

GLOBAL STATUS OF CCS: THE NEXT WAVE IS COMING

25th Annual CO₂ Conference

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Senior Client Engagement Lead

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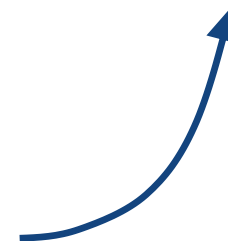
GLOBAL CCS
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International
think tank

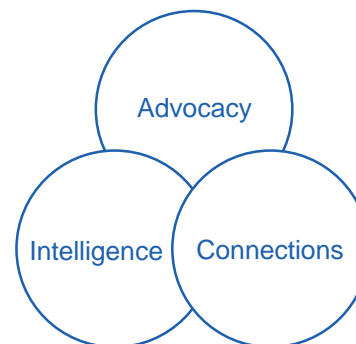
Backed by
governments,
businesses and NGOs



Mission: To accelerate
deployment of CCS

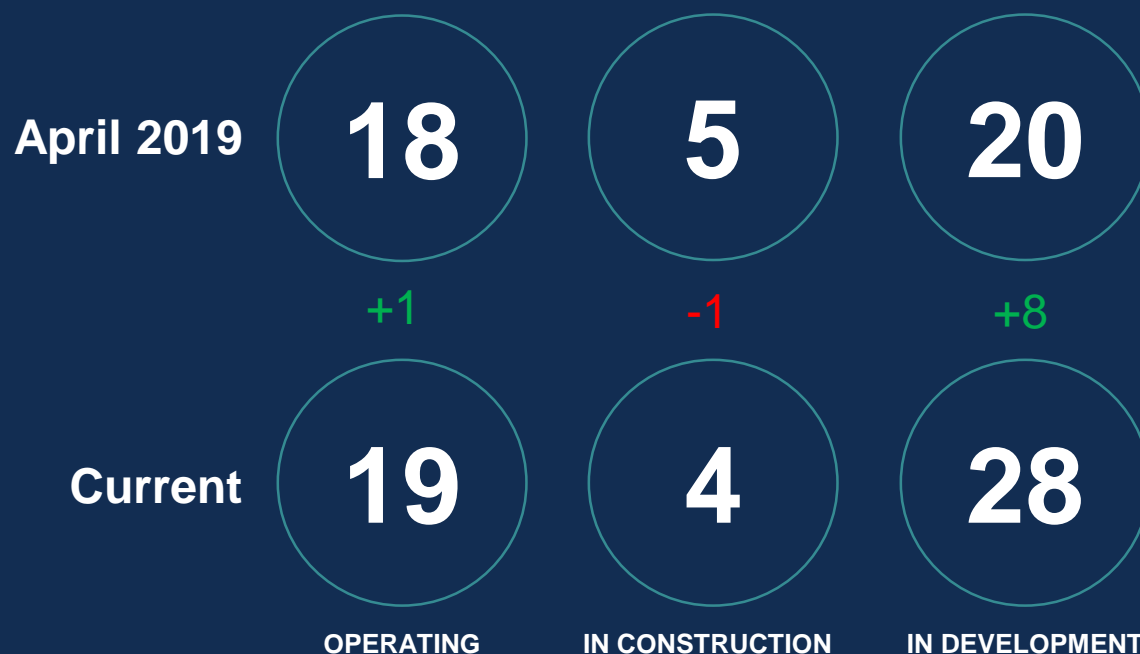
62 MEMBERS

7 locations



LARGE SCALE CCS FACILITIES

Recent developments

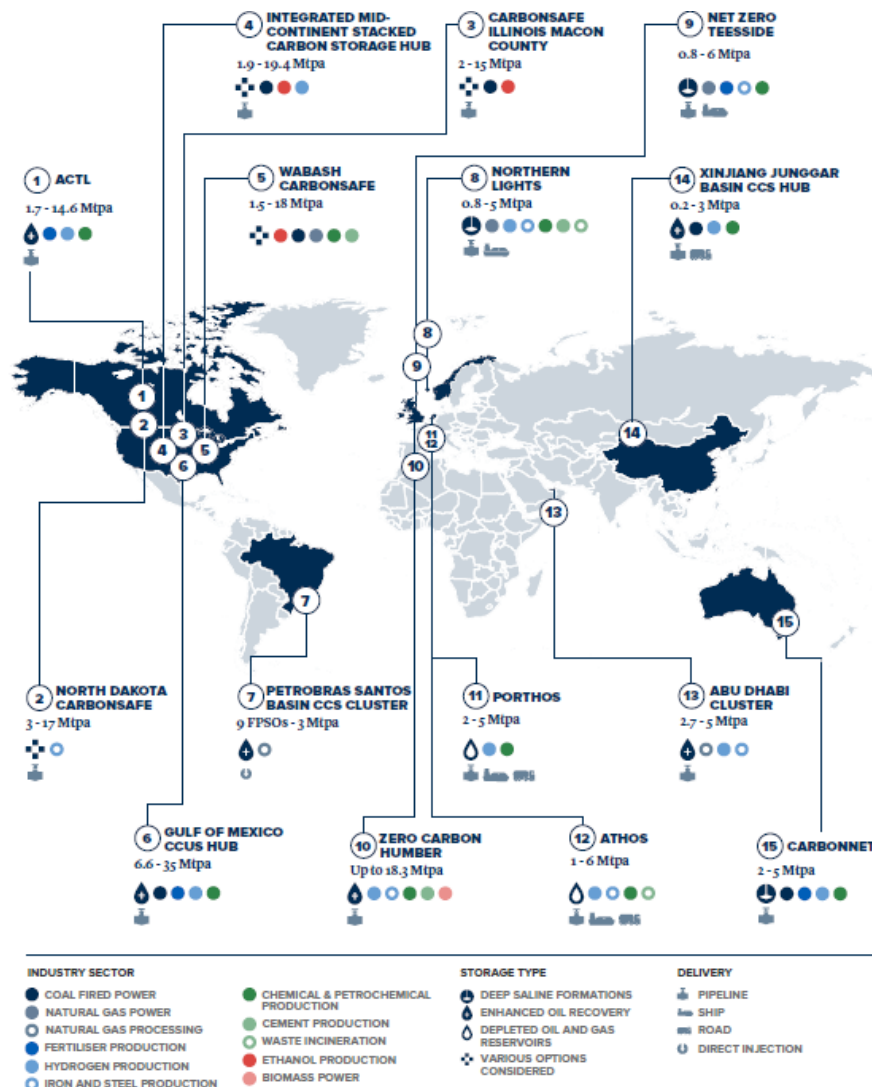


Facilities added

-  ABU DHABI CCS PHASE 2
-  CLEAN GAS PROJECT
-  WABASH
-  OXY AND WHITE ENERGY ETHANOL
-  PROJECT TUNDRA
-  DRY FORK
-  CARBONSAFE ILLINOIS
-  OXY AND CARBON ENGINEERING DAC
-  INTEGRATED MID-CONTINENT
-  ECO2S



NEXT WAVE OF CCS: HUBS & CLUSTERS



- Multiple industrial point sources of CO₂ connected to a CO₂ transport and storage network.
- Access to large geological storage resources with the capacity to store CO₂ from industrial sources for decades.
- Economies of scale deliver lower unit-costs for CO₂ storage.
- Synergies between multiple CO₂ sources and the storage operator reduce cross chain risks and support commercial viability.



PROJECTS – NORTH AMERICA

Established Projects

Project Tundra - North Dakota, USA

- Minnkota Power Cooperative and BNI Energy are collaborating with state resources on carbon capture at the Milton R. Young coal power plant.
- Over 3Mtpa to be stored geologically or via EOR.
- The project is in advanced development stage and will utilize Fluor's Econamine FG Plus technology.
- Received support from DOE via CarbonSAFE storage feasibility study and early design research support.
- Recently granted additional DOE funding for FEED study.
- Could be in operation by 2025.



Lake Charles Methanol – Louisiana, USA

- Project in Lake Charles will capture and store over 4Mtpa.
- Benefiting from \$2billion DOE loan guarantee, 45Q, and Louisiana regulatory support.
- Fluor EPC contract signed in March 2016; working with Morgan Stanley to finalize investors with projected 2024 completion.



OXY and White Energy Ethanol – Texas, USA

- Project would use 300,000tpa CO₂ from each of White Energy's Hereford and Plainview plants for EOR in the Permian.
- Could be operational as early as 2021.
- Would benefit from 45Q and California's LCFS incentives.



PROJECTS – NORTH AMERICA

Wabash Valley Fertilizer plant – Indiana, USA

- Repurposed Wabash Integrated Gasification Combined Cycle plant for ammonia production in Terre Haute, Indiana.
- Will store 1.5 - 1.75Mtpa in Illinois Basin.
