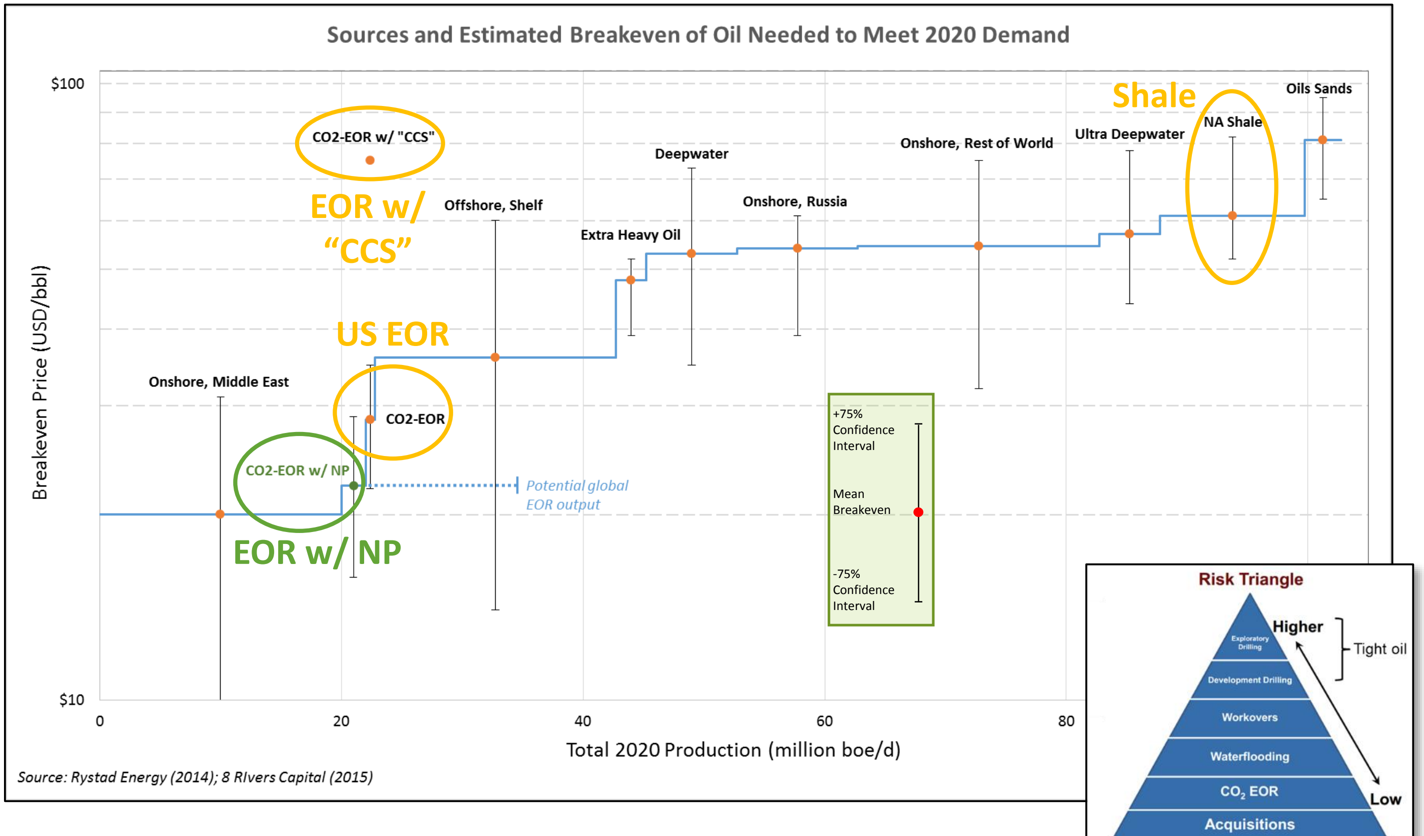
- **$CO_2$ capture**
  - at no extra cost
  - already at pressure (available from 30 bar/450 psi to 300 bar/4500 psi)
  - already at high purity
- **Scalable $CO_2$ uses**
  - Enhanced oil recovery (EOR)
    - Cheaper than geologic $CO_2$ (no associated lifting costs, mineral lease costs or pressurization costs)
    - Current $CO_2$ use in US would by matched by the $CO_2$ output from over 110 Allam Cycle turbines (500 MWth)
    - Industry is drastically under-supplied with affordable $CO_2$
  - Additional $CO_2$ utilization opportunities
    - Building materials
    - Chemical processes
    - Artificial photosynthesis

