GLOBAL CCS INSTITUTE

INTERNATIONAL ACTIVITIES ON NGCC-CCS

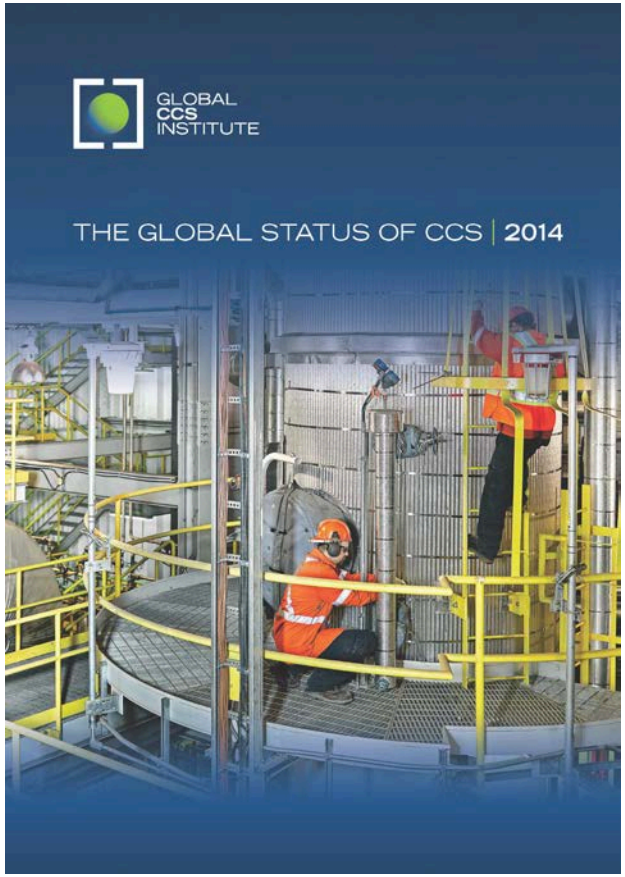
16 April 2015

The Global CCS Institute

- We are an international membership organization.
- Headquarters in Melbourne.
- Regional offices serving the Americas, Europe-Africa-Middle East, and Asia Pacific.
- Our diverse international membership consists of:
  - governments,
  - global corporations,
  - small companies,
  - research bodies, and
  - non-government organisations.
- Specialist expertise covers the CCS/CCUS value chain.

The Global Status of CCS: 2014

The *Global Status of CCS: 2014* – Key Institute publication



This year's report:

