NET Power

Truly Clean, Cheaper Energy

Presentation to NGI at Stanford

October 2016

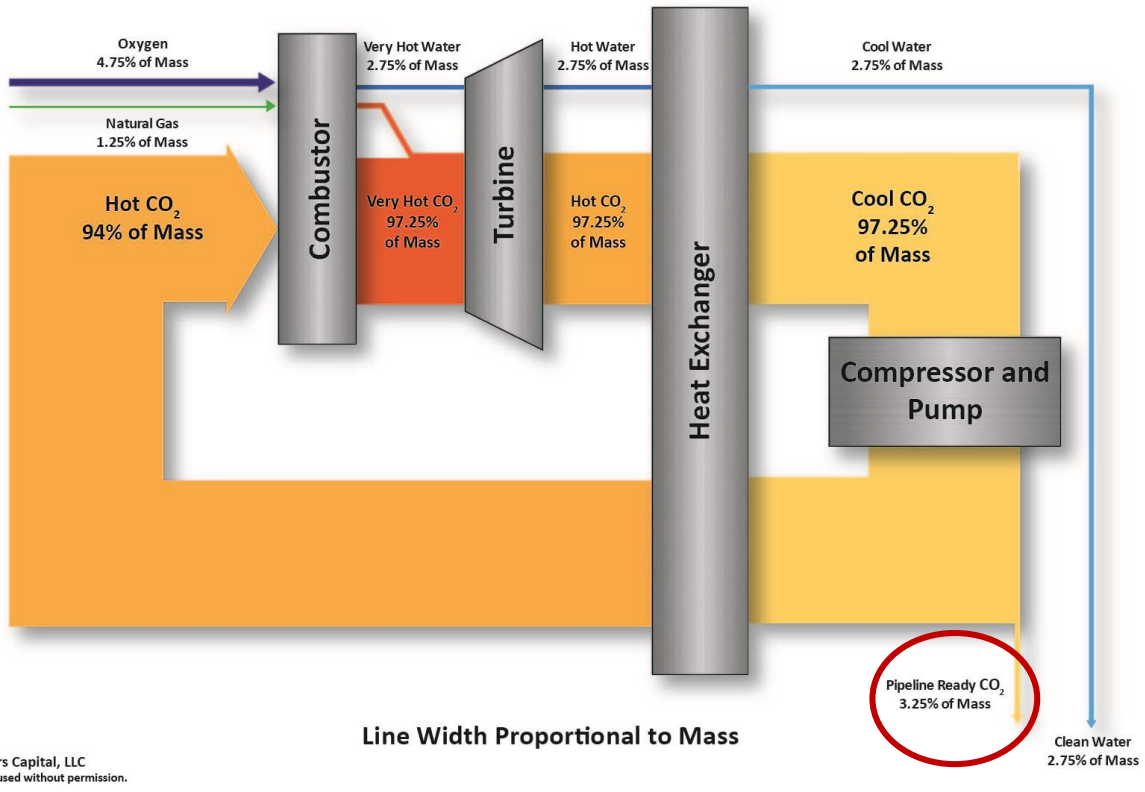
NET Power's first plant is under construction

