The role of woody biomass energy crops in GHG mitigation

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My research area...

The use of woody biomass energy crops as a "carbon dioxide pump" linking biological and physical sequestration technologies for enhanced climate change mitigation.

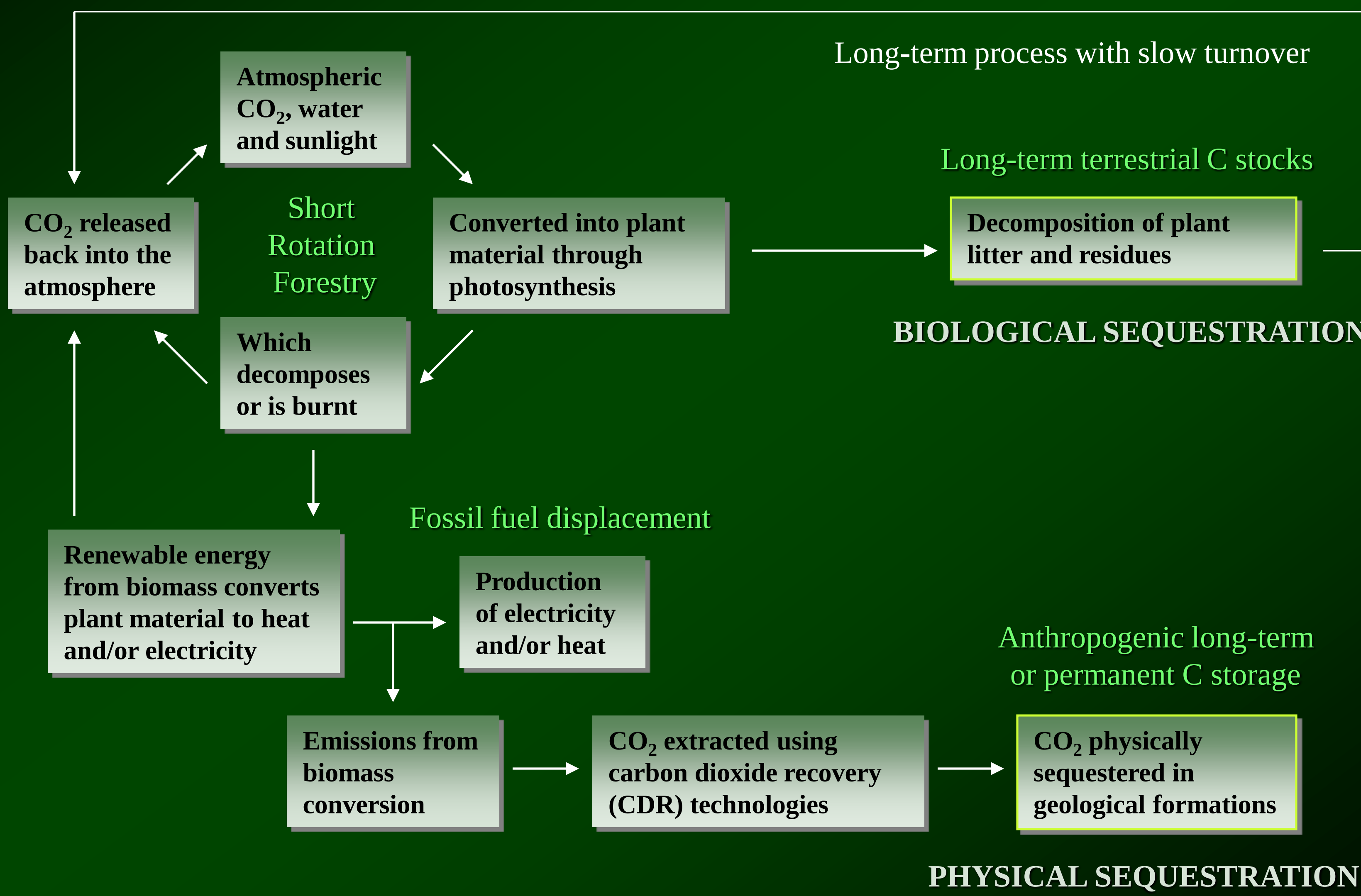
Carbon sequestration

Carbon can be sequestered biologically and physically:

- ***Biological sequestration*** may be described as the increase in long-term terrestrial C stocks through passive in-situ processes.

- ***Physical sequestration*** may be described as the long-term or permanent storage of C in geological or oceanic features.