# NET Power can build upon the large $CO_2$-EOR infrastructure already in place




| Remaining Oil in Place and Technically Recoverable Oil (billion bbls) | | |
|---|---|---|
| Region | Remaining Oil in Place | Technically Recover-able |
| Alaska | 45.0 | 12.4 |
| California | 57.3 | 6.3 |
| Mid-Cont. | 65.6 | 10.6 |
| IL and MI | 11.5 | 1.2 |
| Rocky Mts. | 22.6 | 3.9 |
| Permian Basin | 61.7 | 15.8 |
| East/Cent. Texas | 73.6 | 17.6 |
| Williston Basin | 9.4 | 2.5 |
| Gulf Coast | 27.5 | 7.0 |
| LA Offshore | 15.7 | 5.8 |
| Appalachia | 10.1 | 1.6 |
| Total | 400 | 84.8 |

# NET Power can deliver significant economic and geographic growth in lower oil prices via EOR




*Source: Rystad Energy (2014); 8 RIvers Capital (2015)*

*Source: Chaparral Energy*

- Shutdown of tight oil/high cost plays highlights EOR as a low-cost opportunity for growth from existing fields
- NET Power further improves the economics of EOR and will significantly expand $CO_2$ supplies for producers

# NET Power provides growth opportunities to industries outside of electricity generation

- **Key gases**
  - Synergistic with chemicals and oil & gas industries
  - For each turbine train (operating at an estimated 85% capacity factor for power, 98% for ASU)
    - 13.9 million MMBTU per year NG use
    - 800,000 tons per year $CO_2$ production
    - 4.8 MM tons per year $N_2$ production
    - 166,000 tons per year $O_2$ production (during planned outages for electricity part of plant)
  - Capability of delivering syngas ($H_2$ and CO)
- **Significant flexibility to site where resources exist**
  - Option for zero water usage
  - Insensitive to changes in ambient conditions (altitude, temperature, etc.)
- **Reduces the $CO_2$ intensity of the oil & gas industry**
  - Can utilize flare and waste gases (associated, acid, sour) that are otherwise environmentally harmful
    - Can Integrate directly with operations of oil and gas producers
    - Simplifies operations and reduces costs
  - Integration with LNG-regasification terminals provides high efficiency power generation (67% LHV) and eliminates the need for gas-fired regasification

# Appendix

EOR, EPA, and Carbon Capture

# The NET Power advantage summarized

## Low-Cost

- Utilizes abundant, low-cost natural gas
- Produces electricity that is equal to, or less than, NGCC's cost of electricity
- No additional cost for $CO_2$ capture

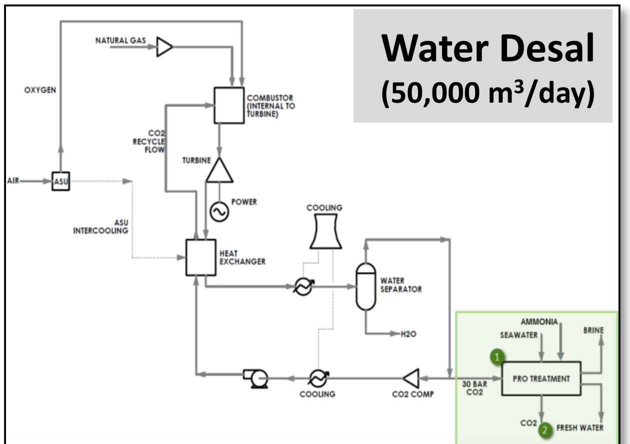
## De-risk fleet

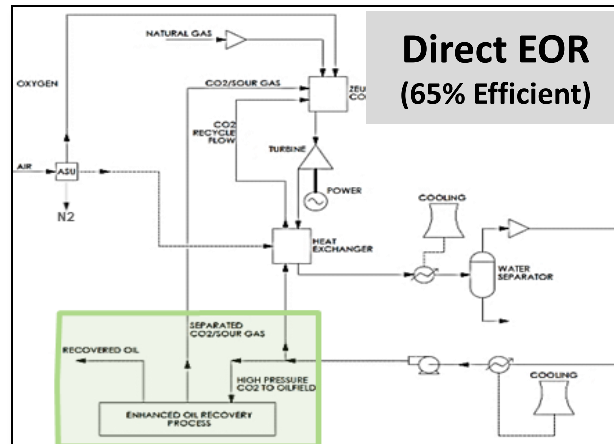
- Near-100% capture of all carbon emissions (>97%)
- No other air emissions, including $NO_x$
- Water usage can be eliminated

