A Steel Roadmap for a Low Carbon Europe 2050

IEA Global Industry Dialogue and Expert Review Workshop
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Dr.-Ing. Jean Theo Ghenda
Steel Institute VDEh
1. Objectives and Phases of the project
2. Steel’s Contribution to a Low Carbon Europe 2050
   2.1. Steel industry overview and technology development
   2.2. Baselining
   2.3. Technology assessment
   2.4. Steel and Scrap forecast
   2.5. Steels’own impact – Abatement scenarios for 2050
   2.6. Steel as mitigation enabler
3. Steel Roadmap for a Low Carbon Europe 2050
   3.1. CO₂ intensity pathways up to 2050
   3.2. Challenges for an adequate set of climate policies for steel
   3.3. Policy recommendations
Objectives of the project

- Respond to the Commission Roadmap with a sound and credible alternative in order to engage constructively with stakeholders.
- Assess the technical-economical options over the mid and long-term. Knowing what our sector can do and at which cost will enable companies to make informed investment decisions.
- Demonstrate that stack emissions are just one side of the problem: steel is a strategic and sustainable material which will be instrumental in achieving the EU’s climate and resource efficiency objectives.
Project Phases

- First phase: technical-economical assessment contracted to the Boston Consulting Group in collaboration with the Steel Institute VDEh: ‘Steel’s Contribution to a Low Carbon Europe 2050’

- Second phase: ‘EUROFER Steel roadmap’ built on BCG/VDEh’s findings but scope broadened to
  - options for deeper cuts (HIstarna, Ulcored, electricity and hydrogen-based reduction, …)
  - main challenges of the various options
  - competitiveness issues
  - policy recommendations
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Work divided in two workstreams

**Workstream 1: Baselining and technology assessment**
- **Emission baselining**
  - Starting point for discussion: What has the steel industry achieved so far?
- **Technology profiles**
  - By how much can individual technologies reduce emissions and how much do they cost?

**Workstream 2: Steel roadmap low carbon Europe 2050**
- **Steel's own impact**
  - How can emissions be reduced until 2050 considering different technology scenarios?
- **Steel as mitigation enabler**
  - \( \text{CO}_2 \) balance: What role does steel play in other industries in enabling mitigation?

**Content**
- Baselining within defined system boundaries
- Assessment of technologies based on abatement potential, costs, possible time of introduction as well as possible penetration rate
- Construction of emission model based on projected steel production and scenarios derived from technology profiles
- \( \text{CO}_2 \) balance for selected use cases where only steel as a material is making mitigation possible in other industries
# Overview of iron- and steel-making routes

<table>
<thead>
<tr>
<th>Raw material preparation</th>
<th>Integration route</th>
<th>Smelting reduction</th>
<th>Direct reduction</th>
<th>Scrap</th>
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Baselining: system boundaries

Scope investigated: Primary/secondary steelmaking to hot rolling

Scope I—direct CO₂ emissions from the following facilities:
- Sintering
- Pelletizing
- Coke-making
  → Iron-making
  → Steel-making
  → Casting + hot rolling

Scope II—indirect CO₂ emissions from purchased electricity

Scope III—indirect CO₂ emissions from purchased materials (produced in EU27):
- Pellets
- DRI
- Pig iron
- Graphite electrodes
- Credits for by-product gases¹
- Oxygen
- Steam
- Coke
- Burnt lime
- Credits for slag²

1. The utilization of by-products, such as process gases or waste heat is not counted as a credit, since such use helps to reduce the energy consumption of aggregates. Only by-product gases that are sold to a second party can be counted as a credit, since they help to reduce emissions of a different sector. 2. Emission factors for BF and BOF to cement industry not finalized yet.

Source: worldsteel; Project team analysis
EU27’s specific CO₂ intensity decreased by 15%; EU27’s absolute CO₂ emissions dropped by 25%; Drivers: mainly Volume changes, Shift from BF-BOF to EAF route, efficiency gains, improved CO₂ emission of electric generation (minor effect)

Note: Includes all direct and upstream emissions as well as casting and hot rolling; OHF route volume 1990: 11 M CS = crude steel
Source: EUROFER Benchmark 2007/08; VDEh data exchange 1990/2010; Project team analysis
Steel intensity (SI) curves used to forecast finished steel consumption (FSC) per country

- Use of SI curves accounting for industrial structure of individual countries
- SI curves calculated for each country by using historical data for FSC in relation to GDP per Capita and population
- FSC forecasts calculated based on population and GDP forecasts by EIU

Assessed parameter for industry development 2012 – 2050

- **Industrialization**
  - Share of industrial production of total economy
  - Assumption: No deindustrialization in EU

- **Industry structure**
  - Development of steel-intensive industries
  - Assumption: Stable industry structure

- **Steel efficiency gains**
  - Efficiency gains in steel application
  - Assumption: Certain efficiency gains

Sources: World Steel Association; EIU; BCG analysis.
Methodology to compute crude steel production from finished steel consumption

- Use Crude steel Production and Finished Steel Production are calculated from Finished Steel Consumption using Self-sufficiency rate and Conversion Rate.
- Assumptions: 1) EU27 Self-sufficiency by 2030 (FSC=FSP);
  2) EU27 Conversion Rate rises to 95% in 2030 and remain constant until 2050.

