



GLOBAL CCS
INSTITUTE

2018 THOUGHT LEADERSHIP REPORT

THE CARBON CAPTURE AND STORAGE READINESS INDEX 2018

IS THE WORLD READY FOR CARBON CAPTURE AND STORAGE?

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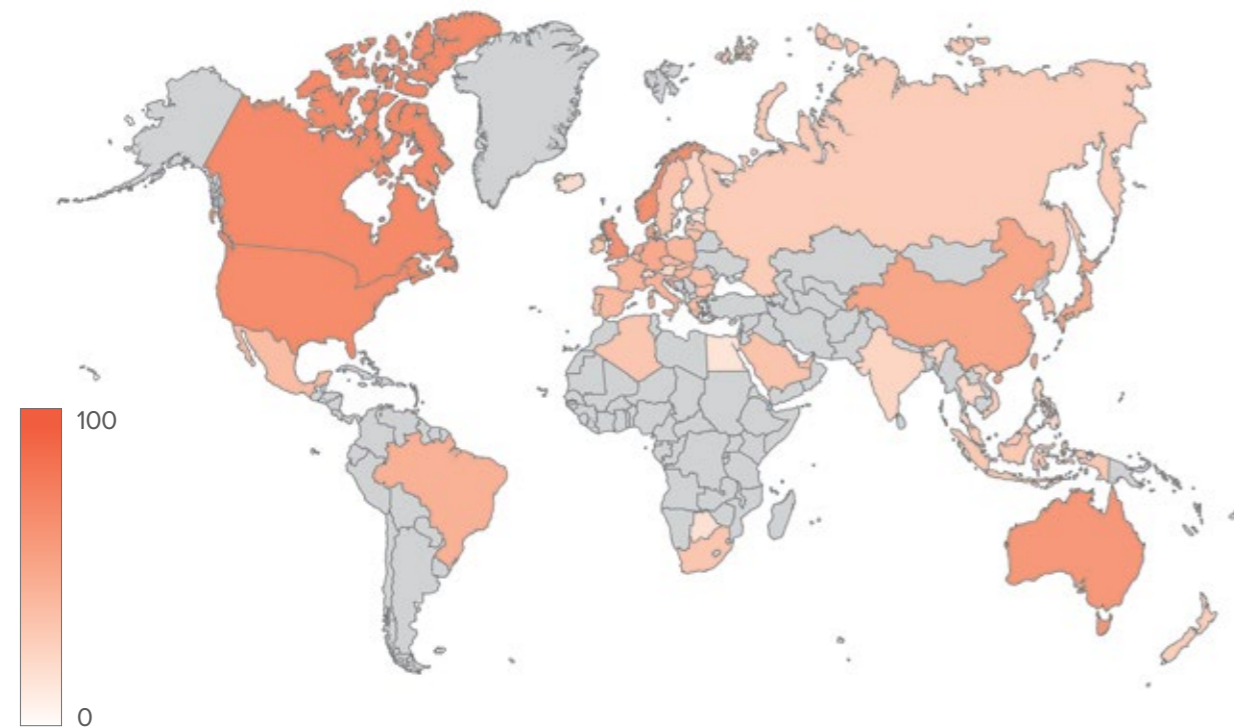
Is the world ready for carbon capture and storage?

The 2018 edition of the Global CCS Institute's (the Institute) Carbon Capture and Storage (CCS) Readiness Index (CCS-RI) identifies those nations which are leaders in the creation of an enabling environment for the commercial deployment of CCS.

However, no nation, including the leaders, have yet established the conditions necessary to drive deployment at the rate required to meet ambition climate targets. It is clear that more must be done.

Tracking progress towards CCS deployment

Figure 1: CCS Readiness Index 2018 Heatmap



The Institute actively monitors the progress of CCS deployment, through a series of targeted 'indicators', which consider a country's:

- Inherent CCS interest
- Policy developments
- Legal and regulatory frameworks
- Geological CO₂ storage development.

Collectively, these indicators establish the CCS Readiness Index (CCS-RI). The 2018 CCS-RI examines over 50 countries using 70 discrete criteria and enables a comparative assessment of countries globally.

