資料 1

GLOBAL CCS INSTITUTE

GLOBAL STATUS OF CCS: 2017

Presentation to Japan Central Environment Committee

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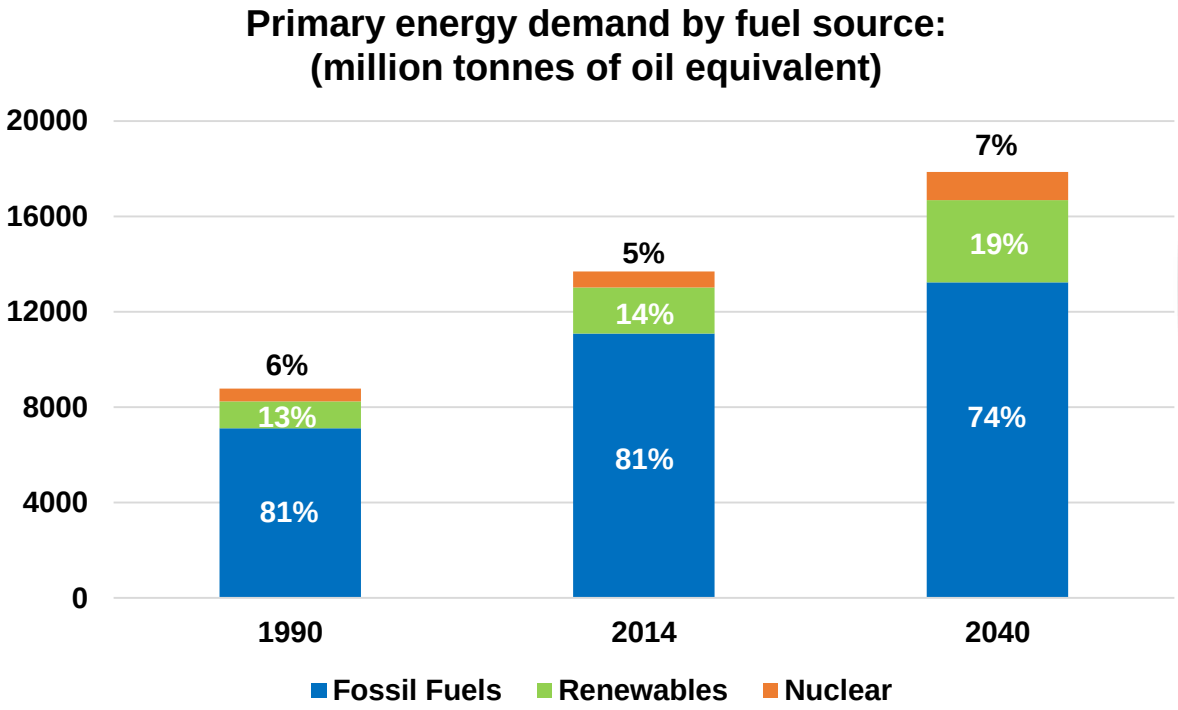
Cover image: Aerial view of Tomakomai CCS Demonstration carbon capture facilities located at Tomakomai City, Hokkaido, Japan. Image provided by JCCS.

Fossil fuel demand growing and reserves robust



Source: *IEA World Energy Outlook*, 2016 (New policies scenario)

Fossil fuel proved reserves:

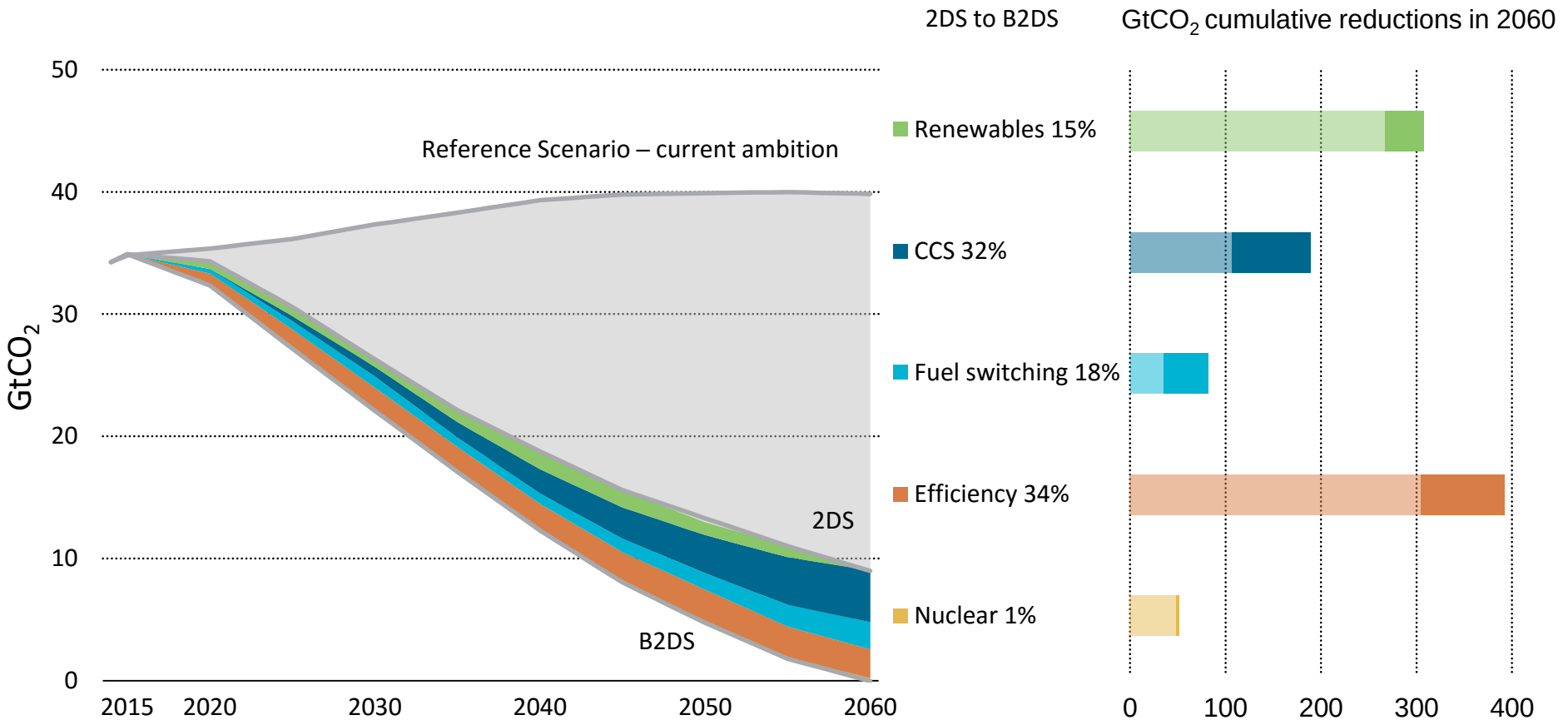
6 trillion barrels of oil equivalent

Reserves to production ratio:

~75 years

Source: *BP Statistical Review of World Energy* 2016

CCS is deployed more widely and more rapidly in moving from 2DS to B2DS



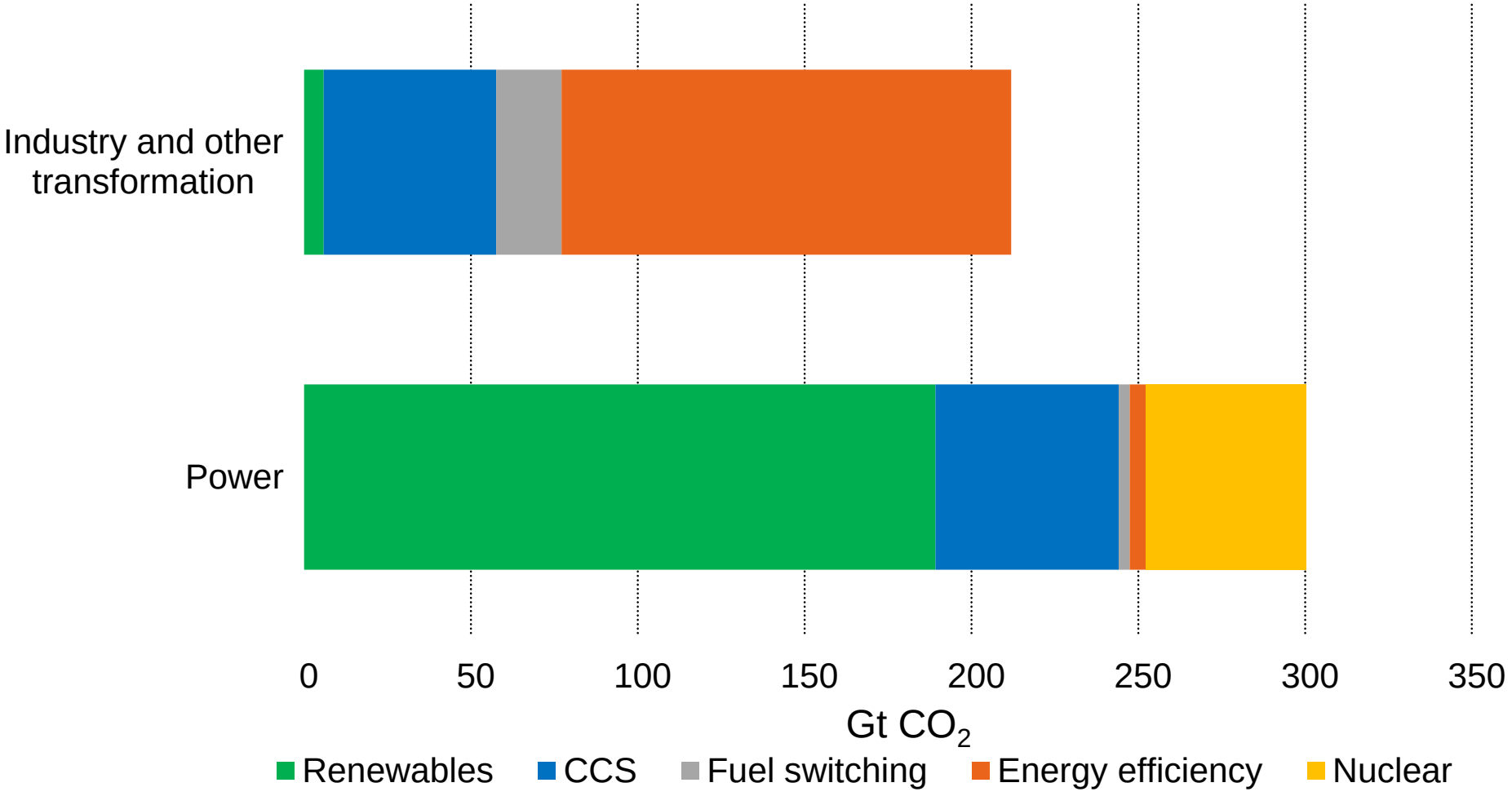
Source: *International Energy Agency (2017), Energy Technology Perspectives 2017, OECD/IEA, Paris*

Note: 2DS refers to a *2°C Scenario;* B2DS refers to a *Beyond 2°C Scenario,* limiting average future temperature increases to 1.75°C

Light areas in the right graph represent cumulative emissions reductions in the 2DS, while dark areas represent additional cumulative emissions reductions needed to achieve the B2DS

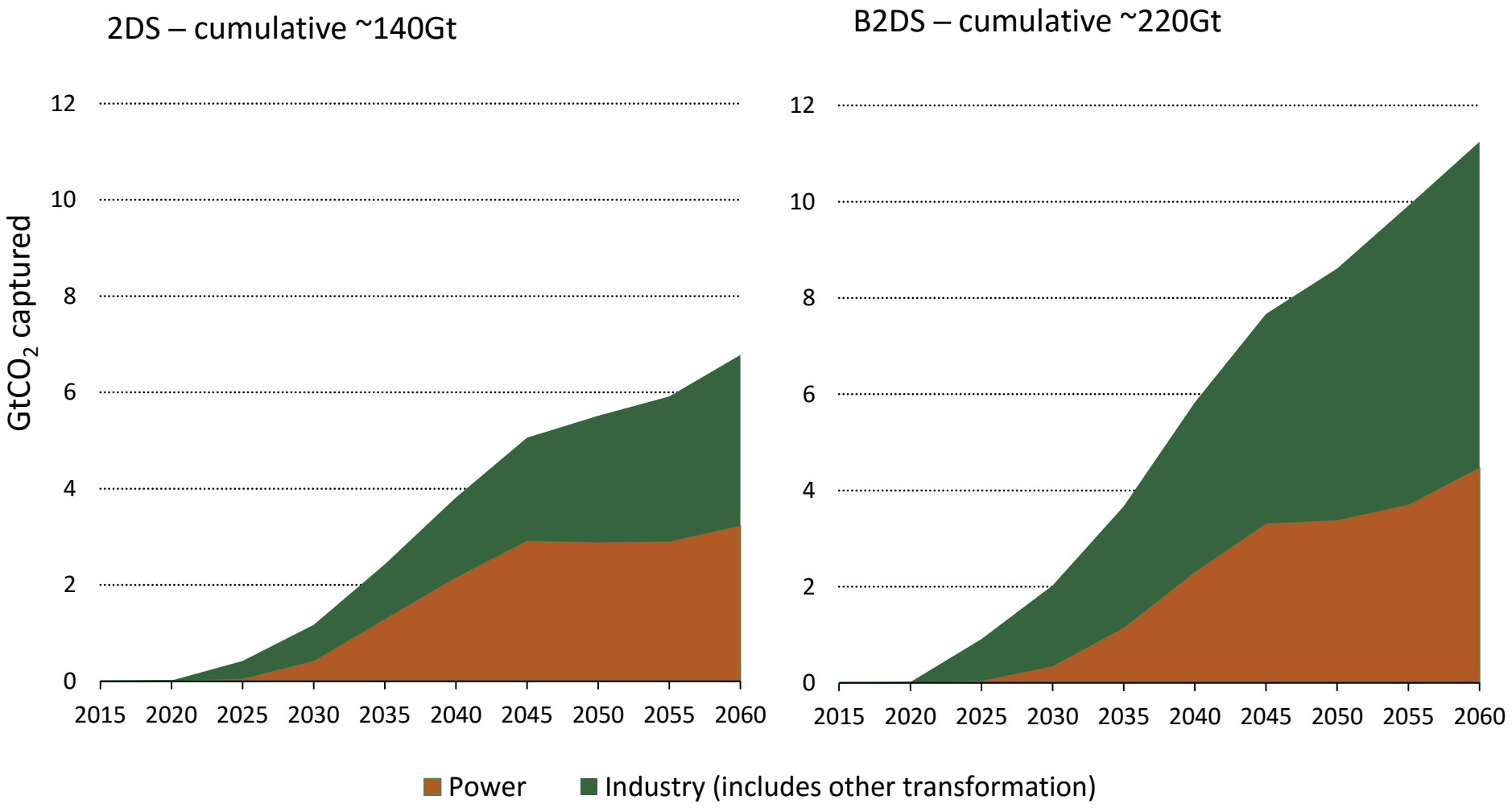
All emissions reductions solutions are necessary