50 MWth Plant in LaPorte, TX, on track for commissioning later this year

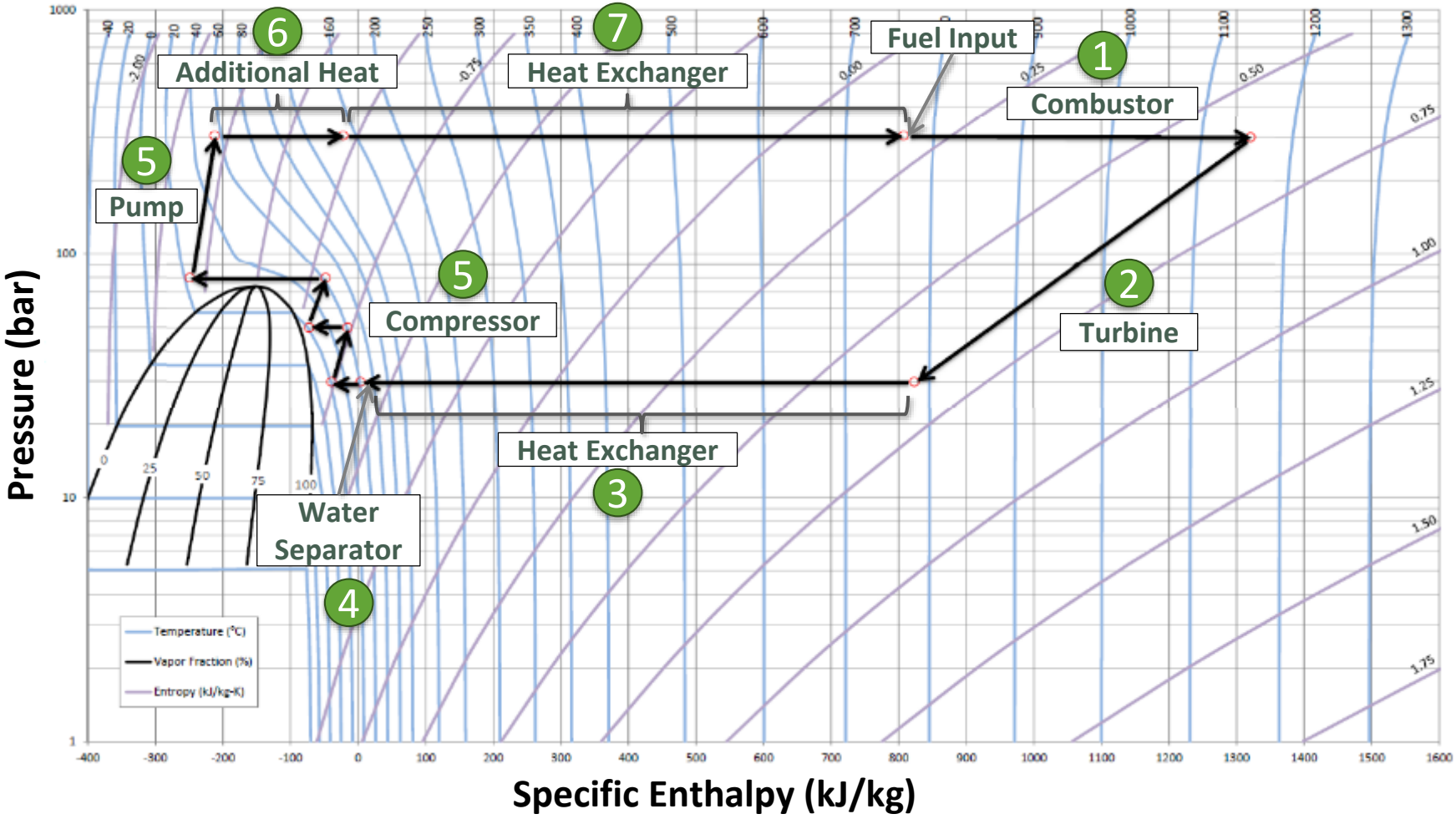
Technology at a Glance

The supercritical CO_2 Allam Cycle is simple

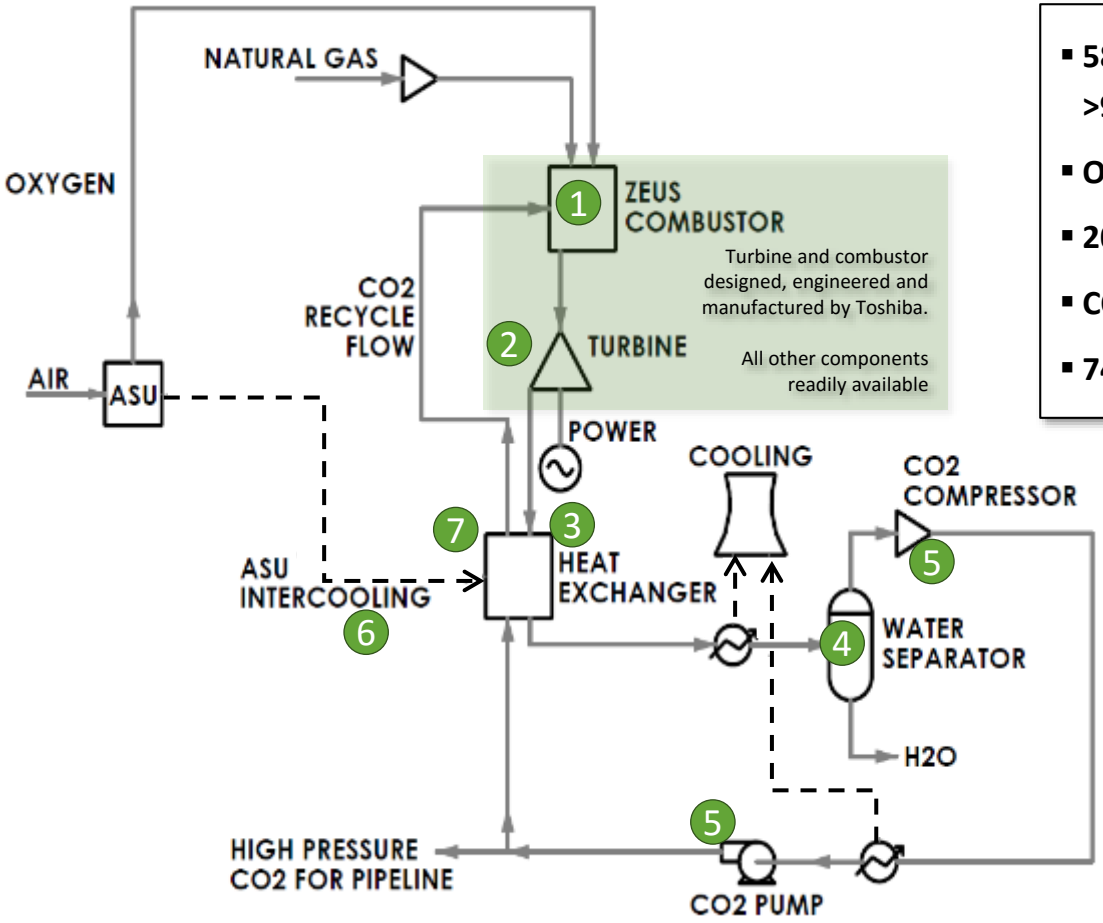
- **Historically, CO_2 capture has been expensive, whether using air to combust or oxy-combustion**
  - Air combustion
    - $\underbrace{8N_2 + 2O_2}_{air} + CH_4 \rightarrow \underbrace{8N_2 + CO_2}_{expensive\ to\ separate} + 2H_2O$
  - Oxy-combustion
    - $\underbrace{2O_2}_{expensive\ to\ produce} + CH_4 \rightarrow CO_2 + 2H_2O$
- **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



