ENHANCED COALBED METHANE RECOVERY

ECBM RECOVERY

- **Enhanced coal bed methane recovery** is a method of producing additional coalbed methane from a source rock. It is achieved by by reduction of partial pressure.

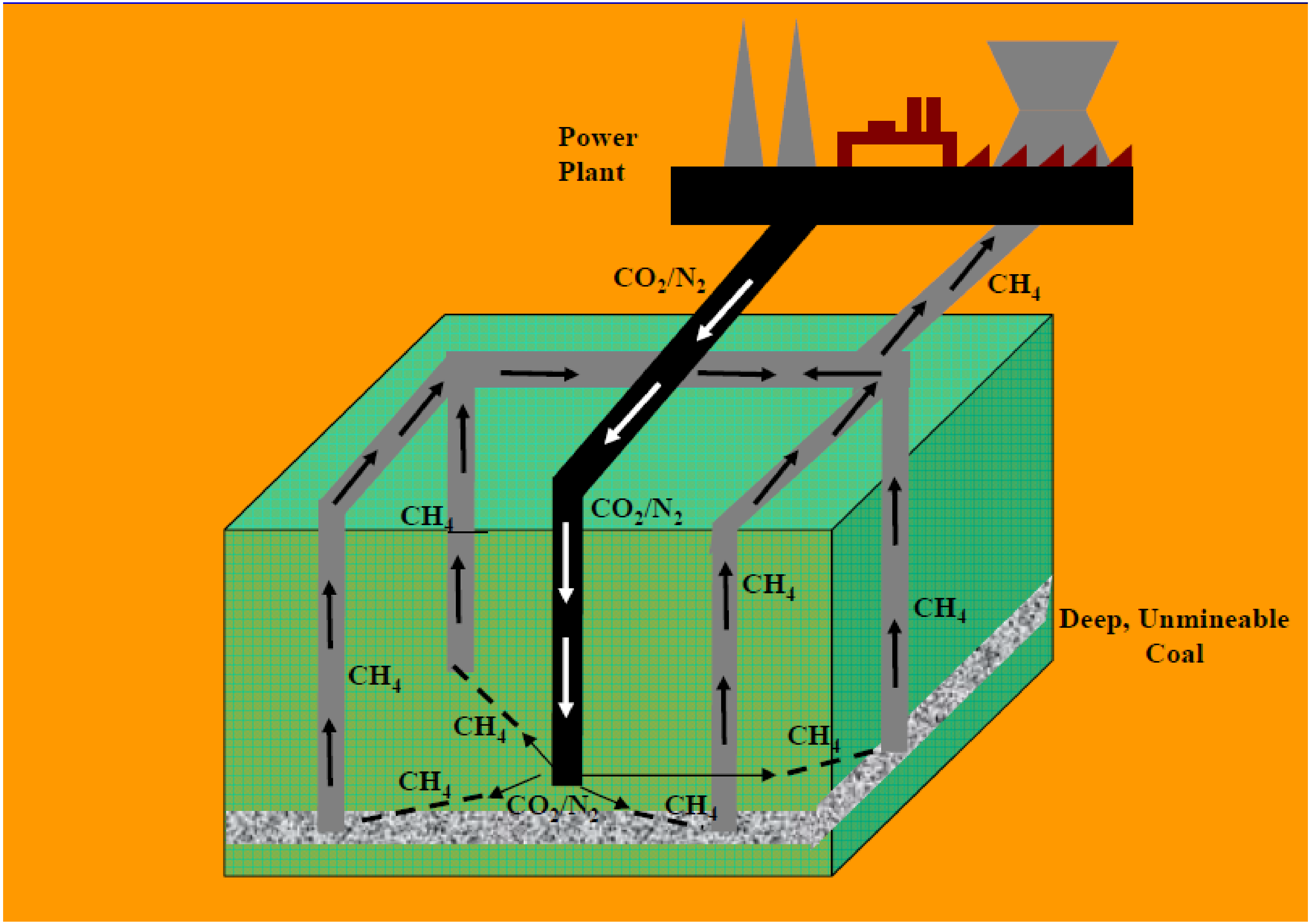
- Enhanced recovery of methane is possible using two methods. Using the first method, the partial pressure of methane is reduced by injecting an inert gas, such as helium or a gas that adsorbs more weakly than methane in coal, such as nitrogen (N_2), into the coal seams and thus maintaining the total pressure. The second method uses the injection of carbon dioxide (CO_2) to displace methane from coal seams.

