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What role can Carbon Capture Technology play in reducing future CO2 Emissions?

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ABSTRACT

2016 will surely be the hottest year since records began in the 19th century. The increase will be very close to the target set in the Paris Agreement to avoid an increase in global temperature by 1.5 oC. Average temperatures in 2016 have risen to 1.2 oC above what they were before the industrial revolution. The dilemma facing the world today, in view of these data, becomes even more urgent: How to reduce greenhouse gas emissions from fossil fuels, accepting that their demand will continue to exist in the coming decades? In the energy sector, many solutions have been proposed to completely replace fossil fuels for electricity generation, such as massive deployment of renewable energy generation and increased energy efficiency. There are many restrictions, however, to achieve this result in the medium term, ranging from technological limitations in the massive deployment of energy efficiency and renewable energies, to the political economy of countries that are unlikely to reduce their oil production And carboniferous as long as demand exists. Carbon capture and storage (CCS) offers an alternative to mitigate CO2 emissions from fossil fuel power plants, considering that, given current and future energy needs, the operation of these plants will continue in the coming

years. CAC could mitigate up to 90% of the carbon dioxide emitted by the use of fossil fuels in electricity generation and industrial processes. Additionally, the use of CAC with renewable biomass is one of the few carbon reduction technologies that can be used in a "carbon-negative" mode. If biomass from fuelwood crops were used, carbon could be absorbed and simultaneously generate electricity. CCS, therefore, is a viable alternative to solve the dilemma of reducing emissions while satisfying the growing energy needs of the world.

WHAT ROLE CAN CARBON CAPTURE TECHNOLOGY PLAY IN REDUCING FUTURE CO2 EMISSIONS?

By Alberto Levy, Ph. D. [1]

The world is awash with oil, and with a persistent, high demand for it. Oil is also the main source of greenhouse gas emissions that cause global warming. It is estimated that two-thirds of carbon dioxide (CO2), the main greenhouse gas, come from the burning of oil and its refined products.[2] From a political economy perspective, it is expected that reducing oil production will be very difficult as long as demand for oil exists. Therefore, means of removing CO2 from the atmosphere, or removing it before it reaches the atmosphere, need to be developed.

Oil production rose 1.9% between 2014 and 2015. In absolute terms, the increase represents a jump of 1.8 million barrels per day (mb/d) to 81.9 mb/d. This number is well above the **0.9%** average growth rate from the previous decade (IEA, 2015). The barrels, interestingly, were not put on the market at the expense of reserves, which remained at the same level as in 2014.

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[1] The author thanks the valuable contributions from Alice Driver, David López-Soto, José Antonio Urteaga and Juan Paredes.

[2] Greenhouse gas emission sources are, according the IPCC, about 65% of CO2 originating from the burning of fossil fuels and industrial processes, including transportation; 11% % of CO2 from forestry and other land use changes, 16% of methane from fossil fuel production, agriculture, municipal waste, and wastewater; 6 % of Nitrous Oxide from industrial processes and agriculture, and fluorinated gases (HFCs, PFCs and SF6) from industrial processes. IPCC (2014a)

The International Energy Agency (IEA) estimates that by 2040, energy consumption will rise by 37%, and oil production will continue growing to 103.5 mb/d, with a compound average annual growth rate of 0.5% in the New Policies Scenario. This amount is marginally lower, 3.7 mb/d, than the equally plausible low oil price scenario, where demand reaches 107.2 mb/d. Given these projections, no amount of energy efficiency and renewable energy could entirely replace the use of fossil fuels while still providing for global energy needs. Reducing CO2 emissions, while still meeting global energy demand, requires a multifaceted approach. We will need to take advantage of all available carbon management strategies in order to protect the environment and provide for future generations.

That multifaceted approach includes calls for increases in energy efficiency and reduction of carbon emissions in all sectors and with all fuels. Because calls to replace all fossil fuels with renewable energy are unrealistic, emissions reduction from the use of fossil fuels requires the consideration of carbon capture and storage (CCS) technology. A strong global market for CCS does not yet exist, but it could play a future role in reducing CO2 given the needs of the global population, which is projected to reach 9.6 billion by 2050. This paper will explore the potential and the limitations of CCS technology, as well as identifying and assessing the role CCS could play in a long-term carbon management strategy.

