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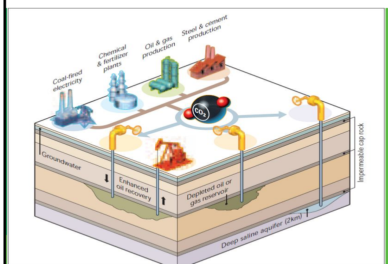

Work Package 5.3
Coal Sector

secure
Security of Energy Considering its Uncertainty, Risks and Economic implications

SECURE Meeting
Brussels, September 29, 20010

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EE²

Chair of Energy Economics and Public Sector Management

Agenda

1. Introduction
2. (Steam) Coal: No Serious Supply Security Issues
3. The Real Issue: CCTS (Carbon Capture, Transport, and Storage)
4. Conclusions

Main Message

- The real issue in European supply security regarding coal is not the resource availability, but the absence of an economically and politically sustainable use of the coal for electricity, liquefaction, gasification, industrial applications etc., due to obstacles in the implementation of a CCTS (carbon capture, transportation, and storage) value-added chain

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Upstream: Threat Identification and Assessment

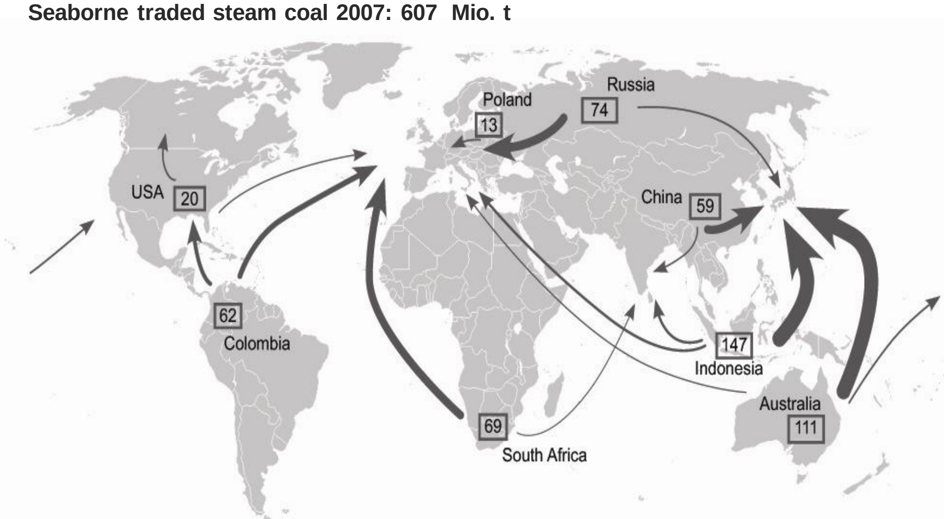
- Large share of imports in many European countries
- Climate policies may result in reduction / abolition of coal use in power generation in Europe

	Import dependency rate	Share of steam coal in electricity production
Germany	69.2%	20.6%
Italy	99.5%	14.4%
Spain	71%	23.5%
UK	63.4%	33.7%
USA	1.8%	47.9%
Japan	99.5%	24.5%
South Korea	95.4%	35.1%
Taiwan	100%	52.8%
China	11%	78.4%

Steam Coal Import Dependency Rate (2006)
Source: Deliverable 5.3.1, based on IEA (2007) Coal Information; IEA (2007) Electricity information

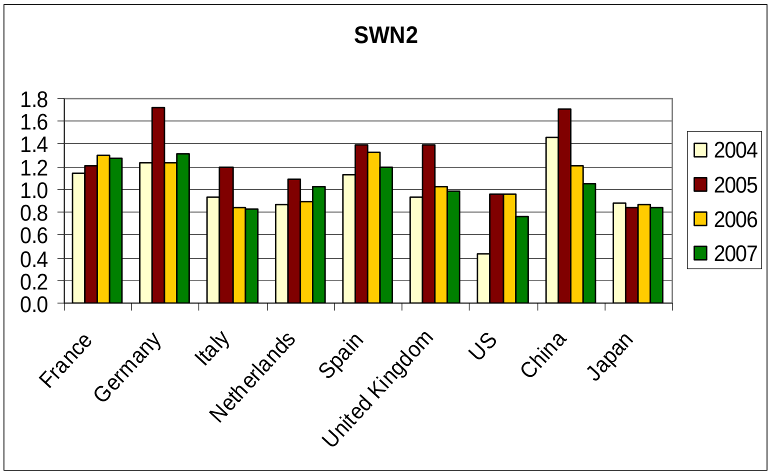
Seaborne Trade of Steam Coal: High Degree of Diversification of European Supplies

Seaborne traded steam coal 2007: 607 Mio. t



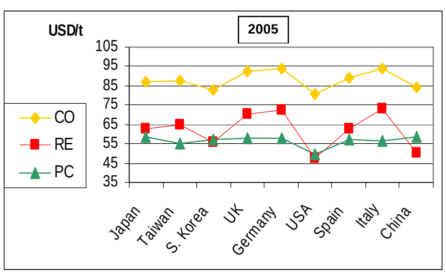
Source: IEA (2008) Coal Information

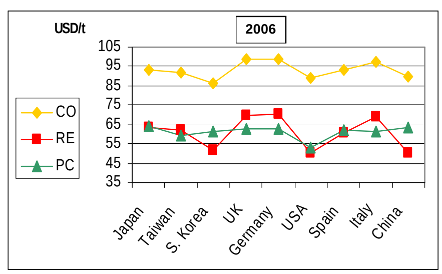
Diversification of Coal Supplies over Time
Taking into Account Political Risk and Domestic Production



