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Biomass Carbon Capture and Sequestration

Biomass refers to the mass of all living matter in a given area that includes all flora and fauna. There are different methods to measure the biomass. Fossil fuel burning releases CO_2 which enters the atmosphere and increase the atmospheric CO_2 concentration. According to IPCC report, forest ecosystem would release about 100 billion tonnes of CO_2 by the next 50 years. Using forest residues (thinnings and logging slash) for bioenergy is an opportunity to restore forest health, wildfire resiliency, and wildlife habitat. Silvicultural operations to improve forest conditions can help revitalize rural economies while providing renewable energy feedstocks. CO_2 storage is an integral part of the carbon capture and storage (CCS) chain, and therefore it is important to quantify the storage potential of geological sites such as coal fields, oil and gas fields, and deep saline water-bearing reservoir rocks. India has joined a number of international initiatives to speed up the development and dissemination of CCS technologies, notably the Carbon Sequestration Leadership Forum (CSLF), which provided a mandate for the involvement of the Department of Science and Technology (DST), and effectively engaged with industry experts. Popularizing the CCS technology is the only option to reduce the emissions and save the planet.

INTRODUCTION

Carbon sequestration refers to the natural and deliberate processes through which carbon dioxide (CO_2) is either removed from the atmosphere or diverted from emission sources and stored in the ocean, terrestrial environments, and geologic formations (Sundquist et al., 2008). Oceans, which mainly store carbon in sediments and dissolved carbonates, are by far the largest global carbon store. Terrestrial carbon sequestration is the process through which CO_2 is absorbed from the atmosphere through photosynthesis and stored in biomass and soils. In ecology, biomass refers to the mass of all living matter present in a given area, including all flora and fauna. It can be measured in a number of ways, including the weight of living tissue or of dried dead tissue. With respect to energy procurement, however, the term biomass is usually restricted to the living and recently dead biological material that can be used for fuel; this definition generally excludes fauna, but includes the trees and wood-chips destined for combustion. Burning either fossil fuels or biomass releases carbon dioxide (CO_2), a greenhouse gas. However, the plants that are the source of biomass for energy capture almost the same amount of CO_2 through photosynthesis while growing as is released when biomass is burned, which can make biomass a carbon-neutral energy source (Figure 1). Biomass burning, largely resulting from the activities of man, accounts for between 20 and 40 million tonnes of methane emissions each year. Methane emissions arising from biomass burning are a result of incomplete combustion and huge amounts can be produced during large scale burning of woodlands, savanna and agricultural waste.

HOW ARE CARBON CAPTURED?

The IPCC Assessment Report in 2007 estimated that about 100 billion metric tons of carbon over the next 50 years could be sequestered through forest management, which would offset 10-20% of the world's projected fossil fuel emissions. These models indicate that annual global emissions during the next century need to be reduced by more than 75% in order to stabilize atmospheric CO_2 at about 550 parts per million (Sundquist et al., 2008). Enhancing the natural processes that remove CO_2 from the atmosphere is one of the most cost effective means of reducing atmospheric levels of CO_2, and also reduces dependency on fossil fuels. At the global level, 19 per cent of the carbon in the earth's biosphere is stored in plants, and 81 per cent in the soil. In all forests, tropical, temperate and boreal together, approximately 31 per cent of the carbon is stored in the biomass and 69 per cent in the soil. Based on their calculations, for above and below ground biomass in metric tons of carbon stored per hectare, cool temperate moist forests store the most carbon, 625 tC/ha, with warm temperate moist storing slightly less, 500 tC/ha. As trees grow, they help stop climate change by removing carbon dioxide from the air, storing carbon in the trees and soil, and releasing oxygen into the atmosphere. Using forest residues (thinnings and logging slash) for bioenergy is an opportunity to restore forest health, wildfire resiliency, and wildlife habitat. Silvicultural operations to improve forest conditions can help revitalize rural economies while providing renewable energy feedstocks (Cloughesy and Lord 2006). In addition to this "triple win" (IFPC 2009; OFRI 2009), forests play a key role in the global carbon cycle by capturing, storing, and cycling carbon (EPA 2009). In savanna regions of the world, burning is often carried out every few years to promote regeneration of the vegetation. The importance of methane emission from biomass burning can be overshadowed by the large amount of carbon dioxide which is also produced, but in many cases the subsequent regrowth, and carbon dioxide uptake, of previously burned woodland and savanna areas mean that the net emission of carbon dioxide is much reduced.

There are myriad predictions for how forest carbon storage will change over the coming decades to centuries, most of which are highly uncertain, even contradictory. Climate change may stimulate forest growth by enhancing availability of mineral N and through the CO_2 fertilization effect, thus increasing both carbon sequestration and storage (Lal 2005). Yet it appears likely that warming will also have the effect of reducing soil organic carbon by stimulating microbial activity more than forest growth (Kirschbaum 2000). However, as increasing CO_2 is likely to simultaneously have the effect of increasing soil organic carbon through increases in net primary productivity, the net effect of changes in soil organic carbon on atmospheric CO_2 over the next decades to centuries is likely to be small (Kirschbaum 2000). CO_2 storage is an integral part of the carbon capture and storage (CCS) chain, and therefore it is important to quantify the storage potential of geological sites such as coal fields, oil and gas fields, and deep saline water-bearing reservoir rocks. Presently, there is a lack of knowledge in this area due to a general dearth of essential data required to characterize these sites.