CALLS TO LEAVE OIL IN THE GROUND

The access and use of non-renewable hydrocarbon fuels such as coal, oil, and gas for the purpose of energy production are subjects of much debate. According to the Intergovernmental Panel on Climate Change (IPCC), two-thirds of hydrocarbon fuel emissions should remain in, or returned to, the ground to avoid irreversible climate change with catastrophic consequences. The panel writes:

Multi-model results show that limiting total human-induced warming (accounting for both CO2 and other human influences on climate) to less than 2°C relative to the period 1861–1880 with a probability of >66% would require total CO2 emissions from all anthropogenic sources since 1870 to be limited to about 2900 [giga tons of] CO2[…], with a range of 2550 to 3150 Gt CO2[…] About 1900 [1650 to 2150] GtCO2 were emitted by 2011, leaving about 1000 GtCO2 to be consistent with this temperature goal. Estimated total fossil carbon reserves exceed this remaining amount by a factor of 4 to 7, with resources much larger still. [3]

The Carbon Tracker Initiative [4] calculated in 2011 that only 20% of the reserves of the largest fossil fuel companies could be burnt if the world were to have a good chance of limiting global warming to 2°C. Many have proposed moving towards a 100% renewable energy future, but such proposals fail to address how the increasing energy needs of the global population will be met solely via renewable energy. [5] The IPCC has said that there are few fundamental technological limits to integrating a portfolio of renewable

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[3] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. Page 63.

[4] http://www.carbontracker.org/

[5] See for example Mark A. Delucchi & Mark Z. Jacobson (2011). "Providing all global energy with wind, water, and solar power, Part II: Reliability, system and transmission costs, and policies". Energy Policy. Elsevier Ltd. pp. 1170–1190.

energy technologies to meet most of total global energy demand. In a 2011 review of 164 recent scenarios of future renewable energy growth, however, the report noted that the majority expected renewable sources to supply more than 17% of total energy by 2030, and 27% by 2050; the highest forecast projected 43% supplied by renewables by 2030 and 77% by 2050 (IPCC 2011).

There are many barriers to transitioning from non-renewable energies to a 100% renewable energy future. First, it is unlikely that oil production will cease. Figure 1, which represents the countries that export about 90% of the oil traded in the international market, shows the very high dependence of the largest oil exporting countries on oil revenues. Their economic stability is largely contingent upon oil extraction and exports, and plans for a 100% renewable energy future typically fail to address how these countries will replace the crucial revenue that would be lost should oil production cease. It is expected, therefore, that these countries will continue to pump and sell oil as long as there is a demand for it.

Renewable energies have the potential to replace oil altogether, but the transition will be slow. One problem with renewables is that the transfer of energy is not efficient. Due to the variability of the resource [6], the transport infrastructure has to be sized to handle an expected value with significant uncertainty on its utilization at full capacity. In the case of a solar panel, for example, all the power captured can not be retained in the battery. Increases in battery capacity, decreases in energy loss, and increased use of energy efficiency measures are all important interventions that must be made to achieve greater energy security, but it is still necessary to take fossil fuel needs into account.

