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Potential for CO_2 Mitigation of the European Steel Industry

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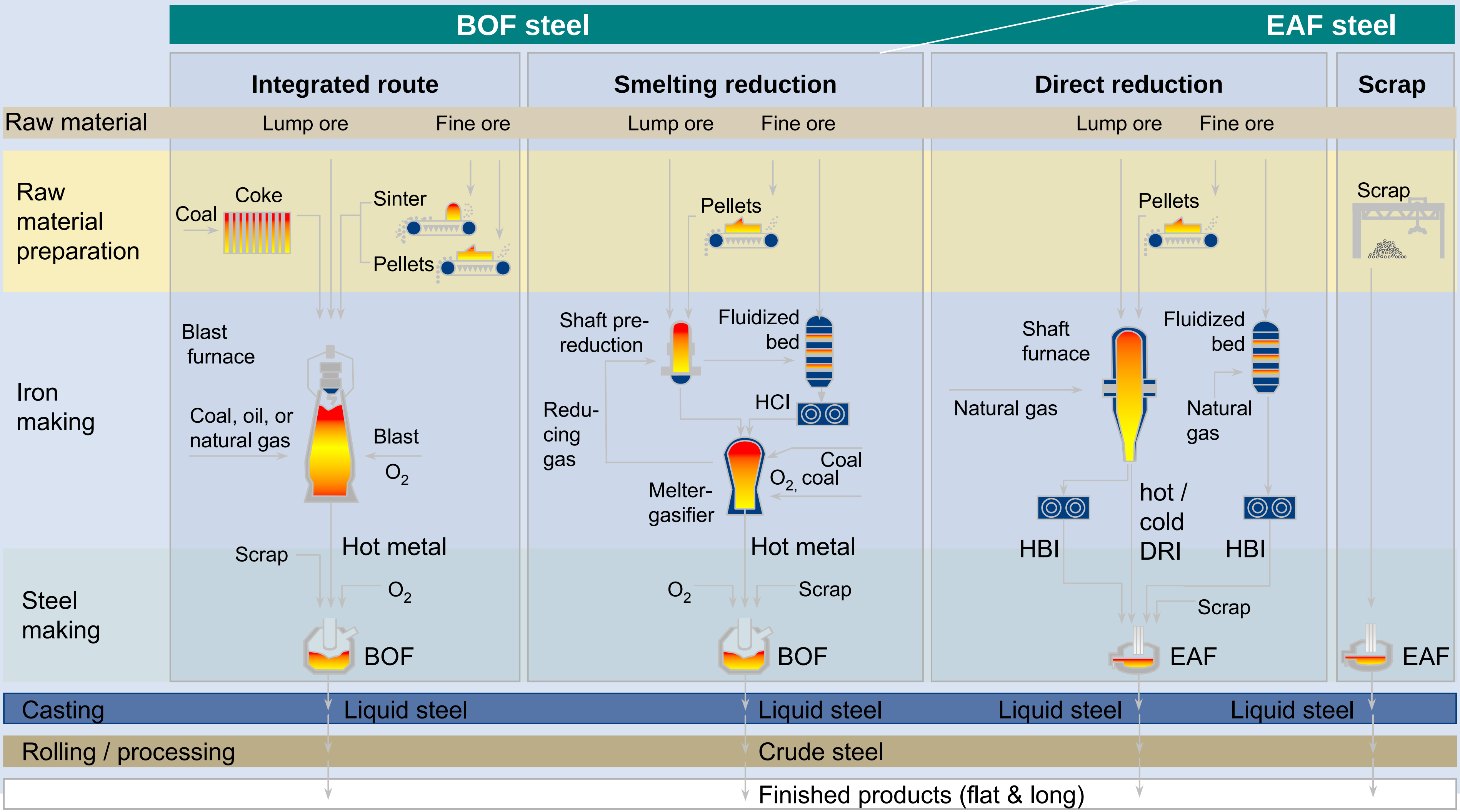
Agenda

- Introduction and background
- Baseline CO_2 emissions calculation of EU27 steel industry in 1990 and 2010
- Technology review
- Incremental CO_2 reduction Potentials
- Forecast for 2050 EU27 steel production and scrap availability
- CO_2 reduction for 2050 scenarios
- CO_2 mitigation by steel application
- Conclusions