SRF carbon sequestration pathway



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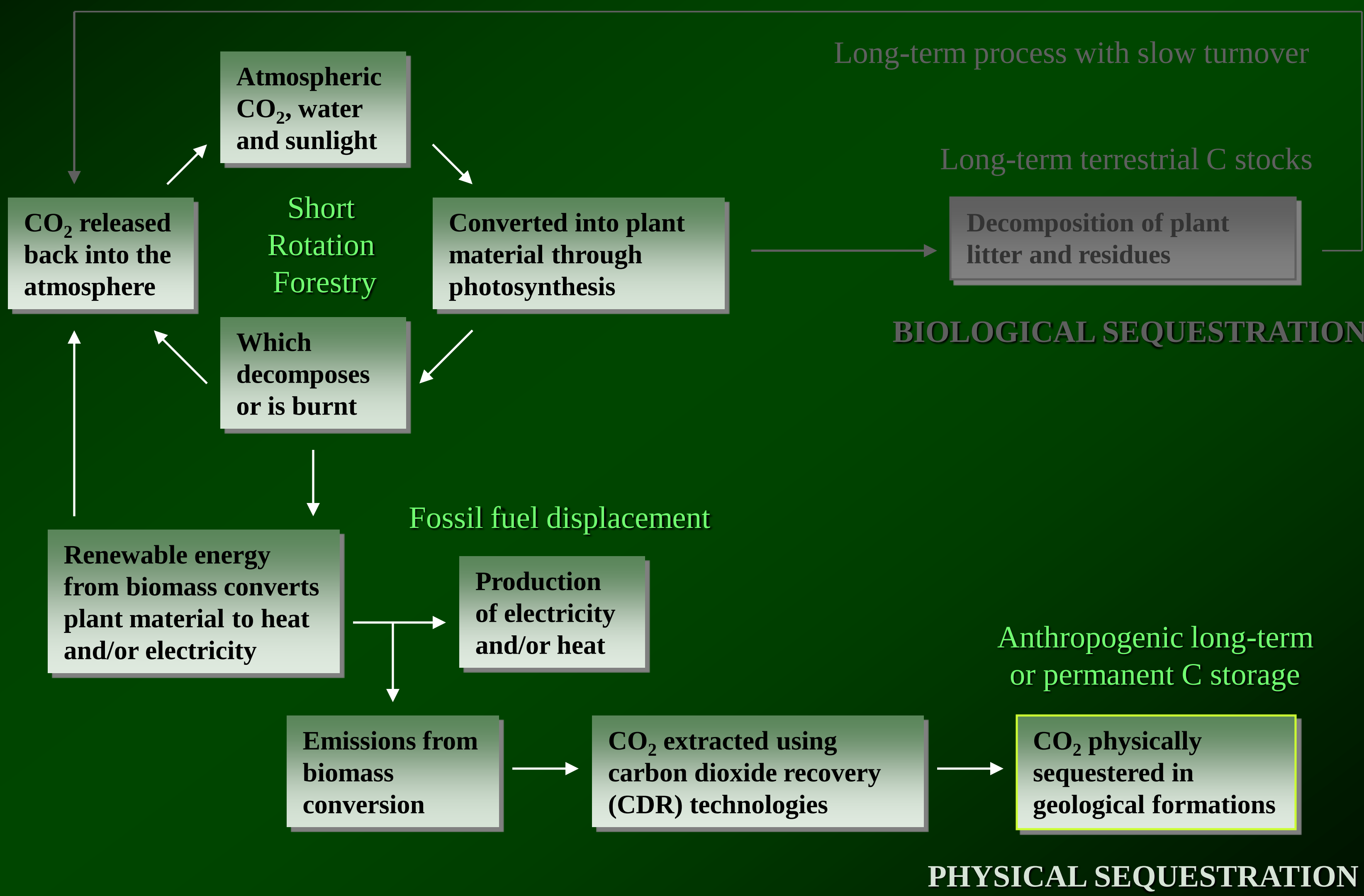