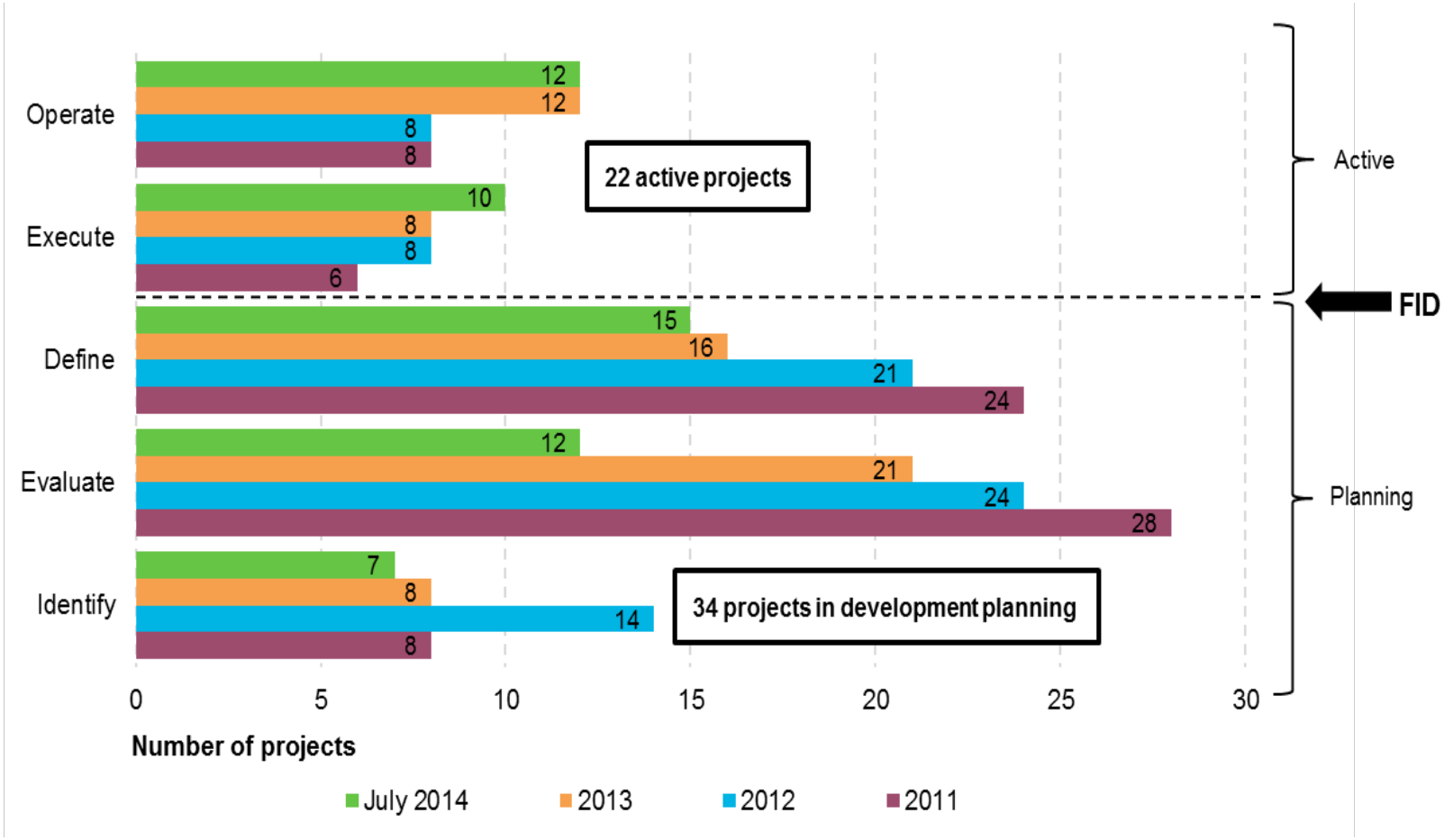
- Provides a comprehensive overview of global and regional developments in large-scale CCS projects, in CCS technologies and in the policy, legal and regulatory environment.
- Introduces and links to project descriptions for around 40 lesser scale 'notable' CCS projects.
- Makes recommendations for decision makers.
- The full report is available online, including supporting resources and data http://www.globalccsinstitute.com/

Large-scale CCUS projects in 2014

	Early planning	Advanced planning	Construction	Operation	Total
Americas	5	6	6	9	26
China	8	4	-	-	12
Europe/UK	2	4	-	2	8
Gulf Cooperation Council	-	-	2	-	2
Rest of World	4	-	1	2	7
Total	19	14	9	13	55