Introduction and background

- European Union defined ambitious target for CO_2 emission reduction for European Industry of 80 to 95% compared to 1990 until 2050
- Therefore EUROFER contracted the Boston Consulting Group in collaboration with the Steel Institute VDEh to obtain a realistic view of the EU 27 steel sector's CO_2 mitigation capabilities based on physical / technical limits as well as economic considerations
- A functioning steel industry is crucial for Europe, hence BCG/VDEh do not assume a deindustrialization of Europe, but rather evaluate;-
  - Steels own CO_2 mitigation potential by sharing best practices, implementing incremental improvements and alternative steel-making technologies as well as combinations with CCS as an end-of pipe option
  - Indirect effects of steel as a mitigation enabler, i.e. the CO_2 savings by applications where steel and only steel leads to CO_2 savings

Overview of iron- and steel-making routes



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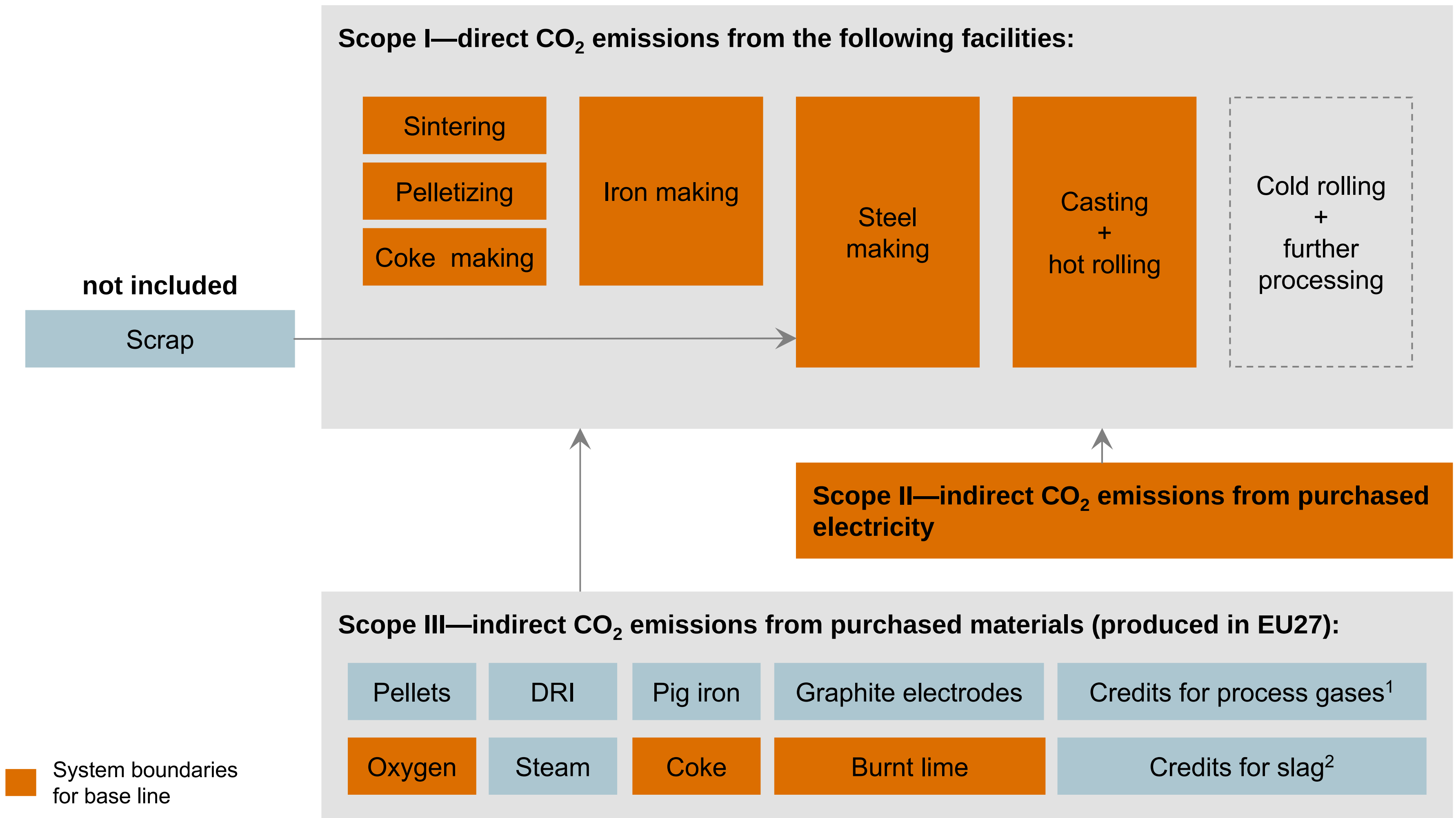
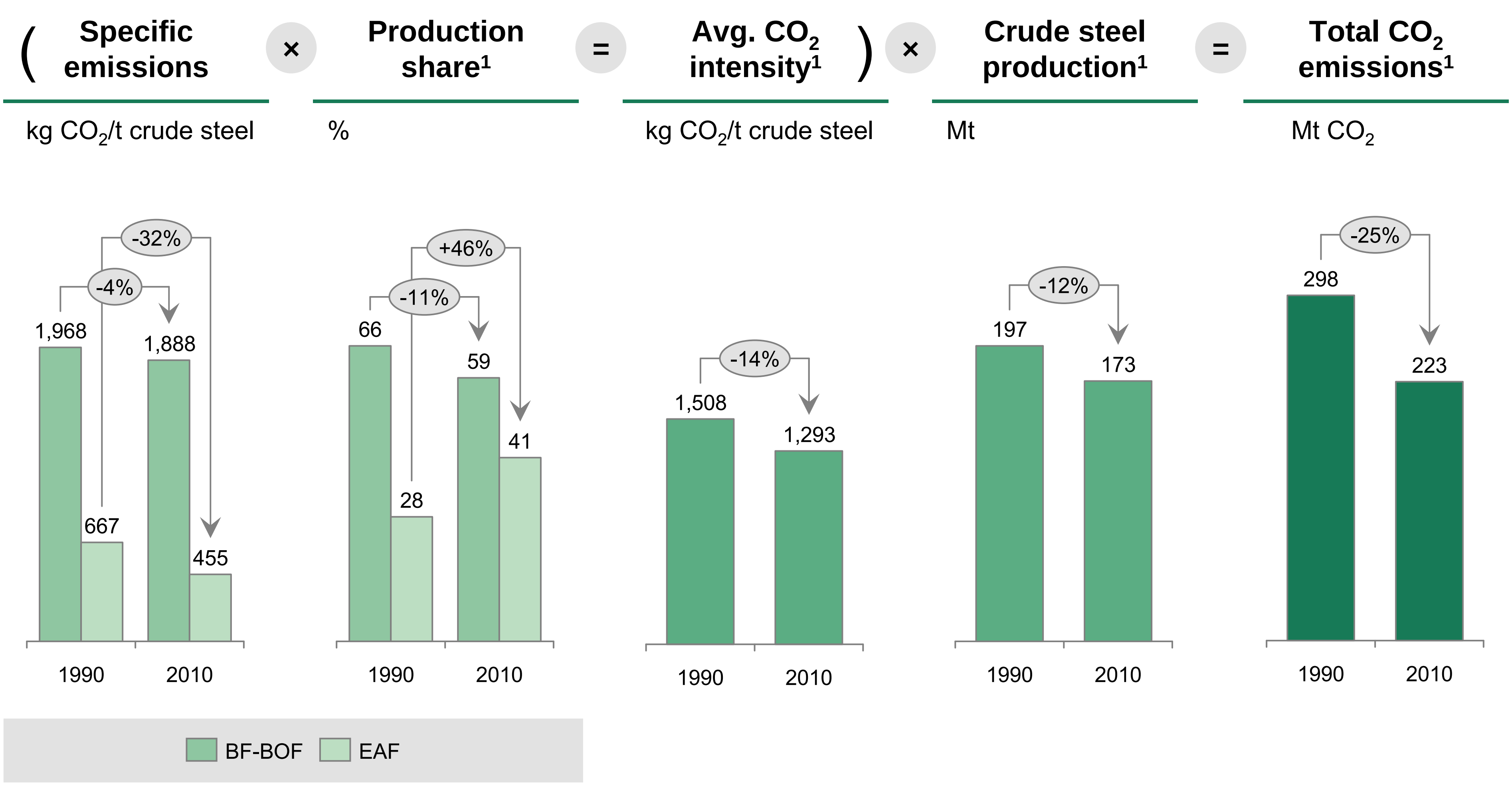
System boundaries mirror steel's CO_2 footprint originated in EU27