Cumulative CO_2 emissions reductions in industry and power (2015 to 2060, Reference Scenario – current ambition to 2DS)



Source: *International Energy Agency (2017), Energy Technology Perspectives 2017, OECD/IEA, Paris*

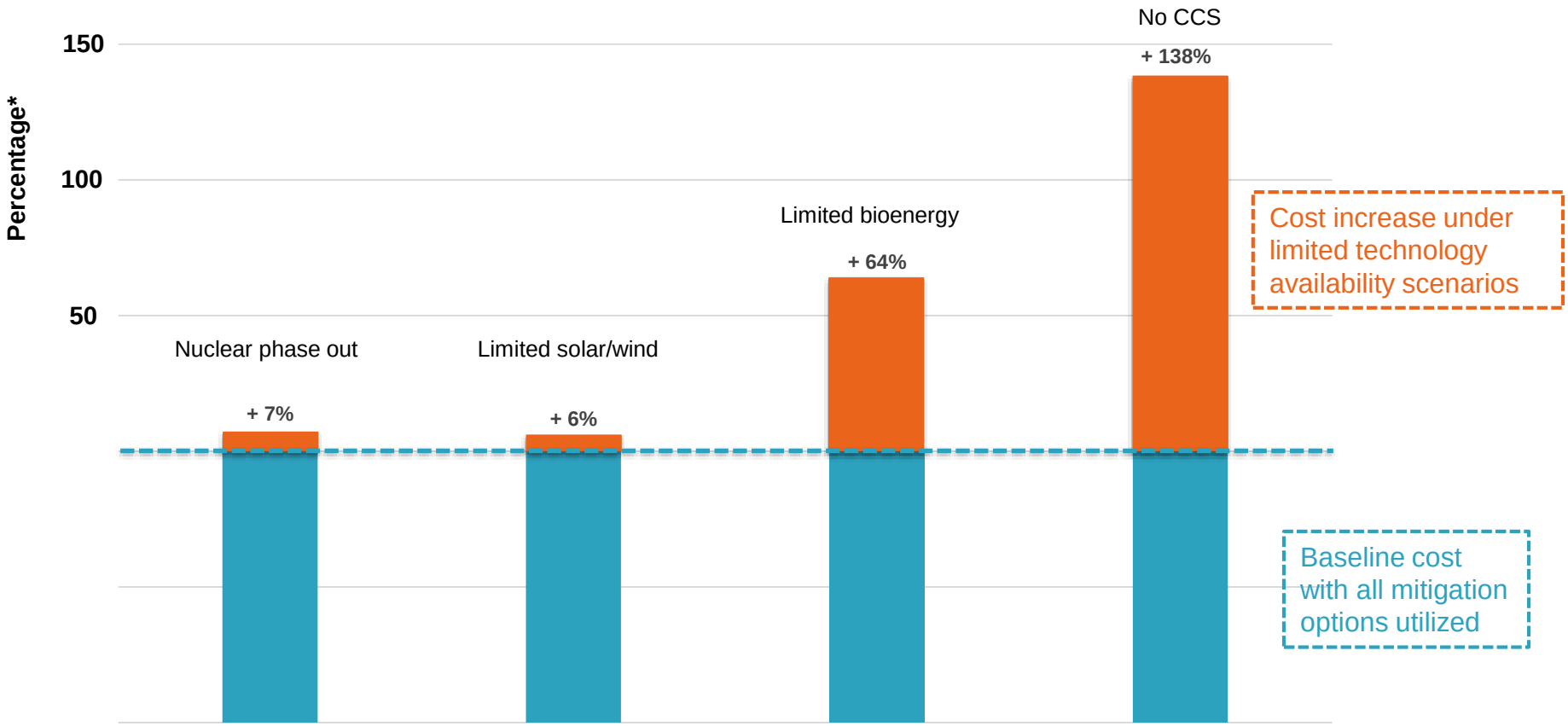
CCS deployment rates – 2DS and B2DS



Source: *International Energy Agency (2017), Energy Technology Perspectives 2017, OECD/IEA, Paris*

Note: B2DS refers to *a Beyond 2°C Scenario,* limiting average future temperature increases to 1.75°C

Mitigation costs more than double in scenarios with limited availability of CCS



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

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

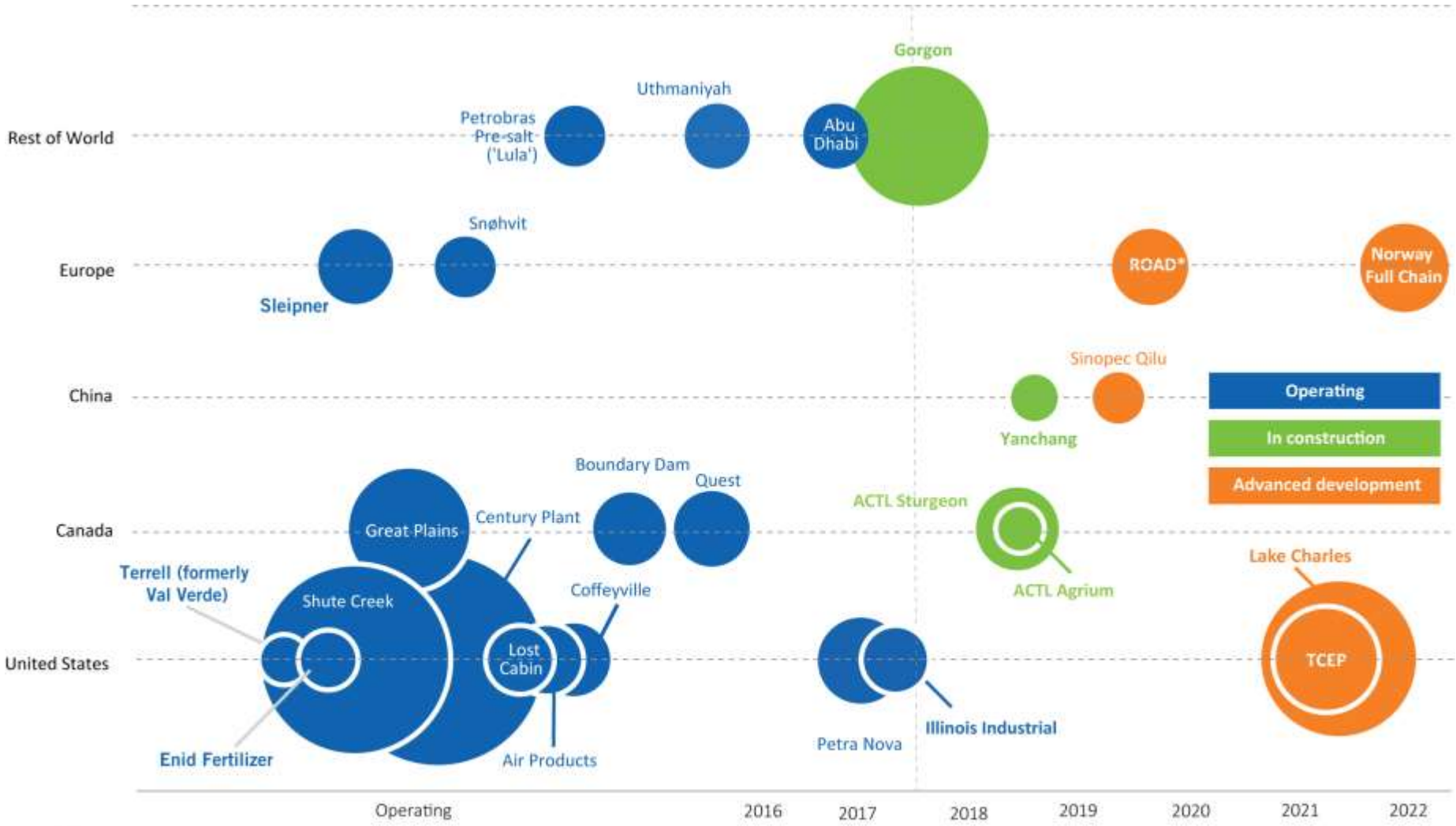
Large-scale CCS facilities by region or country – July 2017

