CO₂ Capture Technologies for Industry
Iron & Steel, Oil Refinery & Cement

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Outline

Overview of CO₂ Emission from Industry

CO₂ Capture from Industry
- Iron and Steel
- Oil Refinery
- Cement

Conclusions
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Conclusions
Steel, Cement and Chemical Industries accounts for nearly 70% of the Direct CO₂ Emissions.

These emissions are not only from combustion of fossil fuel related CO₂ emissions but also to include PROCESS RELATED CO₂ EMISSIONS.
There are important CO$_2$ reduction opportunity from Iron and Steel and Cement Industry.
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Steel Plant

Primary steel production

Raw material preparation:
- coal
- coke
- sinter
- pellets

Steel making:
- Hot metal
- Oxygen
- Scrap

Secondary steel production:
- Scrap

Iron making:
- Blast Furnace: 1500°C
  - Natural gas, oil, or coal
  - Blast
  - O₂

Direct Reduction:
- Coal
- Natural gas, oil
- Shaft furnace
- Rotary kiln furnace
- Fluidized bed

Open Hearth Furnace

Basic Oxygen Converter: 1600°C

Electric Arc Furnace

Source: UNIDO 2010
CO₂ emission from Steel Plant

Coal = 1710 kg CO₂
Limestone = 105 kg CO₂
Total CO₂ emission: 1815 kg/t rolled coil

72 kWh
138 kg scrap

5-10%CO₂
Coal = 12 kg
Limestone = 133 kg

30%CO₂
Sinter strand
Pellet plant

25%CO₂
Blast Furnace

25%CO₂
Hot blast
Coal = 187 kg

1255 kg eq CO₂
in BF gas

20%CO₂
Power plant

10%CO₂
Flares, etc
63 kg

Lime kiln

Coke plant

limestone
109 kg

Coke
382 kg

Coke oven gas

Source UNIDO 2010 %CO₂ is the concentration in the flue gas
Projection of CO$_2$ emission from Steel sector

- 30% by EAF & 70% by BF in 2010
- Steel production doubled, 60% EAF & 40% by BF in 2050 LC

Factor 4 reduction from 2010

Source UNIDO 2010
Strategy to Control CO₂ Emission

- Reducing energy demand from Blast Furnace (BF)
- Using more Scrap Metal
- Major Source of CO₂ emission from still mills will remain ore based route
- Largest EU R&D programme since 2004
  **Ultra Low CO₂ Steelmaking (ULCOS)**
Ultra Low CO₂ Steel making (ULCOS)

Three major CO₂-lean process routes:

1. Decarbonizing: Shifting away from coal, replacing carbon by Hydrogen or Electricity,
2. Using Hydrogen reduction of ore or Electrolysis of iron ore
3. Introduction of CCS technology or the use of sustainable biomass.

In near term Top Gas Recycling Blast Furnace (TGR-BF) is most promising and can be retrofitted
Top Gas Recycling Blast Furnace (TGR-BF)

- CO₂ removal from top gas
- Reheating of CO/H₂ gas
- Re-injection of CO/H₂
- Use of pure Oxygen
- Storage of CO₂

Source: ULCOS
Japanese “Course 50 Programme”

COURSE50 / CO₂ Ultimate Reduction in Steelmaking Process by Innovative Technology for Cool Earth 50

(1) Technologies to reduce CO₂ emissions from blast furnace

- H₂ amplification
- Coke production technology for BF hydrogen reduction
- High strength & high reactivity coke
- Coke substitution reducing agent production technology
- Reaction control technology for BF hydrogen reduction

(2) Technologies for CO₂ capture

- Chemical absorption
- Physical adsorption
- CO₂ storage technology

- Sensible heat recovery from slag (example)
- Waste heat recovery boiler
- Kalina cycle
- Power generation
- Technology for utilization of unused waste heat
Major gaps and Barriers

There are no steel mill in this world which are alike...

- Steel are produced with different processes
- Steel are produced with different type of finished or semi-finished products
- Steel are produced with different grades
- ...

- Cost of CO₂ capture
- Timeline
- Extra burden from CO₂ purity
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Basic Refinery Concept

Source: VALERO
Hydroskimming/Topping Refinery

Light Sweet Crude

Crude Unit

Propane/Butane

Low Octane Gasoline and Naphtha

Reformer

High Octane Gasoline

Hydrogen

Distillation Tower

Distillate

Gas Oil

Vacuum Unit

Heavier Crude

Heavy Fuel Oil

Reformer

HS Kerosene/Jet Fuel

Distillate Desulfurizer

LS Kerosene/Jet Fuel

HS Diesel/Heating Oil

Distillate

Jet Fuel

Diesel

Heating Oil

4% Propane/Butane

32% Gasoline

RFG

Conventional

CARB

Premium

32% Distillate

Jet Fuel

Diesel

Heating Oil

32% Heavy Fuel Oil & Other

100% Total Yield

Simple, low upgrading capability refineries run sweet crude

Source: VALERO
High Conversion: Coking Resid Destruction

Source: VALERO

Complex refineries can run heavier and more sour crudes while achieving the highest light
Forecast EU refinery CO\textsubscript{2} emissions in 2020