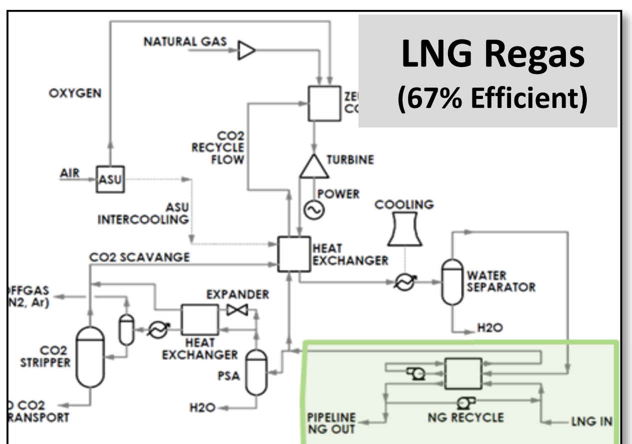
## Reliable

- Less sensitive to changes in siting conditions (high altitude and temp)
- Reactive power and maintaining voltage, frequency, & stability
- Capable of full electrical turndown without emissions issues, enabling fast response

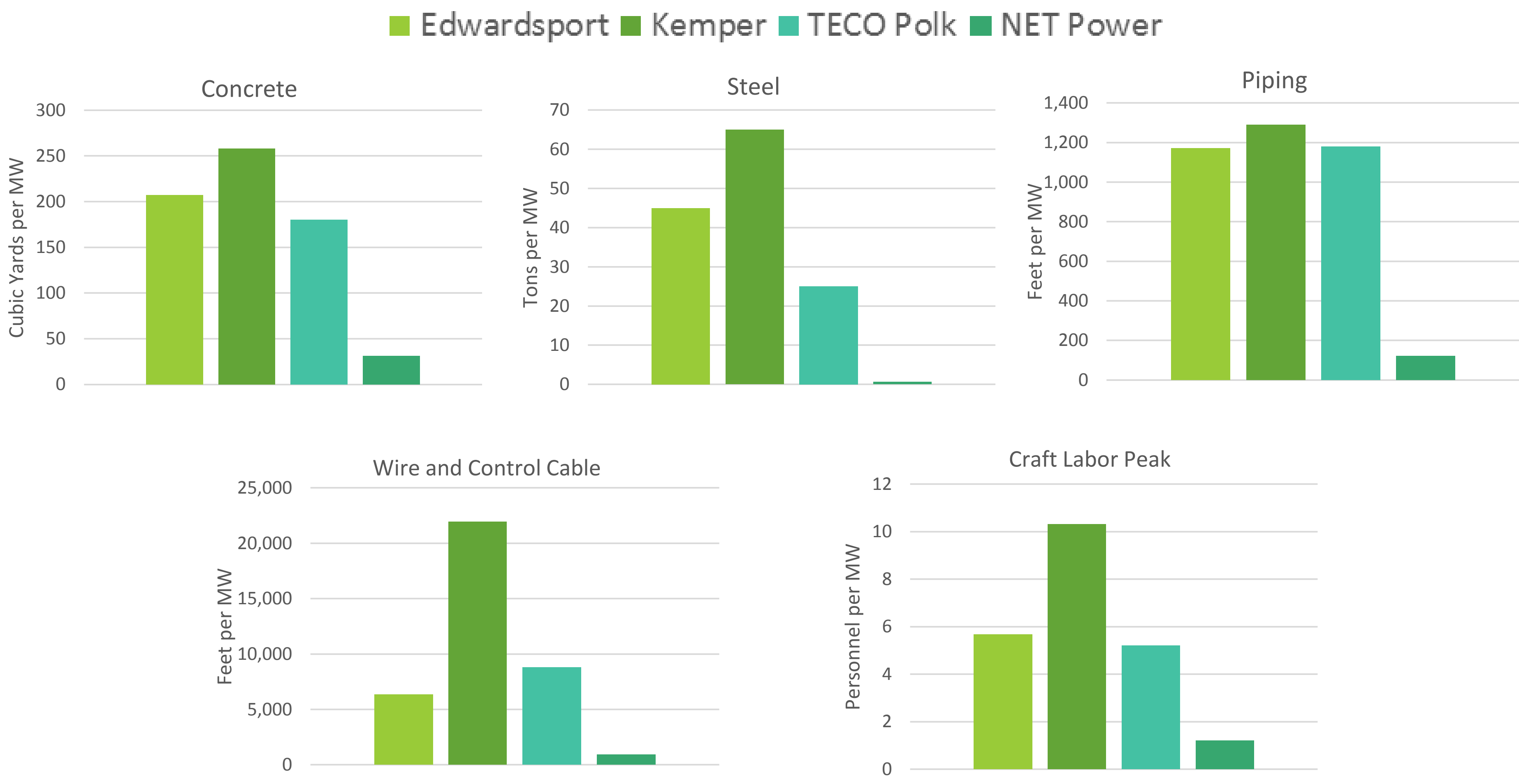
# The Allam Cycle provides a flexible platform with broad applications