Source: Deliverable 5.3.2

Prices and Market Structure Conclusions



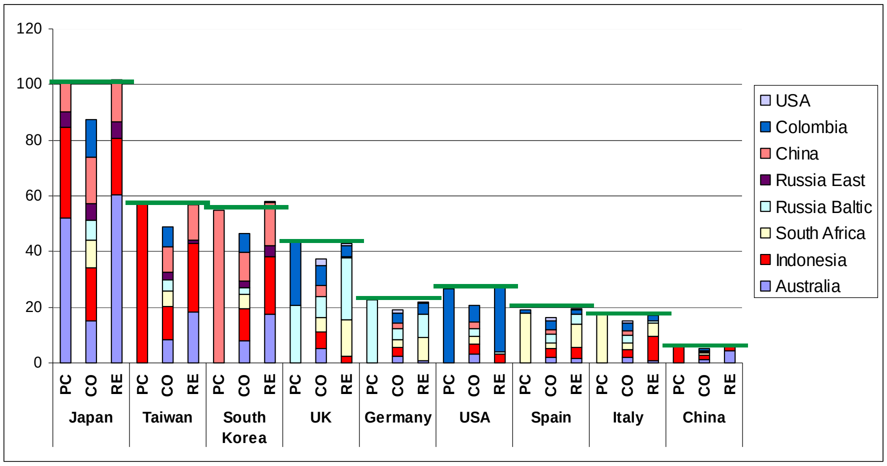


- The real prices are between the modeled price but in 2006 clearly closer to the perfect competition case.
- The results tend to indicate that the international steam coal market is competitive.

Other (than geo-political) risks in the long-term:

- under-investment, especially in transport infrastructure (railways, export terminals), in large exporting countries, e.g. South Africa → scenario analysis
- No reserve risk foreseeable

Results 2006: Imported Quantities in Mt
Evidence of Competitive Market



PC: Perfect competition simulation
CO: Cournot competition simulation
RE: Reference quantities 2006

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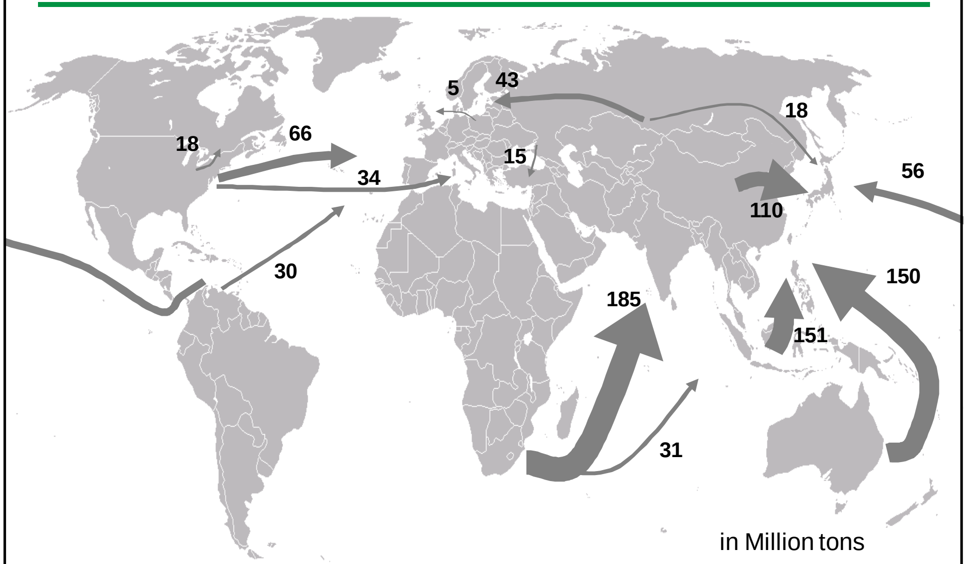
Base Case Results 2030: Diversification Remains (in Mt)



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Policy Conclusions (1): Upstream

- The real issue in European supply security regarding coal is not the resource availability, neither potenetial curtailments due to national export limitatilons
- Upstream, there are little worries about the supply security of (steam) coal
  - Market monitoring should be continued, in particular on developments and prices in specific regions (e.g. China)
  - Competition authorities should continue to monitor international coal markets, with a special focus on mergers& acquisitions of "Big Coal"

Agenda

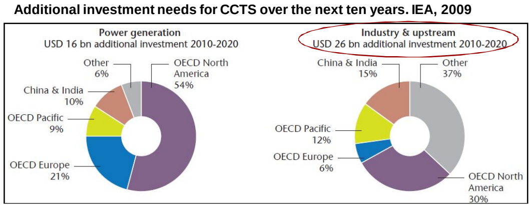
1. Introduction
2. (Steam) Coal: No Serious Supply Security Issues
3. The Real Issue: CCTS (Carbon Capture, Transport, and Storage)
   1. Wishful thinking …
   2. … Reality
   3. Modeling exercise
   4. Focus on industrial emissions
4. Conclusions

