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Sustainability Criteria

and CCS in Germany

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Sustainability and CCS

Structure

I. Lack of Criteria => Criteria Development
II. 8 Sustainability Criteria for CCS
III. EU and German Energy Policy and CCS
IV. European and International Outlook
V. Conclusions

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Section I: Genesis of Sustainability Criteria for CCS

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Sustainability and CCS 1

Defintion and Criteria

- CCS is a new technology
- need for development of sustainability criteria
- Federal Environment Agency: Criteria based on report of a Select Committee of the German lower house "Bundestag"
- „Protection of human beings and the environment – The concept of sustainability – from a guiding principle towards implementation"

(„Enquete-Kommission des 13. Bundestag: Schutz des Menschen und der Umwelt - Konzept Nachhaltigkeit – Vom Leitbild zur Umsetzung")

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Sustainability and CCS 2

Defintion and Criteria

- „Sustainability“ based Rio Declaration / Brundtland report
  - three dimensions (environment, economics and social aspects)
  - intergenerational and international justice (local, regional and national)
- comprehensive and fairly broad approach

$\Rightarrow$ allows for pragmatic compromises

$\Rightarrow$ „common sense“

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Section II: Sustainability Criteria for CCS

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Criterion 1)
Health harmlessness

- No unjustifiable risk or danger for human health may be triggered
- precautionary principle must be applied
- take into consideration lack of (long-term) experience and lack of knowledge ("knows unknowns" and "unknown unknowns")

Criterion 2) Environmental soundness

- No negative consequences or interactions with the living environment may occur
- Neither in underground water, nor soil, nor above ground, nor local air
- take up- and down-stream pollution of the CCS-chain into account

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Criterion 3) Storage safety

- leakage-rates of reservoirs have to be so small that the sum of
  - future CO2-emissions from the storage sites
  - plus future anthropogenic (GHG) emissions

  does not lead to an excessively high or fast rise of global temperature levels.
- No local damages or intergenerational burden may be generated

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Criterion 4: Availability of suitable storage capacity

- availability of suitable storage formation is a precondition:
- situations have to be avoided, where unsafe reservoirs have to be used.

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5) Long-term compatibility with a sustainable energy system

- CCS is based on availability of
  - limited fossil fuels and
  - limited suitable storage reservoirs in vicinity of CO2-sources
- thus can only be a transition technology on the way towards a CO2-free energy system
- the transition towards a CO2-free energy supply will take decades and thus must not be inhibited by the introduction of CCS

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Criterion 6) Cost efficiency

- any reduction target for GHG-emissions is to be met as efficiently and cost-effective as possible
- contribution of CCS will depend on its mitigation costs vis-à-vis other options
- has to be decided by market forces

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Criterion 7: Legal security

- precise and clear-cut responsibility and liability rules
- based on precautionary and "polluter-pays" principle
- "externalisation of internal costs" is to be avoided

Criterion 8: Global cooperation and minimum standards

- a global problem like global warming needs to be addressed at global level
- a multilateral international process needs to develop minimum standards:
  - for site selection and monitoring,
  - management of CO2-reservoirs and remediation
  - to ensure long term protection and storage safety

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Overview:

Sustainabilty Criteria for CCS

1. Health harmlessness
2. Environmental soundness
3. Storage safety
4. Availability of suitable storage capacity
5. Long-term compatibility with a sustainable energy system
6. Cost efficiency
7. Legal security
8. Global compatibility and standards

$\Rightarrow$ Pragmatic approach (Common sense)

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Section III: German Energy & CCS Policy

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Sustainability Criteria and implementation

1. Health harmlessness => legal framework /R&D
2. Environmental soundness => legal framework /R&D
3. Storage safety => legal framework /R&D
4. Availability of suitable storage capacity => R&D
5. Long-term compatibility with a sustainable energy system policy => Policy
6. Cost efficiency of meeting targets => Policy
7. Legal security => legal framework
8. Global compatibility and standards => Policy

R&D:
CCS-Projects

- 2007 KETZIN: First research project onshore CO2-Storage 30 000 t annually
- 2007 ALTMARK: EGR research project
- smaller scale industrial storage projects
- 2007-2008: Schwarze Pumpe 40 MW Oxyfuel Plant
- 2014: IGCC plant (450 MW) and Oxyfuel
- EU: up to 12 demo plants up by 2015

R&D spending in Germany and the EU

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- „Geotechnologien“
  - 8 Mio.€ annually for non-site specific R&D
  - 9 Mio.€ annually for site-specific R&D
- „Cooretec“:
  - Currently 25 Mio.€ annually for Capture technologies
  - increase to approx. 38 Mio. € annually envisaged
- **total 150 Mio.€ over the next three years envisaged**
- „7th Research Framework Program“ of EU:
  - approx. 450-500 Mio. € envisaged for CCS
  - Further support by EIB and EU-COM

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Creation of legal framework for CCS in Germany and EU

- EU to publish a draft regulation by end 2007
  - Site selection criteria
  - thorough scientific screening
  - precautionary approach
  - Proposal to make CCS mandatory from 2020 onwards

- Preparation in Germany currently ongoing

EU Energy Policy targets

Targets: Max. 2° C global temperature increase

- follow-up for post 2012 / Kyoto regime
- cut GHG-Emissions of industrialised countries by 60-80%by 2050
- EU-subtargets by 2020 :
  - GHG-Reduction of 30% compared to 1990 (20% unilaterally)
  - 20% renewables share of total energy demand
  - 20% higher efficiency compared to BAU-scenario
  - 10% Biofules

