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A Steel Roadmap for a Low Carbon Europe 2050

IEA Global Industry Dialogue and Expert Review Workshop

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Steel Institute VDEh

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Agenda

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. CO_2 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

A Steel Roadmap for a Low Carbon Europe 2050

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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 (HIsarna, Ulcored, electricity and hydrogen-based reduction,…)
  - main challenges of the various options
  - competitiveness issues
  - policy recommendations

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Steel's Contribution to a Low Carbon Europe 2050

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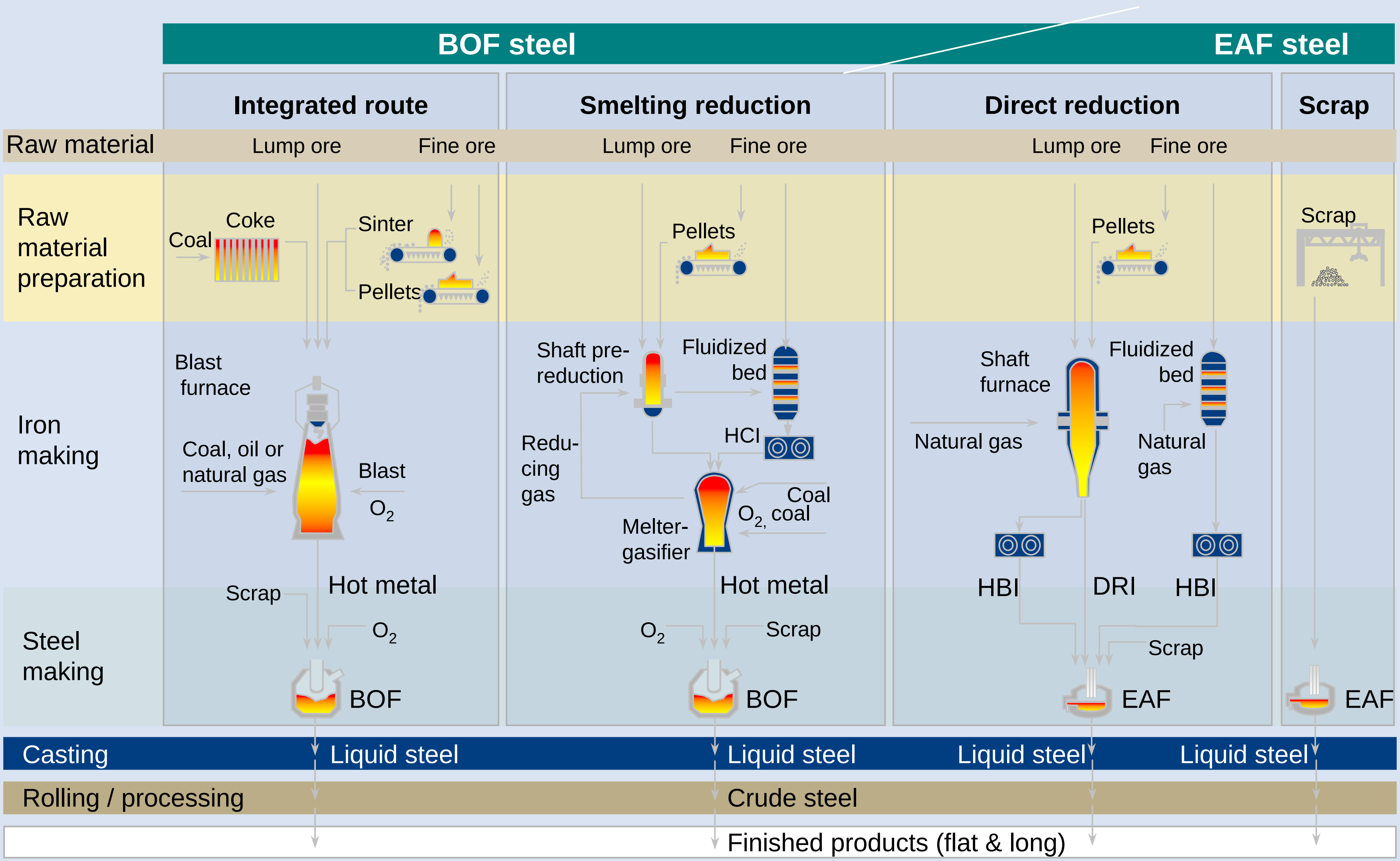
Work divided in two workstreams

		Argumentation logic	Content
1 Workstream 1: Baselining and technology assessment	Emission baselining	**Starting point for discussion: What has the steel industry achieved so far?**	Baselining within defined system boundaries
	Techno-logy profiles	**By how much can individual technologies reduce emissions and how much do they cost?**	Assessment of technologies based on abatement potential, costs, possible time of introduction as well as possible penetration rate
2 Workstream 2: Steel roadmap low carbon Europe 2050	Steel's own impact	**How can emissions be reduced until 2050 considering different technology scenarios?**	Construction of emission model based on projected steel production and scenarios derived from technology profiles
	Steel as mitigation enabler	**CO_2 balance: What role does steel play in other industries in enabling mitigation?**	CO_2 balance for selected use cases where only steel as a material is making mitigation possible in other industries

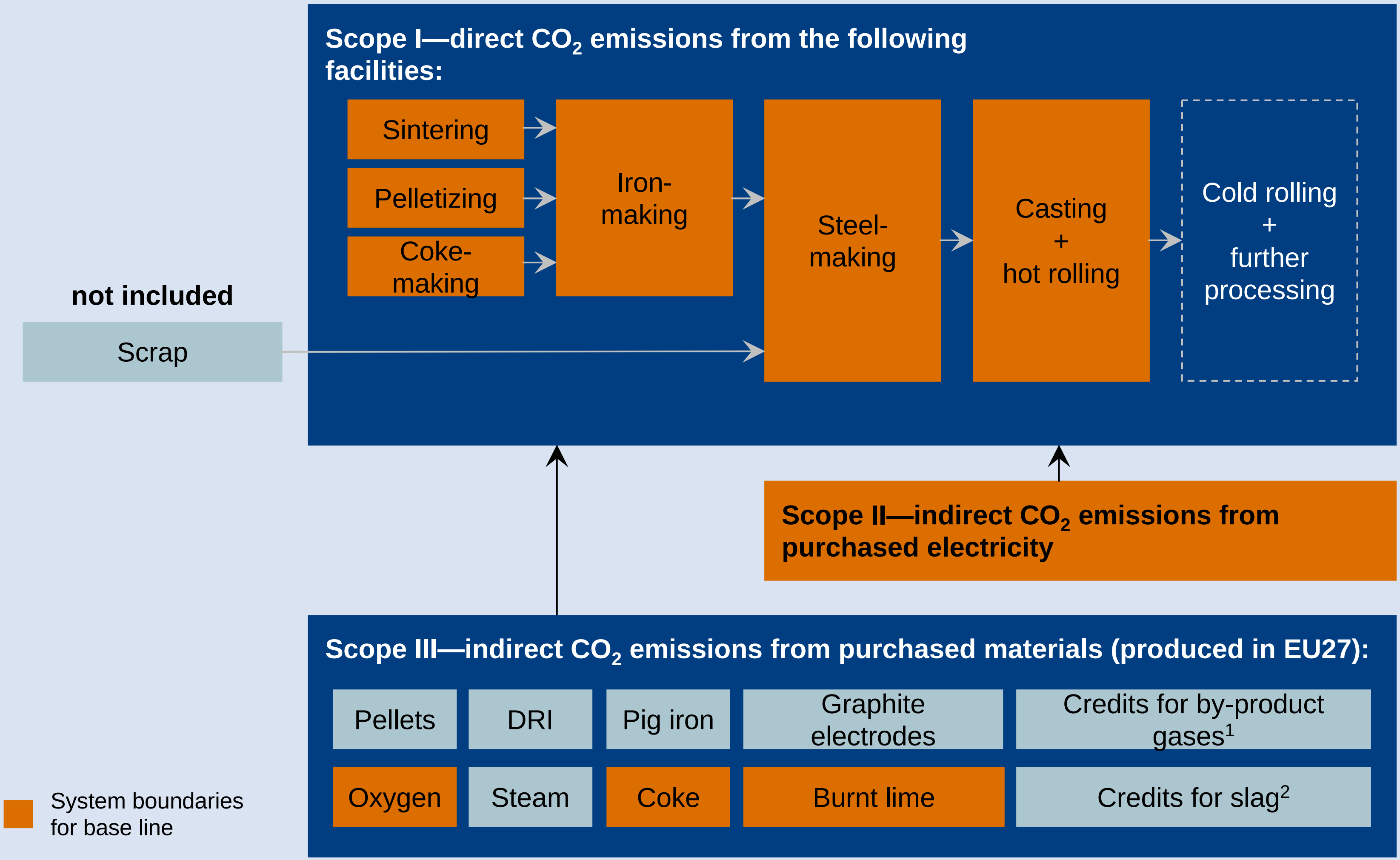
Overview of iron- and steel-making routes



