An Innovative Solution to Energy and Environment Challenges

Ocean CCS

Sigan Peng

President

Clean Energy Project Tech Inc.

Zero Carbon Energy Innovation Union Inc.

Dec 1, 2016

CEPT（Clean Energy Project Tech Inc.)

- Established in 1994, CEPT, is the first company in China specializing in air pollution control and emission reduction by fossil energy.
- Major milestone
  - 1995: implemented NSW FGD in a pilot project for a coal-fired power plant to reduce sulfur emission.
  - 2008: applied NSW EGC technology in cleaning the exhaust gas of ocean ships.
  - 2016: expanded the application of NSW FGD to Ocean CCS.
  - There are multiple patents/patent pending for NSW-“Nature System Work”.
- NSW FGD：only reuses the seawater, originally intended for cooling purpose to scrub the flue-gas, not use any chemical reagent, and not generate any solid waste or additional liquid discharge. It achieves 99% removal of sulfur. In 1995, China was the largest emitter of sulfur into the atmosphere and with the highest growth rate. Because of the outstanding results in first group of coal-fired power plants (approximately 6000MW) from implementing NSW FGD, it enabled the speedy implementation of desulphurization in China for the entire coal-fired power industry and made global control of sulfur emission a feasible goal.
- NSW EGC : only uses seawater to scrub the exhaust gas of ocean ships. Its application avoids the need for oil refinery to remove sulfur from heavy fuel oil, which would require significant energy consumption (i.e. carbon emission). Its implementation complies with UN regulation on ocean environmental protection. A pilot ship was started in 2011. By 2020, the regulation of limiting 0.5% sulfur in exhaust gas will be in effect globally. Applying NSW EGC would reduce over 100 million tons of carbon emission.

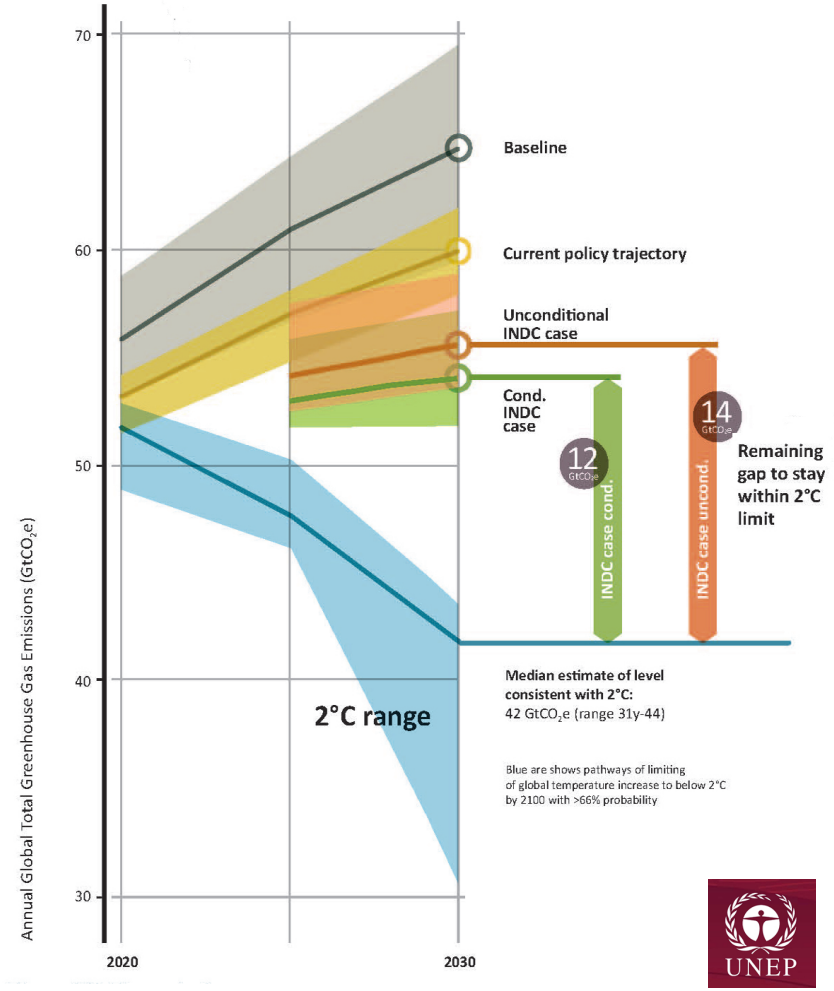
ZCEIU （Zero Carbon Energy Innovation Union Inc.）

- Established in Feb 2016, in California, U.S., working in cooperation with partners globally on commercial projects for Ocean CCS

First CEPT pilot projects of large - scale coal fired power plant NSW FGD, 6000MW, went into commercial operation in 2000

*NSW, Nature System Work. *FGD, Flue-Gas Desulphurization. *EGC, Exhaust Gas Cleaning. *CCS, Carbon Capture & Storage.