High-scoring nations – pioneering CCS models

Only five countries rank in the Index's highest category—Australia, Canada, Norway, United Kingdom and the United States. These five nations have taken significant steps to reduce domestic barriers to CCS, which include the development of:

- Supportive policy frameworks
- Comprehensive legal and regulatory frameworks
- Detailed and targeted storage assessments.

Other nations, including China, Denmark, Germany, Japan and Netherlands, have also scored well in the Index and are also well advanced along the path towards CCS readiness.

Slow progress in meeting global ambition

Global ambition aimed at avoiding the most serious impacts of climate change was confirmed with the ratification of the Paris Agreement. The agreement seeks to keep global atmospheric temperature increase to well-below 2°C and pursue efforts to keep warming below 1.5°C above pre-industrial levels.

CCS plays a critical role in achieving these targets. To meet the objectives of the Paris agreement, CCS will require an unprecedented rate of deployment, to eventually capture, transport and store between 1.8 and 6 billion tonnes of CO₂ per year. The current rate is wholly inadequate with only 37 million tonnes captured, transported and stored. Nations have yet to develop supportive or complete policy frameworks, which are conducive to the scale of deployment necessary under the Paris Agreement. The absence of supportive policy is reflected in many nations' low CCS-RI score.

CCS is critical to nations that rely on fossil fuels

The inherent interest indicator (CCS-CI) uses a range of data on fossil fuel production and demand to determine a relative measure of a nation's economic dependence upon fossil fuels. Countries that produce and/or consume the largest quantities of fossil fuels such as Australia, Canada, China, Germany, India, Indonesia, Russia and the United States have the highest reliance on fossil fuels and the highest CCS-CI scores. CCS is most critical for these nations to protect their economies from the potential deleterious impacts of pursuing deep emission reductions.

Other nations which score highly in the CCS-CI include Brazil, Mexico, Republic of Korea and Poland. CCS is very important to these nations to reconcile the tension between emission reduction and their current dependence on fossil fuels. Of significant concern are the countries with a high CCS-CI score and low CCS-RI score. These nations, which include India, Indonesia, Russia and Thailand have economies that are heavily dependent on fossil fuels but have done relatively little to prepare for the deployment of CCS. They are at greatest risk of suffering significant economic damage as the imperative to reduce emissions grows.

1.0 2018 OUTLOOK

The Institute's 2018 CCS-RI assessment has identified four clear groups of nations. The process enables collective analysis and recommendations based on those country's CCS outlook. The nations are grouped by their similar CCS-RI scores, as well as comparable industrialisation, emissions, and fossil fuel intensity.

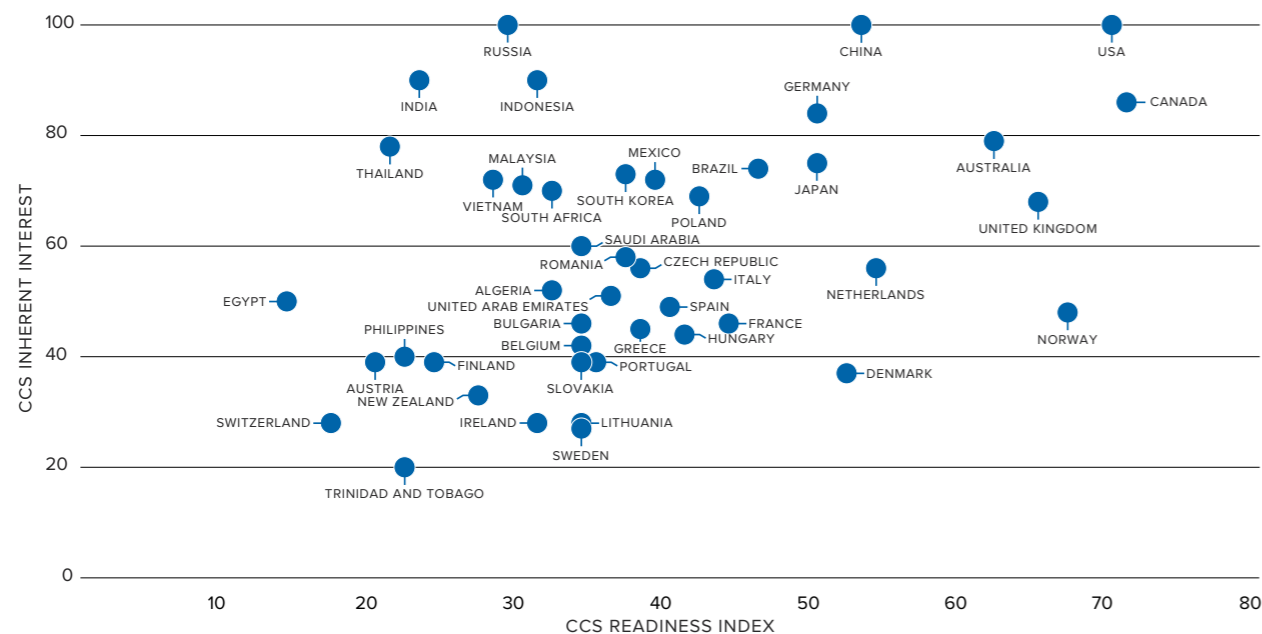
The four groups include:

1. Highest scoring: Australia, Canada, Norway, United Kingdom and the United States. These five nations are:
 - Leaders in both promoting and deploying CCS
 - Possess robust models in all aspects of CCS
 - Require only the establishment of policy to create a business case for investment to rapidly deploy CCS for the deep decarbonisation of power and industry.
2. Progressive nations: China, Denmark, Germany, Japan and the Netherlands. These countries have made significant advancements in CCS deployment. They are now poised to exploit CCS to meet their national climate change ambitions

but some gaps in legislation, policy and/or storage resource development must be addressed before broad deployment can proceed.

3. A cluster of twenty 'moderately performing' nations: predominantly European Union nations, Gulf Cooperation Council and several developing nations. This group has substantial opportunity to accelerate their CCS deployment rates but have yet to fully exploit this potential.
4. High opportunity nations: India, Indonesia and Russia possess low CCS-RI scores but have high dependency on CCS deployment. Meeting emission reduction goals and ensuring future prosperity within a carbon-constrained world will be impossible without immediate action.

Figure 2: 2018 CCS Readiness Index results. Countries are plotted against the CCS-CI



Highest scoring nations

The highest scoring countries in the 2018 assessment are Australia, Canada, Norway, the United Kingdom, and the United States. These nations have:

1. Established, long-term national or state/provincial commitments to addressing climate change and clear low-carbon energy strategies.
2. Invested in CCS for at least two decades. This includes funding initiatives and incentives that support CCS deployment.
3. Robust legal and regulatory frameworks or working towards establishing such a framework.
4. Matured their national storage resources and are taking steps in identifying commercially viable storage sites.

As a direct consequence of these conditions, this group of countries host almost all the world's large-scale CCS facilities (operating or under construction).

Canada and the United States are the highest scoring nations, scoring 71 and 70 respectively. The two nations represent most operating CCS facilities with 12 of the total 18 operating facilities. Prior to 2015, the commercial viability of these 18 facilities depended upon utilising the captured CO₂ for Enhanced Oil Recovery (EOR). However, since 2015 the investment environment for CCS in high ranking countries has proved more favourable. Climate policy, regulation, public funding and incentives have enabled CCS. The Illinois Industrial Carbon Capture and Storage Facility in the United States and Quest in Canada are examples.

Norway is the third highest scoring nation. A favourable investment environment, including a carbon value has driven the deployment of CCS as a key emissions mitigation technology. Two CCS facilities with dedicated geological storage, called Snøhvit and Sleipner are already operating, while a third facility is in advanced planning stage in Norway. The other two highest-ranking nations also have dedicated CO₂ storage facilities, which do not include EOR. The Gorgon facility in Australia is nearing operation and the United Kingdom has three projects currently in the pipeline.

When considering the Inherent CCS Interest (CCS-CI) of this group:

- The United States receives the maximum score and is followed closely by Canada and Australia. These three nations continue to depend heavily upon fossil fuels in consumption and production.
- The United Kingdom receives an average score from the CCS-CI.
- Norway has a low CCS-CI score, due to their mostly fossil-free power generation.

