DRAFT

UNECE Recommendations to UNFCC on how Carbon Capture and Storage (CCS) and CCS for Enhanced Oil Recovery should be treated in a Post-Kyoto Protocol Agreement

I. Background

A. Timeframe for Post-Kyoto Protocol Negotiations

1. The policy architecture under the UN Framework Convention on Climate Change is under discussion, with an expectation that a new agreement with supporting mechanisms could be in effect by 2020. The Ad Hoc Working Group on the Durban Platform for Enhanced Action (ADP) was established to develop a protocol, other legal instrument or an agreed outcome with legal force under the Convention, applicable to all Parties. The ADP is to complete its work as early as possible, but no later than 2015, in order to adopt the protocol, legal instrument or agreed outcome with legal force at the twenty-first session of the Conference of the Parties and for it to come into effect and be implemented from 2020. The mechanisms could provide an important source of financing and technological learning to support uptake of carbon dioxide (CO2) capture and storage (CCS).

B. Role of UNECE Committee on Sustainable Energy and Group of Experts on Cleaner Electricity Production from Fossil Fuels

2. One of the activities agreed for the United Nations Economic Commission for Europe's Group of Experts on Cleaner Electricity Production from Fossil Fuels is to assist the United Nations Framework Convention on Climate Change (UNFCCC) in assessing CCS technologies by preparing a communication to UNFCCC on the use of CCS in reducing GHGs, including recommendations to UNFCCC on how CCS, including CCS for enhanced oil recovery, could contribute to the climate change mitigation policy portfolio. The Group of Experts is working on a report containing recommendations and suggestions that will be transmitted to UNFCCC, with a request that they be given consideration as the post-2015 outcome is discussed and prepared.

II. Context for CCS

A. Needed Contribution from CCS

3. According to all credible projections and forecasts, fossil fuel use is expected to grow significantly by mid-century. Even if Western Europe and North America reduce their coal consumption, oil, natural gas and coal use in the rest of the world is certain to expand.

(i) Intergovernmental Panel on Climate Change Conversations

4. According to the IPCC Working Group III Contribution to AR5 – Summary for policymakers, fossil fuel-related CO_2 emissions reached 32 $GtCO_2$/year in 2010, which was more

than 65% of total anthropogenic GHG emissions (49 $GtCO_2$/year). Without additional efforts to reduce GHG emissions beyond those in place today, emissions growth is expected to persist driven by growth in global population and economic activities.

5. Baseline scenarios, those without additional mitigation, result in global mean surface temperature increases in 2100 from 3.7 to 4.8°C compared to pre-industrial levels. Scenarios in which atmospheric concentration levels of CO_2eq are kept to about 450 ppm by 2100 are consistent with a likely chance to keep global temperatures change below 2 °C relative to pre-industrial levels. Such scenarios oblige substantial cuts in anthropogenic GHG emissions by mid-century through large-scale changes in energy systems and potentially land use management. These scenarios are characterized both by global GHG emissions that are 40% to 70% lower globally in 2050 than in 2010 and by emissions levels that are near zero $GtCO_2eq$ or below in 2100. At the global level, more rapid improvements of energy efficiency, a tripling to nearly a quadrupling of the share of zero and low carbon energy supply from renewables, nuclear energy and fossil energy with carbon dioxide capture and storage (CCS), or bioenergy with CCS (BECCS) by the year 2050 is required.

6. Overshoot scenarios of GHG emissions reductions that keep global mean surface temperatures below 2°C could only be achieved if BECCS and afforestation are deployed widely by the second half of the century.

(ii) International Energy Agency Projections

7. According to the IEA Report "Energy Technology Perspectives - Carbon Capture and Storage" (2013), if the world is to succeed in constraining CO_2 emissions to levels consistent with a two degree rise in global temperatures, then CCS would have to contribute one-sixth of needed CO_2 emission reductions in 2050, and 14% of the cumulative emissions reductions between 2015 and 2050 compared to a business-as-usual approach.

8. Given their rapid growth in energy demand, the largest deployment of CCS will need to occur in non-OECD countries. By 2050, non-OECD countries will need to account for 70% of the total cumulative mass of captured CO_2, with China alone accounting for one-third of the global total of captured CO_2 between 2015 and 2050. OECD governments and multilateral development banks must work together with non-OECD countries to ensure that support mechanisms are established to drive deployment of CCS in non-OECD countries in the coming decades".

9. CCS is not only about electricity generation. Around 45% of the CO_2 captured between 2015 and 2050 in the two degree scenario is from industrial applications. In this scenario, between 25% and 40% of the global production of steel, cement and chemicals would have to be equipped with CCS by 2050.

10. IEA proposed seven key actions that governments would need to take over the next seven years:

- Introduce financial support mechanisms for demonstration and early deployment.

- Develop laws and regulations that effectively require new-build power capacity to be CCS-ready.
- Significantly increase efforts to improve understanding among the public and stakeholders of CCS technology.
- Implement policies that encourage storage exploration, characterization and development for CCS projects.
- Reduce the cost of electricity from power plants equipped with capture through continued technology development.
- Prove capture systems at pilot scale in industrial applications.
- Encourage efficient development of CO2 transport infrastructure.

(iii) World Energy Council Scenarios

11. The World Energy Council (WEC) scenarios (Composing Energy Futures to 2050 (2013)) considers that CCS/CCUS could play an important role after 2030 as a cost effective CO_2 mitigation option if there were a real price for CO2 emissions. The current challenges for CCUS include its technical feasibility at a large scale, public resistance and upfront infrastructure costs.

12. CCS/CCUS technology is already available and is potentially one of the lower-cost, deep decarbonization options. Nevertheless, it will add costs and will require major pipelines and other infrastructure. For CCS/CCUS to work, clear legislative frameworks, investment in infrastructure, and incentives to enable workable business models are all needed.

(iv) US Energy Information Agency Forecast

13. The US Energy Information Agency (EIA) in its report "What is the Role of Coal in the United States" (2011) emphasized that coal and natural gas will remain major sources of energy for the U.S. and global power and industrial sectors. In the United States, both coal and natural gas are in relatively abundant supply and are relatively inexpensive sources of electricity generation. In 2011, the United States generated approximately 42 per cent of its electricity from coal and 25 percent from natural gas. Globally, coal and natural gas will continue to meet growing energy demand, particularly in emerging market counties, such as China and India. From 2008 to 2012, China's total coal consumption increased by nearly 35 per cent, while India's increased by 25 percent. During that same time period, China's total natural gas consumption increased by more than 89 per cent, while India's increased by nearly 37 per cent.

14. CCS technology has the potential to yield dramatic reductions in CO_2 emissions from the power and industrial sectors by capturing and storing anthropogenic CO_2 in underground geological formations. Given the magnitude of CO_2 emissions from coal and natural gas-fired electricity generation, the greatest potential for CCS is in the power sector. The U.S. Energy Information Administration (EIA) notes that natural gas, when used in an efficient combined cycle plant, emits less than half as much CO_2 as coal. The deployment of CCS with both coal- and natural gas-fired generation is necessary to reduce global CO_2 emissions from fossil generation. In the industrial sector, CO_2 can be captured from a number of industrial processes, including natural gas processing; ethanol fermentation; fertilizer, industrial gas, and chemicals production; the gasification of various feedstocks; and the manufacture of cement and steel.

(v) Private Sector Outlooks

15. Private business sees large-scale CCS as a critical technology to reduce emissions while meeting growing energy demand. Alstom Power announced the successful operation of a chilled-ammonia CCS validation project at American Electric Power's Mountaineer Plant in New Haven, WV. The project, the world's first facility to both capture and store CO2 from a coal-fired power plant, represents a successful scale-up of ten times the size of previous field pilots. It achieved:

- Capture rates from 75 per cent (design value) to as high as 90 per cent,
- CO2 purity of greater than 99 per cent,
- Energy penalties within a few percent of modelled predictions,
- CO_2 injection levels of approximately 7,000 tons/month,
- Robust steady-state operation during all modes of operation including load changes,
- Availability of the CCS system greater than 90 per cent.