Source: Steel Institute VDEh; WV Stahl; WSA; BCG

Baselining: system boundaries

Scope investigated: Primary/secondary steelmaking to hot rolling



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

Reduction of CO_2 emission from 1990 to 2010

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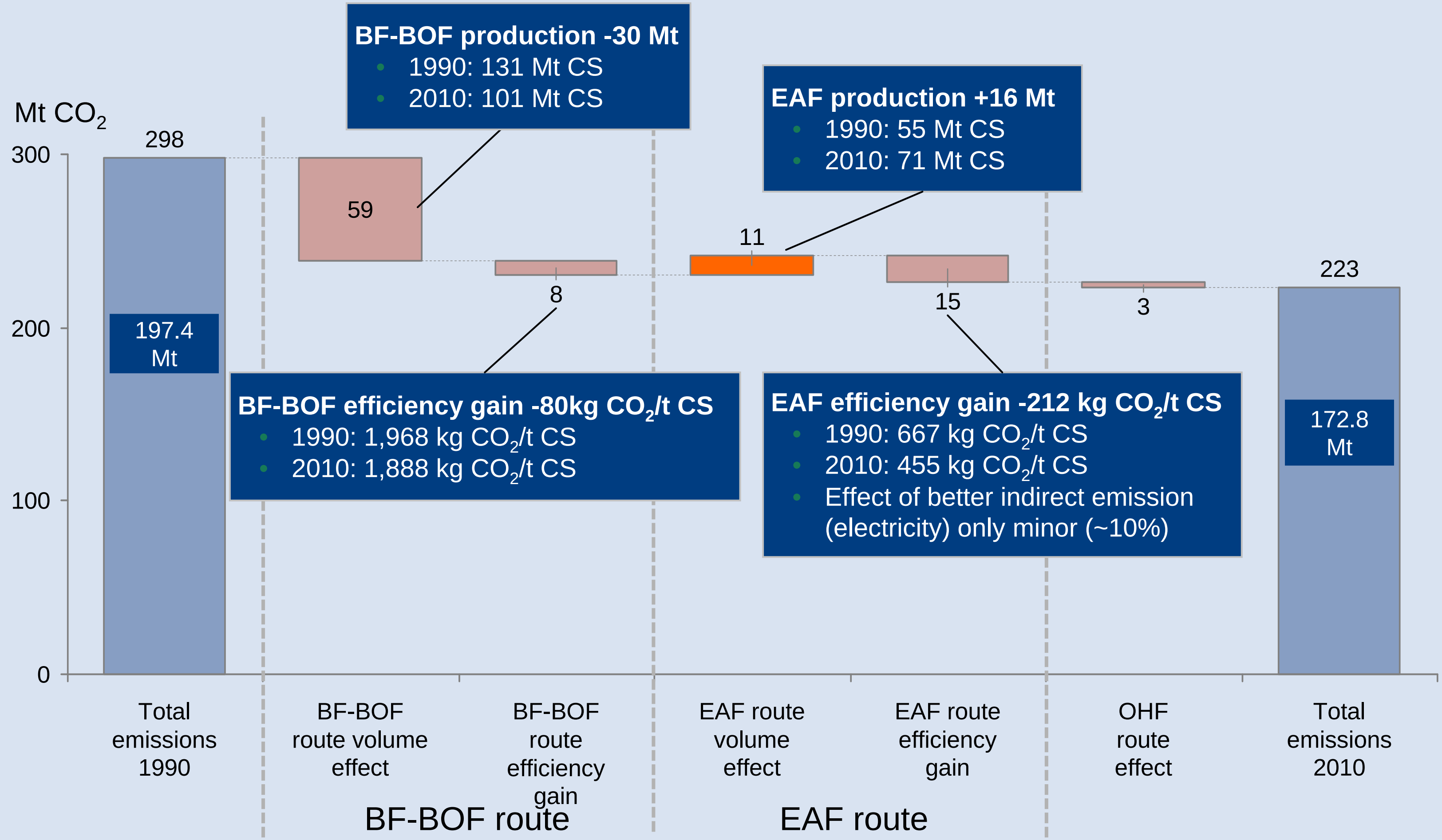
EU27's specific CO_2 intensity decreased by 15%;
EU27's absolute CO_2 emissions dropped by 25%; Drivers: mainly Volume changes, Shift from BF-BOF to EAF route, efficiency gains, improved CO_2 emission of electric generation (minor effect)



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

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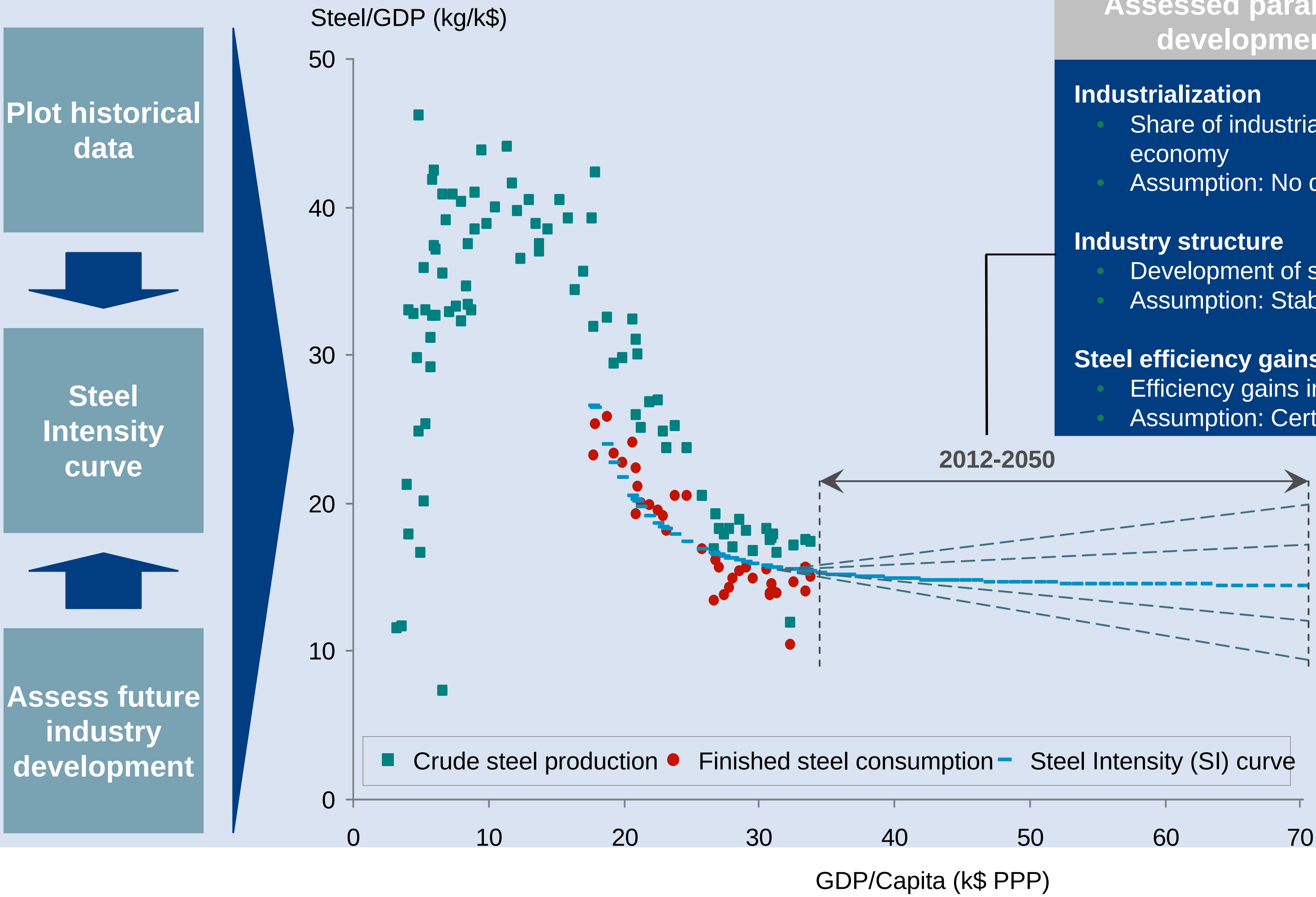
- Use of SI curves accounting for industrial structure of individual countries
- SI curves calculated for each country by using historical data for FSC in relation to GDP per Capita and population
- FSC forecasts calculated based on population and GDP forecasts by EIU



