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Energy research Centre of the Netherlands

Geological CO_2 Storage and Leakage

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CO_2 leakage

ECN

Outline

I. Leakage of geologically stored CO_2
II. Does CO_2 leakage matter?
III. Approach
IV. Results with MARKAL
V. Results with DEMETER
VI. Comparison and discussion
VII. Conclusions

Research done under the EU-funded Transust.Scan project
See: www.transust.org

I. CO_2 leakage

IPCC Special Report on CO2 Capture and Storage (2005) :

"Observations from engineered and natural analogues as well as models suggest that the fraction retained in appropriately selected and managed geological reservoirs is very likely to exceed 99% over 100 years and is likely to exceed 99% over 1000 years."

Today, our natural scientific understanding of geological CO_2 migration and leakage processes is limited, and values of possible leakage rates only speculative. Cap rock integrity seems essential.

II. Does CO_2 leakage matter?

- What are possible leakage rates from a geo-physical and geo-chemical point of view?
- What are acceptable leakage rates from a climatic and economic point of view?
- Are the latter higher or lower than leakage rate speculations based on the natural sciences?
- How urgent is it to increase our natural scientific understanding of possible leakage phenomena?

III. Climatic and economic implications of leakage

Back-of-the-envelope calculation for CO_2 leakage rate λ

λ = 1%/yr: after 100 yrs 37% is left: probably *unacceptable*

λ = 0.1%/yr: after 100 yrs 90% is left: may well be *acceptable*

$$NPV_{leakage} = \tau_\lambda = \int_0^\infty \lambda e^{-(r+\lambda)t} \tau_t \, dt \rightarrow \tau_\lambda = \tau_0 \int_0^\infty \lambda e^{(-r+g-\lambda)t} dt = \frac{\lambda}{\lambda + r - g} \tau_0$$

Locally, leakage rate may be time-dependent (bell- or S-shaped). Globally, CO_2 leakage rate may increase or decrease over time, depending on the knowledge we acquire about physical leakage processes of individual storage sites.

III. Two energy-environment-economy models

The above questions may be addressed through EEE integrated assessment models, with endogenous technical change through learning curves.

MARKAL: Bottom-up energy systems model for Europe;

Many energy technologies, but reduced economic features;

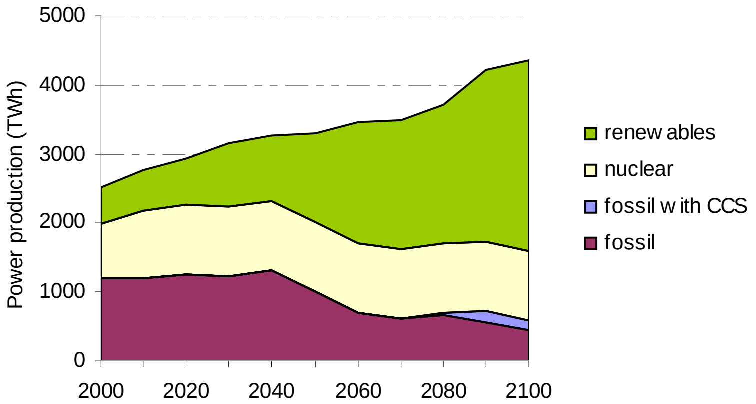
Constant leakage rates: 0.05%/yr 0.1%/yr, 0.5%/yr, 1.0%/yr.