3.1 “Wishful Thinking” (1)
PRIMES Energy System Forecast (Sep. 2010)

- Baseline scenario:
- “For CCS, the scenarios assume that the infrastructure and the regulations will deploy and become operational after 2020. “ (p. 23)
- 5.4 GW installed by 2020
- 35 GW installed by 2030; ~ 8.7% of total generation [23.6% CO_2 captured)

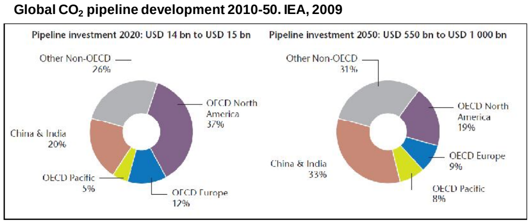
3.1 “Wishful Thinking” (2):
Investment Needs for CCTS

Additional investment needs for CCTS over the next ten years. IEA, 2009



IEA., 2009

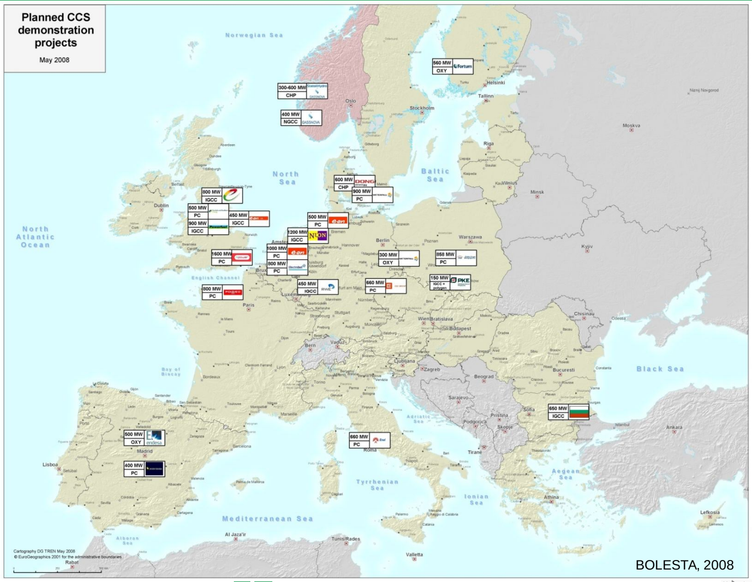
Global CO_2 pipeline development 2010-50. IEA, 2009



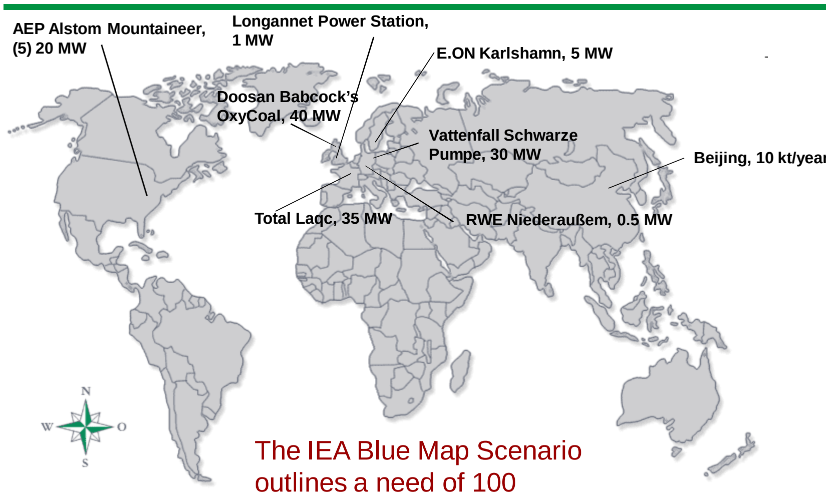
IEA., 2009

- The next 10 years are a critical period for CCTS (IEA, 2009).
- Among the 62 announced CO_2 capture projects, only 7 pilot projects are operating on the pilot scale.
- Assuming that all of the announced projects are realized by 2050 there still remains a gap of 40 projects to reach the IAE blue map scenario.
- This gap is higher with respect to regional projections. Only Europe could reach the IEA forecast by 2020 given 37 announced CCTS projects.

3.1 “Wishful Thinking” (3): Announced EU Demonstration Projects (2008)



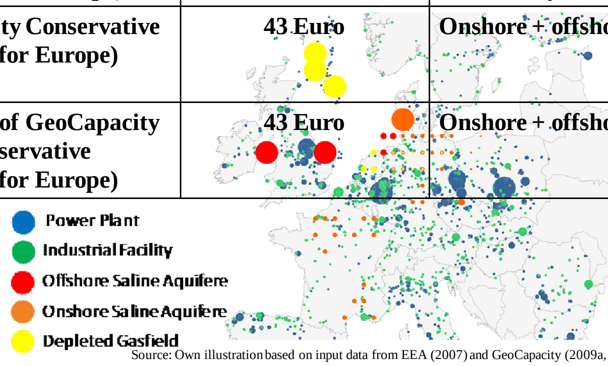
3.2 Reality Check (1) CCTS Power Projects Operating, 09/2010



The IEA Blue Map Scenario outlines a need of 100 serious CCTS demonstration projects until 2020!