All the achievements listed above have been confirmed during long-term, steady-state operation of the CCS validation plant.

16. Royal Dutch Shell is working on CCS commercial technologies and methods for reducing its own and its customers' greenhouse gas emissions. Shell's proposed CCS Project, called Quest, will capture more than one million tonnes of CO2 per year from the Scotford Upgrader in Alberta, Canada and store it deep underground, beneath several layers of impermeable rock layers. The Quest Project will be the first CCS Project to be implemented at an oil sands upgrading operation.

17. ExxonMobil is active in the evaluation and adoption of CCS around the world. ExxonMobil believes that CCS has the potential to play an important role in managing GHG emissions, but it will require additional technological breakthroughs, fully integrated demonstration projects, regulatory and legislative support at all levels, and public acceptance. Exxon Mobil is partnering with the European Commission and other companies on the CO_2ReMoVe project that is evaluating a range of technologies to monitor the injection and storage of CO_2 from gas streams in fields around the world. Exxon Mobil also has a history of proven results in Enhanced Oil Recovery. In the United States alone, more than 11 trillion cubic feet of CO_2 have already been used in EOR projects.

B. Status of CCS Deployment in 2014-2015

18. CCS technologies can capture up to 90 percent of carbon dioxide (CO2) emissions from a power plant or industrial facility and store them in underground geologic formations. Carbon capture has been established for some industrial processes, but it is still a relatively expensive technology that is just reaching maturity for power generation and other industrial processes.

19. According to the Global CCS Institute, as of February 2014, there are 22 large-scale projects in operation or construction - a 50% increase since 2011. These have the capacity to capture up to 40 million tonnes of CO_2 per annum (Figures 1, 2 and 5). The world's first two

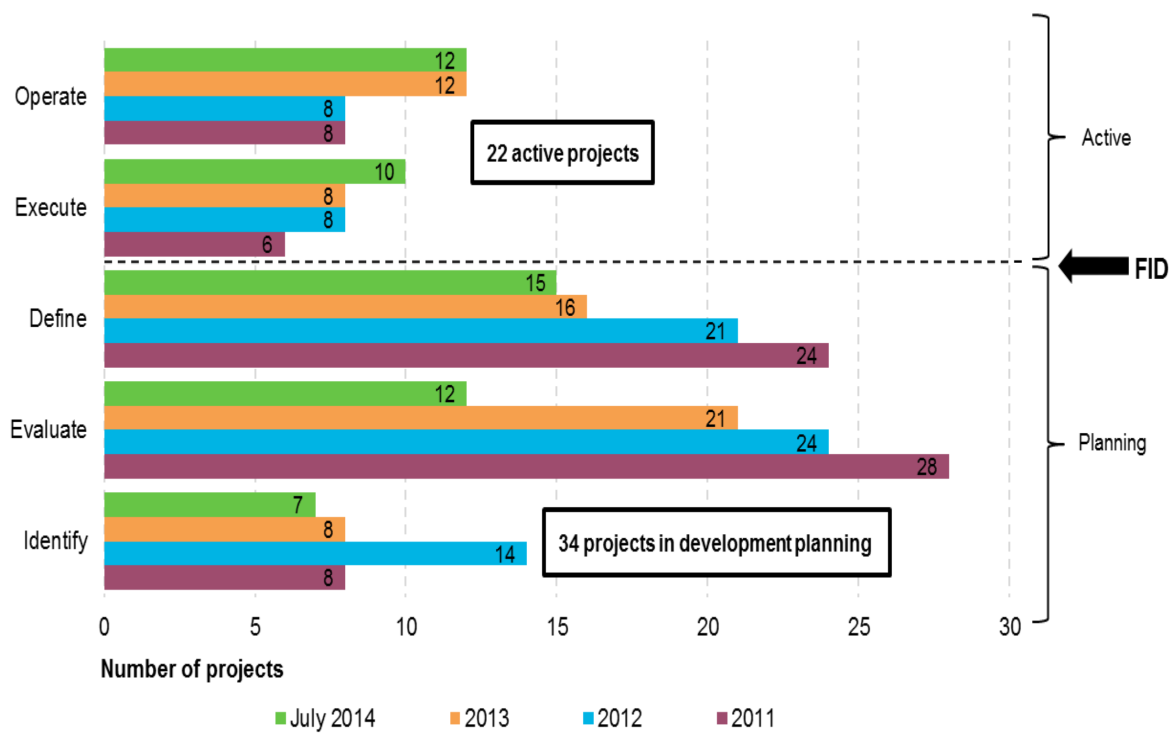
power sector projects with CCS -- Southern Company's Kemper County Energy Facility in Mississippi and SaskPower's Boundary Dam Power Station in Saskatchewan, Canada – will begin operation in 2014 and 2015. The Middle East has the world's first large-scale CCS project in the iron and steel sector under construction. China has doubled the number of CCS projects since 2011 with 12 large-scale CCS projects. In the UK, two projects have recently advanced into front end engineering design (FEED). In the rest of Europe, however, a number of projects have been cancelled or put on hold over the past year. The decline in projects on mainland Europe has largely contributed to a reduction in the number of large-scale CCS projects monitored by the Global CCS Institute to 56 (Figures 1 and 2).

20. There are twelve active commercial-scale CCS projects at industrial facilities around the world (eight of those projects are in the U.S.), and approximately 50 additional projects are in various stages of development around the world.

21. There is a growing market for utilizing captured CO_2, primarily in enhanced oil recovery (CO_2-EOR). Selling captured CO_2 provides a valuable revenue source to help overcome the high costs and financial risks of initial CCS projects.

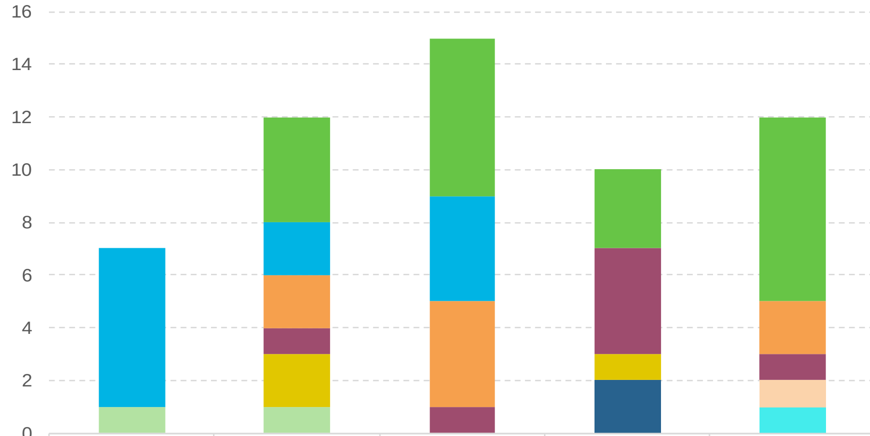
22. Annex 1 provides a list of CCS projects that have operated or that are being developed.