Introduction: The Key to Climate Goal



After the Paris Agreement entering into force, innovative projects of Energy CCS* hold the key to climate goal:

- UNEP*: Even if realizing INDC* emission reductions of the Paris Agreement, there are 12 to 14 Gt* of carbon emission reduction gap by 2030; It recently project by the end of the century , temperature will rise 2.9~3.4℃, UNEP appeal to all nations implement emergency measure to reduce additional 25% from all emission goals.
- IEA*: There needs to be a large number of commercial CCS projects (especially the power industry), hundreds by 2020 and thousands by 2050 globally;
- However, for the two large available carbon storage options at present:

1. geological storage, the cost is high and commercially successful projects are few;
2. marine base, the concern of impacting marine environment is so great, there are zero pilot projects up to now.

- Particularly, in energy industry, innovative project of marine base CCS will play a key role for Asian coastal countries to face the energy and environment challenges.

*CCS, Carbon Capture and Storage. *UNEP, United Nations Environment Programme.
*INDC, Intended Nationally Determined Contribution. * Gt,1 Gt=1 billion metric tons. *IEA, International Energy Agency.

Previous Research: Ocean Storage of CO_2 Is the Most Cost Effective

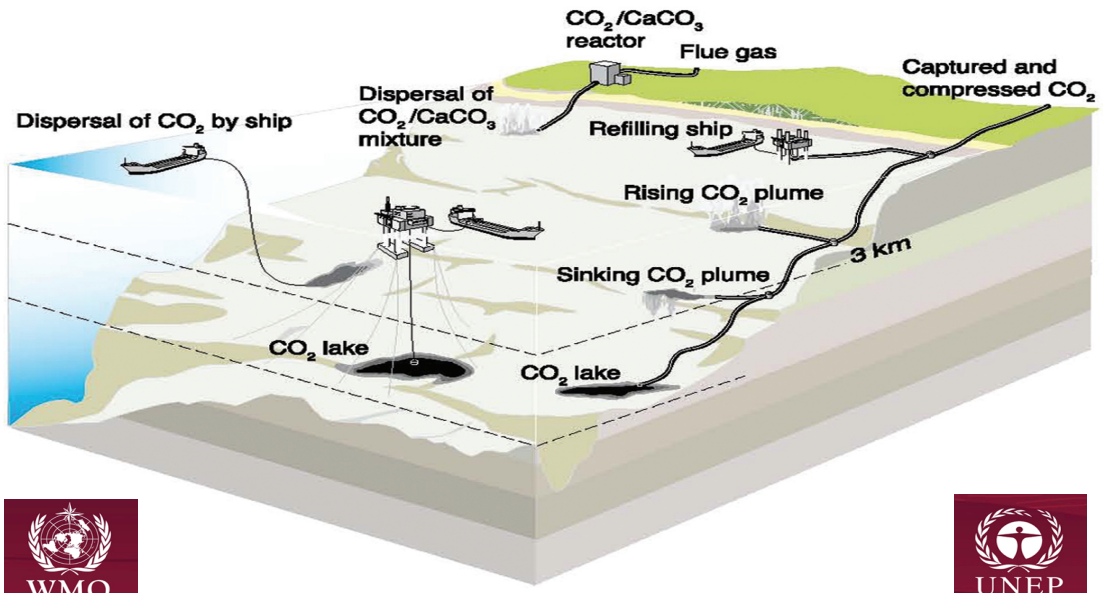
- The UNFCCC*, which came into force in 1994, emphasized "Aware of the role and importance in terrestrial and marine ecosystems of sinks and reservoirs of greenhouse gases",
- Since 1995, IEA GHG* has assembled a number of international expert groups, focusing on ocean storage; "OCEAN STORAGE of CO_2" published in 2002, proposed: "Storing carbon dioxide (CO_2) in the oceans may provide a useful means of limiting climate change caused by the burning of fossil fuels",
- IPCC* (2005) also issued a special report titled "CARBON DIOXIDE CAPTURE AND STORAGE", in which chapter 6 devoted to the ocean storage, "whilst ocean storage will reduce CO_2 emissions and combat climate change, to constitute an active use of sinks and reservoirs as required by the UNFCCC, ocean storage would need to be the most cost-effective mitigation option".

