SRC for carbon sequestration

Adele Calvert
Supervisor: Professor Ralph Sims

Centre for Energy Research, Institute of Technology and Engineering, Massey University,
Palmerston North, New Zealand
A.J.Calvert@massey.ac.nz

1. ABSTRACT

Short rotation coppice (SRC) practices for biomass cultivation offers options for enhancing the resistance and resilience to environmental change while at the same time satisfying the demand for wood fibres. Altering the distribution of CO_2 at the earth/atmosphere interface, silviculture ecosystems may be used to 'pump' CO_2 out of the atmosphere and into terrestrial pools for storage. To introduce a negative carbon balance to the biomass system, carbon dioxide removal (CDR) may be implemented for carbon capture leading to physical sequestration and the effective, safe, and environmentally sound long-term storage of carbon. Hence, SRC has the potential when linked with carbon sequestration technologies to produce a carbon negative process, holding a potential for enhanced climate change mitigation.

2. KEYWORDS

short rotation coppice (SRC), carbon, carbon dioxide, carbon dioxide recovery (CDR), biological sequestration, and physical sequestration.

3. INTRODUCTION

Atmospheric CO_2 levels and carbon flux may be potentially manipulated through changes in stored carbon within fossil fuels, living biomass, soils, forest litter, wood and wood products, and land management activities (Schlamadinger and Marland, 1996). A common method of terrestrial carbon sink expansion is through biological sequestration, deterring deforestation, encouraging forestry production, reforestation, afforestation and improved agricultural and range management (Hughes and Benemann, 1997). Hence, biological carbon sequestration is a process whereby the degree of carbon in long-term terrestrial stocks increases, reducing atmospheric CO_2 load) (West and Marland, 2002). However, carbon storage within any terrestrial environment is limited, fluxing between lower and upper thresholds dependent upon soil type, climatic conditions, disturbance, and management regime (Kirschbaum, 2003).

4. BIOLOGICAL CARBON STORAGE AND SEQUESTRATION

The most easily measured carbon pool is the total standing aboveground biomass of woody vegetation elements, comprising of all woody stems, branches, leaves, creepers, climbers, epiphytes, and herbaceous undergrowth (IPCC, 2000). In plantation forests the carbon pool is seen to be locked up in the biomass of harvestable trees with soil carbon levels potentially increasing over time as a result of organic matter build-up from root growth and litter decomposition (Sims, 2002). When a tree is used for energy purposes, the natural cyclic processes of the biomass being converted to CO_2 and being released are speeded up (Sims, 2002). Generally assumed to be a CO_2-neutral energy carrier, biomass allows the carbon stored in plants to be emitted through combustion and up-taken once again in the re-growth of new plants (Schlamadinger and Marland, 1996). In a natural forest environment the process continuously repeats as trees and plants grow and die leaving the carbon cycle in balance (Sims, 2002). However, in plantation forests, the initial planting acts as a sink of carbon, a process that must be repeated after each harvest in order to continue to leave the carbon cycle in equilibrium (Sims, 2002). Options to further increase the sequestration of carbon in wood products include increasing consumption and production of wood products, improving the quality of wood products, improving processing efficiency, and enhancing recycling and re-use of wood and wood products (IPCC, 2000).

Under the terms of the Kyoto protocol, plantations established after 1990 may be counted as offsets to GHG emissions contributing to a country's international commitments addressing climate change (Paul *et al.*, 2003). Altering the distribution of CO_2 at the earth/atmosphere interface, silviculture ecosystems may be used to 'pump' CO_2 out of the atmosphere and into terrestrial pools for storage (Lee *et al.*, 2002). Production forestry offers the opportunity to sequester carbon from the atmosphere to offset CO_2 emissions from the combustion of fossil fuels (Dyck & Bow, 1992). A major advantage is gained by woody crops in their ability to sequester CO_2 during growth, serving as a transient carbon sink (Cook & Beyea, 2000), reducing GHG emissions, as well as potentially serving as a 'carbon offset' by the long term replacement of fossil fuels (Malik *et al.*, 2001).