The NET Power Advantage - The Allam Cycle



NET Power is Based on the Allam Cycle Platform

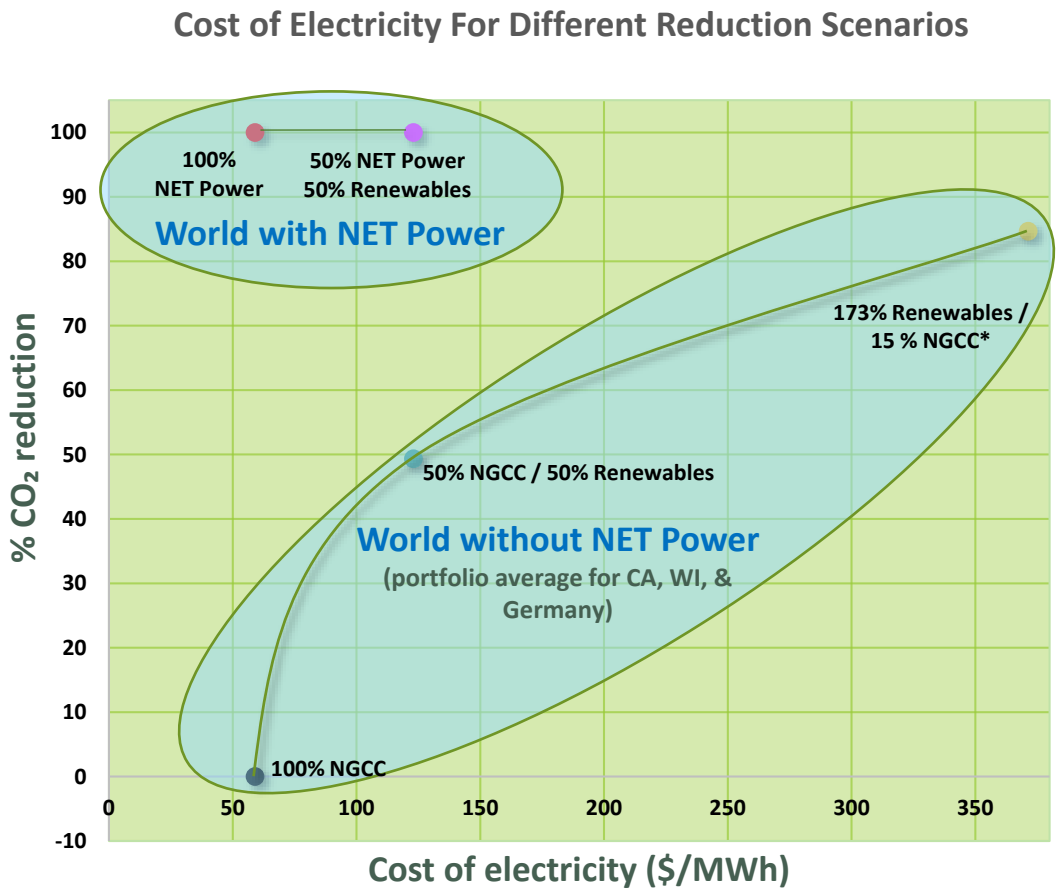


- 58.9% (LHV) net efficiency, with capture of >97% of carbon
- Oxy-fuel, closed-loop, CO_2 working fluid
- 200-400 bar; 6-12 pressure ratio
- CO_2 and water are the only byproducts
- 740H now in commercial use at two facilities

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

Drive for NET Power

NET Power eliminates atmospheric CO_2 at no extra cost



- **System level studies consistently show that high levels of renewable penetration (50-80%) result in greater system costs than balanced and "high CCS" scenarios even assuming *today's* high CCS costs.**
- **Fossil deployment remains roughly equal compared to reference or balanced scenarios; higher levels of renewable penetration do little to offset need for baseload generation.**