North America, China and UK (with 5) have the most projects

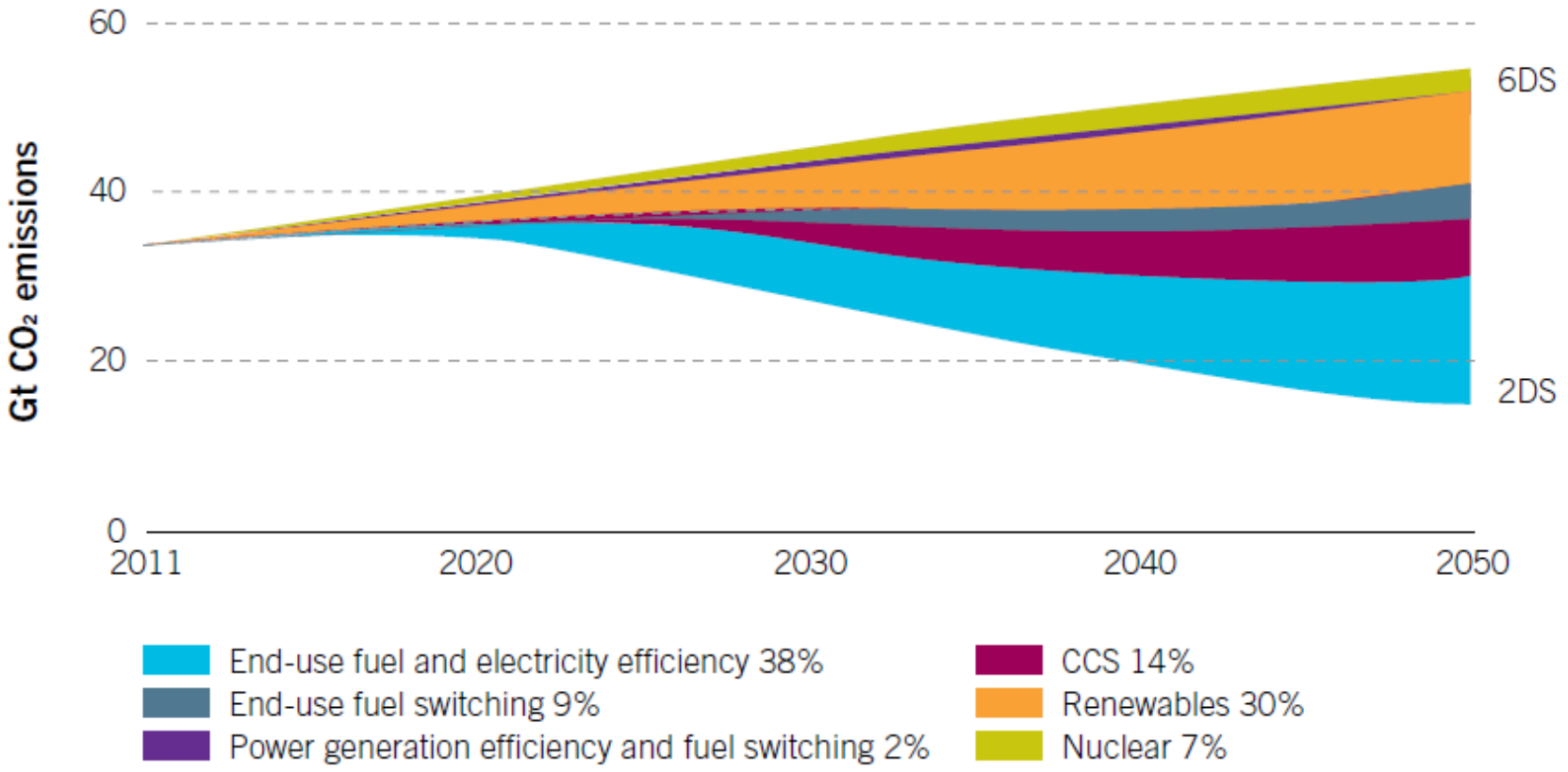
Large-scale CCS projects by project lifecycle and year



22 projects in operation or under construction – 8 more than in 2011

Meeting deep emissions cuts requires ccs on natural gas power

Figure 2.4 **CCS contributes 14% of cumulative CO_2 emission reductions through 2050 in a 2°C world compared to 'business as usual'**