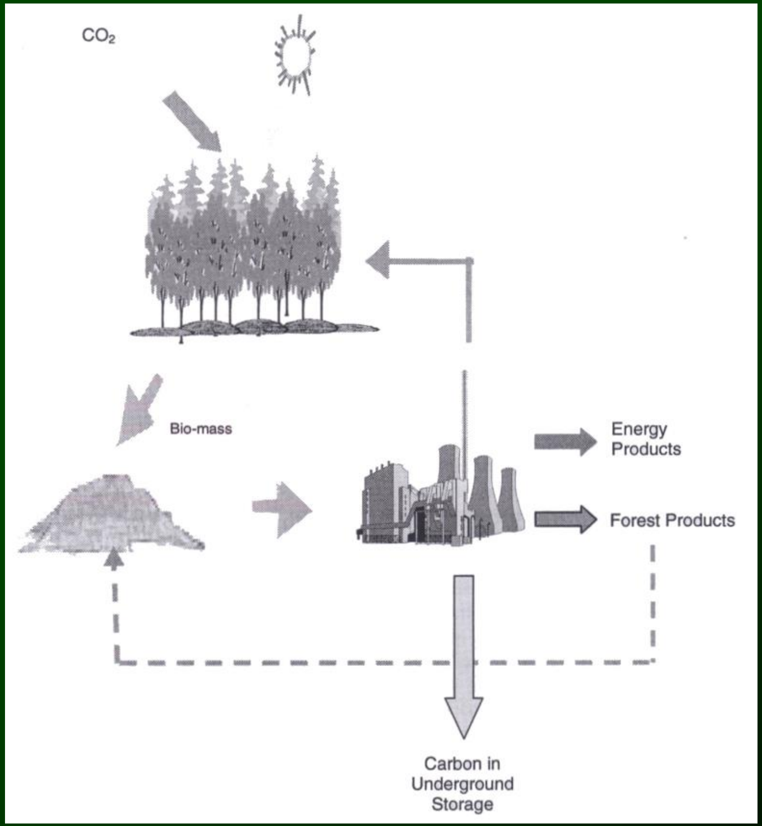
Short rotation forestry (SRF)

- SRF has the ability to act as a transient carbon sink through the growth, harvest and re-growth of a bioenergy crop.
- Biomass as a source of energy can be considered to a ‘carbon-neutral’ process.
- However, CO_2 emissions currently arise during the harvesting, transportation, and reprocessing stages.

SRF and CO_2

The conversion of woody biomass to heat and energy produces a cyclic mechanism of CO_2 uptake through photosynthesis and CO_2 emission during combustion.

Intercepting the combustion emissions with Carbon Dioxide Recovery (CDR) processes provides opportunity for physical sequestration technologies to be utilised and a carbon negative bioenergy process to be developed.



Carbon dioxide recovery (CDR)

- CDR is a commercially available and applied technology capturing CO_2 from fossil fuel emissions.
  - Sleipner gas field, North Sea (climate change)
  - Various schemes, USA (enhanced oil recovery)
  - Allison Unit, New Mexico (enhanced coalbed methane recovery)

- Although developed within the fossil fuel industry, the techniques evolved may be applied to biomass facilities.

- To date there is no known application of CDR operating alongside bioenergy conversion.

Carbon dioxide recovery (CDR)

Various techniques available to recover CO_2 these include:

- ***Flue gas absorption*** using chemical, physical, and hybrid solvents to capture CO_2 by assimilation.

- ***Flue gas adsorption*** selectively capturing the components of the flue gas using either:
  - Pressure swing adsorption (PSA)
  - Temperature swing adsorption (TSA), or
  - Electrical swing adsorption (ESA)

- ***Flue gas membranes separation*** using partial pressures as the driving force for gas separation or absorption via a membrane.

Carbon dioxide recovery (CDR)

Various techniques available to recover CO_2 these include:

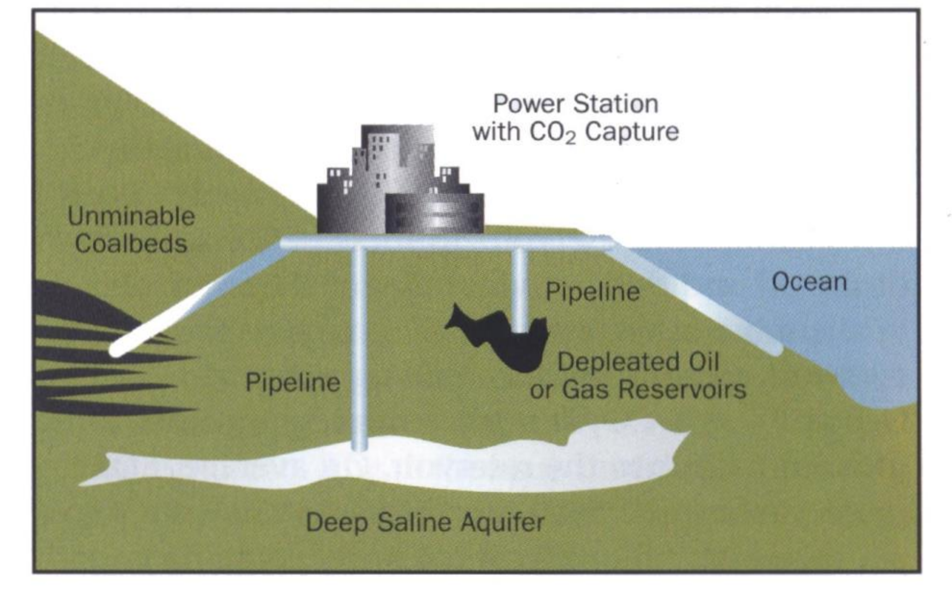
- ***The oxygen combustion approach*** increases the CO_2 concentration within the flue gases by increasing O_2 levels and reducing N_2 content within the air supply during combustion.

- ***The Hydrogen/Syngas approach*** a pre-combustion process to remove the carbon content of the feedstock to produce a CO_2-rich by-product. The standard and most efficient method is the water/gas shift reaction:

$$CO + H_2O \longrightarrow CO_2 + H_2$$

Physical sequestration

The long-term or permanent storage of C in geological or oceanic features.



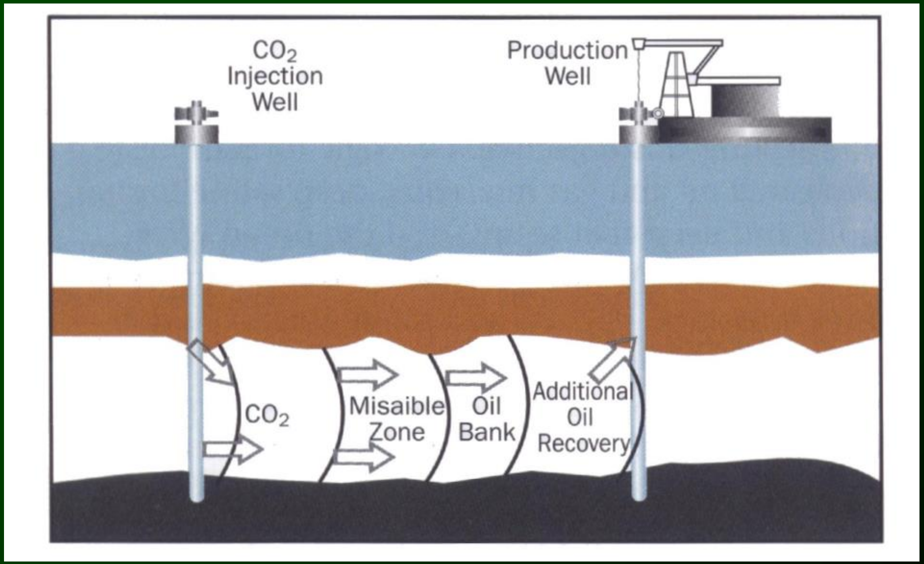
Primary objective: the effective, safe, and environmentally sound permanent or long-term storage of C.

Oil and gas fields

- Oil and gas reservoirs are structural traps that have contained oil and gas over geological timescales.
- Enhanced oil recovery (EOR) is a method of increasing output from depleted oil reservoirs.
- A mature technology, EOR has been used for decades within the oil industry.

Oil and gas fields

- CO_2 is injected into the reservoir.
- Dissolving into the oil the viscosity is reduced.
- Outcome: the oil is more mobile and easier to capture via the production well.



Oil and gas fields

- The Weyburn CO_2 monitoring project in Canada is using EOR for carbon sequestration.
- CO_2 derived from the Great Plains Synfuels Plant in Beulah, USA is injected into the oil reservoir for permanent storage.
- Canada's largest CO_2 sequestration project.

Oil and gas fields

- Using the same techniques as in oil fields, abandoned or depleted gas fields may also be used for carbon sequestration.