FIGURE 1 Large-scale CCS projects by project lifecycle and year



Source: Global CCS Institute

FIGURE 2 Large-scale CCS projects by lifecycle stage and region/country as of July 2014



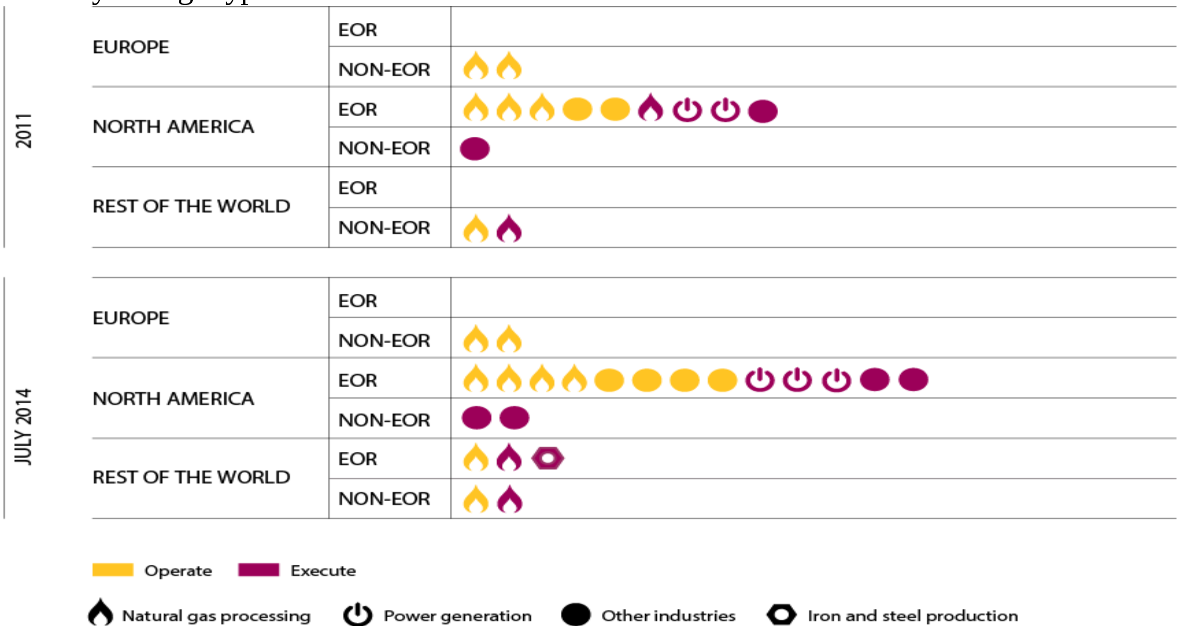
	Identify	Evaluate	Define	Execute	Operate	Total
United States	0	4	6	3	7	**20**
China	6	2	4	0	0	**12**
Europe	0	2	4	0	2	**8**
Canada	0	1	1	4	1	**7**
Australia	0	2	0	1	0	**3**
Middle East	0	0	0	2	0	**2**
Other Asia	1	1	0	0	0	**2**
South America	0	0	0	0	1	**1**
Africa	0	0	0	0	1	**1**
Total	**7**	**12**	**15**	**10**	**12**	**56**

Source: Global CCS Institute

23. In 2014, there were a number of important national and regional policy, legal and regulatory developments, with an emphasis on CO_2 emissions standards and targets:

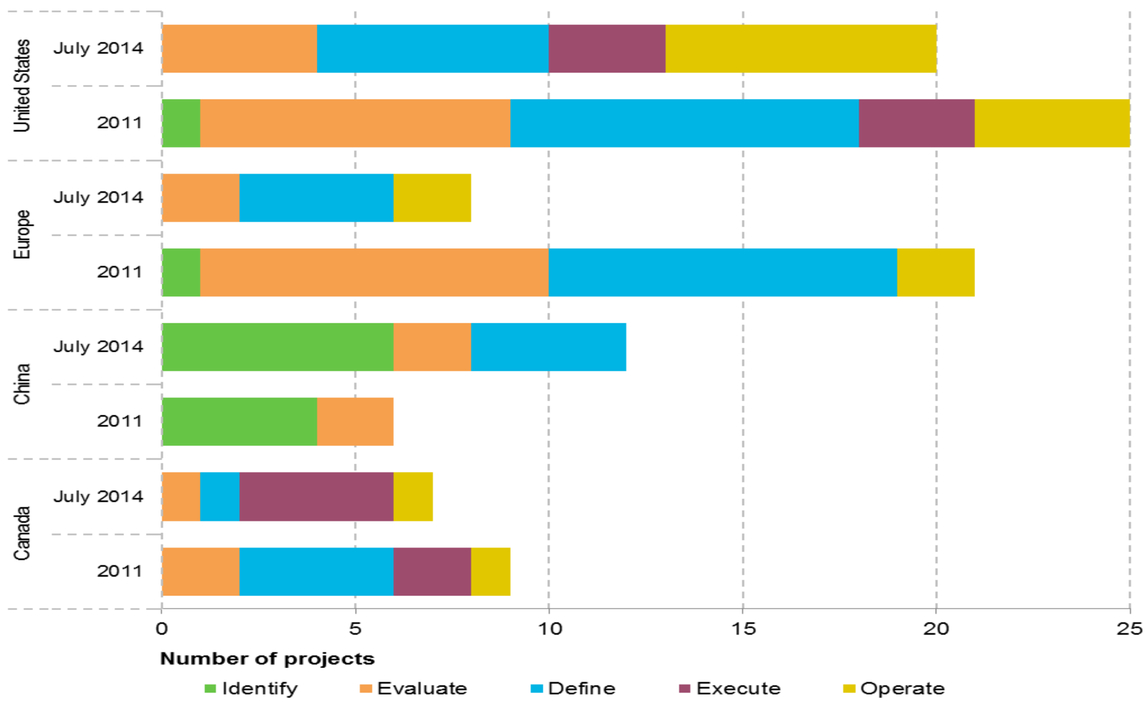
- The US Environmental Protection Agency (EPA) released proposals dealing with power plant CO_2 emissions and geologic carbon storage.
- The *UK Energy Act* received Royal Assent and became law in December 2013 – critical parts impacting CCS include the establishment of emissions performance standards and the eligibility of CCS projects for Contract for Difference (CfD) payments.
- The European Commission in January 2014 proposed a new package of measures aimed at addressing climate and energy targets to 2030, including a 40% EU-wide reduction target for greenhouse gas emissions (below 1990 levels).
- At the provincial level, the Government of Alberta issued a final draft of the Alberta Regulatory Framework Assessment (RFA) report in August 2013, which evaluated Alberta's CCS regulatory regime and global best practice.

FIGURE 3 Large-scale CCS projects proceeding to the 'Operate' and 'Execute' stages since 2011 by storage type



