Wuppertal Institute for Climate, Environment and Energy

Integrated assessment of the potentials for CCS in India, China, South Africa ("CCSglobal")

LCS-R Net 4th Annual Meeting

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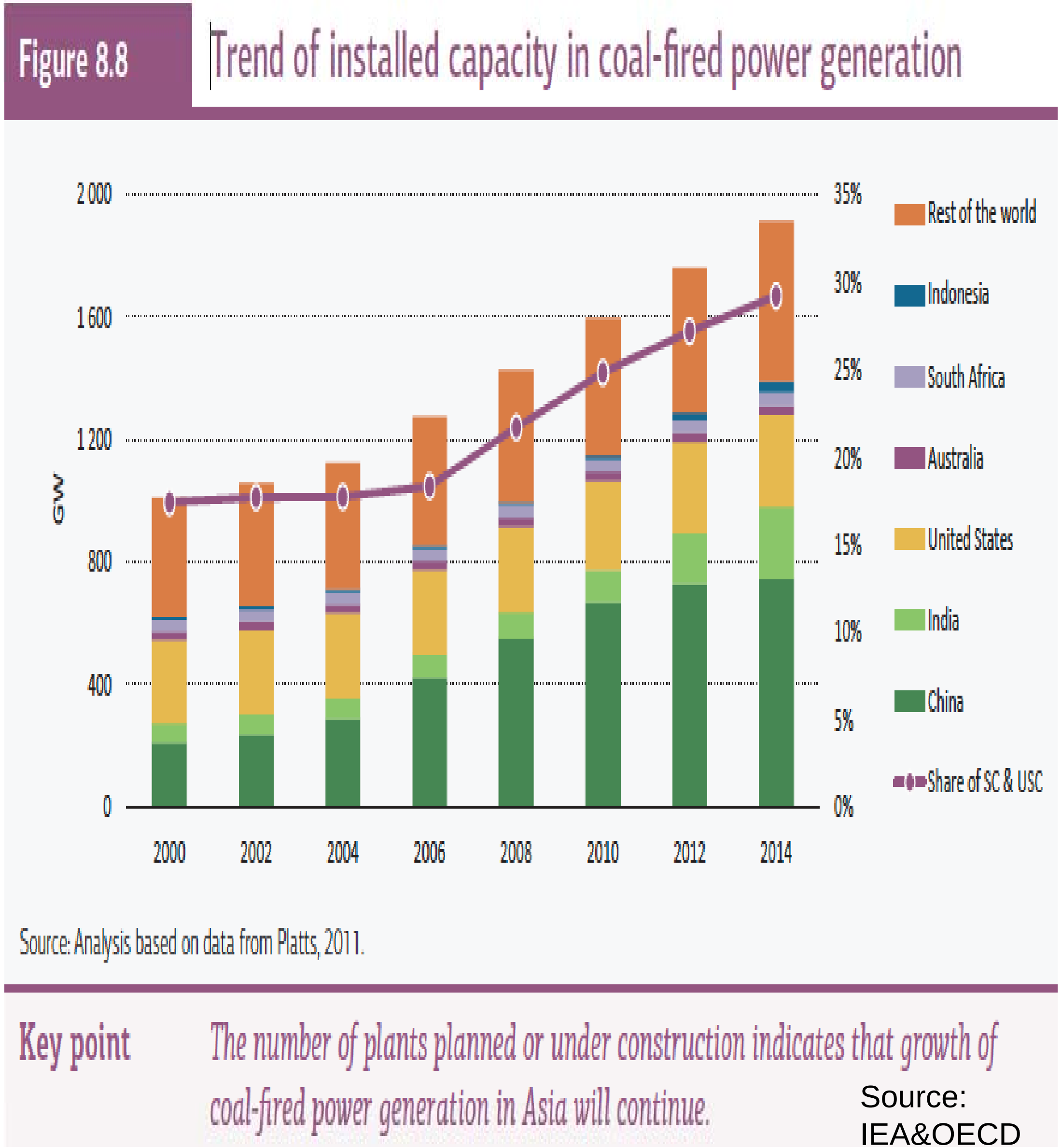
Carbon Capture and Storage as a Low Carbon Technology
Subject of Intensive Debate

- Research and demos focused mainly on USA, EU, Australia, Canada.
- Recent studies for Germany
  - CCS is not necessarily needed for power generation
  - Due to large potentials of energy efficiency and renewable energies.
- However, currently strong increase of coal use by emerging countries

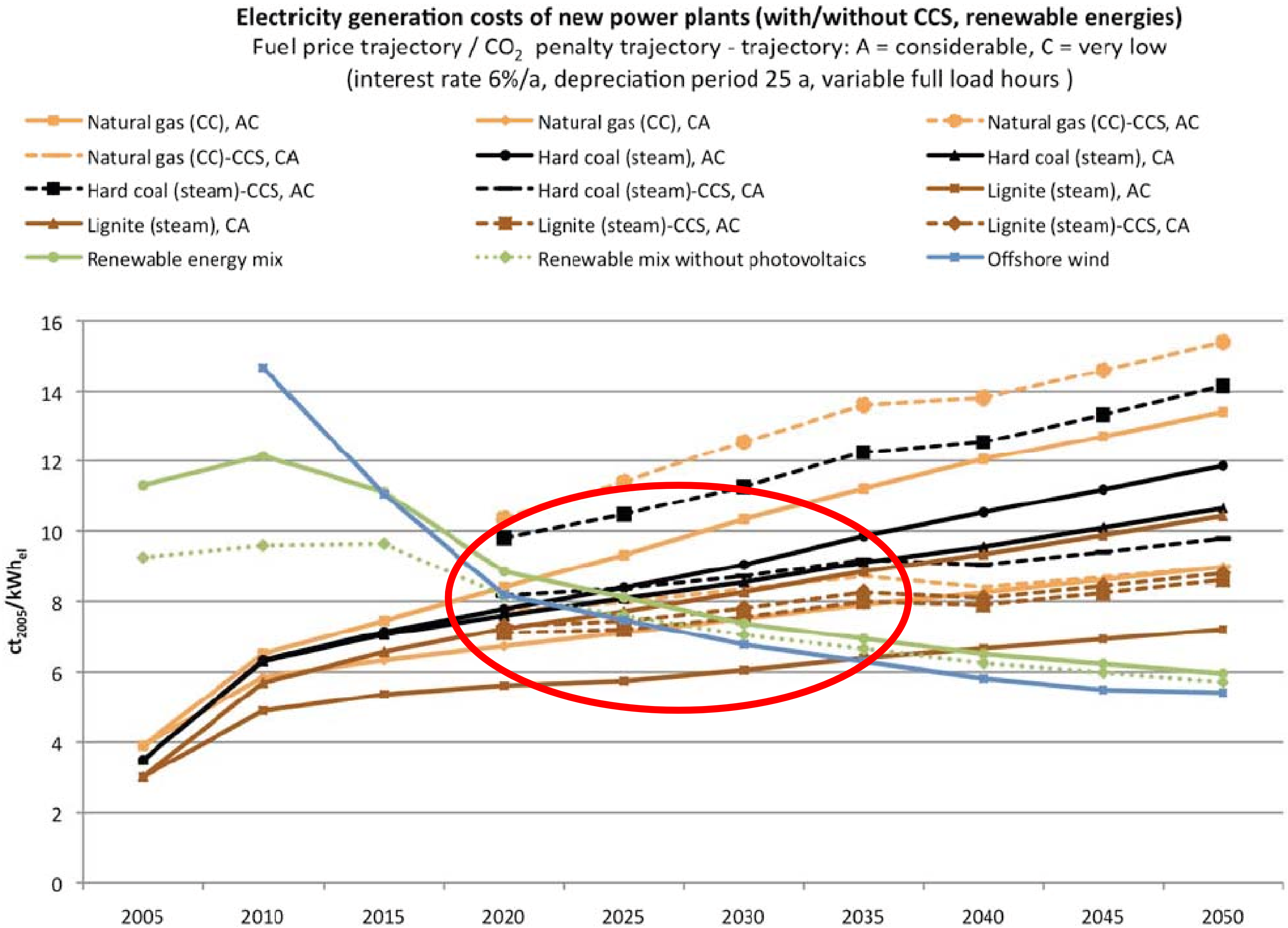
→ possible role for CCS in large coal-based emerging countries until 2050 (India, China, South Africa)



