



Role of CCS in the Energy Transition

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Role of CCS in the Energy Transition



- This latest ERM policy study for the oil& gas industry Carbon Capture Project (CCP) was published in September 2018.
- The report is on the Carbon Capture Project website.
- The report covers CCS in:
 - Nationally Determined Contributions (NDCs)
 - Mid-Century Strategies (MCSs)
 - Transition scenarios including:
 - IEA 2DS
 - IEA Sustainable Development Scenario
 - MIT research
 - Global Energy and Climate Outlook (GECO) 2015
 - Deep Decarbonisation Pathways projects
 - The public domain



*Role of CCS
in the Energy Transition*
April 2018





CCS IN NDCS, MCSS AND OTHER LONG- TERM PLANS



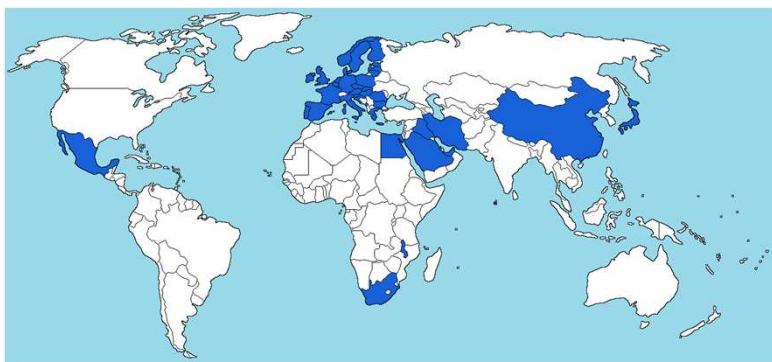
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CCS in Nationally Determined Contributions



163 parties have submitted nationally determined contributions (NDCs) to the UNFCCC, only 13 countries and the EU on behalf of its 28 member states have mentioned carbon capture and storage:

- Bahrain
- China
- Egypt
- Iran
- Iraq
- Japan
- Malawi
- Mexico
- Montenegro
- Norway
- Saudi Arabia
- South Africa
- United Arab Emirates
- The EU



Countries with NDCs mentioning CCS are shown in dark blue



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CCS in Nationally Determined Contributions



Topic included in NDC	Number of Countries	Countries	Comments
R&D or technological needs	4	China, Iran, Malawi, Saudi Arabia	China and Saudi Arabia aim to invest in R&D, while Iran says CCS could address its technological needs. Malawi needs better technology to install CCS.
Investment required	3	Iran, Malawi, South Africa	All three countries state that investment is required for CCS to be successful
Cost of CCS	2	Iran, South Africa	These two countries attempt to estimate the cost needed to install CCS in their country, US\$0.45 billion for South Africa, whilst Iran estimate up to US\$52.5 billion for their 6 plans to be introduced, but do not mention an individual CCS cost
Importance of CCS for tackling Climate Change	3	Egypt, Iran, Norway	Egypt claim CCS is essential, Iran state it has high potential, while Norway class CCS as a priority in their NDC.



- Egypt, Iran and Norway stress the importance of CCS for tackling climate change
- There is a need for research and development and/or investment for CCS to be implemented according to the NDCs of China, Iran, Malawi and Saudi Arabia
- South Africa estimates CCS will cost them US\$0.45 billion

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CCS in Nationally Determined Contributions



Topic included in NDC	Number of Countries	Countries	Comments
Mention specific projects	3	Bahrain, Saudi Arabia, UAE	Bahrain: BAPCO Carbon Recovery Plan and GPIC Carbon recovery plan. Saudi Arabia: Enhanced Oil Recovery project. UAE: project relating to steel industry and enhanced oil recovery
Other benefits of CCS addressed	2	Saudi Arabia and UAE	Both these countries talk about the potential economic benefits and the opportunities for enhanced oil recovery
Aims to be leading countries for CCS	2	Saudi Arabia and UAE	Saudi Arabia wants to build the world's largest CCS plant, while UAE wants to build the region's first commercial-scale network for CCS
Minimal coverage of CCS	5	EU, Japan, Malawi, Mexico or Montenegro	These countries only mention CCS as an option within certain sectors or for mitigation without giving much further detail



- 5 parties have minimal coverage of CCS in their NDCs, but they are only small references; otherwise the EU and Mexico give more detail in their MCS
- The Middle Eastern countries are aiming to be leading countries for CCS, mentioning specific projects and discussing other benefits including CO₂ EOR