As seen in Figure, nitrogen has a significantly lower affinity to coal than methane and carbon dioxide. The coal can adsorb roughly twice as much CO_2 at a given pressure than CH_4 and about half as much N_2. In general, CO_2 will commonly be more adsorptive onto coal than methane; however, the relative adsorptivity between CO_2 and CH_4 is a function of coal rank.

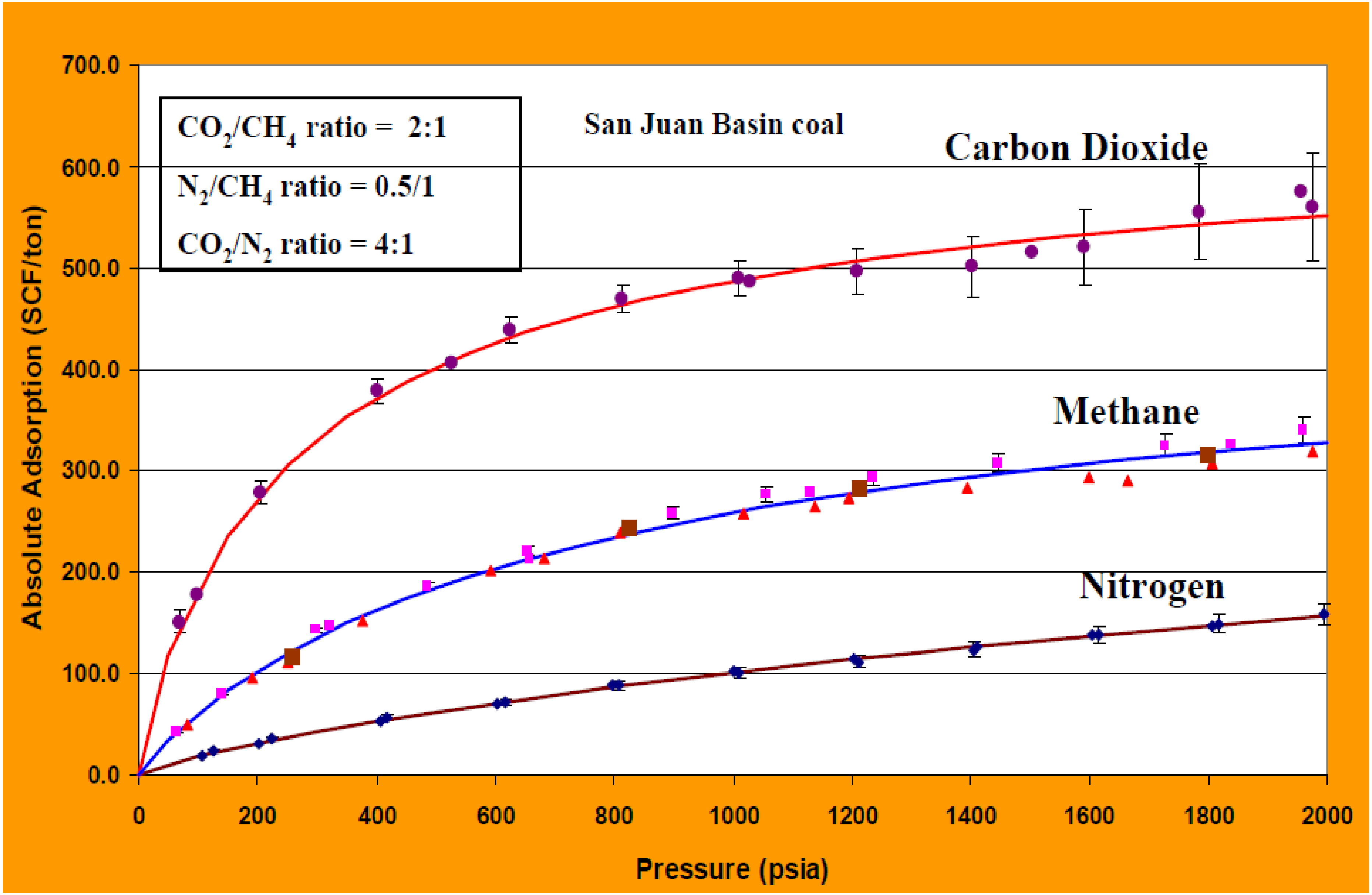
On average two molecules of CO_2 are trapped for every molecule of CH_4 released