Source: IEA&OECD 2012 (ETP)

Main results of the German CCS studies

Electricity generation of CCS based power plants versus RES



CCSglobal
Research agenda

Integrated assessment covering five different dimensions

1. Analysis of (effective) CO_2 **storage capacity** and source-sink matching with the amount of available CO_2 (according to coal development pathways)
2. Analysis of **levelised cost of electricity generation** without/with CCS
(using learning-curve approach)
3. **Ecological assessment** of electricity generation without/with CCS
(via life-cycle assessment)
4. **Reserves, availability and price of coal**
5. Analysis of **stakeholder positions** towards CCS
(literature analysis, expert meetings and interviews, surveys)

CCSglobal – CO_2 storage assessment and source-sink matching

CO_2 emissions that could be stored in China

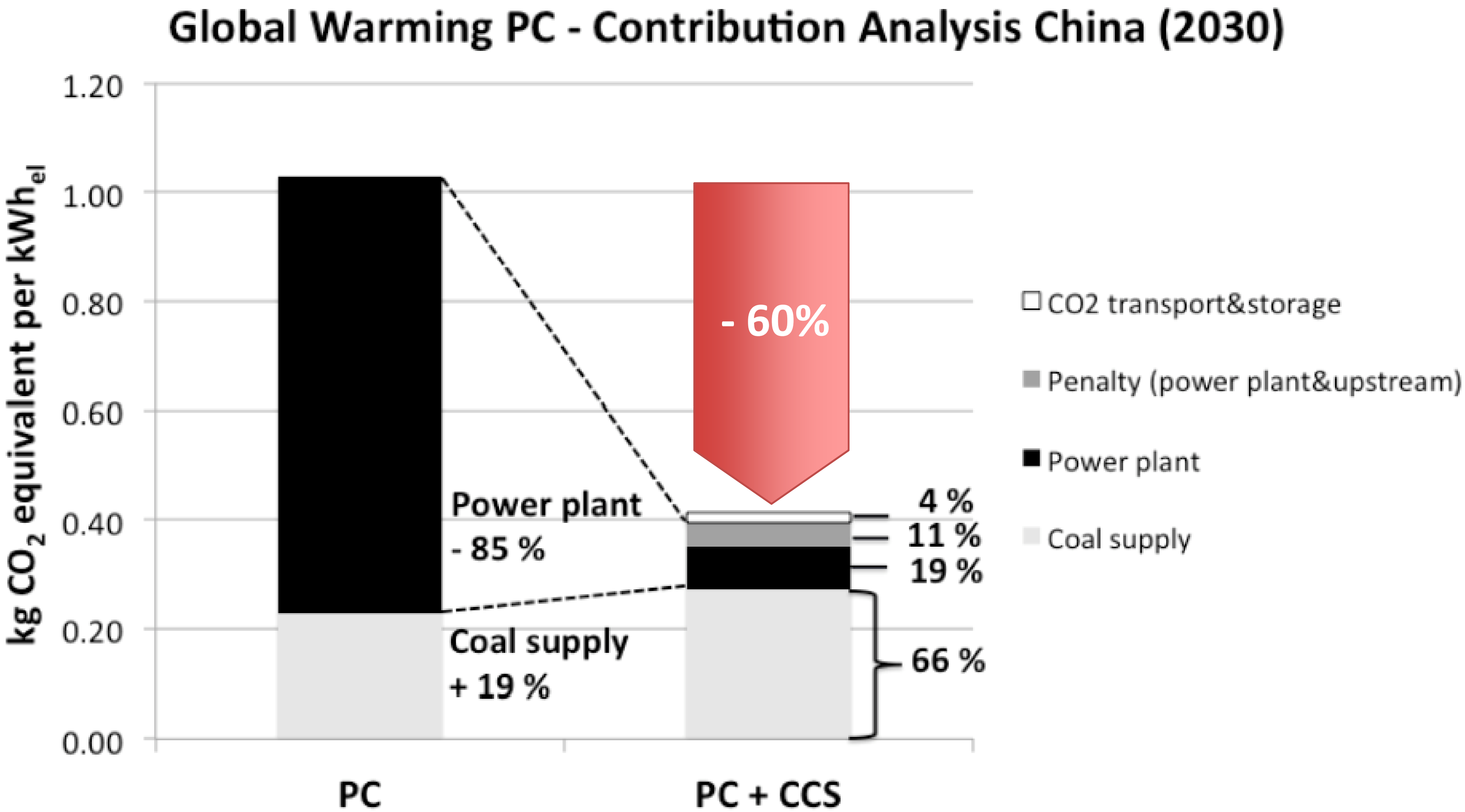
Effective storage capacity scenarios	Energy and industry emission pathways E1+I: high (250 Gt CO_2)	E2+I: middle (178 Gt CO_2)	E3+I: low (60 Gt CO_2)
	Matched capacity (Gt CO_2)		
S1: high (1,541 Gt CO_2)	216	154	52
S2: intermediate (494 Gt CO_2)	205	154	52
S3: low (65 Gt CO_2)	45	44	36
	Share of effective storage capacity used (%)		
S1: high (1,541 Gt CO_2)	14	10	3
S2: intermediate (494 Gt CO_2)	41	31	10
S3: low (65 Gt CO_2)	70	68	55
	Share of emissions that could be stored (%)		
S1: high (1,541 Gt CO_2)	87	87	87
S2: intermediate (494 Gt CO_2)	82	87	87
S3: low (65 Gt CO_2)	18	25	60

The maximum transport distance is assumed to be 500 km.