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Mid-Century Strategies



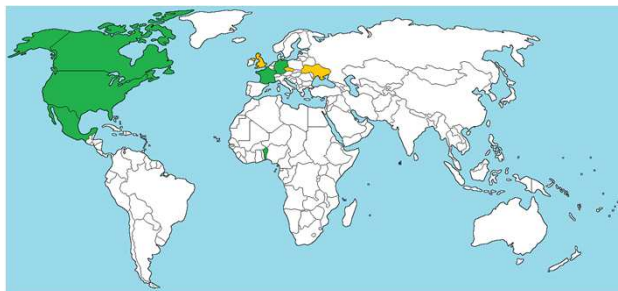
Under the UNFCCC Paris Agreement (COP21), Parties should strive to create a long-term plan, or a mid-century strategy for addressing climate change

At the time of publication, the following countries had submitted MCSs to the UNFCCC:

- Benin
- Canada
- France
- Germany
- Mexico
- USA

Since publication the following countries have also submitted MCS:

- Ukraine
- UK
- Czech Republic



World map showing countries who have submitted a MCS and are included in the report in green, and countries who have since submitted a MCS in orange



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Summary of CCS in MCSs and Roadmaps



	Used Scenarios	Values for CCS	Barriers
Canada	✓	Reduction of 23 Mt CO ₂ e by 2050, 17% energy production in 2050 from gas CCS and 2% from coal CCS	Investment, Infrastructure
France			Investment, R&D
Germany			R&D
USA	✓	Reduction of 40 Mt CO ₂ e by 2030	Investment, R&D
Mexico	✓		R&D
Benin			
EU	✓		Investment, R&D
NW Europe			Investment, Public opinion
China		20% energy production from fossil fuel usage with CCS	

- Only 4 documents identified scenarios for how to reach their 2050 goal
- Only 3 reported values for savings or reductions from CCS
- Most of the MCSs and roadmaps discussed possible barriers to CCS implementation



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UK Clean Growth Strategy

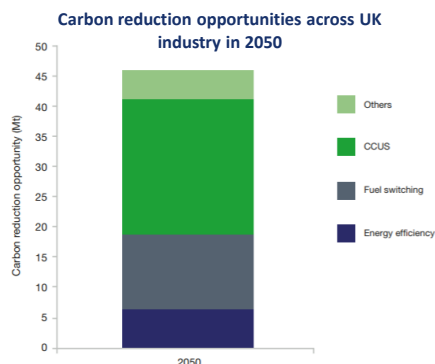


The following MCS is not included in the latest CCP report

UK

Goal: at least 80% reduction in emissions by 2050 compared to 1990

- UK will invest a further £10 million in CCUS through UK's £60 million international CCS programme,
- Main focus on Industry emissions
- 3 scenarios are used, one does not include CCS
 - Hydrogen scenario – with CCS
 - Hydrogen production is approx. 700 TWh in 2050, with Steam Methane Reforming and CCUS being the primary generation method.
 - The role for CCUS in this pathway is greater than the other pathways with **over 170 MtCO₂e being captured and stored in 2050.**
- Need to continue to bring down the costs to ensure UK can deploy CCS at scale during the 2030s



The above graph was produced by the UK government as part of the *Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050*. CCS in this pathway has a carbon reduction potential of **over 20 Mt**

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Other Long Term Plans



- 80% reduction in emissions by 2050
- "Almost impossible without 95-100% decarbonisation of the power sector"
- 3 main pathways in the roadmap, CCS for power generation was required in all – doesn't state quantity**
- All pathways include CCS to reduce industrial emissions



China: CCS Roadmap



- Main focus on coal
- Only available technology to cut 90% of CO₂ emissions from large industrial processes and power plants
- CO₂-EOR is "inevitable to maintain economic viability of oil fields"
- By 2030, CCS is expected to result in 40 Mt CO₂e a year in emission reductions**
- After 2030 expected cost reduction and carbon pricing will enable wider application of CCS

