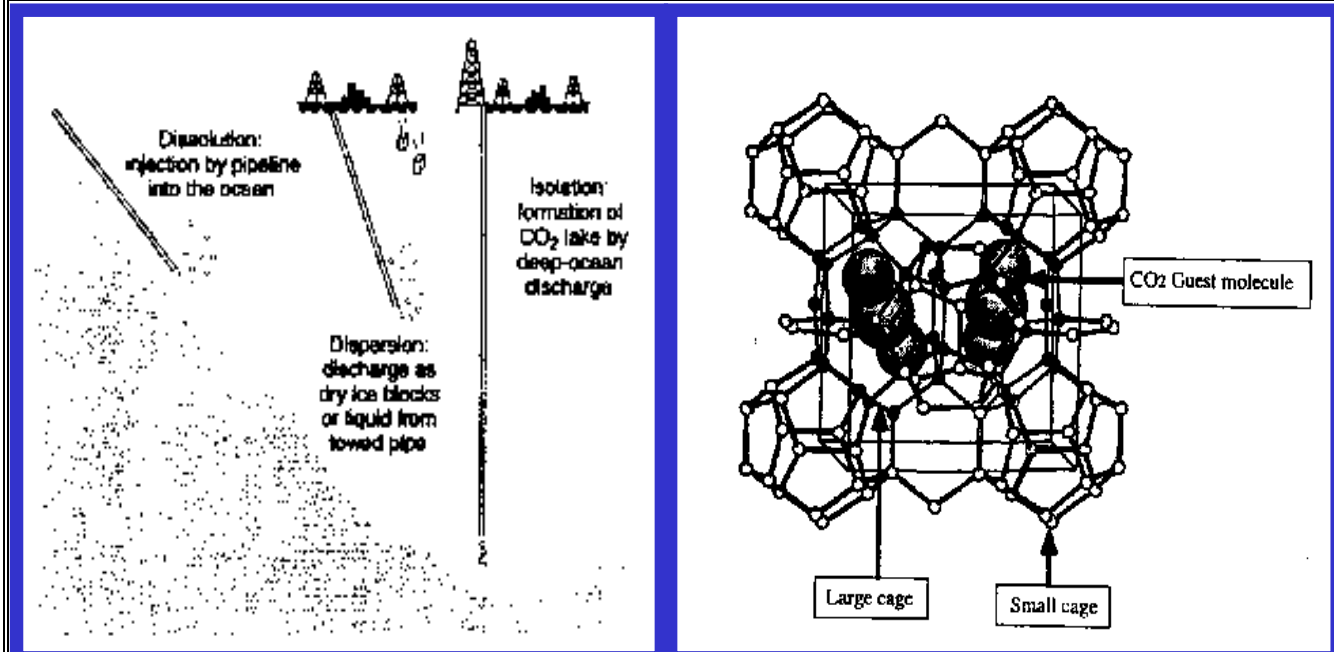


### 3.3 OCEAN SEQUESTRATION

#### 3.3.1 OCEAN SEQUESTRATION – DIRECT INJECTION

##### Technology Description



Sketch of various ocean CO<sub>2</sub> disposal options (left). Structure of a CO<sub>2</sub> hydrate (right).

Ocean sequestration technologies strive to reduce carbon emissions by injecting captured CO<sub>2</sub> into the ocean, rather than releasing it into the atmosphere. The captured CO<sub>2</sub> is concentrated, and then pressurized into a liquid state. The physical chemistry of CO<sub>2</sub> is such that at high pressure and low temperatures (which exist at depth in the ocean), the CO<sub>2</sub> molecule reacts with seawater wrapping itself in a cage of water to form a solid compound much like ice (clathrate). This reaction profoundly changes its behavior. However, there are significant environmental questions that need to be examined.

##### System Concepts

- CO<sub>2</sub> is captured from a large point source of anthropogenic emissions, transported, and injected into the ocean via pipeline or tanker.
- CO<sub>2</sub> molecule reacts with seawater wrapping itself in a cage of water to form a solid compound much like ice (clathrate).

##### Representative Technologies

- Technologies will potentially be borrowed from the petroleum industry in the areas of drilling simulation and wells; processing, compression, and pipeline transport of gases; and operational experience of CO<sub>2</sub> injection.

##### Technology Status/Applications

- The injection technology is technically ready for adaptation for mid- to deep-ocean injection. However, technology is not ready for deployment. This is due to insufficient data detailing hydrate interactions with marine community structure, as well as knowledge gaps about physical and chemical behavior concerning dispersion and transport of hydrate plume by ocean hydrology.

##### Current Research, Development, and Demonstration

##### RD&D Goals

- Demonstrate that CO<sub>2</sub> direct injection is safe and environmentally acceptable.
- Improve global circulation simulation with more accurate biology modules.

**RD&D Challenges**

- Develop field practices that optimize CO<sub>2</sub> direct-injection retention times.
- Develop the ability to predict plume effects on marine organisms.
- Develop the ability to track the fate of direct injected CO<sub>2</sub>.
- Develop a better understanding of the CO<sub>2</sub> chemistry in ocean waters, and its effects on indigenous organisms, e.g. hypercapnia (effects of elevated CO<sub>2</sub> levels), and acidification of plume waters (depressed pH).

**RD&D Activities**

- Key DOE activities are targeted to determine physical, chemical and biological impact of direct injection.
- Conduct an appropriate-scale field experiment to adequately assess unit operations and potential impacts on marine environment at a sufficient scale downstream of injection zone.
- Formulate future experiments to evaluate community effects (long term) and the total impact on the ecology of multiple regions of deep oceans.
- Develop other small-scale field experiments to understand fundamental biogeochemical cycles.
- Current expenditures for field experiment estimated to be \$6 million.

**Recent Progress**

- A survey cruise of Hawaiian biology occurred during the summer of 1999.
- Small-scale release (one liter) at 3,600 m off the California coast demonstrating hydrate formation.
- Properties of hydrate formation determined in lab utilizing high-pressure, low-temperature reaction vessels.
- Conducted 10-day cruise off Loihi seamount (Hawaii) during December 2002, to determine effect of natural analogues of CO<sub>2</sub> on amphipod community in vent waters.