Setting the Stage for Commercial-Scale Carbon Capture and Storage

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Geological CO_2 Storage Technology Research Association

経済産業省
Ministry of Economy, Trade and Industry

Presentation Outline

- Global emissions and the outlook for energy use to 2040
- Trends in electric generation for Japan
- Developments in carbon capture and storage to date
- CCS leadership in Japan
- Advancing CCS commercialization

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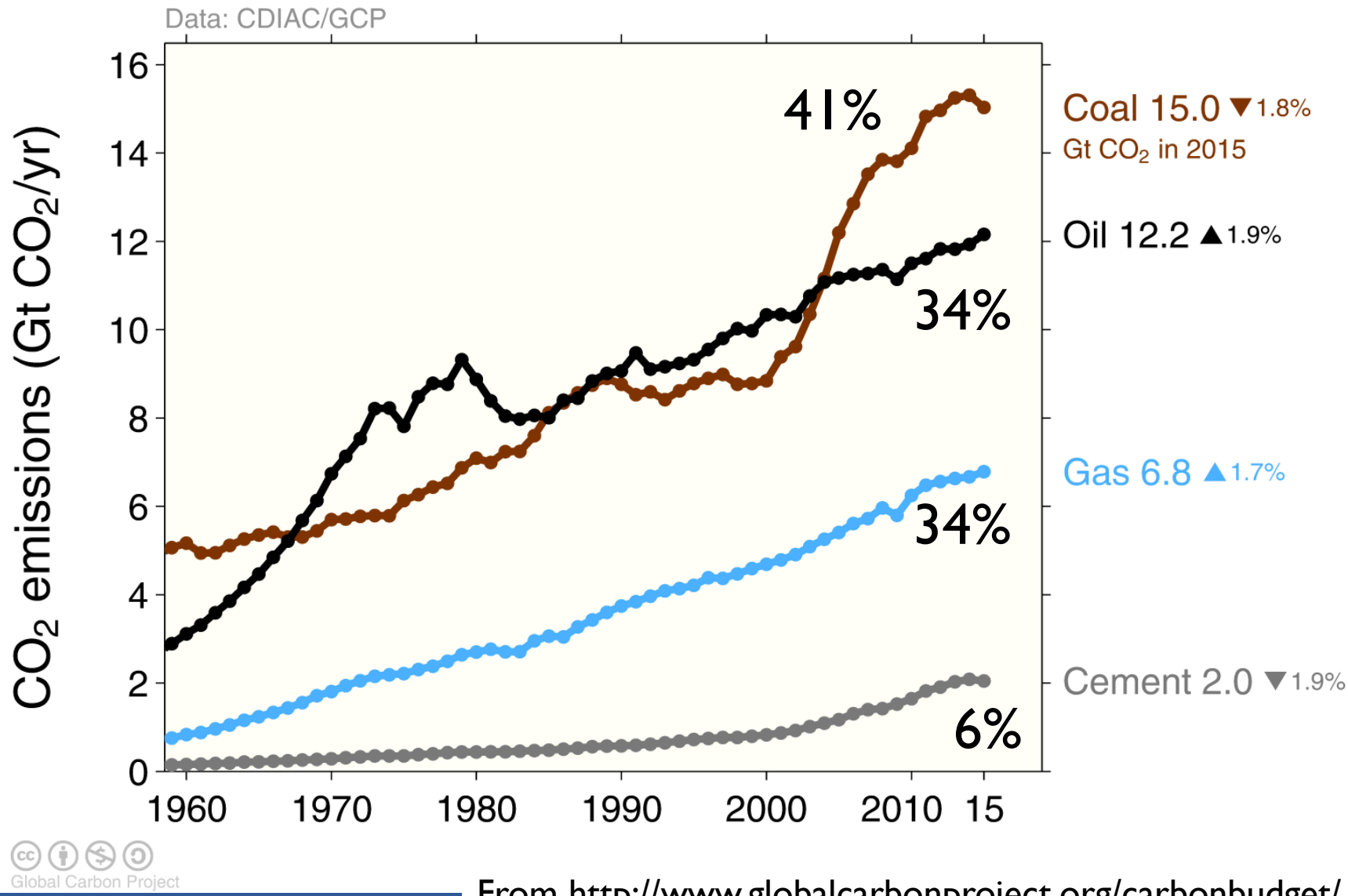
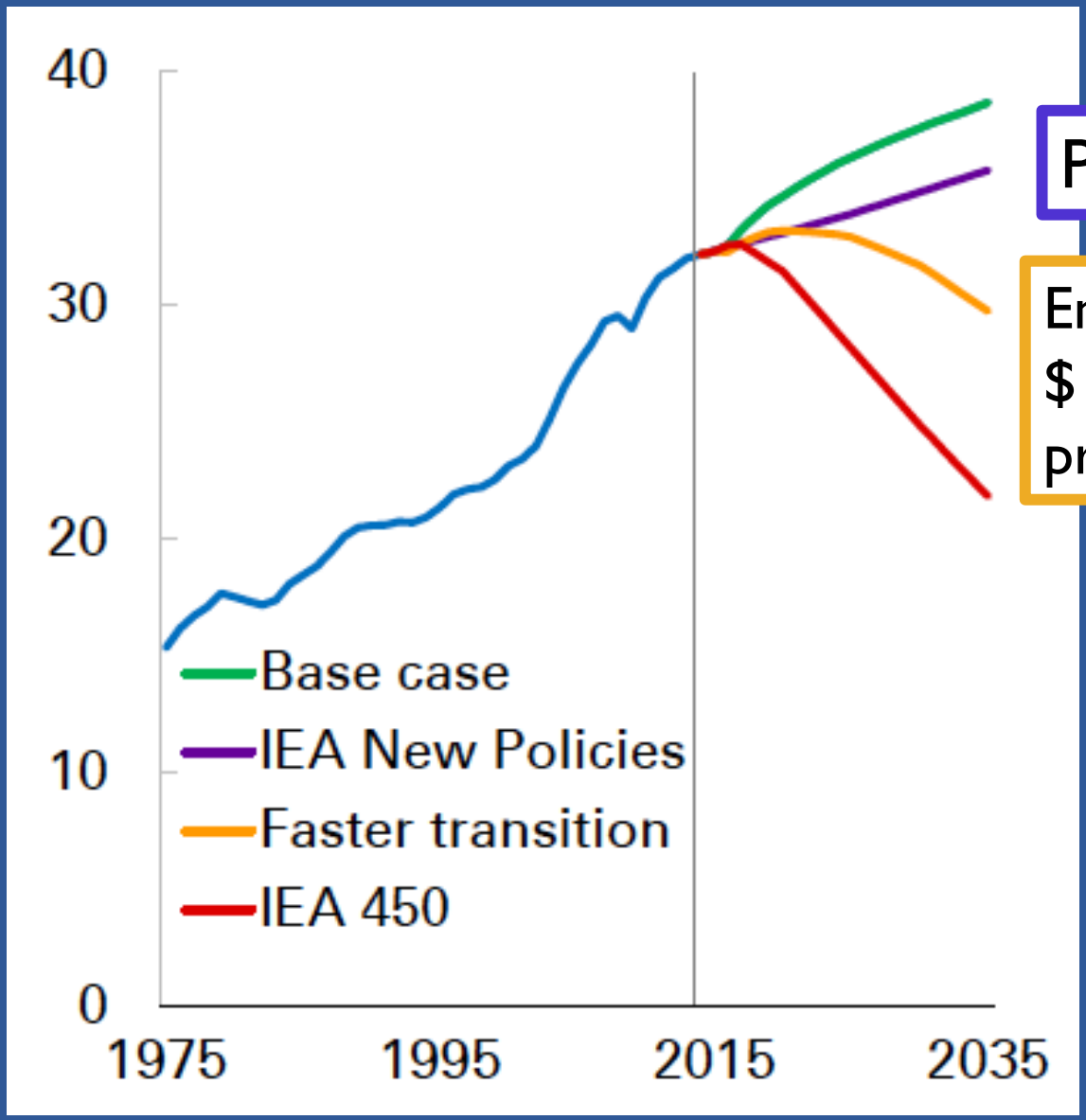
Shares of Global Emissions in 2015



