Federal Ministry
of Education
and Research

SIEMENS

Joint Seminar of BMBF and Siemens "CO_2 Utilization Potential"

22/23 September 2009, Steigenberger Grandhotel Petersberg, Bonn

22 September 2009

General introductory talk

Dr. Johannes Ewers, RWE Power AG

Keynote presentations on "CO_2 utilization on the basis of biological processes"

Dr. Ulrich Schurr, Forschungszentrum Jülich GmbH

Dr. Martin Kerner, SSC Strategic Science Consult GmbH

Keynote presentations on "Inorganic CO_2 utilization, mineralization"

▶ Prof. Hans Geerlings, TU Delft, DelftChemTech

Prof. Ron Zevenhoven, Åbo Akademi University

Keynote presentations on "Alternative fuels and energy sources for industry and transport"

Prof. Dr.-Ing. Kai Sundmacher, Max-Planck-Institut Dynamics of Complex Technical Systems

Prof. Dr. Eckhard Dinjus, Forschungszentrum Karlsruhe

Inorganic CO_2 Utilization, Mineralization

Hans Geerlings

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Three Hard Truths regarding our Global Energy System

- Surging energy demand
  - Population increase
  - Economic development (especially China and India)

- Supply will struggle to keep pace
  - No silver bullets for supply growth

- Environmental stresses are increasing

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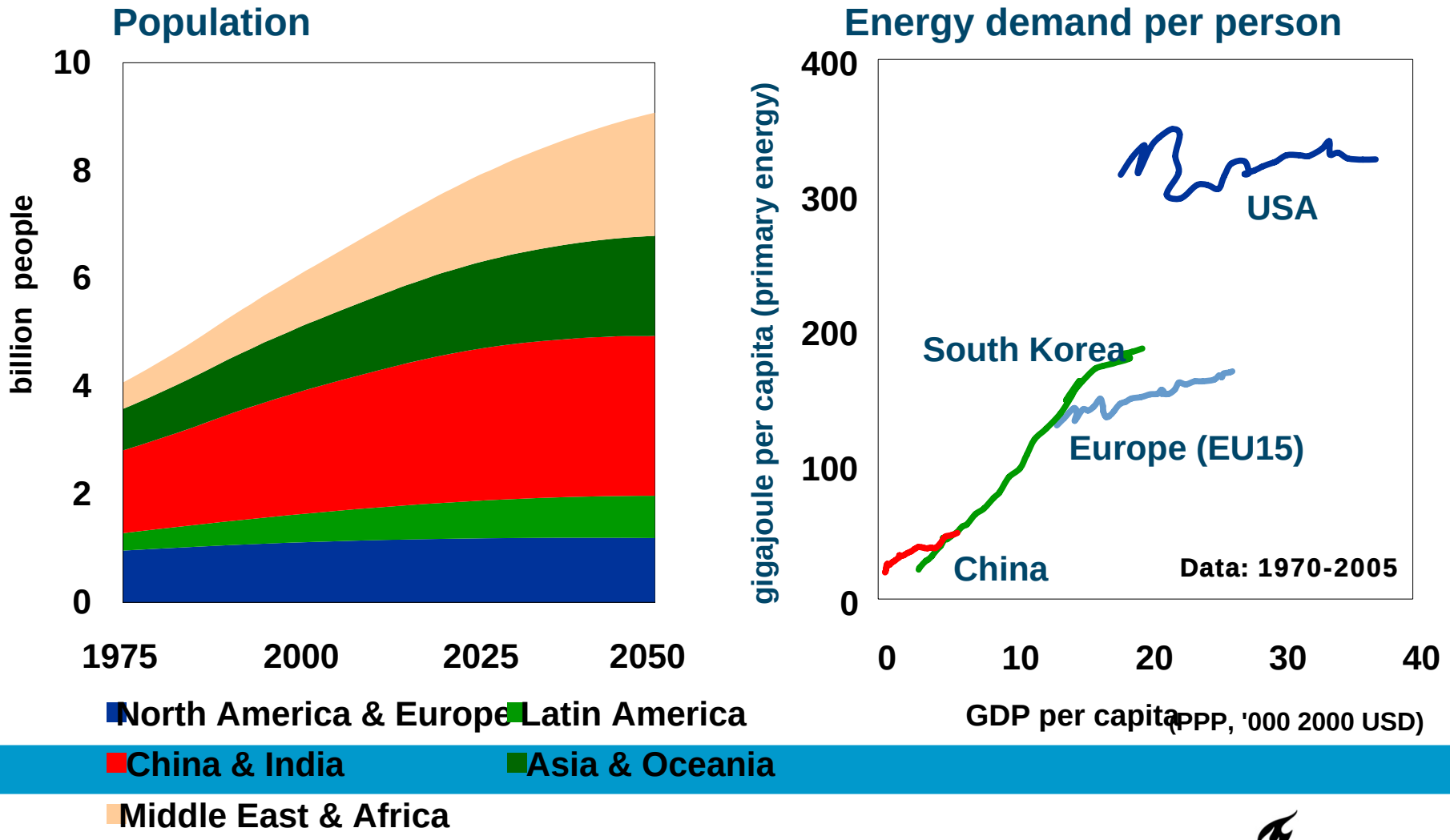
Growth in population and prosperity are key drivers of energy demand