Nonetheless, some attempts have been made at evaluating the storage potential in India, initially by Singh et al., (2006) who estimated that roughly 5 Gt CO_2 could be stored in unmineable coal seams, 7 Gt

CO_2 in depleted oil and gas reservoirs, 360 Gt CO_2 in offshore and onshore deep saline aquifers, and 200 Gt CO_2 via mineralization in basalt rocks. The latter refers to laboratory experiments conducted by McGrail et al (2006) that demonstrated a relatively rapid chemical reaction of CO_2-saturated pore water with basalts to form stable carbonate minerals. This could be quite an appealing opportunity for India as a very extensive portion of the central peninsula consists of one of the world's largest basalt lava flows known as the Deccan trap formation. However, this concept is still in the experimental phase and can only be considered a possibility if the basalt is adequately permeable to the CO_2 and can be demonstrated to be safe and secure (McGrail et al., 2006). India has joined a number of international initiatives to speed up the development and dissemination of CCS technologies, notably the

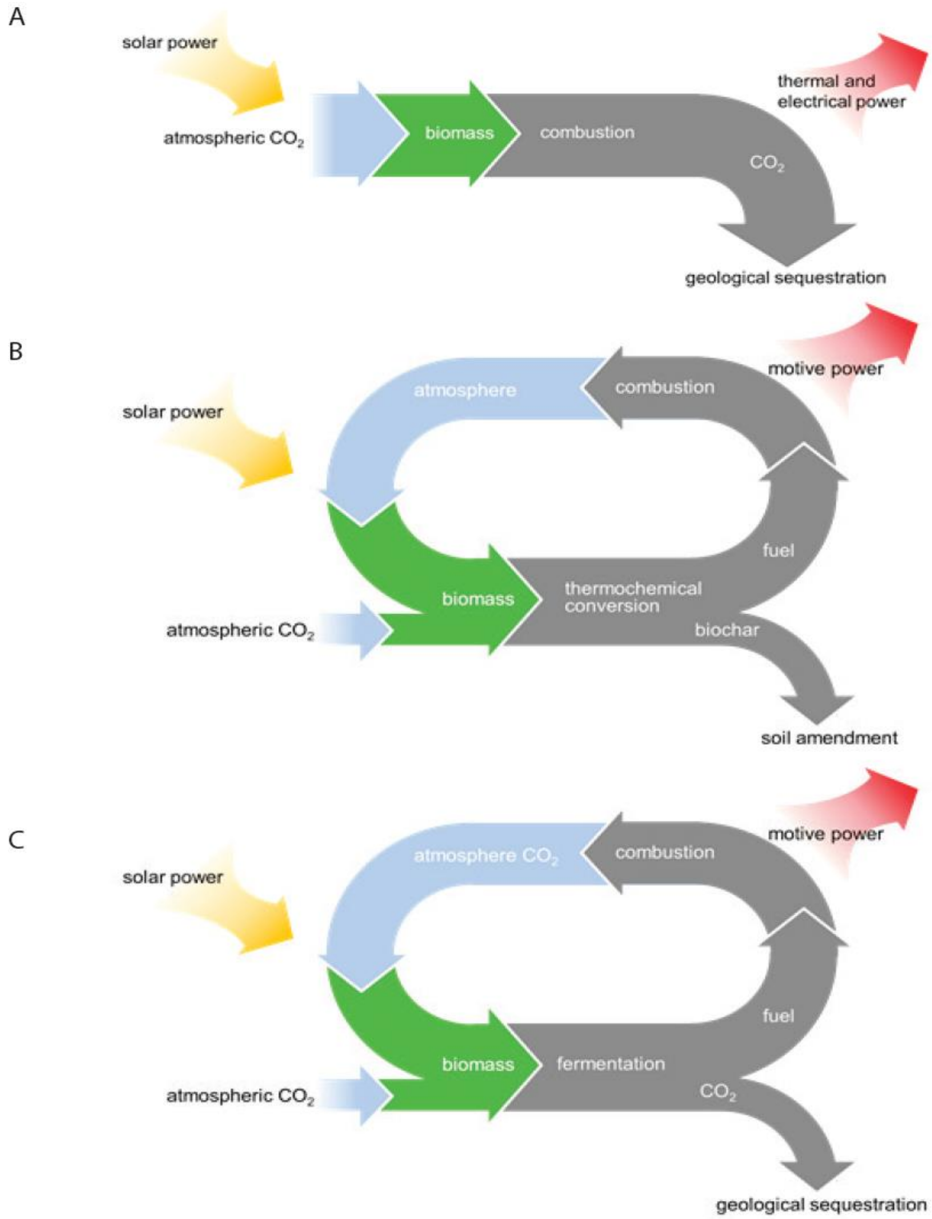

Figure 1. Generic biomass energy based carbon dioxide removal pathways: a) biomass to power with carbon capture, and sequestration b) biomass to fuel and biochar and c) biomass to fuel with carbon capture and sequestration