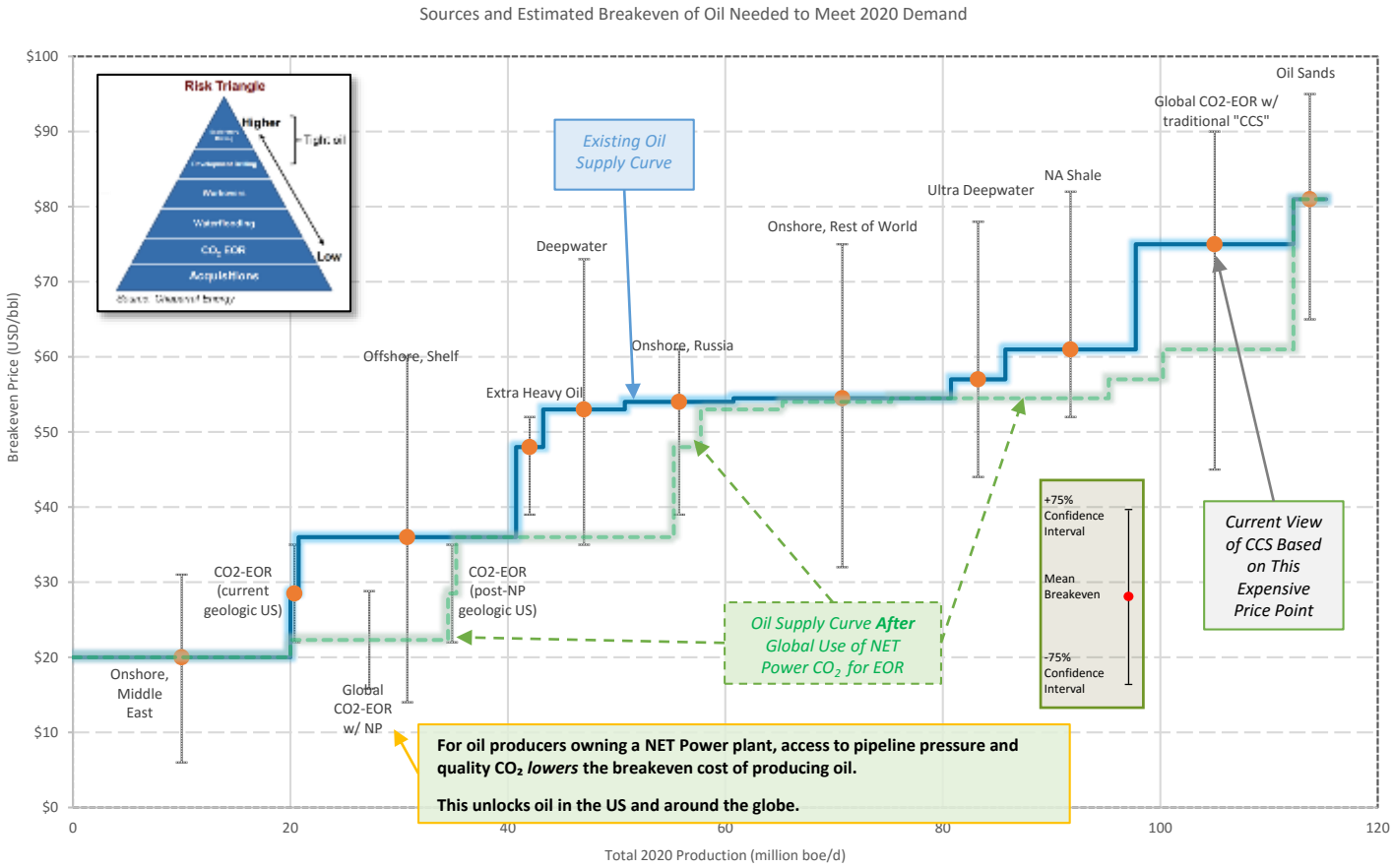
Data obtained from: Brick, S., and Thernstrom, S., Renewables and decarbonization: Studies of California, Wisconsin, and Germany, *The Electricity Journal,* **2016**, 29, 6-12.

*Renewables and storage capacity build-out 173% above total capacity demand, with NGCC still providing consistent baseload support.

NET Power will

- **Allow the world to meet its climate targets**
- **Without having to pay more for electricity**