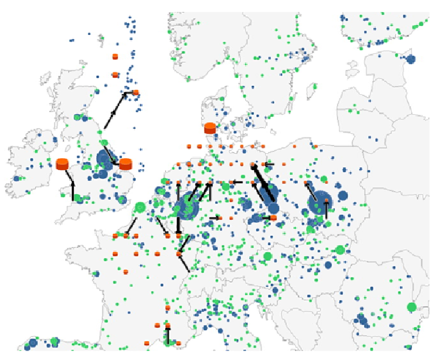
3.3 Modeling a European CCTS Infrastructure: Scenario Key Assumptions

Scenario	Geological storage potential	CO_2 certificate price in 2050	Public acceptance
BAU	GeoCapacity (100 Gt for Europe)	43 Euro	Onshore + offshore
Off 120	GeoCapacity (100 Gt for Europe)	120 Euro	Offshore storage only
Conservative storage potential	GeoCapacity Conservative (50 Gt for Europe)	43 Euro	Onshore + offshore
Low storage potential	50 percent of GeoCapacity Conservative (25 Gt for Europe)	43 Euro	Onshore + offshore

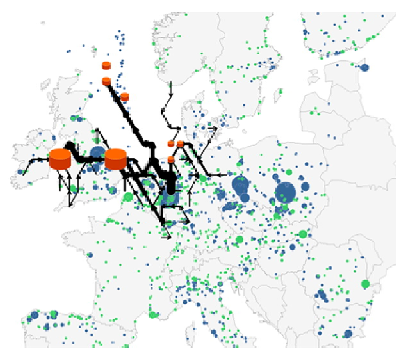


Source: Own illustration based on input data from EEA (2007) and GeoCapacity (2009a, b)

Modeling Results: Pipeline Deployment by 2050 in Different Scenarios



BAU: CCTS infrastructure in 2050



Offshore 120: CCTS infrastructure in 2050

Modeling a European CCTS Infrastructure: Scenario Results

Scenario	CO_2 price in 2050 [€]	CO_2 stored via CCTS in 2050 [%]	Infrastructure length in 2050 [km]	Share of CO_2 from industry [%]
BAU	43	19.4	2897	54.0
Off 120	120	24,7	15889	47,2
Conservative Storage Potential	43	13.5	1333	60.6
Low Storage Potential	43	5.6	-	66.8

- **Under certain assumptions, CCTS may theoretically contribute significantly to the decarbonization of Europe's electricity and industry sector**
- **Results reveal that the development of the CCTS infrastructure is highly sensitive to the availability of storage sites.**
- **An early integration of Europe's industry and electricity sectors in the CO_2 infrastructure planning increases network efficiency.**
- **In all scenarios, industry plays an important role as a first mover to induce deployment of CCTS.**

Alternatives to CCTS in Industrial Applications

- **Cement: responsible for more than 5% of global anthropogenic CO_2 emissions.**
  - Production of 1 ton Portland cement results in 0.65 – 0.92 tons of carbon
  - Alternative production processes under development,
- **Iron/Steel: the iron and steel industry accounts for about 19% of final energy use and about a quarter of direct CO_2 emissions from the industry sector.**
  - CO_2 neutral iron production in combination with biomass gasification (CO),
- **Pulp/paper: responsible for ~ 6% of industrial final energy use**
  - Already high share of biomass co-firing (~50%) and CHP
- **Hydrogen: due to much lower costs and technical maturity, H_2 production primarily based on the steam reformation of natural gas.**
  - Electrolysis with renewable based electricity could lower carbon emissions significantly
- **Ammonia: CO_2 emissions**
  - Use of "green" hydrogen possible, but uneconomical (q.v. hydrogen)
- **Refineries: the use of hydrogen will increase with the use of heavy oils, oils sands and oil shale**
  - Use of "green" hydrogen possible, but uneconomical (q.v. hydrogen)

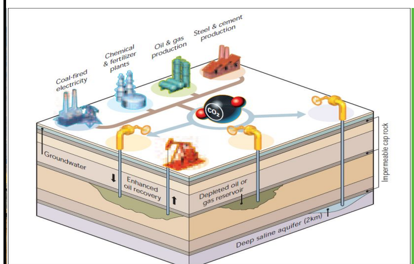
Agenda

Conclusions (Downstream)

- The technical, financial, and institutional structures of the entire chain pose significant challenges
- The real bottleneck towards CCTS is the transport and storage infrastructure:
- The focus should be extended to industrial applications, which can be highly vulnerable to an abandonment of coal.
  - Due to a larger number of small emissions sources, this will pose higher challenges to network development.
  - Technical alternatives to CCTS are available
- Early planning of transport routes is of paramount importance should large-scale CCTS deployment ever become reality
- Future regulation should specify the allocation and financing principles as well as access for third parties

➔ **The potential contribution of CCTS to a decarbonised European electricity sector should be reconsidered given new data available on CCTS costs**

➔ **The idea that CCTS could constitute an "energy bridge" into a new, largely renewable-based energy system, should be discontinued.**



Thank you very much
for your attention!