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

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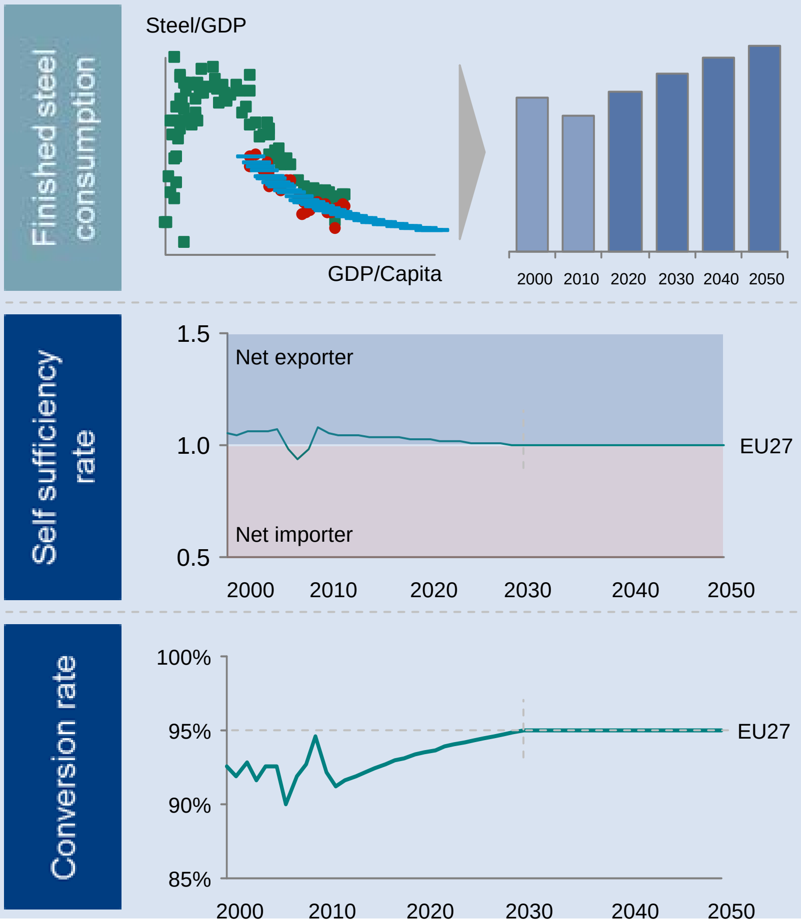
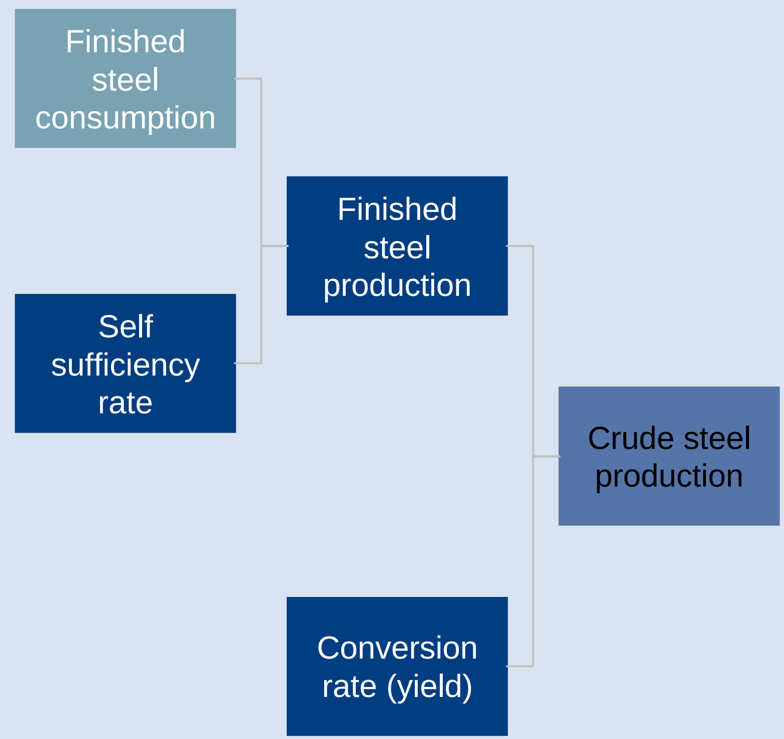
- Use Crude steel Production and Finished Steel Production are calculated from Finished Steel Consumption using Self-sufficiency rate and Conversion Rate
- Assumptions: 1) EU27 Self-sufficiency by 2030 (FSC=FSP);

  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

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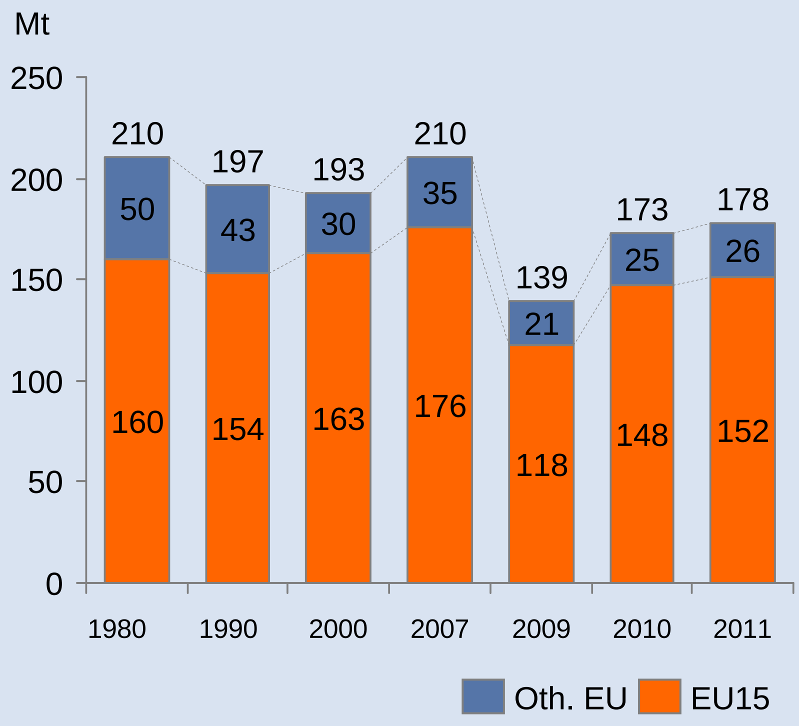
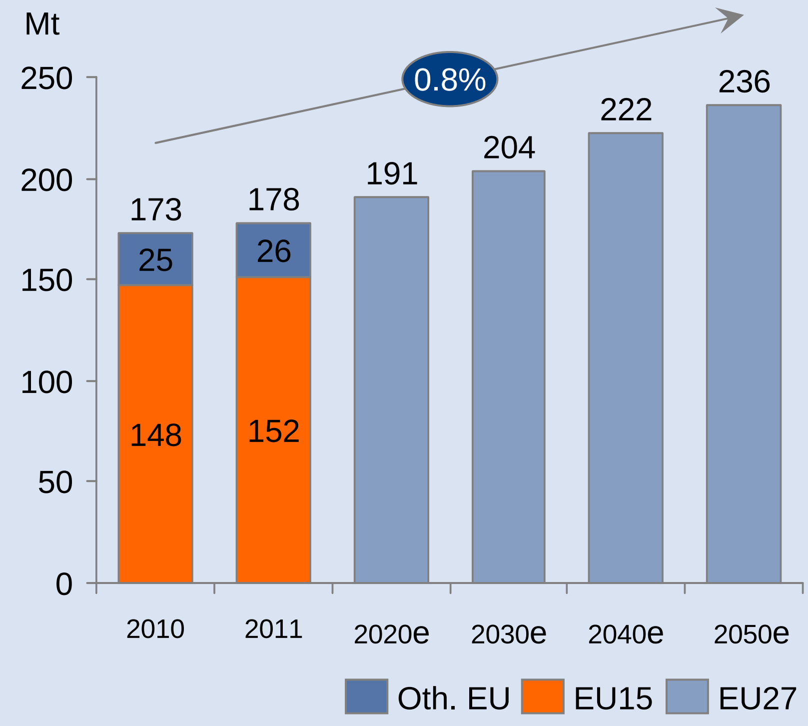
Historically, crude steel production stable in EU15 but declining in Eastern Europe



