Transition to Sustainable use of Fossil Fuels

- A Research Programme funded through the "Stimuleringsprogramma Energieonderzoek" of NWO and NOVEM

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Rationale behind the programme

- Fossil fuels likely to remain the backbone of the energy supply for long time to come.
- Available at low prices
- Sustainable use (low carbon) vital.
- Implementation depends on wide variety of aspects: techno-economic options & potentials, ecological and societal.

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Three integrated research projects

- "System analyses of transition routes to advanced fossil fuel utilisation with CO2 removal and sequestration". Utrecht University (UU), Ph.D. project.
- "Carbondioxide injection in coal seems for sequestration and enhanced methane production". Delft University of Technology (DUT), Ph.D. project.
- "Informed opinions of the general public as a tool for policy measures regarding advanced fossil fuel options". University of Leiden (UL), Ph.D. project.

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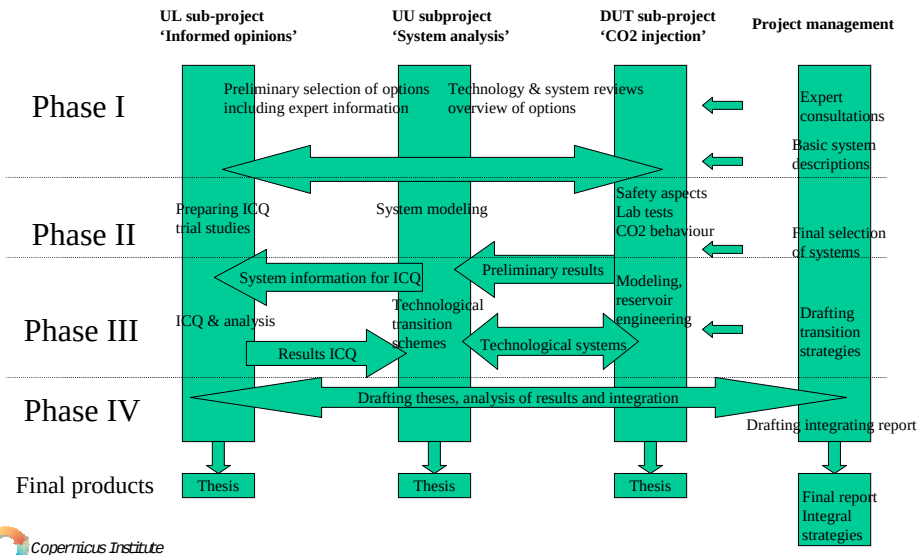
Project organisation and main flows of information



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Research timetable

Activity / Year	Year 1	Year 2	Year 3	Year 4
Project coordination				
General project management & meetings				
Expert consultations				
Basic system descriptions				
Final selection of systems				
Drafting transition strategies				
Drafting integrative report				
UU PhD project (1)				
State of the art review				
Definition of systems				
Global assessment and comparison				
System modeling				
Technological transitions schemes				
Formulation of integral strategies				
Finalizing thesis				
DUT PhD project (2)				
State of the art review				
Laboratory tests				
Modeling				
Safety aspects				
Reservoir engineering				
Formulation of integral strategies				
Finalizing thesis				
UL PhD project (3)				
State of the art review				
Trial studies				
Setting up ICQ's				
Holding ICQ's				
Evaluation of results and small scale follow-ups				
Formulation of integral strategies				
Finalising thesis				

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Research goals: System analysis of transition routes to advanced fossil fuel utilisation with CO_2 removal and sequestration (UU)

Identifying hydrogen and electricity production systems using fossil fuels with low CO_2 emissions through carbon capture and sequestration

Identify transition routes and technological options over time

Focus on performance of technological systems impacts of e,g:

- Natural gas or coal as feedstock
- Short term or long term system
- Small scale or large scale system
- (Energy) infrastructure required.