Policy: Energy and Climate Package Jan. 07

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German Energy Policy targets

- Targets by 2020:
  - GHG-Reduction of 40% compared to 1990
  - 25-30% renewables share in electricity by 2020
  - 100% increase of energy productivity between 1990 / 2020
  - 3% annual increase of energy efficiency in the economy
  - 17% biofuel share (20% in Vol%)
- Policies:
  - energy and climate protection package (Meseberg)
  - make CCS commercially available from 2020 onwards

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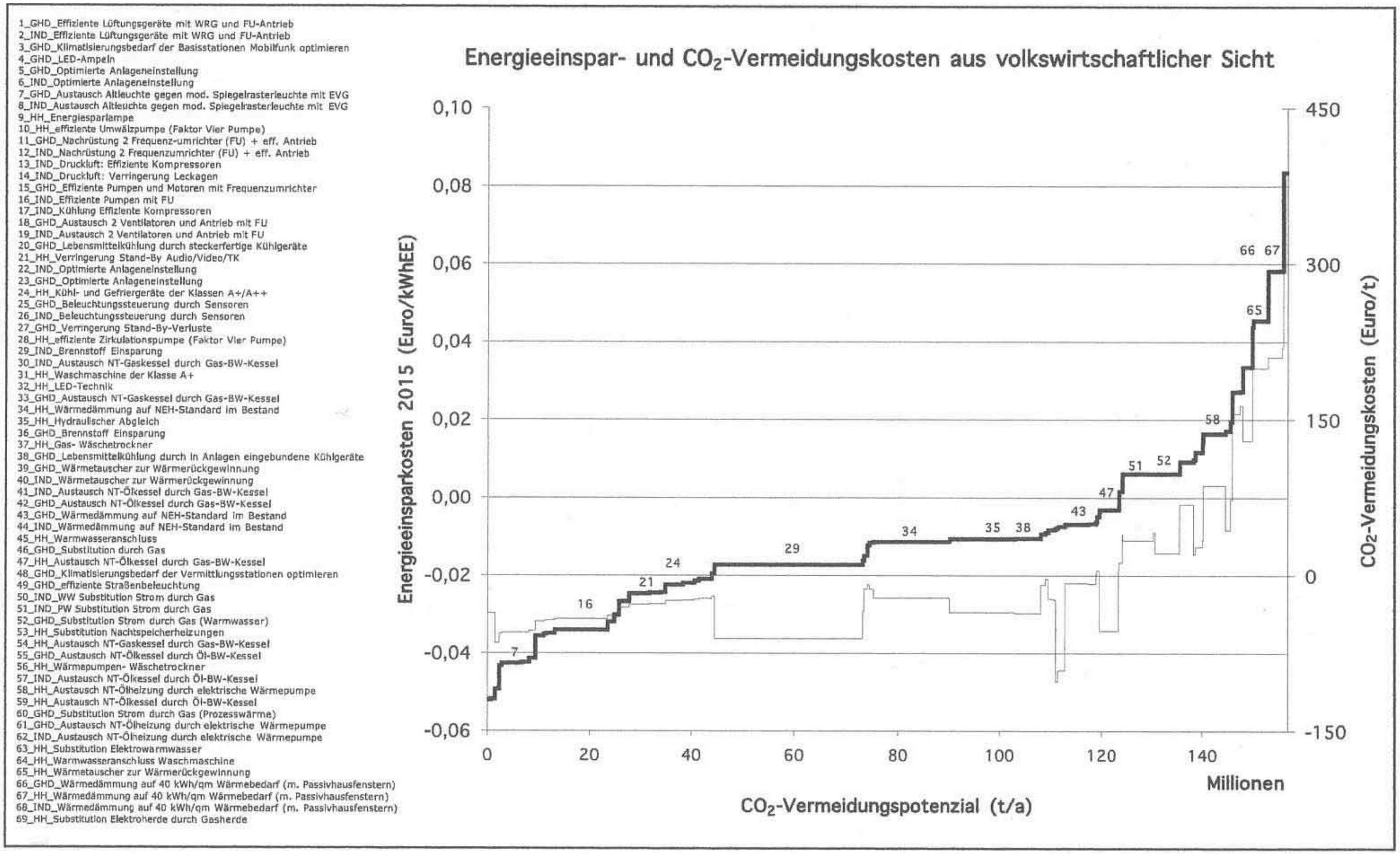
German Energy & Climate Package (Meseberg Aug.2007)

- 1 Combined heat-and-power generation
- 2 Expansion of renewable energies in the power sector
- 3 **Carbon Capture and Storage**
- 4 Smart metering
- 5 Clean power-station technologies
- 6 Introduction of modern energy management systems
- 7 Support programmes for climate protection and energy efficiency (other than housing)
- 8 Energy-efficient products
- 9 Provisions on the feed-in of biogas to natural gas grids
- 10 Energy Saving Ordinance
- 11 Operating costs of rental accommodation
- 12 Modernisation programme to reduce CO2 emissions from buildings
- 13 Energy-efficient modernisation of social infrastructure
- 14 Renewable Heat Act
- 15 Programme for the energy-efficient modernisation of federal buildings
- 16 CO2 strategy for passenger cars
- 17 Expansion of the biofuels market
- 18 Reform of vehicle tax on CO2 basis
- 19 Energy labeling of passenger cars
- 20 Reinforcing the influence of the HGV toll
- 21 Aviation
- 22 Shipping
- 23 Reduction of emissions of fluorinated greenhouse gases
- 24 Procurement of energy-efficient products and services
- 25 Energy research and innovation
- 26 Electric mobility
- 27 International climate-protection and energy-efficiency projects
- 28 Energy and climate-policy reporting by German embassies and consulates
- 29 Transatlantic climate and technology initiative