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

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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

Crude steel production × Scrap rate (%)

Home scrap

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

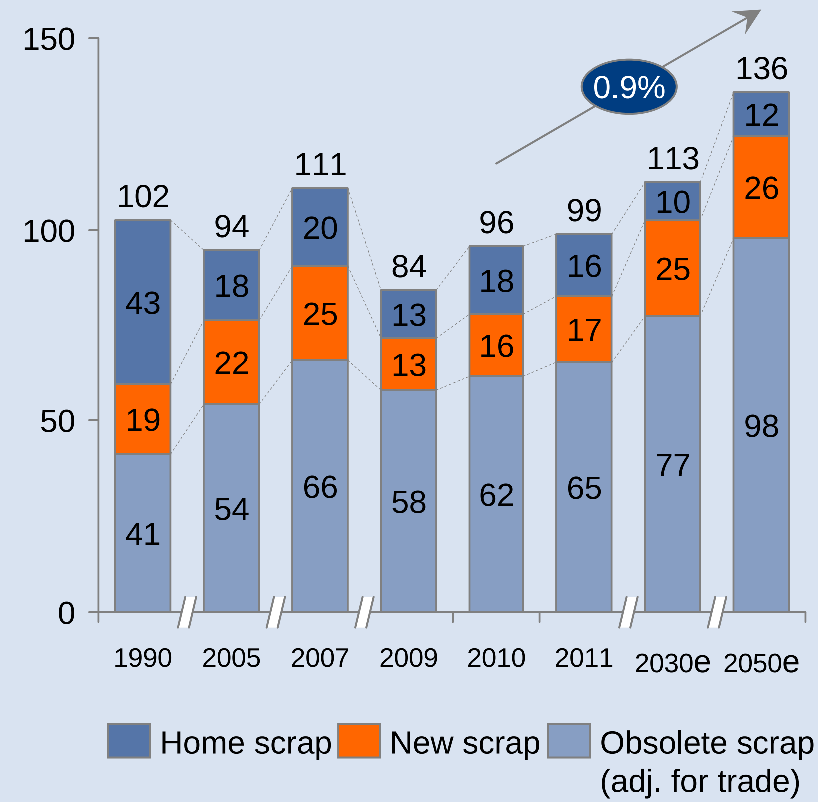
Finished steel cons. per sector × Scrap rate (%)

Obsolete / old scrap

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

Finished steel cons. per sector × Recycling rate (%) ÷ Life time (y)

Total available scrap in EU27 (in Mt)



Source: BCG analysis.

CO_2 emission projections

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Technology review

	Agglomeration	Integrated route	EAF route
Incremental	• Sinter plant cooler heat recovery • Coke dry quenching (CDQ)	• Injection of H_2 rich reductants[1] • Injection of H_2 into shaft • Optimization of Pellet ratio to Blast Furnace • Top gas recovery turbine (TRT) • Waste gas recovery	• Heat recovery • Optimization
Substitution		• Corex • Finex • HIsarna	• Midrex / HyL based on natural gas • Finmet / Ulcored based on natural gas + fine ores
		Synergies between different technologies[2]	
Breakthrough		• Top gas recovery (TGR)	
		Combination of technologies with CCS[3]	

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

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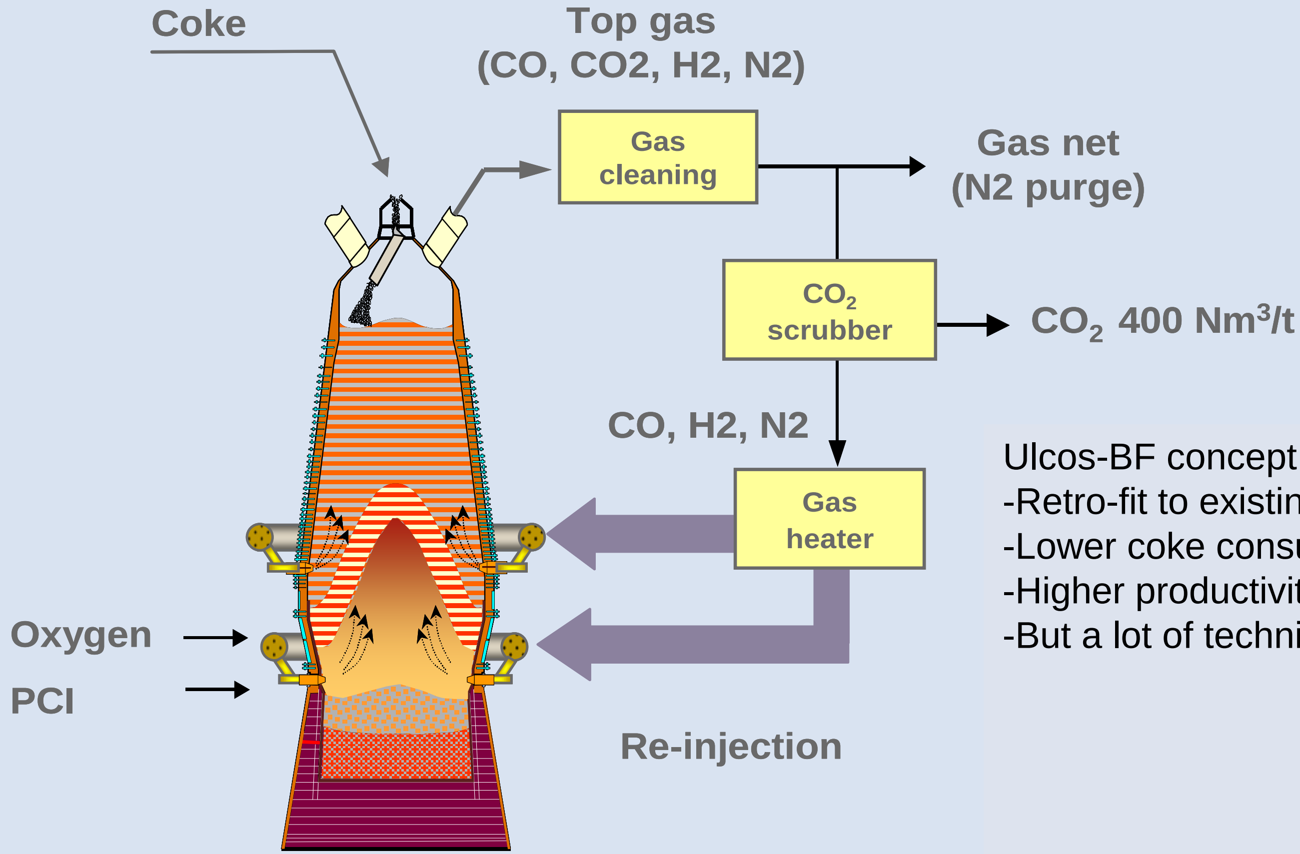
Economic feasibility assessment of the technologies