DEMETER: Top-down general equilibrium model for the World;

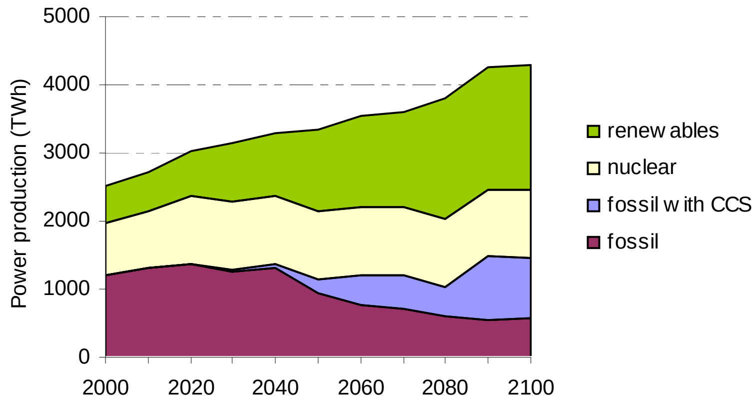
Global economy, but only three basic energy resources;

Constant leakage rates: 0.5%/yr, 1%/yr, 2%/yr.

IV. Results with MARKAL



(c)



(d)

Figure 1. *Annual electricity generation (in TWh) from renewables, nuclear, fossil fuels with CCS, and fossil fuels without CCS. Scenario (a) is the base case without climate change constraint; in scenario (b) a climate constraint of 550 ppmv* CO_2 *concentration is imposed; in scenarios (c), (d), (e), and (f) the same climate constraint of 550 ppmv is assumed, plus a geological* CO_2 *leakage rate of, respectively, 1%/yr, 0.5%/yr, 0.1%/yr, and 0.05%/yr.*

IV. Results with MARKAL

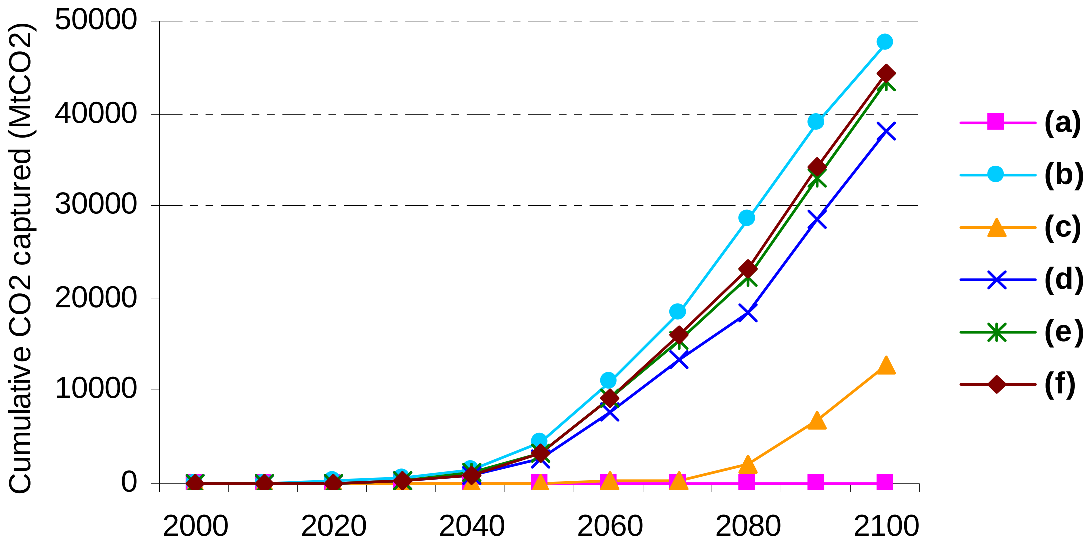


Figure 4. *Cumulative amount of CO_2 captured in the electricity sector (including both fossil-based and biomass-based power plants, expressed in $MtCO_2$) in scenarios (a)-(f).*