From http://www.globalcarbonproject.org/carbonbudget/16

CO_2 Emissions Outlook to 2035



Paris Agreement

Emissions peak in 2020; $100/t to $50/t carbon price by 2035

From BP 2016 Energy Outlook

International Energy Agency Looks Out to a 2040 Energy World

- 30% rise in global energy demand to 2040
- Changes already seen underway have slowed growth in CO_2 emissions, mainly due to 1.8% decrease in energy intensity
- Yet, 500 million will still have no electricity and 1.8 billion will still rely on biomass for cooking

From IEA

International Energy Agency World Coal Outlook to 2040

- After years of rapid expansion, increases in coal use to be much slower (0.2%/year), with reductions in China, the US, and Europe
- Coal use will still increase by 214 million tonnes oil equivalent (Mtoe) in 2040
- Yet, even with Paris Agreement world is not on a 2°C global warming pathway
- Future of coal seen as tied to carbon capture and storage

From IEA

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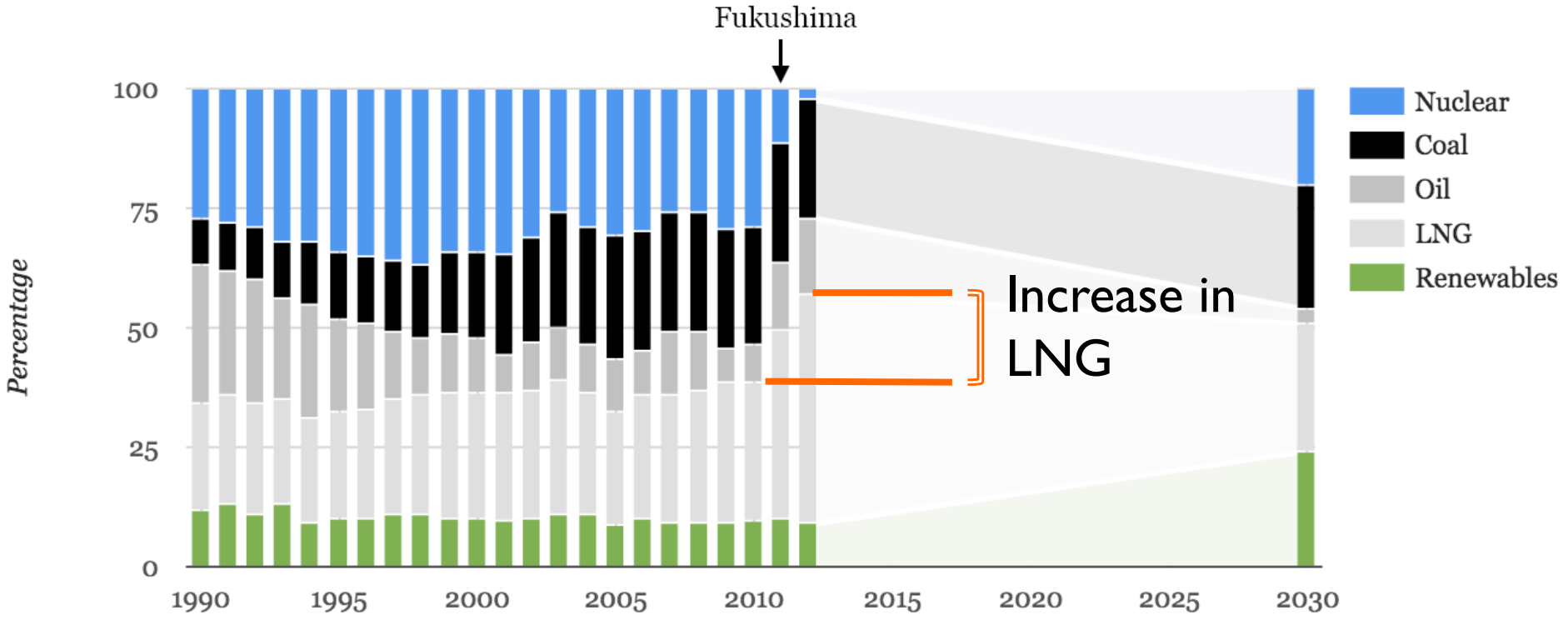
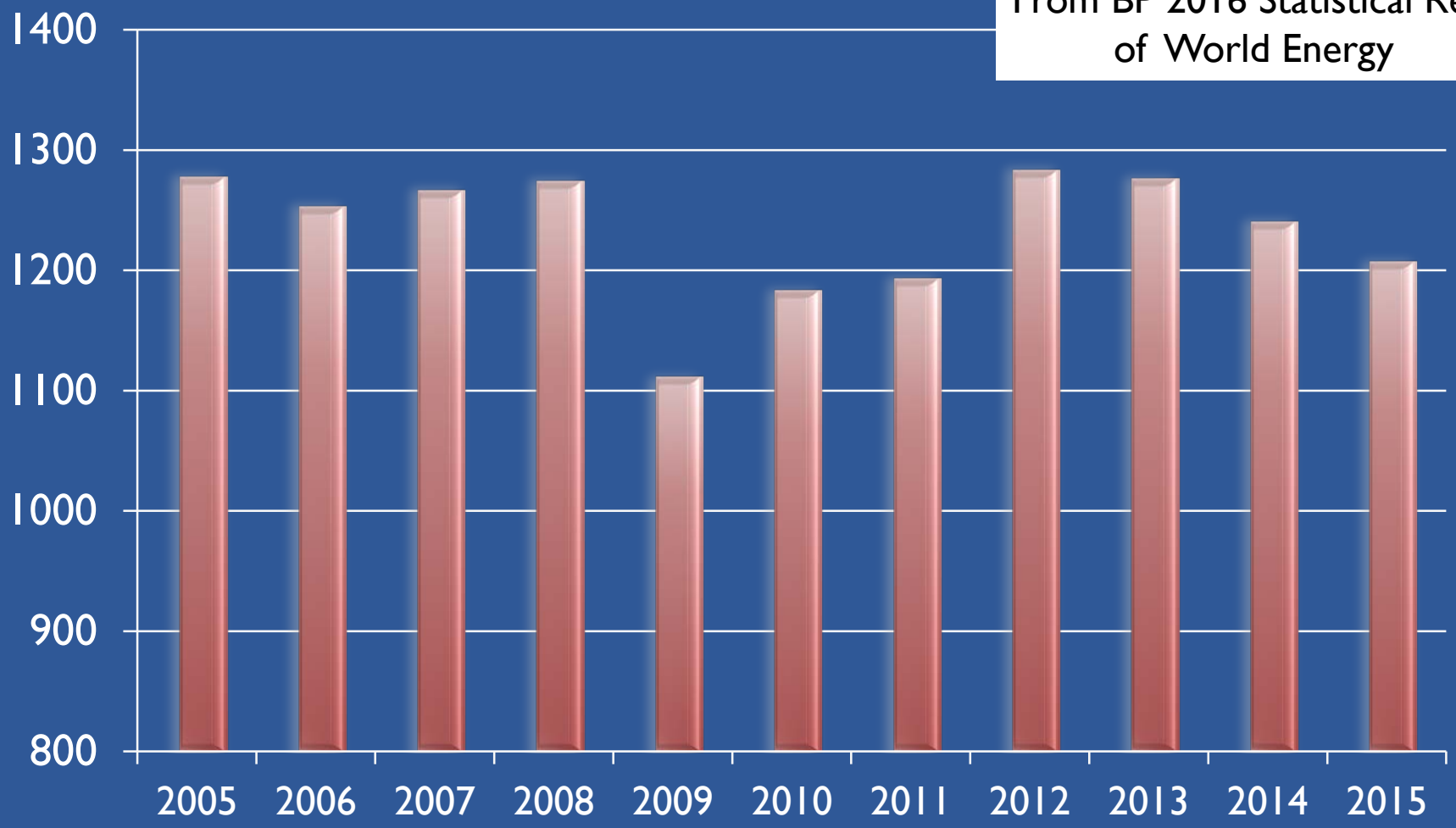
Increase in LNG Use in Japan Following Nuclear Plant Shutdowns