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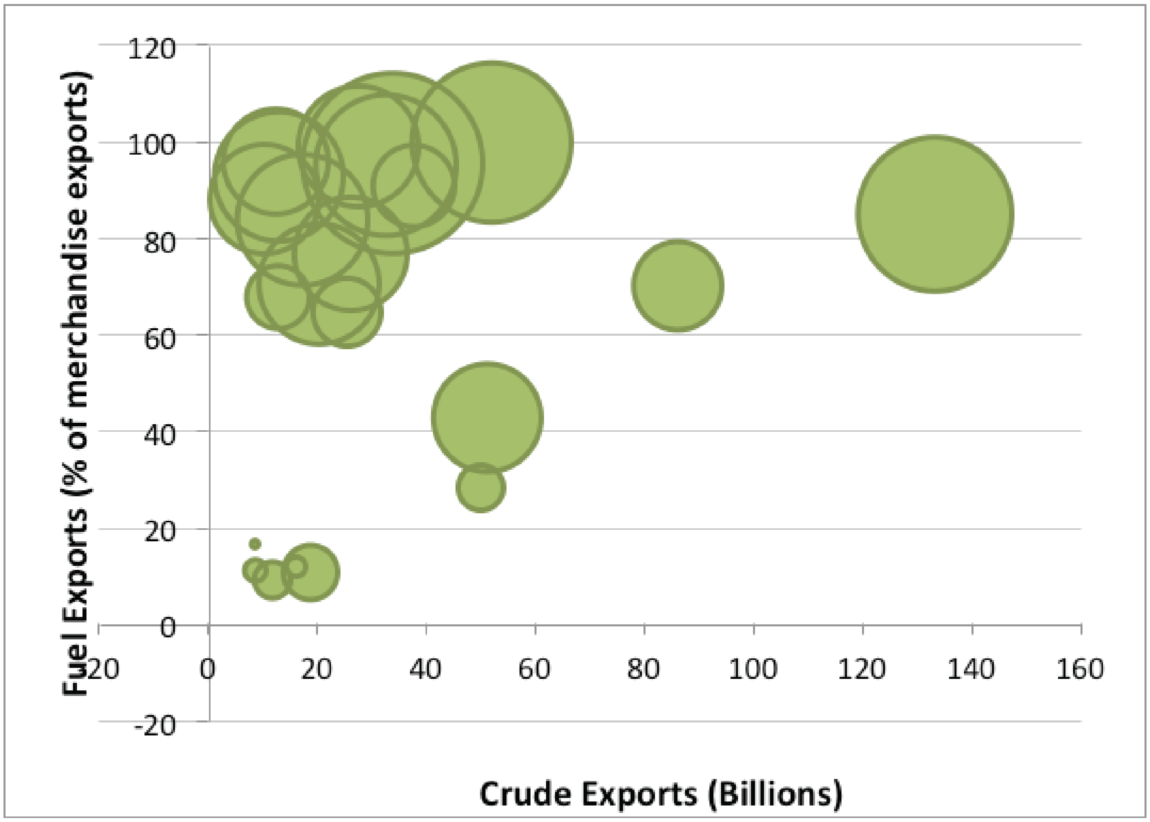
[6] The production of a solar panel depends on the level of radiation and temperature, and whether a cloud passes over the panel. A wind turbine requires wind speeds within certain levels, otherwise it will not produce energy.

Figure 1. Dependence of oil-producing countries* from oil rents (2014**)



* Bubble size represents oil rents as percentage of GDP; **Venezuela (2012); Ghana (2013); Libya (2010); Iraq (2013); Iran (2010); Sudan (2011). Source: Authors' original calculations based on data from the World Bank "Indicators" database (http://data.worldbank.org/indicator)

According to the IEA, renewable energy projects accounted for 40% of investment in all new power projects globally in 2015, a fact that suggests the worldwide interest in renewable energies is high. Fossil fuels, however, continue to dominate the energy supply, not only in terms of remaining the primary energy source, but also with respect to their status as the largest recipient of investments, representing 45% of the total (the remaining 15% goes to transport infrastructure), despite the drop in oil prices that has been occurring since the end of 2014 (IEA, 2016b). Given the dependence of oil-exporting countries on revenues coupled with growing global energy needs, it is unlikely that energy needs can be provided solely by renewables or that oil-exporting countries will stop exporting entirely.

Any realistic strategy to meet energy needs is going to require planning for both an increase in renewable energy and strategies for making fossil fuel use cleaner, which is why carbon capture technology should be explored fully in terms of research and development for future applications. In the past two years, global CO2 emissions have stagnated. The average carbon intensity of power generation from new capacity worldwide continued to fall, reaching 420 kilograms CO2 per megawatt-hour in 2015 (IEA, 2016b). The current pace of de-carbonization of power generation, however, remains insufficient to meet the climate goal of keeping average temperature increases below 2°C.

The IEA highlighted the importance of reaching the 2° C goal set out at COP21 by using various low carbon approaches, including “additional emissions reductions in the power sector and industry (e.g. carbon capture and storage).” Carbon capture and storage offer a means of dealing with carbon dioxide from fossil fuel power plants in a context in which, despite an increased interest in renewable energy sources, non-renewable sources remain dominant.