	Early development	Advanced development	Construction	Operating	Total
North America	1	2	2	12	17
China	5	2	1	-	8
Europe	2	2	-	2	6
Gulf Cooperation Council	-	-	-	2	2
Rest of World*	3	1	1	1	6
Total	11	7	4	17	39

** Includes facilities in Australia, Brazil and South Korea.*

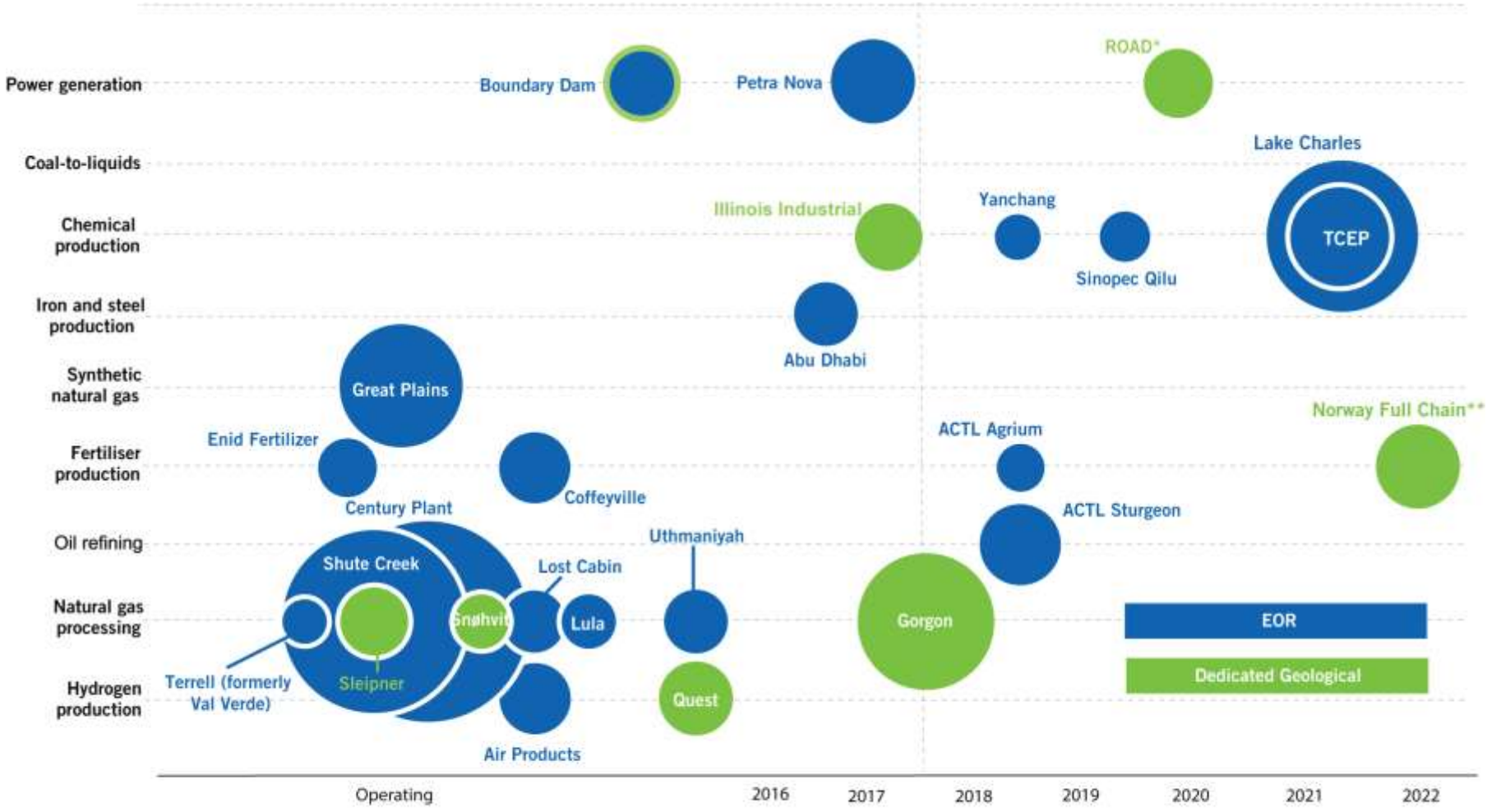
North America dominates – 14 (of 21) facilities in operation or construction, China has most facilities in development, facility pipeline needs replenishment

Actual and expected operation dates up to 2022 for large-scale CCS facilities by region and lifecycle stage



**Uniper and Engie have announced they are withdrawing from ROAD, effective September 2017*

Actual and expected operation dates up to 2022 for large-scale CCS facilities by industry and storage type#