2,7 bn. € annually and 40% CO2 reduction by 2020

Abb. 12: CO_2-Vermeidungspotenziale in Deutschland im Jahr 2015, summiert über alle Sektoren, **durchschnittliche** Energieeinsparkosten (dicke Linie) und CO_2-Vermeidungskosten (dünne Linie) **im Vergleich** zu den Kosten bei ohnehin durchzuführenden Maßnahmen, unter Berücksichtigung der eingesparten Energiesystemkosten (netto), aus **gesamtwirtschaftlicher Sicht – ausführliche Darstellung**



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German Energy & Climate Package (Meseberg Aug.2007)

- Current situation: If lignite and coal-burning power stations are also to have a future over the medium to long term, given the tightening of reduction targets under emissions trading, it will be necessary to develop power stations with high efficiency factors and CCS technologies (capture and storage of CO2) capable of meeting the challenges of the future. A suitable framework should be created for the implementation of CCS technologies.
- Goal: The technical, environmental and economic feasibility of CCS technologies is to be confirmed by demonstration power stations. This has also been agreed at the EU level. Other storage projects under which several hundred thousand tonnes of CO2 are deposited each year should be implemented as soon as possible.
- There must be rapid moves to organise the legal framework for the capture, transport and storage of CO2 (CCS) so that the planned pilot facilities and, subsequently, power stations have a stable legal basis for the installation and operation of these systems. Taking into consideration the results of relevant R&D projects, the German Government will draw up proposals for a "capture-ready" standard**.** This standard could then be applied when new power stations are constructed.
- Two or three commercial size demo plants shall be built in Germany by 2015.

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Section IV:
EU and International Outlook

CCS Sustainability Criteria: Benefits and the way forward

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- Sustainability Criteria may foster **public acceptance**
- enable **common** international **understanding**
- **enable** and speed up the creation of a **legal framework**
- **assign CCS an appropriate share within a wider strategy towards a sustainable energy system**
- provide **added value**

⇒start to work in appropriate fora (i.e. UN CSD)

⇒enable environmentally friendly, economically viable and socially acceptable CCS (across regions, nations and future generations)

CCS Sustainability Criteria applied to Policy 1

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- ensure balanced approach and division of supply sources, fuels and technologies
- focus on future technologies: renewables and efficiency
- reduce fierce competition for increasingly scarce fossil fuels (oil/gas)
- contribute to peaceful coexistence
- increase security of supply

CCS Sustainability Criteria applied to Policy 2

- focus on low hanging fruits for deployment of CCS
- decentralised energy supply without CCS, where suitable
- large-scale centralised energy supply structures in highly industrialised and densely populated regions with CCS
- for climate change reasons coal requires either
  - CCS, or
  - "compensation" via other GHG-reduction measures (CDM/JI), c
  - cease use of coal

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V Conclusions

- Shift towards more sustainable energy system urgently needed
- CCS shall contribute during a transition period for some decades from 2020 onwards
- as part of a "no regret" strategy
- which focuses on the potential that can be deployed today

