The Innovative Role of Steel in the 21th Century

Inspiration through Collaboration

Carl De Maré, Vice-President Technology Strategy
93mt in 2016
5% Market Share
ArcelorMittal worldwide

- 245,000 employees
- 59 Blast Furnaces in 20 countries
- In 60 countries
- 93 MT/y crude steel
- 64 MT/y iron ore prod
- Largest Scrap recycler in the world
- 80 b$ turnover
Steel – The Fabric of Life
Steel is essential in modern society

- Steel is crucial to the white goods industry
- Steel is used to produce sustainable energy
- Steel is irreplaceable for the car industry
- Steel for sustainable housing
Steel is the example of a global circular economy

Figure for EU28

- Primary Steel EU28: 101 mt/yr
- Secondary Steel EU28: 65 mt/yr
- 25 mt Cement substitute
- 26 mt Fresh Steel
- 65 mt 4 ton => 10 ton / capita
- 102 mt Scrap
- 11 mt Export

Net Scrap Export: 11 mt/yr
Expected Evolution of Steel use in 21th Century

GROWTH PHASE:
- Steel is needed to develop a sustainable society
- Correlated with population and with GDP up to ca 10 ton per capita

SUSTAINABLE PHASE:
- Steel need correlated to replace end of life products

Daniel MULLER, Tao WANG and Benjamin DUVAL, Patterns of iron use in societal evolution, Environ. Sci. Technol. 2011, 45
10,000 kg/person steel in use

1 kg/person/day steel consumption

30 billion ton is currently “in use” in the global economy
Steel stock per region per capita

Cumulative in-use steel stock [ton per capita]

- Western EU
- Eastern EU
- Africa
- Australia & New Zealand
- Canada
- Central & South America
- China
- India
- Japan
- Middle East
- Mexico
- Other Dev., Asia
- Former USSR
- South Korea
- USA
- World

ArceleorMittal
12 > 10 > 8 ton/p steel stock
1000 g/day/p steel consumption

20 x

= 400 kg/p steel stock +
50 g/day/p steel consumption
Evolution of PPP and Population per Region

Purchasing Power Parity/capita

<table>
<thead>
<tr>
<th>Region</th>
<th>2010</th>
<th>2050</th>
<th>2100</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>1.367</td>
<td>1.393</td>
<td>1.093</td>
</tr>
<tr>
<td>India</td>
<td>1.205</td>
<td>2.120</td>
<td>2.825</td>
</tr>
<tr>
<td>Africa</td>
<td>1.031</td>
<td>3.622</td>
<td>3.548</td>
</tr>
<tr>
<td>ROW</td>
<td>2.784</td>
<td>530</td>
<td>495</td>
</tr>
</tbody>
</table>
Apparent Steel Consumption per Region

Source: Study KTH, Vito, ArcelorMittal
Evolution of Primary and Secondary steelmaking in the 21st Century

Source: Study KTH, Vito, ArcelorMittal
Evolution of Scrap Arising in the 21th Century

Global scrap use

Source: Study KTH, Vito, ArcelorMittal
Impact on the Scrap Flows

Source: Study KTH, Vito, ArcelorMittal
Steel & Climate
Steel is responsible for 6% of global emissions

- Climate Impact ArcelorMittal
  - 59 blast furnaces in 20 countries
  - 1/3 of production based on scrap recycling
  - 207mt CO2 Emissions = ca 80% of CO2 (NL+B)

Source: Designing Climate change mitigation plans that add up – B. Bajzelj, J. Allwood, J. M. Cullen
Steel is a low emission material
Accounting for recycling and LCA sets the record straight

<table>
<thead>
<tr>
<th>Material*</th>
<th>Primary CO2 tCO2/t</th>
<th>Life Cycle CO2 tCO2/t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Stone</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Pine</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>Steel</td>
<td>2.5</td>
<td>0.86</td>
</tr>
<tr>
<td>Clincker</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Carbon fibre</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Ti</td>
<td>40</td>
<td>17</td>
</tr>
</tbody>
</table>

*Elaboration on M. Ashby Materials and the Environment

Based on D/C system and WARR, after one cycle emissions are < 50% of what conventionally is believed
Low Capex Secondary Steelmaking with primary energy melter
Pilot Project ArcelorMittal and SMS for 200,000 ton per year melting

Pilot Project ArcelorMittal and SMS for 200,000 ton per year melting

Energy consumption (kWh/t, total)

- Electric: 1,500
- Natural gas: 1,000
- Oxygen: 1,000
- Coal: 1,000

Pre-melting with gas
Mix with liquid steel or iron

EAF* PEM

* Average according to a study by World Steel Association
Primary steelmaking is built on the efficient use of carbon.

FeO + C + O₂ → Fe + CO + CO₂
Not the use of Carbon, but the emission of CO2 is the problem

FeO + C + O2 \rightarrow Fe + CO + CO2

Iron Ore
Cokes

Cleaned SynGas
CO/CO2/H2

% Powder Coal
Oxygen

Recycle the Carbon

Power Plant

Chemicals & Fuels
Nature is already recycling Carbon billions of years

Carbon Waste Gas (CO) from Iron-Ore Reduction In Blast Furnace

Water H2O

Microbe

Ethanol C2H5OH

Ethanol is used for transport (fuel), chemicals (plastics), food and pharmaceutics
AM Gent Commercial Demonstration Project to produce Ethanol from waste gas with our partner Lanzatech

BF Gas eq. 600,000 t steel (ca 15%)

80 million liter per year

Sponsored by Horizon2020 LCE-12
AM Gent Commercial Demonstration Project
2015-2019
Sustainability impact of Steelanol Demo

Scale up to global steel industry: 1000x

80 million liter of Demo Project = 100,000 electrical cars

27% less kWh consumed per 100km (w/o energy impact of battery disposal end of life)
Potential for next step 10x larger units
Potential impact if implemented world wide: 1000x
Cradle to Cradle: closing the carbon loop

FeO + C + O2 → Fe + CO + CO2

Iron Ore
Cokes

Cleaned SynGas
CO/CO2/H2

Recycle the Carbon

% Powder Coal
Oxygen

Biomass & Waste

Chemicals
Ethanol Derivatives – Value Chain
Ethanol based petrochemicals have been shown to have 30-40% lower carbon footprint as compared to fossil fuel.

Low carbon ethanol leads to sustainable products

<table>
<thead>
<tr>
<th>Product</th>
<th>Market Size*</th>
<th>Million MT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethylene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethylene oxide (EO)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethylene glycol (MEG)</td>
<td></td>
<td>21</td>
</tr>
<tr>
<td>Ethylene dichloride</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vinyl chloride</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PVC</td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>Ethyl Benzene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Styrene</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polystyrene</td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Acetaldehyde</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetic Acid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poly Vinyl Acetate &amp; Poly Vinyl Alcohol</td>
<td></td>
<td>8</td>
</tr>
</tbody>
</table>

Source: IHS, ICIS, Nexant
Forrest Plantation in Brasil
A Clean and Renewable Energy

See Poster of Forestry Engineer Roosebelt de Paula Amado of AM BioFlorestas in Brasil
Steel is a key enabler for circular economy and cross sectorial collaboration.
Inspiration through Collaboration

Thanks for your attention
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