Facilities in the Operating, In construction and Advanced development stages

** Uniper and Engie have announced they are withdrawing from ROAD, effective September 2017*

** * Assessing CCS possibilities from ammonia production, from cement production and from waste-to-energy sources*

Key CCS facility developments globally

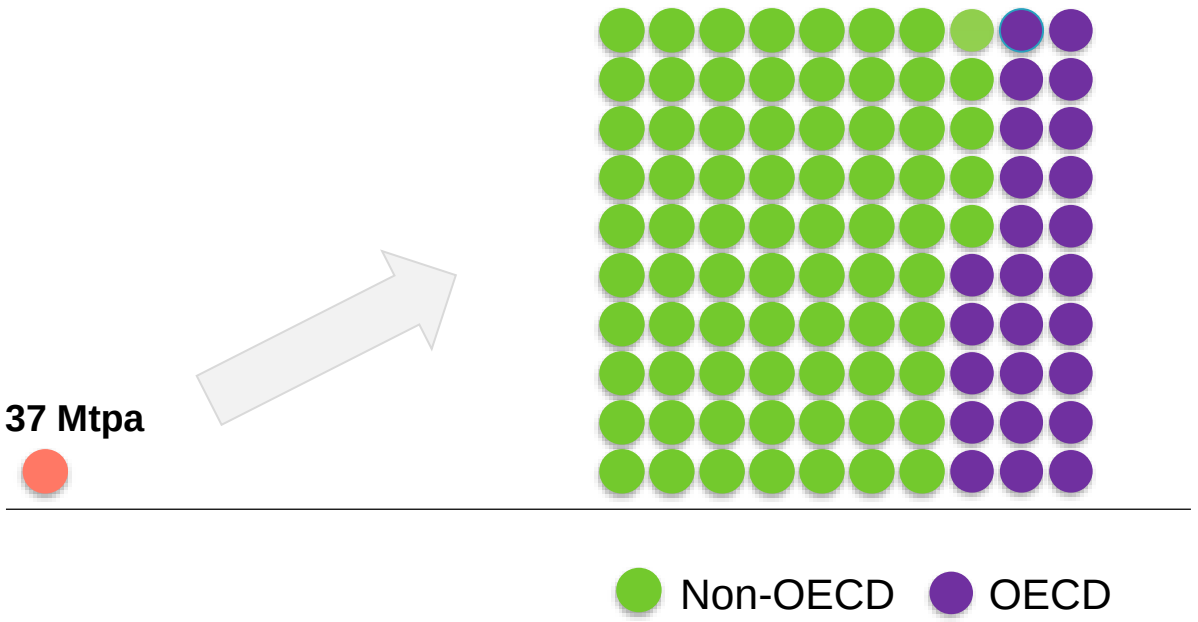
A significant task within one generation

Global Status of CCS July 2017

3,800 Mtpa of CO_2 captured and stored by 2040 (IEA 2DS)**

39 large-scale CCS facilities - combined CO_2 capture capacity of approximately 69 Mtpa*:

- 21 facilities in operation or construction (**~37 Mtpa**)
- 7 facilities in advanced development (~13 Mtpa)
- 11 facilities in earlier stages of development (~19 Mtpa)