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References

Dooley, et al.

Carbon Dioxide Capture and Geological Storage - a core element of a global energy technology strategy to address climate change [Report] / Global Energy Technology Strategy Program (GTSP). - College Park, USA : Battelle, Joint Global Change Research Institute, 2006.

Fritze K.

Modeling CO2 Storage Pipeline Routes in the United States [Report] / Master's Project ; Nicholas School of the Environment . - USA : Duke University, 2009.

IEA, 2009: CO2 CAPTURE AND STORAGE - A key carbon abatement option

Edenhofer et al., (2009): Report on Energy and Climate Policy in Europe - The Economics of Decarbonization

EU, 2010: European Union notifies EU emission reduction targets following Copenhagen Accord, press release http://www.co2-handel.de/article185_13555.html

International Energy Agency

Technology Roadmap - Carbon Capture and Storage [Report]. - Paris, France : International Energy Agency

Kobos et al.

The 'String of Pearls': The Integrated Assessment Cost and Source-Sink Model [Conference] // 6th Annual Carbon Capture & Sequestration Conference, May 7-10 2007. - Pittsburgh, USA : Sandia National Laboratories, 2007.

Middleton R. and Bielicki J.

A Comprehensive Carbon Capture and Storage Infrastructure Model [Conference] // Proceedings of the 9th International Conference on Greenhouse Gas Technologies, 2009.

McPherson et al.

Southwest Regional Partnership on Carbon Sequestration [Report] / Revised Semiannual Report. - Socorro, New Mexico, USA : New Mexico Institute of Mining and Technology, 2006.

Zero Emissions Platform

Zero Emissions Platform – Information, October 15, 2008 – January 23. 2010 / www.zeroemissionsplatform.eu

Backup

The Role of Coal in a Carbon Constraint World

The real issue in European supply security regarding coal is the absence of an economically and politically sustainable use of the coal for electricity, liquefaction, gasification, industrial applications etc.

- Over 50% of EU electricity comes from fossil fuels, mainly coal, which accounts for about 30% of overall electricity generation in the EU (EU, 2010).
- In 2005 CO_2 emissions from coal-based electricity generation accounted for 70% of total CO_2 emissions due to electricity generation in the EU, and 24% of CO_2 emissions from all sectors taken together (EU, 2010).
- The EU is committed to an independent economy-wide emissions reduction target of 20% by 2020, compared with 1990 levels, and this cut could be increased to 30% under the conditions agreed by the European Council.
- Carbon Capture, Transport and Storage (CCTS) could give the possibility to continue to use of coal in electricity production and industrial processes while at the same time considerably reducing CO_2 emissions.

If CCTS deployment continues at the current slow pace, there is a real danger that European energy security for coal electrification could be in danger.

CCTS Impact Assessment

The short-term substitution of coal for high temperature heat for industrial processes or a switch in production processes is less feasible than the substitution of coal for electricity production.

Medium impact on Electricity production:

- Significant changes in the European electricity generation mix; in particular the role of renewable energy sources would become more important than currently forecasted.
- This would imply the necessity for large electricity infrastructure changes such as substantial investments in new transmission infrastructures or smart grids, for example.

Higher impact on the Industrial Applications of Coal and Process Emissions:

- The cement industry, steel production, glass, ceramic, and paper industries all use coal. There are only limited substitutes available, due to high temperatures needed, or the underlying production processes.
- Coal to Liquids as fuel for cars and planes. The coal to liquids process is more CO_2 intensive than conventional oil refining but is particularly qualified for CCTS.

Literature Overview

Model	Feature	Main Findings	Authors
MARKAL model for Blue map Scenario	• different technologies • cost minimizing	CCTS is an important CO_2 mitigation option	IEA (2009)
Global Energy Technology Strategy Program (GTSP)	• Fossil-fuel-intensive electricity generation regions of the USA • CO_2 price sensitivity of CCTS	Storage site characteristics are the most significant factor for the CCTS deployment	Dooley, et al. (2006)
Modeling CO_2 Storage Pipeline Routes in the United States	• Aspects of CCTS infrastructure financing • Public trunk lines	No significant advantage of Pipeline Provision	Fritze (2009)
SimCCS	• Scalable • Scale Economies • Cost minimizing	Optimal development of a CCTS infrastructure given different CO_2 price paths in California	Middelton (2007, 2009)
CCTSMOD	• Scalable • Multi Period • Scale Economies • Cost minimizing	• Price sensitivity to CO_2 price • Dependency on Onshore Storage	Oei et al. (2010)

Model Description – Indices, Parameters and Variables

Indices

a, b	–	Model Period ($b > a$)
P	–	Individual CO_2 Producer
S	–	Individual CO_2 Storage site
i, j	–	Nodes
d	–	Pipeline Diameter

