CCS Workshop IEA / VDEh

Düsseldorf, 8. and 9. November 2011

Prof. Dr. Gunnar Still
Corporate Adviser
for Environment

ThyssenKrupp Steel Europe
Anthropogenic part of Greenhouse gas concentration* in the atmosphere in dependence of content of water vapour

*Calculation in dependance of the substance-specific CO₂-aequivalent

Climate Change is a global issue in all walks of life

Source: Deutsches Bundesministerium für Wirtschaft und Technologie, BP

Workshop CCS IEA / VDEh
8. - 9. November
Prof. Dr. Gunnar Still
3

1990

2005

> 5 billion t
1 - 5 billion t
0.3 - 1 billion t
0.1 - 0.3 billion t
< 0.1 billion t

Source: World Resource Institute

2007

21% China
21% USA
8% Russia
4% Japan
12% India
remaining EU-25
rest of world

21% Germany

‘total: 30.9 billion t CO₂'

EU27

Transport
20 %
Industry (Energy and direct)
18 %
Electricty and other Energy generation
32 %
Housing, etc.
13 %
Others
8 %
Agriculture
9 %

Iron and Steel
2.3 %
NF-Metals
0.3 %
Chemical
3.5 %
Paper
0.6 %
Food
0.9 %
Minerals
(Cement, Lime, etc.)
3.1 %

Source: World Resource Institute
Greenhouse Gas Emissions originate from all areas of life
GHG (CO₂ u. a.) in the EU 2007: 5,054 *10⁹ t CO₂-Equivalents

- Transportation: 20%
- Industry (energy and direct): 18%
- Electricity and other kinds of energy: 32%
- Agriculture: 9%
- Others (waste, diffuse emissions): 8%
- Living etc: 13%
- Other: 7.0%
- Minerals (cement, lime, etc.): 3.1%
- Chemical industry: 3.5%
- Paper: 0.6%
- Food: 0.9%
- NF-Metalls: 0.3%
- Iron and steel: 2.3%
Power station has only one source of CO$_2$

Mass balance for 1,000 MWh /100 pers per year

- 1,400 m$^3$ cooling water
- 3,0 mio. m$^3$ waste gas (source of CO$_2$
- 3,0 mio. m$^3$ air
- 61 MWh
- 340 t coal
- 36 t ash
- 28 t gypsum
- 2,1 t ammonia
- 8,5 t lime
- 2,000 m$^3$ intake
- 460 m$^3$ discharge
- 1000 MWh
- Generator
- Boiler
- Turbine
- Waste water treatment
Coal Power plants: Ecological balance sheet for CO₂, with and without CCS

- **Powerplant without CCS**
  - CO₂-emission to air
  - CO₂-storage
  - Real CO₂-abatement
  - Additional CO₂-production

- **Powerplant with CCS**
  - CO₂-emission to air
  - CO₂-storage

Remark: additional CO₂-production $\cong$ Energy demand for capture, transport and storage
An integrated steel mill is composed by numerous facilities. From iron ore to steel products.
ThyssenKrupp Steel Europe - Main CO₂-Emitters (schematically)
up to 20 mio t CO₂ p.a.
Consumption of reducing agents of the blast furnaces in Germany
Close to theoretical borderlines

Source: 10th CO2 monitoring report of the steel industry in Germany
Even usage of waste heat from processes has a long history

- TKSE is managing 3 waste heat network pipes in the North of Duisburg to heat own houses, public and other houses in the neighborhood
- Total length more than 200 km
- Water 80/60°C and 6 bar
- Sources: 70% from direct waste heat and 30% BOF-steam
Emissions trading: The hot metal benchmark of the EU Commission is not even reached by the best blast furnaces in the EU

$\text{kg CO}_2 / \text{t hot metal}$

CO$_2$-emissions in EU blast furnaces

Average of the EU-steel industry: 1,630

Benchmark on the basis of the 10% best blast furnaces in the EU

Source: Stahl-Zentrum
What are the concepts for way out? New processes? CO₂-capture??
Europe is worldwide the strongest driver with the ULCOS processes

### ULCOS brand process families

<table>
<thead>
<tr>
<th>Coal &amp; sustainable biomass</th>
<th>Natural gas</th>
<th>Electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revamping BF</td>
<td>Brownfield</td>
<td>Revamping DR</td>
</tr>
<tr>
<td>TGR-BF</td>
<td>HIsarna</td>
<td>ULCORED</td>
</tr>
<tr>
<td>Pilot tests (1.5 t/h)</td>
<td>Pilot plant (8 t/h) start-up 2010</td>
<td>Pilot plant (1 t/h) to be erected in 2011?</td>
</tr>
<tr>
<td>Demo phase launch in 2015</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Greenfield Revamping DR
- Brownfield Revamping BF
- Electricity
- Natural gas
- Coal & sustainable biomass