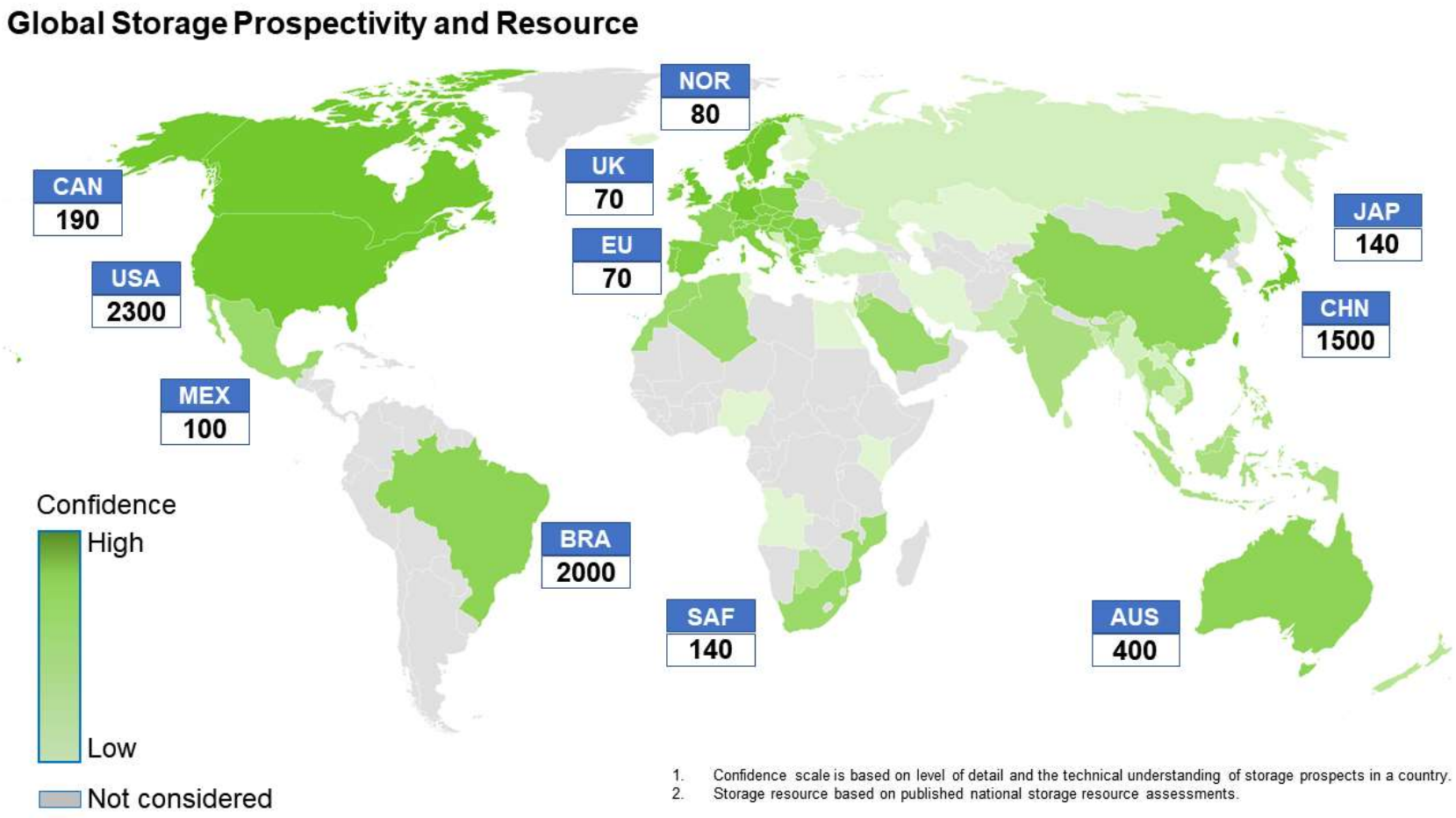


**Mtpa = million tonnes per annum*

****Source**: *International Energy Agency (2017), Energy Technology Perspectives 2017, OECD/IEA, Paris*

Note: 2040 IEA 2DS data includes ~0.6 Mtpa "negative emissions" from BECCS

Storage is available

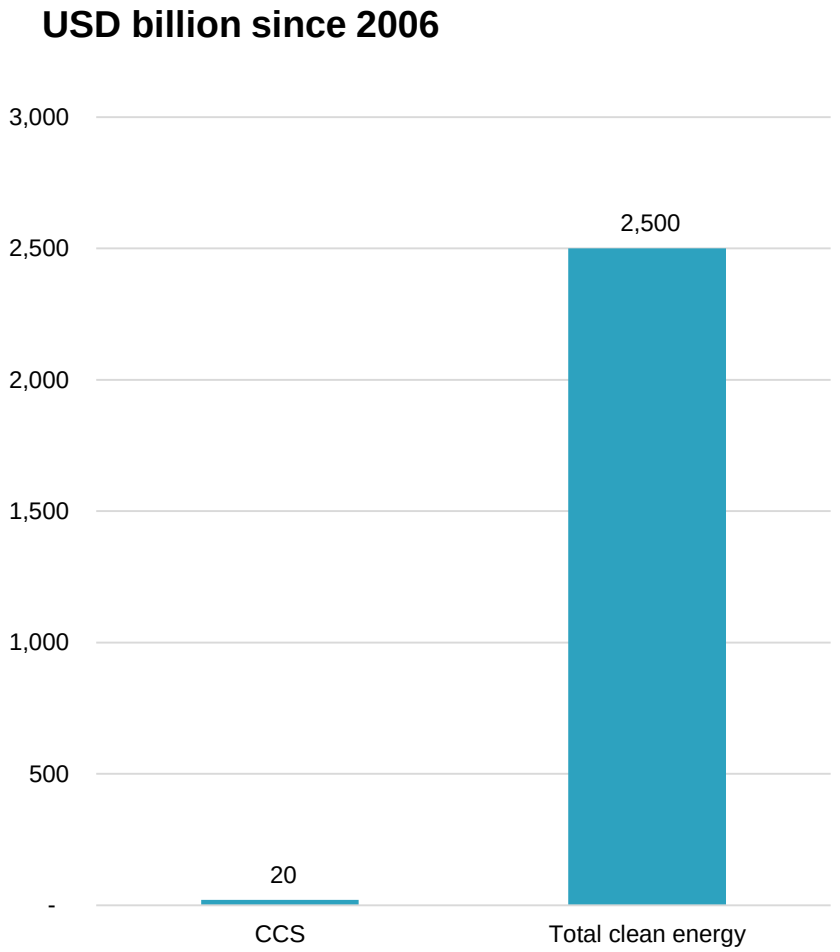


Well structured sites will be not be compromised by seismic activity

- California: world class oil and gas province
  - One of the most seismically active places on earth
  - Secured oil and gas over many millions of years
  - Production of oil and gas has not resulted in earthquakes
- Weyburn: 3 MTPA CO2 injection site
  - Long-running, large-scale CO2 injection site
  - Largest CO2 monitoring programme to-date
  - Seismic monitoring has shown
    - Induced seismicity mostly below detectable levels
    - These levels will not compromise storage
- Japan: example of secure storage after an event
  - Host of CO2 injection and storage site, near Nagaoka
    - 2003-2005: 20-40 tons per day of CO2
    - 2004 major earthquake: 6.8 Richter Scale
    - 20km from CO2 injection point
    - No leaks detected, CO2 contained

Strong policy drives investment – CCS must be afforded 'policy parity'

- Scale of renewables investment is instructive
- CCS has not enjoyed commensurate policy support
- Enhanced oil recovery has provided impetus in North America
- Policy parity is essential
- How do we get CCS onto a similar curve?

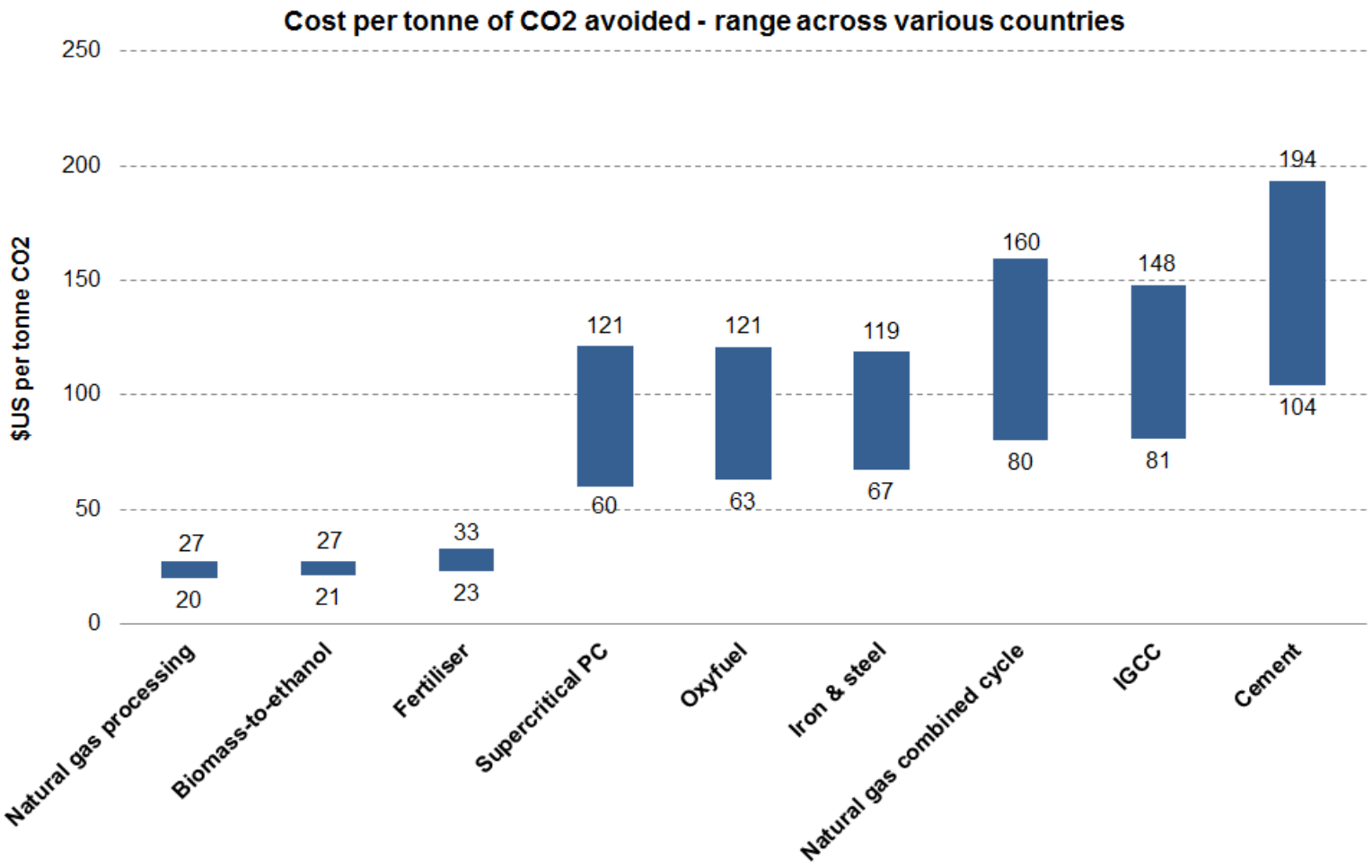


Data source: **IEA 2015 "Tracking Clean Energy Progress". Bloomberg New Energy Finance "Clean Energy Investment By the Numbers – End of Year 2015" fact pack.**