IEA,IPCC: Depth 1000m, Storage 1000 years

- Marine base has several times larger massive potential storage capacity than geological storage.
- The ocean is already absorbing CO_2 in the atmosphere, about 2Gt C or 6Gt CO_2 per year, and naturally plays a role in climate change mitigation. Concomitant with this natural regulation of ocean storage of CO_2 can further mitigate climate change such as, CO_2 dissolved into the oceans water depth 800-1000 meters, can be stored about 1000 years.
- "CO_2 is a naturally occurring product and its overall impact on the ocean environment should be very small, because of the large size of the ocean carbon reservoir." Even if CO_2 of all the fossil energy on earth is dissolved into the ocean, it will only increase the marine dissolved inorganic carbon 10%.

*UNFCCC, United Nations Framework Convention on Climate Change.
*IEA GHG, International Energy Agency Greenhouse Gas R&D Programme.
*IPCC, Intergovernmental Panel on Climate Change.

But High Concentration of CO_2 Into the Ocean is Illegal



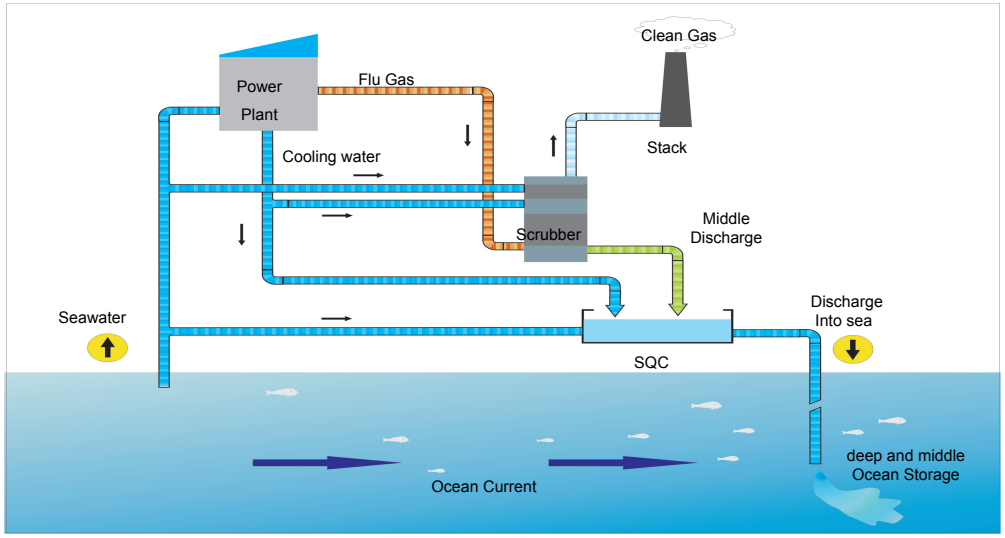
- The previous research, focused on the high concentration of CO_2 (normally 99%) storage mode (liquid or highly concentrated phase gas or solid), the injection into the marine water column, has shown that marine organisms exposed to high concentrations of CO_2 immediately die. Thus, Hawaii and Norway, the two field experiments were banned.
- In 2007, it is basically believed that the high concentration of CO_2 injected into the ocean, fell under the London Convention(1972) and the OSPAR* Convention banned dumping conduct, in violation of the International Convention on the Law of the Sea. Therefore, the research of ocean storage has been discontinued for 10 years.

*OSPAR, Convention for the Protection of the Marine Environment of the North-East Atlantic .