- Effective storage capacity and therefore matched capacity will further be reduced when technical, legal, economic and acceptance factors are introduced.
- More rigorous assessments of the countries' effective and matched storage potentials required

CCSglobal – ecological assessment

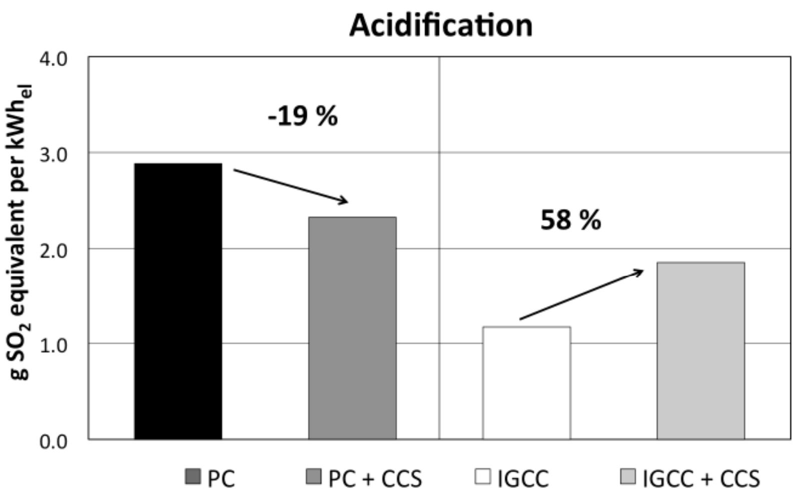
Low net greenhouse gas emissions reduction
(pulverised-coal fired power plant, China)

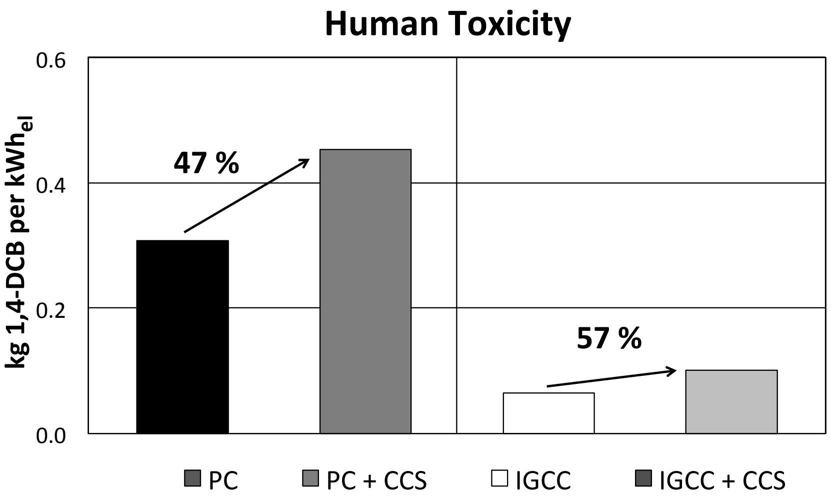


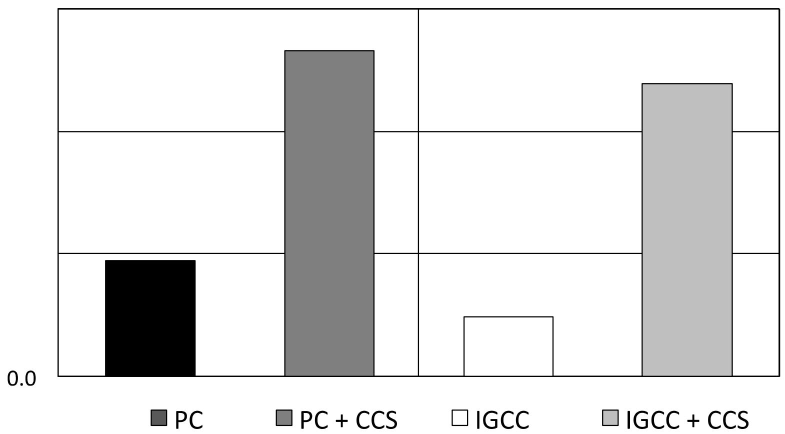
- Similar effect as in Germany, enhanced by the large coal-bed methane emissions during mining in China.

CCSglobal – ecological assessment

Increase of most other environmental impact categories
(per kWh, selected categories, example of China)

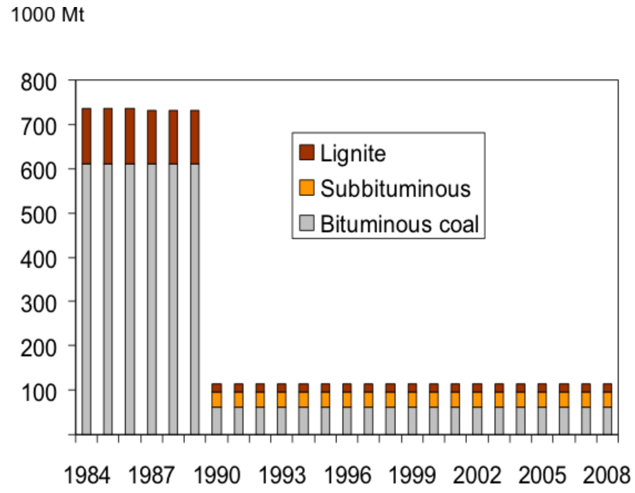




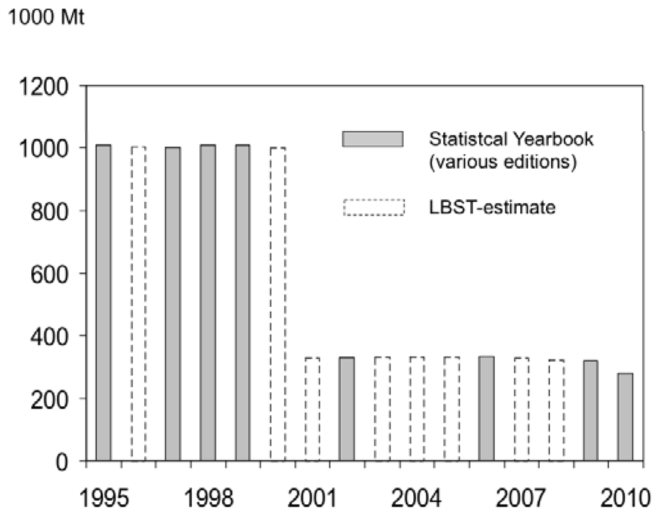


CCSglobal – resource assessment
Reserves, availability and price of coal (example of China)