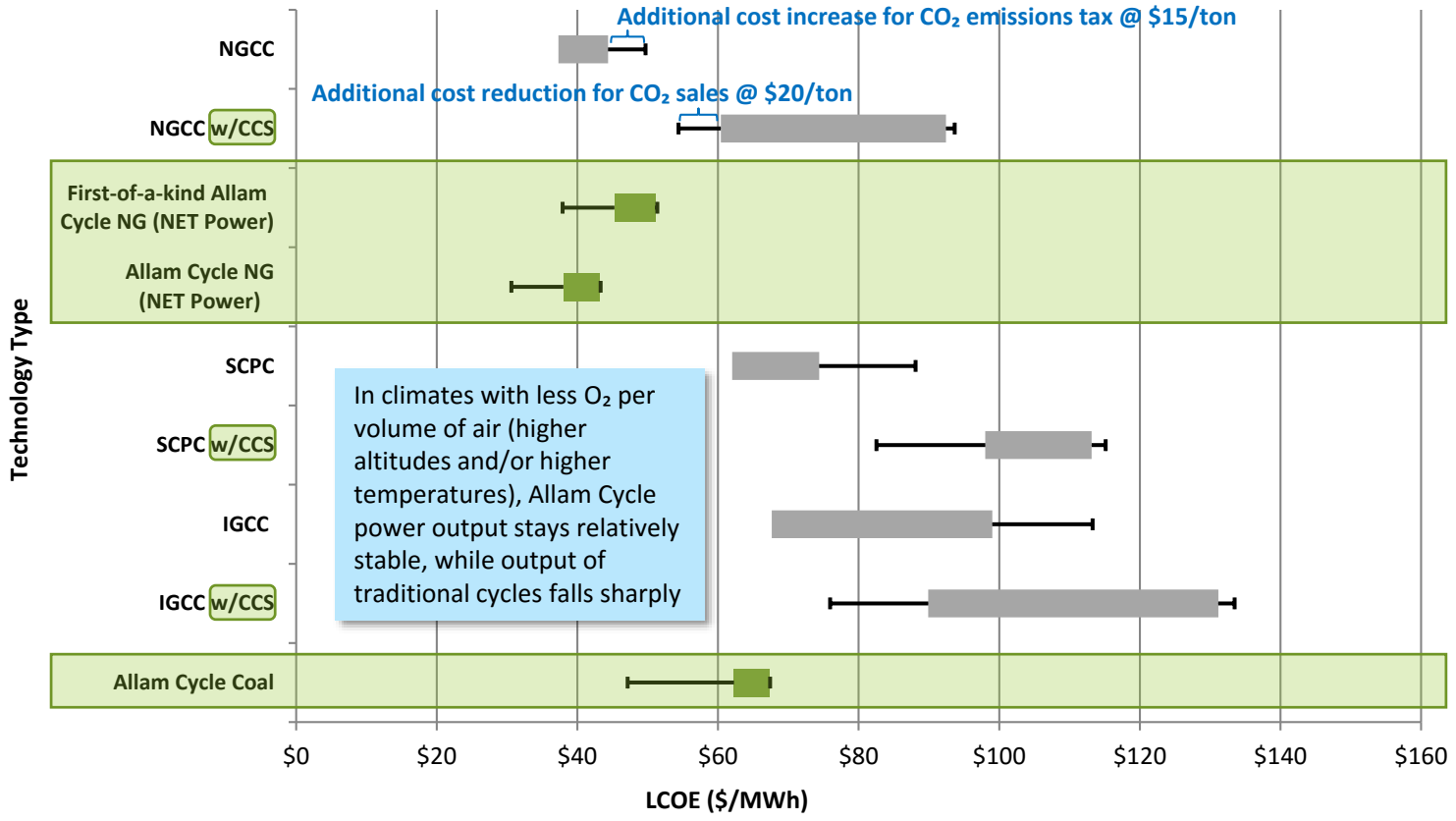
Global CO_2 EOR – Economics



- **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 solves the challenge of carbon capture adoption by achieving lower cost and higher efficiency than current non-carbon capture power generation options**