Depend critically on CCS
Decoupling of $CO_2$ mitigation and energy saving
Positive combination turns into conflicting goals

Reduction of energy use on basis carbon e.g. steelmaking

Additional Energy for
• CCS
• loss of efficiency
• converting losses

needs CO2-free energy
ULCOS-Technologies for huge BF`s are not available before 2030-40
### Timeframe of Operations much longer than ETS phases

<table>
<thead>
<tr>
<th>Cokeplants</th>
<th>Hamborn</th>
<th>Schwelgern - 2004</th>
<th>Schwelgern 2 - 1964</th>
<th>Schwelgern 3 - 1970</th>
<th>Schwelgern 4 - 1979</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blast Furnaces</td>
<td>HO 4 1964 - 2008</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HO 8 1962 - 1987</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>HO 9 1964 - 1987</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Schwelgern II</td>
<td>1993 - 1999</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steelplant</td>
<td>Beeckerwerth</td>
<td>1962 - 1969</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CC1 74-85</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CC2 80-90</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bruckhausen</td>
<td>1969 - 1996</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CC1 79-96</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GWA 1999 - 2001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hot Rolling</td>
<td>WBW 1 1964 - 1966</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>WBW 2 1964 - 1966</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>WBW 3 (Bo)</td>
<td>1966 - 1966</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Stopped Operations**
- **Current Operations**
- **Decisions shortly**
- **Decisions later**

Availability of ULCOS, etc
Interacting Chain: Capture – Transport – Storage
Common task cannot be mastered without dedicated political support

Capture
Industry/site specific:
• Processes
• Energy use

Transport
Independent of source:
• Transport routes and means
• Transportability
• Energy consumption

Storage
Defined by geology and political decision

CAPEX • OPEX

CAPEX • • OPEX

CAPEX • • • OPEX

Industry

Government

Workshop CCS IEA / VDEh
8. - 9. November
Prof. Dr. Gunnar Still
17
ThyssenKrupp Steel Europe
### Summary Results of the economic assessment of CCS technologies

#### Levelized Production Cost (2010)

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Blast furnace steel production</th>
<th>Cement production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without CCS</td>
<td>[US$_\text{2010}/\text{t}_{\text{steel or cement}}])</td>
<td>570 - 800</td>
<td>66 - 88</td>
</tr>
<tr>
<td>Additional</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With CCS (First Operation)</td>
<td>[US$ (\text{€})/\text{t}_{\text{CO}_2}]</td>
<td>82 (59*)</td>
<td>34 (24*)</td>
</tr>
<tr>
<td></td>
<td>[US$ (\text{€})/\text{t}_{\text{CO}_2}]</td>
<td>74 (53*)</td>
<td>31 (22*)</td>
</tr>
</tbody>
</table>

* € (1.40 US-$ = 1 €)

Source: IEA
Remarkable cost disadvantage by CCS
Cash-costs slab, BOF-route, 2010/11 (% costs / t)

Calculation:
1,40 US-Dollar is 1,00 Euro
1) Western Europe
2) Exporting Producer

<table>
<thead>
<tr>
<th>Region</th>
<th>Cash-costs slab, BOF-route, 2010/11 (% costs / t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Europe incl. CCS</td>
<td>100</td>
</tr>
<tr>
<td>CCS</td>
<td>25</td>
</tr>
<tr>
<td>Japan</td>
<td>99</td>
</tr>
<tr>
<td>China incl. CCS</td>
<td>87</td>
</tr>
<tr>
<td>LAM</td>
<td>83</td>
</tr>
<tr>
<td>NAM</td>
<td>96</td>
</tr>
</tbody>
</table>

Possible Scenario
Summary and Conclusion

Is CCS indispensable to reach ambitious CO$_2$-mitigation for steel industry?
- As long as carbon based processes (e. g. blast furnace process or even ULCOS technology) exists it is a potential bridge technology.

What is the result of a cost-benefit analysis of CCS for steel industry today?
- It is unaffordable expensive in view of competitivness and so not „solving“ the problem of CO$_2$.

What are the political aspects of CCS for steel industry?
- Obstacles for CCS are gaps in economic efficiency and acceptance in society

**meaning thus:**
Without a special solution for steel as long as no worldwide regime for CO$_2$-ETS exists, compulsory CCS is the end of steel production in Central Europe
Is that the end of European BF production?
- Remarkable cost disadvantage by CCS -
But without Steel
the Danger of Climate Change could never be overcome!

Many thanks for your kind attention!