- 1st in coal resources, 2nd in coal reserves but reliable data are difficult to obtain
- High ash (23%), low sulphur (1%) content
- Proved recoverable reserves about 115 Gt
  - 1,018/5,570 Gt identified reserves/resources
  - Cumulative production between 1991 and 2010 = 30% of reserve →R/P ratio of 25 ys
- Market mechanisms lead to typical supply pattern
  - Increasing depletion of best qualities in early years, followed by
  - declining production at rising prices and lower quality in the second half of production history
- In recent few years, coal demand of power plants rose much faster than the expansion of domestic production



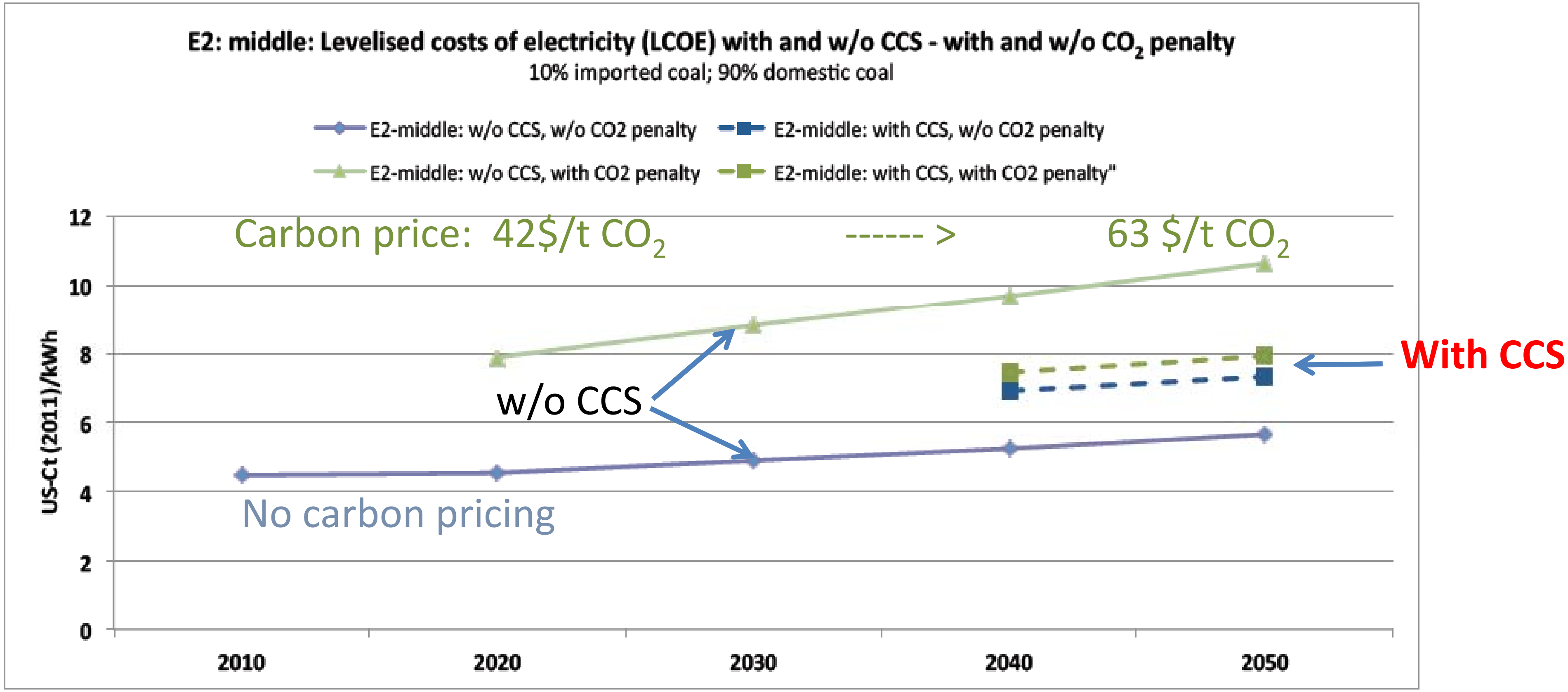
Source: BP 2010, WEC



Source: CSY, diverse

CCSglobal – economic assessment

Development of levelised cost of electricity generation of CCS based power plants (from 2020) (example of China)