Sources: World Steel Association; EIU; BCG analysis.
Moderate annual crude steel production growth of 0.8% from 2010 until 2050 expected.


Going forward, slow growth expected for EU27, 2007 production level will be reached in 2032.

Note: e = estimate.
Sources: World Steel Association; BCG analysis.
Scrap availability forecasted to grow by 0.9% annually until 2050, mainly driven by obsolete scrap.

Scrap availability driven by three scrap types:

- **New / prompt scrap**
  - Production waste and errors in conversion of crude to finished
  - Depending on efficiency of production process

- **Home scrap**
  - Production waste and errors in steel-using sectors
  - Depending on industry sector

- **Obsolete / old scrap**
  - Steel in products at the end of their life cycle
  - Depending on scrap recovery rate and life cycle per sector

Total available scrap in EU27 (in Mt)

Source: BCG analysis.
## CO₂ Emission Projections

### Technology Review

<table>
<thead>
<tr>
<th>Incremental</th>
<th>Agglomeration</th>
<th>Integrated route</th>
<th>EAF route</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Sinter plant cooler heat recovery</td>
<td>• Injection of H₂ rich reductants¹</td>
<td>• Heat recovery</td>
</tr>
<tr>
<td></td>
<td>• Coke dry quenching (CDQ)</td>
<td>• Injection of H₂ into shaft</td>
<td>• Optimization</td>
</tr>
<tr>
<td>Substitution</td>
<td>• Heat recovery</td>
<td>• Optimization of Pellet ratio to Blast Furnace</td>
<td></td>
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<tr>
<td></td>
<td>• Top gas recovery turbine (TRT)</td>
<td>• Top gas recovery turbine (TGR)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Waste gas recovery</td>
<td></td>
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<tr>
<td>Breakthrough</td>
<td>• Corex</td>
<td>• Corex / Finex / HIsarna</td>
<td>• Midrex / HyL based on natural gas</td>
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<tr>
<td></td>
<td>• Finex</td>
<td></td>
<td>• Finmet / Ulcored based on natural gas + fine ores</td>
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<tr>
<td></td>
<td>• HIsarna</td>
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**Synergies between different technologies**²

**Combination of technologies with CCS**³

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¹ Includes the potential use of coke oven gas as reductant
² E.g., use of coke oven gas for DR, BF+Corex/Finex+DR, use of Corex/Finex gas for DR
³ BF: CCS after power plant, TGR with CCS, Corex/Finex with CCS, HIsarna with CCS  
EAF: gas based DR with CCS, Ulcored with CCS
CO$_2$ emission projections

Economic feasibility assessment of the technologies

- Likely outcomes analyzed using 2-step logic:
  1. Determination of economic feasibility under different price scenarios.
  2. Gradual implementation of the economically feasible technologies on the basis of varying adaptation curves for different scenarios.
- Economic feasibility was computed by comparing costs (CAPEX et OPEX) with the potential savings over considered investment period, depending on different price scenarios.
- The price scenarios included a reference-price scenario (inflation only), medium-price scenario (doubling of real input factor costs) and high-price scenario (fivefold increase of input factor costs).
BF-TGR (top gas recycling)

Ulcos-BF concept:
- Retro-fit to existing BF
- Lower coke consumption
- Higher productivity
- But a lot of technical challenges to overcome
Comparison of the Operating Expenses (OPEX) of Alternative Steelmaking Technologies

Source: BCG/VDEh

 Costs are normalized to BF-BOF = 100

OPEX

2010

BF-BOF

Smelting reduction

Scrap-EAF

DRI-EAF

100

103

114

133

Sources: Steel Institute VDEh; project team analysis.
Note: CS = crude steel
1. Based on Midrex direct reduction technology. 2. Based on Finex smelting reduction technology

Sources: Steel Institute VDEh; project team analysis.
Note: CS = crude steel
1. Based on Midrex direct reduction technology. 2. Based on Finex smelting reduction technology
Comparison of Capital Expenditures (CAPEX) for Alternative steelmaking technologies

Source: BCG/VDEh

CAPEX

<table>
<thead>
<tr>
<th>Technology</th>
<th>CAPEX 2010 (€ / t CS)</th>
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<tr>
<td>BF-BOF retrofit</td>
<td>100</td>
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<tr>
<td>Scrap-EAF</td>
<td>108</td>
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<tr>
<td>Smelting reduction</td>
<td>231</td>
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<tr>
<td>DRI-EAF</td>
<td>242</td>
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<tr>
<td>BF-BOF greenfield</td>
<td>259</td>
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Cost are normalized BF-BOF retrofit = 100