Parameters

r	–	Discount Rate
$year_a$	–	Starting Year of a Model Period a
$start$	–	Starting Year of the Model
c_ccs_{Pa}	–	Variable Costs of Carbon Capture for Producer P in Period a
$c\_inv\_x_P$	–	Invest. Costs of Carbon Capture for Producer P
$CO2_{P_a}$	–	Total Quantity of CO_2 Produced by Producer P
$cert_a$	–	CO_2 Certificate Price in Period a
c_f	–	CO_2 Flow Costs
$c\_inv\_f_d$	–	Pipeline Investment Costs
cap_free_{ija}	–	Pipeline Capacity between Nodes i and j in Period a which is Provided for Free
c_land	–	Pipeline Planning and Development Costs
max_pipe	–	Max. Number of Pipelines Built on Developed Land
c_stor_{Sa}	–	Variable Storage Costs of Sink S in Period a
$c\_inv\_stor_{Sa}$	–	Invest. Costs for Storage in Sink S in Period a
$match\_P_{Pj}$	–	Location Indicator of Producer P at Node j
$match\_S_{Sj}$	–	Location Indicator of Sink S at Node j
E_{ij}	–	Adjacent Matrix of possible Connections between Nodes i and j
L	–	Shortest Distance between Two Neighboring Nodes

Variables

h	–	Net Present Value of Total CO_2 Abatement Costs over the whole Model Time Frame
x_{Pa}	–	Quantity of CO_2 Injected in Pipeline by Producer P in Period a
inv_x_{Pa}	–	Investment in Additional CO_2 Capture Capacity for Producer P in Period a
z_{Pa}	–	Quantity of CO_2 Emitted into Atmosphere by Producer P in Period a
f_{ija}	–	CO_2 Flow from Node i to j in Period a
inv_f_{ijda}	–	Investment in Additional Pipeline Capacity with Diameter d Connecting Nodes i and j in Period a
$land_{ija}$	–	Pipeline Planning and Development between Nodes i and j in Period a
y_{Sa}	–	Quantity of CO_2 Stored in Sink S in Period a
cap_d_d	–	CO_2 Flow Capacity of a Pipeline with Diameter d
cap_stor_S	–	Storage Capacity of Sink S

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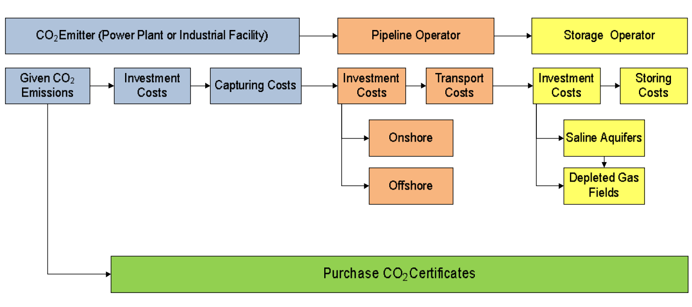
Model Description – Objective Function

$$\min_{\substack{x_{Pa}, inv\_x_{Pa}, z_{Pa}, f_{ija}, \\ inv\_f_{ijda}, land_{ija}, y_{Sa}, inv\_y_{Sa}}} h = \sum_a \left[\left(\frac{1}{1+r}\right)^{(a-start)} \cdot \left(\sum_P \left[c\_ccs_{Pa} \cdot x_{Pa} + c\_inv\_x_P \cdot inv\_x_{Pa} + cert_a \cdot z_{Pa} \right] + \sum_i \sum_j \left[E_{ij} \cdot L \left(c\_f \cdot f_{ija} + \sum_d \left(c\_inv\_f_d \cdot inv\_f_{ijd} \right) + c\_land \cdot land_{ija} \right) \right] + \sum_S \left[c\_stor_{Sa} \cdot y_{Sa} + c\_inv\_y_{Sa} \cdot inv\_y_{Sa} \right] \right) \right]$$



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Model Description – Constraints

Constraint	Equation
CO_2 Balance (P, a)	$x_{Pa} + z_{Pa} = CO2_{Pa}$
Capture Capacity (P, a)	$x_{Pa} \le \sum_{b<a} \left(inv\_x_{Pb} \right)$
Transport Capacity (i, j, a)	$f_{ija} \le cap\_free_{ija} + \sum_{b<a} \sum_{d} \left(cap\_d_d \cdot inv\_f_{ijdb} \right)$
Flow Balance (i, j, a)	$\sum_{i} f_{ija} - \sum_{i} f_{jia} + \sum_{P} \left(match\_P_{Pj} \cdot x_{Pa} \right) - \sum_{S} \left(match\_S_{Sj} \cdot y_{Sa} \right) = 0$
Routing Prioritization (i, j, a)	$\sum_{d} \left(inv\_f_{ijda} \right) \le max\_pipe \cdot \sum_{b \le a} \left(land_{ijb} \right)$
Storage Development + Storage Capacity (S, a)	$\sum_{a} \left(5 \cdot y_{Sa} \right) \le \sum_{b<a} \left(cap\_stor_S \cdot inv\_y_{Sb} \right)$

Input Data

Capture (Sample Plant Jänschwalde)

Parent Company Name	Primary Energy Resource	Launch	Lon	Lat	Installed power in MW	Yearly rated power in TWh	Yearly output of CO_2 in Mt	Investment Costs in M€	Variable Costs in €/t
Vattenfall Generation AG	Brown Coal	2015	14.5	51.8	500	4.20	3.91	190	9.35