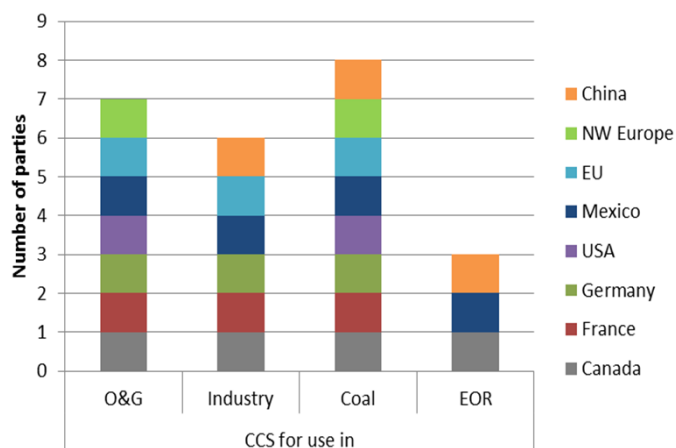
Climate and Energy Roadmaps



- Report by PBL Netherlands Environment Assessment Agency in 2012
- Considered essential to Netherlands and the UK**
- An additional or secondary option in Germany and France
- Possible importance for coal and steel in Belgium
- Denmark mention CCS in combination with biomass

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CCS in MCSs and Roadmaps



- All documents covered CCS for coal
- Only China didn't cover the O&G industry
- China, Mexico and Canada discuss EOR
- NW Europe and the US do not cover CCS for industrial uses



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Energy Transition Scenarios



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Deep Decarbonisation Pathways Project (DDPP)



- The DDPP looks at how countries can limit global temperature rise to 2 degrees.
- 13 of 14 country reports released in 2015 included CCS
- 10 of the 13 quantified values for CCS in their scenarios
- This study expects CCS to be present in 10% of electricity production capacity in 2050

Country	Findings on CCS
Australia	- Up to 21% of electricity supply with CCS in 2050 (9% gas, rest is coal) - CCS will capture 25-50% of emissions from non-energy sectors by 2050
Canada	- 23 Mt CO ₂ e captured and stored by 2050
China	- In 2050, CCUS is projected to annually remove 2737 Mt CO ₂ (1867 Mt CO ₂ from the power generation sector and 807 Mt CO ₂ from industry emissions) - Accumulated CO ₂ capture is approximately 27 Gt CO ₂ between 2010 and 2050
France	- By 2050, about 10 Mt CO ₂ will be stored annual using CCS, equating to 20% of gas and 40% of coal consumed
Germany	- 57 Mt CO ₂ captured from industrial sector in their 90% GHG reduction scenario by 2050
India	- 7099 to 9929 Mt CO ₂ captured depending on the scenario (mainly coal) by 2050
Indonesia	- Power supply in 2050 in renewable and CCS scenario: 19% coal with CCS and 18% natural gas with CCS
Japan	- Decarbonisation in power sector "notably thanks to large deployment of CCS" approximately 97% reduction in carbon intensity of electricity from 2010 level by 2050
UK	- 318 Mt CO ₂ captured between 2033 and 2050 in the industrial sector
US	- In the mixed scenario, 12.2% of electricity generation is from natural gas with CCS - In the high CCS scenario, 26.3% of the supply is from gas with CCS, 28.6% is from coal with CCS

Captured quantities of CO₂:

- Canada: 23 Mt by 2050
- China: 2737 Mt/year
- France: 10Mt/year
- Germany: 57 Mt by 2050
- India 7099-9929 Mt by 2050
- UK: 318 Mt by 2050

Expected contribution of CCS to electricity supply:

- Australia: 21%
- Indonesia: 37%
- US: 12.2-54.9%

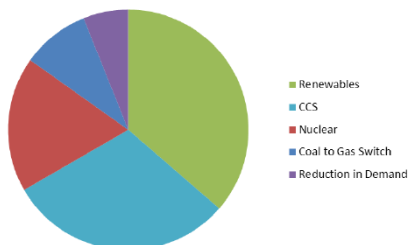


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GECO: CCS must account for 23% reductions in a 2DS



- Global Energy and Climate Outlook (GECO) report in 2015 by the Joint Research Centre (an EU academic consortium)
- Assessment of countries' ability to reach 2 degree goal
- On a global scale CCS account for 7% of total reductions by 2030, but increasing to **23% by 2050**
- **In this report CCS includes coal, gas and biomass**



Emission reductions expected in the power sector by 2050:

- 6% reduction in demand
- 9% fossil fuel switch from coal to gas
- 18% nuclear
- 36% renewables
- 30% CCS

In addition MIT research report "Mid Century Strategies to stay within Paris Agreement Temperature Limits" published in 2016, shows nations mid-century strategies are not accomplishing the 2DS or 1.5DS