- 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

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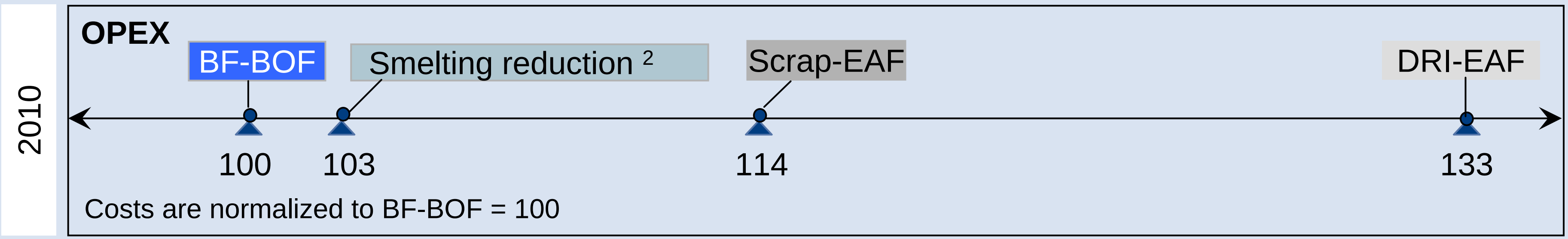
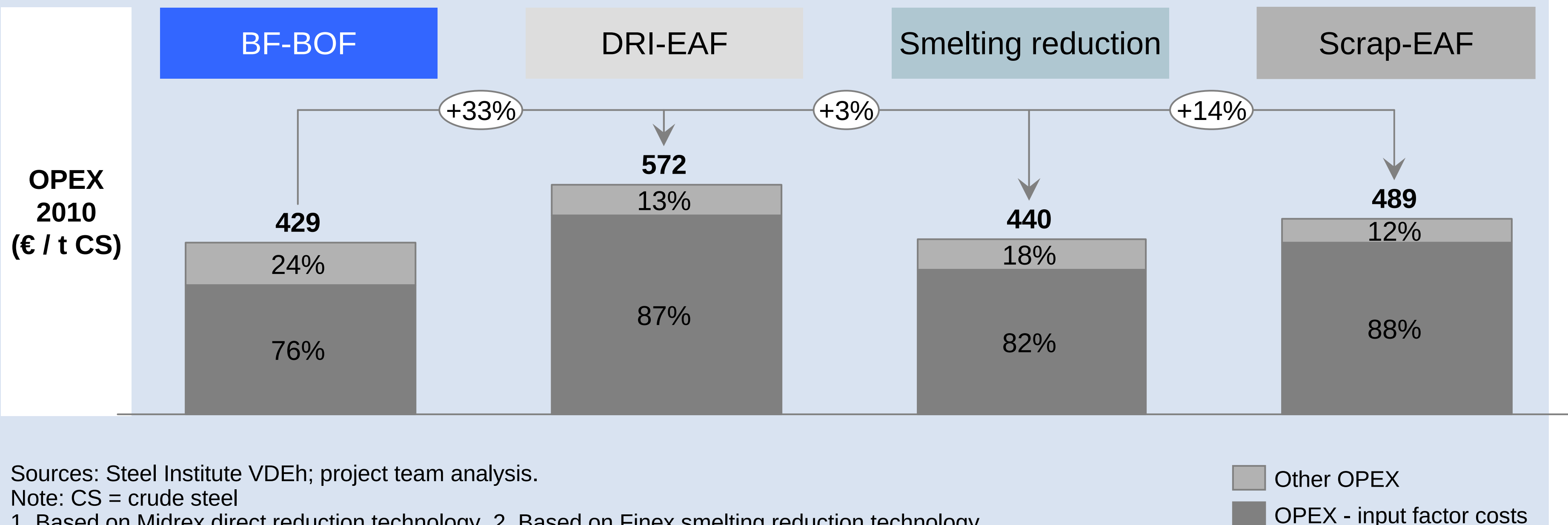
Source: BCG/VDEh





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

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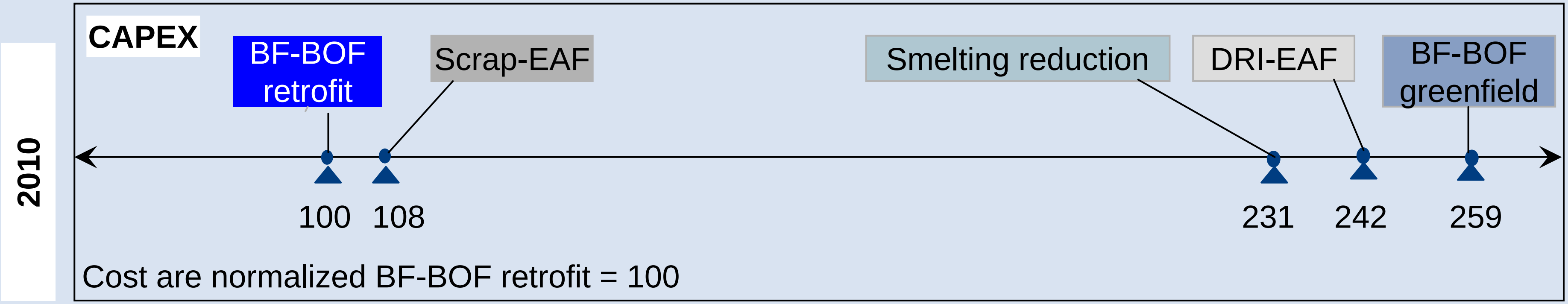
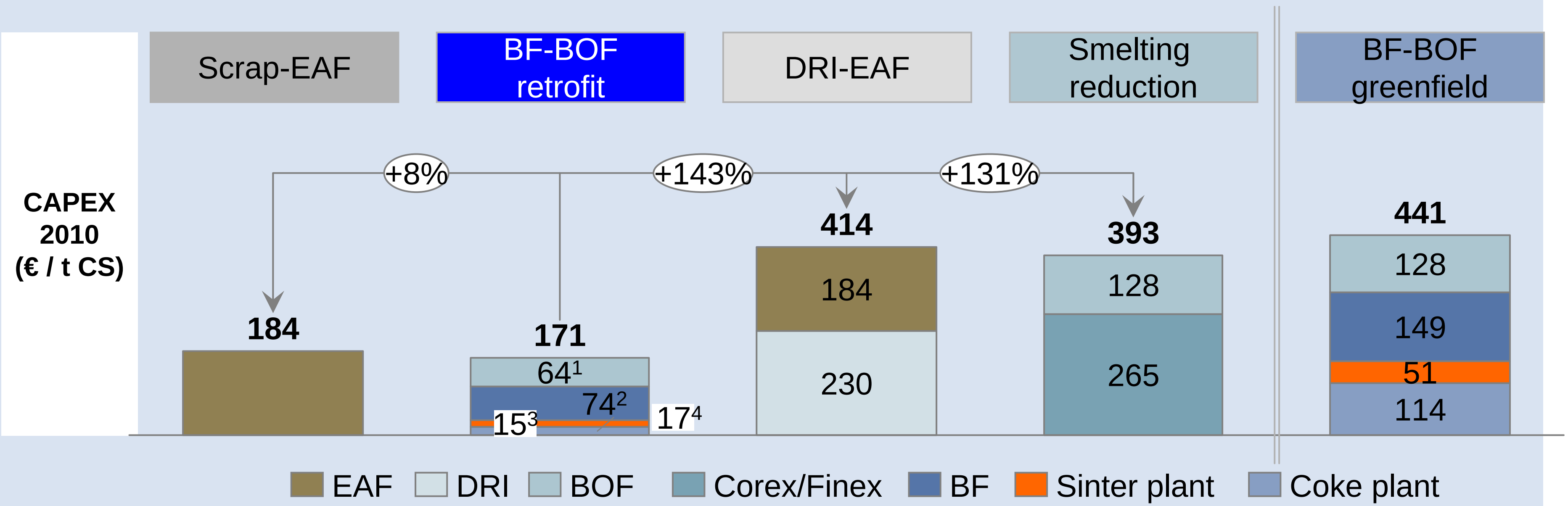
Source: BCG/VDEh





1. BOF: 50% of Greenfield investment 2. BF: 50% of Greenfield investment 3. Sinter: 30% of Greenfield investment 4. Coke: 15% of Greenfield investment

Note: CS = crude steel

Sources: Steel Institue VDEh; Project team analysis

Absolute CO_2 emissions in 2050 only 56% lower than 1990's if CCS fully implemented in 2050