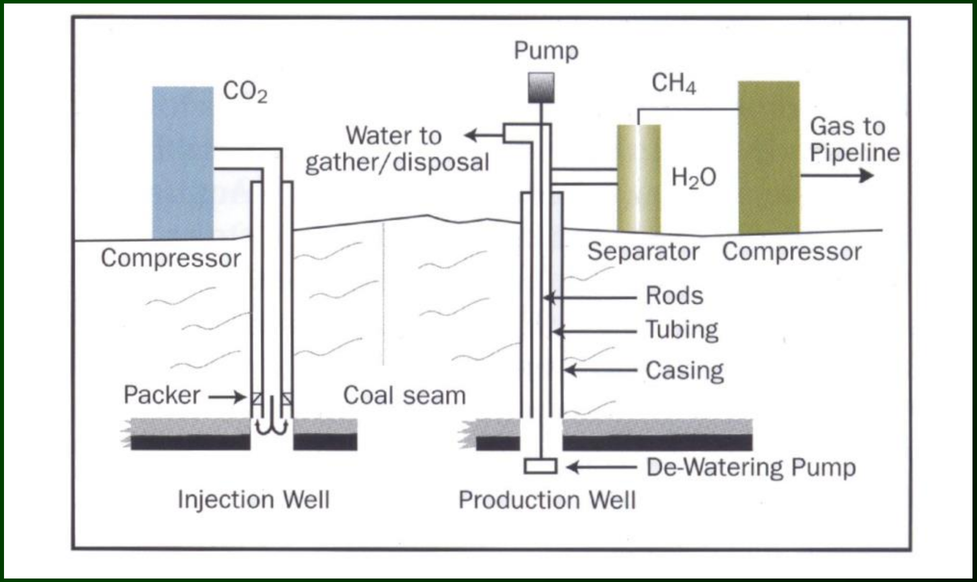
- Unlike oil fields, CO_2 injection into gas field is purely a sequestration motivated activity.

- The potential to utilise recovered CO_2 from CDR for EOR is small in comparison to the potential for CO_2 storage in depleted oil and natural gas fields.

Deep coalbeds

- Deep formations provide an opportunity to simultaneously sequester CO_2 whilst increasing the production of coal bed methane (CBM).

- As CO_2 is a high-adsorbing gas, it displaces and desorbs the CBM.



Deep coalbeds

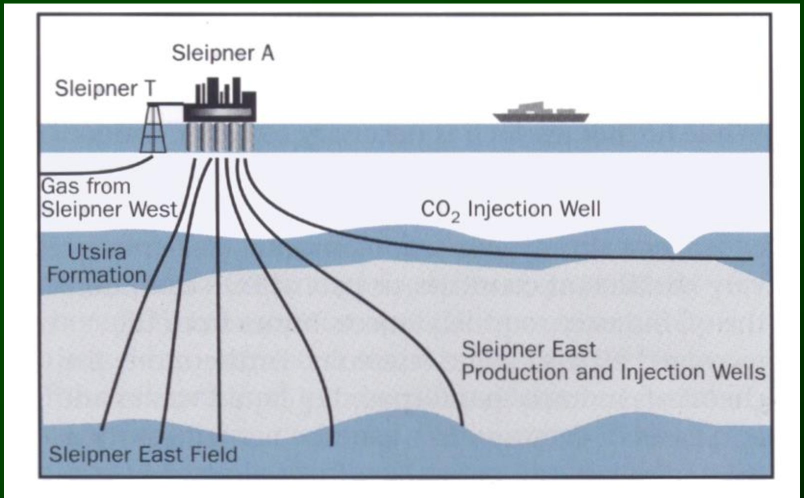
- Typically two molecules of CO_2 are absorbed for each CBM molecule released.
- CBM technology is widely available and commercially used to produce heating or electricity.
- First commercial application launched in 1996 at Burlington Resources' Allison Unit, San Juan Basin, New Mexico.

Deep saline aquifers

- Widely distributed.
- Physical requirements for CO_2 injection and disposal include:
  - Top of aquifer must be at least 800m below the surface
  - Aquifer should be capped by a regional aquitard (a sealing unit)
  - Hydrological separation from drinking and surface water supplies must be ensured
  - Aquifer should have sufficient porosity and permeability near the injection site
  - Regional permeability should be low to ensure long CO_2 residence times

Deep saline aquifers

- A proven technology.
- Currently demonstrated at Norway's Sleipner gas field.
- CO_2 from the gas field is injected into the Utsira formation for permanent storage preventing venting to the atmosphere.