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

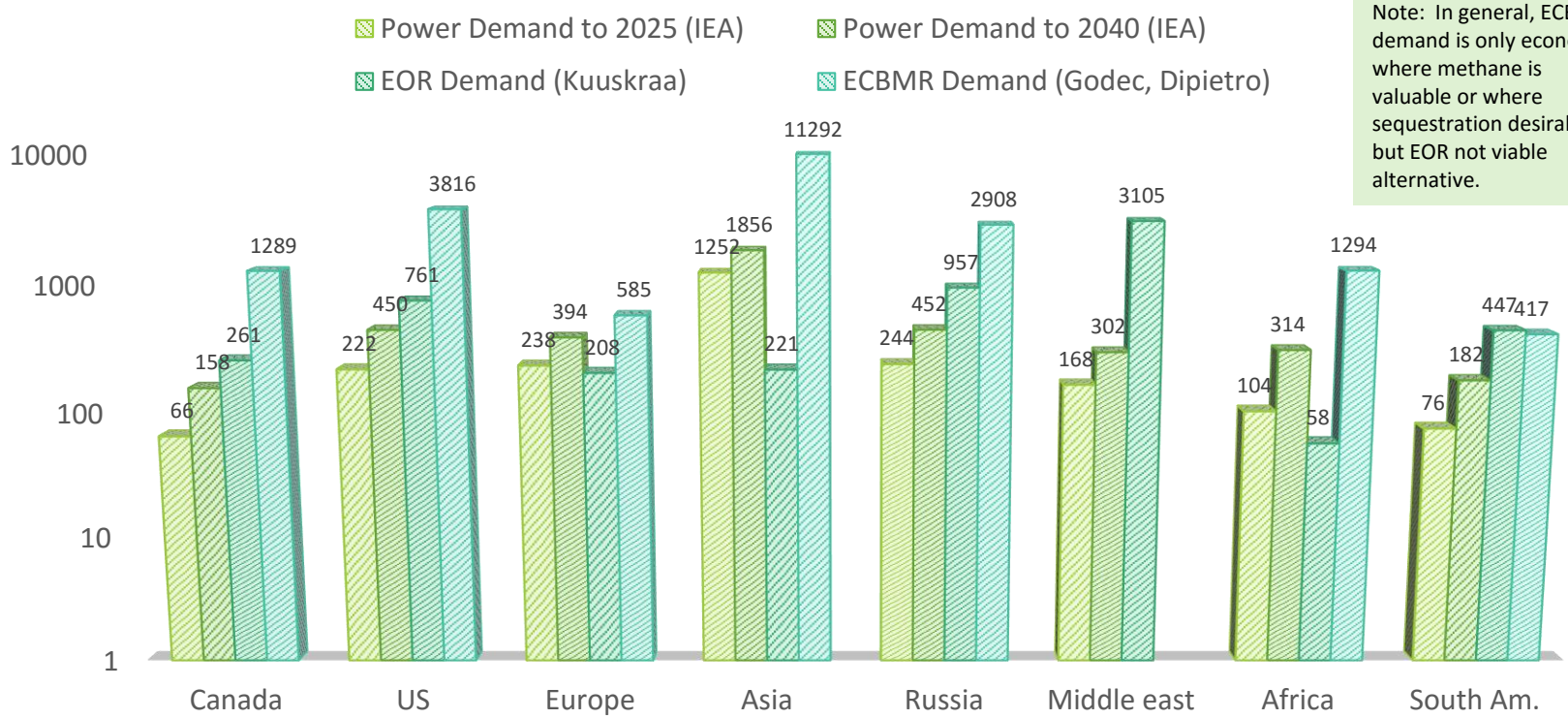
NET Power Economics



- **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)**

Global turbine sales will be driven by power demand and CO_2 demand

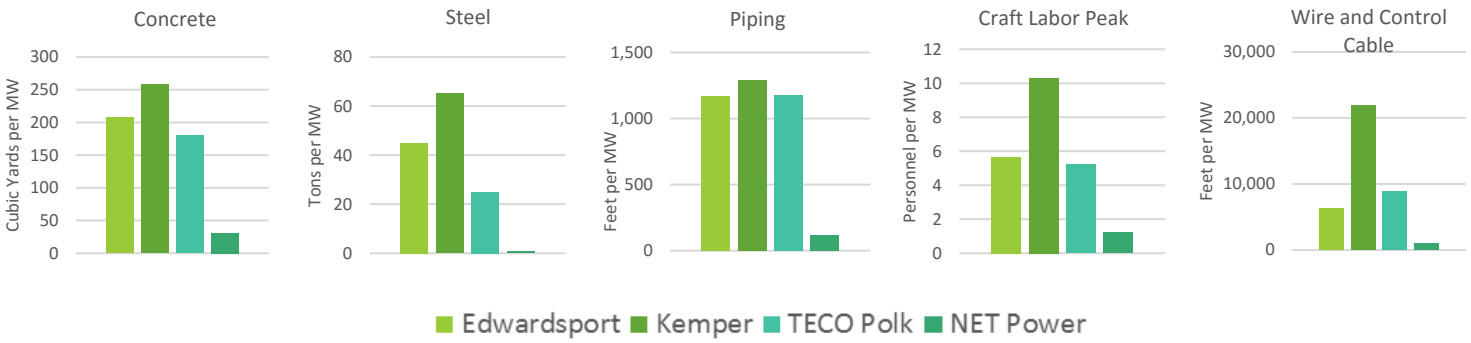
NUMBER OF NET POWER TURBINES NEEDED TO SATISFY DIFFERENT MARKETS



Note: In general, ECBMR demand is only economic where methane is valuable or where sequestration desirable, but EOR not viable alternative.

NET Power is much simpler (and less expensive) than recent IGCC attempts at CCS

- **Bulks were a significant driver of cost increases at major IGCC projects:**
  - Huge quantities required.
  - On-going design changes required further ordering.
  - Ordered during a period of rapid price escalation (2005-2008).
  - Premium craft rates and on-site training required; scale of plants meant massive number of workers on site, exacerbating cost-impact of project delays.



- **NET Power's footprint per MW is ¼ of that needed for IGCC**

The Chemicals Industry and NET Power Integration

CO_2 conversion to value added chemicals

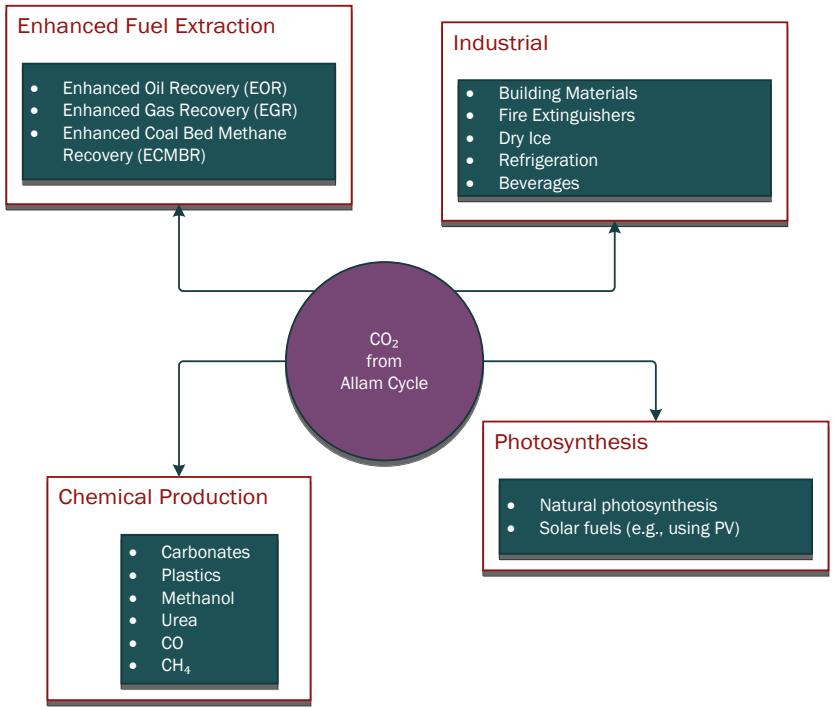
Availability of CO_2 utilization opportunities not driven by potential uses, but by cost of anthropogenic CO_2.

- **NET Power offers CO_2 capture at:**
  1. no extra cost
  2. high pressure (available from 30 bar/450 psi to 300 bar/4500 psi)
  3. high purity