Transport

Pipeline Diameter in m	Pipeline Capacity in Mt/y	Variable Flow Costs in M€/tCO_2*km	Investmet Costs in M€/Ø m* km	Investments in Pipeline Development in M€/km
0.2-1.4	1-144 (Economies of Scale are implemtented)	0.01	0.9	0.01

Storage

Type of Storage	Depleted Gas Field	Saline Aquifer	Offshore Aquifer
Investment Costs in M€	231.0	571.2	3176.0
Variable Costs in €/t	4.0	2.4	8.0

Capture Projects 1/4

Project Name	Location	Leader	Feedstock	Size MW	Capture Process	CO_2 Fate	Start-up	Current project status	Cost estimation	Public funding
Abu Dhabi project	Abu Dhabi	Masdar	Various industrial	Various	various	EOR	2013	Planning	$ 2 bn	
Callide-A Oxy Fuel	Australia	CS Energy	Coal	30	Oxy	Seq	2011	Construction	$ 200 Mio	
Wandoan	Australia		Coal	334	Pre	Seq				
ZeroGen	Australia	ZeroGen	Coal	400	Pre	Seq	2015	Planning	A$ 4.3 bn	
Maritsa	Bulgaria	BEH	Lignite	600	Pre	EOR/EGR	Undecided	Announced	€ 850 Mio	
Fort Nelson	Canada	PCOR	Gas	Gas Process	Pre	Brine Res	2012	Feasibility Study		
Boundary Dam	Canada	SaskPower	Coal	120	Oxy	EOR	2015	Announced	$ 1.4 bn	
Bow City	Canada	BCPL	Coal	1000	Post	EOR	2014	Announced		
Project Pioneer	Canada	TransAlta	Coal		Post		2015	Planning		
Shell Quest Project	Canada	Shell	Gas	Various	Pre	Seq/EOR	2015	Planning		
GreenGen	China	GreenGen	Coal	250 (pilot) 600	Pre	Seq	2010 2015	Announced		
NZEC	China	UK,EU,China	Coal	Undecided	Undecided	Seq	2014	Announced		
Hodonin CEZ	Czech Republic	CEZ	Lignite, Biomass	105	Post	Depleted Oil & Gas Field	2015	Planning		
Ledvice CEZ	Czech Republic	CEZ	Lignite	660 (CR)	Post	Saline aquifer	2015	Planning		
Kalundborg	Denmark	DONG Energy	Coal	600	Post	Saline aquifer	2016	Planning		
Aalborg	Denmark	Vattenfall	Coal	410	Post	Saline aquifer	2013	Planning		
Meri Pori	Finnland	Fortum	Coal	400	Post	Unknown	2015	Planning		
Total Lacq	France	Total	Gas	35	Oxy	Seq	2010	Operating	€ 60 Mio	
Schwarze Pumpe	Germany	Vattenfall	Coal	30 (pilot) 300 (demo) 1000	Oxy	Seq / EOR	2008	Operating	€ 70 Mio (pilot)	
Jänschwalde	Germany	Vattenfall	Coal	375	Oxy & Post	EGR	2015	Planning	$ 1.58 bn	180 Mio, EEPR
Wilhelmshaven	Germany	E-ON	Coal	5,5 (pilot)	Post	Deep Saline Aquifer	2010	Planning completed	10 Mio € (pilot)	
Großkrotzenburg /Staudinger	Germany	E-ON/Siemens	Coal	510	post		2010	Construction		
Niederhausem	Germany	RWE	Coal	Pilot Project	Post		2009	Operating	9 Mio €	
Brindisi	Italy	Enel &Eni	Coal	242	Post	Seq	2010	Construction		
Porto Tolle	Italy	Enel	Coal	660	Post	Saline Formation in sea	2015	Planning	€ 800 Mio	100 Mio, EEPR
Saline Joniche	Italy	SEI	Coal	1320 (CR)	Post	Undecided	Undecided	Announced		