Source: Shell International BV, Oxford Economics and Energy Balances of OECD and Non-OECD Countries © OECD/IEA 2006

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In summary: 'The Global Energy System'

- The three hard truths are very hard
- Transition is both inevitable and necessary
- Tackling all three hard truths TOGETHER is essential for a sustainable future

No simple solution exists
It is important to explore all relevant technologies

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CO_2 Mineralization is such a relevant technology

$$Mg_2SiO_4 + 2CO_2 \longrightarrow 2MgCO_3 + SiO_2 + Q$$

Accelerated weathering of abundant magnesium silicate rocks

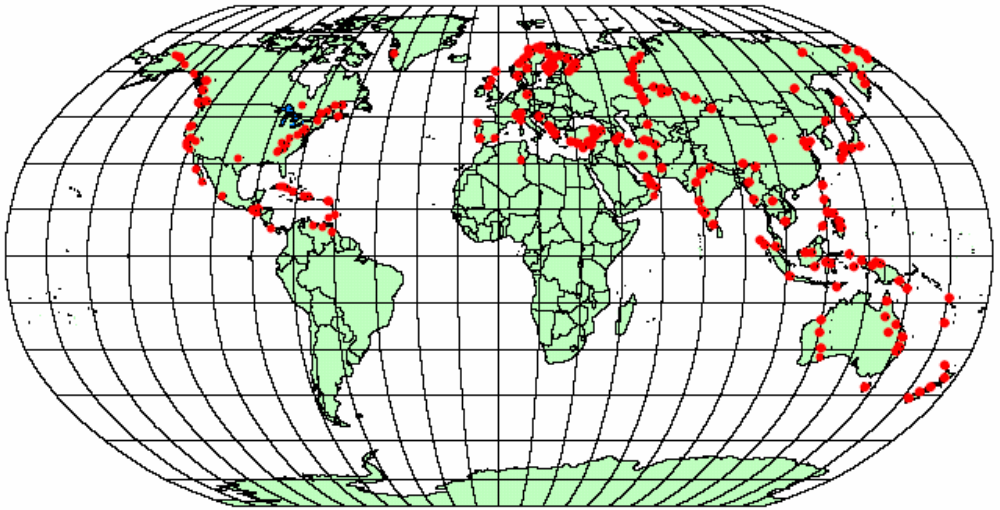

Figure 4: *Locations of known peridotite or serpentinite ore bodies are marked in this map of the world. The map is drawn after Ref. 81. Many of these deposits are known to be quite large, i.e., they are measured in cubic kilometers of ore. For more detail see Appendix B.*

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Estimated potential of sequestration options (Gt CO_2)

	MIN*	MAX*
Oil + Gas fields / EOR+EGR	675	1,125
Coal bed methane	10	200
Saline aquifers	1,000	10,000
Mineralization		All fossil CO_2
Oceans (ocean acidic)	*Acceptability ??*	
Others (industrial use, biomass)	negligible	

* IPCC Special report on carbon dioxide capture and storage (2006)