A techno-economic evaluation of a complete hydrogen/electricity production systems with CO_2 removal is performed

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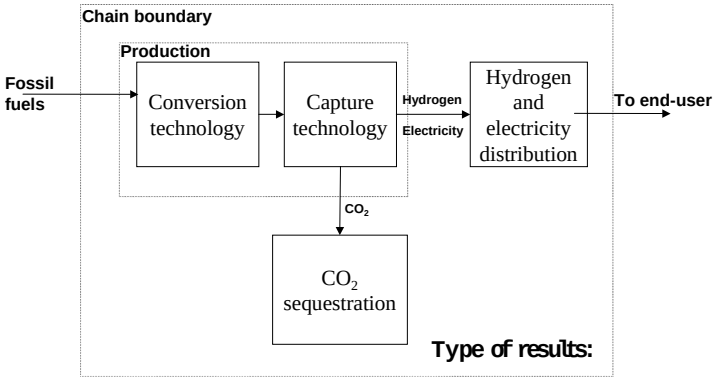
Research approach: System analysis



Type of results:

- Hydrogen/electricity cost (euro/GJ)
- CO_2 emission (kgCO_2/GJ)
- CO_2 stored per chain (kgCO_2/GJ)
- Cost of CO_2 avoided (Euro/tonCO_2)

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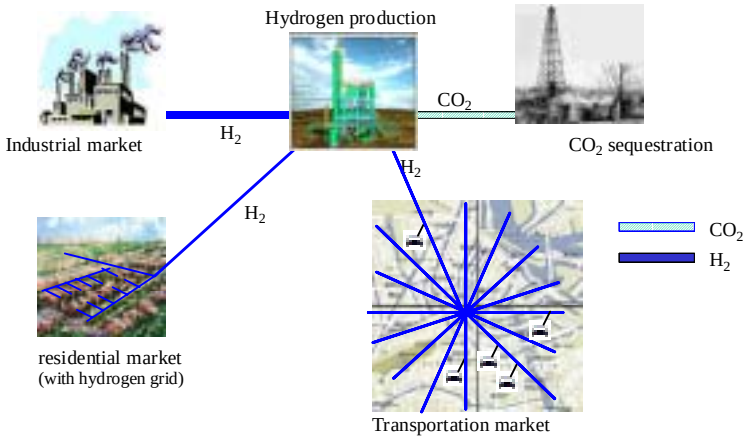
Hydrogen distribution to various end-users



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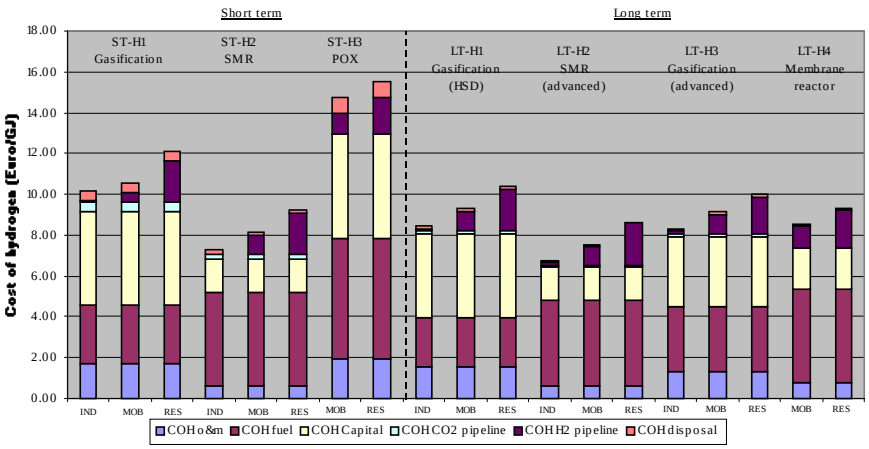
Economic results hydrogen chain analyses



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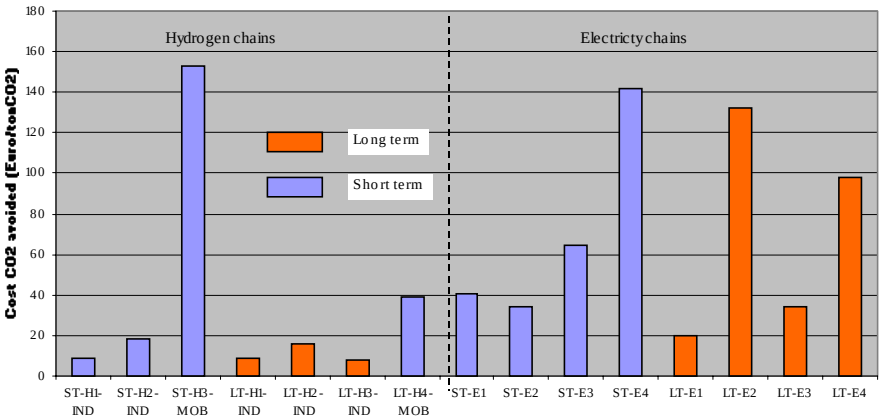
Cost of CO_2 avoided of hydrogen and electricity chains