5. SRC FOR BIOENERGY

Short rotation coppice (SRC) can be used as a renewable energy source whereby combustion releases photosynthetic energy for use as electricity and/or heat (Varela *et al.*, 2001). Bioenergy from SRC can be used to avoid GHG emissions from fossil fuels by providing equivalent energy services such as electricity, transportation fuels, and heat (IPCC, 2000) whereby a common objective of biomass conversion technologies is to produce a continuous form of energy from a non-uniform feedstock (CAE/EECA, 1996). The use of biomass for heat and energy is regarded as CO_2 neutral because CO_2 emissions arising at the combustion process have been absorbed before the growth of the plants (Nagel, 2000). However, to introduce a negative carbon balance to the biomass system, carbon dioxide recovery (CDR) may be implemented for carbon capture leading to physical sequestration (Nagel, 2000). Although CO_2 emissions in the process chain arising from harvesting, transportation, reprocessing, would still contribute to CO_2 emissions, a greater emission offset after combustion would be created (Figure 1) (Kraxner *et al.*, 2003). Besides the CO_2 emissions it must be noted that other products within the waste gas are produced during the combustion process, each influencing the environment including NO_x, SO_2, CO, dust and soot (Nagel, 2000).

6. CARBON DIOXIDE RECOVERY (CDR)

CDR is an end-of-pipe technology originally developed for fossil fuel combustion facilities and is readily applied to the conversion of biomass for bioenergy production (Kraxner *et al.*, 2003) with various CO_2 separation, capture and sequestration techniques being currently implemented for commercial projects technologies (IPCC, 2001). Carbon dioxide recovery has the potential to deliver a substantial contribution to the reduction of CO_2 emissions when combined with physical sequestration techniques, whilst efficiently using energy and materials, and being economically affordable, socially acceptable and environmentally sound (Turkenburg, 1997). To allow CDR to play a major role in enhanced climate change mitigation, attention should be given to the environmental soundness of the technologies involved. Special attention is required for the reliability, safety and environmental consequences of CO_2 storage and disposal (Turkenburg, 1997).

The various techniques of CDR currently available and/or under research and development include:

- **Flue gas absorption** using chemical, physical, and hybrid solvents
- **Flue gas adsorption** using either:
  - — Pressure swing adsorption (PDS)
  - — Temperature swing adsorption (TSA)
  - — Electrical swing adsorption (ESA)
- **Flue gas membrane separation**
- **Oxygen combustion** approach (increasing CO_2 concentrations by increasing O_2 levels and reducing N_2 content in the air supply during combustion
- **Hydrogen/Syngas** approach ($CO + H_2O \rightarrow CO_2 + H_2$)