New Technology, New Solutions

A new technology may lead to ocean storage back to the stage of climate change, Ocean CCS:

- Firstly, carbon capture process utilizes flue- gas from power plant with seawater scrubbing technology. CO_2 is easily soluble in seawater, so it can be easily separated from the flue-gas by seawater scrubbing. Thus, seawater with low concentration of CO_2 is formed. Then, the produced scrubbing seawater containing low concentration of CO_2 is collected and directly injected into the water column to realize the ocean carbon storage. It stores CO_2 into the Ocean Water Column by cooling water with ocean current diffusion mechanism originally adopted by power plants and the newly developed deep and middle ocean current diffusion mechanism.
- CO_2 with concentration index sits in existing environmental regulations and standards limits (under this condition, the CO_2 concentration only depends on the pH of the drainage) has always been regarded as natural substances of the sea, which is ecological environment friendly, obviously, no violating marine environmental regulations of London Convention, OSPAR Convention.
- The Paris Agreement entering into force enhance a legal constrain on carbon release into the air, the innovative Ocean CCS technology will resolve the legal issue of CO_2 ocean storage.



- The cost of new designed technologies are very low: carbon capture method with seawater scrubbing and the transport process of middle and deep sea, in addition to reusing cooling discharge water, so the cost of the whole CCS process is lower, which is lower than some CCS traditional program by 1 to 2 orders of magnitude.
- In particularly, the risk and capital threshold of Ocean CCS experimental demonstration projects are substantially lower, and the time period from experiment to demonstration and then to operation is shorten.

A Preliminary CCS Example

- Among projects we designed, there is a large scale power plant that has been operating for over 10 years, with preliminary functions of Ocean CCS: 99% SO_2 of flue-gas has been captured with seawater scrubbing as well as 10% CO_2; Its uniqueness is: unlike most other FGDs most of whose captured CO_2 is driven back into the atmosphere, most of the CO_2 captured by this power plant goes into the ocean with scrubbing seawater to realize ocean storage in shallow layer; so far, tens of million tons of CO_2 is captured and stored. The environmental monitoring agency inspected the pH of the discharge and found it met national environmental standards and regulations.
- This preliminary Ocean CCS project has a low carbon capture rate, shallow storage, and not optimized. The next generation Ocean CCS design has a carbon capture rate of more than 90% and is stored to middle and deep ocean, with the same concentration of CO_2 (both are less than 1%) and the discharge pH can be controlled and regulated. Therefore, the large-scale operation of the CCS in the long term can be proven that the Ocean CCS technology is a feasible way of legally using the marine base.

Outlook and Conclusion

- Ocean CCS application is limited at coastal areas where are more large-scale discharge locations, and its cost benefit will enlarge. For example, China's annual carbon discharge is 11 Gt in 2013(32Gt globally), with the goal of reaching peak at 2030(about 15Gt) or earlier. About 1/3 of China's coal-fired power plants are located in coastal areas now, and such areas can be considered for more new allocations. Applying the Ocean CCS technology may help China to meet the goal of reaching peak ahead of time. Asian countries such as Japan, India, and Indonesia who have rich ocean resources can all rely on Ocean CCS technology to help them to ease carbon reduction burden. If Asia countries reduce carbon emission, global emission will be reduced as well.
- Looking at the distribution of power plant around the world, fossil-fuel energy is over 50%. We believe Ocean CCS could achieve greater than 1/3 of global CCS gap (> 4GT) .
- The research model predicts that some CO_2 may return to the atmosphere after centuries to thousands of years storage in oceans, and it seems not so ideal. However, all current CCS programs are not "permanent storage", they all aim to buy time for the realization of next energy revolution. Ancient Chinese story of DaYu flood control told us that: it is not possible to "kick the can down the road" when human face the challenge like global warming, "dredging" flood into the sea is the most efficient solution because it complies with rules of nature and uses the most abundant ocean resource in an ocean environment friendly way. Obviously, ocean carbon storage is more similar to such "dredging", so it is more cost effectiveness, more conducive to people to buy time.
- Ocean carbon storage may cause acidification which need to be researched, experimented, and demonstrated under the climate change coping condition. Ocean CCS is a mean that with low risk and low cost, can be gradually conducted, and reversible.
- With UNEP appeal to all nations to implement emergency action to address the carbon reduction gap. We hope UNEP & IEA should put Ocean carbon storage back on high priority, recommend practical steps, and strongly support Ocean CCS pilot projects, including the one presented today.

Thanks!
Q&A

Sigan Peng (psg@zceu.org)

CEPT (www.cept.com.cn)

ZCEIU (www.zceiu.com)

CCS：the cost of C purity & capture rate curve