When comparing the 2018 results to those of the 2015 assessment, key changes include:

- Norway has significantly improved its performance due to positive policy announcements. The funding of the Norway Full Chain CCS Facility has proven a critical aspect of this development.
- The United States has witnessed a slight regression in its broader climate policies. This is countered by the additional tax incentives for CO₂ storage, provided under modifications to the existing 45Q tax credit.
- The United Kingdom's lower score is due to the removal of public funding, but is countered by:
 - New funding (albeit at a reduced level).
 - Improved policy environment resulting in the Teesside Collective and Caledonia Clean Energy facility announcements.
- Australia and Canada's scores remain unchanged.

Well-advanced and primed to deploy

A further group of nations includes China, Denmark, Germany, Japan and the Netherlands. These high scoring countries are well-advanced and, save for Germany, are preparing for the deployment of CCS. These countries have a strong potential to rapidly advance the deployment of CCS, however, their slightly lower scores reflect a weaker performance in one of the indicators. As shown in the highest scoring nations above, a strong score across all indicators is required to create a favourable environment for CCS deployment.

China and Japan are currently taking significant steps towards CCS deployment and both countries have improved their scores in comparison to the 2015 CCS-RI results. China has seen notable CCS policy improvements, including:

- Significant advancements in storage characterisation.
- Completing a national, standardised, high-detailed assessment for storage suitability.
- A decade of test injections.
- The Yanchang CCS Facility entering the construction phase.
- Several other projects progressing through their deployment timeframes.

Improvements to national CCS policy settings, project deployment, and ongoing storage characterisation has also enhanced Japan's overall score in the 2018 assessment. The Tomakomai CCS Demonstration project became operational and the Mikawa demonstration plant is now under construction. Japan is also completing an ambitious national offshore assessment which includes acquiring subsurface data to characterise the basins in Japan's offshore waters. There have also been favourable policy decisions around the role of CCS in future energy scenarios in Japan.

The Netherlands has also scored highly in the 2018 CCS-RI, a reflection of the nation's promising policy developments in late 2017. CCS is now viewed as a critical technology to help the Netherlands achieve its domestic emissions reduction goals. The renewed positive messaging around the technology led to the announcement of the Port of Rotterdam CCS project.

Germany is also a high scoring nation but has not improved its score since 2015. The country has ceased any real progress on CCS and national policy and regulatory statements have been largely negative. Germany retains a high score by virtue of earlier CCS developments.

Denmark is a new country added to the 2018 CCS-RI. Notably, the nation is a strong performer in the legal and regulatory assessment.

Moderately performing nations

The third grouping of nations is represented by a cluster of 20 countries, which possess moderate CCS-RI scores and moderate CCS-CI scores. The group is similar to the 2015 assessment and is demonstrative of a period of inertia amongst these nations.

In most instances, national scores are a result of weaker policy settings. The nations within the cluster are predominantly European Nations and the domestic implementation of broader EU initiatives (e.g. the EU storage Directive, EU Emissions Trading Scheme, CO₂StoP EU-wide storage characterisation study) are typically the reason for these countries' moderate scores. Few EU nations in this group have national CCS initiatives. The obvious recommendation is for those nations to build on existing frameworks in:

- Storage site identification.
- National policy.
- Domestic and European regulatory frameworks.

The group of moderate scoring nations also includes several countries with high emissions, including: Saudi Arabia, United Arab Emirates, Malaysia, South Korea, Vietnam, Brazil, Mexico and South Africa. Collectively, all these nations have yet to create a policy environment to encourage investment in CCS, nor have they developed their regulatory and legal frameworks to enable its deployment. It must be noted, that while Brazil, Saudi Arabia and the United Arab Emirates all currently have active CCS facilities, it is CO₂-EOR which is the commercial driver for these CCS facilities.

High opportunity

India, Indonesia and Russia have significant opportunity for CCS deployment. These nations have very high CCS-CI and equally low CCS-RI scores. They would benefit significantly from the deployment of CCS, but are not taking the necessary steps to advance deployment at the required rate.

The same three nations were found to be high opportunity countries in the 2015 assessment. However, to-date only Russia has improved its score. Russia's improvement is the identification of existing storage studies and experience in CO₂ storage.