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CCS in the IEA NPS and SDS Scenarios



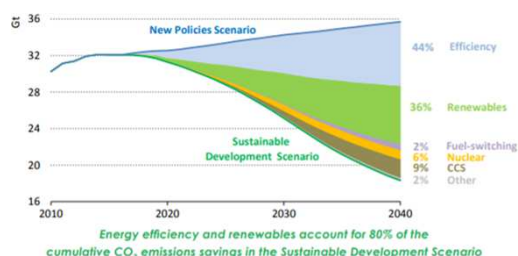
New Policies Scenario (NPS) : 2.7-3 degree outcome

Existing policies and announced intentions, which leads to a slight increase in CO₂e emissions by 2040

Sustainable Development Scenario (SDS) : 1.7-1.8 degree outcome

Aims to achieve goals relating to climate change, reducing air pollution and universal energy access security.

CCS accounts for 9% of emission reductions between the NPS and the SDS, more than 60% of this is from the power sector



SDS in 2040

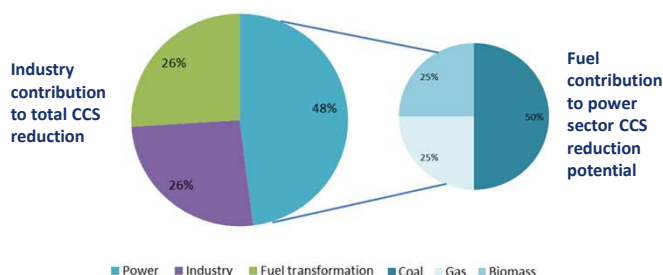
Fossil fuelled plants are progressively phased out, accounting for just 22% of total generation in 2040. Of this, almost 30% are equipped with CCS by 2040, reducing CO₂ emissions per unit of output by an order of magnitude. **Overall CCS equipped power plants supply less than 1% of electricity supply in 2040**

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CCS Deployment is not in line with IEA 2DS expansion



- IEA 2DS in 2013: CCS could deliver **16.7%** of total cumulative emission reductions needed by 2050
- Reduced to **14%** in the IEA Energy Technology Perspectives 2017
- The beyond 2 degree scenario, which has a 50% chance of limiting temperature rise to 1.75 degrees, assigned **32%** of emissions reductions to CCS
- ETP 2DS: store 400 Mt CO₂e/year by 2025, and **142 Gt CO₂e total by 2060**



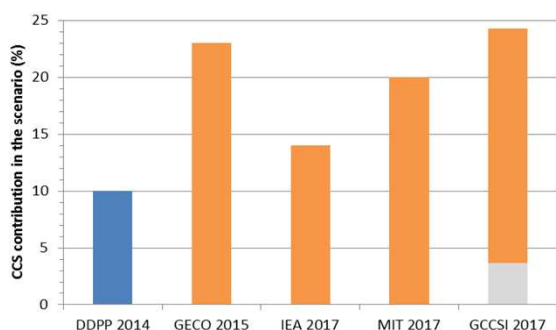
CCS contribution of **6.8 Gt CO₂** a year in 2060, in the ETP 2DS (2017), with 48% of CCS reductions from the power sector, of which 50% is for coal fired power stations.



So far, CCS deployment is not in line with this trajectory, with the IEA estimating a **10-fold expansion** to meet the 2DS by 2025

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CCS seen as significant in the Energy transition



All scenarios which include a contribution from CCS to reach a 2 degree scenario, have CCS accounting more than 10%, therefore CCS is expected to play a substantial role in the future



- The IEA 2DS expects CCS to account for 14% of carbon reductions against the reference transition scenario
- In addition, 13 of 14 DDPP country scenarios include CCS
- The International Energy Agency, Massachusetts Institute of Technology, Intergovernmental Panel on Climate Change, Global CCS Institute, Deep Decarbonization Pathways Project, and others have all projected the need for CCS in order to achieve the Paris Agreement goals

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Conclusions



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Conclusions of ERM's report for CCP