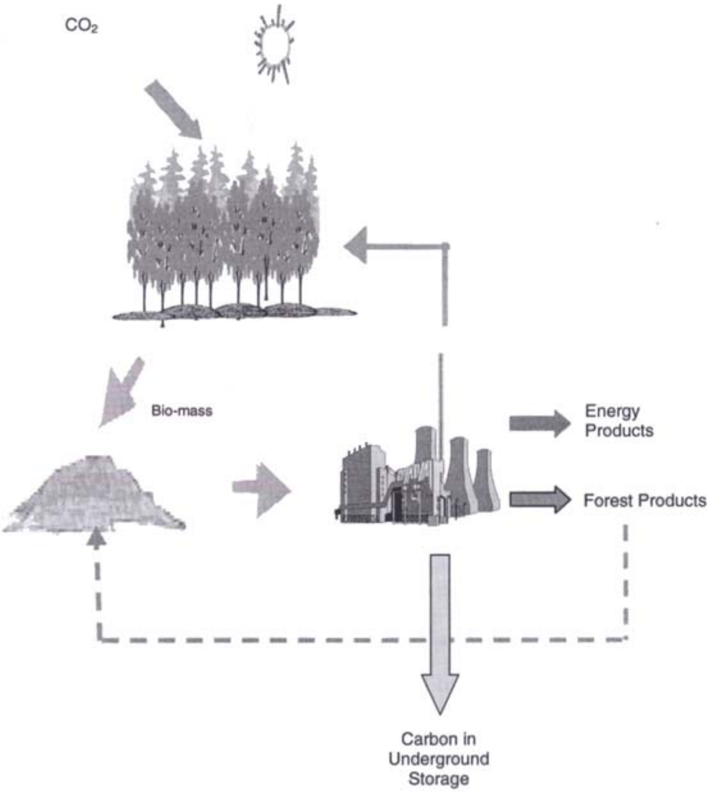

Figure 1. The carbon balance of bioenergy with carbon capture and sequestration included (Kraxner *et al.*, 2003)

Two major components affect the potential of CDR for physical sequestration purposes; the efficiency of the process and, the efficiency of the industrial metabolism in general (Kraxner *et al.*, 2003). Once captured, CO_2 can then be stored in permanent features to prevent venting to the atmosphere or utilised for activities that include enhanced oil recovery (EOR), a chemical feedstock in food production, fish farms and agricultural greenhouses (IEA, 2002).
However, the resources available to be used as CO_2 reservoirs are subject to substantial uncertainty, with exploration only having been conducted in parts of the world thus far (IPCC, 2001).

7. PHYSICAL SEQUESTRATION

Physical sequestration describes the whole process from the separation of CO_2 to the storage and disposal to the selected sink (Grimston *et al.*, 2001). The prime objective for the development of physical CO_2 sequestration is the effective, safe, and environmentally sound storage of carbon, with the viability of carbon storage being hinged on criteria fulfilment (IEA, 2002). Deep underground disposal is regarded as the most mature storage option today with four main geological settings appropriate for deep storage: oil fields, gas fields, deep rocks containing saline waters and unminerable coal formations (Figure 2) (IPCC, 2001; Kraxner *et al.*, 2003). Oceanic storage of CO_2 is also a possibility, however significant environmental concerns are associated.