From carbonbrief.org



Japan's CO_2 Emissions
(million metric tons per calendar year)

From BP 2016 Statistical Review of World Energy



Japan's *Intended Nationally Determined Contribution* under the 2015 Paris Agreement

- Cut emissions by 26% from 2013 levels by 2030
- Reach INDC target of 1.042 billion tonnes by 2030, a reduction of 234 million tonnes CO_2
- Additional reductions in methane and nitrous oxide pledged

Japan Moves to Add Coal-Fired Electric Generation

- 43 new coal plants to be built in next 12 years (*the guardian*, 26 May 2016)
- 3,039 Mw under construction and 19,045 Mw announced, pre-permit, or permitted
- 92 million tonnes/year CO_2 emissions potentially to be added
- Could increase by 39% the CO_2 reduction needed to meet INDC emissions reduction

Benefits and Impacts of Added Coal Generation for Japan

- Makes up for lost nuclear baseload electric generation with reliable, proven coal technology
- Adds diversification to Japan's fuel mix and mitigates the high cost of imported LNG

- Likely increases the importance of carbon capture and storage as one method of achieving Japan's INDC pledge
- Increases the value to Japan of basic and applied research focused on CO_2 emissions reduction

International Energy Agency Comment on Japan's Climate Pledge

"This emissions reduction commitment requires a balancing act between energy security, economic efficiency, environmental protection, and safety."

From Energy Policies of IEA Countries – Japan - 2016

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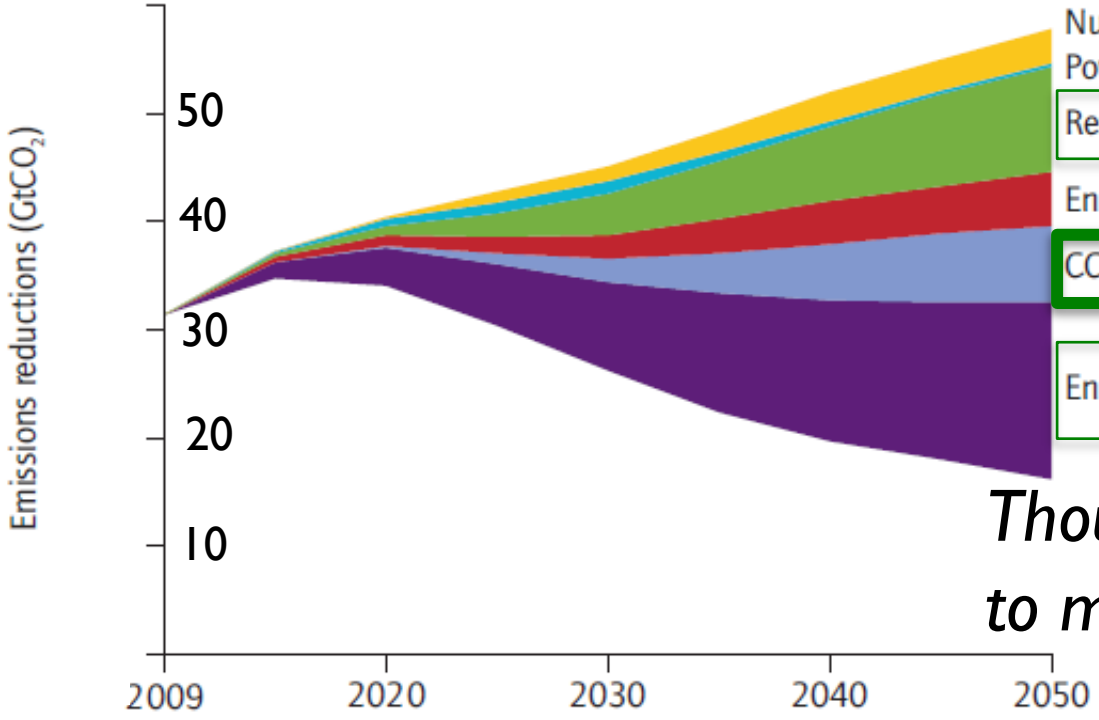
Key Technologies for Reducing Global CO_2 Emissions (billion metric tons)



Nuclear 8% (8%)

Power generation efficiency and fuel switching 3% (1%)

Renewables 21% (23%)

End-use fuel switching 12% (12%)

CCS 14% (17%)

End-use fuel and electricity efficiency 42% (39%)

Thousands of projects needed to meet 450 ppm scenario

Source: IEA Roadmap, 2013

Non-Power Plant Large-Scale Capture and Geological Storage Projects: Commercial Scale

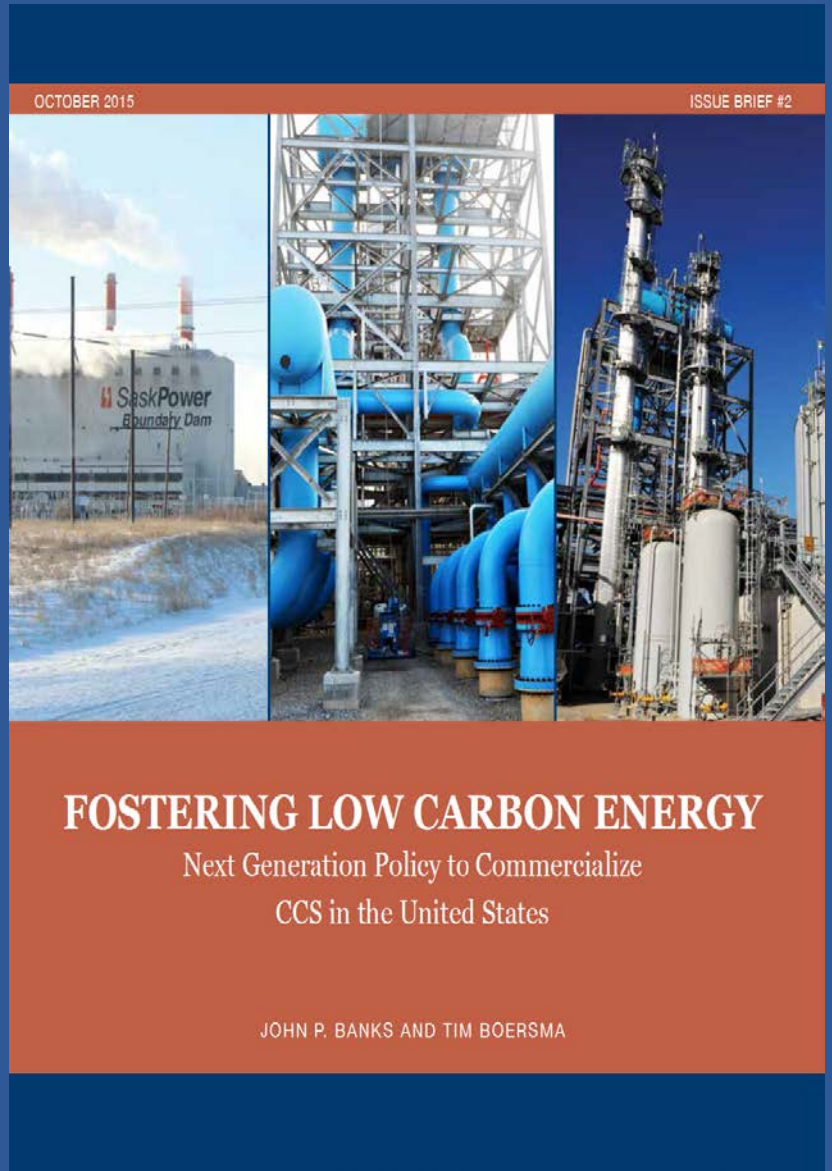
- Sleipner and Snøhvit (Norway)
- Shell Quest (Canada)
- Illinois Industrial CCS (USA) (in 2017)
- Gorgon (Australia) (in 2017)
- In Salah (Algeria) (3.8 mtonnes, ended 2011)