In order to advance their position, the three nations should focus their efforts on:

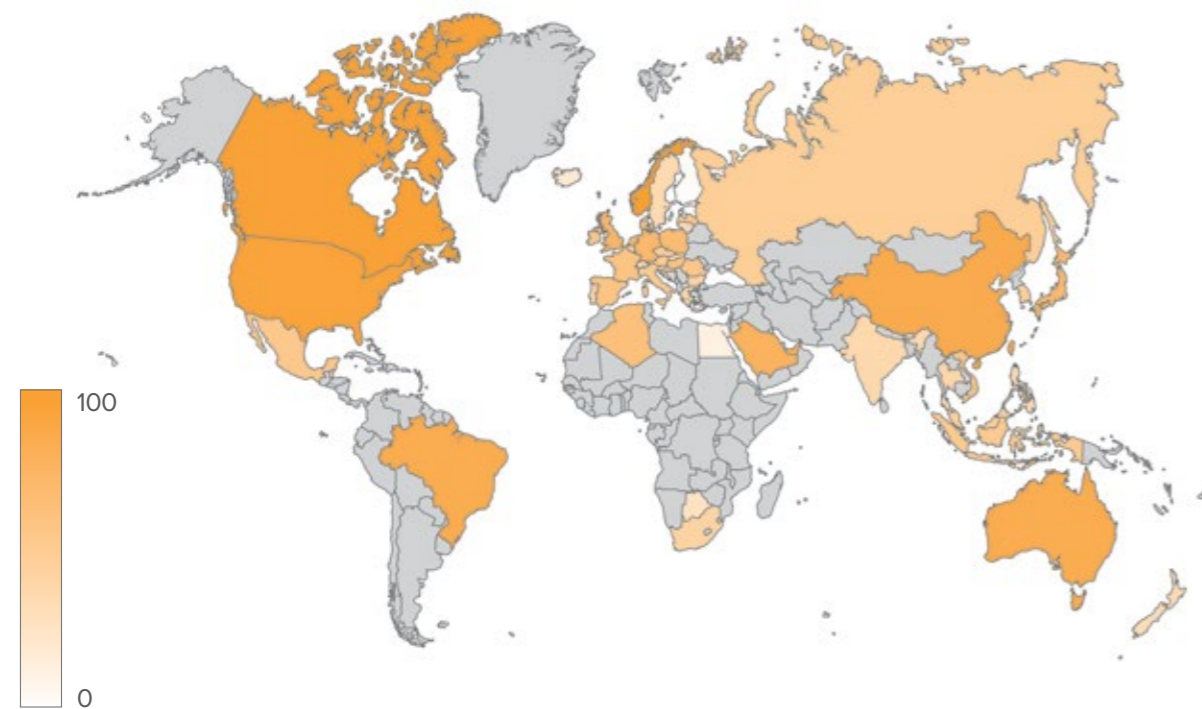
- Developing favourable policy settings to support the deployment of CCS.
- Undertaking national storage characterisation studies.

2.0 STORAGE

Knowledge is building, but development is slowing.

The Global CCS Storage Indicator (CCS-SI) evaluates each country's geological storage potential and the maturity of their storage assessments. It also tracks the progress of CO₂ storage project deployment and large scale CCS facilities. The Institute refers to this assessment as "storage readiness".

Figure 3. CCS Storage Indicator 2018



The results of the CCS-SI 2018 suggest:

- CO₂ storage knowledge continues to grow. Many countries have improved their understanding of the subsurface and domestic CO₂ storage potential. Overall scores have improved accordingly.
- Canada, Norway, and the United States have the highest scores and are prepared for wide-scale deployment. With the addition of the next nine high scoring nations, there is high confidence in the world's global storage resource potential.
- The development of storage resources and site characterisation globally is slowing. Fewer storage assessments have been completed than in the previous decade.