Note: CS = crude steel


Sources: Steel Institute VDEh; Project team analysis
Absolute CO₂ emissions in 2050 only 56% lower than 1990’s if CCS fully implemented in 2050

Abatement cost of moving from existing BF-BOF to DRI-EAF: 260 to 700€/tCO₂

Upper boundary
A Crude steel production forecast & CO₂ intensity on 2010 level
B Increased EAF-share on the basis of scrap availability & best-practice sharing

Economic scenarios
Lower theoretical boundary without CCS
C 44% Scrap-EAF, 45% DRI-EAF, 11% BF-BOF; increased improvements, especially for BF-BOF

Lower theoretical boundary with CCS
D 44% Scrap-EAF, 56% BF-BOF+TGR, DRI-EAF, or SR-BOF

Sources: EUROFER Benchmark 2007/2008; VDEh data exchange 1990/2010; Project team analysis.
1. 2009 crude-steel production with 2010 CO₂ intensity and 2010 Scrap-EAF share.
Abatement potential up to 2050

Abatement potential compared to 2010 (intensity)

<table>
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<tr>
<th>Reference year 2010 (specific emissions)</th>
<th>2030</th>
<th>2050</th>
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<tbody>
<tr>
<td>Economic scenario</td>
<td>-9%</td>
<td>-15%</td>
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<tr>
<td>Maximum theoretical abatement without CCS</td>
<td>-19%</td>
<td>-40%</td>
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<tr>
<td>Maximum theoretical abatement with CCS</td>
<td>-9%</td>
<td>-57%</td>
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Commission Roadmap for a Competitive Low Carbon Economy 2050
(table 9, source: PRIMES, GAINS)

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<th>Reference year 2005 (absolute emissions)</th>
<th>2030</th>
<th>2050</th>
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<tr>
<td>Overall</td>
<td>-35% to -40%</td>
<td>-77% to -81%</td>
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<tr>
<td>ETS</td>
<td>-43% to -48%</td>
<td>-88% to -92%</td>
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<tr>
<td>non-ETS</td>
<td>-24% to -36%</td>
<td>-66% to -71%</td>
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Steel as a mitigation enabler

- Innovative steel-based emission-saving applications may help reduce CO₂ emissions
- Only saving that are 100% attributable to steel are taken into account
- Stringent 4-step logic applied to isolate the case studies for evaluating steel’s own mitigation potential

**Initial list**
- Weight reduction-cars
- Onshore/offshore wind power
- Leaf springs
- Rubber-enforcing steel structures for tires
- Motor systems
- Assembled camshafts
- CCS
- Structural steel
- …

**1. Geography**
- Focus on EU-27

**2. Potential impact vs. 2010**
- Relevant potential by 2030

**3. Substitution of materials**
- No comparative examination of alternatives

**4. Absolute potential**
- Cases with abatement ≥ 5 MtCO₂/year

8 case studies with distinct potential

Sources: VDEh; BCG analysis.
Case studies for EU27 result in annual CO₂ savings of about 440 Mt while emitting only 70 Mt of extra CO₂.

<table>
<thead>
<tr>
<th>Case study</th>
<th>Net CO₂ reduction potential¹</th>
<th>Emissions in the steel production</th>
<th>Ratio between CO₂ reduction / emission</th>
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<tbody>
<tr>
<td>Energy industry</td>
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<tr>
<td>Efficient fossil fuel PPs</td>
<td>103.0</td>
<td>0.7</td>
<td>~ 155:1</td>
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<td>Offshore wind power</td>
<td>69.7</td>
<td>3.0</td>
<td>~ 23:1</td>
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<td>Other renewables¹</td>
<td>22.2</td>
<td>0.16</td>
<td>~ 148:1</td>
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<tr>
<td>Efficient transformers</td>
<td>19.6</td>
<td>1.2</td>
<td>~ 17:1</td>
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<tr>
<td>Efficient e-motors</td>
<td>6.9</td>
<td>3.2</td>
<td>~ 2:1</td>
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<tr>
<td>Traffic</td>
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<tr>
<td>Weight reduction cars</td>
<td>165.9</td>
<td>42.1</td>
<td>~ 4:1</td>
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<td>Weight reduction trucks</td>
<td>6.3</td>
<td>14.0</td>
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<td>Household / industry</td>
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<td>Combined heat / power</td>
<td>49.6</td>
<td>5.3</td>
<td>~ 9:1</td>
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¹: Bioenergy
²: Net reduction refers to reduction attributable to steel.