Ocean disposal

- Ocean CO_2 storage is a natural part of the carbon cycle.
- The oceans provide a tantalising opportunity for enhanced carbon sequestration.
- Several approaches to ocean carbon disposal have been proposed including:
  - the release of dry ice from a ship
  - the introduction of liquid CO_2 into a sea floor depression to form a ‘deep lake’
  - the release of CO_2 enriched seawater at a depth of 500-1000m
  - the injection of liquid CO_2 at 1000-1500m
  - The release of iron minerals to promote ocean fertilisation and plankton growth

Ocean disposal

- Considerable uncertainties are associated with ocean disposal.
- Large unquantified risk exists for environmental damage.
- Long-term isolation and permanence of the CO_2 sequested is questionable.
- Much more research and development is required.

Other physical sequestration methods

- Char incorporation into terrestrial environments.
- Long-lived carbon based products e.g. wooden or carbon fibre infrastructure.

The ‘carbon dioxide pump’

The biomass crop pulls the CO_2 out of the atmosphere via photosynthesis for crop growth and biological sequestration.

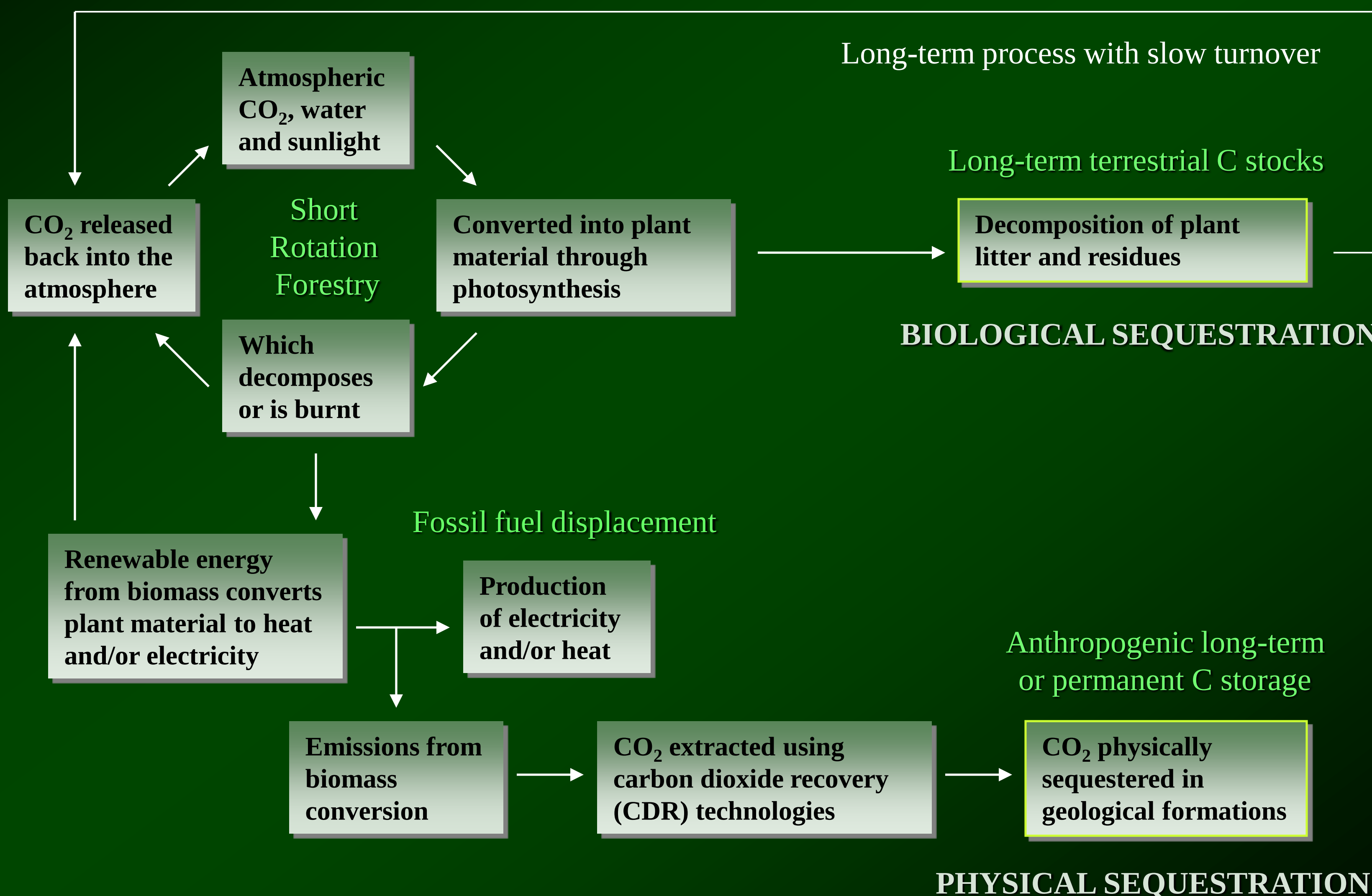
Through processing, energy conversion and C capture, C can be placed into a variety of physical sequestration options for long-term or permanent storage.