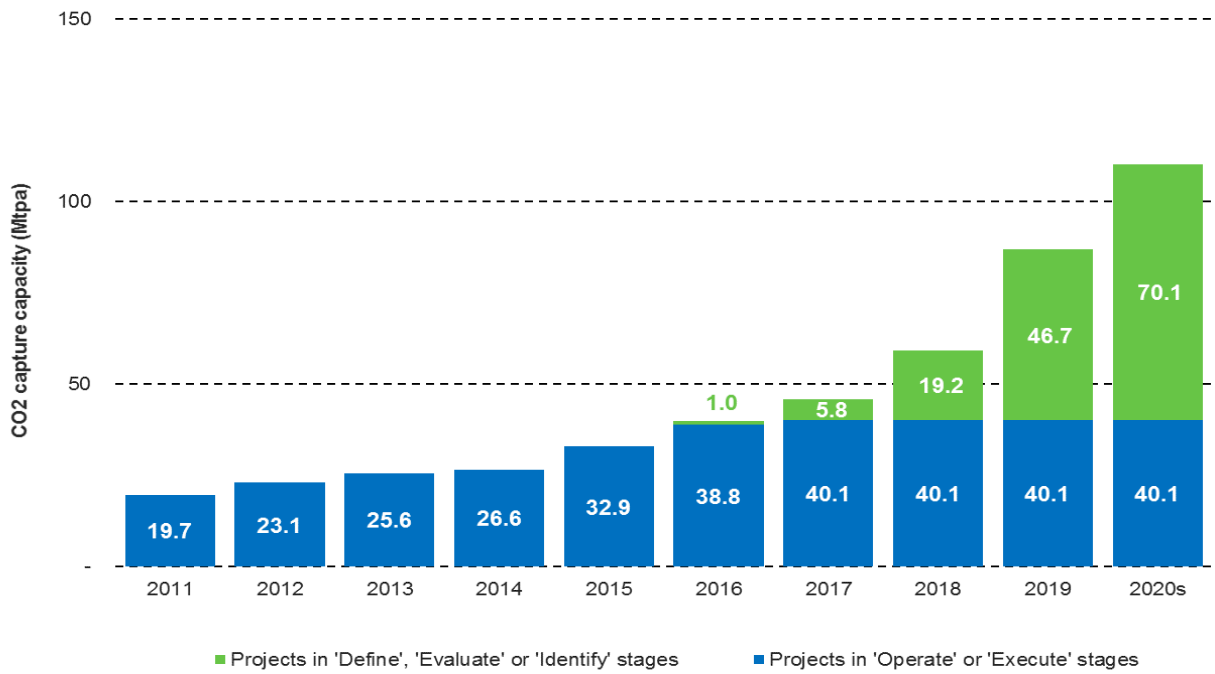
Source: Global CCS Institute

FIGURE 4 Large-scale CCS projects in key markets by project lifecycle



Source: Global CCS Institute

FIGURE 5 CO_2 capture capacity by actual and expected year of operation as of July 2014



Source: Global CCS Institute

C. The CO_2 Reduction Gap

A World Without CCS

24. Substantial and swift deployment of CCS is imperative if the increase in global mean surface temperature is to be limited to 2℃ cost-effectively. If all large factories and coal and gas power plants are equipped with CCS, about half of global man-made CO_2 emissions can be eliminated. For many industrial sectors CCS is the only available technology which allows for deep CO_2 emission reductions. According to the IEA, a 10-year delay in CCS deployment will increase the global costs of decarbonising the power sector alone by EUR 750 billion. CCS deployment in Europe will create and secure an estimated total of 330,000 jobs in fuel supply, CCS equipment manufacture, plant operation and CO_2 storage facility operation. CCS in combination with sustainable bioenergy, also referred to as BECCS, can deliver negative emissions, thereby removing excess CO_2 from the atmosphere over time. This will be necessary to compensate for our inability to abate emissions quick enough. The recent 5th Assessment Report of the IPCC highlights the need for both CCS and BECCS. The failure to undertake steps now, to advance CCS and BECCS, will mean Europe will miss its objective to decarbonize by 80-95 per cent by 2050, while damaging its competitiveness and missing out on hundreds of thousands of jobs.

III. Critical Timing of CCS Deployment

25. The global community is not on the schedule it set for deploying CCS demonstration projects. In the years immediately following the turn of the millennium, hopes were high for having several dozen demonstration projects underway. Many projects were stalled when the 2007-2008 global financial crisis hit. Both governments and corporations were forced to curtail spending and policymakers and corporate executives in many cases where forced into a "survival mode" of funding priorities. Investments in CCS demonstrations suffered as did other longer-term infrastructure investments. The effects of the global financial crisis linger but the urgency of CCS deployment remains critical.

26. Policymakers and corporate executives have to find a way(s) to make these key investments in the 2015-2025 timeframe such that critical learning occurs that is needed to drive down the costs of CCS technology such that wide-spread deployment (almost universal deployment on all fossil fuel utilization facilities) is achievable by mid-century.

A. Business Case for CCS

27. Energy markets, laws and regulations vary from country to country and even within countries. For nations where the energy business is operated by state-owned enterprises, decisions to deploy CCS are national policy/political decisions. In more free market countries, businesses are subject to national, state, provincial regulation and sometimes even regulation by municipal governments. The regulatory model often determines the business case, or lack thereof, for CCS. In regulated electricity markets, for example, electric utilities may be able to convince regulators to allow cost recovery of CCS to socialize the cost of demonstration projects. However, in competitive power generation markets when units have to "clear" a price to get dispatched, any business activity that raises generation costs can lead to units not being called upon by the system operator and the unit owner suffers financially. Competitive market forces will not be adequate to force CCS deployment.

28. Hence, government policies are needed to correct market imperfections. A description of possible financial incentives for CCS is included as Annex II, and a range of possible business models for CCS is set forth in Annex III.

Policy Parity

29. Some countries encourage deployment of some clean energy technology, but not others, often with the fiscal instruments noted above. Policymakers should treat all low/no greenhouse gas emission technologies in the same manner. National/global goals should be to achieve greenhouse gas reductions with the array of technologies available, not for governments to pick technology winners and losers.

Establishing business models

30. Policymakers should create legislative/regulatory frameworks that facilitate sustainable business models for CCS. These will vary by country and by industry sector. Industry ownership,

structure, economic conditions, legislation, economic regulation, environmental regulation, availability of domestic resources, energy security, system resilience, availability of capital, foreign investment, trade rules, availability of skilled workers, human capital and technological prowess are some of the factors that facilitate sustainable business models for CCS. It is clear that "one size does not fit all" and policymakers will have to be very deliberate in sculpting a domestic business model for CCS that is sustainable.

31. For CCS to be widely deployed in Europe by 2030, CO_2 transport and storage infrastructure must be in place – at the right time, in the right place, at the right capacity. In the current policy environment, however, this is unlikely to happen. Innovative business models are therefore needed which align commercial interests across the entire CCS chain; and given the long lead times – 6 to 10 years for both pipelines and storage sites – development must start now, ahead of wide-scale deployment. Business models need to create the market certainty and long-term secured cash flows required for private capital and industry investment. In the currently immature CCS market, this means being able to fund business development costs, capital, operating costs, plus the closure and post-closure phases of projects. Funding also needs to be flexible and in large enough amounts to accelerate the development of large-scale infrastructure. Finally, as capture, transport and storage are usually independent businesses, minimizing counterparty risk for the duration of a storage project (ca. 60 years from beginning to end) is essential. This means decoupling capture businesses from transport and storage. Different business models are effective for different phases of CCS development. Three distinct business models have been identified for the three stages of market development, namely demonstration, pre-commercial and mature industry. These are set forth in Annex III.

32. A key difference between the models is the role played by state intervention. The level of state intervention is highest in the demonstration stage (Contractor to the State model) and reduces naturally as the industry matures. The Zero Emissions Platform (ZEP) Report on '*Business models for commercial CO_2 transport and storage: Delivering large-scale CCS in Europe by 2030'* will be released in December 2014.

B. Need to Mobilize Private Investment

33. Investment requirements in the global energy sector are estimated to exceed $2,000 billion by 2035 by the International Energy Agency. Few governments will afford the sums required. World trade rules will need to encourage both domestic and international private capital investment. Investments in technologies to reduce greenhouse gas emissions will compete with needed investments in other infrastructure requirements as well as other social needs such as health care, education, public safety and national defense.

C. Role of Public-Private Partnerships

34. Public/private partnerships are one mechanism to facilitate the capital investments in near-term CCS deployment. Few demonstration projects have moved forward with some blending of government and corporate capital investment. For the next two decades CCS projects are likely to have too high of a risk profile for corporations alone to invest in technology demonstrations. At the same time, many national government budgets are not fully recovered from the global

financial crisis and remain in a deficit spending mode. Projects will need a combination of public and private investments with a sustainable business model framework to come to realization.