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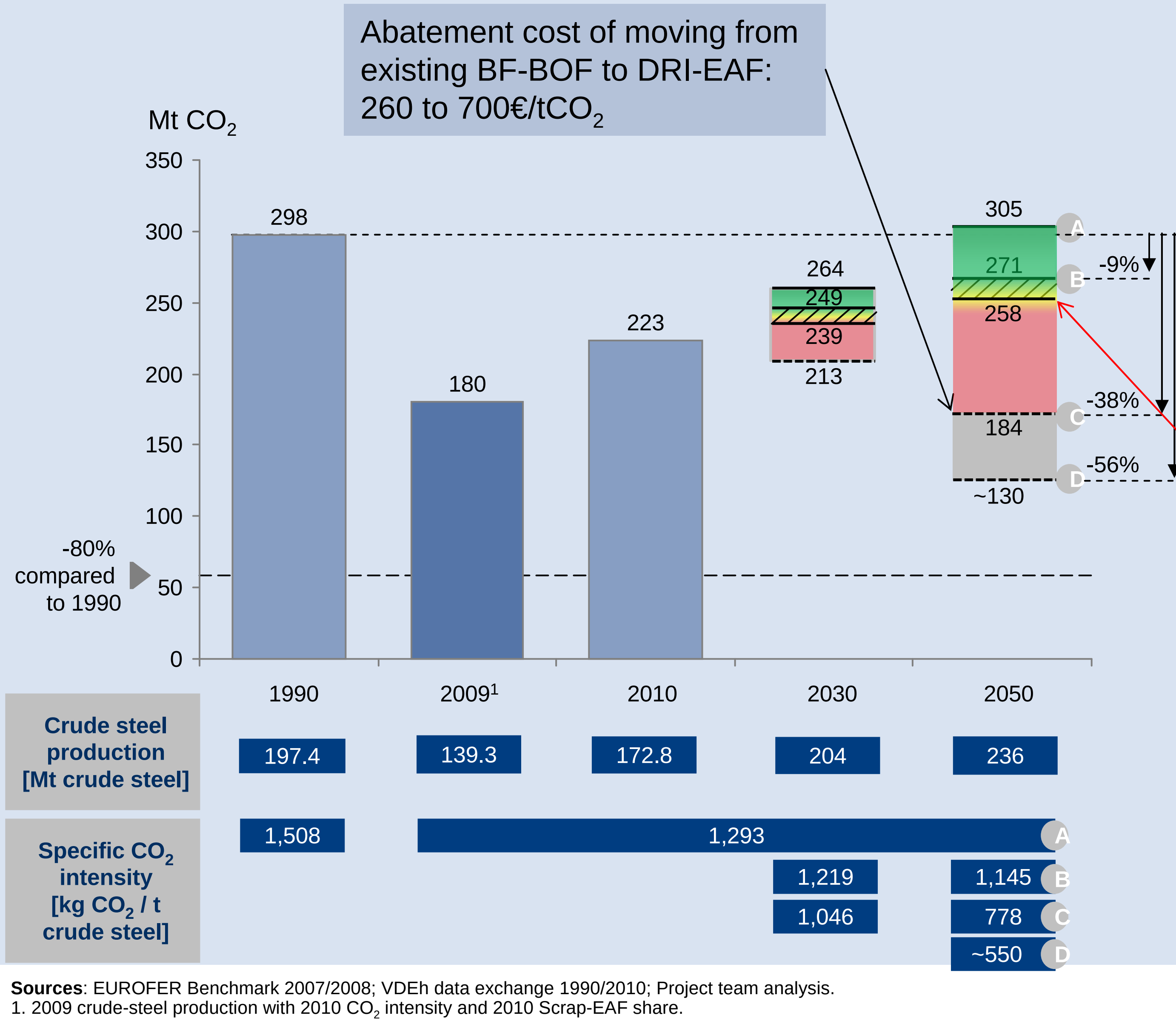

Upper boundary

- **A** Crude steel production forecast & CO_2 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 CO_2 intensity and 2010 Scrap-EAF share.

Abatement potential up to 2050

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Abatement potential compared to 2010 (intensity)

Reference year 2010 (specific emissions)	2030	2050
Economic scenario	**-9%**	**-15%**
Maximum theoretical abatement without CCS	-19%	-40%
Maximum theoretical abatement with CCS	-9%	-57%

Commission Roadmap for a Competitive Low Carbon Economy 2050 (table 9, source: PRIMES, GAINS)

Reference year 2005 (absolute emissions)	2030	2050
Overall	-35% to -40%	-77% to -81%
ETS	-43% to -48%	-88% to -92%
non-ETS	-24% to -36%	-66% to -71%

Steel as a mitigation enabler

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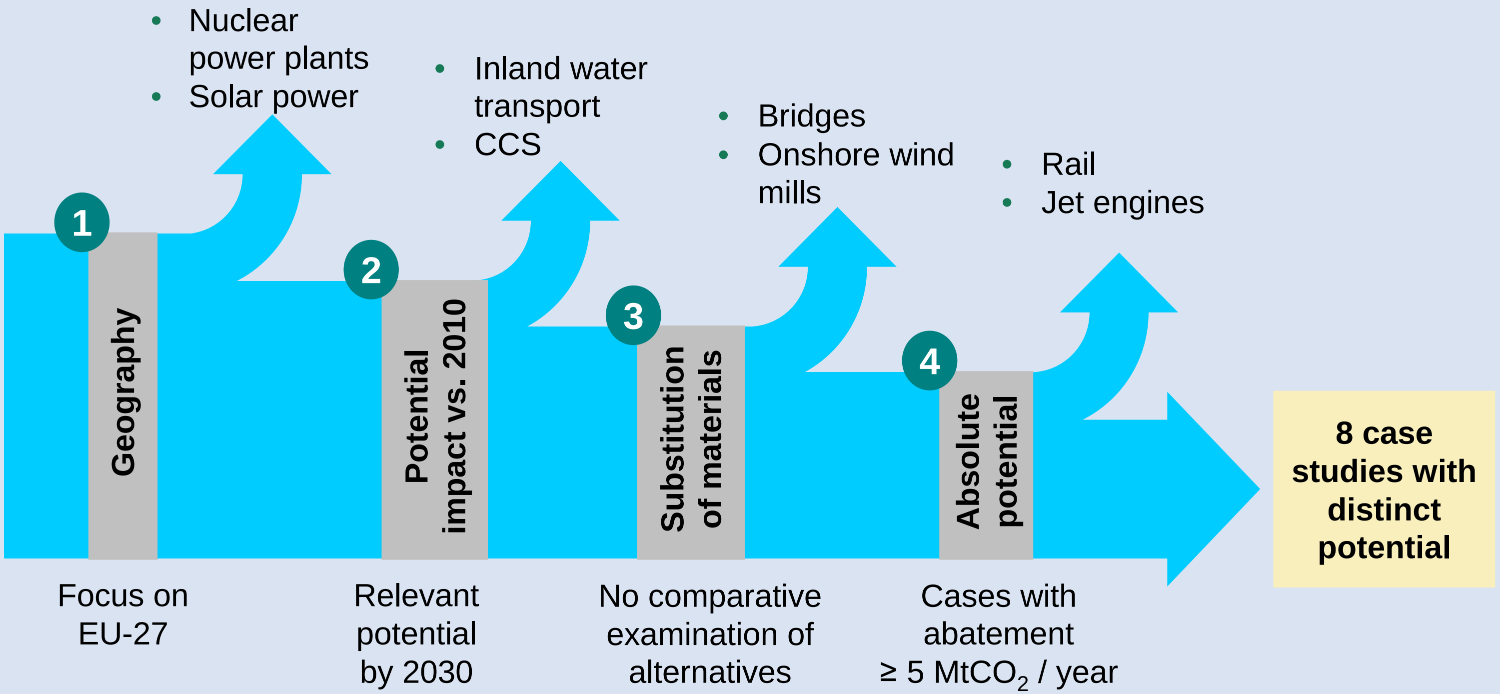
- Innovative steel-based emission-saving applications may help reduce CO_2 emissions
- Only saving that are 100% attributable to steel are taken into account
- Stringent 4-step logic applied to isolate the case studies for evaluating steel's own mitigation potential

Initial list

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



Sources: VDEh; BCG analysis.