The ‘carbon dioxide pump’

Hence:

The biomass crop pumps the CO_2 out of the atmosphere and into a form of biological or physical sequestration facilitating long-term C retention and enhanced climate change mitigation.

SRF carbon sequestration pathway



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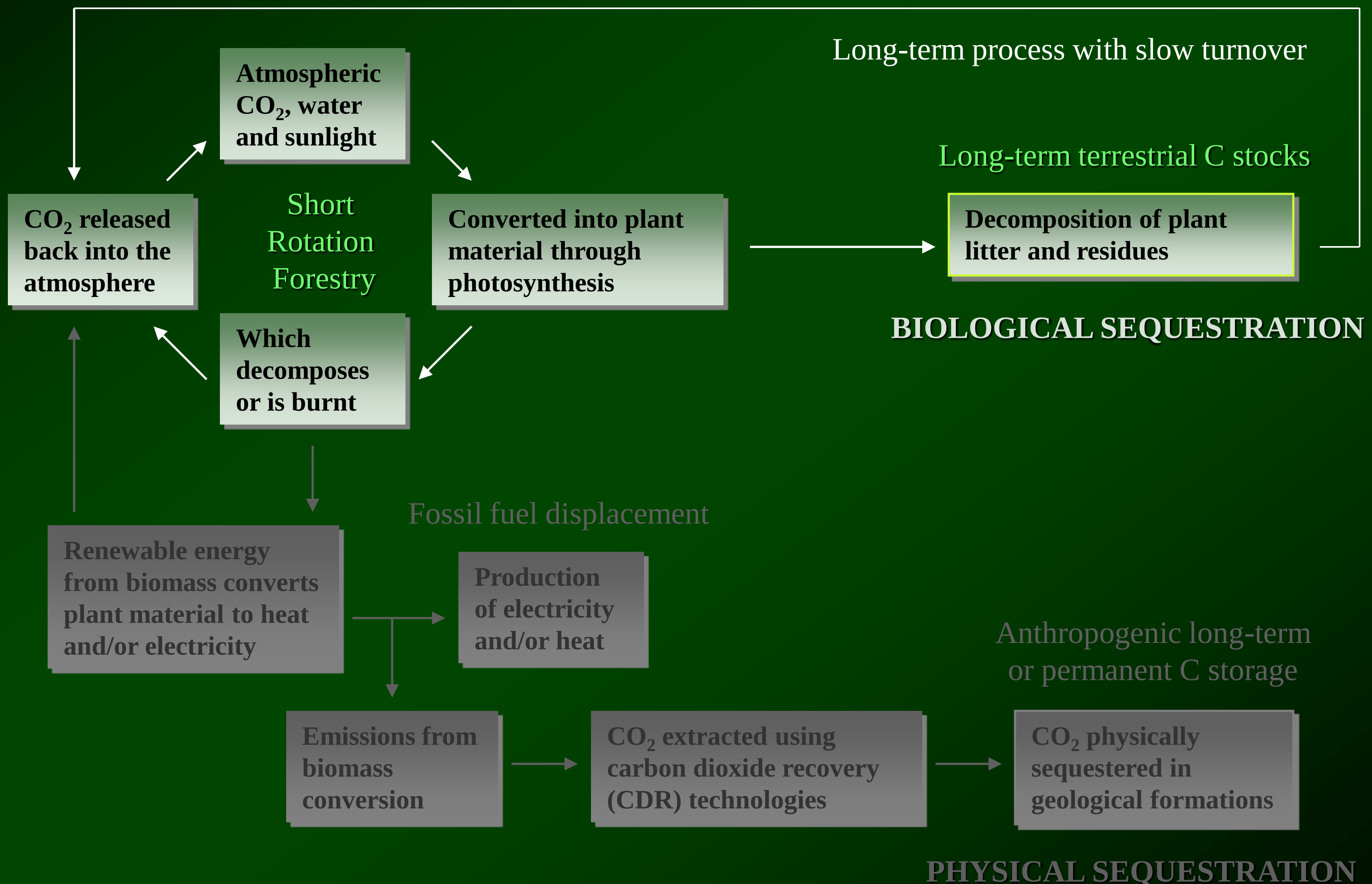

Biological sequestration

The increase in long-term terrestrial carbon stocks through passive in-situ processes.