35. Direct emissions from industry account for roughly 25 per cent of total EU CO_2 emissions. Petroleum refining, iron and steel, cement and chemical industries account for 60 per cent of total EU CO_2 emissions from industry. Many industrial processes in the EU are operating at or close to the theoretical limits of efficiency, while the release of CO_2 is unavoidable in several manufacturing processes. CCS is the only technology that can deliver the deep emission cuts required by several EU energy-intensive industries. Ensuring a European stake in the global CCS industry will increase the employment in green industries – creating and preserving thousands of jobs; while deploying CCS in industries beyond power will help ensure a competitive position for existing EU industries in a future carbon-restrained world – reconciling EU climate goals with the desired re-industrialisation of the economy. In some industrial processes, mainly in the petroleum refining and chemical sectors, the removal of CO_2 is an integral part of the production stream. Such cases could therefore represent relatively lower-cost CCS projects compared to processes with dilute CO_2 off-gases – and interesting candidates for early demonstration of the CCS value chain. The deployment of CCS for energy-intensive industries in parallel with fossil-fuel power generation could facilitate clusters of CCS projects – improving economies of scale for both CO_2 transport and storage, and significantly reducing capital costs compared to stand-alone projects.

36. CCS deployment, however, requires a technological and investment step change via supportive policy mechanisms – in terms of both direct project funding and creating a long-term business case. Stimulating a European CCS supply chain that takes into account emissions from both power and industrial sectors must be a key deliverable of a European CCS policy. Significant investment is needed in the near-term in order to substantiate performance and reliability, and develop operational and safety standards in line with existing industrial practices. Near-term actions, both at national and European level, must therefore focus on supporting the technological progress of industrial CCS applications by enabling the shift from small-scale pilots to large-scale demonstration projects.

IV. Recommendations

A. Public Policy Parity

(i) Emission reduction credits

37. Carbon capture and storage and carbon capture, utilization and storage should be technologies which earn emission reduction credits for each tonne of carbon dioxide that is captured and prevented from being emitted to the atmosphere.

(ii) Policy Parity Regarding Incentives

38. It is critical that policies that address CCS/CCUS are on parity with other no carbon/low carbon technologies and should receive identical incentives.

(iii) Intellectual Property Agreements

39. While knowledge sharing regarding CCS/CCUS deployment is valuable, international agreements must ensure that the developers of intellectual property rights are protected. Any post Kyoto instrument should not require technology developers to release/forego intellectual property rights as a condition of earning carbon credits.

(iv) Fiscal Tools

40. A post Kyoto international agreement should accept a broad array of fiscal instruments to encourage CCS/CCUS, but the selection of instruments should not be mandated but rather left to the discretion of national governments. Any revenue from fiscal instruments should be received by national governments where the project is located and not flow to any international governments or non-governmental organization.

(v) Electric Power Dispatch Ranking

41. CCS projects should receive preferential dispatch ranking when "stacking" electric power generating units for dispatching.

(vi) Public-Private Partnerships

42. Public-private partnerships should be encouraged and decisions left to national governments as to how best encourage these arrangements in their jurisdiction.

(vii) Policies regarding other economic sectors.

43. A post Kyoto international agreement must recognize that capturing CO2 from all industrial sectors will be essential to reach climate goals. Cement, steel, chemicals, refining and transportation must be addressed in a manner similarly to how energy production, transportation, distribution and utilization are addressed.

B. Government Support for Global Demonstration Projects

(i) Intergovernmental Frameworks

44. Deployment of CCS/CCUS will accelerate if governments work together to financially sponsor demonstration projects. An international agreement should allow for and encourage joint venture projects, particularly between developed and developing nations. A framework should be established to recognize these projects and prescribe how a sharing of benefits can be achieved.

(ii) Intellectual Property Agreements

45. A framework of joint projects should suggest how technology developer's intellectual property can be protected.

C. OECD Investments in Developing Countries

46. Developed countries investments in developing countries can take many forms. The agreement should be flexible to accommodate a broad variety of mechanisms including:

(a) Foreign direct investment.
(b) Development assistance efforts.
(c) A follow-on to the Clean Development Mechanism that recognizes carbon capture and storage and carbon capture, utilization and storage.
(d) Sharing emission credits.
(e) Recognizing the role of regional development banks and rewarding national governments for financing projects through regional development banks.
(f) Recognizing the role of the World Bank Group and recognizing national government contribution to financing projects through World Bank facilities.

D. Role of the United Nations as a Governor and Enabler of Progress

47. A post Kyoto international agreement is a major opportunity to give proper treatment to CCS, CCUS and carbon capture and transportation for enhanced oil recovery. It is crucial that enhanced oil recovery be treated as storage. Properly addressing CCS/CCUS in an international agreement may be one of the few strategies to enable progress toward rapid deployment of CCS.

48. Public outreach and communication is a determining factor for the future of CCS. The UNFCCC should consider its potential role with outreach and communication regarding carbon capture and storage as a carbon dioxide emissions reduction strategy. Coordination should occur between UNFCCC and other United Nations organizational units, with multilateral government organizations, e.g. the International Energy Agency (IEA), the IEA Greenhouse Gas Centre; the Carbon Sequestration Leadership Forum; the World Bank Group; Regional Development Banks; and with multi-national non-governmental organizations, e.g., the Global CCS Institute; the World Energy Council; the World Coal Association, etc.

V. Conclusions

49. Combating climate change requires a shift to a low-carbon economy powered by a range of clean energy technologies. In view of the current levels of usage for fossil fuels, it is expected that energy systems will continue to be mainly dependent on using them for the foreseeable future. CCS is important because it provides the means of dealing with the resultant CO_2 emissions while preparing to make the transition to an energy system with intrinsically lower emissions.

50. Application of CCS will increase the cost of electricity (produced at thermal power plants) and other industrial products. Since economics controls the future of any technology, CCS might become economically feasible under the proper regulatory framework, which encourages financial incentives to make carbon sequestration commercially attractive. New regulatory frameworks are also needed to address CCS as such, while at the same time CCS issues might be integrated into existing frameworks. Thus, the cost of technologies, financial schemes for their

development and implementation, legal and regulatory issues are interconnected and can be considered as the main barriers to achieving large scale implementation of CCS technologies.

51. The environmental aspects of CCS are mainly related to the assessment of possible risks during CO_2 capture, compression, transport and storage. Mitigation and risk reduction process can be applied to avoid not only the emission to the atmosphere, but also occurrence for people and local environment.

52. Since the implementation of CCS might directly and indirectly have an economic impact on the public (increased cost of electricity) or environmental concerns (risk of CO_2 leakage), the attitude of the public is critical. Public support, which could be achieved through awareness campaigns related to general policies as well as particular sites, will become increasingly important for CCS projects.

53. Inclusion of CCS under the UNFCCC is important since it would result in a substantial reduction of CO_2 emissions. The policy architecture under the UNFCCC is presently in a state of transition, with a process underway to set down a new agreement and supporting mechanisms, expected to be in place after 2020. These mechanisms can provide an important source of financing and technological learning to support uptake of CO_2 capture and geological storage in developing countries. Without such mechanisms, the current cost of CCS means it is unlikely that it would be a high priority measure for many developing countries, which would most likely prefer to first use smaller-scale and lower cost measures, of which there are many, even though these would not make such deep reductions in emissions as CCS. It is important to realize that the overall value of these market mechanisms to CCS activities is to determine a threshold price for CCS activities.