- First hub and cluster model in US with co-benefits on storage side from ADM project.
- Could be operational in 2021.
- Funded in part by OGCI Climate Investments and received DOE funding for its pre-feasibility study.
- Project will benefit from Indiana state government legislative support and 45Q.

California Research Corporation – California, USA

- Planned CCS facility capable of capturing 1.4Mtpa CO₂ from the 550 MW Elk Hills Power Plant located in the Elk Hills oil field and fired using natural gas produced by the field.
- The captured CO₂ would be used for enhanced oil recovery in the Elk Hills oil field.
- This project would benefit from both 45Q and California LCFS.
- Electric Power Research Institute received DOE funding to conduct FEED study using Fluor technology.

Oxy and Carbon Engineering – TBC Permian, USA

- Oxy announced plans with Carbon Engineering to put a Direct Air Capture facility near an oil field in the Permian.
- The captured CO₂ would be used for EOR.
- Estimated that the plant will capture between 0.5 and 0.9Mtpa.
- This project would take advantage of 45Q and the California LCFS.



PROJECTS – NORTH AMERICA

Early Development

Pacific Ethanol - Illinois, USA

- Aim to sequester CO₂ from facilities located in Pekin, IL.
- Will benefit from work done at ADM and project with Wabash Valley, partnering with the Illinois State Geological Survey.

DTE California Carbon Capture Program - California, USA

- Project is envisioned to be a regional network of carbon sequestration hubs to serve industrial customers in California.
- The initial goal to store 1Mtpa in deep saline aquifers or depleted oil and gas formations.

Elysian - Texas, USA

- Aim to execute 10 projects at 1,000,000 tons per year before the expiration of 45Q legislation.
- Target sites in Texas have already been identified with a focus on natural gas fired power plants.

Velocys – Natchez, Mississippi

- Oxy signed an agreement to capture and store the CO₂ from their Bayou Fuels biomass-to-fuels project in Natchez, Mississippi. It is presumed that the CO₂ will be used for EOR.

Additional projects supported through latest round of DOE funding:

Basin Electric's Dry Fork Station – Gillette, Wyoming, USA

- Funding for commercial-scale FEED.
- Using MTR's Membrane CO₂ Capture Process.

San Juan Generating Station - Waterflow, New Mexico, USA

- DOE funding for FEED study to determine the technical and economic feasibility.

Prairie State Generating Station- Marissa, Illinois, USA

- US DOE funded \$15 million for a FEED study for the installation of capture system at the Prairie State Generating Company's Energy Campus using Advanced KM CDR Process KS-21 solvent.