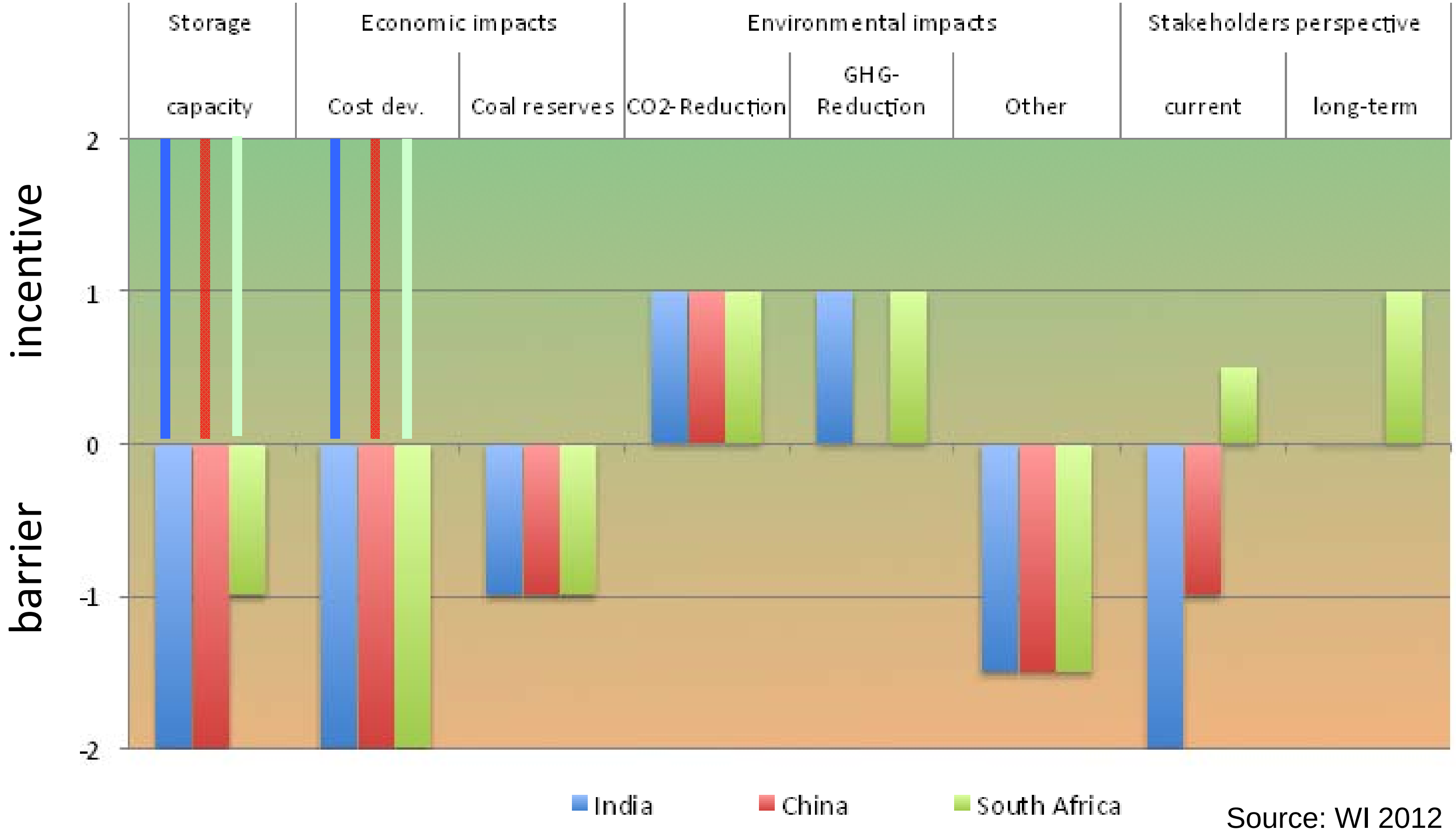


Basic result

- China: Only with high CO_2-price CCS will be competitive. (Note: Additional GHG-emissions not taken into account)
- For other analysed countries (SA, India) this result does not hold

Concluding hypotheses – main result

Overall integrated assessment of the role of CCS in India, China and South Africa



Source: WI 2012

- Ranking from -2 (strong barrier to CCS) to +2 (strong incentive for CCS)
- Bars: Indicate possible impact variations of storage capacity and cost development.

Main results
Prospects of CCS in India, China and RSA

CCS is not *per se* a low carbon option:

- estimates of the **storage potential** currently highly **speculative**
- **Economic viability** depends on the introduction of a **CO_2 pricing scheme** (With quite high price level for CO_2)
- Reduction of CO_2 (GHG) emissions per kWh of electricity by 74 to 78 (59 to 74) per cent, but **increase of most other environmental impacts**.
- High coal demand development pathway may lead to significant **resource constraints** and rising coal prices in the medium term.
- Public is not yet involved in the debate and **political decision-makers are currently very cautious**.

Main results

What would be needed to make CCS viable?

- In order to overcome barriers
  - a stronger commitment from the industrialised world in terms of technology demonstration and implementation would be required
  - alongside actions from individual countries and analysis.

- Furthermore,
  - a substantial cost reduction and
  - mechanisms for technology cooperation and transfer to developing countries and emerging economies

  would be needed.

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Thank you for your attention!

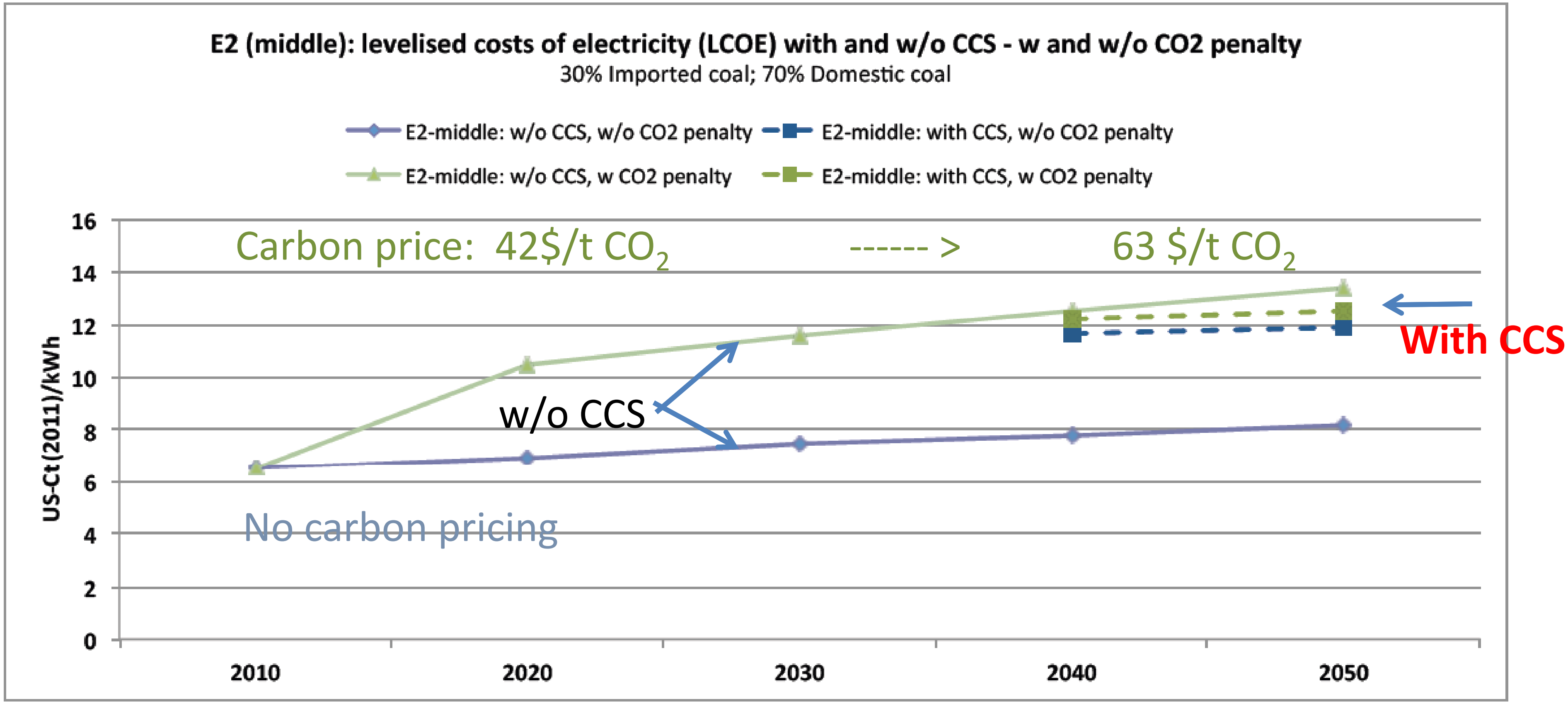
Final reports (*case studies, summary)* of CCSglobal available at: www.wupperinst.org/CCS/