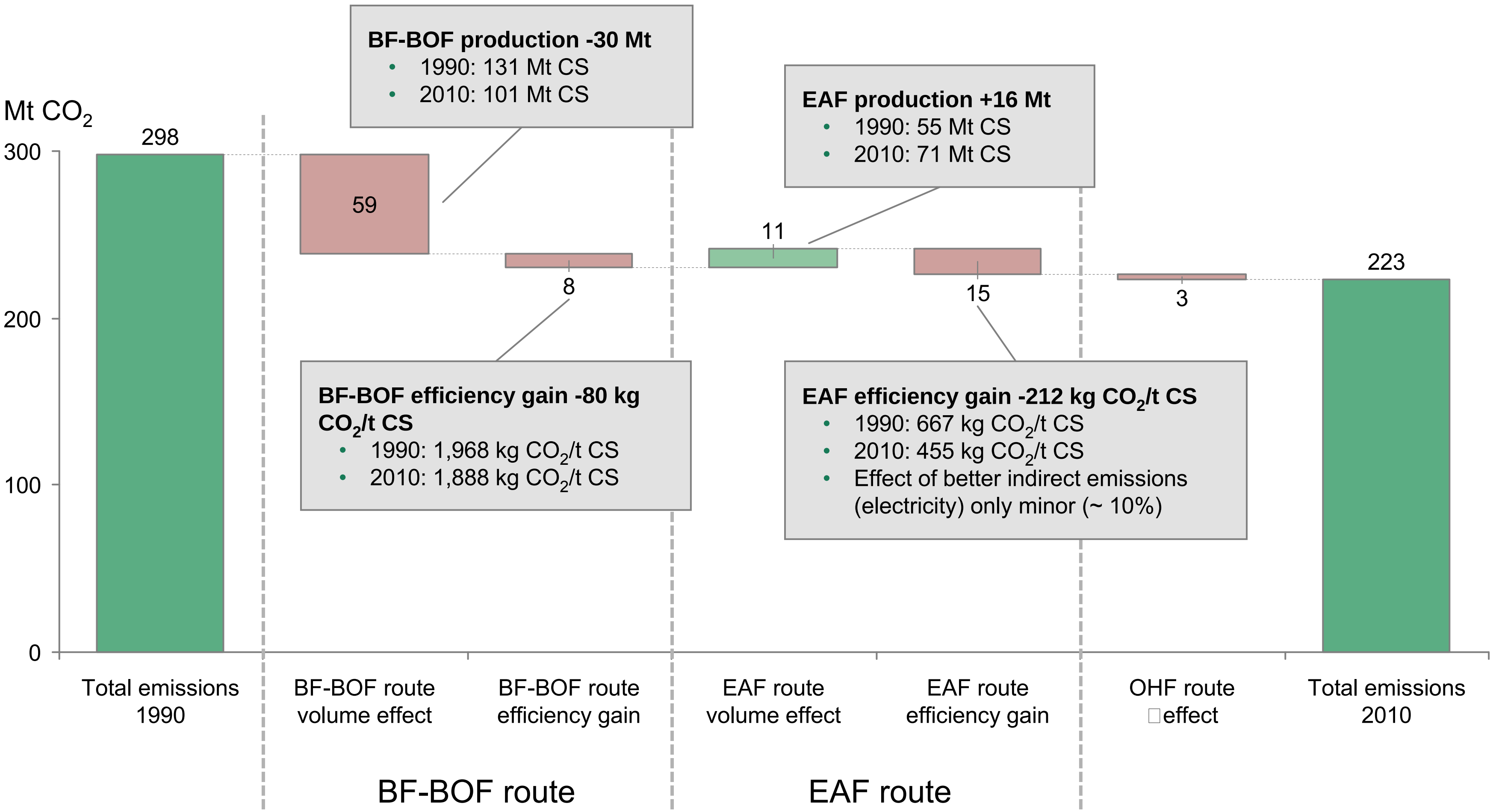
Sources: World Steel Association; Project team analysis.
1. The utilization of byproducts, such as process gases or waste heat, is not counted as a credit, because such use helps reduce the energy consumption of aggregates. Only byproduct gases that are sold to a second party can be counted as a credit, because they help to reduce emissions of a different sector. 2. Currently no credits are given for the CO_2 savings through slag usage in cement production.