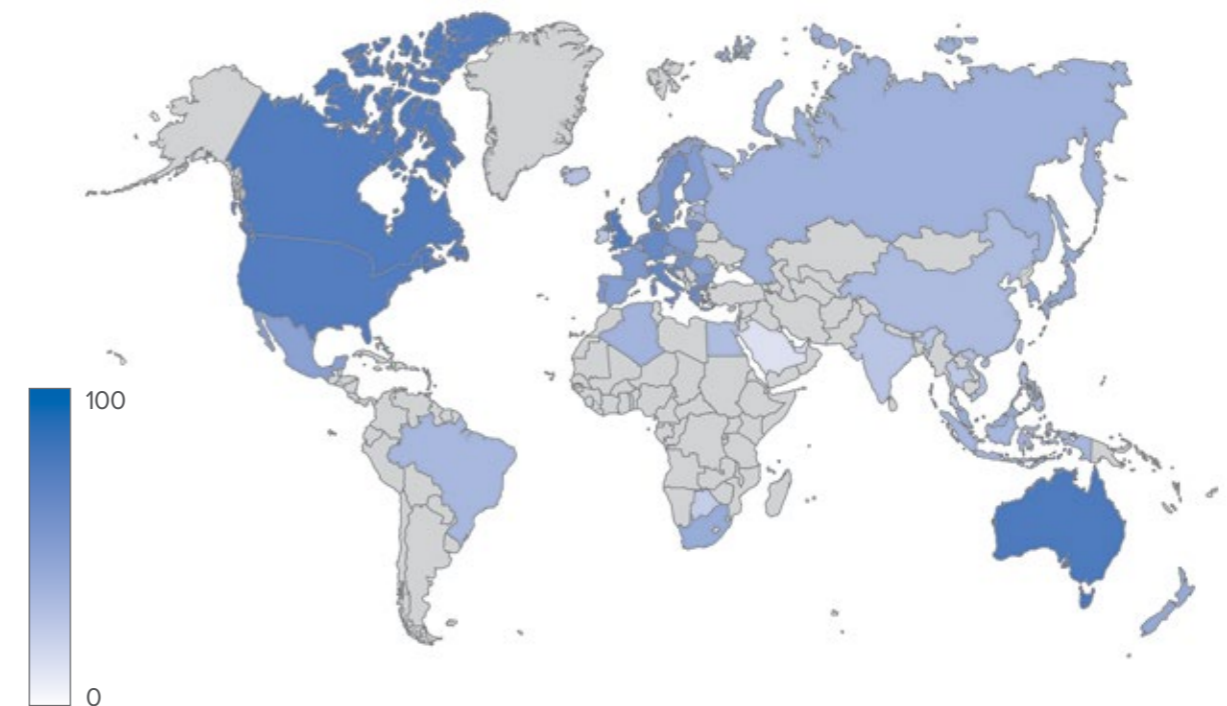
Further details are available in the Institute's 2018 CCS-SI.

3.0 LAW AND REGULATION

A greater level of development is required to build on global progress.

The CCS Legal and Regulatory Indicator (CCS-LRI) offers a detailed examination and assessment of national legal and regulatory frameworks, by considering a range of legal and regulatory factors likely to be critical for the domestic regulation of CCS operations. The CCS-LRI focuses upon a broad spectrum of administrative and permitting arrangements across the project lifecycle, including issues related to environmental assessment, public consultation and long-term liability.

Figure 4. CCS Legal and Regulatory Indicator 2018



The CCS-LRI 2018 review reveals that:

- Australia, Canada, Denmark, UK and the United States remain the only nations with CCS-specific laws or existing laws that apply to most parts of the CCS project lifecycle.
- The majority of countries possess limited or very few CCS-specific or existing laws applicable across aspects of the CCS project lifecycle.
- The absence of CCS policy drivers in many jurisdictions worldwide, suggests that there are few incentives to enhance legal and regulatory regimes.
- Existing legal and regulatory regimes may offer a strong foundation for the further development of CCS-specific models.