Contact: peter.viebahn@wupperinst.org

Back-up

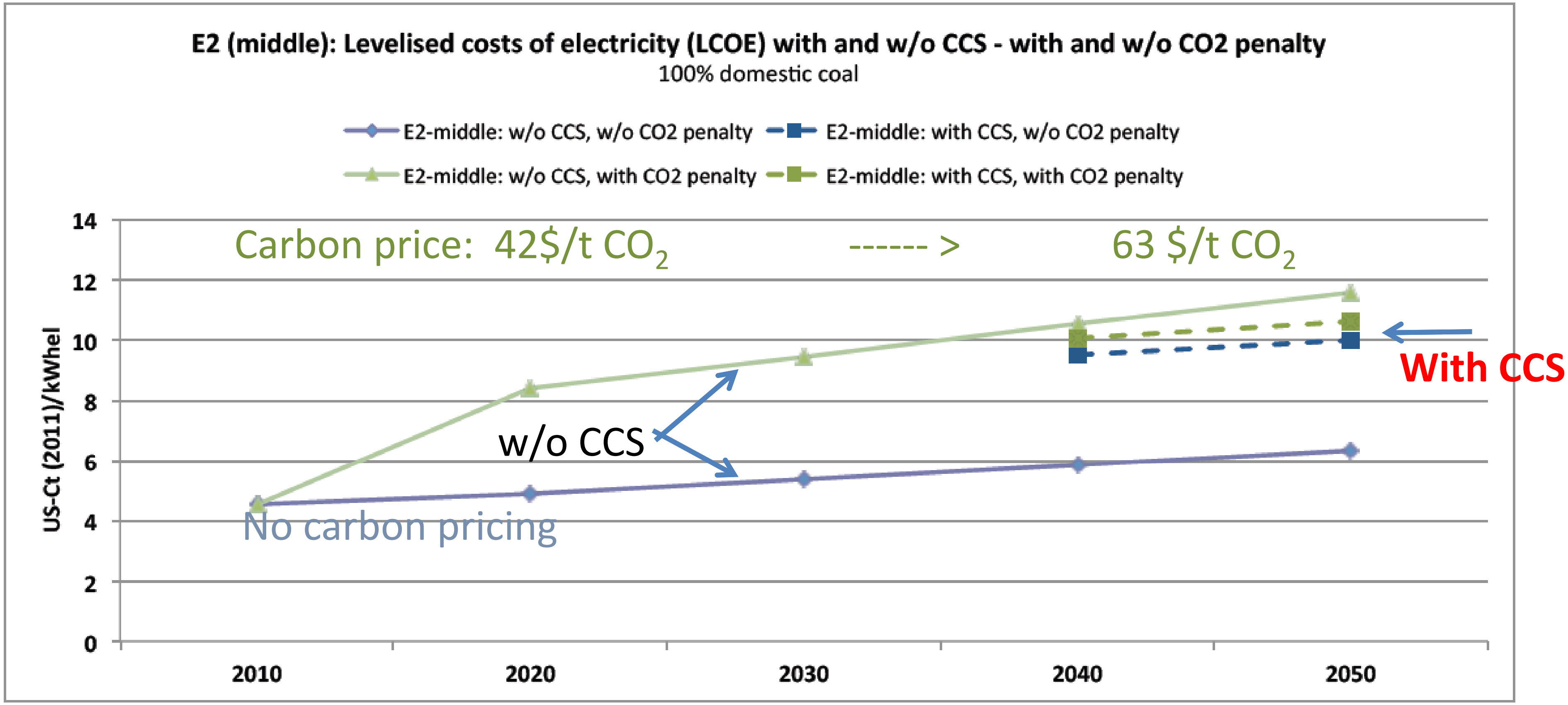
CCSglobal – economic assessment

Development of levelised cost of electricity generation of CCS based power plants (from 2020) (example of **INDIA**)



CCSglobal – economic assessment

Development of levelised cost of electricity generation of CCS based power plants (from 2020) (example of **SOUTH AFRICA**)

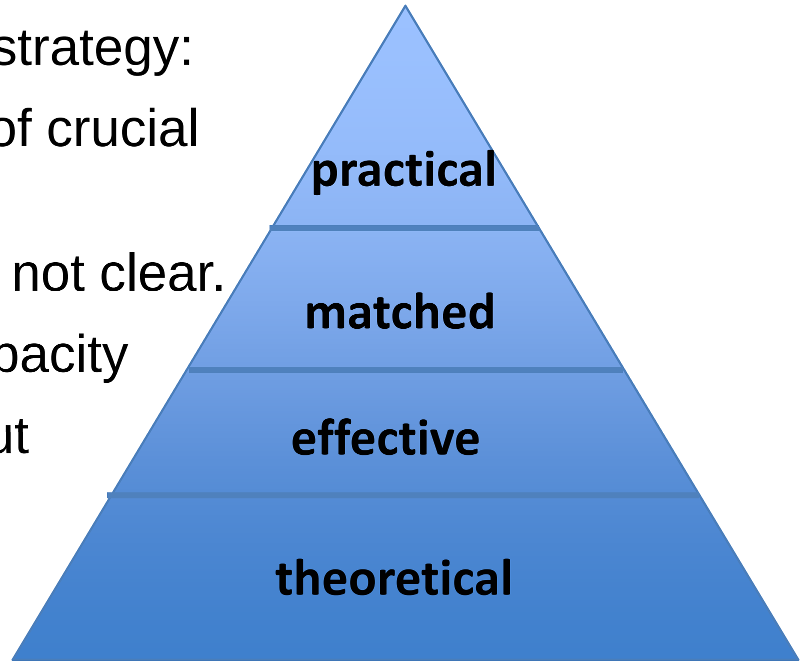


CCSglobal

Research agenda (1)

Main part: analysis of CO_2 storage capacity

- Storage potential is the basic part of a CCS strategy:
  - Assessments in Europe showed the role of crucial parameters like the efficiency factor.
  - Assumptions for storage calculation often not clear.
- Objective: Estimation of effective storage capacity
  - Desktop study: no geological research, but discussion with national geologists.
  - Screening, discussing and assessing of existing national studies.
  - Classifying the quality of the estimation.