54. These Recommendations to UNFCC on how Carbon Capture and Storage (CCS) and CCS for Enhanced Oil Recovery should be treated in a Post-Kyoto Protocol Agreement have been prepared in cooperation with UNECE member States and other interested stakeholders with the goal to limit the increase in global mean surface temperature to 2℃ cost-effectively

VI. Acknowledgements

55. UNECE expresses its thanks to all those who contributed to this document. In particular the following contributors are acknowledged: *to be completed.*

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ANNEX 1 Project by Project Summary (Historical Status & Status of Projects under Development)

(a) Norway

1. By developing CCS, Norway could deliver on its responsibility as a major contributor to the climate challenge while maintaining its position as one of the world's largest exporters of fossil fuels. Norway is ideally situated to profit from the future CO_2 storage industry due to its geology as well as existing skills and infrastructure. Norway is central in developing European CO_2 storage capacity. The absence of CO_2 infrastructure and uncertainty on storage capacity poses the largest risk to CCS deployment in Europe. CO_2 storage development takes time (ca. 10 years) and storage is location specific. While capture technologies can be imported, storage cannot and a lack of clarity around CO_2 storage capacity therefore increases the barrier of entry for all future European CCS projects. CCS projects in Norway and Norwegian engagement in CCS projects elsewhere can pave the way for CO_2 capture in European countries that consume Norwegian gas exports.

2. The opportunities for CCS in Norway break down into two groups, namely gas power plant CCS and industrial CCS. The development of successful Combined Cycle Gas Turbines (CCGT) CCS projects is in Norway's interest as a major gas exporter. There are three central options for CCS projects in Norway. On gas, both Mongstad and Naturkraft CCGT at Kårstø are technically and commercially feasible CCS projects. A Naturkraft CCS project is co-dependent on offshore electrification. In the Greenland area, the Norcem cement and Yara fertilizer facilities can together constitute the scale necessary to be regarded as a full-scale industrial CCS project. The facilities are in near proximity to each other and both have ports and thus the opportunity to ship CO_2. Such shipping allows for selective and targeted CO_2 storage characterization in the southern North Sea. The provision of bankable CO_2 storage capacity in this region is of high value for the development of CCS in Europe.

3. Norcem is a Norwegian cement producer part of Heidelberg Cement Northern Europe and is currently exploring a variety of CCS technologies at the cement plant at Brevik, Norway. A small-scale test centre, with pilot and demonstration plant for testing various CO_2 capture technologies, is already running. Results from these tests will serve as the basis of qualifying the technologies and assessing the possibilities of full-scale capture plants. Experiences from the project will be shared with the cement industry on a European level through the European Cement Research Academy (ECRA). It has been estimated that 80% of the emissions from a cement plant can be abated using post-combustion capture.

(b) United Kingdom

4. As a CCS leader in Europe, the United Kingdom (UK) is committed to supporting the commercialization and cost reduction of CCS alongside the efforts of industry and governments internationally. The UK government foresees CCS development and deployment in three broad phases, where each phase represents a further commercialization of the technology. Phase 1 is heavily state supported, with the aim of realizing the UK's first commercial scale project(s), through which experience will be gained with respect to market-led commercial and legal frameworks. With the Peterhead and White Rose projects under development, this is the current

phase. Phase 2 will be a transition phase, with reduced levels of government support, before full commercialization is reached in Phase 3, where projects are able to compete in the market on the basis of cost with other low-carbon technologies.

5. The White Rose project, developed by Capture Power Limited, a consortium between Drax, Alstom, and BOC, is officially the first CCS project to have received up to EUR 300 million in funding as part of the second round of the European Union's NER300 programme. This 426MW CCS power plant is expected to burn coal to meet the equivalent power needs of over 630,000 homes, while capturing 90% of the CO_2 produced by the plant and transporting it by pipeline for permanent storage deep beneath the North Sea seabed. In addition, engineers are hopeful that the project can serve as a hub for future CCS projects in the region, which would allow the UK north east's heavy industry to reduce its CO_2 emissions while creating up to 6,000 jobs. The White Rose project is also planned to be the first large-scale oxyfuel project in the world with the ability to use biomass for co-firing. What this means is that, in addition to capturing nearly 90% of CO_2 emissions, if the biomass fuel is sustainable and the right circumstances prevail, zero or even negative emissions could be attained. The key role of CCS combined with biomass, also known as Bio-CCS, in attaining carbon negative emissions needed to avoid an increase in global mean surface temperatures beyond 2°C, was highlighted in the 5th Assessment Report of the IPCC.

(c) Netherlands

6. ROAD (Rotterdam Capture and Storage Demonstration Project) is a project of E.ON and GDF Suez to deliver CO_2 capture at a coal power plant in Maasvlakte outside Rotterdam in the Netherlands. ROAD would be able to prevent 1.1 million tonnes of CO_2 emissions each year from 2017. This CO_2 will be stored in a depleted gas field in the North Sea, transported there by pipeline. The North Sea has the largest CO_2 storage potential in Europe and is directly available to other leading CCS countries including the UK and Norway.

7. In June 2014 the Norwegian Petroleum Ministry committed EUR 12 million to assist in meeting the financing gap of the project. Norway's financial contribution will form part of the minimum EUR 40 million that European states will have to provide in order for the EU to release a further EUR 20 million. If states stick to this minimum, the EUR 60 million stands a chance of not being sufficient. ROAD project operators E.ON & GDF Suez have claimed in recent months that EUR 100 to 150 million is needed. Given this insecurity, strict conditions must be attached to any funding to the ROAD project. The facility, once built, is expected to capture and store CO_2 for 4 years.

8. ROAD will enable Rotterdam to become the European continent's first CO_2 transport hub to the North Sea, enabling CO_2 captured in western and central Europe to be permanently stored offshore. Studies have also shown that Rotterdam may receive CO_2 via pipeline or barge from the heavily industrialized and CO_2 intensive Rhine valley region of Germany. The Rotterdam Port has also already set aside space for CO_2 shipping that can be transported to other potential North Sea storage sites. This network can be expanded to build out Europe's first CO_2 hub. In fact the Rotterdam area already has the beginnings of a CO_2 transport network, developed for use in local industry and greenhouses.

(d) France

9. Steel manufacturer ArcelorMittal and the ULCOS CCS Project consortium have been developing plans to retrofit post-combustion CO_2 capture at the now-idled Florange steelworks in northern France. ULCOS stands for Ultra–Low CO_2 Steelmaking. It is a consortium of 48 European companies and organizations from 15 European countries that have launched a cooperative research & development initiative to enable drastic reduction in CO_2 emissions from steel production.

10. The project applied for funding from the European Union's NER300 scheme, but it was subsequently withdrawn in late 2012 despite emerging as the only project expected to meet financial criteria. Despite the withdrawal from the NER300 project ArcelorMittal has committed to keeping the plant available for CO_2 capture demonstrations at a later date if needed.
The proposed retrofit would reduce the emissions by up to 50%. The captured CO_2 will be compressed and transported by a pipeline 50-100 km that will be built specifically for this project. The project will store at least 0.7 MT/year and up to 1.2 MT/year. Over the projected 10 year lifetime that amounts to approximately 10 MT of CO_2. Construction was planned to start in 2012/2013; Injection testing to start in 2014; and full scale operations to start in 2016. ArcelorMittal has established a subsidiary company, ArcelorMittal Geo Lorraine to manage the capture, transport and injection on behalf of the ULCOS consortium. ArcelorMittal would invest EUR 180 million in the project. Total cost of the project has not been specified. The budget for the ULCOS research consortium is EUR 75 million over a 6 year period.