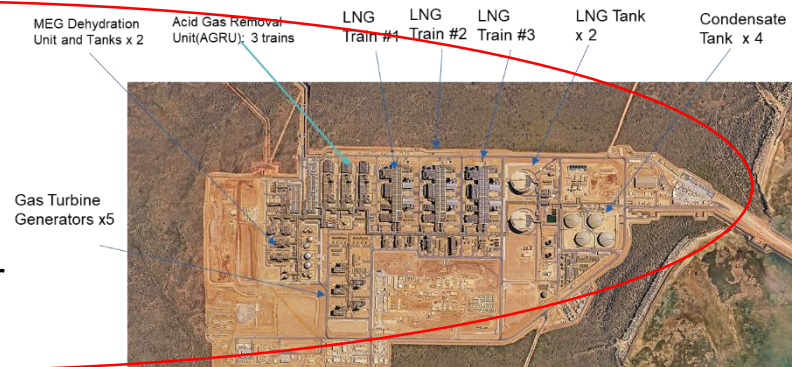


PROJECTS – ASIA PACIFIC

Operation/Construction

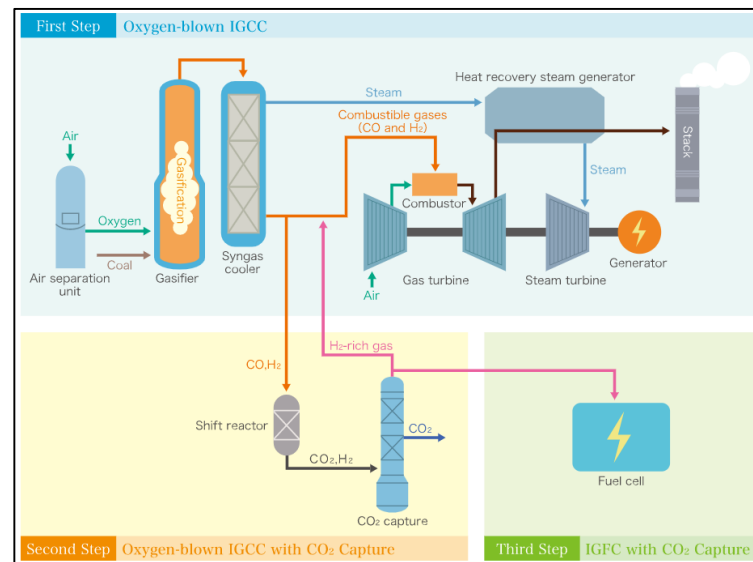
Chevron Gorgon- Western Australia

- In August Chevron announced safe startup and operation of Gorgon CO₂ injection facilities.
- When fully operational, this will be the largest geological storage facility in the world with capture capacity of 3.4 - 4Mtpa.
- Chevron has blamed technical issues for the 2 year delay, citing excess water entering the pipeline and injection well, which increases the risk of corrosion.



Osaki CoolGen - Hiroshima, Japan

- A166MW oxygen blown Integrated Coal Gasification Combined Cycle (IGCC) demonstration plant.
- First phase of the project, construction and demonstration of IGCC completed 2018.
- CO₂ capture plant is currently being commissioned and is expected to commence operation in December.
- Plant uses a physical adsorbent (Selexol Max) and will capture up to 400t CO₂ per day.
- The next stage is the installation of two 600kW Solid Oxide Fuel Cells to produce additional electricity from hydrogen produced by the gasifier.



PROJECTS – ASIA PACIFIC

Established Projects

CarbonNet Project - Victoria, Australia

- CarbonNet will drill an appraisal well between early-November and December to verify suitability of the Pelican site in the Bass Strait.
- During drilling, the Noble Tom Prosser rig will be approximately 8km offshore and may be observed from the shoreline.
- Environment plan for the offshore appraisal well was approved by the National Offshore Petroleum Safety and Environmental Management Authority in April 2019.
- Call for submission regarding business model/financing expected.

Sinopec, Shengli Oil Field - Shandong province, China

- The project captures CO₂ from fertilizer production for CO₂-EOR.
- The project had difficulties in contracting with the fertilizer producer (pricing of CO₂).
- FEED has been completed and pilot injection started.
- Supercritical CO₂ transportation by pipeline had public opposition so trucks are currently being used for transport.

Xinjiang Dunhua Oil – Xinjiang, China

- CO₂ from PetroChina methanol plant captured using amines.
- The project has been operational since November 2015.
- The company has management contract with PetroChina for CO₂-EOR operation (whole-chain).
- The plant has a capacity of 100,000tpa.



PROJECTS – ASIA PACIFIC

Early Development

Santos CO₂-EOR – Cooper basin, Australia

- CO₂-EOR project in central Australia.
- Project is currently at pre-FEED stage.
- CO₂ from natural gas processing.

Bridgeport Energy CO₂-EOR - Queensland, Australia

- CO₂-EOR project in southern Queensland.
- Currently identifying economical CO₂ sources.