Source: IEA, 2014. *Energy Technology Perspectives 2014.*

Natural gas power projects

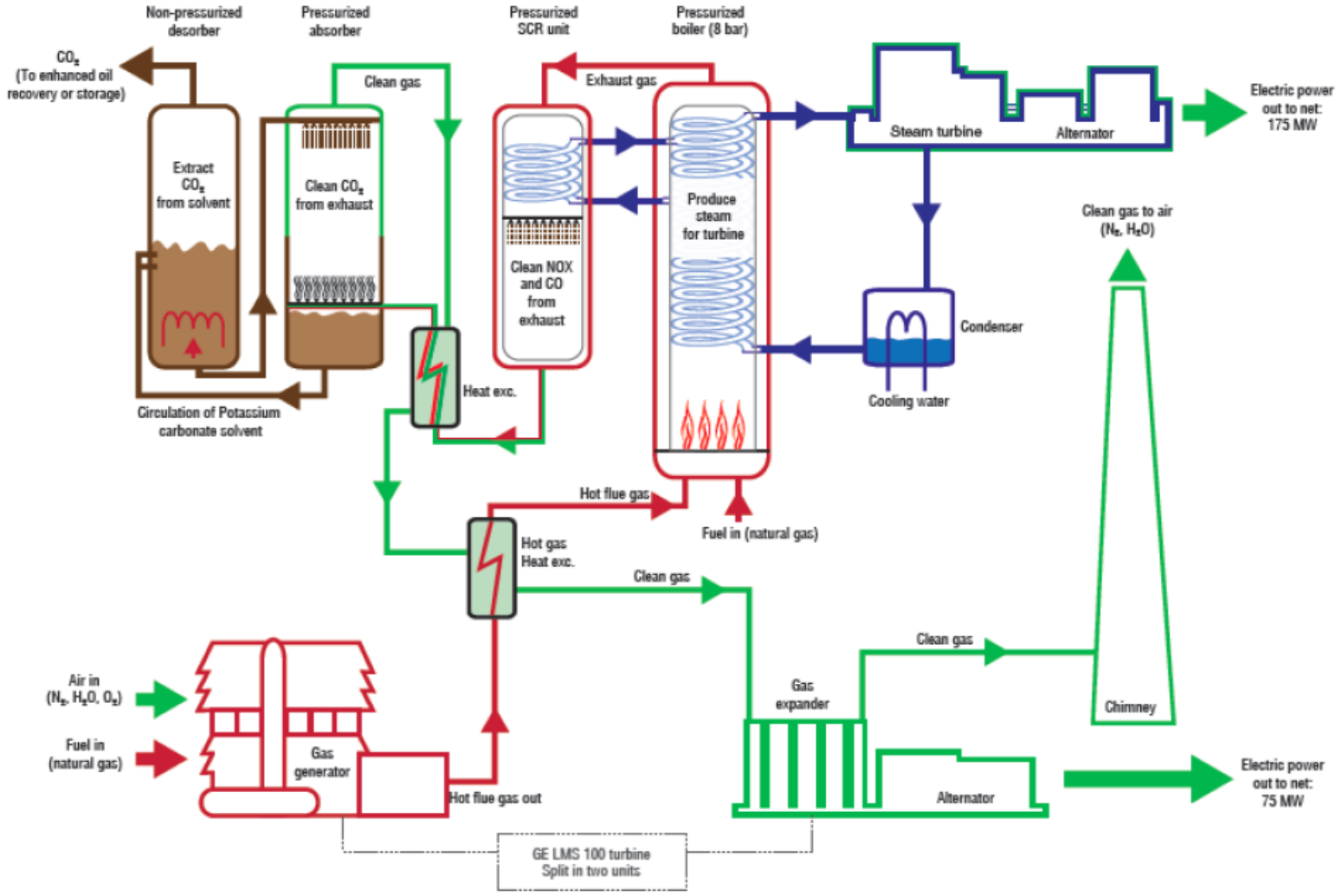
- Sargas Texas Point Comfort Project—define stage, 0.8MTPA, power sector, post combustion, natural gas feedstock, United States
- NET Power Oxy-combustion Pilot, Texas
- Peterhead CCS Project—define stage, 1.0 MTPA, power sector, post-combustion, natural gas feedstock, Scotland
- TCM, Norway
- Taweelah. United Arab Emirates
- Gaojing CHP Plant Pilot Project, China