Case studies for EU27 result in annual CO_2 savings of about 440 Mt while emitting only 70 Mt of extra CO_2

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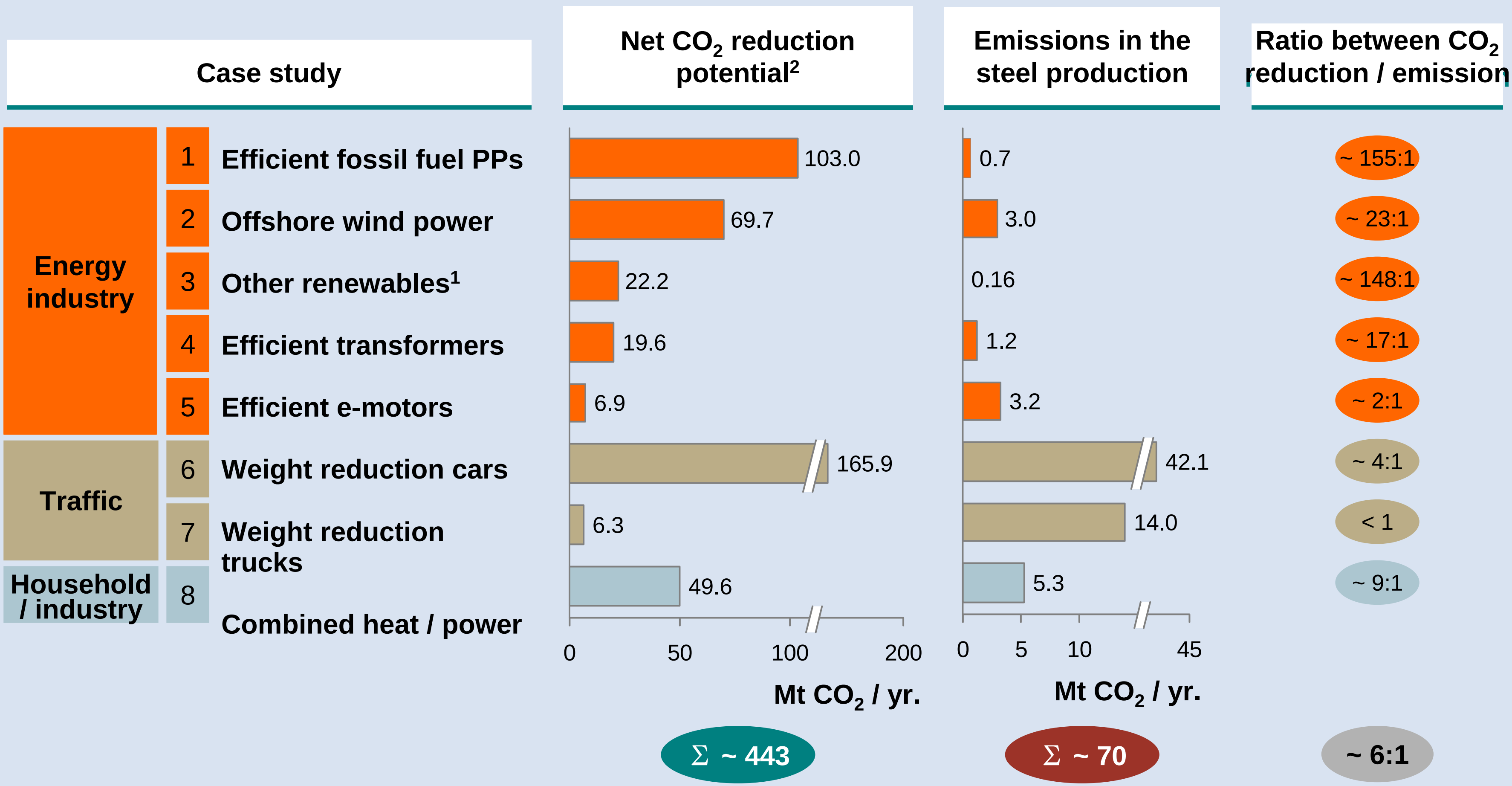

1. Bioenergy . 2. Net reduction refers to reduction attributable to steel.
Note: PP = power plant
Source: BCG analysis

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Steel Roadmap for a Low Carbon Europe

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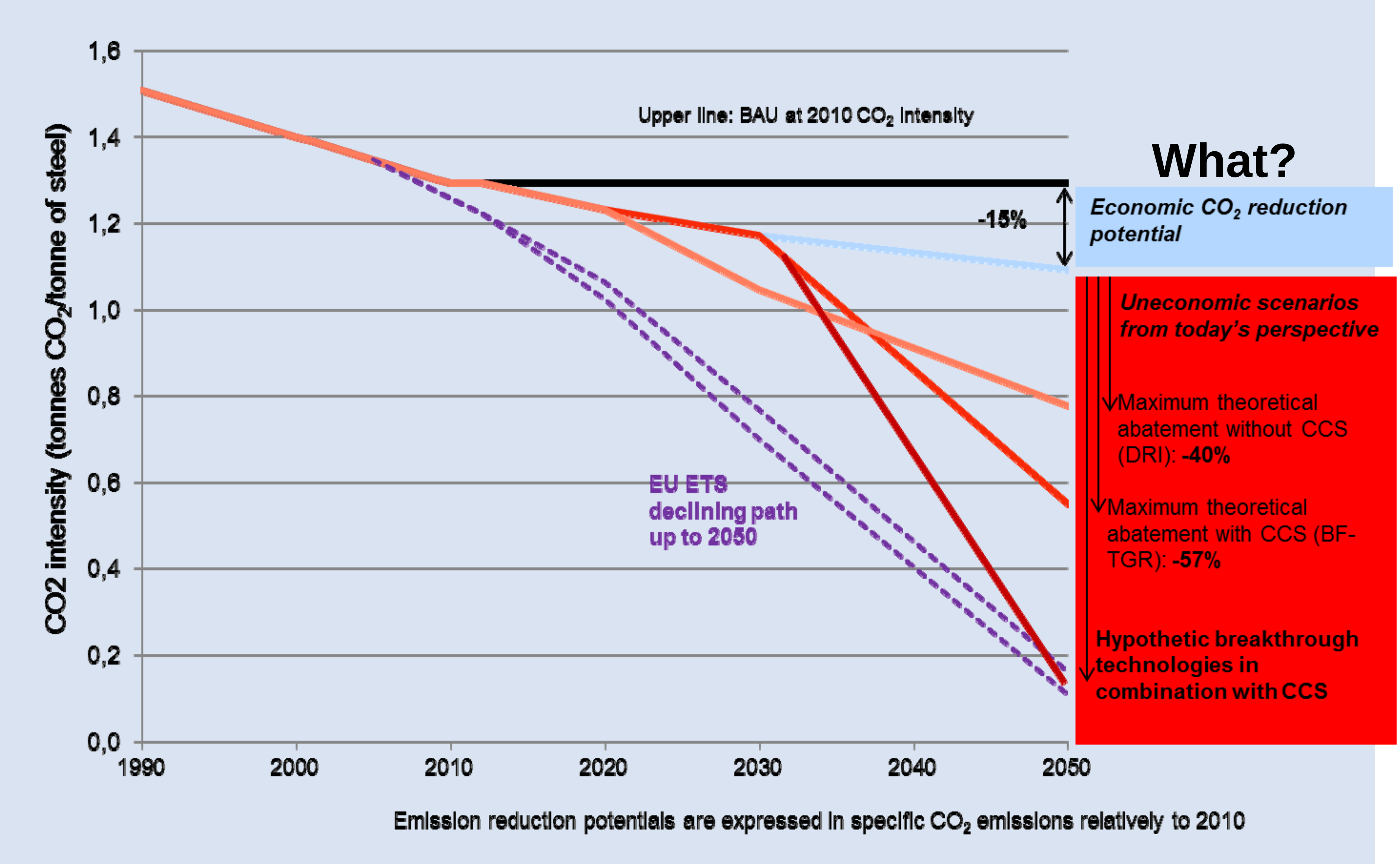
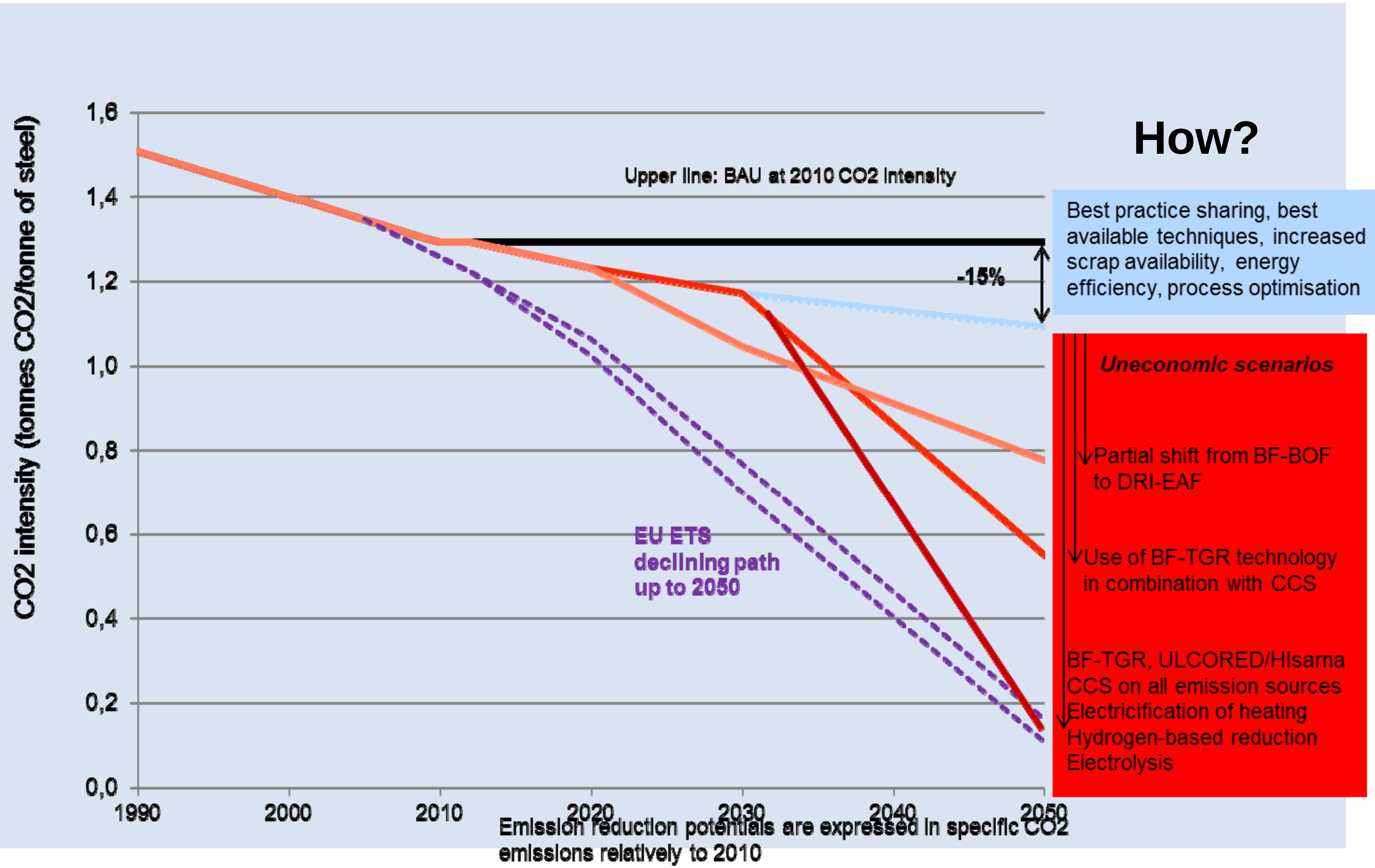
- Base on findings of the BCG/VDEh study
- Broader scope:
  - options for deeper cuts (HIsarna, Ulcored, electricity and hydrogen-based reduction,…)
  - deeper look into CCS
  - main challenges of the various options
  - competitiveness issues
  - policy recommendations (role of the ETS)
- Steel Low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