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Capture Projects 2/4

Project Name	Location	Leader	Feedstock	Size MW	Capture Process	CO_2 Fate	Start-up	Current project status	Cost estimation	Public funding
Nuon Magnum, Eemshaven	Netherlands	Nuon	Coal	1200 (CR)	Pre	Seq	2013	Construction		reserve list, EEPR
Maasvlakte, Rotterdamm	Netherlands	Rotterdam Climate Initiative E.ON Benelux,Electra bel	Coal	1040 (CR)	Post	EGR	2015	Construction	€ 1.2 bn	180 Mio, EEPR
Eemshaven RWE	Netherlands	RWE	Coal	40	Post	Depleted Oil & Gas Field	2016	Planning		
Rotterdam CGEN	Netherlands	CGEN NV	Coal, Biomass	450	Pre	Depleted Oil & Gas Field	2013	Announced		
Rotterdam Essent	Netherlands	Essent	Coal, Biomass	1000	Pre	Depleted Oil & Gas Field	2016	Announced		
Statoil Mongstad	Norway	Statoil	Gas	630 CHP	Post	Seq	2011	Construction	$ 2.7 bn	
Tjeldbergodden	Norway	Shel/Statoil	Gas	700	Post	EOR	2011	Planning		
Belchatow	Poland	PGE EBSA	Coal	858	Post	Undecided	2011 (pilot project), 2015	Planning/Construc tion		180 Mio, EEPR
Siekierki	Poland	Vattenfall	Coal	480 (CR)	Post	Undecided	2016	Planning		
Kędzierzyn	Poland	PKE	Coal	300	Pre	Seq	2014	Planning	1300 Mio €	
Compostilla	Spain	ENDESA	Coal	30 (pilot), 500 (demo)	Oxy	Deep Saline Aquifer	2010 (pilot), 2015	Planning	€ 500 Mio	180 Mio, EEPR, (280-450 Mio EU Allowances)
Puertollano	Spain	Bellona	Coal, Petcoke	14	Pre	Saline aquifer	2009	Construction	18,5 Mio €	
E.ON Karlshamn	Sweden	E.ON	Oil	5	Post	Undecided	2009	Operating	€ 11 Mio	
Scottish & Southern Energy Ferrybridge/Yorkshire	UK	SSE	Coal	500(CR)	Post	Seq	2012	Planning	£ 250 Mio + 100 Mio CCS	
Teesside	UK	CE	Coal	800	Pre	Seq	2015	Announced	$ 1500 Mio	
Powerfuel Hatfield	UK	Powerfuel	Coal	900	Pre	EOR	2014	Construction	$ 1.6 bn	180 Mio EEPR + 180 Mio (UK)
Longgannet	UK	Scotish Power	Coal	300	Post	Undecided	2014	Testing 1 MW prototype	£ 1 bn	reserve list, EEPR
Drym	UK	Progressive Energy	Coal	450	Pre	Undecided	Undecided	Announced		
Immingham	UK	ConocoPhillips	Gas	450	Post	Seq	2010?	Construction		
Aberthaw	UK	RWE		3 (pilot), 25 (2. phase)	Post		2010	Construction	£ 8.4 Mio	
Onllwyn	UK	Valleys Energy	Coal	450	Pre		2014	Planning		

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Capture Projects 3/4

Project Name	Location	Leader	Feedstock	Size MW	Capture Process	CO_2 Fate	Start-up	Current project status	Cost estimation	Public funding
Renfrew	UK	Doosan Babcook, DECC, Scotish/Southern Energy		40	Oxy		2009	Operating		
Pleasant Prairie	USA	AEP	Coal	5	Post	Seq	2008	Operating		
AEP Alstom Mountaineer	USA	AEP	Coal	30 235	Post	Seq	2009	Operating	$ 800 Mio	$334 Mio
Williston	USA	PCOR	Coal	450	Post	EOR	2014	Announced		
Kimberlina	USA	CES	Coal	50	Oxy	Seq	2010	Announced		
AEP Alstom Northeastern	USA	AEP	Coal	200	Post	EOR	2011	Announced		
Plant Barry	USA	MHI	Coal	25 (pilot) 160 (demo)	Post	Seq	2011	Planning		$ 295 Mio
Antelope Valley	USA	Basin Electric	Coal	120	Post	EOR	2012	-		
Appalachian Power	USA	AEP	Coal	629	Pre	Undecided	2012	Announced	$ US Mio	
WA Parish	USA	NRG Energy	Coal	60	Post	EOR	2013	Planning		
Wallula Energy Resource Center	USA	Wallula Energy	Coal	700	Pre	Seq	2014	Announced	$ 2.2 bn	
Hydrogen Energy California	USA	HEI	Petcoke	390	Pre	EOR	2014	Planning		$ 308 Mio
Trailblazer	USA	Tenaska	Coal	765	Post	EOR	2014	Planning		
ZENG Worsham-Steed	USA	CO2-Global	Gas	70	Oxy	EOR	Undecided	Announced		

Capture projects 4/4

Project Name	Location	Leader	Feedstock	Size MW	Capture Process	CO2 Fate	Operation	Current project status	Cost estimation	Public funding
Restructuring/ Dormant										
FutureGen	USA	FutureGen Alliance	Coal	275	Pre	Seq	2009			
BP Carson (DF2)	USA	Hydrogen Energy	Petcoke	500	Pre	EOR	Re-Structuring		$ 2 bn	
E.ON Killingholme	UK	E.ON	Coal	450	Pre	Seq	Dormant	Cancelled?		
Monash Energy	Australia	Monash	Coal	60 k bpd	Pre	Seq	Dormant	Cancelled?		
UAE Project	UAE	Masdar	Gas	420	Pre	EOR	Delayed	Cancelled?		
Greifswald	Germany	Dong Energy						Cancelled?	$ 2-3 bn	
RWE Goldenbergwerk , Huerth	Germany	RWE	Coal	450	Pre	Seq	2015	Postponed?	2 bn €	reserve list, EEPR
Kingsnorth	UK	E-ON	Coal	800 (CR)	Post	Depleted Gas Field	2014	Postponed?	£ 1 bn	reserve list, EEPR
Sargas Husnes	Norway	Sargas	Coal	400	Post	EOR	2012	Postponed?	$ 700 Mio	
Naturkraft Kårstø	Norway	Naturkraft	Gas	420 (CR)	Post	Undecided	2011-2012	Postponed?	$ 1.8 bn	
ZENG Risavika	Norway	CO2-Norway	Gas	50-70	Oxy	Undecided	Undecided	Postponed?		