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Thank you

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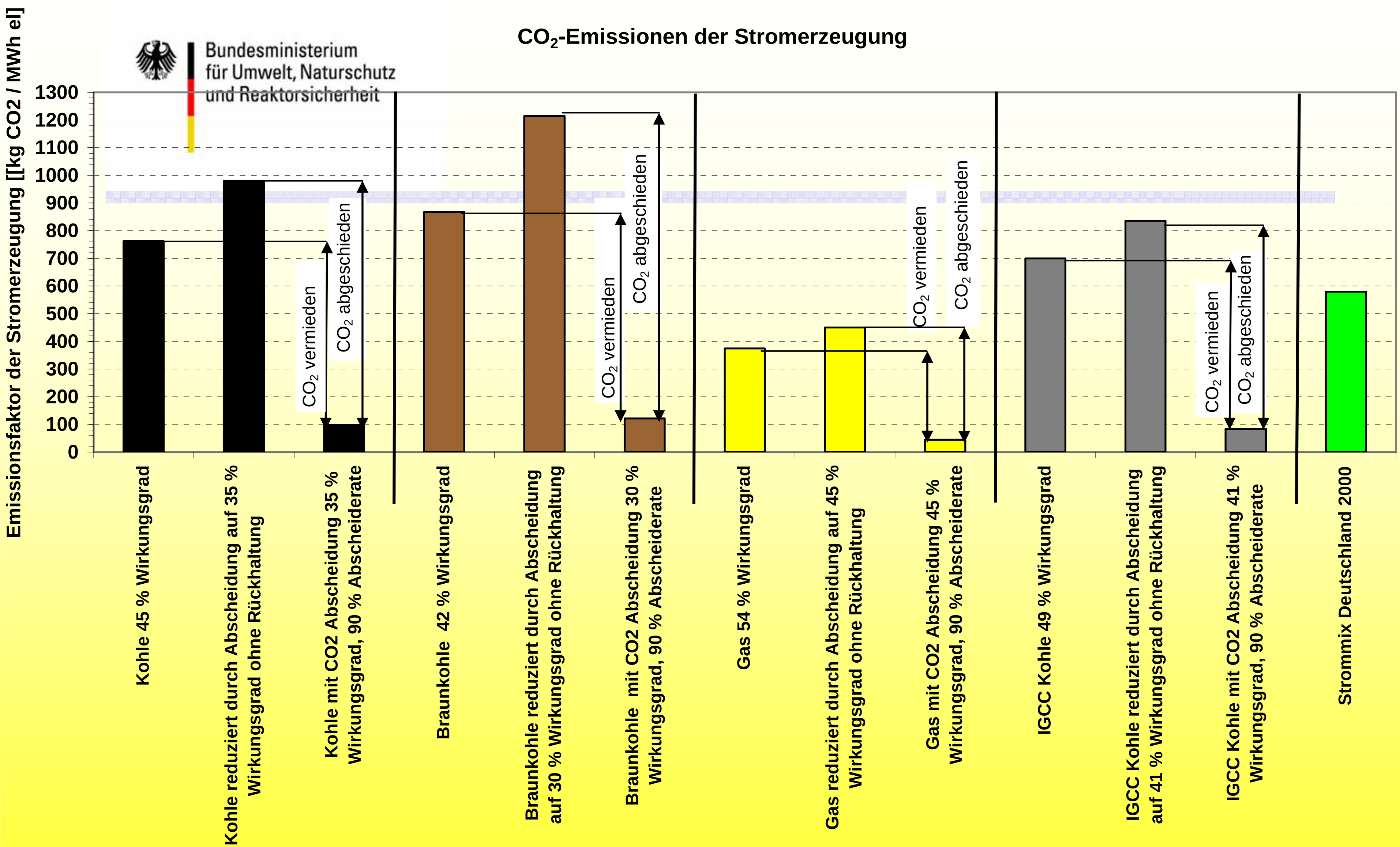
VI CCS Annexes



Source: „Bewertung von Verfahren zur CO_2-Abscheidung und Deponierung“ (ISI Karlsruhe & BGR)

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storage capacity estimates

Tabelle 2: Übersicht über Speicherpotenziale in Ölfeldern, Gasfeldern und salinen Aquiferen in Deutschland, Europa und der Welt (Quelle: eigene Darstellung auf der Basis der genannten Quellen)

Speicher-kapazi-täten	Ecofys 2004 [1] in Pg (=Gt) CO_2		IPCC 2005 [2] in Gt CO_2		COORETEC [3] 2003 in Gt CO_2		VGB 2004 [4] In Gt CO_2		MAY et al. 2005 und 2006 in Gt CO_2	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Olfelder D	k.A.	k.A.	k.A.	k.A.	k.A.	k.A.	k.A.	k.A.	„kommen kaum in frage, weil zu klein"[5]	
Gasfelder D	k.A.	k.A.	k.A.	k.A.	2,56		k.A.	k.A.	2,3[6]	2,5[7]
Aquifere D	k.A.	k.A.	k.A.	k.A.	22,8	43,5	k.A.	k.A.	>2,5[8] bzw. 12[9]	28[10]
Olfelder Nordsee	k.A.	k.A.	k.A.	k.A.	k.A.	k.A.	5,8 Gt Nordsee[11]		k.A.	k.A.
Gasfelder Nordsee	k.A.	k.A.	k.A.	k.A.	k.A.	k.A.	13,3 Gt Nordsee[12]		k.A.	k.A.
Aquifere Nordsee	k.A.	k.A.	k.A.	k.A.	k.A.	k.A.	k.A.	k.A.	k.A.	k.A.
Olfelder Europa	0,5 ons[13] 3,7offs[14] =4,2 total	7,0 ons[15] 58,1offs[16] =65,1 total	k.A.	k.A.	k.A.	k.A.	0,2Gt onshore[17] 5,9Gt offshore[18] = 6,1 Gt total		k.A.	k.A.
Gasfelder Europa	7,8ons[19] 23,2offs[20] =31,0 total	37,8ons[21] 125,2offs[22] =163 total	k.A.	k.A.	k.A.	k.A.	12,5Gt onshore[23] 14,4Gt offshore[24] = 26,9 Gt total		k.A.	k.A.
Aquifere Europa	k.A.	k.A.	30[25]	577[26]	k.A.	k.A.	57Gt onshore[27] 716 Gt offshore[28] = 773 Gt total		k.A.	k.A.
Olfelder global	54Gt[29]	1194Gt[30]	675 Öl- und Gasfelder [31]	900 Öl- & Gasfelder [32]	k.A.	k.A.	147 Gt [33]	697 Gt[34]	k.A.	k.A.
Gasfelder global	392Gt[35]	2126Gt[36]			k.A.	k.A.	513Gt [37]	1503Gt [38]	k.A.	k.A.
Aquifere global	30Gt[39]	1081Gt[40]	1000[41]	"uncertain, but possib-ly 10^4" Quelle: [42]	k.A.	k.A.	"there appears to be a consensus that the storage capacity is a few thousand Gt CO_2 at the most"		350 [43] (nach White et al.)	11000 (nach Manancourt 2004)
"beste" verfügbare Schätzung (global gesamt)	1700 Gt[44]		220[45]	2200 [46]	k.A.	k.A.	k.A.		k.A.	k.A.