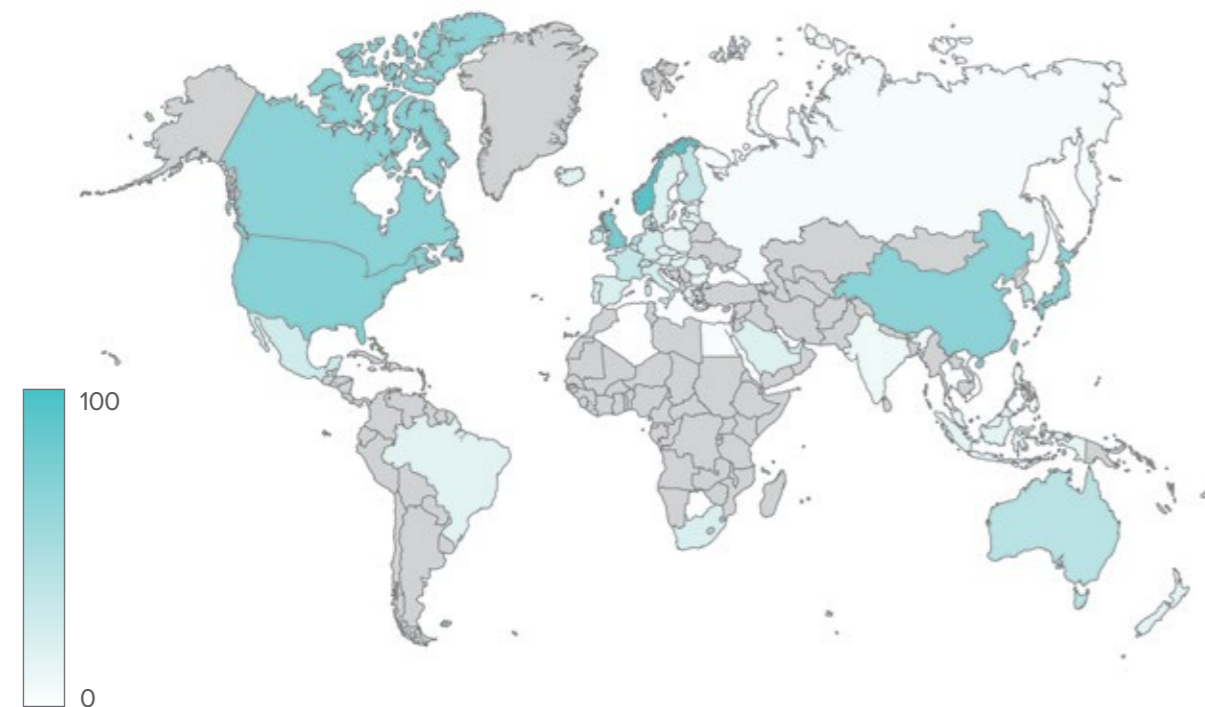
Further details are available in the Institute's 2018 edition of the CCS-LRI.

4.0 POLICY

Policy is a strong driver of deployment, but greater action is required.

CCS Policy Indicator (CCS-PI) assesses the CCS-specific policy measures of national and sub-national governments. The assessment includes direct support for CCS and the CCS-PI also includes broader implicit support through measures such as emission reduction targets, carbon pricing and research or project funding.

Figure 5: CCS Policy Indicator 2018



The CCS-PI 2018 assessment finds:

- Norway is the highest-ranking country by a significant margin. The nation's position in the Index is demonstrative of government and industry's sustained commitment to CCS. Recent government announcements highlight the strong institutional support for the technology. A range of critical supportive measures including carbon taxes, research and project feasibility studies are underway.
- The United Kingdom, USA, China, Canada and Japan follow Norway to make up Band A. There is strong evidence that these nations are committed to CCS. This commitment enabled the Teesside and Acorn projects in the United Kingdom. Policy support allowed China to become the world leader in the number of large-scale CCS facilities in various stages of planning and construction.
- Countries with higher index scores have developed long-term, clear and targeted support mechanisms for CCS and are generally leaders in climate policy and regulation.
- The majority of countries were found to have very few or no CCS-relevant policies. In many instances, the scores awarded to countries are only by virtue of national climate change initiatives.

Further details are available in the Institute's 2018 CCS-PI.

5.0 INHERENT CCS INTEREST

Nations with high inherent CCS interest are moving forward.

The Inherent CCS Interest Indicator (CCS-CI) is a relative index based on a nation's global share of fossil fuel production and consumption. It provides one indication only (among many possible methods) of a nation's economic dependence upon fossil fuels and their need to implement CCS to reduce greenhouse gas emissions. The CCS-PI and indeed all indicators are compared to the CCS-CI. The hypothesis for this approach is that countries with a higher "inherent interest" should place a higher priority on CCS deployment and be more advanced in driving deployment. The most advanced countries will have done more to establish appropriate policy environments and legal frameworks, and to identify and assess geological storage resources.