Resource-reserve pyramid for CO_2 storage capacity (modified)

Source: WI 2012

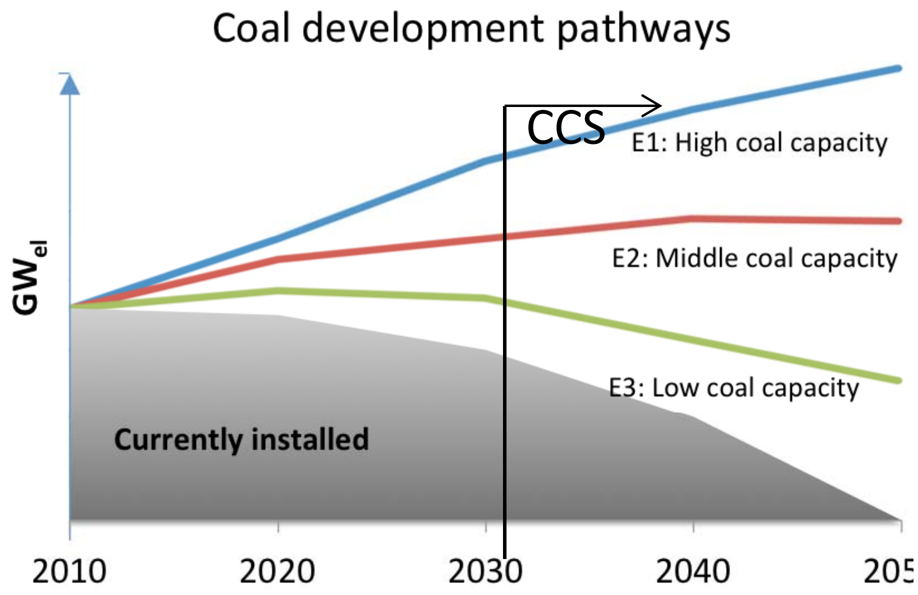
Second step: source-sink matching

- Relating effective storage capacity to amount of cumulated, separated CO_2.
- Geographical matching of sources and sinks concerning transport distance.

CCSglobal
Research agenda (2)

Using results of long-term estimation of $CCS\text{-}CO_2$

- Power plants
  - Analysis of existing long-term energy scenarios
  - Providing coal development pathways E1–E3 by 2050
  - Illustrating high, middle and low deployment of coal
  - Application of CCS according to certain conditions
  - *Not* illustrating a coherent scenario framework



Source: WI 2012

- Industry
  - Providing rough industrial development pathways
  - In case figures on CCS capacity available
- Commercial availability of CCS from 2030

Concluding hypotheses – storage potential

How much CO_2 could potentially be held in geological storage?

Hypothesis: Estimates of the storage potential in the considered countries are currently highly speculative. Consequently any estimates of the large-scale deployment potential of CCS have an unreliable basis.

- The main potential storage sites are saline aquifers, and a small capacity is considered within oil and gas fields. Storage in basalts and coal seams was excluded from all scenarios due to the extent of technical uncertainty.
- Storage scenarios S1–S3 matched with emission pathways E1–E3 yield quite different results for India, China and South Africa, respectively:
  - Using extremely optimistic assumptions, theoretically, a large quantity of CO_2 emissions could be stored (75, 192 and 22 Gt of CO_2).
  - If more realistic calculations of the countries' effective and "matched" storage potential are taken into account, only a fraction of the separable CO_2 emissions may potentially be stored (less than 5, 30 and 4 Gt of CO_2).
- In practice, this potential will decrease further when technical, legal, economic and acceptance factors are introduced.

Concluding hypotheses – economic assessment

Are CCS-based coal-fired power plants economically viable compared to equivalent power plants without CCS?

Hypothesis: Even in the presence of a carbon-pricing regime, only Chinese CCS-based power plants may potentially have an economic advantage compared to equivalent power plants without CCS.

- Under current conditions, which are characterised by a low CO_2 price development, there is a significant barrier to the economic viability of CCS in each of the analysed countries.
- The introduction of a CO_2 pricing scheme would therefore be a crucial prerequisite for the commercialisation of CCS in India, China and South Africa.
- A higher CO_2 price development (in this study, a CO_2 price starting at USD 42/t CO_2 by 2020 and rising to USD 63/t CO_2 by 2050 was assumed) would provide a strong incentive for installing CCS equipment in China's coal-fired power stations.
- However, power plants in India and South Africa would require a more ambitious CO_2 price development.

Concluding hypotheses – ecological assessment

What are the ecological advantages and disadvantages of CCS-based power plants in India, China and South Africa?

Hypothesis: CCS-based coal-fired power plants have the potential to achieve a substantial reduction in specific greenhouse gas emissions. However, most other environmental impacts would increase. For this calculation, the durability of CO_2 storage sites was presumed.

- The prospective life cycle analysis (LCA) of future CCS-based pulverised power plants and integrated gasification combined cycle (IGCC) plants yields conflicting results regarding the environmental impacts of CCS.
- On the one hand, CCS-based power plants could provide lower-carbon electricity by 2030 since the CO_2 emissions per kilowatt hour of electricity would be reduced by 74 to 78 per cent and total greenhouse gas emissions by 59 to 74 per cent.
- However, the reduction rates are lower than the CO_2 capture rate due to the additional energy consumption and the emissions released in the whole process chain.
- On the other hand, most other environmental and social impacts (such as stratospheric ozone depletion and health risks) would increase.

Concluding hypotheses – reserves/resources analysis

What are the possible constraints of CCS in India, China and South Africa with regard to coal resources supply?

Hypothesis: In each of the considered countries, a high coal demand development pathway may lead to significant resource constraints and rising coal prices in the medium term. This trend would be strengthened by the increased coal consumption of CCS-based coal-fired power plants, thereby questioning the underlying assumptions on the economic feasibility of CCS.