ENI, Australia – Offshore, Northern Australia

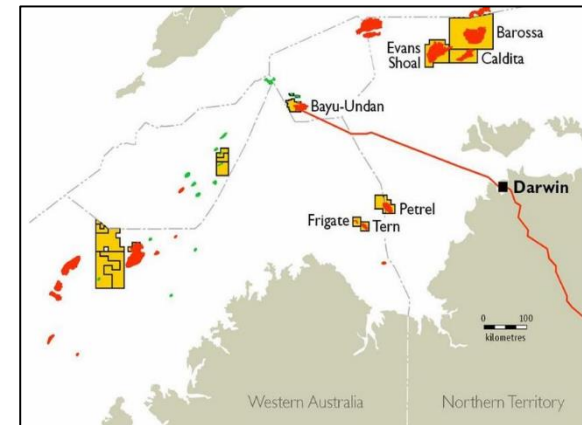
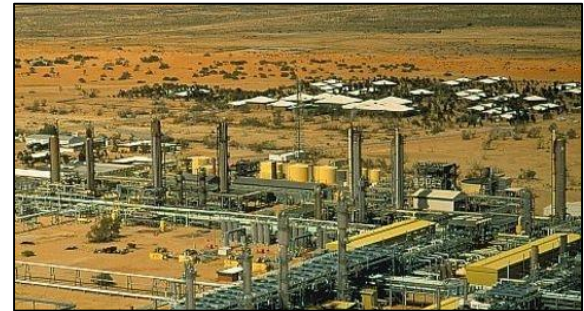
- Offshore high CO₂ gas field.
- Growing regional interest in CCS to address increased CO₂ emissions from LNG plants.
- Export will be via Darwin LNG plant.
- Early storage potential appraisal completed.

CNPC Changqing Oilfield – Inner Mongolia, China

- CO₂ from natural gas processing.
- CO₂ EOR storing 100,000tpa.

China Energy Corporation –China

- CO₂ captured from Coal-fired power station.
- Capturing 120,000tpa.
- Currently at FEED stage.



PROJECTS – ASIA PACIFIC

Gundih CCS Project - Central Java, Indonesia

- Captures CO₂ from a natural gas processing plant in Gundih, Central Java, Indonesia.
- Oil/gas field is owned by Pertamina and contains circa 20% CO₂.
- Technical Assistance project funded by Asian Development Bank.
- Japan International Cooperate Agency also provided support.
- Includes capturing and preparing CO₂; transporting and injecting CO₂; monitoring .
- The project includes study of CCS regulation in Indonesia.

Petronas K5 - Offshore Sarawak, Malaysia

- High CO₂ gas field(70% CO₂).
- Pilot injection planned 2022.
- CO₂ storage assessment stage.

ERG – North East, Kazakhstan

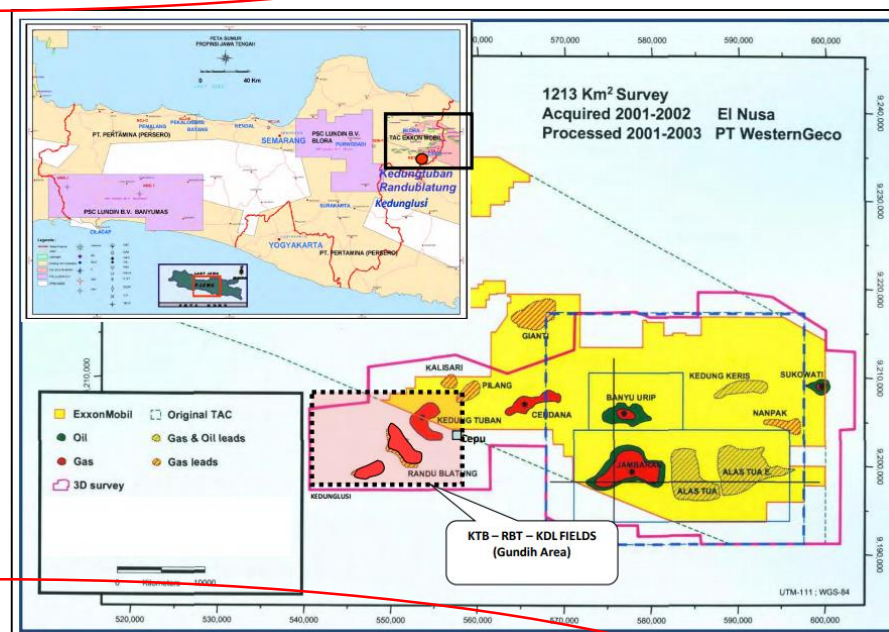
- CO₂ captured from power stations.
- Early concept stage.

KEPCO Boryeong Power Station - Korea

- CO₂ from a coal-fired power station.
- Storage unclear.

Dalmia Cement – Tamil Nadu, India

- Dalmia is the first cement company to commit to being 'Carbon Negative' aiming to do so by 2040.
- Dalmia Cement and Carbon Clean Solutions have teamed up to develop a 500,000tpa CCU plant at one of Dalmia's facilities in Tamil Nadu, India.
- The partnership will explore how CO₂ can be used, including direct sales to other industries and using the CO₂ as a precursor in manufacturing chemicals.



PROJECTS – EUROPE



Established Projects

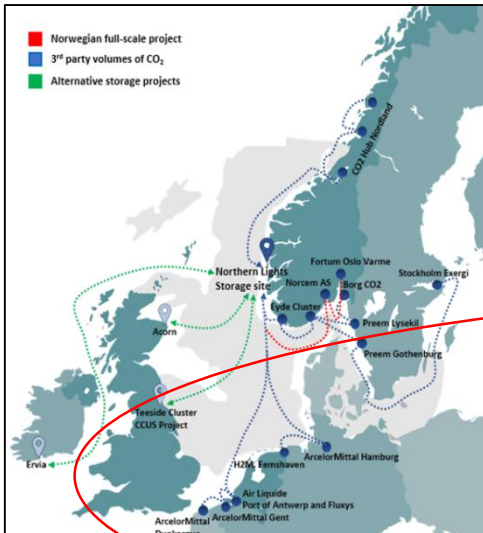
Acorn - St Fergus, Scotland

- Shell is working on technical studies for the Acorn project.
- E&P firm Chrysaor has also become a partner in Acorn.
- Pale Blue Dot were awarded £453,706 by the UK Government for Feasibility work as part of Hydrogen supply programme during August.