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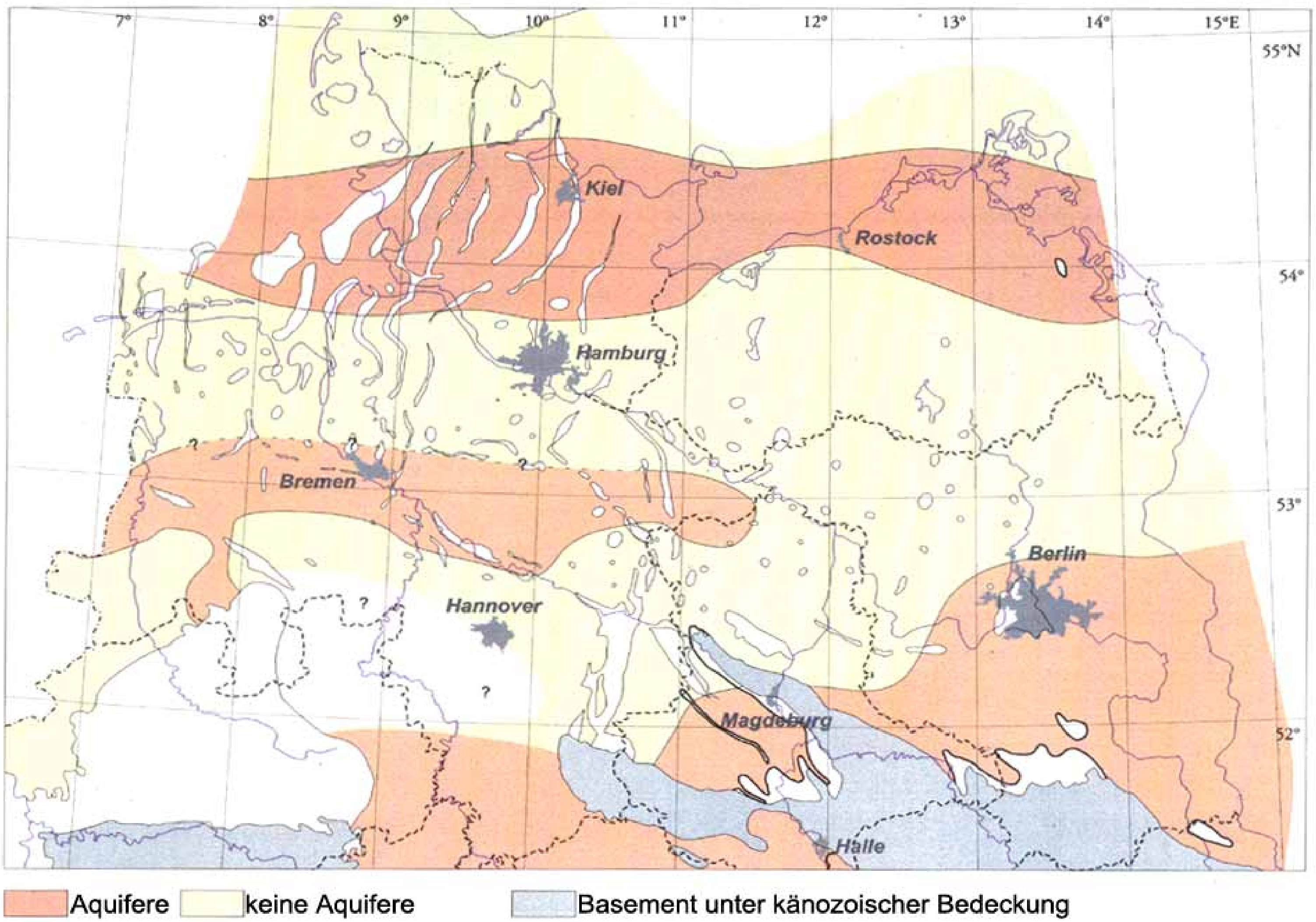
Saline Aquifer formations in North Germany