Coal has a different affinity for different gases
– Affinity for: $CO_2 > CH_4 > N_2$

Integrated Power Generation, CO_2 Sequestration & ECBM Vision



Example Coal Sorption Isotherms



N_2-ECBM Recovery Mechanism

- Inject N_2 into cleats.
- Due to lower adsorptivity, high percentage of N_2 remains free in cleats:

✓ Lowers CH_4 partial pressure which allows methane to diffuse from the matrix of the coal with greater ease, hence improving the recovery of coalbed methane at a faster rate

✓ Creates compositional disequilibrium between sorbed/free gas phases

- Methane "stripped" from coal matrix into cleat system.
- Methane/nitrogen produced at production well.
- With nitrogen injection, the initial recovery rate is higher, but the breakthrough time of N_2 is also earlier, hence, nitrogen must be separated from the produced gas for a longer period of time.

CO_2-ECBM Recovery Mechanism

- Inject CO_2 into cleats.
- Carbon dioxide is more strongly adsorbed on coals than both nitrogen and methane in coals.
- Due to high adsorptivity, CO_2 preferentially adsorbed into coal matrix.

✓ Methane displaced from sorption sites.

- Methane produced at production well.
- With CO_2 injection, the initial recovery is lower but the total recovery of original gas in place is earlier than with nitrogen. The breakthrough of CO_2 is delayed when compared to nitrogen because the affinity for CO_2 is very high in coals and so carbon dioxide moves through the coalbed very slowly. This increases the production of methane-rich gas for a longer time interval and reduces the amount of separation required.

Reservoir Screening Criteria for ECBM with CO_2

- Reservoir screening criteria are essential for locating favourable areas for the successful application of CO_2 - ECBM. The reservoir characteristics that are likely to be important for CO_2 - ECBM are

❖ **Homogeneous reservoir**: The coal seam reservoirs should be laterally continuous and vertically isolated from surrounding strata.

❖ **Simple structure**: The reservoir should be minimally faulted and folded.

❖ **Adequate permeability**: Although a minimum permeability cannot be specified, preliminary simulation indicates that at least moderate permeability is necessary for effective ECBM (1-5 md).

❖ **Optimal depth range**: Shallow reservoirs tend to be low in reservoir pressure and gas content, whereas deep reservoirs suffer from diminished permeability. For deep measures, CO_2 injection may actually improve permeability by maintaining pore pressure. Normally, coal seams at depths of 300-1500 m are considered to be appropriate for CBM.

❖ **Coal geometry**: Concentrated coal deposits (few, thick seams) are generally favored over stratigraphically dispersed (multiple, thin seams) measures.

- **Gas saturated conditions**: Coal reservoirs that are saturated with respect to methane are preferred from an economic viewpoint. Undersaturated areas can experience delay in methane production, although CO_2 injection could reduce delays by raising saturation. From a sequestration viewpoint, undersaturated coal seams are still effective reservoirs.

In addition to the first-order reservoir criteria presented above, other secondary reservoir criteria that are likely to affect ECBM recovery include gas saturation, coal rank (optimal R_0 = 0.8-1.5%), coal maceral composition (high vitrinite preferred), ash content (because ash does not adsorb methane), gas composition, and numerous other factors.

- **High gas saturation**: Ideally, in-situ coal reservoir gas content should be approximately 90 to 100% of the sorption isotherm (saturated conditions). However, ECBM should also work in undersaturated areas with somewhat lower gas saturation, but methane recovery will be delayed and costly.
- **Optimal coal rank**: Rank is an indication of the thermal maturity of a coal, reflecting past burial pressure and temperature history, and in the CBM industry, it is generally measured using vitrinite reflectance (R_0). Traditionally, CBM operators held that optimal coal rank for CBM was in the range of R_0 = 0.8% to 1.5%.

- **Low ash content**: Because ash is not capable of storing (adsorbing) methane, low ash content is desirable. In general, low-ash coals are more permeable, although San Juan basin Fruitland Formation coal seams can have permeabilities in excess of 100 md with high ash contents of 25-35%.
- **High vitrinite content**: Vitrinite is the most brittle coal maceral (component). Coals that are high in vitrinite (rather than inertinite, a less brittle maceral) tend to be well cleated and thus more permeable.