V. Results with DEMETER

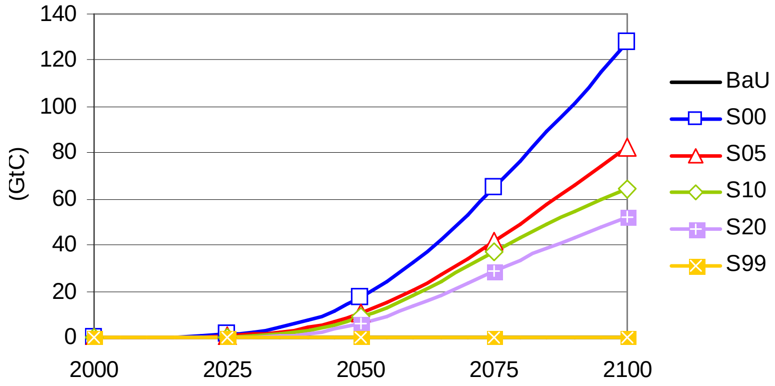


FIGURE 3.Cumulative *geological CO_2 storage (GtC) for various leakage scenarios (450 ppmv target).*

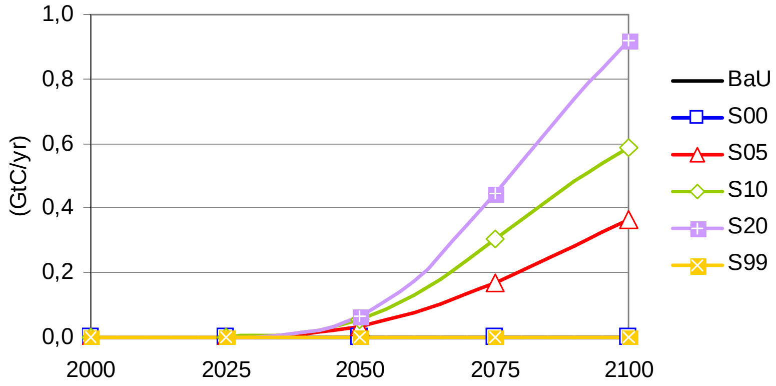


FIGURE 4. *Annual geological CO_2 seepage (GtC/yr) for various leakage scenarios (450 ppmv target).*

V. Results with DEMETER

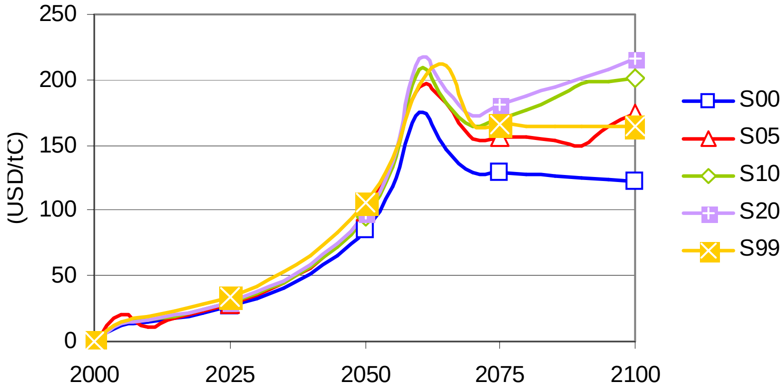


FIGURE 5. *Carbon tax (US$/tC) for various leakage scenarios (450 ppmv target).*

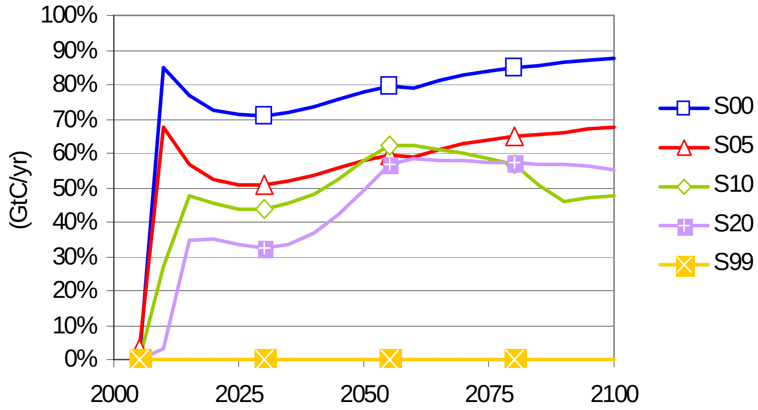


FIGURE 6. *Share of carbon tax to CCS (%) for various leakage scenarios (450 ppmv target).*