In part from GCCSI 2016 Report

Large-Scale Capture and Supply to Enhanced Oil Recovery (EOR): Commercial Scale

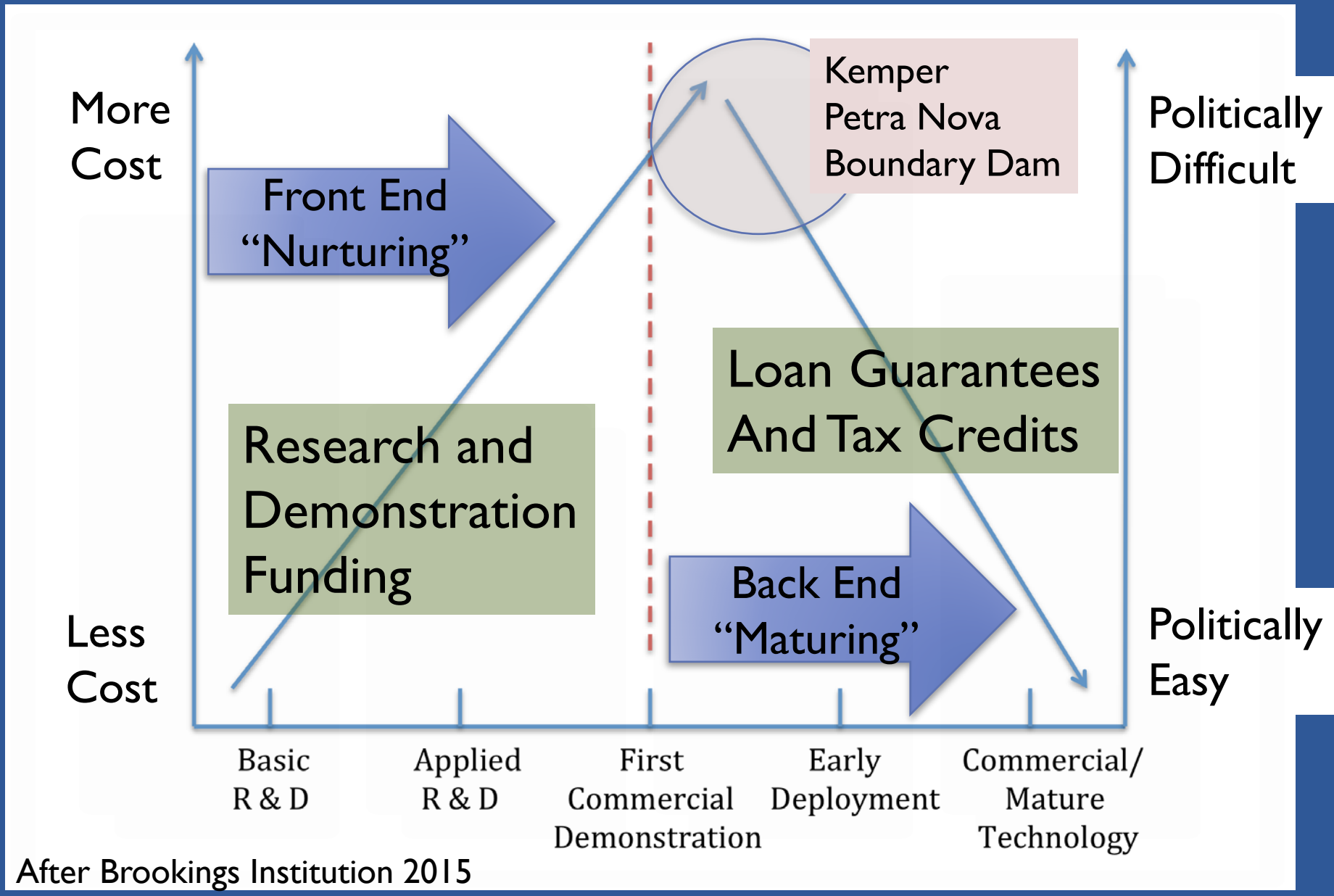
- SaskPower Boundary Dam Project (Canada)
  - about 800,000 tonnes in 2016
- Kemper County Energy (USA) (early 2017)
  - about 3 million tonnes/year at 65% capture
- Petra Nova Project (USA) (early 2017)
  - 1.6 million tonnes/year at 90% capture, 240 Mw
- Alberta Carbon Trunk Line (Canada) (late 2017)
  - Fertilizer plant source, initially 1.8 million tonnes/year

2015 Brookings Institution Study on Policy to Commercialize CCS in US



- CCS necessary to lower overall costs of low-carbon transition
- US support to date in research and demonstration
- In the US, there is a lack of integrated, commercial-scale projects at power plants with only two in development: Kemper and Terra Nova

Policy Pathway to CCS Commercialization



After Brookings Institution 2015

2015 Brookings Institution Study on Policy Pathway to Commercialize CCS in the US

- Government financial support necessary to lower costs of existing technologies and develop new ones
- Off-budget funding mechanism needed for technology development, such as a dedicated trust fund
- Revise financial incentives to improve loan guarantee and tax credit programs
- Create markets for CCS based on a predictable carbon policy

future US climate policy in question

DOE Loan Guarantee for Commercial-Scale Project: Lake Charles Methanol

Announced 21 December 2016

- Produces methanol from petroleum coke
- Up to $2 billion in loan guarantees offered for $3.8 billion project
- 90% CO_2 capture
- 4.2 million tonnes/year CO_2 for EOR in Texas