PLEDGES DURING THE 21ST CONFERENCE OF THE PARTIES (COP21) IN PARIS IN DECEMBER 2015

Before COP21, ten countries made CCS part of their climate commitments, and at the conference in Paris a CCS deployment and development roadmap was launched (ADB, 2015). The roadmap outlines a strategy for balancing economic growth needs with energy security and environmental and climate change concerns. In addition to the COP21-related commitments, 20 countries made a commitment to double public funding for clean energy research and development as part of a project titled Mission Innovation. [7] More than 150 countries that account for about 90% of global economic activity and close to 90% of the global energy-related CO2 emissions submitted pledges, in what is known as the Paris Accord, to control emissions of greenhouse gases (GHG) via Intended Nationally Determined Contributions (INDCs). INDCs are actions and targets that countries commit to in order to keep global temperatures from rising 2° C. Under the INDC scenario, growth in global energy-related GHG emissions will slow, and the link between global economic output and energy-related GHG emissions will weaken significantly. The INDCs are pledges made at a political level that send a clear sign to the energy sector about expectations for low-carbon development. By October 2016, the Paris Accord entered into effect, as more than 55 countries responsible for more than 55% of global CO2

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[7] http://mission-innovation.net/

emissions ratified it. The IEA estimates, however, that investment in renewable energy -- both conventional, such as hydropower and nuclear, and non-conventional, such as wind, solar, and geothermal -- will not suffice to fulfill the INDCs pledged.

SOLUTION IS TO STORE CO2 EMISSIONS

Carbon Capture and Storage (CCS) technology can collect up to 90% of the CO2 emissions produced from the use of fossil fuels in electricity generation and industrial processes, preventing the carbon dioxide from entering the atmosphere. Furthermore, the use of CCS with renewable biomass is one of the few carbon abatement technologies that can be used in a "carbon-negative" mode – actually taking carbon dioxide out of the atmosphere. Figure 2 shows the line for carbon neutrality for the generation of electricity with a combination of biomass from woody crops and bituminous coal. The trees used to generate the wood have absorbed CO2 while growing. If 90% of the CO2 produced from its combustion is captured and stored in a saline aquifer, some 900 kg of CO2e/MWh are removed from the atmosphere. On the other hand, if bituminous coal is used to generate electricity, and 90% of the CO2 produced from its combustion is captured, some 300 kg of CO2e/MWh[8] are released to the atmosphere. A combination of biomass and bituminous coal can be used to generate electricity without net release of GHG to the atmosphere.

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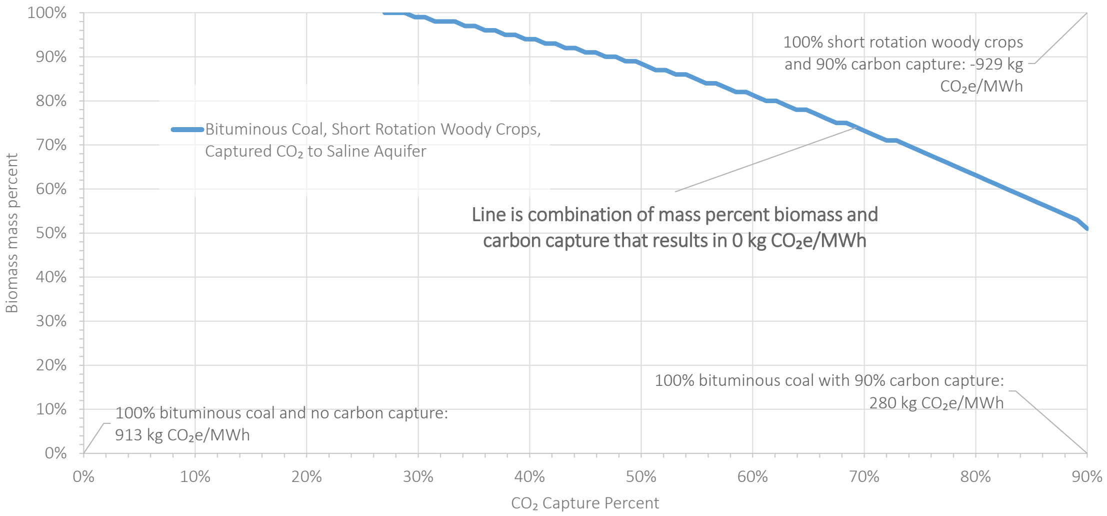
[8] CO2 equivalent per Megawatt-hour (CO2e/MWh) is the amount of emissions from burning fossil fuels to produce one MWh of energy, and includes not only CO2 produced but other GHG such as Nitric Oxide and Nitrogen Dioxide (NOx) or Sulphur Oxide(SOx), accounting for their warming power and contribution to climate change.