- **Current NDC commitments are not enough to reach a 2 degree goal**, therefore, there is an emissions gap which requires added responses such as CCS.
- **CCS is hardly mentioned or described in the discussion of potential policy developments** by the nations of the world. Those handful of nations that do mention CCS do so with extensive **discussion about barriers** to investments in CCS projects including the cost of CCS, the lack of finance and the lack of implementation of government policies and incentives.
- This points to **the critical need for the rapid scale-up of CCS in the coming decades** which has yet to begin. The pipeline of major CCS projects has dried up in recent years and no new significant CCS projects are being developed
- Further, because of costs and a range of issues from lack of policy framework, policy uncertainty, public perception, and potential long-term storage site stewardship issues, some business leaders in a World Energy Council survey have expressed negative sentiments about the prospect of deploying CCS.
- These difficult challenges point to a **fundamental gap** between the ambitious goal of the Paris Agreement and the reality of deployment of CCS projects.
- **All scenarios which include a contribution from CCS to reach a 2 degree scenario, have CCS accounting more than 10%, thereby CCS is expected to play a substantial role in the future**



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Barriers to CCS cited in sources related to long-term climate change strategies



"Lack of economic capture technology and infrastructure to connect carbon source with sequestration formations" and CCS "will require **significant investments** and pipeline network construction" as well as "more **technological advances** to make CCS economic". (Canada)

"Will require defining further steps in implementation no later than 2020-2030", therefore Germany aims to commence "immediate major **research and development** work targeted to specific process innovations and to CCU". CCS has a "potential role" if it turns out to be "necessary and acceptable". (Germany)

Lack of "interested **investors**" and **public resistance** (PBL NL)

Concerns over "**long term storage**" (EU)

CCS will involve "taking account of the **storage options** available when choosing where to locate facilities". The point of **cost** is raised, with France aiming to make CCS economically viable through **research and innovation** (France)

"It is not widely due to **high costs and the lack of sufficient market incentives**. Without further innovation and additional policies that drive down emissions, (USA)



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IEA recommends 7 actions in its CCS roadmap



In order for CCS to meet the 2 degree goal, the following key actions before 2020 have been identified by the IEA in their CCS roadmap:

1. "Introduce **financial support mechanisms** for demonstration and early deployment of CCS to drive private financing of projects
2. Implement policies that **encourage storage exploration**, characterization and development for CCS projects
3. Develop national **laws and regulations** as well as provisions for multilateral finance that effectively require new-build, base-load, fossil-fuel power generation capacity to be CCS-ready
4. Prove capture systems at **pilot scale in industrial applications** where CO₂ capture has not yet been demonstrated
5. Significantly increase efforts to **improve understanding among the public and stakeholders** of CCS technology and the importance of its deployment
6. **Reduce the cost** of electricity from power plants equipped with capture through continued technology development and use of highest possible efficiency power generation cycles
7. Encourage efficient development of CO₂ transport infrastructure by **anticipating locations of future demand centres** and future volumes of CO₂."



2020

- At least 30 projects
- 50 Mt CO₂e/year stored

2030

- Routine usage in power sector
- 2000 Mt CO₂e/year stored

2050

- Routine usage in all sectors
- 7000 Mt CO₂e/year

US\$2.5-3 trillion investment needed between 2010-2050

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Future Work



Despite these challenges, the ERM report for CCP also points out that even if nations did not mention CCS in their nationally determined contributions or included CCS in a mid-century strategy, considering **CCS could still help these nations to reduce emissions significantly.**

- Some of the possible ways to **promote CCS** as an energy transition solution may include, but will not be limited to:
 - ☐ More information on CCS to address concerns of stakeholders and governments
 - ☐ More analysis to address outstanding issues or lack of awareness regarding CCS
 - ☐ More analysis and measures to address costs and benefits of CCS
 - ☐ More analysis and measures to address reliability, permanence and storage potential of CCS

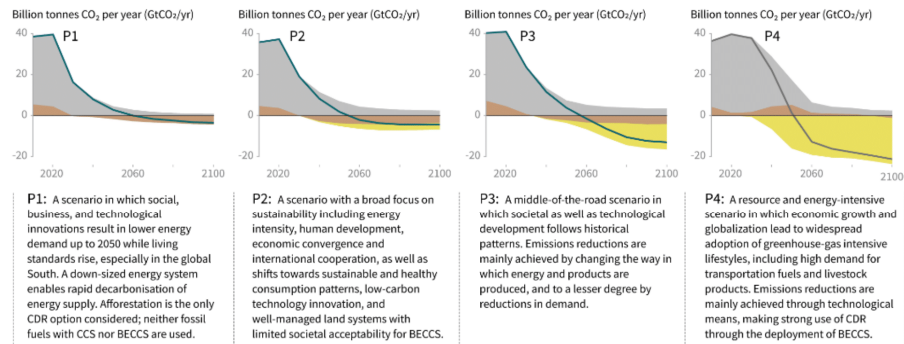


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SPM3b | Characteristics of four illustrative model pathways