CO_2 intensity pathways up to 2050



CO_2 intensity pathways up to 2050



CO_2 intensity pathways up to 2050

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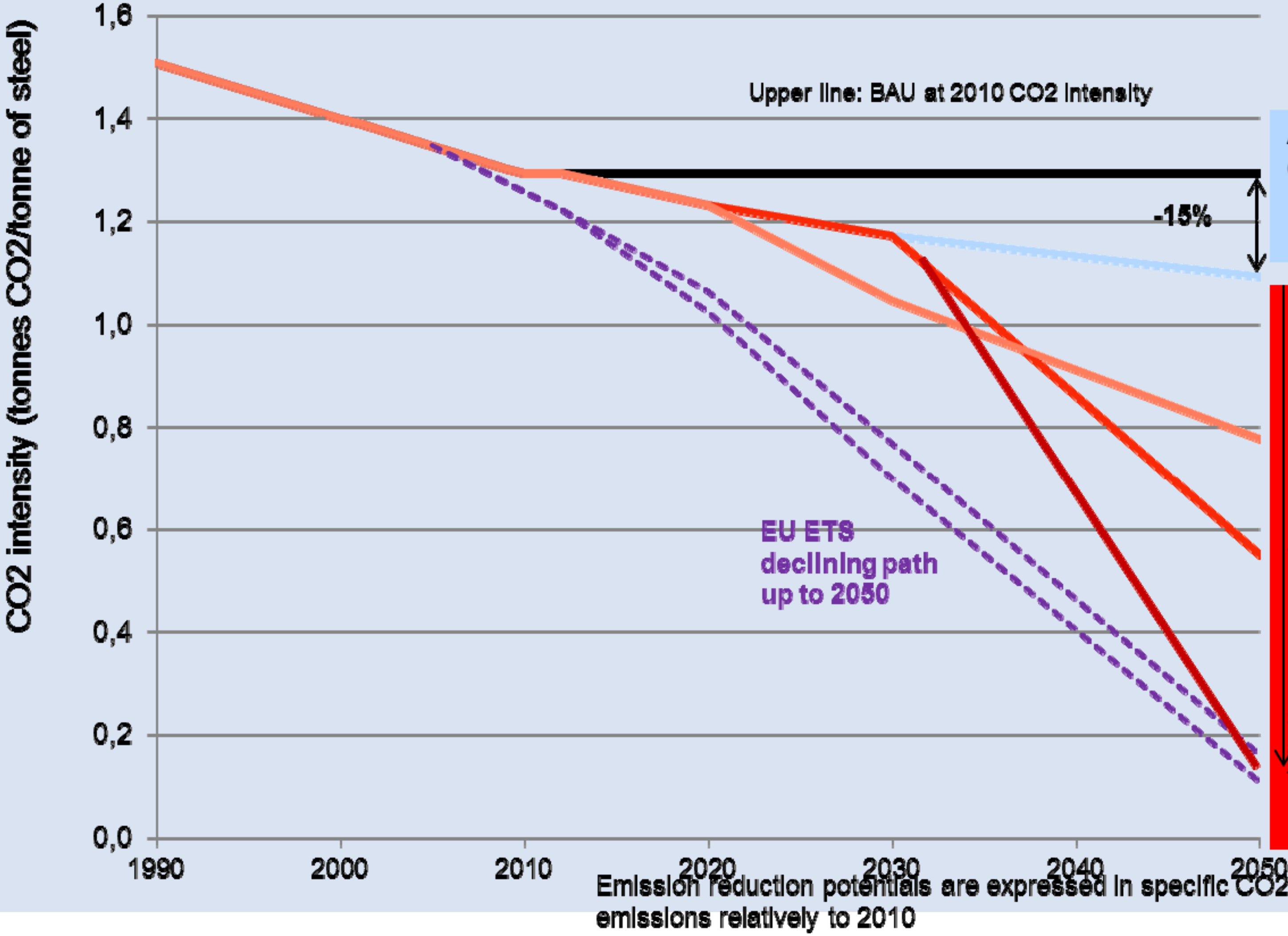

Conditions for success

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

What?	How?	Conditions for success
economic CO2 reduction potential	• continued decarbonisation of the power sector • increased scrap availability • best practice sharing • implementation of cost-effective incremental technologies	• access to scrap and energy at competitive prices • incentives through e.g. sectoral energy efficiency programmes • full offset of distortive CO_2 costs until level-playing field is restored
maximum theoretical abatement without CCS: **-40%**	partial shift from BF-BOF to DRI-EAF	NG and electricity prices such that natural gas-based DRI becomes competitive in Europe +
maximum theoretical abatement with CCS: **-57%**	use of BF-TGR technology in combination with CCS	support for demonstration and deployment of BF-TGR, access to CCS widespread at competitive prices +
hypothetic breakthrough technologies in combination with CCS	BF-TGR, ULCORED/HIsarna CCS on all emission sources electricification of heating hydrogen-based reduction electrolysis,…	support for R&D, demonstration and deployment of breakthrough technologies +

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An adequate set of climate policies for steel

What's wrong with the projected policy framework

- The CO_2 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 CO_2 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