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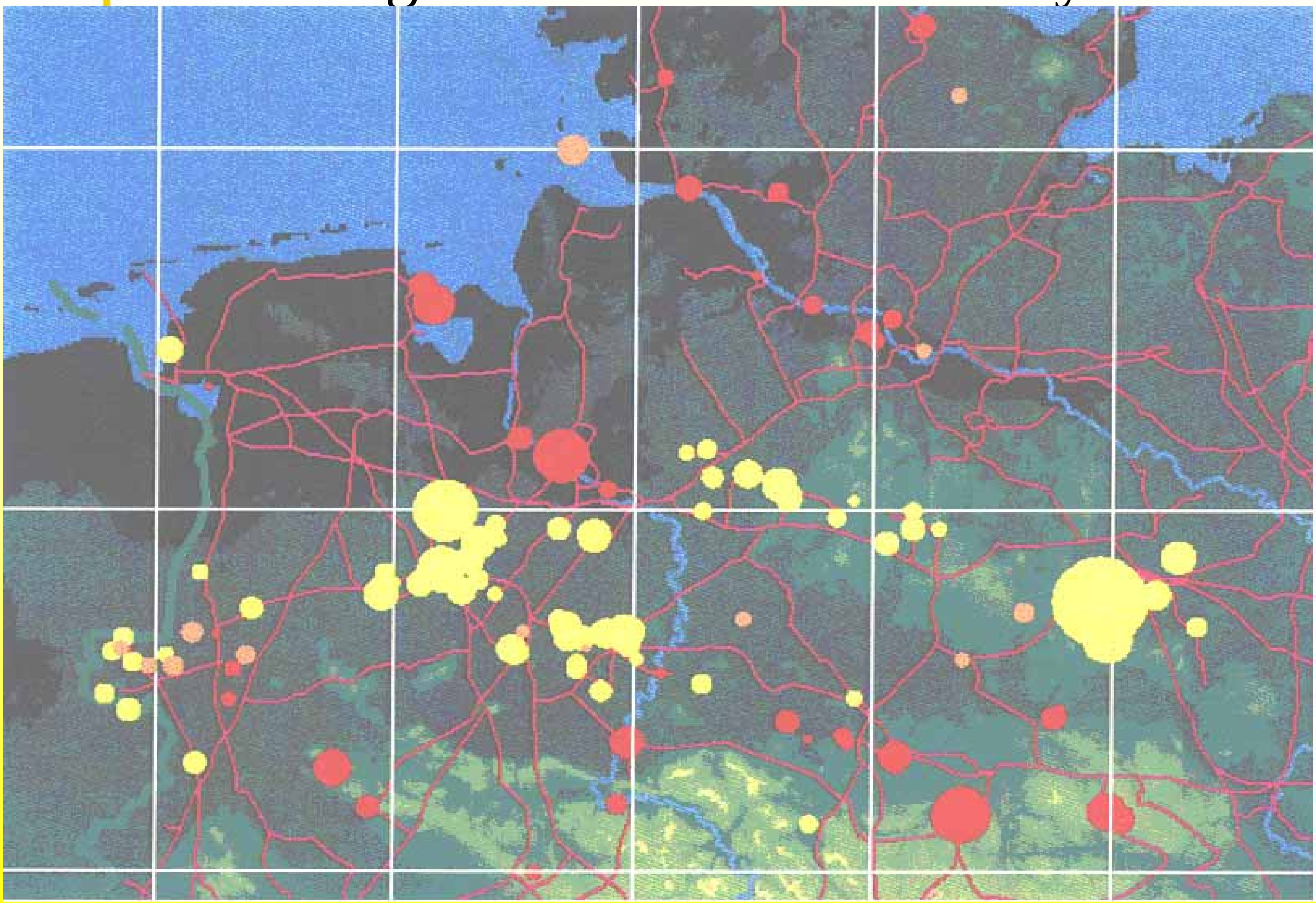
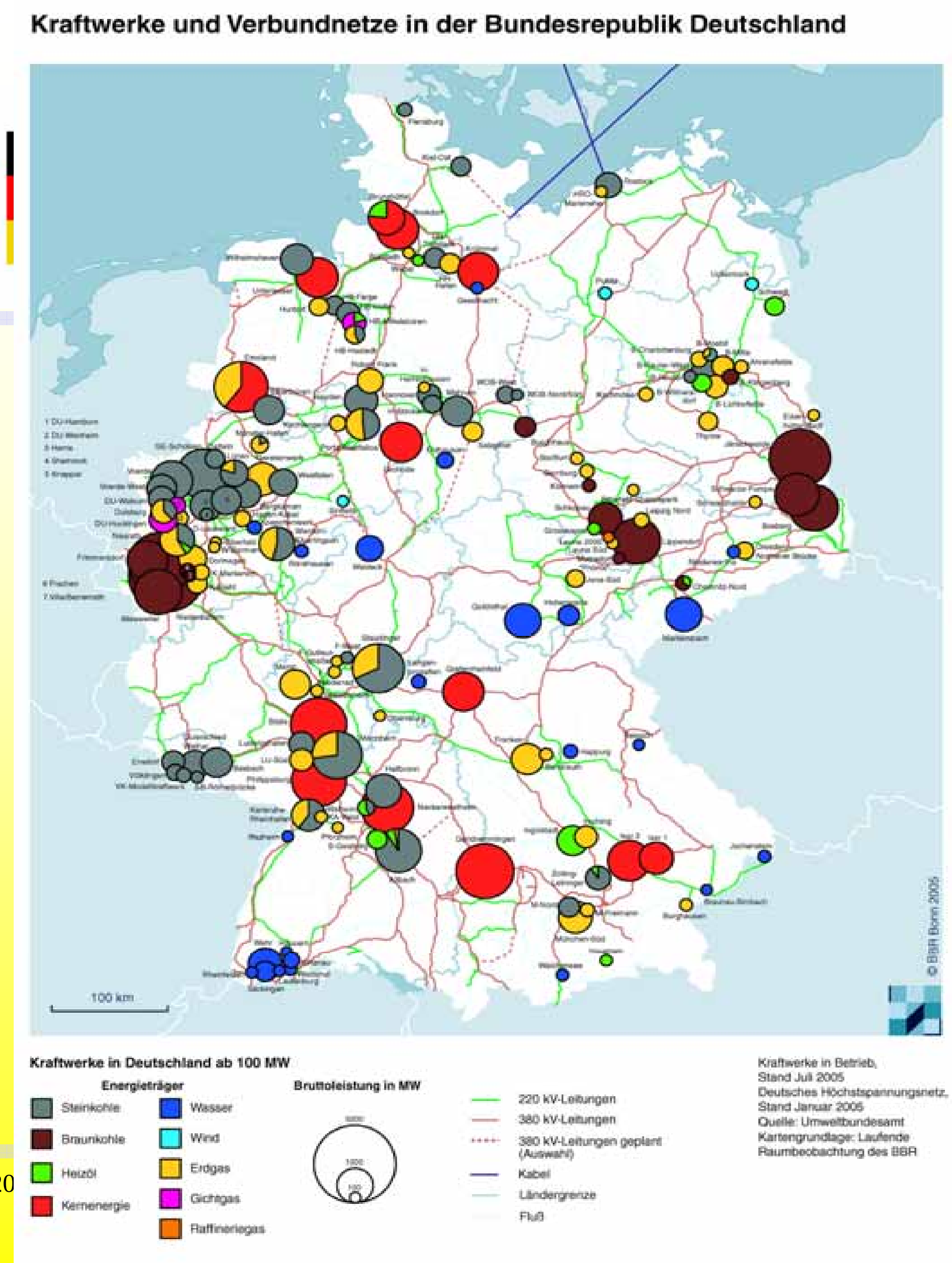
Location of gas reservoirs in Germany