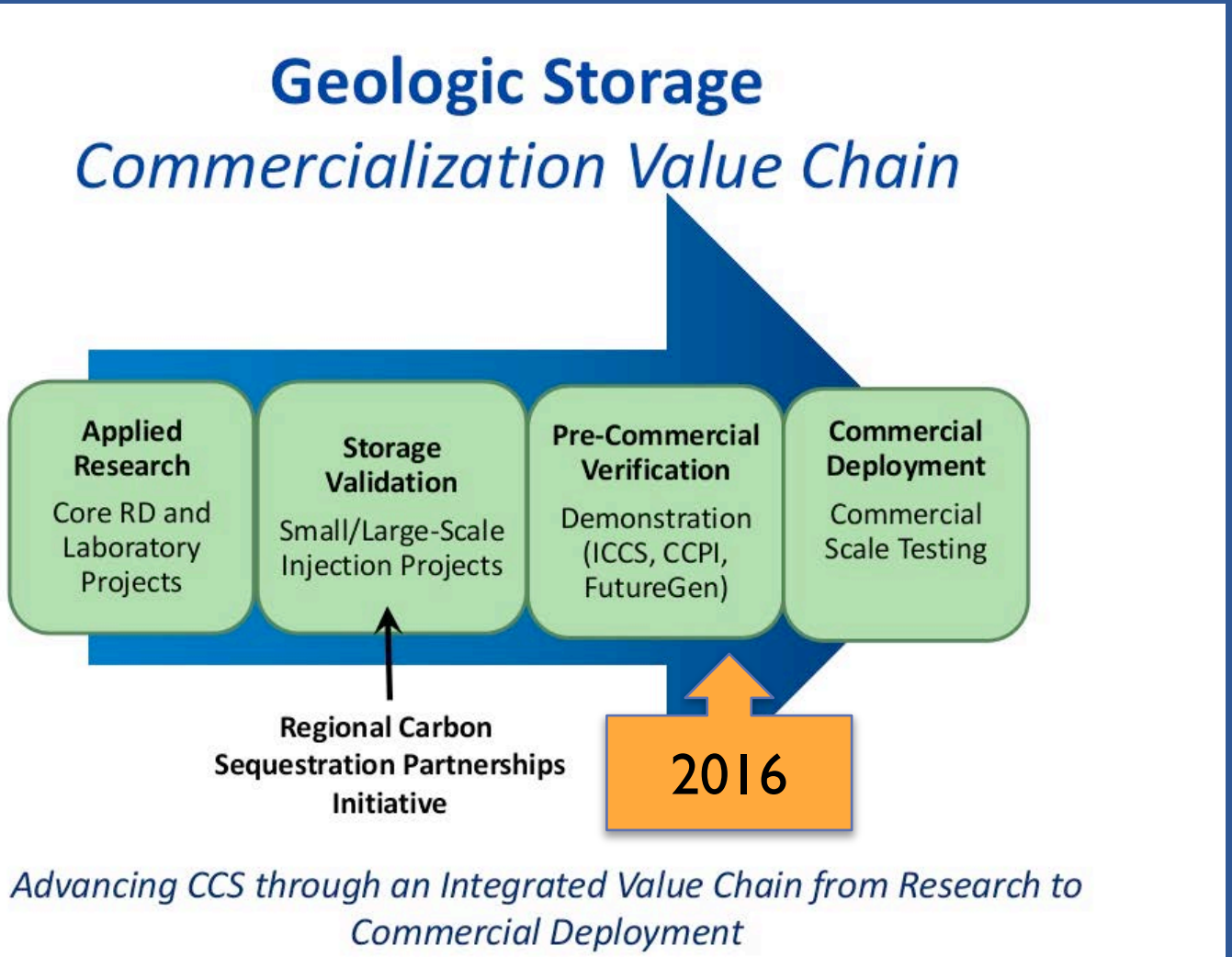
Carbon Capture Commercialization at Lake Charles (Louisiana) Methanol Plant

- *First* US petroleum coke to methanol facility
- Avoids burning petroleum coke, which emits 10 to 30 percent more CO_2 than coal
- *First* in the world methanol production facility to use carbon capture
- *World's largest* industrial manufacturing facility to use carbon capture
- EOR retains CO_2 in depleted oil reservoirs

Technical Pathway to Commercialization

- 1. Capture Costs Reduced: for large dilute sources, both power plant and industry
- 2. Adequate Storage: well understood, high-volume geological (saline reservoir) storage
- 3. System Efficient at Scale: multi-million tonnes/year for tens of years per project
- 4. Verifiably Safe and Effective: acceptable to all stakeholders

US Department of Energy CCS Commercialization Pathway



From US DOE and Hill, G. 2014 SECARB

Carbon Capture and Storage Pilot-Scale US and Japan

- US DOE Regional Carbon Sequestration Partnerships, US:
  - Early tests with truck-delivered CO_2 with injection of 5,000 to 10,000 tonnes
  - Later tests 30,000 to 50,000 tonnes
- Nagaoka Project, Japan: 10,400 tonnes
- Injection into oil reservoirs, coal seams, and saline reservoirs

Carbon Capture and Storage has Moved from Pilot-Scale to Demonstration-Scale

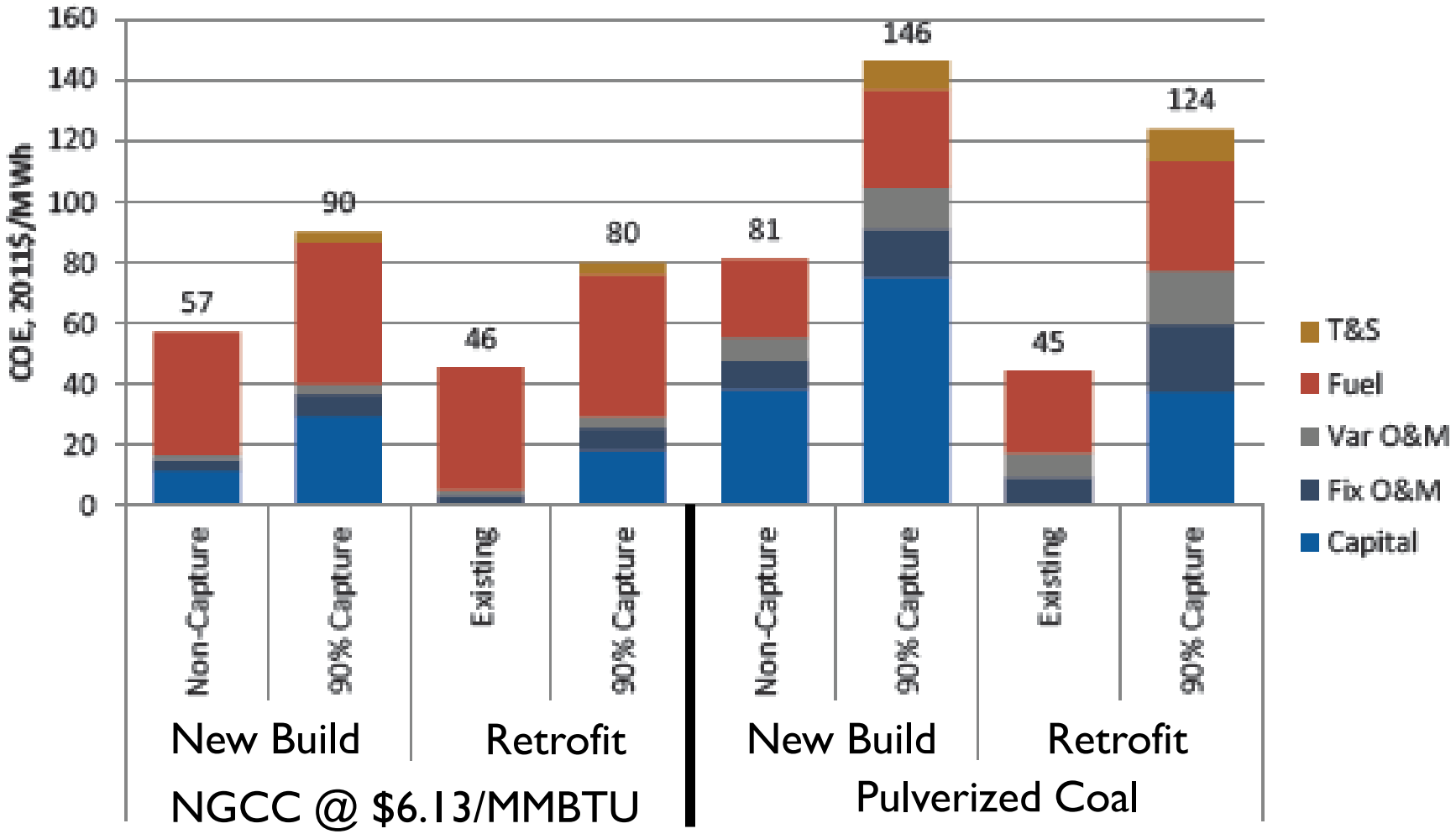
- Illinois Basin – Decatur Project, USA: 1 million tonnes saline reservoir (completed)
- Tomakomai, Hokkaido, Japan: 300,000 tonnes/3 years
- Boundary Dam and Aquistore, Saskatchewan, Canada: EOR and geological storage
- Otway Project, Australia: 80,000 tonnes
- Bell Creek, Montana USA: 1 million tonnes/year, EOR
- Weyburn-Midale, Saskatchewan, Canada: >40 million tonnes stored, EOR