Primary objective: the conservation and expansion of long-term terrestrial C stocks through various land management techniques.

Biological sequestration

- Biological sequestration can be enhanced by reducing decomposition rates via physical, chemical, or biological intervention.

- For biological sequestration to be sucessful, the available sinks must be identified, potential carbon storage evaluated, and an understanding of the impacts of associated carbon management be acquired.

Terrestrial carbon stocks

- Terrestrial carbon storage can be partitioned into three pools or stocks, vegetation, litter, and soil.
- Terrestrial C sink expansion can be encouraged through, afforestation, reforestation and improved land management and deterring deforestation.
- Increases in terrestrial C stocks may pose a risk for potentially significant CO_2 emissions at a later date, should carbon conserving practices be discontinued or disturbance occur.

Terrestrial carbon stocks

- C storage within any terrestrial environment is limited, fluxing between lower and upper thresholds.
- Terrestrial C storage is dependent upon factors that include soil type, climatic conditions, disturbance, and management regime.
- The most easily measured C pool is the above ground biomass however, globally, the amount of carbon stored in soils is much larger than that stored in vegetation.

The soil carbon pool

- In terrestrial ecosystems Soil Organic Carbon (SOC) constitutes the largest persistent carbon pool with a potential mean residence time of several hundred years.
- Carbon compounds such as cellulose and lignin enter the SOC pool as plant litter, root material, root exudates, or if consumed by animals, as excreta.
- Over time, carbon compounds abrade into smaller particles via decomposition, humification, and Dissolved Organic Carbon (DOC) formation.

The soil carbon pool

- The rate of decomposition, humification and DOC formation determines the quantities and rate of carbon sequestered.

- The rate of carbon sequestration and carbon pool content may both be relatively high however, they cannot be maximised simultaneously.

- Land management strategies should take into account the goal of either short-term enhanced accumulation or the maintenance of carbon reservoirs through time.

SRF carbon cycling

- Initial planting of SRF acts as a C sink, with the majority of C locked up in the harvestable biomass.
- However, in order to leave the plantation forest carbon cycle in equilibrium, the crop must be re-grown after each harvest.
- Upon harvesting SRF much of the above ground biomass is removed or returned to the soil leaving SOC to be the only long-term reservoir of carbon storage.

Research focus

Can the carbon balance of a bioenergy crop be manipulated during the growth stages to enhance terrestrial carbon sequestration?

Primary objective: facilitate enhanced C sequestration under SRF.

Hydrophobic protection of Humus

- Humified organic carbon, humic acids and humin represent the most persistent pool of SOC with a mean residence time of several hundred years.
- Multiple hydrophobic interactions among humic molecules and fresh organic compounds have been identified as the main reason for humic substance bioresistence.
- Humic material of appropriate hydrophobic composition may reduce organic matter mineralisation, increasing organic carbon sequestration.

Hydrophobic protection of Humus

- The application of suitable hydrophobic substances onto litter and plant residues may provide a mechanism of protection against microbial decomposition.
- Studies by Spaccini *et al*. (2002), have noted enhanced protection from 12 - 30 % depending on the chemical composition of the humic matter.

Current research

- The hydrophobic protection of litter and residues against degradation holds the potential to significantly reduce CO_2 emissions from soils.
- Innovative soil management practices aimed to increase the hydrophobicity of organic matter include the use of mature compost or humic acids.
- The possibilities associated with biodiesel for hydrophobic protection of humic substances are to be investigated, coupling litter and residue sequestration with the sequestration of the biodiesel hydrocarbons.

Current research

- *E. brookerana* & *E. macarthurii*
- Concurrent pot & radial trials.
  - Radial trial on a 3 year rotation
  - 4rth harvest in April 2004
- Observations to include:
  - Soil respiration
  - Dehydrogenase activity
  - Litter decomposition rates
  - Soil hydrophobicity
  - C:N ratios
  - Humus fractions (including humic & fulvic acids)

Current research

- Approximately 18 months of experimental work to be conducted.
  - Trials to begin in March 2004
  - Observations to continue through to mid- to late- 2005
  - Evaluated results available December 2005

Thank you for listening.

Any questions or comments?