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Future Plans

- Article: "Techno-economic analysis of hydrogen and electricity production chains with CO_2 capture and storage" in Int. Journal of Energy
- Selections of promising hydrogen and electricity production options for detailed case studies
- Developing a methodology to classify CO_2 storage sites based on risks, storage potential, storage costs and their uncertainties:
  - Classification used for making scenarios of how CO_2 storage network could develop in the Netherlands
  - performed by Simon Jorritsma (MSc student)
  - In co-operation with TNO-NITG

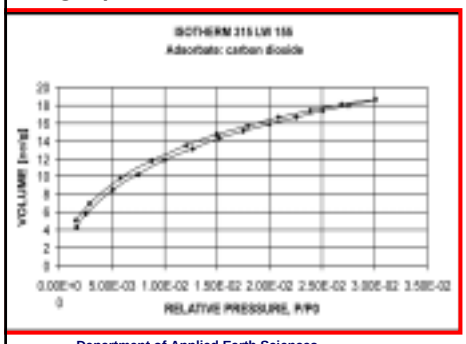
Targets and methods: "Carbondioxide injection in coal seams for sequestration and ECBM". (DUT)

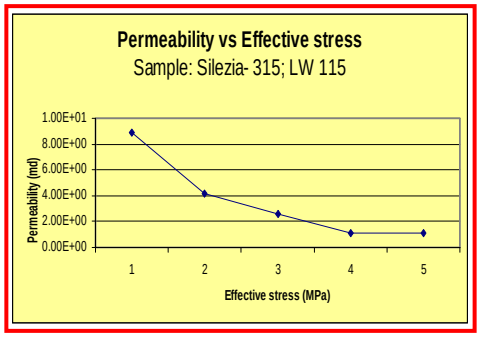
1. **Coal Characterization:** *Micropore volume and specific surface measurements.*
2. **Experimental work:**
- **Flushing experiments:** *Removing methane and/or water of (partly) saturated coal by injection of carbondioxide or other gases*
- **CO_2 oxidation experiments:** *Study on reaction speed of the conversion of carbon dioxide to carbon monoxide under in-situ conditions.*
- **CO_2 / flue gas sorption experiments:** *Study on the ability of injected carbon dioxide and flue gas to replace methane and water.*
- **Capillary pressure experiments:** *Defining the wettability of coal with the water - methane - carbon dioxide system, under in situ conditions.*
3. **Theoretical work:** *Development of sorption/diffusion/permeability relations specific for coal at micro-level, cleat level and seam level. Results are to be used as input parameters for a field scale reservoir model.*
4. **Co-operation with Utrecht and Leiden:** *Providing information relevant for injection logistics, safety and I.C.Q. preparations, in an interactive way.*

Coal Characterization

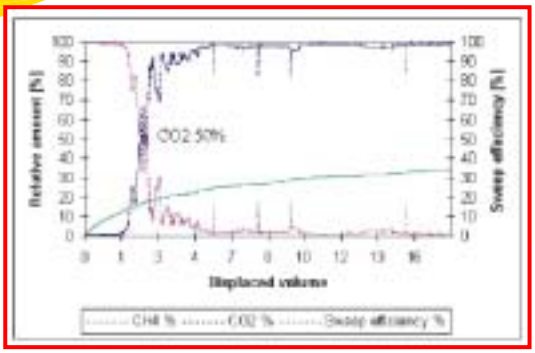
Petrophysical measurements on coal for reservoir purposes:

- Porosity, specific surface (see example down left)
- Stress dependent fracture permeability (see example down right)





FLUSHING EXPERIMENTS

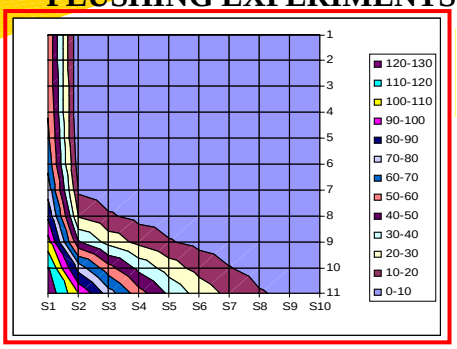


Example of GC-gas composition and sweep efficiency as a function of the displaced volume.