Carbon Capture and Storage is Moving from Demonstration-Scale to Expanded Commercial-Scale

- Kemper County Power Plant: pre-combustion capture for EOR
- Petra Nova Power Plant: post-combustion capture for EOR
- Biofuel (ethanol) Production: Illinois Industrial CCS for saline reservoir storage
- Gorgon Natural Gas Processing: for saline reservoir storage

Cost of Electricity for Reference Natural Gas and Coal Power Plants

Gerdes, K., 2014, US DOE, NETL



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Two Key Centers of Basic and Applied CCS Research In Japan

- RITE (Kyoto) and I^{2}CNER (Fukuoka) are globally important centers of CCS research
- RITE CO_2 Research Storage Group:
  - Analysis of CO_2 behavior in storage layers
  - Analysis of CO_2 migration outside of storage reservoirs
  - Compilation of best practices for commercialization
  - Successful pilot injection test and monitoring at Nagaoka Test Site and support for Tomakomai

Leak Simulation Adds to Understanding of Possible Ocean Impacts

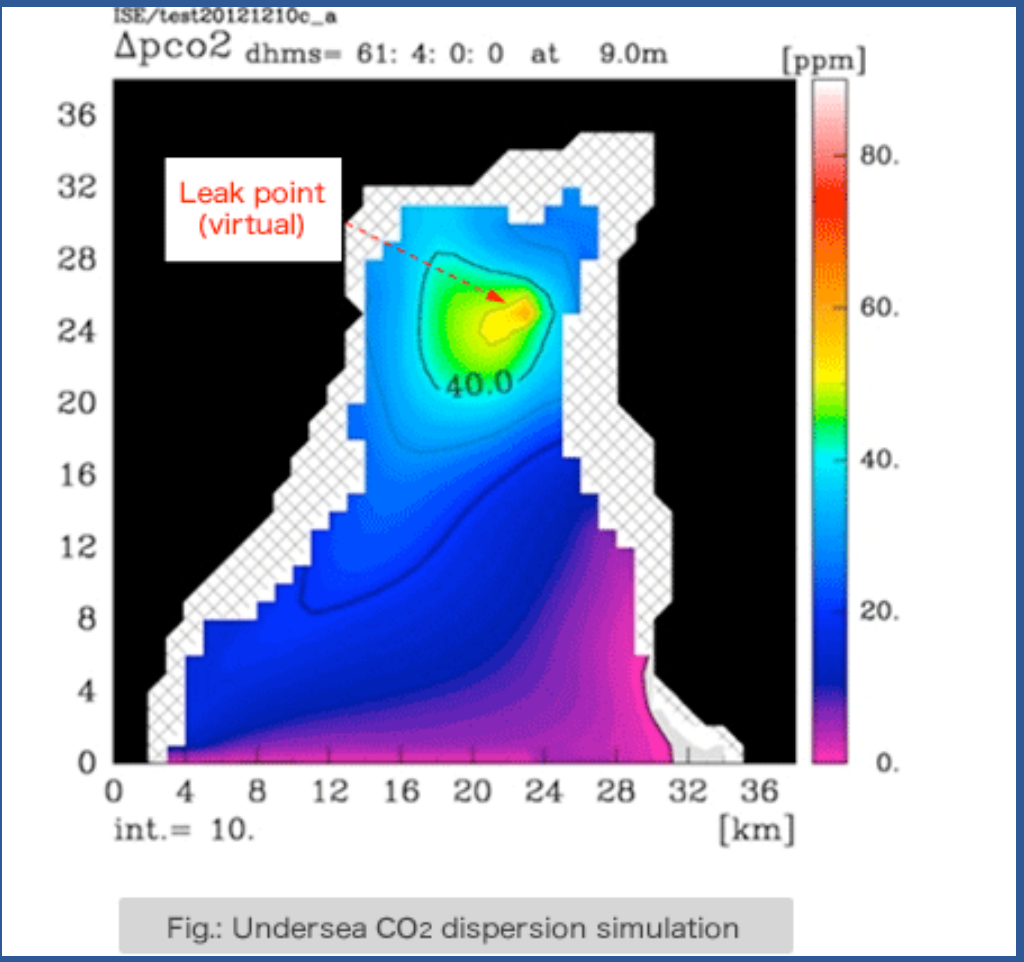


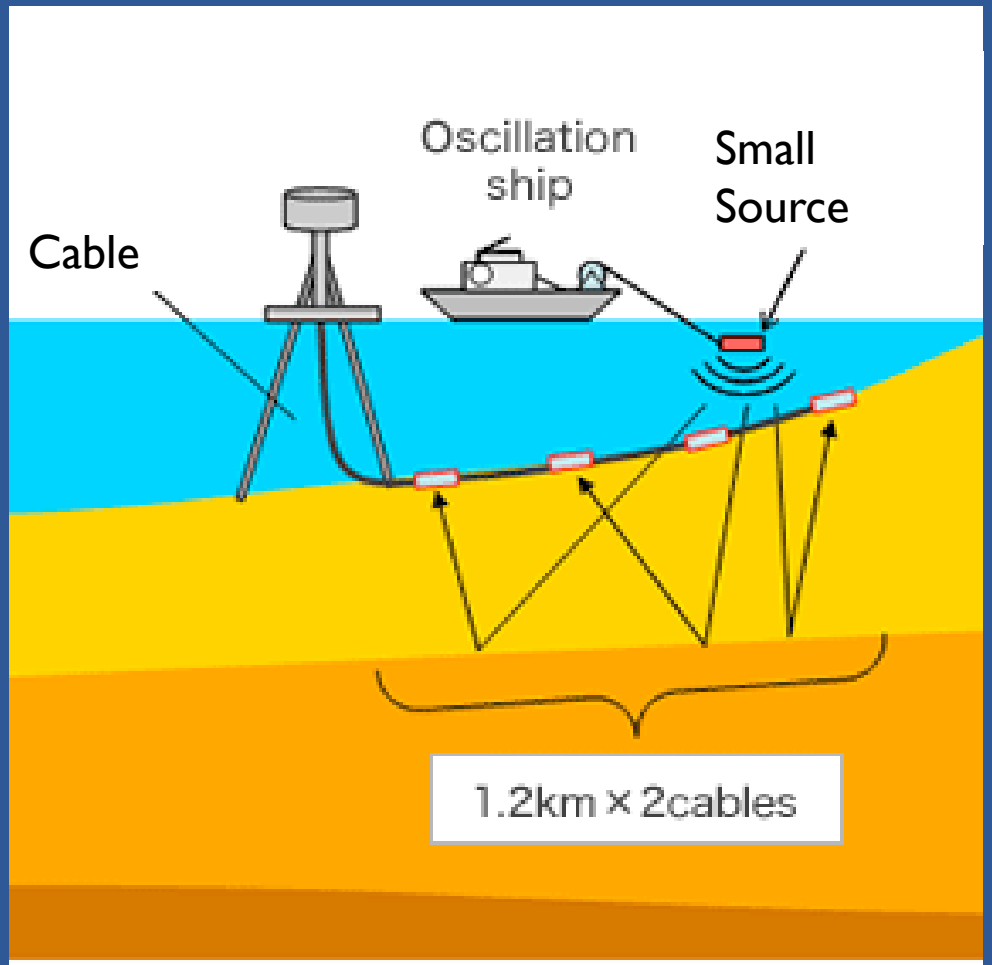
Fig.: Undersea CO_2 dispersion simulation

- Provides understanding to scientists, regulators and general public
- Supports permitting of offshore storage
- Enhances risk assessment
- Essential to development of commercial-scale projects