Porthos - Rotterdam, Netherlands

- Early 2019 several companies signed a non-binding EOI for storage. Companies who sign agreements by October 1st will get preferential right to capacity. Porthos aims to finalise T&S contracts summer 2020.
- A second phase is proposed to increase offshore network capacity. Emitters in NL and imports from Germany are likely CO₂ sources.
- Wim Lieshout appointed as Project Director succeeding Tim Bertels.
- FID currently expected early 2021.



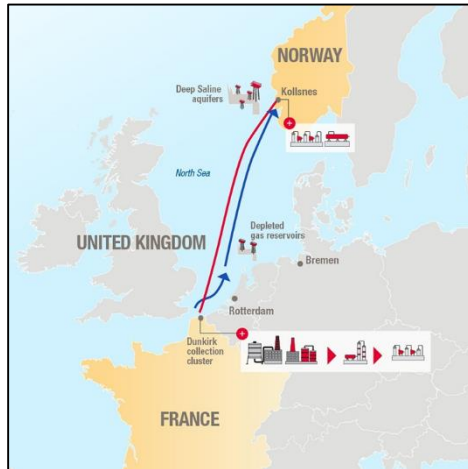
Norwegian Full Chain - Various, Norway

- Partners to undertake investment decision late 2019/early 2020.
- Project will be subject to parliamentary approval 2020/2021.
- Characterisation drilling is expected to begin mid-October and last 79 days. The North Atlantic-owned rig, West Hercules will be used.
- On September 5th Equinor announced the signing of agreements to develop CCS value chains with Air Liquide, Arcelor Mittal, Ervia, Fortum Oyj, Heidelberg Cement AG, Preem, and Stockholm Exergi.



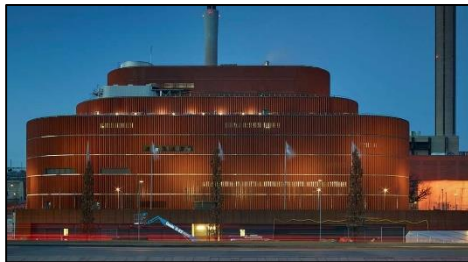
PROJECTS – EUROPE

Early Development



3D project ArcelorMittal - Dunkirk, France

- The “3D” project (DMX Demonstration in Dunkirk) is part of the Horizon 2020 research and innovation program.
- Coordinated by IFPEN, the project brings together 10 partners from research and industry: ArcelorMittal, Axens, Total, ACP, Brevik Engineering, CMI, DTU, Gassco, RWTH and Uetikon.
- The project objective is threefold:
 - Demonstrate the DMX process at industrial scale.
 - Prepare the implementation of a first industrial unit at the ArcelorMittal steel production site in Dunkirk, which could be operational in 2025.
 - Design the future European Dunkirk North Sea cluster, which should be able to capture, transport and store 10Mtpa.



Värtan CHP plant – Stockholm, Sweden

- Stockholm Exergi AB will install a carbon capture test facility at its biomass-fired KVV8 unit at the Värtan CHP plant in Stockholm.
- An eight-month test programme will start during autumn 2019
- In January 2019, Hot Potassium Carbonate was selected as the capture technology due to energy efficiency, siting requirements, availability, the possibility to scale up, environmental impact and low risk.
- Calculations show there is potential to capture 800,000tpa.












Policies & project characteristics	 Carbon tax	 Tax credit or emissions credit	 Grant support	 Provision by government or SOE	 Regulatory requirement	 Enhanced oil recovery	 Low cost capture	 Low cost transport and storage	 Vertical integration
US									
Terrell						○	●	●	
Enid Fertiliser						○	●	●	
Shute Creek					●	○	●	●	
Century Plant		●				○	●		
Air Products SMR		●	○			○			
Coffeyville		●				○	●		
Lost Cabin		●				○	●		
Illinois Industrial		●	○				●	●	●
Petra Nova		●	○			○			
Great Plains						○	●		
Canada									
Boundary Dam			○	●	●	○		●	
Quest		●	○						●
ACTL Agrium			○			○	●		
ACTL Sturgeon			○			○	●		
Brazil									
Petrobras Santos				●		○	●	●	●
Norway						○			
Sleipner	●			●			●	●	●
Snohvit	●			●	●		●		●
UAE									
Abu Dhabi CCS				●		○		●	
Saudi Arabia									
Uthmaniyah				●		○	●	●	●
China									
CNPC Jilin				●		○	●	●	●
Sinopec Qilu*				●		○	●	●	
Yanchang*				●		○	●		
Australia									
Gorgon			○		●		●	●	●

FIGURE 6 CONDITIONS THAT ENABLED LARGE-SCALE FACILITIES

*In construction

3 December 2019 |

54.5%

WHO IS READY FOR CCS?