Source: Concawe 2011
CO₂ Emission Breakdown by Process

Hydroskimming Refinery
0.6MtCO₂/annum

- Alkyl Iso.: 3%
- Hydro treating: 5.4%
- Cat. Reformer: 20.3%
- Offsites: 18%
- Sulphur Recovery: 0.4%

Conversion Refinery
1.4MtCO₂/annum

- Hydrogen: 20.6%
- FCC: 21.7%
- CDU: 18.4%
- Offsites: 11.7%
- VDU: 6.4%
- Alkyl Iso.: 5.5%
- Sulphur Recovery: 0.6%
- Cat. Reformer: 9.8%
- Hydro treating: 5.3%

Source: Concawe 2011
Distribution of CO₂ emission by Source in a Complex Refinery

Source: Concawe 2011
Technology Selection for CO$_2$ capture

Source: Concawe 2011
Possible Refinery CO\textsubscript{2} Capture

Vent Low CO\textsubscript{2}
Gas (IV)

Absorber (III)

Gas from Quench Tower
SO\textsubscript{2}x removal

Lean Amine to Other Absorbers

Source: Concawe 2011
Alternative CO$_2$ Capture Technology

Oxyfuel Combustion

- FCC unit air is replaced with pure oxygen diluted by recycled CO$_2$ to maintain thermal balance and catalyst fluidization will produce 95% CO$_2$

Chemical Looping Combustion

- Continuous Fluidized circulation of oxygen career in FCC

Pre Combustion

- Can be applied to gasify the carbonaceous feed to produce Hydrogen and pure CO$_2$
Challenges and Barriers

- Refinery retrofit is complex and expensive

- CO$_2$ Capture needs Utilities $\rightarrow$ require more energy production from utilities

- Increases Capex and Opex

- Different CO$_2$ capture cost will be achieved with different refinery Specification

- Require CCS design guideline for new Refinery
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Cement Industry

Process Control

Emission Monitoring

Electrostatic Precipitator

Duct

Raw material, Limestone
Calcium Carbonate

Clinker
Send for blending & grinding to make cement

Rotary Kiln
Pre Calcinator

Coal Mill
Coal Mill Dedusting

Raw material, Limestone
Calcium Carbonate

homogenizing and storage Silo

Electrostatic Precipitator

Direct
Compound

Raw Mill

Air to Air Cooler

Cooler
Decusting

Clinker Cooler

Rotary Kiln

1450°C
Direct CO₂ Emission - Clinker

CO₂ Emission from Clinker Production

- Calcination: 61%
- Combustion (Fuel): 39%
CO₂ Emission Reduction Strategy

- Improving Thermal and Electrical Efficiency
- Using Alternative Fuel e.g. Municipal waste, Discarded tyre, Plastic, textile, paper, Biomass
- Substitution of Carbon-Intensive Clinker by using blast furnace slag, fly ash from coal power plant
- Capturing CO₂ before emission to atmosphere by CCS from fuel combustion and kiln by Post and Oxy Combustion Capture
Post Combustion at Cement plant

- Require low pressure steam, CHP
- More Cleaning

Source: Mott MacDonald 2010
Oxy fuel Combustion at Cement plant: Partial Capture

Using O$_2$ instead of air in the kiln

Source: Mott MacDonald 2010
Oxyfuel Combustion at Cement plant: Total Capture

Source: Mott MacDonald 2010
Gaps and Challenges for Cement Industry

- Low SO$_2$ and NO$_2$ concentration in flue gas for post combustion.
- Overall plant integration is required.
- Steam requirement for solvent regeneration may be an issue in countries like India
- Increase requirement of land use
- Influence of O$_2$/CO$_2$ atmosphere on the design and operation of the preheater, pre-calciner and kiln
- Oxyfuel changes the product quality
- Reliability issue due to change in combustion characteristic
Gaps and Challenges for Cement Industry

- Main bottleneck for CO$_2$ Capture is the cost
- Cement Kilns are mostly located at limestone quarries which may not be near to storage site.
- Increase water demand with CO$_2$ capture unit may represent significant challenge based on site
- Intermittent operation of the cement plant due to market demand
- Technical and financial implication for cement industry is not well understood require more R&D.
- Carbon capture technology in the cement industry will not be ready before 2020.

Source: Mott MacDonald 2010
Current CCS Activities in Industry

Top Gas Recycle, Pilot Plant for 24% CO₂ reduction, 2007, LKAB, Lulea, **Sweden**

Top Gas Recycle Demo Plant 2010 & 2015, Arcelor Mittal, **Germany and France**

Pre-combustion, Pilot 0.4mtCO₂ /annum, 2010, Shell, **The Netherlands**

Mongstad Refinery TCM, Pilot 0.3 mt CO₂ /annum Bergen, **Norway**

European Cement Research Academy (ECRA) Phase III, IV and V CCS project: Demo plant DOE Funded **CEMEX** Demo Plant, **USA**
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Concluding Remark

✓ **CCS represents the most important new technology option** for reducing direct emissions in Industry

✓ Development of **CO\(_2\)** transportation and Storage needs to be coordinated between sectors to lower the cost

✓ Greater *investment from Government and Industry is needed* for research, develop, demonstrate and deploy CCS

✓ **Clear and Stable long term policies** that put a price on CO\(_2\) emissions will be required when industry is to implement the technology for deep emission reduction
Thank you

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