Sargas, Port of Port Lavaca-Point Comfort, Texas

- Sargas Texas LLC (a subsidiary of Sargas AS, Norway)
- 500 MW new-build NGCC,—2 units using Stargate 250® technology
  - gas turbine modified by the manufacturer to accommodate the project;
  - heat recovering steam generator capable of high pressure operation;
  - steam turbine;
  - Catacarb hot potassium carbonate post-combustion capture system.
- Storage via EOR in South Texas oil fields (location not yet finalised)
- 800,000 tonnes per year
- Pipeline 80 km / 50 miles
- FEED complete 2014
- Operational 2017

Stargate technology

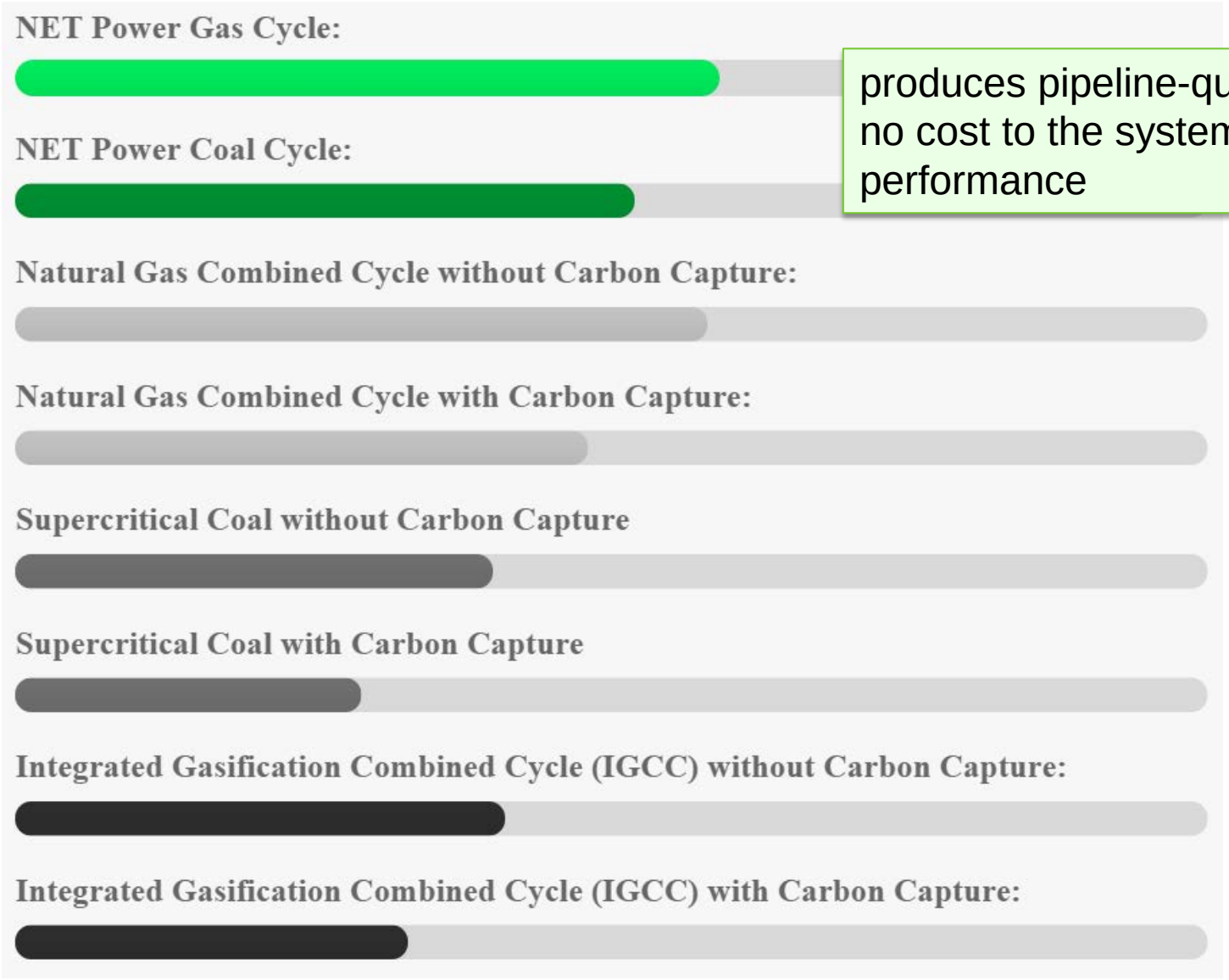
Stargate 250: Overview for 250MW Natural Gas CCGT (1 x 1) with CO_2 Capture