Figure 2. Coal and biomass to electricity. Net zero global warming potential.



Source: Balash (2016)

The CCS chain consists of three parts: capturing carbon dioxide, transporting it, and securely storing the emissions underground in depleted oil and gas fields or deep saline aquifer formations. First, capture technologies allow the separation of carbon dioxide from gases produced in electricity generation and industrial processes by one of three methods: pre-combustion capture, post-combustion capture, and oxyfuel combustion. Carbon dioxide is then transported by pipeline or by ship for safe storage. Millions of tons of carbon dioxide are already transported annually for commercial purposes by road tanker, ship, and pipelines. The U.S. has four decades of experience transporting carbon dioxide by pipeline for enhanced oil recovery projects. The carbon dioxide is then stored in carefully selected geological rock formations that are typically located several kilometers below the earth's surface.

Globally, there are 15 operating CCS projects and seven more under construction, the newest of which are in Canada’s oil sands (capturing 1 million tons of CO2 per year) and in Saudi Arabia (capturing 800,000 tons of CO2 per year).

The technology can be used to reduce emissions in both power production and in power generation in industrial sectors such as iron and steel, refining, petrochemical, and cement manufacturing. In power production, CCS can be used as a bridging technology, but there are limitations because global storage capacity for geo-sequestration is limited. In addition, highly compressed carbon is a potential environmental risk, given the fact that underground storage security is not ensured. The process of geo-sequestration is made safer by natural trapping mechanisms such as structural trapping, residual trapping, solubility trapping, and mineral trapping, which reduce the risk of CO2 leakage, but natural disasters like earthquakes could cause trapped pollutants to be released. This point is particularly relevant because the techniques used to inject compressed CO2 into geological formations have been shown to trigger earthquakes. In light of these issues, one important element of promoting the use of CCS involves engaging with communities to raise awareness about the pros and cons of CO2 storage.

Despite these risks, CCS technology could prove useful for power generation in industrial sectors, because those sectors are unlikely to stop using fossil fuels in the near future. The technology is applicable to the following sectors: industrial, natural gas processing, gas-fired power, coal-fired power, CCS with bioenergy, and enhanced oil recovery. According to the IEA, CCS could deliver 13% of the cumulative emissions reductions needed by 2050 to prevent the 2° C rise in temperatures and avoid the worst effects of global warming. In order for CCS to gain traction and be implemented safely and responsibly, financial and policy support are needed from governments to encourage the development pipeline. Until the cost of emitting CO2 increases or there is more government support for CCS, it will not be a financially viable option for many countries.

CCS is often perceived as a coal technology, which has caused some problems in terms of its reception among the energy community as a long-term solution to helping reach climate goals. Some argue that CCS will promote a continued use of coal by making it appear to be a cleaner fuel. It is also important to recognize that coal is the fossil fuel that most contributes to climate change, and carbon capture technology has provided some breakthroughs for making it cleaner. However, the technology remains expensive: the amount of emissions is reduced by 80-100%, but the cost of coal-fired electricity generation increases the same amount, on average. Even with a sharp increase in renewables, coal will be a part of the future energy matrix, which is why more research is needed to create more efficient and less costly CCS technology to make it cleaner.