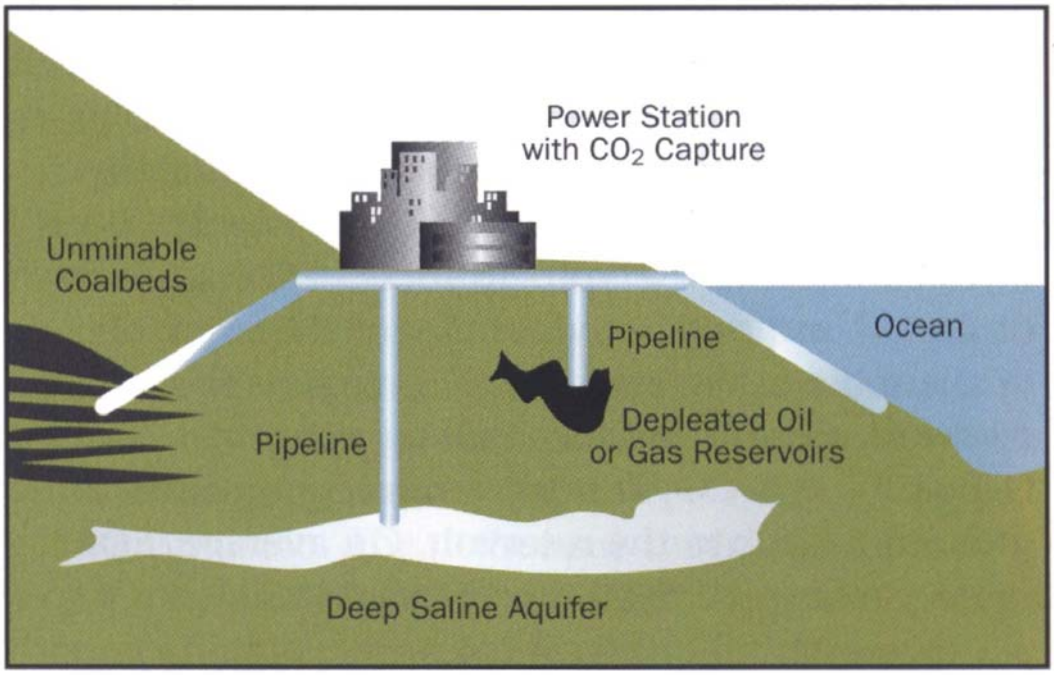

Figure 2. Integrated gasification combined cycle using pre-combustion CO_2 capture in a coal driven system (IEA, 2002)

Analysis of physical CO_2 storage potentials is a relatively new field of study with variations in criteria being apparent for assessing site suitability and storage capacity although efforts are being made to establish international methodological standards (Table 1) (IEA, 2002).

Geosphere sinks such as active and uneconomical (abandoned) oil and gas reservoirs, aqueous formations, including saline formations, and deep unminerable coal formations and coalbed methane formations, have a potential to store large amounts of CO_2 (Grimston *et al.*, 2001). Other possibilities such as marine and arctic hydrates, CO_2 reservoirs, oil shales and mined cavities in salt domes may increase sequestration capacities or provide site-specific opportunities, but are only likely to be developed after other sequestration techniques have been explored (Grimston *et al.*, 2001).

Table 1. Preliminary estimates of worldwide CO_2 storage capacities (IEA, 2002)

Sequestration Option	Worldwide Capacity (Gtcarbon)
Ocean	1000s
Deep saline formations	100s-1000s
Depleted oil and gas reservoirs	100s
Coal seams	10s-100s
Terrestrial ecosystems	10s
Utilisation	< 1

8. THE 'CARBON PUMP'

Once connected to a physical sequestration technology, biomass production for energy utilisation may provide a means to draw out CO_2 from the atmosphere, to be placed in long-term or permanent storage. In this manner, the biomass crop will act as a '*carbon pump*' drawing in the GHG to be later segregated, captured and stored via a bioenergy utilisation process. Hence, SRC has the potential when linked with carbon sequestration technologies to produce a carbon negative process, and holds a potential for enhanced climate change mitigation (Figure 3).

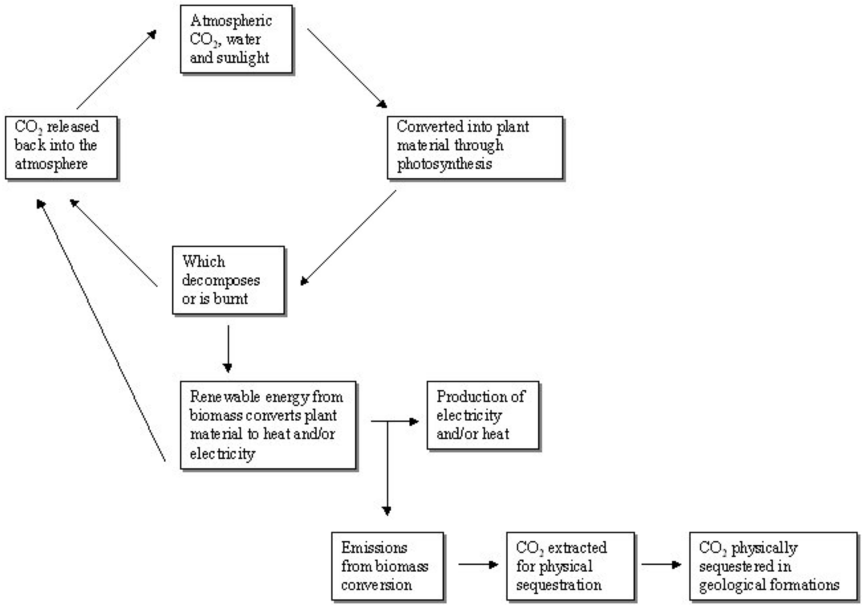

Figure 3. A schematic of the process linking SRC for bioenergy use and physical sequestration for enhanced climate change mitigation purposes

9. REFERENCES

CAE/EECA, 1996. *New and Emerging Renewable Energy Opportunities in New Zealand*. Energy Efficiency and Conservation Authority (**EECA**), Wellington. ISBN: 0-908993-11-0.