Note: PP = power plant
Source: BCG analysis

∑ ~ 443
∑ ~ 70
~ 6:1
Agenda

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Steel Roadmap for a Low Carbon Europe

- Base on findings of the BCG/VDEh study
- Broader scope:
  - options for deeper cuts (HIsarna, Ulcored, electricity and hydrogen-based reduction, …)
  - deeper look into CCS
  - main challenges of the various options
  - competitiveness issues
  - policy recommendations (role of the ETS)
- Steel Low C Roadmap published in July 2013 but the work doesn’t stop there.
CO₂ intensity pathways up to 2050

Emission reduction potentials are expressed in specific CO₂ emissions relatively to 2010

Upper line: BAU at 2010 CO₂ Intensity

-15% Economic CO₂ reduction potential

Uneconomic scenarios from today’s perspective

- Maximum theoretical abatement without CCS (DRI): -40%
- Maximum theoretical abatement with CCS (BF-TGR): -57%

Hypothetic breakthrough technologies in combination with CCS
CO\textsubscript{2} intensity pathways up to 2050

How?

Best practice sharing, best available techniques, increased scrap availability, energy efficiency, process optimisation

Uneconomic scenarios

- Partial shift from BF-BOF to DRI-EAF
- Use of BF-TGR technology in combination with CCS
- BF-TGR, ULCORED/Hitlarna
- CCS on all emission sources
- Electricification of heating
- Hydrogen-based reduction
- Electrolysis
CO₂ intensity pathways up to 2050

Conditions for success:
- Access to scrap and energy at competitive prices
- NG and electricity prices such that natural gas-based DRI becomes competitive in Europe
- Support for demonstration and deployment of BF-TGR, access to CCUS widespread at competitive prices
- Support for R&D, demonstration and deployment of breakthrough technologies

Emission reduction potentials are expressed in specific CO₂ emissions relatively to 2010
**What?**

- economic CO2 reduction potential
- maximum theoretical abatement without CCS: -40%
- maximum theoretical abatement with CCS: -57%
- hypothetic breakthrough technologies in combination with CCS

**How?**

- continued decarbonisation of the power sector
- increased scrap availability
- best practice sharing
- implementation of cost-effective incremental technologies
- partial shift from BF-BOF to DRI-EAF
- use of BF-TGR technology in combination with CCS
- BF-TGR, ULCORED/Hlsarna
  - CCS on all emission sources
  - electricification of heating
  - hydrogen-based reduction electrolysis,…

**Conditions for success**

- access to scrap and energy at competitive prices
- incentives through e.g. sectoral energy efficiency programmes
- full offset of distortive CO₂ costs until level-playing field is restored
- support for demonstration and deployment of BF-TGR, access to CCS widespread at competitive prices
- support for R&D, demonstration and deployment of breakthrough technologies
An adequate set of climate policies for steel

What’s wrong with the projected policy framework

- The CO₂ reduction potential in the EU steel industry estimated to be about 10% between 2010 and 2030 (specific emissions).

- Steel will not be able to come anywhere near the interim reduction objectives suggested in the Commission Low Carbon Roadmap of 43-48% for the ETS sector between 2005 and 2030.

- Going beyond the 10% mark would require having recourse to yet unproven technologies, as well from a technical point of view as in terms of cost-effectiveness.

- These technologies need further research and funding for pilot and demonstration tests.

- Their implementation will be costly, not only because of the investments involved but also because of the higher operating costs stemming a.o. from the use of CCS and the problems stemming from it.

- In a long-term perspective, the EU ETS carbon price signal alone will not to put steelmaking breakthrough technologies on-stream.

- Breakthrough technologies can only be put on-stream via adequate funding in R&D, pilot, demonstration and deployment.
An adequate set of climate policies for steel

Policy recommendations

- The 2030 Climate and Energy Framework has therefore to acknowledge that steel cannot move at the same pace than other sectors. Leading principles for the 2030 policy framework:
  - Policies have to make industry more competitive by securing globally competitive energy prices (NG, electricity) instead of increasing (carbon) costs.
  - Emission reduction pathways for the steel industry have to be built ‘bottom-up’, based on the technical and economic abatement potentials of the sectors (sectoral approaches).
  - Climate goals should be dependent upon comparable reduction effort by other major economies.

- In the context of cap and trade, best performers need 100% of their allowances for free (no correction factor should apply) and their indirect CO₂ costs must be fully and consistently offset through a truly effective EU mechanism (based on realistic benchmarks) at least until international distortions to competition are removed.

- The continuation and generalization of exemptions from energy taxation, levies and tariffs stemming from support for renewables and other climate-related initiatives (CCS).

- Funding in research, demonstration and deployment of potential new technologies is therefore key to success. In this regard, ambitious climate objectives require public funding commitment that is consistent with the level of effort envisaged.
Thank you