STATE OF THE TECHNOLOGY

According to the National Energy Technology Laboratory (Figueroa, 2016), the Technology Readiness Level [9] of CCS is in the stage of Process Engineering and Systems Integration, having already passed the applied research stage. At present, it is not yet developed enough to reach the demonstration phase. The technology is being tested in small- and large-scale pilots, under real operating conditions, reaching a cost of about 60 USD per ton of CO2. As of mid-2016, 13 Carbon Capture Small Pilot Projects have been or are about to be completed in the U.S. in the areas of post-combustion solvents, sorbents, and membranes, as well as pre-combustion, to make the process of capture more efficient. Their capacity ranges from 100 kWe to 3 MWe.

CCS is under an accelerated deployment timeline: new technology in the power industry traditionally passes through 10-15 years of laboratory development and 20-30 years of process scale-up, all of which will now be accomplished in a total of 15 years. Under multi-disciplinary research efforts coordinated to accelerate development between National Energy Technology Laboratory, other U.S. government laboratories, universities, and private sector partners, Large Scale Post-Combustion Pilot Projects, from 10 MWe to 25 MWe are in the construction phase, and expected to produce first results in 2020. Commercial scale projects, with capacities above 500 MWe are expected to come online by 2030, with costs dropping to about USD $40 per ton of CO2. This price is considered commercially competitive in a scenario with globally functioning carbon pricing schemes.

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[9] Technology readiness levels (TRL) are a method of estimating technology maturity of Critical Technology Elements (CTE) of a program during the acquisition process. TRLs are based on a scale from 1 to 9, with 9 being the most mature technology. See for example http://energy.gov/sites/prod/files/em/Volume_I/O_SRP.pdf .

Outside of the U.S., two new large-scale CCS projects began operating in 2015. One is the Quest Project in Canada; it captures about 1 million tons of CO2 from hydrogen production, storing the CO2 about two kilometers below ground in an on-shore saline aquifer. The second large-scale CCS project is the Uthmaniyah project in the Eastern Province of Saudi Arabia, which will capture about 800,000 tons of CO2 from a natural gas liquids recovery plant. The first removes CO2 that would have gone to the atmosphere. The second, however, will be used to extract more oil from the ground, or what is called Enhanced Oil Recovery (EOI) CCS. Besides these two projects, another 13 CCS projects are currently operational, with a total annual storage capacity rate of 28 million tons of CO2. The IEA indicates, however, that no new projects are being added to the development pipeline nor are investment decisions being made regarding new projects (IEA 2016a). This dearth of projects suggests the need of public policy for its support, in terms of making CCS cost effective, for example by increasing the cost of CO2 emissions, reducing the cost of investments, or introducing cap mandates from fossil fuel burning [10].

The majority of CCS projects supply or have the objective of supplying a medium to recover more oil from a well when other recovery methods fail to generate additional yields. With enhanced oil recovery (EOR), the CO2 is injected into the well, where it mixes with oil, allowing it to flow more freely within the formation, and it is pushed to the production well, where it is pumped out. This method is called tertiary production [11].