Figure 6: Inherent CCS Interest Indicator 2018



The CCS-CI 2018 assessment finds:

- China, India, Indonesia, Russia and the United States are the highest scoring nations. They are recognised as nations inherently dependent on CCS to meet emission reduction goals due to their fossil fuel dependency.
- The majority of nations that score high (greater than 75) contribute significantly to the world's emissions. Many have also invested in CCS. Those countries have often identified CCS a key technology for their low emissions future.
- The CCS-CI's methodology readily identifies nations that could potentially benefit from CCS to mitigate carbon risk and associated loss of economic activity in key industries.

The CCS-CI is part of the analysis of the Institute's 2018 CCS-PI.

6.0 METHODOLOGY

All four indicators score an individual country's performance against a series of criteria. The CCS-RI is created through the compilation and normalisation (out of 100) of the final scores for each country in each of the three indicators. It should be noted, that the underlying dataset reflects the status of each country as of late 2017/early 2018 and a country's score can change dramatically, particularly in the policy and regulatory space.

Herein we present a summary of the four individual sub-indicators:

- STORAGE READINESS INDICATOR** — The Global Storage Readiness Assessment (CCS-SI) examines each nation's ability to deploy multiple, large-scale storage projects. The basis of the final score is a series of criteria that encompass all geological and technical aspects that could impact a storage project within the borders of that country. Criteria used in the assessment include the geology, the maturity of storage assessments and the technical ability to store CO₂.
- LEGAL AND REGULATORY INDICATOR** — The CCS Legal and Regulatory Indicator (CCS-LRI) provides a detailed assessment of each country's CCS-specific legal and regulatory regime. The basis for the final scores is the detailed examination and assessment of a country's national legal and regulatory frameworks, which are critical to the regulation of CCS. Assessment criteria examine a country's environmental assessment, public consultation and long-term-liability regimes.
- CCS POLICY INDICATOR** — The CCS Policy Indicator (CCS-PI) draws from an extensive Institute database of policy measures for a wide range of countries. The assessment considers direct support for CCS, as well as broader implicit support through measures such as carbon pricing.
- CCS INHERENT INTEREST** — The CCS Inherent Interest Indicator (CCS-CI) represents a country's reliance on the burning of fossil fuels either in production or consumption within the country or as an export product. The maturity of a country's oil, gas and coal resources and development are also part of this assessment. This indicator is published with the CCS Policy Indicator.

7.0 APPENDICES

COUNTRY ¹ In alphabetical order	TOTAL 2018 SCORE Out of a possible 100	MOVEMENT From 2015 assessment score
Algeria	34	▲
Australia	62	-
Austria [^]	20	New entrant
Belgium	34	New entrant
Botswana	16	New entrant
Brazil	43	▼
Bulgaria	34	▲
Canada	71	-
China	53	▲
Croatia*	44	New entrant
Czech Republic	28	New entrant
Denmark	52	New entrant
Egypt	14	▼
Estonia	15	New entrant
Finland	24	New entrant
France	44	▼
Germany	50	-
Greece	38	New entrant
Hungary	41	New entrant
Iceland	19	New entrant
India	23	▲
Indonesia	31	-
Ireland	31	New entrant
Italy	43	-
Japan	50	▲
Latvia	33	New entrant
Lithuania	34	New entrant

COUNTRY ¹ In alphabetical order	TOTAL 2018 SCORE Out of a possible 100	MOVEMENT From 2015 assessment score
Luxembourg	24	New entrant
Malaysia	30	-
Malta	24	New entrant
Mexico	39	▼
Netherlands	54	▼
New Zealand	27	▼
Norway	67	▲
Philippines	22	New entrant
Poland	42	▲
Portugal	35	New entrant
Romania	37	▲
Russia	29	▲
Saudi Arabia	34	▲
Slovakia	34	New entrant
Slovenia	30	New entrant
South Africa	32	▼
Republic of Korea	37	▼
Spain	40	▲
Sweden	34	▼
Switzerland [^]	17	New entrant
Thailand	21	New entrant
Trinidad and Tobago	22	▲
United Arab Emirates	36	▲
United Kingdom	65	▼
USA	70	▼
Vietnam	28	New entrant

¹ Croatia is not included in the original database used to formulate the CCS-CI.

² Country has banned the injection of CO₂ and given an LRI score of 0.

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