From www.rite.or.jp/co2storage/en/safety/

RITE
Research Institute of Innovative Technology for the Earth

Ocean Bottom Cable Improves Reservoir Imaging and Seismic Monitoring



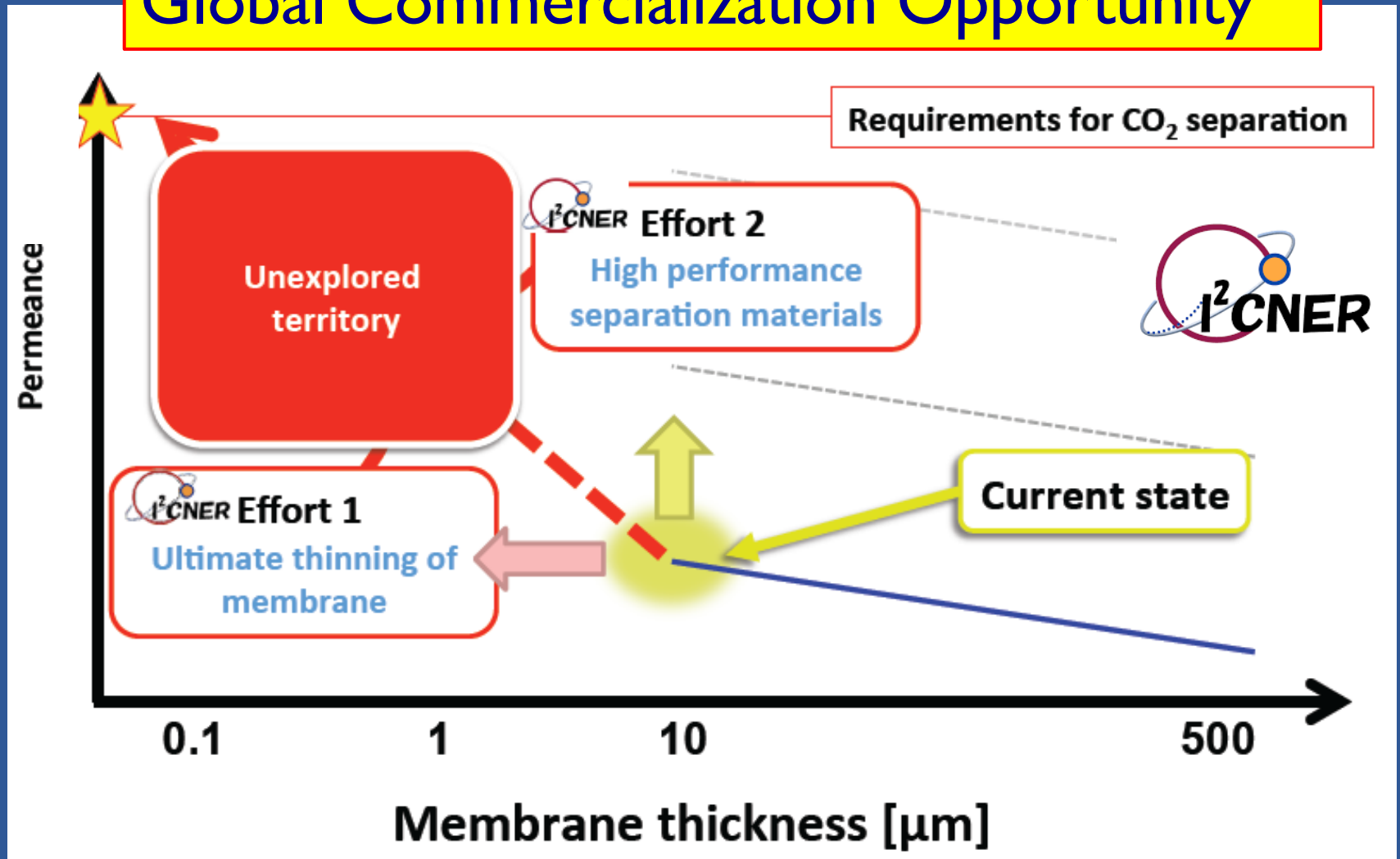
From www.rite.or.jp/co2storage/en/safety/

- Ocean bottom cables provide high repeatability
- Small ship can operate in confined areas nearshore
- Sensors also can record microseismic data

RITE
Research Institute of Innovative Technology for the Earth

Thin, High-Flux High Performance CO_2 Separation Membranes

Global Commercialization Opportunity



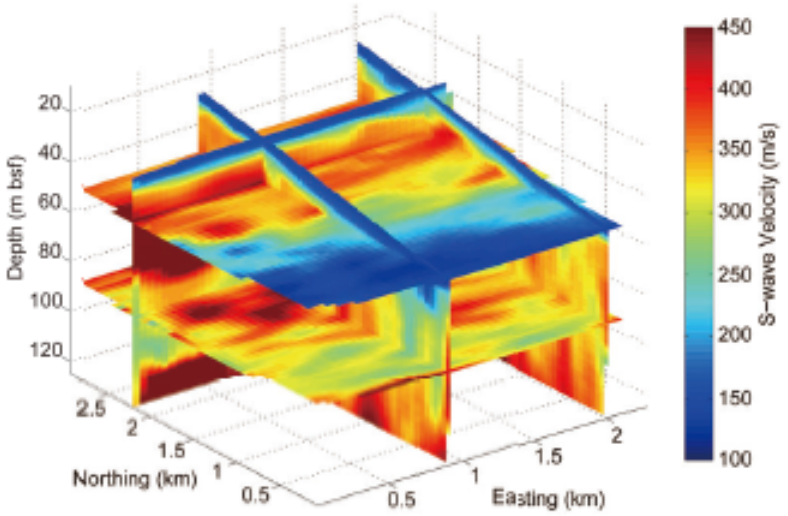
Advanced Reservoir Characterization Can be Applied Worldwide

New Method for High Resolution Geologic Modeling Applied to Geologic Heterogeneity at Tomakomai Site

- Estimations of lithology strength
- Permeability heterogeneity for modeling

- First application of surface-wave analysis using 3D seismic data in a CO_2 storage site

- We used geophysical data of Tomakomai CCS project under the project of **METI**