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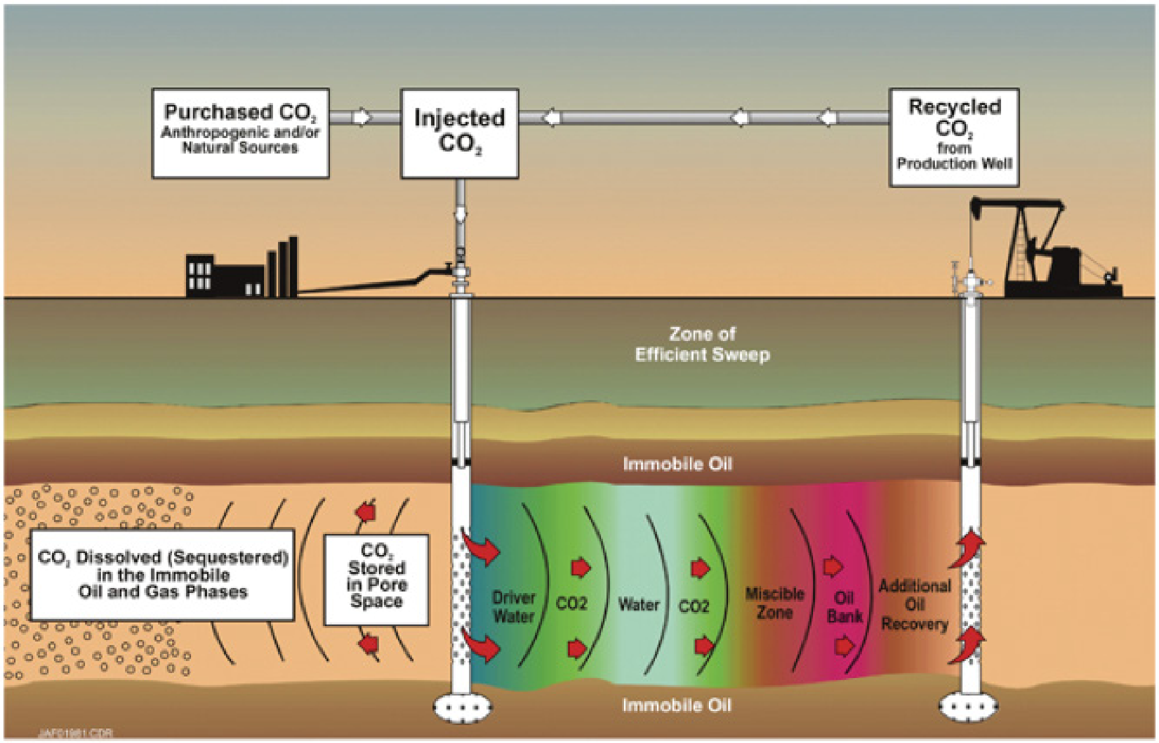
[10] To increase the cost of the emissions, two approaches have been used; cap and trade, and carbon taxes (see for example http://www.c2es.org/publications/cap-trade-vs-taxes). Both have the effect of removing the incentives for producing emissions or removing them from the atmosphere by adding the cost of CO2 to the cost of production, making CCS more attractive. An alternative is to provide incentives to invest in CCS by either providing funds or reducing tax liabilities, such as the S.3179 - Carbon Capture Utilization and Storage Act of 2016 (https://www.congress.gov/bill/114th-congress/senate-bill/3179/text). Cap mandates limit the amount of emissions by fiat. Command-and-control policies require polluters to take specific actions to reduce emissions by installing a particular technology or meeting a specific performance (emissions) standard.

[11] During tertiary production, oil field operators use an injectant (usually CO2) to react with the oil to change its properties and allow it to flow more freely within the reservoir. Almost pure CO2 (>95% of the overall composition) has the property of mixing with oil to swell it, make it lighter, detach it from the surface of the rock, and cause the oil to flow more freely within the reservoir to produce wells. In a closed loop system, CO2 mixed with recovered oil is separated in above-ground equipment for reinjection. CO2-EOR typically produces between 4-15% of the original oil in place (ARI, 2011). Conventional oil production practices such as primary and secondary production do not modify the product.

IMPLICATIONS FOR LAC COUNTRIES

Latin America and the Caribbean is a region rich in hydrocarbon-based fuels. By the end of 2014, proven reserves reached 344 million barrels, making it the second largest reserves region in the world. Colombia is rich in coal, Venezuela has the largest oil reserves in the world, and Argentina has one of the largest shale gas fields in the world. CCS, therefore, is a technology that could be relevant to the region. No CCS projects are currently being evaluated in the region.

Figure 3. Schematic of Enhanced Oil Recovery using CO2 as injectant



Source: Advanced Resources International and Melzer Consulting, Optimization of CO_2 Storage in CO_2 Enhanced Oil Recovery Projects, prepared for UK Department of Energy & Climate Change, November 2010.

CONCLUSIONS

In the past few years onshore wind has seen cost reductions that have made it one of the most competitive options for new energy generation capacity. In part, it has benefited from a virtuous circle of support policies that have driven risk reduction and technological improvements that in turn increased deployment. According to the International Renewable Energy Agency (IRENA), off-shore wind and solar photovoltaic systems (PV systems) are seeing similar effects (2016). It is expected that in ten years, CCS will become a transformational technology, that is, the emerging technologies that today are in the early stages of development will offer the potential for game-changing improvements in cost and performance. CCS is scheduled to complete large-scale pilot testing by 2020 and complete demonstration scale testing by 2025.

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