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The chemistry of CO_2 Mineralization

Liquid water essential

$$CO_{2\,(g)} + H_2O_{\,(l)} \leftrightarrow H_2CO_3 \leftrightarrow HCO_3^-{}_{(aq)} + H^+_{(aq)} \leftrightarrow CO_3^{2-}{}_{(aq)} + 2H^+_{(aq)}$$

$$2H^+_{(aq)} + {}^1/_2\, Mg_2SiO_{4\,(s)} \leftrightarrow Mg^{2+}_{(aq)} + {}^1/_2\, SiO_{2\,(s)} + H_2O_{\,(l)}$$

Step 1: leaching

$$Mg^{2+}_{(aq)} + CO_3^{2-}{}_{(aq)} \leftrightarrow MgCO_{3\,(s)}$$

Step 2: precipitation

Acceleration of natural weathering rates through tuning of:
Particle size, CO_2 pressure, reaction temperature etc.

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Mineralization routes

Step 1 only: 'ocean neutral'

$$1/_2\, Mg_2SiO_4 + 2CO_2 + H_2O \longleftrightarrow Mg^{2+}{}_{(aq)} + 2HCO_3^-{}_{(aq)} + {}^1/_2\, SiO_2$$

Step 1 + 2: 'maximal production of solids'

$$1/_2\, Mg_2SiO_4 + CO_2 \longleftrightarrow MgCO_3 + {}^1/_2\, SiO_2$$

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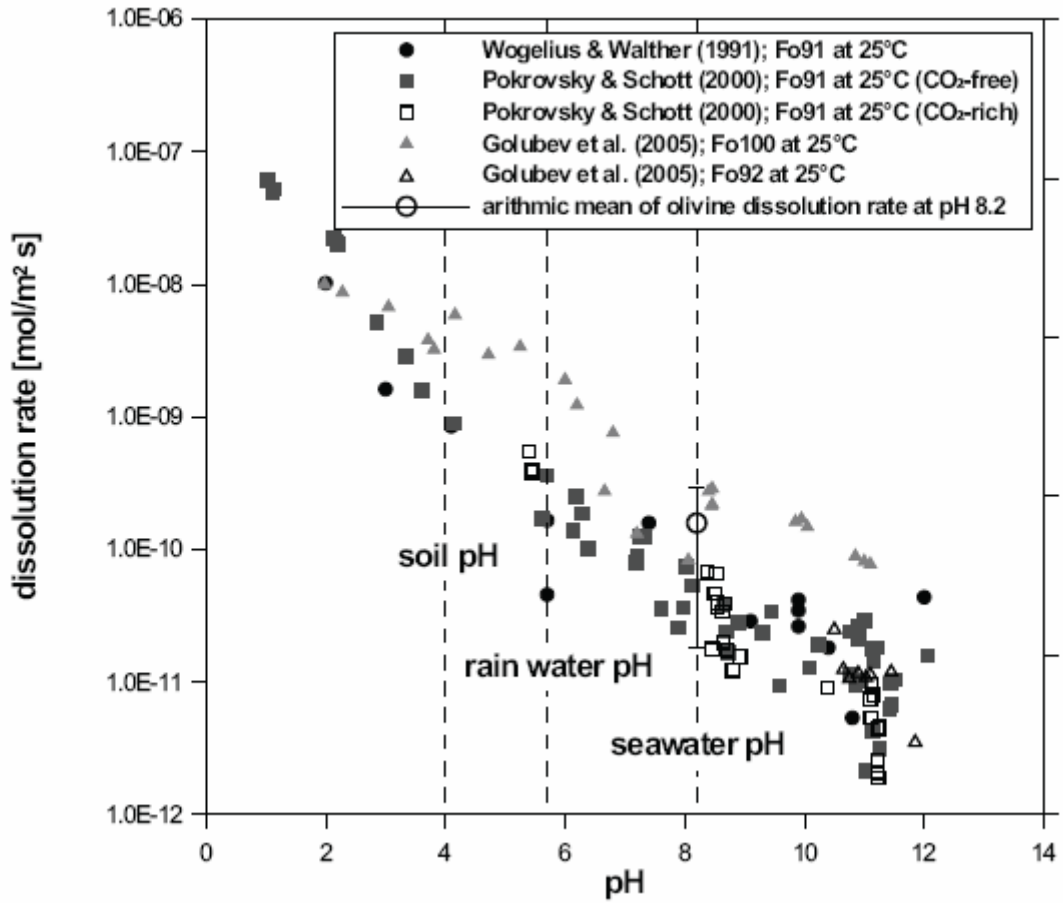
CO_2 Mineralization processes