Ikeda and Tsuji (2015), JGGC

I²CNER

Tomakomai CCS Large-Scale Demonstration Project

Japan's First CCS Demonstration Project
100,000 tonnes/year

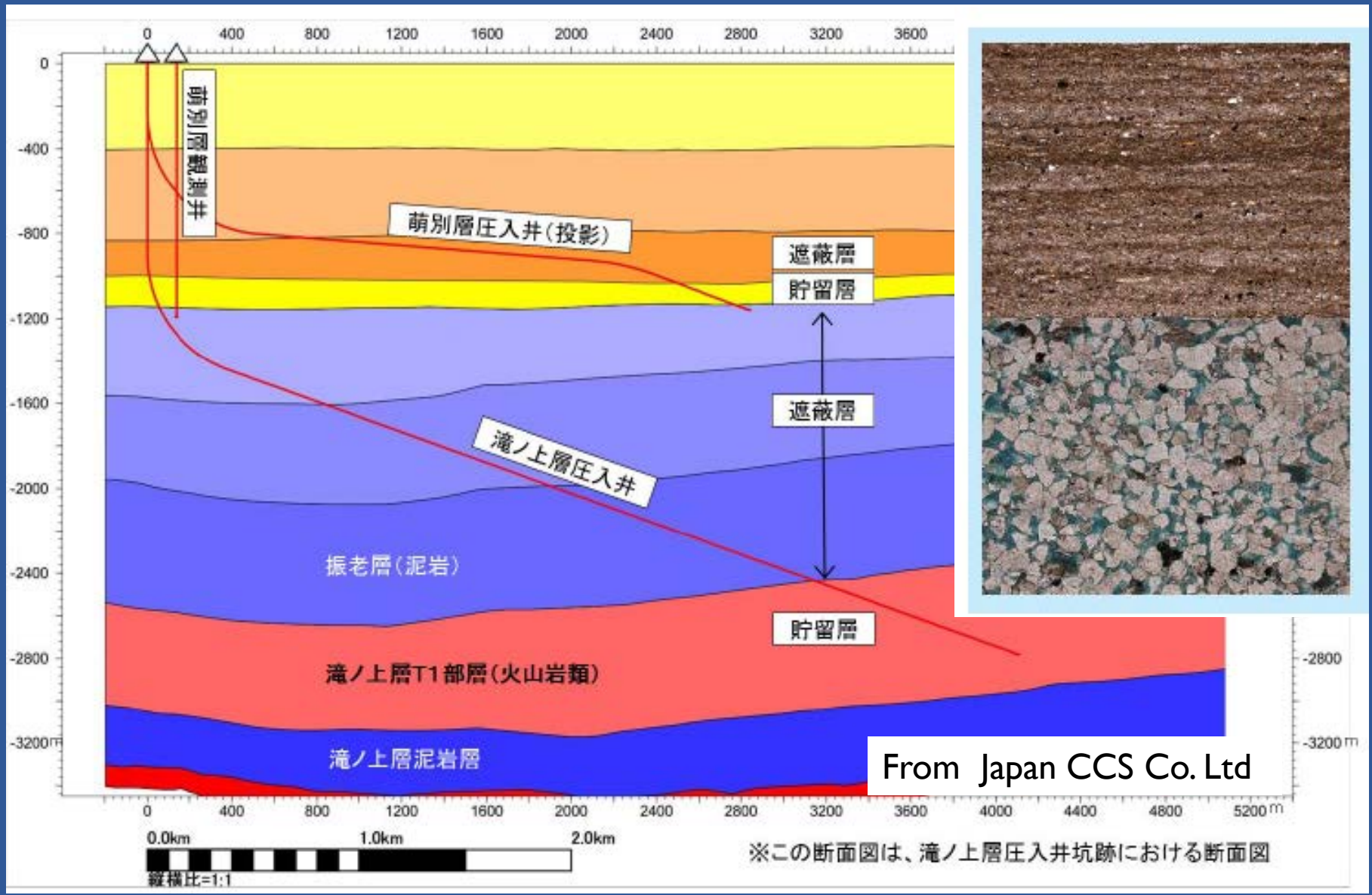
Strong focus on understanding the geological storage reservoir, safety, monitoring, and the environment

From Japan CCS Co. Ltd

Onshore Refinery Source of CO_2 Supports Offshore Reservoir Storage

From Japan CCS Co. Ltd

Two Geologically Different Reservoirs Targeted with Deviated Wells



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Climit Program in Norway

- Advancing technology such as separation membranes, improved sorbents, and new desorber technology to reduce parasitic heat load
- Aims to reduce overall CCS costs and addresses industry as well as power

US Department of Energy *CarbonSAFE* Program in the US

- Phase II awards just issued in late 2016
- Three projects to receive $29 million to initially characterize a storage complex for commercial scale of 50 million tons or more
- Projects build on Regional Carbon Sequestration Partnerships with locations in North Dakota, Illinois, and Mississippi

Shell Quest Project in Canada
Experience Reduces Costs

Petra Nova Project in US (Texas)
Experience Reduces Costs

- $1 billion joint venture of NRG Energy and JX Nippon Oil and Gas Exploration
- NRG estimates that "the next plant it builds could cost 20 percent less, thanks to lessons learned"

--as reported by the New York Times
2 January 2017

FOSSIL FORWARD:
Bringing Scale and Speed to CCS in the US

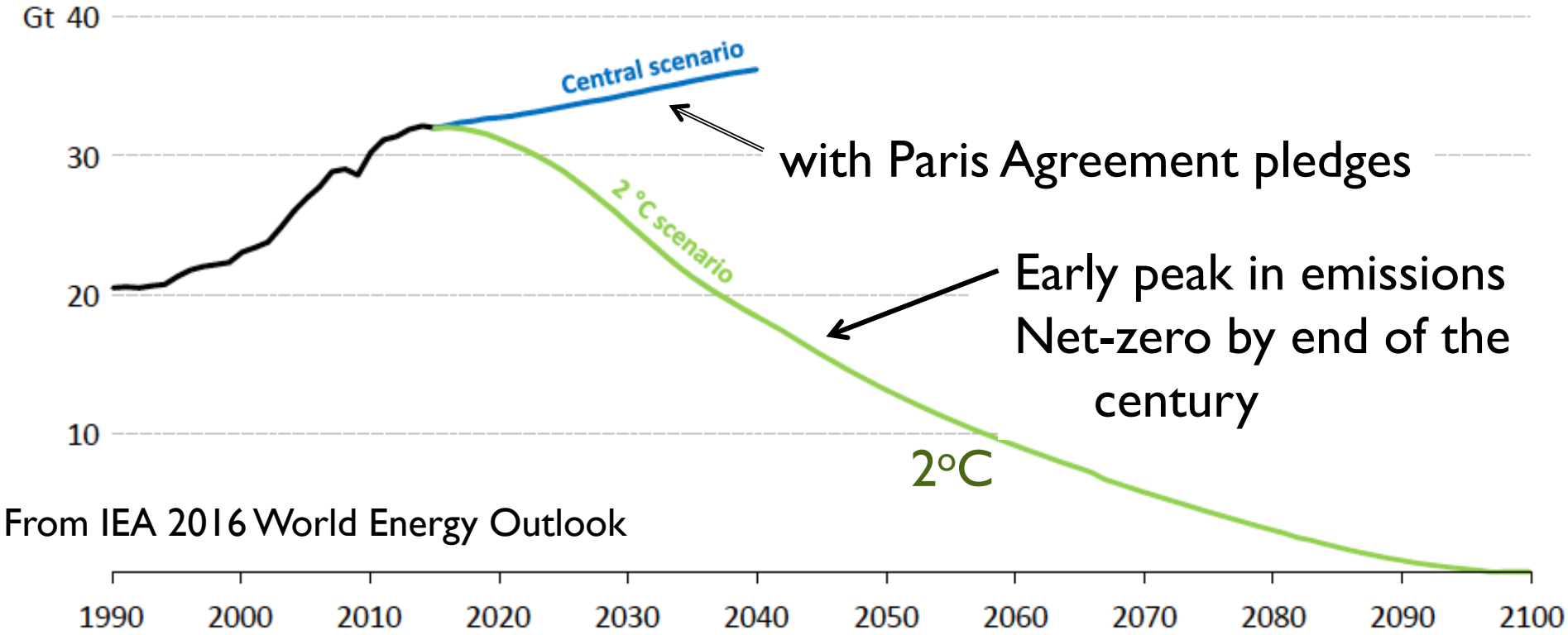
US National Coal Council 2015 Report
to the US Secretary of Energy

- Policy parity needed for CCS compared to other low-carbon options
- 5,000-10,000 Megawatts of demonstration projects needed by 2025 to advance CCS technologies to Technology Readiness Level 9 (Kemper County IGCC is TRL8)
- Without adequate demonstration, commercialization will not proceed

FOSSIL FORWARD:
Bringing Scale and Speed to CCS in the US

- CCS is the only large-scale technology that can mitigate CO_2 emissions from industrial processes: cement, iron and steel, oil refining, chemicals manufacturing
- No projects (to 2015) have reached TRL9, a threshold for commercialization, which requires extended operation (typically years) at full scale with minimal risk of failure

World Energy-Sector CO_2 Emissions: Reductions Needed Beyond Initial Paris Agreement Pledges



Setting the Stage for Commercial-Scale Carbon Capture and Storage

- Policy pathways must support commercialization based on developing many more large-scale capture and storage projects
- Technology pathways must reduce capture costs for large-volume, saline reservoir storage that is efficient, safe, and acceptable to society
- Both pathways must be developed in parallel