- All of the investigated countries have a typical coal production supply curve. Assuming the current proven coal reserves, even the present growth rates will not facilitate continued coal production in the long run.
- Since both India and China are importing increasing amounts of coal, coal trading prices are expected to increase on the global market.
- These trends would be reinforced by an increased coal consumption per unit of electricity, caused by the application of CCS.
- Increasing prices of national coal production has not yet factored in regarding the economic calculation which may cause worse economic feasibility of CCS.

Concluding hypotheses – stakeholder analysis

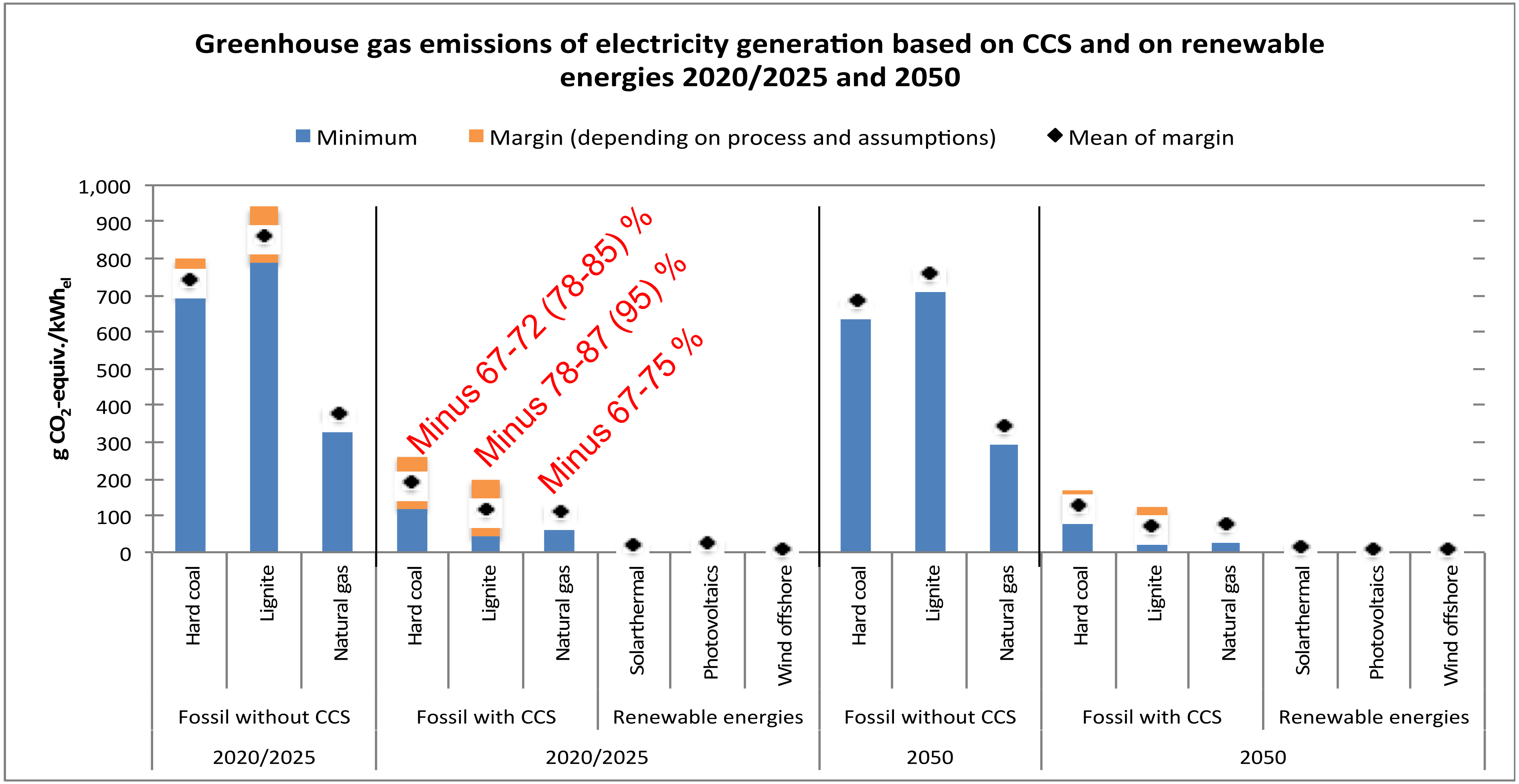
How do decision-makers and the public perceive the possible role of CCS in India, China and South Africa?

Hypothesis: The political decision-makers in the three analysed countries are very cautious with regard to CCS. The public is not yet involved in the debate.

- Due to the high costs involved, a significant energy penalty and a lack of large-scale demonstration projects in the industrialised world, political decision-makers in the considered countries have adopted a cautious approach towards the commercialisation of CCS.
  - The *Indian* government has a cautious attitude towards the commercialisation of CCS.
  - The *Chinese* government is not an enthusiastic advocate of CCS. However, political and industrial decision-makers regard CCS as a back-up or emergency technology for complying with possible long-term CO_2 mitigation obligations.
  - In *South Africa*, key players have taken important action in terms of the research and development and the politics of CCS. The South African government recognises that CCS could become an important CO_2 mitigation technology.
- In most cases, the public is not yet involved in the discussion process.

Main results of the German CCS studies

Net greenhouse gas emissions reduction (over the whole life cycle)



Basic assumptions

- Capture rate of around 90 per cent
- Future efficiencies and energy penalties of 4-18 percentage points assumed

Basic results

- Energy penalty and additional processes like production of solvents, transport and storage decrease the net reduction rate of GHG

General conclusions for Germany

- The existing energy policy targets of considerable improvements in efficiency and the required significant expansion of renewable energies leave only minimal scope for the substantial use of CCS technology, even in the case of ambitious climate protection targets.
- Use of CCS would be prudent in a future energy supply that only achieves moderate successes in increasing efficiency and renewables.
- The significant expansion of renewables and the intended higher share of CHP will have an increasing impact on the utilisation period of fossil fired power plants (base load operation will gradually decrease, average utilisation period decreases from 5,600 h/a to 3,600 h/a).
- A power plant mix from the perspective of optimum CCS operation would have a much smaller share of renewable energies. They would have to be base loadable renewables such as biomass, geothermal energy or solar thermal power plants.
- Large-scale availability will be later than previously assumed (rather 2025-2030 than 2015). CCS therefore looses the role as bridging technology towards renewable energies.