11. The following key project observations can be noted:

- The Petra Nova Carbon Capture Project (formerly NRG Energy Parish CCS Project) in Texas, US, has moved into the construction phase under a 50/50 joint venture between NRG Energy and JX Nippon Oil & Gas Exploration.
- The US Department of Energy (DOE) has approved formal funding for the Lake Charles CCS Project (US$264.1 million) and for the FutureGen 2.0 Oxy-Combustion Project (approximately US$1 billion) under a cooperative agreement with the respective project proponents. In August 2014, the US EPA approved four Underground Injection Control (UIC) Class VI permits for the FutureGen 2.0 Project.
- The Abu Dhabi CCS Project has progressed to the 'Execute' stage after the joint venture between Masdar and the Abu Dhabi National Oil Company (ADNOC) awarded an engineering, procurement and construction (EPC) contract to the Dodsal Group.
- In China, the Yanchang Integrated Carbon Capture and Storage Demonstration Project has progressed to the 'Define' stage after the project proponents approved construction of compression and dehydration facilities for 360,000 tonnes of CO_2 per annum.
- Two newly identified projects, both in the power sector, have been added to the Institute's listing of large-scale CCS projects – the Sargas Texas Point Comfort Project in the US (CO_2 capture capacity of 0.8 Mtpa) and the China Resources Power (Haifeng) Integrated Carbon Capture and Sequestration Demonstration Project in China (CO_2 capture capacity of 1 Mtpa).
- In the UK, the Department of Energy and Climate Change (DECC) has awarded funding from its CCS Commercialisation Programme to the White Rose CCS Project and to the Peterhead CCS project to support FEED studies, thereby advancing the projects to the 'Define'

stage of planning. The White Rose project has also been awarded funding under the EU's NER 300 programme.

- The number of large-scale CCS projects in Europe (including the UK) has fallen from 14 in 2011 to just eight in July 2014. Two of these are operating CCS projects in the gas processing industry sector (the Snøhvit and Sleipner CO_2 storage projects in Norway) leaving only six projects in the planning stage – the most advanced being the ROAD project in the Netherlands (Figure 4).
- CO_2-EOR can provide added impetus for a number of first-mover projects. The approach is most evident in regions of mature oil extraction such as North America, the Middle East and China, where market opportunities to utilize CO_2 as a commodity with value are strongest (Figures 3).
- Supporting European projects into operation is particularly important in broadening the successful demonstration of large-scale carbon capture in power and industrial applications in combination with geologic/non-EOR storage options.

Annex II Financial Incentives for CCS

1. Policy options to encourage CCS deployment can take the form of tax incentives, production tax credits, investment tax credits, direct subsides, government investment in projects, which are the “carrot” approach. Incentives can also take the “stick” approach of penalties for emissions, taxes, a cap and trade style policy or outright emission limits or bans.

2. The substantial and swift deployment of CCS requires both sticks and carrots. Most effective amongst these are industrial funds, feed-in-tariffs or contracts for difference, and CCS certificates, alongside firm CO_2 pricing and emission performance standards.

3. Industrial funds need to cover both CAPEX and OPEX to ensure CCS plants are dispatched and first movers are compensated for taking the lead in CCS deployment. This is because CAPEX alone does not ensure that the power plant will dispatch and operate over the lifetime of the project so that the return on the investment is realized. In addition incremental operating costs for CCS will not be covered at low CO_2 price levels. A large enough CCS fund is therefore essential to support EU demonstration projects in the power and industrial sectors, and also take into account the lessons learnt from recent EU funding schemes.

4. **Feed-in-tariffs (FiT)** offer targeted subsidies to production, setting total fixed price per unit of electricity for a generation technology or technologies. FiTs are designed to cover the long-term average costs of generation, which means initial capital costs are included in the tariff. Generally the tariff is set for 10 or 20 years to provide transparency, longevity and certainty (TLC) to investors. After this set period, the price returns to market levels. A variation of the fixed price schemes are premium payment schemes. These provide a fixed premium to be paid to the generator on top of the market price for electricity. FiTs can provide support to power plants in a form that best ensures them access to the electricity grid, reducing both revenue risk and price risk for investors. This correspondingly lowers the cost of capital. Only the technological risk therefore remains, as is typical for projects at this stage of development. FiT therefore offer investors the greatest security of income. However, this risk reduction for the generators comes at a high cost to consumers.

5. In the EU it has been estimated that 85% of all new wind systems and nearly 100% of all new solar PV systems since 1997 have been installed with FITs. A 2005 EC study concluded that ‘well-adapted FiT regimes are generally the most efficient and effective support schemes for promoting renewable electricity’. Given their success elsewhere it is believed that a FiT scheme for the electricity generated by CCS plants could also successfully drive the deployment of CCS in the EU. Alternatively, a FiT for the volume of CO_2 stored could act as an effective supplement to the electricity market price, making the business case for CCS whilst incentivizing operators to strive for ever greater emissions savings against the electricity produced. This latter approach could also be used to drive CCS deployment at industrial facilities. Eligible sectors, such as steel or cement, would receive a predetermined price for CO_2 stored.

6. It is important to note that FiT schemes for CCS would most likely be applied at national – not EU – level. They would however be incentivized via EU policy and targets which would then place obligations on Member States to achieve. The effect of such schemes is to allocate the cost

of installing and operating the selected technology to electricity consumers across all technologies. In the UK for instance, the Government will be introducing long-term FiT schemes, offering technology-specific, centrally-set strike prices for nuclear, large-scale RES and CCS, while capping prices in times of generation scarcity. Because these FiT schemes will distinguish between intermitted and baseload low-carbon generation, as well as investment risk profile (e.g. for early CCS projects), it is highly likely that they will be effective in driving CCS deployment. In combination with CCS certificates and other grant schemes, the UK is therefore an attractive place for the first CCS projects to be built.

7. **CCS certificates** are another option of enabling the timely development and delivery of CO_2 storage capacity, CO_2 transport infrastructure and advancing capture technologies. An EU-wide CCS certificate scheme could see the EU issue tradable certificates to CCS power plants for the electricity they produce. Utilities would then be obliged to acquire a certain number of certificates for the CO_2 they emit, giving the certificates a monetary value that would provide a supplementary income to CCS producers. There would be no need for EU institutions to directly manage revenues – the Union would simply control the scarcity of certificates, indirectly giving them value to their bearers. The advantage of a pan-European CCS market incentive scheme is that it is more compatible with the EU's single-market ambitions. The larger market for tradable certificates would also put greater downward pressure on CCS costs. Whilst an EU-wide market-based instrument for CCS is attractive, care will have to be taken to ensure it neither falls prey to the shortcomings of the EU ETS, nor undermines its operation.

8. An **emission performance standard (EPS)** sets a clear signal for investors, operators and technology vendors. At present no EU wide legislation or sufficient CO_2 price signal exist to dissuade investment or reinvestment in CO_2-intensive generation capacity. Under the existing framework of a generally unenforced CO_2 capture ready requirement and a poor outlook for the CO_2 price, investments in CO_2-intensive generation capacity are little affected by EU climate policy. This is resulting in investments now leading to carbon lock-in and eventually costly stranded assets. An EPS would not replace the carbon price but would complement it by providing a safeguard that encourages investment flows only to energy resources that can contribute to achieving EU decarburization objectives. An EPS for existing plants should also be introduced. This could be done in line with existing timetables under the Industrial Emissions Directive, allowing newer, more efficient and flexible plants to operate for a limited timeframe, but removing older, inefficient and inflexible plants from the system.

9. The UK already has an EPS in place for thermal electricity generation at (450 g CO_2/kWh). Internationally, EPS have been implemented to help promote CCS deployment in both Canada and the US. In 2012 the Canadian government finalized an EPS affecting coal electricity generation. All new coal facilities post-2015 and existing facilities over 50 years will be mandated to reduce CO_2 emissions to the level of CCGT (420kg/MWh), requiring application of CCS. This EPS was a critical policy in the delivering of the Boundary Dam CCS facility in Saskatchewan Canada (as the Canadian EPS is retroactive – applying to plants 50 years old). This CCS facility was retrofitted to an existing lignite fired plant that would otherwise have been forced to retire. The Canadian EPS has also resulted in the Thunder Bay generating station in Ontario to be converted from coal to biomass. An EPS set at 225/kWh in 2030 disincentives gas

without CCS. By 2025 it would result in the advancement of CCS on lignite, coal and gas and by 2050 – an increase in the total level of CCS deployment.