VI. Comparison MARKAL - DEMETER

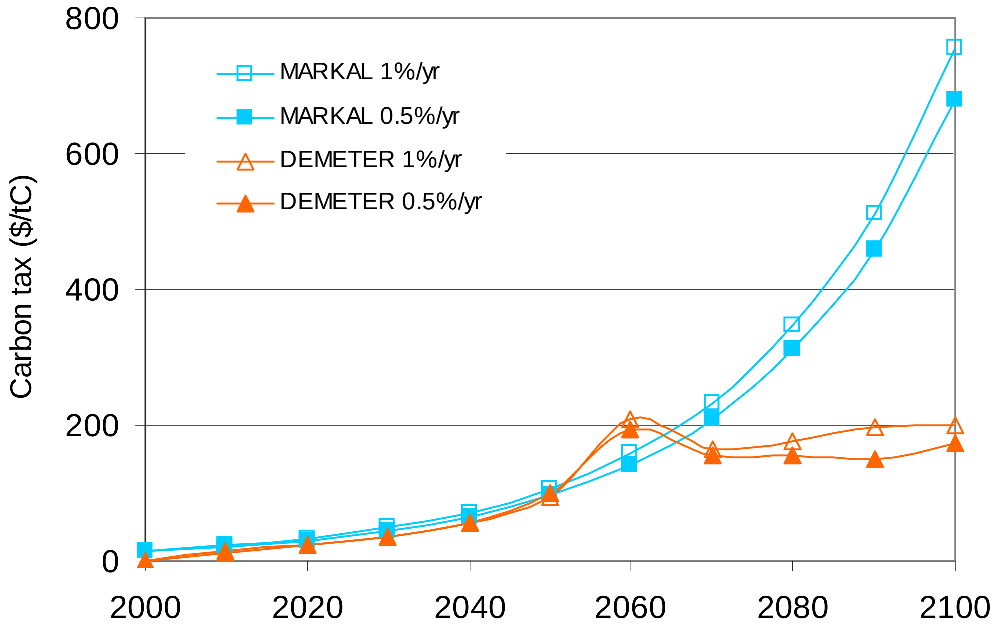


FIGURE 7. *Optimal carbon tax (in US$/tC) as calculated by MARKAL and DEMETER under a stringent climate constraint for two values of the leakage rate (1 and 0.5%/yr).*

VII. Conclusions

- MARKAL: A CO_2 leakage rate of up to 0.5 %/yr is allowable from an overall energy system cost minimisation point of view.
- DEMETER: CCS with CO_2 leakage of even a few %/yr possesses non-negligible economic and climatic control value.
- In both cases, economically and climatically acceptable leakage rates are well above our current geo-scientific speculations.
- Hence, *from a combined economic-climatic point of view at least*, there seems today little urgency to increase our natural scientific understanding of possible leakage rates.
- But, of course, for other reasons increasing our understanding of geological CO2 leakage remains very important.

VII. Papers

• Smekens, K. and B.C.C. van der Zwaan (2006), "Atmospheric and Geological CO_2 Damage Costs in Energy Scenarios", *Environmental Science and Policy*, 9, 3.

• Gerlagh, R. and B.C.C. van der Zwaan (2006), "Options and Instruments for a Deep Cut in CO_2 Emissions: Carbon Capture or Renewables, Taxes or Subsidies?", *The Energy Journal*, 27, 3, pp.25-48.

• van der Zwaan, B.C.C. and K. Smekens (2007), "CO_2 Capture and Storage with Leakage in an Energy-Climate Model", *Environmental Modeling and Assessment,* forthcoming.

• van der Zwaan, B.C.C. and R. Gerlagh (2007), "The Economics of Geological CO_2 Storage and Leakage", *Under review*.