Breakdown of contributions to global net CO₂ emissions in four illustrative model pathways

● Fossil fuel and industry ● AFOLU ● BECCS



ipcc

INTERGOVERNMENTAL PANEL ON climate change



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Thank you

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Additional Slides for Reference



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Other CCS Research Results



Organisation name	Sources	CCS context	Energy transition (Y/N)
World Bank	Several reports published by the WBG and in partnership with other bodies	Past technical assessment on deployment. Now in the context of low-carbon goals	Y
World Energy Council	Annual report on the main issues facing the energy industry; based on a survey of 1200 energy leaders	The importance of CCS has been steadily moving down the agenda and its future is perceived as uncertain	N
IEA	2016 summary report on the global status of the CCS industry and technological development	CCS is an important part of low-carbon scenarios for the IEA. Industry assessment and recommendations for improving its prospects	Y
OECD	Similar to the WB, some sector-specific reports, e.g. steel industry, but also more assessment of the possible low-carbon technologies available	Work on national & international policy alignment needed to stimulate CCS investment; CCS as probably the only option available to some industrial sectors for decarbonisation	Y
GCCSI	The Global Status of CCS: 2017	A clear advocate of CCS, at times overly so, but sets out the roles CCS can play in the energy transition	Y



- The World Bank produced a report titled *Toward a Sustainable Energy Future for All* in 2017. This includes a statement to support new clean energy topics such as CCS but states CCS has had little technological progress and can be very water-intensive.
- CCS occupies a “low impact” and “uncertain” scoring on the World Energy Council agenda.
- OECD report in partnership with the Grantham Institute in 2016/17 states that CCS is one of the few options for heavy industry such as steel, cement and chemical to achieve low carbon processes

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Other CCS Research Results



Organisation name	Sources	CCS context	Energy transition (Y/N)
CDP	A recent report on technology risks in CCS deployment	Acknowledges the role of CCS in scenarios and some of the key barriers to development	Y
UK Government	Clean Growth Strategy, 2017	The UK's CCS strategy is outlined. THE UK gov. clearly sees an important role for CCS in its low-carbon pathways and will put aside funds for investment. Clearly, larger scale demonstrations are necessary before deployment can go ahead	Y
BNEF	News article by Bloomberg New Energy Finance covering CCS and BHP Billiton's plans for developing CCS	Acknowledges the role of CCS in scenarios and how a private company can take some of the lead in CCS development	Y
MIT	2016 report on critical analysis of success factors for CCS projects. Many other reports available that cover technical development	Analyses a sample of global CCS projects and gives reasons for why some have failed or succeeded. In the context that CCS will be needed to meet emissions reduction goals	Y
Imperial College	Most reports cover technical development but one 2016 report assesses the challenges currently facing CCS commercialisation	Outlines some new approaches that could be taken to promote the deployment of CCS (as necessary to meet climate goals), with a focus on the UK	Y



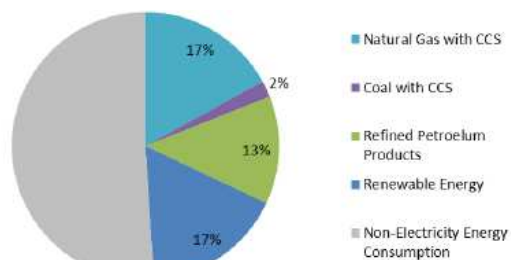
- CDP report from 2017 on CCS deployment states a carbon priced of €65-215 per metric tonne of carbon is needed to make CCS economic. However this level of pricing is not expected to develop for years
- The UK Clean Growth Strategy shows the UK commit to invest a further £10 million into the UK's £60 million international CCs programme
- The Bloomberg New Energy Finance article from 2017 states 2,000 CCS facilities are needed under IEA scenarios, with just 27 large-scale facilities operational at the time.