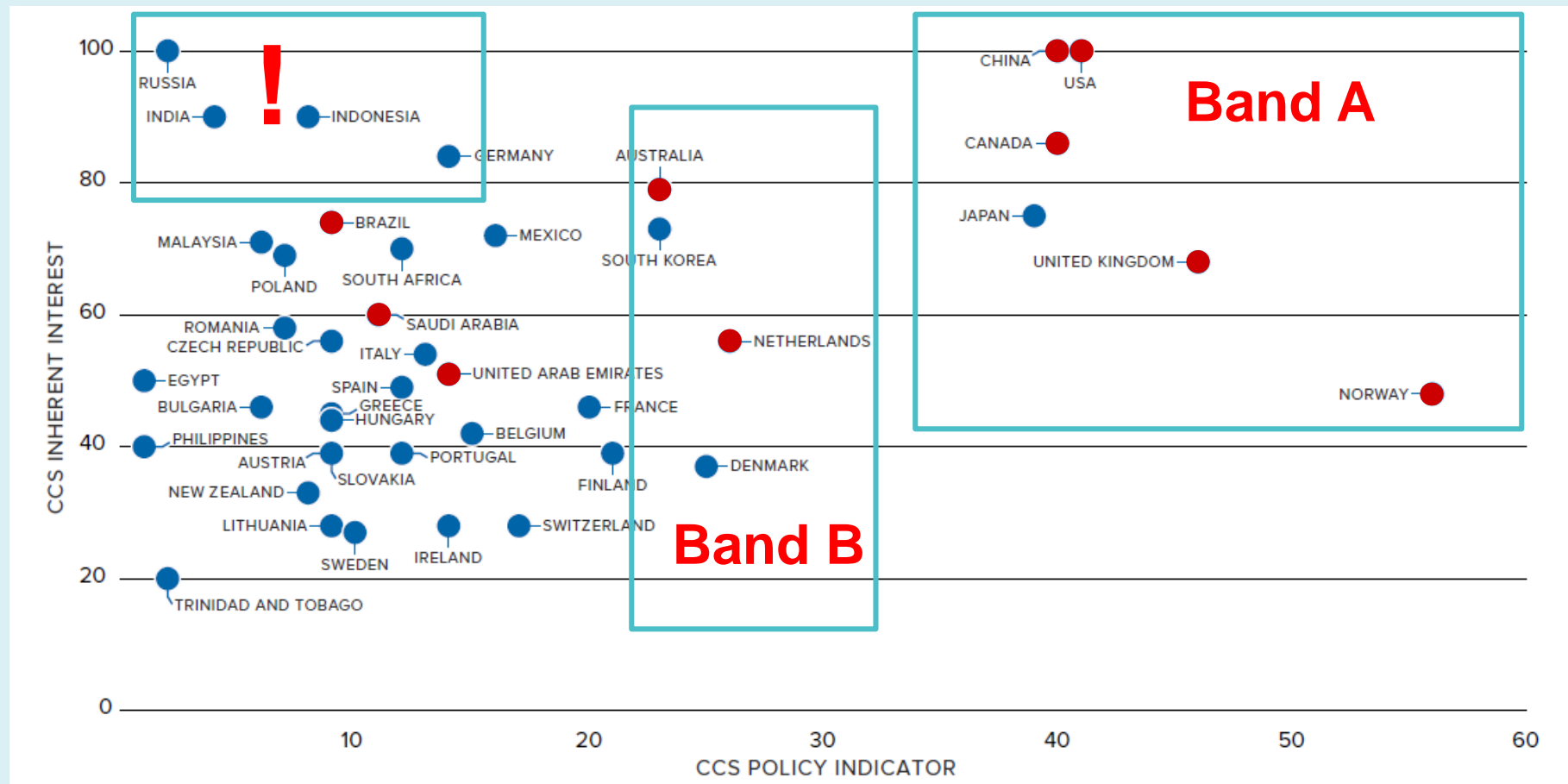


CCS READINESS INDEX

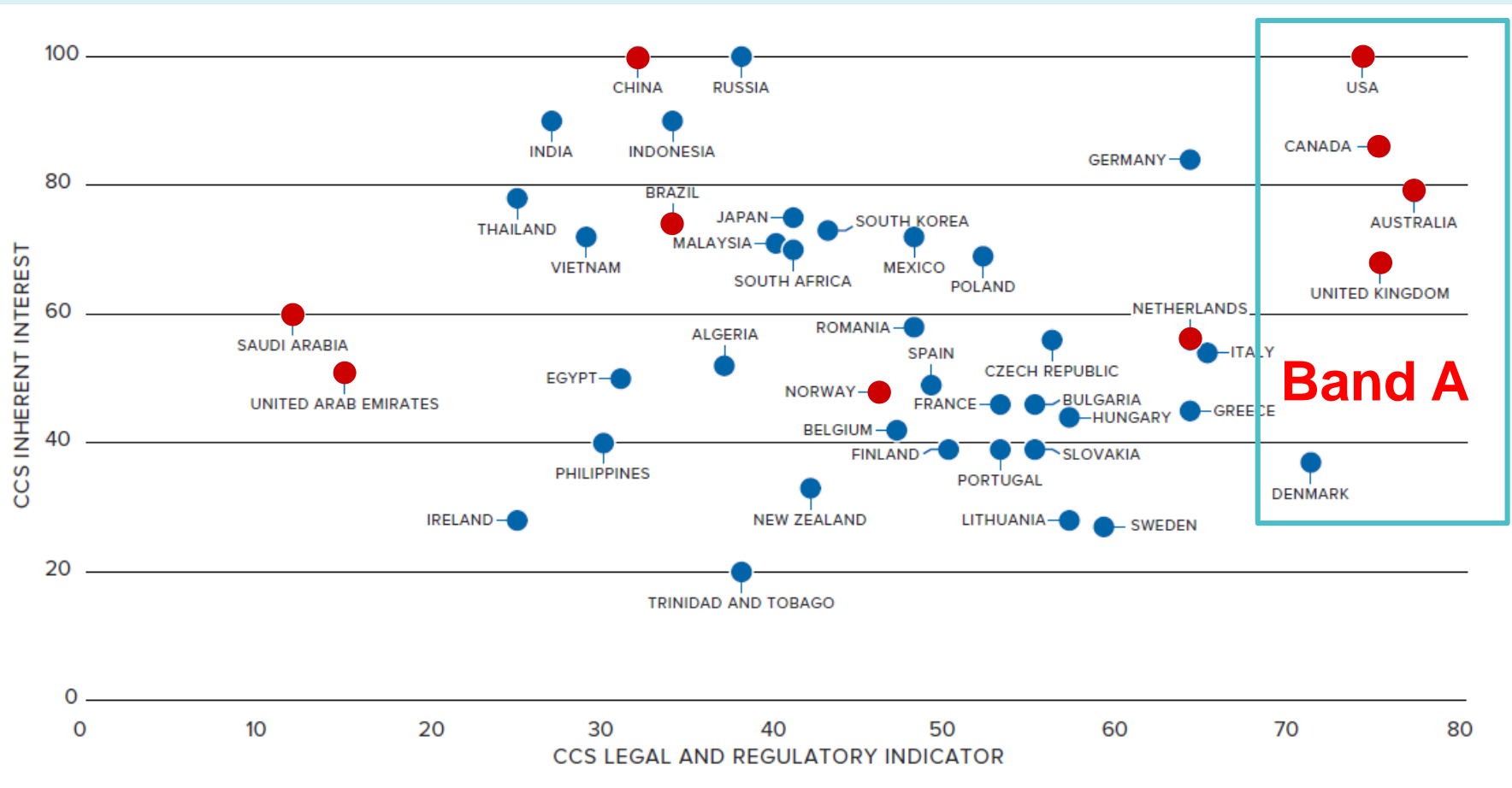
- Established in 2015
- Ranks over 50 countries:
 - Attractiveness for investment and deployment
 - Identifies leaders, fast followers
- Comprises four indicators:
 - Policy
 - Legal
 - Storage
 - Inherent CCS Interest