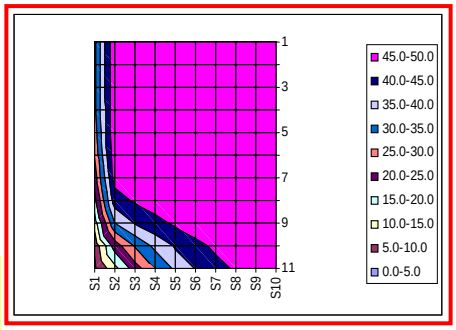
The results are used to verify theory and modelling work.

Recopol I	CO_2 = 1 %	CO_2 = 50%	CO_2 = 90%
Sweep efficiency	11.6 [%]	16.5 [%]	19.5 [%]
Displaced volume	1.26 [mole/mole]	2.09 [mole/mole]	2.86 [mole/mole]
Time after production	2.7×10^5 [sec]	4.5×10^5 [sec]	6.1×10^5 [sec]

FLUSHING EXPERIMENTS:Simulations



Density distribution of CO_2, Kg / m³



Density distribution of CH_4, Kg / m³

Conclusions: Simulations hold good for experimental inputs.

Upscaling to be done.

Results and plans

Results, which will be continued in the coming year:

1. Four flushing experiments under various in-stu conditions.
2. Sorption experiments with coal/methane/water/CO_2/Flue gas.
3. Development of a capillairy pressure device
4. First series of CO_2 CO experiments.
5. First results on theory, with modelling at cleat/matrix level
6. Started with petrography.
7. Interactive discussions with Utrecht and Leiden on their activities.

Informed opinions of the general public on advanced fossil fuel options (UL)

- A crucial condition for succesfull implementation of clean fossil fuel options is societal support for these options.
- Thus, it is important to have some indication of future societal support (or the lack of it).
- Because most people do not have a clue about these new options, it is senseless to "just ask" for their opinions on these options.
- So, a conventional public opinion survey is unsuitable to learn more about societal support.
- In this subproject we plan to administer Information-and-Choice-Questionnaires (ICQ) to representative samples of the Dutch population

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The Information-and-Choice Questionnaire

- Confront respondents with a realistic policy problem e.g., which fossil fuels options are (sub-)optimal to supply our energy after 2010 <u>and</u> to comply to Kyoto norms.
- Provide respondents with well-balanced, expert information on the most important consequences of each option; this information should be translated for laymen
- Facilitate the processing of this information e.g., evaluation of each of the consequences by respondents results in deeper processing (e.g., Neijens, 1987)
- Provide respondents with decision support when they determine their overall preferences regarding options and choose options e.g., help them to aggregate their evaluations of separate consequences of options into overall judgements

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Expert consultation

Aims:

- define "realistic policy problem"
- gather valid and balanced information
- on most important consequences of each option
- (preferably quantitative information)

Consultation of experts at GTI's, companies, government

Options, goal and scale

- six promising "sustainable fossil fuels systems"(primary fuel to end use)
- each option will be applied in the Netherlands (and Dutch North Sea) from 2010 to such a scale that 40 Mton CO2 per year will be avoided in 2030

Consequences

Costs / development costs / environmental impacts / safety risks/ reliability energy supply / total potential of the option / changes in energy infrastructure / innovations and development required / macro economic impacts.

Round 2

- Consultation of the same experts by e-mail (and by phone).
- Check on results of Round 1
- Ratings of the importance of consequences (needed for selecting information to be inserted in the ICQ; six A4-pages may be processed by respondents).
- Next, expert information will be translated for lay people and comprehensibility of information will be tested.
- The ICQ will be administered by NIPO to a representative computer panel. Parallel a questionnaire without information will be administered also to a representative sample.

Some pros and cons of ICQ data

- ICQ is usefull instrument to collect informed opinions of a population (e.g., Van Knippenberg & Daamen, 1996; Price & Neijens, 1998)
- Information inserted in ICQ should be valid, balanced and comprehensible, otherwise one get manipulated opinions.
- Results do not (necessarely) reflect present public opinion but may predict future public opinion (e.g. after public information campaigns)
- ICQ can help respondents to define their view especially if survey topic is new / complex

Global status of the programme

- Major time delays; finding right personel (DUT) and leave of appointed Ph.D.-candidate (UU).
- UL preparatory phases (method & contents) for ICQ in collaboration with UU well underway.
- UU broad scan and system comparison almost complete; start evaluation storage options, selection for cases now.
- Not fully paralel; finalisation stage programme approx. second half 2005.
- Fun team; project is a platform for many new activities!