NET Power System, Texas

- NET Power LLC, Durham, NC --Project Partners: Exelon, CB&I, Toshiba and 8 Rivers Capital
- Pressurized Natural Gas Oxy-combustion - resulting exhaust stream consists of high-pressure CO_2 and water
- Supercritical CO_2 Power Cycle – high efficiency, minimizes heat losses compared to traditional steam cycle
- Low Water Use
- Pressurized Operation Reduces Equipment Size
- 50 MWth (25MWe) pilot facility to provide data for scale up
  - Commissioning 2016
  - Operation 2017
- 250 MWe facility to follow pilot operations
  - Initiate construction 2018 – 2019
  - Operational early 2020s

NET Power Efficiency Comparisons



produces pipeline-quality CO_2 at no cost to the system's performance

https://netpower.com/technology/

Peterhead project

- Scottish and Southern Energy (SSE) and Shell
- 385 MW NGCC (1 Mt/yr CO2) (one of three at existing power station)
- Post-combustion retrofit
- 102 km pipeline to offshore depleted Goldeneye gas reservoirs at a depth of 2km
- FEED study began October 2014
- Final investment decision (2015) Operational (2019)

http://www.shell.co.uk/energy-and-innovation/the-energy-future/peterhead-ccs-project.html#vanity-aHR0cDovL3d3dy5zaGVsbC5jby51ay9nYnIvZW52aXJvbm1lbnQtc29jaWV0eS9lbnZpcm9ubWVudC10cGtnL3BldGVyaGVhZC1jY3MtcHJvamVjdC5odG1s

European CO_2 Test Centre Mongstad, Norway

- Norwegian Government, Statoil, Sasol and Shell
- Exhaust gases from:
  - Residue Catalytic Cracker (RCC) 74,000-82,000 tCO_2/yr;
  - Natural Gas CHP plant 22,000-25,000 tCO_2/yr
- Two post-combustion capture plants:
  - chilled ammonia technology (Alstom)
  - amine technology (Shell CANSOLV)
- Started operation in May 2012
- Phase 2 was to be a full-scale capture plant at Mongstad refinery—plan for scale up cancelled September 2013.

TAPCO-EMAL Taweelah Project, Abu Dhabi, United Arab Emirates

- Abu Dhabi Future Energy Company (Masdar), Taweelah Asia Power Company (TAPCO) and Emirates Aluminium (EMAL)
- 2 Mt/yr
- Retrofit Post Combustion absorption
- EOR
- Operation (2018)

http://www.ega.ae/

CCS roadmap for China shows growth in natural gas application

Table 3 Roadmap for CCS in China (Jiang and others 2009b)

	2020	2030	2050
CO_2 emission reduction by CCS, Mt			
CO_2 emission reduction by CCS in power generation, million ton	18	421	1,589
CO_2 emission reduction by CCS in coal fired power generation, million ton	17	244	1,202
Number of coal fired power plants units with CCS	10	130	412
CO_2 emission reduction by CCS in natural gas fired power generation, million ton	1	177	387
Number of natural gas fired power plants units with CCS	1	140	310
CO_2 emission reduction by CCS in industry, million ton	8.4	76	273
Number of industry CCS projects	9	52	165