Location of large power plants



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Potential leakage pathways and remediation measures (IPCC, Special Report 2005)

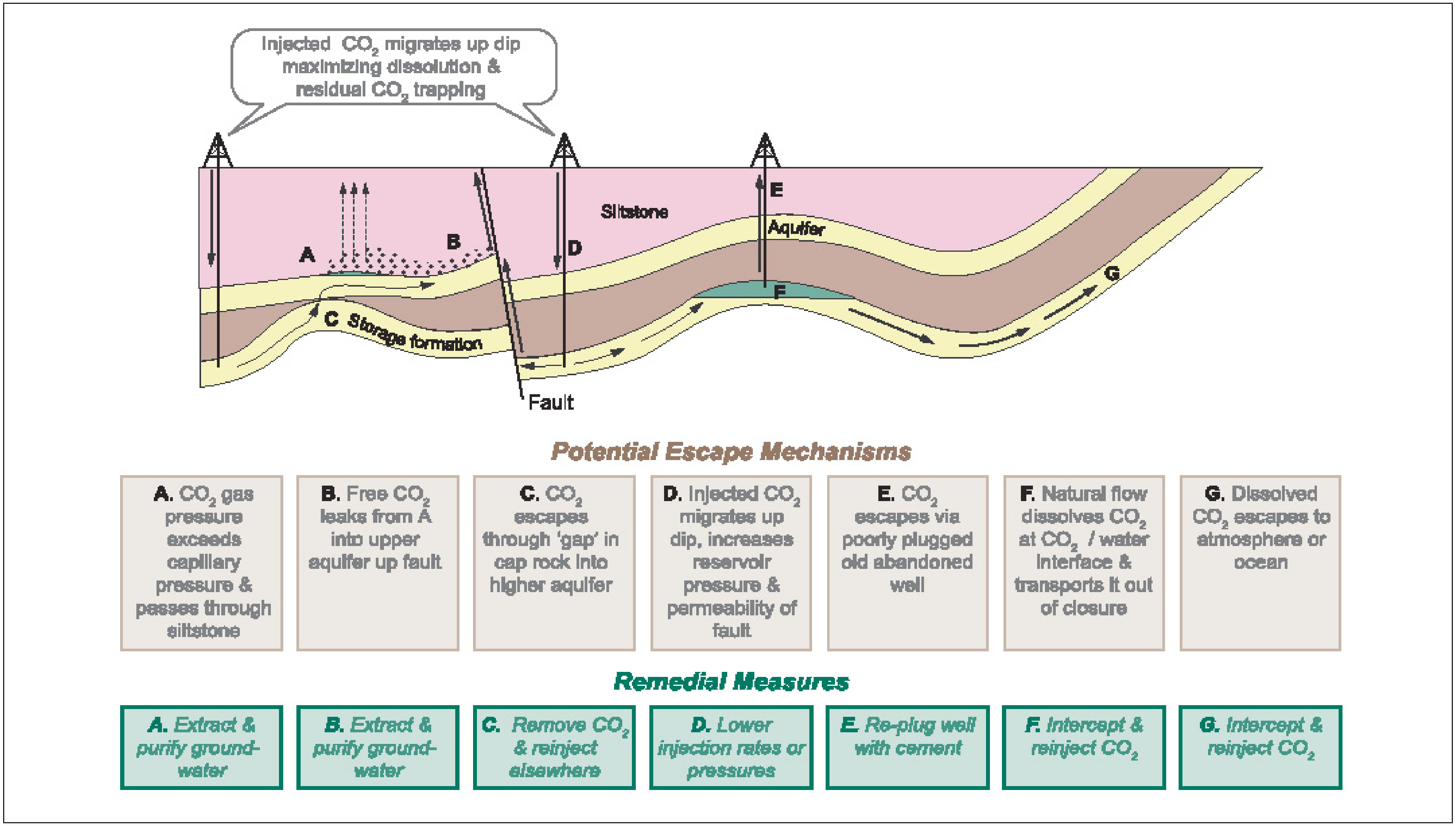

Figure TS.8. Potential leakage routes and remediation techniques for CO_2 injected into saline formations. The remediation technique would depend on the potential leakage routes identified in a reservoir (Courtesy CO2CRC).