Carbon Sequestration Leadership Forum (CSLF), which provided a mandate for the involvement of the Department of Science and Technology (DST), and effectively engaged with industry experts. The cost of building a plant with CCS technology is currently very high as there are no major demonstration projects ready on the scale required by India. This cost should come down over time, especially if the EU's plans for twelve demonstration projects by 2015 come to fruition. An incentive could be the gaining of revenues through certified emission reductions (CERs) under the Clean Development Mechanism (CDM), as India is a signatory to the UNFCCC and its Kyoto Protocol. However, with the current pace of climate change negotiations, it seems unlikely that CCS would have much of a role to play in meeting CO_2 emission reductions via the CDM in the first commitment period (Shackley and Verma, 2008).

HUMAN IMPACT

Though fires caused by lightning strikes have, and still do, account for some large biomass burning events, the activities of man in the last 100 years have dwarfed methane emissions from such natural biomass burning. Huge areas of woodland and grassland are now periodically burned for land clearance. Burning of agricultural waste also produces significant amounts of methane due to it's generally high water content. Additionally, wood burning, as a domestic fuel source and for charcoal production, releases significant amount of methane on a global scale. Accidental fire and arson account for further large scale biomass burning events each year around the world.

POTENTIAL FOR CONTROL

The uncontrolled way in which most biomass burning happens means that the only real route to reducing emissions from this source is to reduce the amount of burning itself. Some biomass burning is required if environments such as the savanna are to be retained, but it is the large scale destruction of forest areas for cash crop agriculture and urban spread which stand out as areas to be tackled. Biomass burning is currently being developed as an alternative to traditional fossil fuel energy production methods, with power stations fuelled by wood chips and the like already a reality. By making use of a renewable resource, like pine wood chips, and avoiding incomplete combustion, these biomass power stations are able to have a much reduced net greenhouse gas impact compared to equivalent coal, oil and gas fired power stations.

Considerations for safe storage of carbon on, in, or deep under the soil create roles for forestry (Read 2009). Five types of carbon reservoirs are preferable to storing carbon in the atmosphere, and only the last item does not have an obvious role for forestry: 1) new forestry plantations; 2) new timber structures and other durable wood products from harvested wood; 3) underground wood burial, perhaps in abandoned mines; 4) biochar storage in soil reservoirs with co-produced bio-oil; and 5) carbon capture and storage in deep geological strata or as bicarbonates in the ocean or insoluble carbonates on land in played-out coal mines. In addition, the existing fossil carbon reservoir is maintained *in situ* through technology chains that involve bioenergy and other renewable sources of energy that substitute for fossil fuel (Read 2009).

THE BECCS FACILITY

Bioenergy with carbon capture and storage (BECCS) is the process of extracting bioenergy from biomass and capturing and storing the carbon, thereby removing it from the atmosphere. The carbon in the biomass comes from the greenhouse gas carbon dioxide (CO_2) which is extracted from the atmosphere by when the biomass grows. Energy is extracted in useful forms (electricity, heat, biofuels, etc.) as the biomass is utilized through combustion, fermentation, pyrolysis or other conversion methods. Some of the carbon in the biomass is converted to CO_2 or biochar which can then be stored by geologic sequestration or land application, respectively, enabling carbon dioxide removal and making BECCS a negative emissions technology.

The IPCC Fifth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC), suggests a potential range of negative emissions from BECCS of 0 to 22 giga tonnes per year. As of 2019, five facilities around the world were actively using BECCS technologies and were capturing approximately 1.5 million tonnes per year of CO2. Wide deployment of BECCS is constrained by cost and availability of biomass.

At the moment, CCS is the only technology that can help reduce emissions from large industrial installations. It could be an essential technology for tackling global climate change. When combined with bioenergy technologies for power generation.

Many scientists and policymakers argue that this is crucial if the world is to limit temperature rise to under 2°C, the goal of the Paris Agreement. The International Energy Agency states that a tenfold increase in capacity is needed by 2025 to be on track for meeting that target and the Global CCS Institute estimates that 2,500 CCS facilities would need to be in operation by 2040 worldwide, each capturing around 1.5 million tonnes of CO_2 per year.

CONCLUSION

India's growing population is predicted to emit huge quantities of CO_2 compared to other countries. According to the Intergovernmental Panel on Climate Change (IPCC), some of the most severe impacts of climate change will hit India's agriculture and natural resources. Considering that just over half of India's current CO_2 emissions are from large point sources, it may be that such current and future sources could be a suitable starting point for capturing emissions, transporting them, and then storing them in porous rock as a mitigation strategy against dangerous climate change. Popularizing the CCS technology is the only option to reduce the emissions and save the planet.

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