# NET Power's commercial plant is much smaller and simpler than previous carbon capture projects



# NET Power transforms U.S. EOR and $CO_2$ storage potential

## $CO_2$ demand far outstrips supply

- As current geologic supply drops, the gap will grow wider.

## NET Power produces the lowest-cost $CO_2$

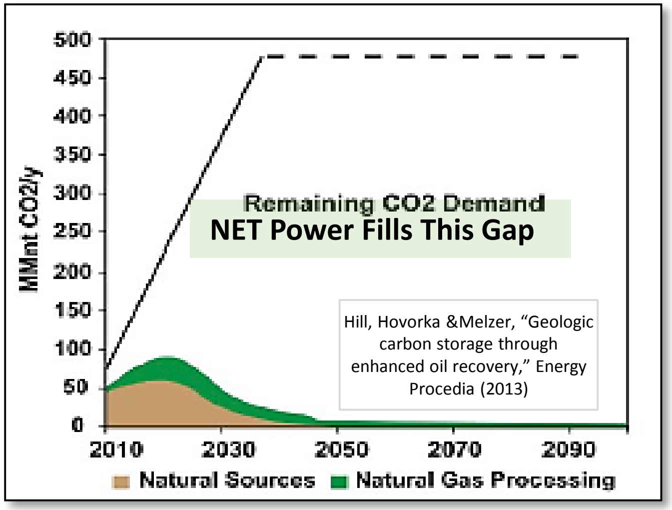
- The Allam Cycle can produce pipeline $CO_2$ at a cost lower than any existing source, including geologic, which is currently the lowest cost, and by far the most common, source of $CO_2$ for EOR.

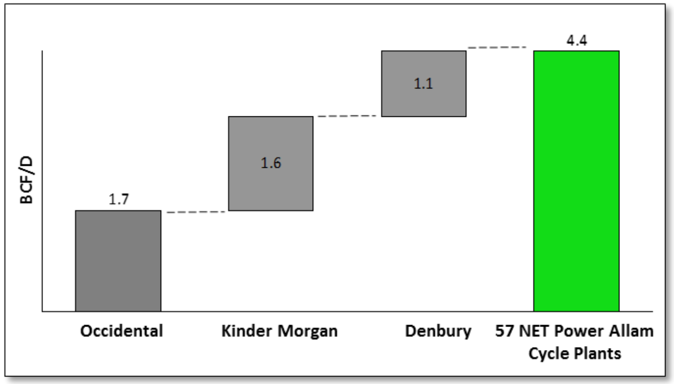
## NET Power will have a major supply impact

- 57 commercial NET Power Allam Cycle plants would match the entire combined geologic $CO_2$ supply of the 3 largest US EOR operators (OXY, Kinder, Denbury).

## NET Power untethers EOR from the current geologic $CO_2$ supply network

- NET Power-based $CO_2$ hubs enable utilization of EOR assets isolated from the geologic $CO_2$ network and justify a major expansion of $CO_2$ supply network.