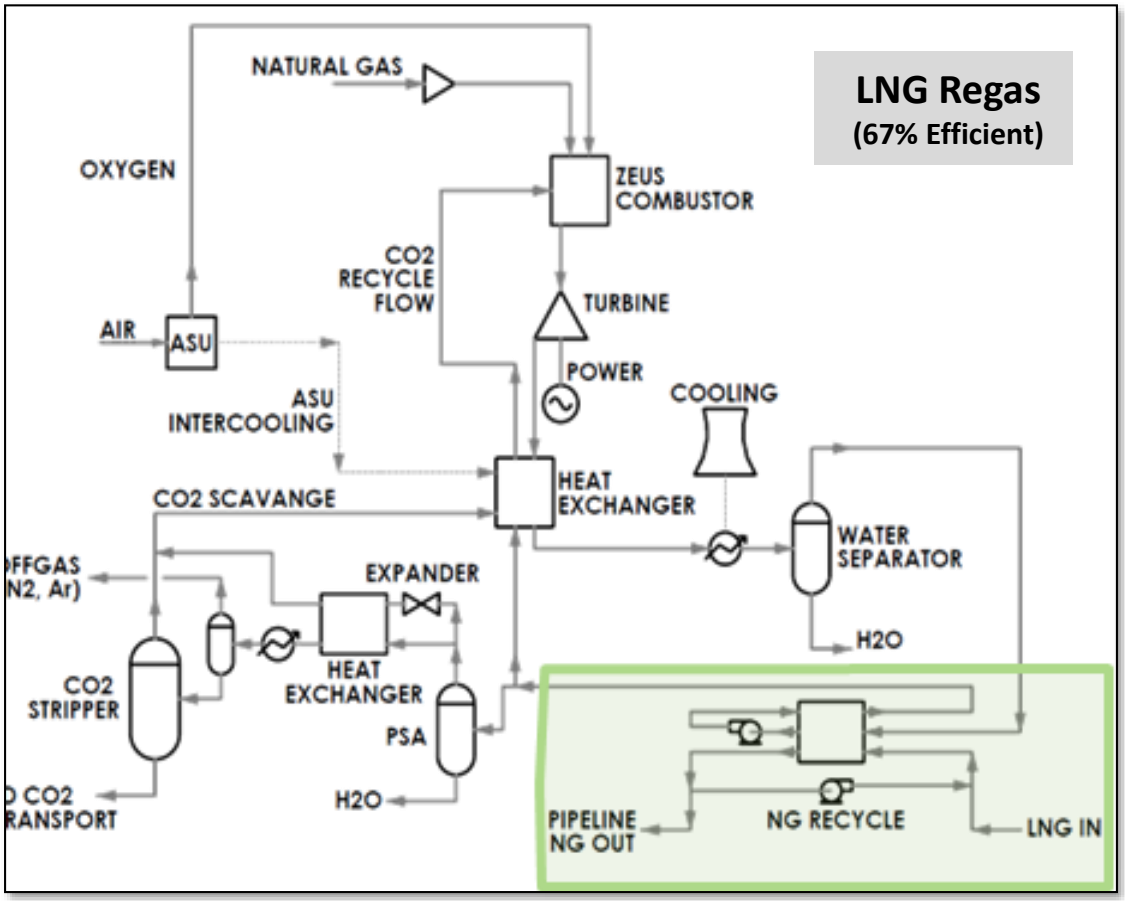
Providing a usable, affordable by-product to the chemicals industry.

NP is more than just power production

- **NET Power co-produces gases that are synergistic with chemicals and oil & gas and chemical 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 (at pressure and purity)
    - 4.8 MM tons per year N_2 production
    - 56,965 tons per year Ar 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)
- **Scalable CO_2 uses**
  - Additional CO_2 utilization opportunities
    - Building materials
    - Chemical processes
    - Artificial photosynthesis



Integration increases energy efficiency when integrated with LNG Regas



Governmental and Environmental Support

Exceeds regulations of tomorrow, reduces risk today

"NET Power does not make natural gas a bridge—or a pier.
It makes it a destination.“

-Senior government official

NET Power's economics enable CCS to be implemented in stages

- **NET Power is economically competitive with NGCC even when not capturing CO_2**
  - If CO_2 transportation infrastructure is not available when plant operation commences, CO2 capture can be enabled later in the plant's life
- **While awaiting transportation and storage to be developed:**
  - NET Power plants would vent CO_2, increasing plant efficiency by 1-2% while remaining competitive with conventional power plants
  - The plant would still be cleaner than NGCC: plant emissions would be almost entirely pure CO_2, with virtually no NOX emissions
  - No further investment is required to begin commence CO_2 capture
- **This allows deployment of CCS to be implemented in stages**
  - Power infrastructure developed today is fully CO_2 capture ready
  - CO_2 transportation, utilization and storage infrastructure can be developed on its heels

NET Power is *necessary*, not just helpful, to meeting global climate goals

IPCC Fifth Assessment: CCS is most critical component to models meeting 450 ppm CO2 limit; "no CCS" scenario results in least number of successful models (4) and mitigation **costs that were 138% higher than baseline scenarios**.*

Mitigation cost increases in scenarios with limited availability of technologies [6] *[% increase in total discounted [e] mitigation costs (2015–2100) relative to default technology assumptions]*					Mitigation cost increases due to delayed additional mitigation until 2030 *[% increase in mitigation costs relative to immediate mitigation]*	
2100 concentrations (ppm CO_2-eq)	no CCS	nuclear phase out	limited solar/wind	limited bioenergy	medium term costs (2030–2050)	long term costs (2050–2100)
450 (430 to 480)	138% (29 to 297%) 4	7% (4 to 18%) 8	6% (2 to 29%) 8	64% (44 to 78%) 8	44% (2 to 78%) 29	37% (16 to 82%) 29
500 (480 to 530)	not available (n.a.)	n.a.	n.a.	n.a.		
550 (530 to 580)	39% (18 to 78%) 11	13% (2 to 23%) 10	8% (5 to 15%) 10	18% (4 to 66%) 12	15% (3 to 32%)	16% (5 to 24%)
580 to 650	n.a.	n.a.	n.a.	n.a.		