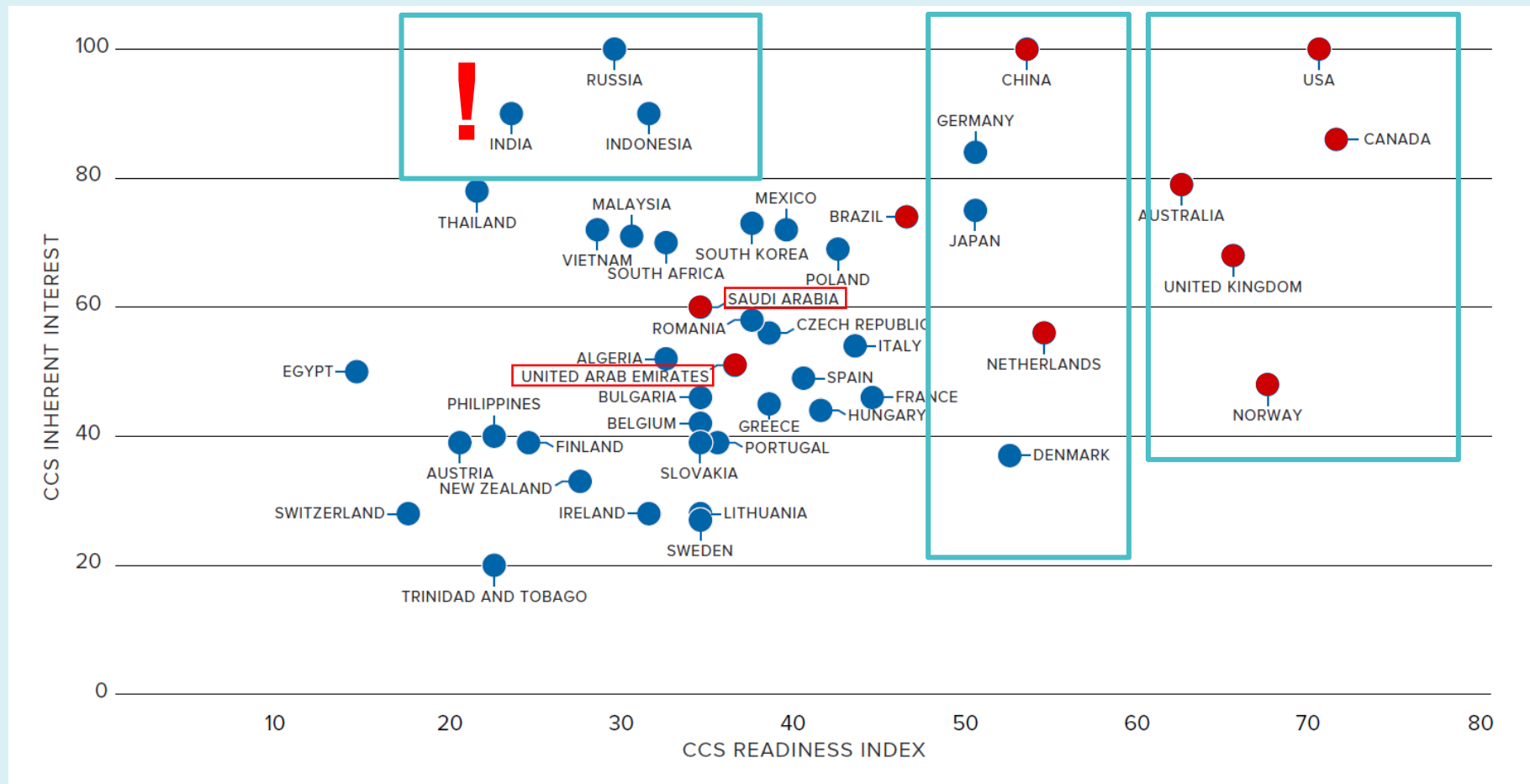
CCS POLICY INDICATOR



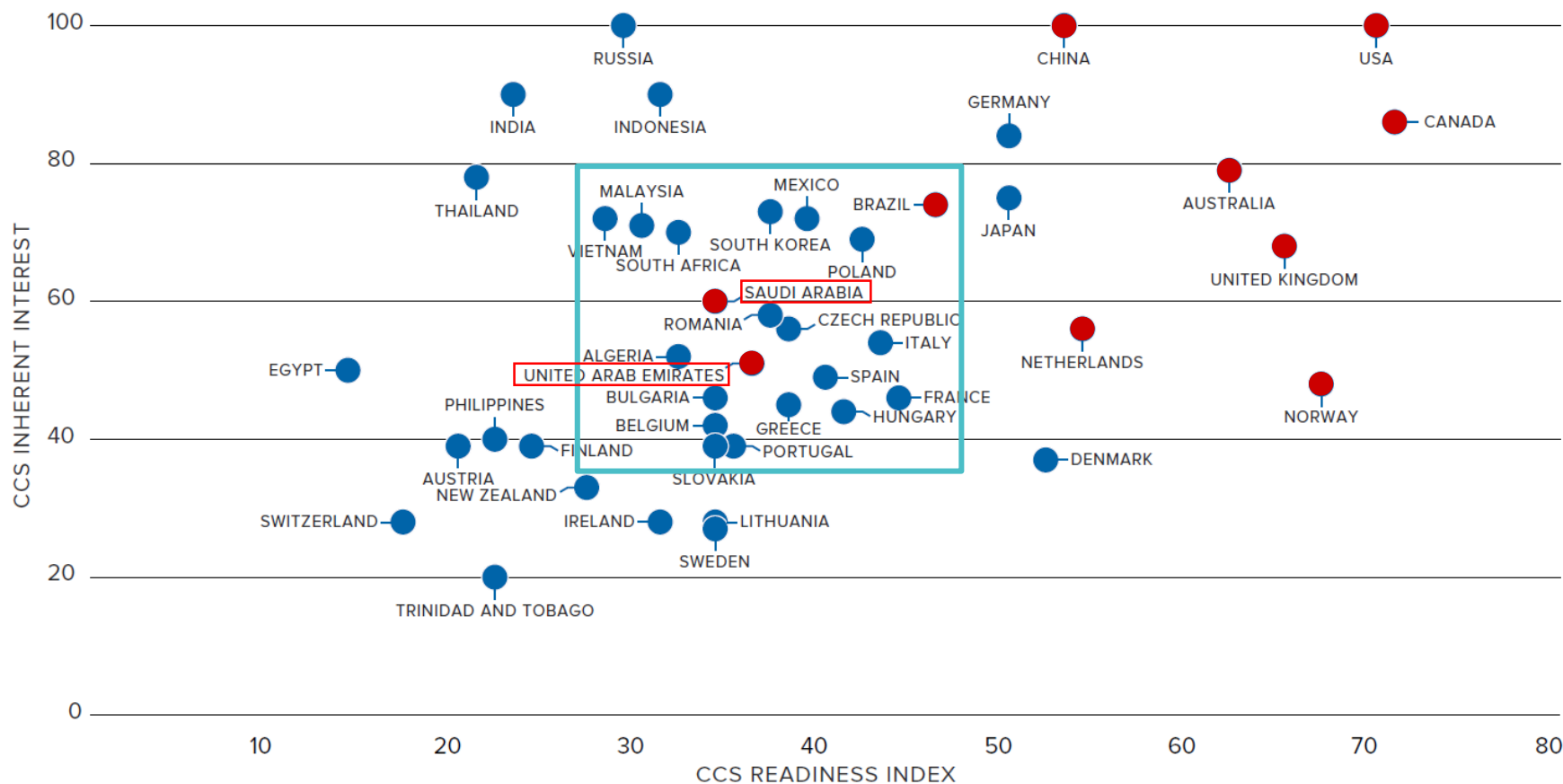
CCS LEGAL & REGULATORY INDICATOR



CCS READINESS INDEX



CCS READINESS INDEX



POLICY DEVELOPMENTS

Global

- Paris Accord – 10+ NDCs indicate CCS, Article 6
- Green Climate Fund – funding for CCUS projects
- ICAO – Carbon Offsetting and Reduction Scheme
- London Protocol amendment – bi-lateral agreements



POLICY DEVELOPMENTS

Europe

- Innovation Fund – €10 billion for carbon reductions
- EC vision for climate neutral Europe – CCS one of seven building blocks
- EU ETS – €25/tonne
- EU taxonomy for sustainable investments

Norway

- Carbon tax – \$53/tonne
- Gassnova
- TCM
- Grant funding for full chain project – FID in Q3 2020

UK

- 80% GHG reduction by 2050
- Clean Growth Strategy – £100 million for CCUS
- CCUS Deployment Pathway – 2018
- Hydrogen

Netherlands

- 49% CO₂ reduction by 2030
- 20 MMT by CCUS

Germany

- Ban on storage
- Merkel: CCUS essential



POLICY DEVELOPMENTS

China

- State-sponsored projects: 1 operating, 2 in construction, 7 in planning
- Numerous pilots and demonstrations
- Roadmap for CCUS in China, 2019
- CCUS in 5-year plans
- R&D - \$500 million
- ETS - 1700 power plants

Japan

- Deep R&D investment – NEDO, AIST, JCOAL, RITE
- Numerous testing and pilots
- Focus on capture technologies, partnerships with industry
- Tomokomai demo – METI
- Hydrogen Energy Supply Chain

Australia

- Gorgon – CCS required
- Hydrogen Energy Supply Chain
- CarbonNet – offshore storage
- CO2 storage-enabling regs
- R&D – CO2CRC
- National Energy Guarantee



THANK YOU

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