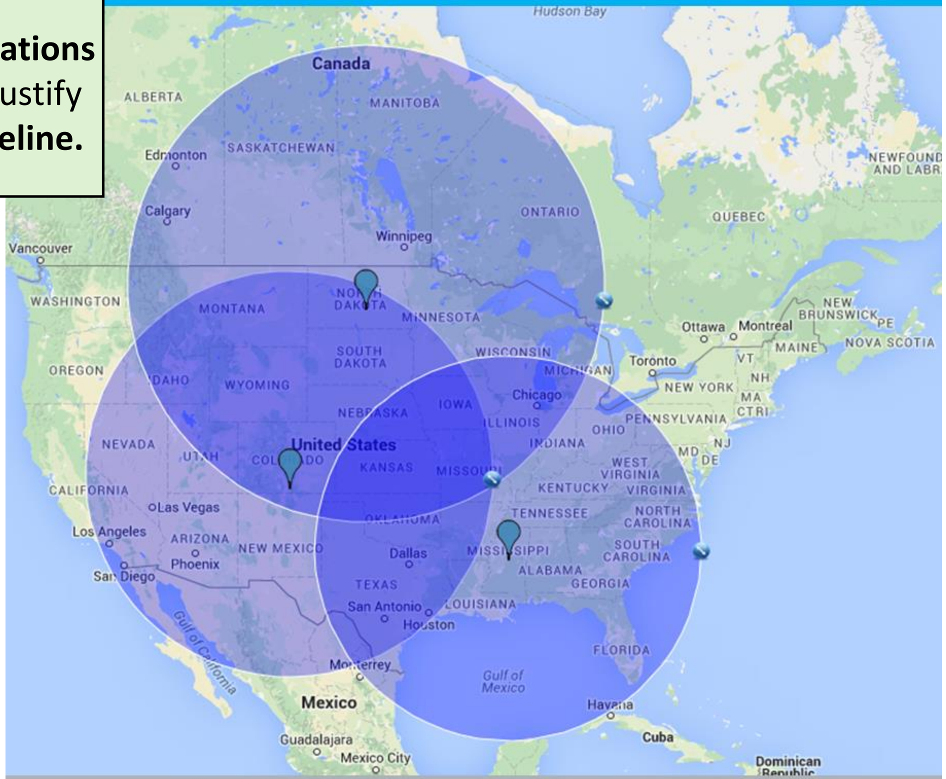



# NET Power Allows the $CO_2$ Pipeline Network to Grow Rapidly

**Low-Cost $CO_2$ production would support a massive network expansion**

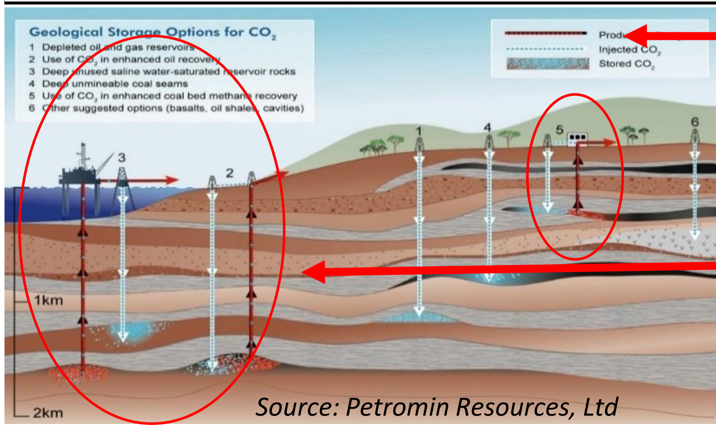
**Approximately 7 NET Power 590 MWe stations** would produce enough low-cost $CO_2$ to justify the development of an **800 mile $CO_2$ pipeline.**

800-mile radius of existing $CO_2$ pipelines




"Larger" radius for northern circles due to distortions from map projection.

# CO2 sequestration can generate revenue with EOR and ECBMR



*Source: Petromin Resources, Ltd*

**ECBMR:** Enhanced Coal Bed Methane Recovery. Injection of $CO_2$ into coal seams than cannot be mined. $CO_2$ is sequestered and $CH_4$ is produced.

**EOR:** Enhanced Oil Recovery. $CO_2$ is injected into mature oil wells to stimulate additional oil production.

| | Gross Fossil Capacity Builds to 2035 (IEA) | Fraction of Gross Build That Would Be Justified by EOR Demand* | Fraction of Gross Build That Would Be Justified by ECBM Demand* | 500MWt/295MWe Trains justified by EOR and ECBM demand for $CO_2$ | |
|---|---|---|---|---|---|
| | | | | **Total** | **10% market share** |
| Europe | 213 GW | 67% | 72% | 722 | 72 |
| Former Soviet Union | 262 GW | 299% | 313% | 888 | 89 |
| Asia Pacific/Oceana | 1408 GW | 9% | 226% | 4,773 | 477 |
| Middle East | 185 GW | 1091% | 197% | 627 | 63 |
| Latin America | 96 GW | 334% | 123% | 325 | 33 |
| United States and Canada | 239 GW | 254% | 603% | 810 | 81 |
| **Total** | **2,403 GW** | | | **8,146** | **815** |

*A value greater than 100% indicates that EOR/ECBM demands exceed CO2 supply from gross capacity builds between now and 2035.

Sources: Godec et al. Potential global implications of gas production from shales and coal for geological CO2 storage. Energy Procedia. GHGT-11 (2013)

Kuuskraa,, A., et. al. "$CO_2$ Utilization from "Next Generation" CO2 Enhanced Oil Recovery Technology," GHGT-11, 2013)

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