ADB TA-8001 (PRC) People's Republic of China: Study on Carbon Capture and Storage in Natural Gas-Based Power Plants Final Report 2013

Gaojing CHP plant and capture pilot, Beijing, China

- Datang International Power Group (DIPGCL)
- Replace Beijing Gaojing coal-based CHP with 3×350 MWe NGCC units linked to the existing CHP plant.
  - 3 Class-9FB natural gas-fired turbines, with a configuration of two NGCC power plant units operated independently.
    - single gas turbine coupled with a steam cycle;
    - two gas turbines discharging through a Heat Recovery Steam Generator (HRSG)
- Annual 6,240 GWh of electricity and heat for one-tenth of the city's total heating coverage;
- 3.35 MTPa CO_2 without capture
- Both the pilot project and the CHP plant planned to be completed simultaneously..
- Pilot capture facility designed for post-combustion capture of 5 tonnes CO_2 per day of exhaust from waste heat boiler of the single gas turbine

Demonstration objectives of Gaojing pilot plant

- Continuous capture from an NGCC exhaust gas;
- Investigate start up and shut down protocols and part load operation;
- Solvent attrition rates due to oxidation, evaporation and thermal degradation;
- Optimum configuration for minimization of the energy requirement as steam for regeneration of the absorbent;
- Optimum steam conditions for the absorbent regeneration duty;
- Optimum feed temperature for the absorber;
- Optimum internal design features required for the absorber and regenerator columns;
- Optimum operating temperatures of the regenerator column;
- Auxiliary power requirement for capture and compression;
- Requirements for an absorbent reconditioning process;
- Provide data for assessment of the capital and operating costs of a full scale plant.

Performance parameters for pilot plant

Items	Units	Amount	Notes
CO_2 capture rate	kg/hour	208	600 t/a* at 2880 hours/year continuous operation
Absorption efficiency	%	≥80% 85%	Guaranteed minimum CO_2 capture design point
Sorbent concentration **A) MEA system** **B) Ionic liquid**	%	 18-22 20-40	Two alternative CO_2 capture chemistries are proposed for investigation and comparison
Absorber operating temperature	℃	40-50	
Regenerator operating temperature	℃	105~115	
Recirculating flow of sorbent solution	t/h	5~6	
LP steam demand **A) MEA system** **B) Ionic liquid**	t/kg CO_2	 2.75 1.75	Saturated steam** conditions:- 150°C (< 0.475 MPa) 130°C (< 0.27 MPa)
Electricity for CO_2 capture plant	kWh/tCO_2	200	For pumps and fans***
Electricity for CO_2 compression	kWh/tCO_2	274	To prepare CO_2 as a supercritical fluid for dispatch to storage
Demineralized water	kg/tCO_2	48	For absorbent solution make up and direct contact gas washing
Cooling water	t/ tCO_2	234	32~40°C****
Attrition rate **A) MEA** **B) Ionic liquid**	kg/tCO_2	2.3 0.15-0.25	Loss of sorbent material as vapour with discharge gas and due to oxidative and thermal degradation

* CO_2 product will be used within the power station for operational purposes
** Saturated steam will be supplied from gland sealing steam system in power station
*** Electricity will be supplied from power station's "own use" supply
**** Cooling water will be drawn from power station's cooling water system

Mitigation cost increases in scenarios with limited availability of technologies

Percentage increase in total discounted mitigation costs (2015-2100) relative to default technology assumptions – median estimate

2100 concentrations (ppm CO_2eq)	no CCS	nuclear phase out	limited solar/wind	limited bioenergy
450	138% 	7% 	6% 	64% 

Symbol legend – fraction of models successful in producing scenarios (numbers indicate 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**

Source: *IPCC Fifth Assessment Synthesis Report, November 2014.*

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Please submit any feedback to: elizabeth.burton@globalccsinstitute.com