CCS – The key to the new energy economy

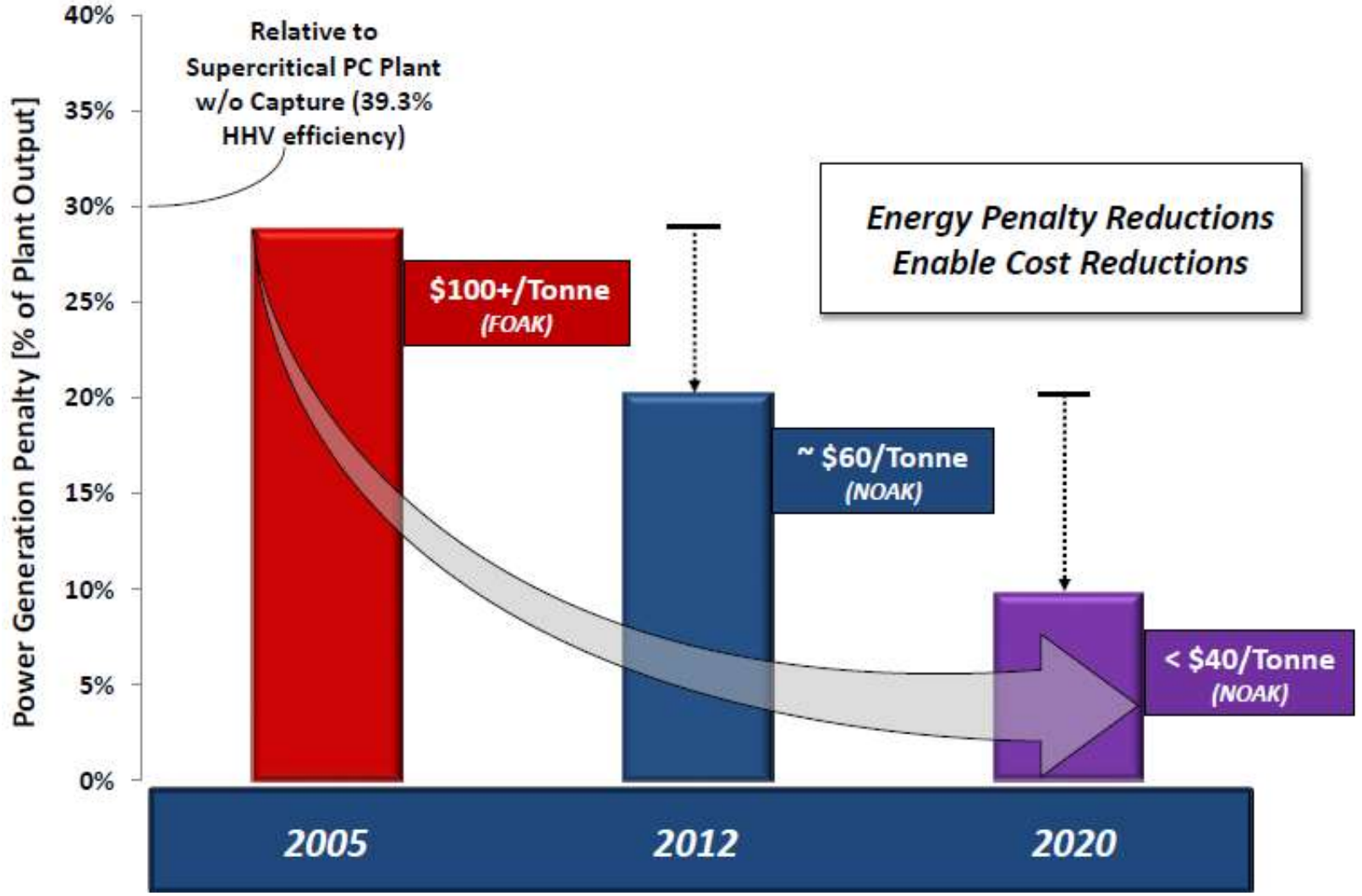
- Time to move on from narrow view of CCS as ***only*** a coal fired generation technology. It's much bigger than this.
- Production of ***clean*** chemicals, plastics, steel, fertilisers, cement, etc requires CCS
- Hydrogen production and use vital addition to energy system; coal gasification and SMR both with CCS key to cost effective delivery
- New opportunities for climate friendly industrial hubs centred on using CCS for clean production of essential products and fuels
- Opportunity to re-fuel generators with hydrogen?
- Policy essential to realise these opportunities

First of a kind costs: Global



Source: Institute estimates

US DOE cost reduction targets and timing



Source: US Department of Energy/ National Energy Technology Laboratory

Cost reduction through *learning by doing*

Boundary Dam (retrofit lignite power generation – 2014)

- LCOE: ~US$130/MWh*
- Expected 30% cost reduction on next unit

Petra Nova (retrofit black coal power generation – 2017)

- LCOE: ~US$117/MWh*
- Expected 20% cost reduction on next unit

Shell QUEST (new hydrogen/ oil refining – 2015):

- Budgeted C$120/tonne, cost ~C$95/tonne
- Expected 20% cost reduction on next attempt

Source: Institute estimates

Cost reduction through *new and innovative technologies*

Carbon Clean Solutions - CDRMax proprietary solvent (coal-fired power)

- 30% opex reduction relative to conventional technologies
- low-corrosion solvent – capex reductions by allowing carbon steel instead of stainless steel.

Net Power - 50MW Allam Cycle pilot plant (gas-fired power)

- CO_2 is the working fluid rather than water/ steam
- generates a high-pressure stream of CO_2 at minimal increased cost

Inventys - VeloxoTherm™ process (all post combustion capture)

- utilizes a capital- and energy-efficient rotary adsorption technology
- solid sorbent-based separation of CO_2 rather than liquid solvents

Calcium looping (cement)

- more efficient alternative to solvent-based capture
- Industrial Technology Research Institute (ITRI) has been employing this process in Taiwan since 2013

Legal and regulatory development

Canada

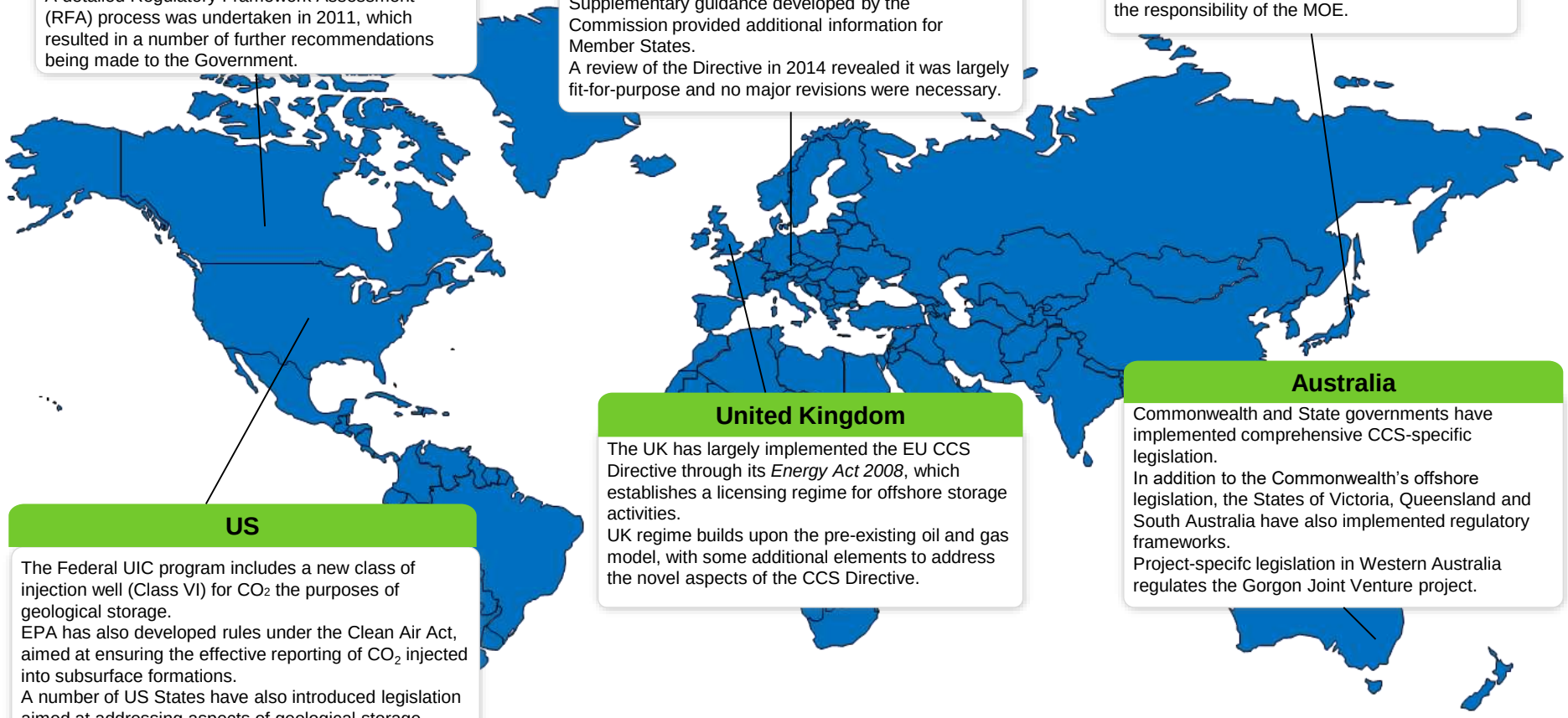
Provincial governments have led the development of CCS-specific legislation in Canada.
Alberta has developed a comprehensive regime, which amends several energy statutes to clarify the regulation of CCS in the Province.
A detailed Regulatory Framework Assessment (RFA) process was undertaken in 2011, which resulted in a number of further recommendations being made to the Government.