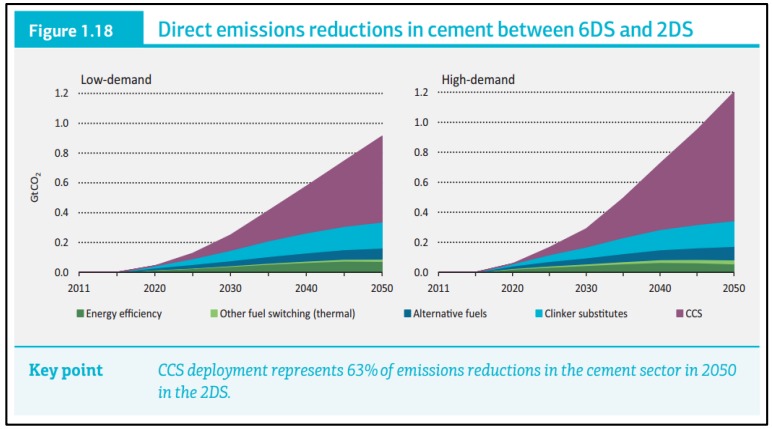
Symbol legend—fraction of models successful in producing scenarios (numbers indicate the number of successful models)

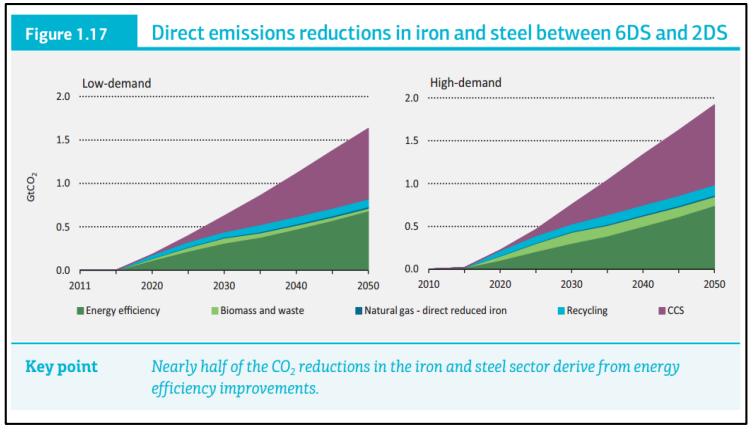
: all models successful
: between 80 and 100% of models successful
: between 50 and 80% of models successful
: less than 50% of models successful

*(IPCC 5th Assessment, Synthesis Report)

Even in the most promising renewable scenarios, the industrial sector must be primarily addressed by CCS

- **The IEA views CCS as the only viable solution in the industrial sector**
  - In order to meet the 2DS target, 2050 CO_2 emissions from the industrial sector must be reduced to 66% of current levels, while energy use will increase 44% over current levels
  - "Reaching these targets will require…rapid increases in CCS capacity."





- **The Allam Cycle addresses these industries.**

Images obtained from: IEA Energy Technology Perspectives 2014

NET Power and CO_2 Sequestration

- **Regulatory opportunities and incentives exist that enhance NET Power's economics**
  - The federal 45Q Tax Credit is applicable to NET Power anywhere it sequesters CO_2 or utilizes it for EOR
  - 21 states have incentives and policies in place the provide value or preferential treatment to NET Power for capturing CO_2

U.S. locations with acceptable geology for CO_2 sequestration (yellow, orange, red, and blue).

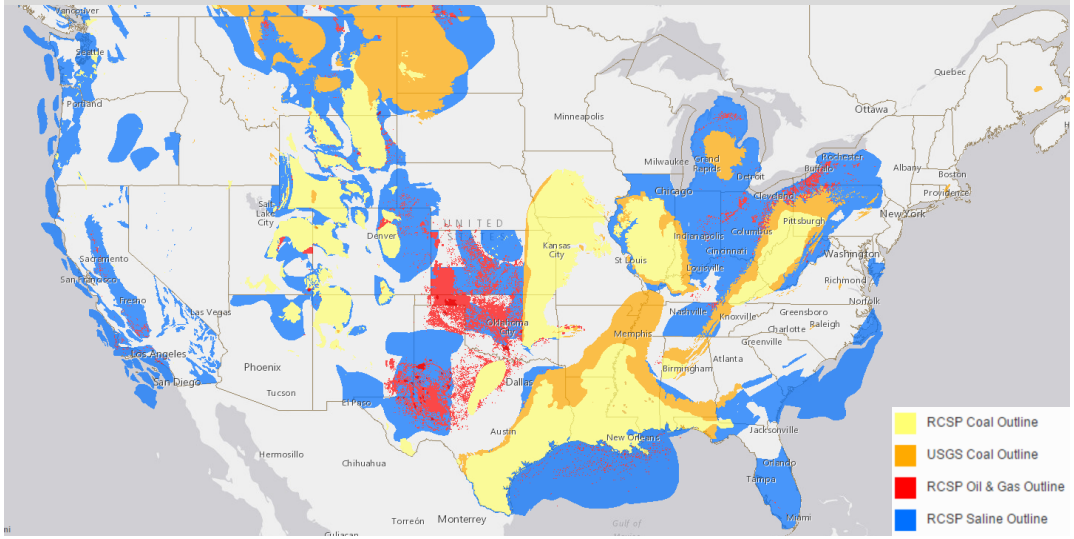


Image obtained from:
http://www.natcarbviewer.com/

EPA Regulations Increase NET Power's Competitive Advantage

- **NET Power can help customers comply with the EPA's new Clean Power Plan**
  - Under mass-based + new source compliment standard, NET Power enables existing assets to be run longer while meeting CPP targets
  - The plan will likely result in the creation of carbon markets in most (if not all) of the US
  - Potential to be included in Clean Energy Incentive Program (final rule under development)
- **New source standards likely to eventually move towards NET Power**
  - New EPA standards for new power plants regulate carbon emissions to the lowest limit that can be achieved while remaining economically competitive
  - As efficiencies increase and costs come down, standard likely to be tightened
  - NET Power ensures customers are able to meet any future CO_2 standard
- **Elimination of NOx emissions enables siting in Ozone Non-attainment Zones without requiring offsets**

NET Power

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