- Using pure CO_2
  - Technically feasible, abatement costs, product value, competing with alternative sequestration routes
- Using CO_2 from flue gas
  - Capture and sequestration in 1 step, feasibility needs to be demonstrated, costs
- Using CO_2 from the atmosphere
  - Spreading of olivine particles over land in a suitable climate for instance wet tropics (Prof. R.D. Schuiling), effectiveness to be demonstrated

Dissolution rate of olivine in water



T = 25 °C

From: Suzanne Hangx, PhD thesis, Utrecht University, The Netherlands (2009)

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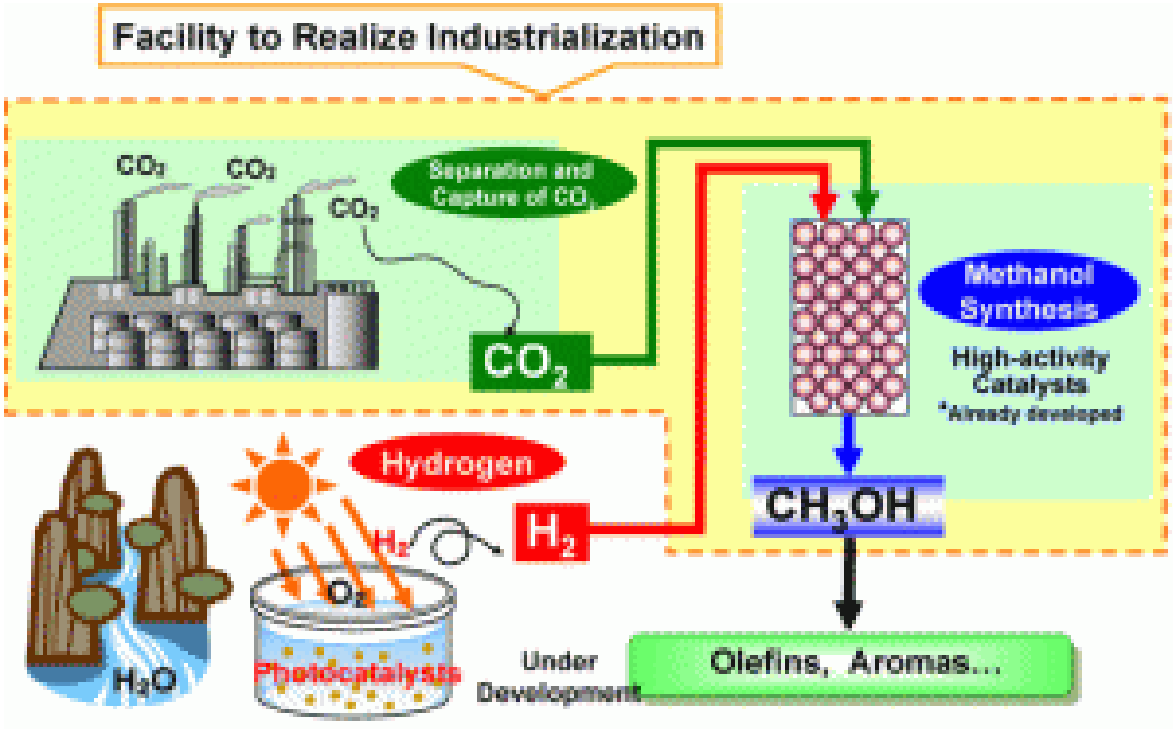
Another possibility to make use of captured CO_2
The inorganic route to solar fuels



'Fossil' CO_2 + 'solar' hydrogen → Solar fuels

http://newenergyandfuel.com/http:/newenergyandfuel/com/2008/08/29/a-new-leading-process-for-co2-to-methanol/

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THANK YOU

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