10. Furthermore, the **EU ETS** requires a comprehensive reform to cure the low and volatile EUAs price and send a strong signal to investors thereby allowing the transition between demonstration and commercialization. Although cost estimations for CCS from energy-intensive industries are currently uncertain and highly variable, any investment in the technology will require an EUA price of at least EUR 40 for the lower end of the cost curve, excluding transport and storage. Bellona recommends the establishment of a discretionary price-based adjustment mechanism into the ETS to adjust the overall supply of EUAs available at auctions in the market. To ensure that these adjustments have the desired impact on the EUAs price, allowances should be permanently cancelled in cases where the EUA price is below a certain threshold as opposed to temporarily depositing them in a reserve. This adjustment mechanism is to be regulated by an independent bank; the European Central Bank of Carbon. This bank is to be delegated the responsibility of ensuring the smooth functioning of the market, and avoiding situations of over-supply. Moreover, Bellona sees the setting of a price collar, i.e. price floor and price ceiling, as a direct and immediate means to increase the current EUA price. A price collar would incentivize investment in low-carbon technologies and reduce price uncertainty. Imposing a maximum price would also address concerns of a too high carbon price which in turn would remove EU competitiveness concerns and those of carbon leakage. For the Bellona Europa brief on 'Comprehensive ETS Reform' see here.

11. For more detail on financial incentives for CCS deployment see Bellona's report on 'Driving CO_2 Capture and Storage in the EU: New Policies, New Perspective'.

Annex III – CCS Business Models

1. ‘*Contractor to the State’* is effective before an established incentive mechanism exists and when market failure requires state support. It has the following characteristics:

- The state can take full control of the planning, development and operation of CCS transport and storage.
- Investments and operating costs are predominantly financed (or guaranteed) by the state (with the contractor holding some ‘skin in the game’).
- The state may pre-invest in infrastructure, in which case future users pay compensation to the state for utilization of the infrastructure.

The contractor to the state acts as a technical service provider for the state, providing central overview – in all phases of the project.

2. Several options and hybrids exist: the contractor to the state may be a national industry/body or a private industry; it may also own the infrastructure. Cash-flows, risks and liabilities are also issues which may be tailored to respective projects in order to establish a risk-reward balance acceptable to the contractor. This model may require exceptions from mature market rules that are prevalent, and indeed enshrined in law, in mature economies such as the EU: while suited to extremely rapid action, it has the potential to be slow and expensive if mature market rules are rigidly applied. It has been suggested that CCS should follow a fully nationalized route: the ‘state storage board’.

3. The state makes each investment decision on a case-by-case basis, which requires it to have a view of future infrastructure scenarios and gain assurance of the delivery of proposed solutions. It underwrites project revenue and sets the direction/dictates the pace. It can supply capital directly and bear risk/liabilities to facilitate progress, bearing in mind the need to ensure appropriate contractor incentives and satisfy State Aid guidelines. With respect to the handover of a storage site to the state at the end of a project, the state has several distinct roles – recipient of the store, client for the contractor and regulator. For early projects, the state should identify and intervene as appropriate to remove barriers to the project. It also needs to ensure that learnings are disclosed and shared across other European CCS projects.

4. Non-CCS examples include Member State infrastructure (e.g. Ministry of Transport in the UK) and Member State owned or controlled industry (e.g. CEGB historically or Scottish Water currently in the UK). The work conducted (up to FID so far) on the first demonstration project under the UK CCS Commercialisation Programme (providing FEED funding, capital grants and a payment for the cost of clean electricity), and on EEPR funded projects, is also effectively under this model.

5. State funding is divided into smaller, project-size pieces, determined on a case-by-case basis. This model has already proved successful for the North Sea region and will be key to incentivizing early movers in other regions.

6. *An ‘Enabled Market’* is a hybrid model comprising state intervention in some parts of the market and managed competition in other parts. The Enabled Market consists of a regulated entity (the ‘Market Maker’) which has two key roles:

- To manage the development of primary CCS infrastructure on behalf of the state (trunk pipeline + back-up storage site). This ensures optimal design, construction and operation in order to achieve system efficiencies, including economies of scale.
- To have a duty to take all captured CO_2 and ensure corresponding storage is available (including for low-cost EOR storage projects): thereby decoupling capture, transport and storage. Geographical constraints mean that there is likely to be a number of storage hubs. There may be multiple Market Makers – one per hub – or potentially one per nation or region, e.g. the North Sea.

7. A Market Maker does not need to own infrastructure and could be limited to a guaranteeing function, but it is more natural for there to be some link with infrastructure. However, a key point is that the Market Maker can be a company independent of the state, although it will be strongly regulated. It will have the obligation to act as an aggregator to manage intra-chain FID timing issues for private market operators emitting CO_2 from individual sources, transporting CO_2 or storing CO_2 at individual storage facilities.

8. The Market Maker may also be an efficient mechanism for separating post-closure monitoring and stewardship activities from development and injection by allowing the development of specialist service companies optimised for development or optimised for stewardship. Using a Market Maker to accelerate the development of primary infrastructure for CCS will create economies of scale and subsequent cost reduction; it will also send out a clear message to capital providers that there is an industry in which to invest.

9. What is crucial for private operators is that the balance sheet and credit-worthiness of the Market Maker is sufficiently robust to underpin the financing of their capital expenditure. If the Market Maker is a financially weak counterparty, private sector operators will struggle to raise their required finance. Much consideration also needs to be given to the extent of primary infrastructure provided by the state and the basis for charging for that infrastructure. In particular, private sector operators will be looking for primary infrastructure to come close to their boundaries, while any desire to ‘oversize’ will run the risk that subsequent customers do not materialise.

10. The Market Maker can either be a state-owned entity or a regulated private company; the two roles can be undertaken by different bodies. The state’s key role is to agree the location/scale of key infrastructure investments and set the access and charging methodologies of the Market Maker (both for CO_2 offtake from emitters and CO_2 supply for EOR). It allows the Market Maker to operate independently with a regulated framework that provides the vehicle for state direction and the reward mechanism (e.g. CfDs in the UK).

11. The state can provide capital directly or indirectly (e.g. by granting the Market Maker a levy income) and can also underwrite risk (including storage exploration/appraisal risk and leakage liabilities). A mature storage industry should ultimately generate sufficient revenue to

cover such risk. Independently funded extensions to infrastructure (storage and transport) are encouraged. The state requires comprehensive market knowledge to inform long-term plans, provide direction and identify the need for interventions to accelerate deals. Regarding the transfer of a storage site to the state at the end of a project, the state is both the recipient of the store and the regulator. Where the Market Maker is independent, the state will also be its principal customer.

12. *The 'Liberalised Market'* model describes a market in which private companies involved in the CCS chain develop and manage pipelines, hubs and storage sites without specific state direction. Individual participants are free to decide how their business will be structured – whether to pre-invest in over-sized transport and storage capacity, and how to allocate risk and return. A comparable example is the development and operation of the oil and gas industry in the UK North Sea.

13. A free market model may suit a mature market best, as the high costs and risks for the first projects in the CCS industry, and for isolated projects distant from aggregated hubs, may require substantial additional state intervention. Here, the role of the state is reduced to that of light touch regulator to ensure unplanned monopolies are avoided and creating the mechanism that enables CCS to be a viable business opportunity (whether through a high, robust ETS, a premium power price for low-carbon power, or an incentive to store). Government has no ownership and no central planning role. The offshore oil and gas industry in the North Sea is a clear analogue for delivery of infrastructure via a liberalised market. With respect to transfer of a storage site to the state at the end of a project, the state is again both the recipient of the store and the regulator.