European Union

The EU CCS Directive sets out a regulatory regime for the permitting of exploration and storage activities.
The Directive includes operational, closure and post-closure obligations for operators and regulators, as well as detailed provisions regarding long-term liability
Supplementary guidance developed by the Commission provided additional information for Member States.
A review of the Directive in 2014 revealed it was largely fit-for-purpose and no major revisions were necessary.

Japan

The *Marine Pollution Prevention Law* implements in Japan, the CCS-specifc amendments made to the London Protocol.
The regulatory framework, which is primarily aimed at protecting the marine environment, is the responsibility of the MOE.



United Kingdom

The UK has largely implemented the EU CCS Directive through its *Energy Act 2008*, which establishes a licensing regime for offshore storage activities.
UK regime builds upon the pre-existing oil and gas model, with some additional elements to address the novel aspects of the CCS Directive.

Australia

Commonwealth and State governments have implemented comprehensive CCS-specific legislation.
In addition to the Commonwealth's offshore legislation, the States of Victoria, Queensland and South Australia have also implemented regulatory frameworks.
Project-specifc legislation in Western Australia regulates the Gorgon Joint Venture project.

US

The Federal UIC program includes a new class of injection well (Class VI) for CO_2 the purposes of geological storage.
EPA has also developed rules under the Clean Air Act, aimed at ensuring the effective reporting of CO_2 injected into subsurface formations.
A number of US States have also introduced legislation aimed at addressing aspects of geological storage.
North Dakota has applied for 'primacy' to administer the federal injection program within their state.

Long-term liability

- The treatment of liability, throughout the project lifecycle, is an important aspect of the legal and regulatory model.
- Essential to distinguish the types of liability relevant to CCS operations.
- Some early models provide well-characterised examples of how to address the long-term liabilities associated with CCS operations:
  - Development of the transfer model, where liability is transferred from the operator to the state;
  - Emphasis upon site selection and ‘front-loading’ requirements.
- Early views on liability models:
  - Not all liabilities may be managed through legislation;
  - Mechanisms remain untested, largely by virtue of status of projects globally;
  - Models will likely evolve with project-level experience.

CCS Readiness

- The EU Carbon Capture Readiness (Article 33, *EU Directive 2009/31/EC*): over 300MWe new combustion power station
- UK Carbon Capture Readiness Guide[1]:
  - that *sufficient space* is available on or near the site to accommodate carbon capture equipment in the future;
  - the *technical feasibility* of retrofitting their chosen carbon capture technology;
  - that a *suitable area of deep geological storage* offshore exists for the storage of captured CO2 from the proposed combustion station;
  - the *technical feasibility of transporting* the captured CO2 to the proposed storage area; and
  - the *economic feasibility* within the combustion station's lifetime of the full CCS chain, covering retrofitting, transport and storage
- South Africa
  - CCS-ready requirement in environmental approval process for Kusile power plant[2]

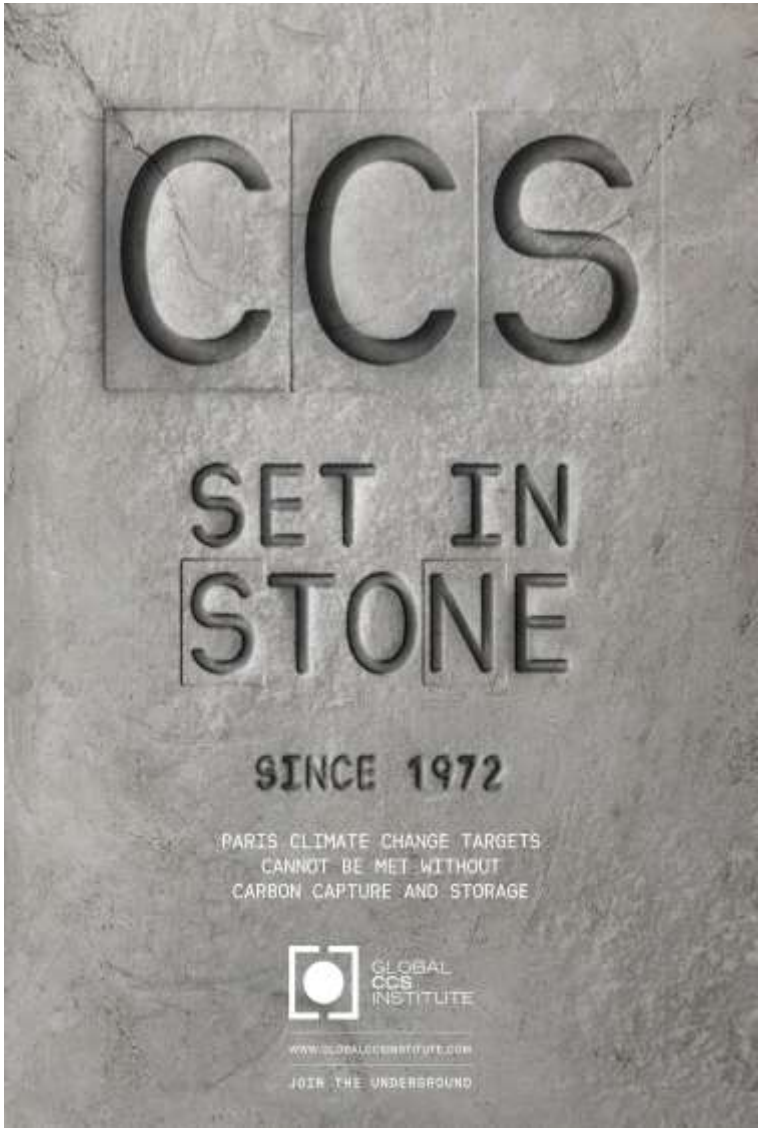
1. Department of Energy & Climate Change 2009, *Carbon Capture Readiness (CCR): A guidance note for Section 36 Electricity Act 1989 consent applications*, November 2009
2. International Energy Agency 2010, *Carbon Capture and Storage Legal and Regulatory Review.*

Lastly…

- CCS is safe, proven and versatile
- Endorsed by internationally verifiable climate change experts
- Vital to our time:

  - energy security under threat
  - cannot afford to play favourites
  - most sensible option for industry, coal and gas-fired power generation
  - keeps people in employment and economies alive

- Requires incentivisation, education and advocacy



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