Electricity generation and CO2 avoidance cost (BMU, 2004, P.54)

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Tab. 3-12 Kosten verschiedener Prozessketten von CO_2-Abscheidung, -Transport und Speicherung

Kraftwerk [a]		CO_2-Abtrennung *vor* Verbrennung				CO_2-Abtrennung *nach* Verbrennung					
		Typ 1 Erdgas (NGCC)	*Band-breite* [e]	Typ2 Kohle (IGCC)	*Band-breite* [e]	Typ 3 Erdgas (NGCC)	*Band-breite* [e]	Typ 4 Erdgas (Dampf)	*Band-breite* [e]	Typ 5 Kohle (Dampf)	*Band-breite* [e]
Stromkosten [Ct/kWh$_{el}$]	**Ohne CO_2-Seq.**	**3,1**	***2,5 - 4,1***	**4,8**	***4,2 - 6,8***	**3,1**		**3,8**		**4,0**	***2,8 - 4,6***
	Abscheidung	**1,5**	***0,7 - 1,8***	**1,6**	***1,4 - 2,6***	**1,0**		**1,2**		**2**	***1,4 - 4,8***
	Weitere Kosten, darin	**0,3 - 0,7**	***0,66 - 1,4***	**0,7 - 1,4**	***0,22 - 1,8***	**0,3 - 0,7**		**0,3 - 0,7**		**0,7 - 1,4**	***0,78 - 1,8***
	- Verdichtung	0,2 - 0,3	*0,4 - 0,6*	0,4 - 0,6	*0,1 - 0,8*	0,2 - 0,3		0,2 - 0,3		0,4 - 0,7	*0,5 - 0,8*
	- Transport	0,1 - 0,2	*0,2 - 0,3*	0,2 - 0,3	*0,1 - 0,4*	0,1 - 0,2		0,1 - 0,2		0,2 - 0,3	*0,2 - 0,4*
	- Speicherung	0,03 - 0,2	*0,06 - 0,5*	0,1 - 0,5	*0,024-0,6*	0 - 0,2		0 - 0,2		0,1 - 0,6	*0,08 - 0,6*
	Mit CO_2-Seq.	**4,9 - 5,3**	***3,86 - 7,3***	**7,1 - 7,8**	***5,82-11,2***	**4,4 - 5,1**		**5,3 - 5,7**		**6,7 - 7,6**	***4,98-11,2***
	Differenz	**58 - 71%**	***54 - 78%***	**48 - 63 %**	***39 - 65%***	**42 - 65%**		**40 - 50%**		**68 - 90 %**	***78-143 %***
Kosten CO_2-Vermeidung [€/t$_{CO2}$]	**Abscheidung**	**43**	***27 - 62***	**26**	***18 - 110*** ***14 - 32*** [c]	**37**	***25 - 39*** [c]	**30**		**29**	***18 - 60*** ***38 - 39*** [c]
	Weitere Kosten, darin	**10 - 23**	***16 - 34***	**10 - 23**	***16 - 34***	**10 - 23**	***16 - 34***	**10 - 23**	***16 - 34***	**10 - 23**	***16 - 34***
	- Verdichtung	6 10	*6 - 10*	6 10	*6 - 10*	6 10	*6 - 10*	610	*6 - 10*	610	*6 - 10*
	- Transport	3 -5	*6 - 18* [c]	3 - 5	*6 - 18* [c]	3 - 5	*6 - 18* [c]	3 - 5	*6 - 18* [c]	3 - 5	*6 - 18* [c]
	- Speicherung	1 - 8 [d]	*4 - 6* [c]	1 - 8 [d]	*4 - 6* [c]	1 - 8 [d]	*4 - 6* [c]	1 - 8 [d]	*4 - 6* [c]	1 - 8 [d]	*4 -6* [c]
	Kosten CO_2-Seq.	**53 - 66**	***43 - 96***	**36 - 49**	***30 - 144***	**47- 60**	***41 - 73***	**40 - 53**	***46 - 64***	**39 - 52**	***34 - 94***
	Anteil Abscheidung	6 - 81%	*63 - 65%*	53 - 2%	*47 - 76%*	2 -%	*53 - 61%*	57 3%	*47 - 65%*	56 4%	*53 -64%*

[a] Alle fünf Kraftwerke sind auf eine einheitliche Leistung von 500 MW$_{el}$ standardisiert.

[b] Die Wirkungsgrade beziehen sich auf den Hzwert H.

[c] Die mit c) gekennzeichneten Werte stammen aus BMWA 2003.

[d] Ohne Kohleflöze

[e] Wenn nicht anders gekennzeichnet, stammen die Werte für die Bandbreiten aus ECOFYS 2004.

Abb. 12: CO_2-Vermeidungspotenziale in Deutschland im Jahr 2015, summiert über alle Sektoren, **durchschnittliche** Energieeinsparkosten (dicke Linie) und CO_2-Vermeidungskosten (dünne Linie) **im Vergleich** zu den Kosten bei ohnehin durchzuführenden Maßnahmen, unter Berücksichtigung der eingesparten Energiesystemkosten (netto), aus **gesamtwirtschaftlicher Sicht – ausführliche Darstellung**