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Canada's MCS



- **Goal: Mid-century goal of 80% reduction in emissions from 2005 levels**
- The Canadian MCS uses 5 different scenarios to compare methods to reach its goal. Only the **Deep Decarbonisation Pathways Project – high ambition** scenario uses oil and gas CCS as a significant supplier of fuel use in 2050.
- This scenario estimated electricity will generate **48%** of energy consumption in Canada by 2050



*Values may not total 48% due to rounding.

and 2% from coal 19% of energy consumption in 2050 is expected to come from CCS, 17% from natural gas



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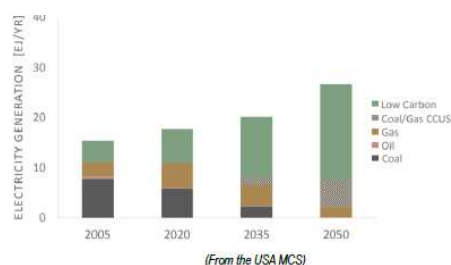
USA's MCS



Goal: 80% reduction in emissions from 2005 levels by 2050

- The USA's MCS was published to the UNFCCC on 16th November 2011, 8 days after Donald Trump was elected president. However the report is the work of the Obama administration. President Trump announced on 1st June 2017 that the USA intends to withdraw from the Paris Agreement, which would occur in November 2020, so it is unknown to what extent this strategy will be followed.
- The MCS uses a benchmark scenario, referenced throughout their report
- For the energy sector, the aim was to replace nearly all fossil fuel electricity production with renewables, nuclear and fossil fuels or bioenergy with carbon capture, utilization and storage (CCUS) by 2050
- There is also a scenario excluding CCS should the emergence of the required technology for CCS be unsuccessful

Benchmark scenario: electricity supply in 2050 would be 55% renewables, 17% nuclear and **20% CCUS with fossil fuels**.
Nearly all fossil fuels plants with CCUS would be phased out by 2050 (making up the remaining 8%)



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Mexico's MCS



Goal: Mid-century goal of 50% reduction in emissions from 2005 levels

Models used by Mexico in their MCS “rely on energy efficiency improvement and the deployment of renewable energy” which includes gas or coal with CCS in some instances.

One scenario to achieve this reduction target was through the DDPP which shows an “important role for natural gas CCS technology”. However, there are no more details about the extent of CCS or the DDPP scenario pertaining to Mexico.

Mexico has set a wide range of aims to achieve their reduction target, two of which refer to CCS.

- ✓ “To continue exploring carbon capture and sequestration (CCS) technologies aimed at the implementation of projects. This will include the possibility of using CCS for enhanced hydrocarbon recovery”
- ✓ “To promote highly efficient technologies, fuel substitution, industrial process redesign, and CO₂ capture technologies in energy-intensive industries such as cement, steel, petroleum, chemical, and petrochemical industries”

This shows that Mexico has good intentions to implement CCS in the future in a range of sectors as well as enhanced oil recovery (EOR).



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Other MCSs



France

Goal: 75% reduction of total emission in 2050 compared to 1990

- Decarbonisation by a factor of 10 of the energy mix by 2050.
- Achieving this level of decarbonisation relies on "significant deployment of carbon capture and storage systems by 2050"
- Aim to install across all fossil fuel power stations still in operation then
- No quantification of how significant the implementation of CCS will be
- France acknowledges it must deploy CCS systems by 2050
- Long term focus on CCS, in particular in the chemical industry



Germany

Goal: 80-95% reduction of total emission in 2050 compared to 1990

- CCS is considered a "new technology" for Germany
- Long term focus mainly on CCU
- CO2 emissions from the industrial sector can be reduced using CCU and could be an option for a "circular carbon economy"
- "If emissions are unavoidable, it may be necessary to lower them through long-term carbon capture and storage (CCS)"
- No definition of what Germany means by "unavoidable"

Benin

Goal: Plan only up to 2025, no obvious target

- No references to CCS

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Most Recently Published MCSs



• The following MCSs are not included in the latest CCP report



Czech Republic

Goal: 80% reduction in emissions by 2050 compared to 1990

- 8 scenarios across 3 categories have been tested
- Only the 3rd category achieves their goal, including 3 scenarios, one of which includes the development of CCS technology
- The scenarios are 'intended to be illustrative' to show that the 2050 target cannot be achieved without the combination of many different measures

Ukraine

Goal: 31-34% reduction in emissions by 2050 compared to 1990

- Refers to CCS as an option to increase power plant efficiency via enforcement envisions to ensure all or certain parts of coal power plants apply certain technology e.g. CCS or integrated gasification in combined cycle
- Recognises the need for R&D



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