Cook, J.; Beyea, J. 2000. Bioenergy in the United States: progress and possibilities. *Biomass and Bioenergy* **18**, 441-455.

Dyck, W.J.; Bow, C.A. 1992. Environmental impacts of harvesting. *Biomass & Bioenergy* **2**, 173-191.

Grimston, M.C.; Karakoussis, V.; Fouquet, R.; van der Vorst, R.; Pearson, P.;Leach, M. 2001. The European and global potential of carbon dioxide sequestration in tackling climate change. *Climate Policy* **1**, 155-171.

Hughes, E.; Benemann, J.R. 1997. Biological fossil CO_2 mitigation. *Energy Conversion and Management* **38**, S467-S473.

IEA (2002). *Solutions for the 21st Century. Zero Emissions Technologies for Fossil Fuels. Technology Status Report*. International Energy Agency Working Party on Fossil Fuels (Chairman: Barabara McKee). IEA, Paris, France.

IPCC, 2000. Land use, land-use change, and forestry. A special Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

IPCC, 2001. Climate Change 2001: Mitgation. Contribution to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

Kirschbaum, M.U.F. 2003. To sink or burn? A discussion of the potential contributions of forests to greenhouse gas balances through storing carbon or providing biofuels. *Biomass & Bioenergy* **24**, 297-310.

Kraxner, F.; Nilsson, S.; Obersteiner, M. 2003. Negative emissions from Bioenergy use, carbon capture and sequestration (BECS) – the case of biomass production by sustainable forest management from semi-natural temperate forests. *Biomass and Bioenergy* **24**, 285-296.

Lee, J.; Morrison, I.K.; Leblanc, J.; Dumas, M.T.; Cameron, D.A. 2002. Carbon sequestration in trees and regrowth vegetation as affected by clearcut and partial cut harvesting in a second-growth boreal mixedwood. *Forest Ecology and Management* **169**, 83-101.

Malik, R.K.; Green, T.H.; Brown, G.F.; Beyl, C.A.; Sistani, K.R.; Mays, D.A. 2001. Biomass production of short-rotation bioenergy hardwood plantations affected by cover crops. *Biomass & Bioenergy* **21**, 21-33.

Nagel, J. 2000. Biomass in energy supply, espeically in the state of Brandenburg, Germany. *Ecological Engineering* **16**, S103-S110.

Paul, K.I.; Polgase, P.J.; Richards, G.P. 2003. Sensitivity analysis of predicted change in soil carbon following afforestation. *Ecological Modelling* **164**, 137-152.

Schlamadinger, B.; Marland G. 1996. The role of forest and bioenergy strategies in the global carbon balance. *Biomass & Bioenergy* **10**, 275-300.

Sims, R.E.H. 2002. *The brilliance of Bioenergy. In business and in Practice*. James & James (Science Publishers) Ltd., London, UK.

Turkenburg, W.C. 1997. Sustainable development, climate change, and carbon dioxide removal (CDR). *Energy Conversion and Management* **38**, S3-S12.

Varela. M.; Sáez, R.; Audus, H. 2001. Large-scale economic integration of electricity from short-rotation woody crops. *Solar Energy* **70**, 95-107.

West, T.O.; Marland, G. 2002. Net carbon flux from agricultural ecosystems: methodology for full carbon cycle analyses. *Environmental Pollution* **116**, 439-444.