The starting point: EU27's specific CO_2 intensity decreased 14%, absolute emissions in 2010 dropped by 25%, from 1990 figures



1. Includes BF-OHF share of 6 percent in 1990 and 0.4 percent in 2010, accounting for 3 and 0.2 Mt CO_2, respectively
Note: Figures include the process step of hot rolling
Source: EUROFER Benchmark 2007/2008; VDEh data exchange 1990/2010; Project team analysis

The development since 1990: Significant reduction of CO_2 emissions from 1990 to 2010, mainly driven by volume effects



Note: Includes all direct and upstream emissions as well as casting and hot rolling; BF-OHF route volume 1990: 11 M; CS = crude steel
Source: EUROFER Benchmark 2007/2008; VDEh data exchange 1990/2010; Project team analysis

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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 • Waste gas recovery	• Heat recovery • Optimization
Alternative (Substitution and Breakthrough)		• Corex • Finex • HIsarna	• Midrex / HyL based on natural gas • Finmet / Ulcored based on natural gas + fine ores
		Synergies between different technologies[2]	
		• 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

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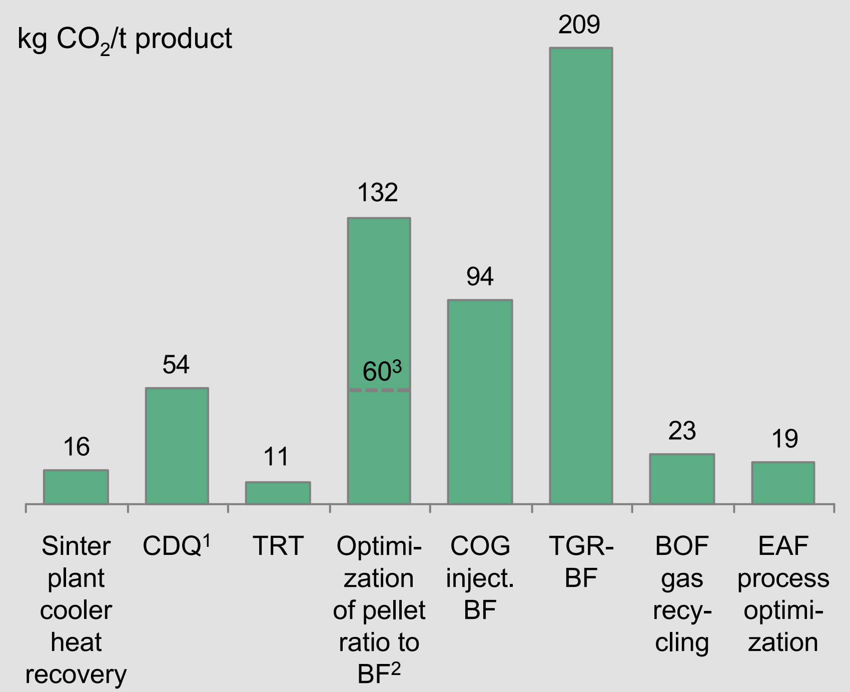
Overview of the CO_2 abatement potential of incremental technologies applied in economically viable scenarios

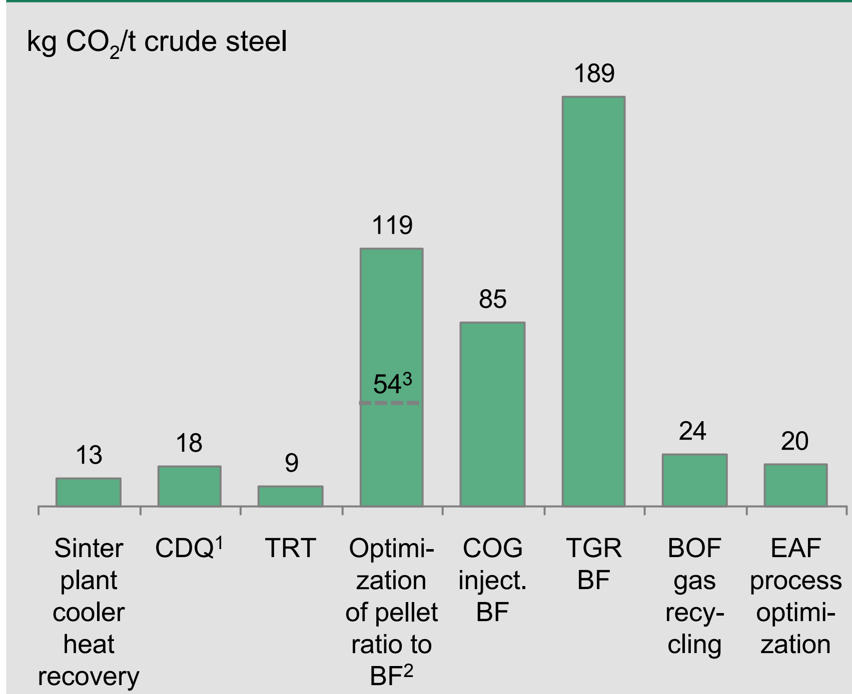
Per ton product: CO_2 saving potential



Penetration in 2010 (%):

Sinter plant cooler heat recovery	CDQ[1]	TRT	Optimization of pellet ratio to BF[2]	COG inject. BF	TGR-BF	BOF gas recycling	EAF process optimization
20	10	45	8	2	0	75	0

Per ton of crude steel: CO_2 saving potential



1. It is sometimes argued that during wet quenching around 1 percent of the coke produced is lost because of burning when the coke is in contact with the surrounding air during transport to the quenching facility. This would reduce CO_2 savings from 54 to 22 kg CO_2 per ton of coke for 2010. Assuming a CO_2 intensity of 210 g CO_2 per kWh, this would even result in a negative CO_2 balance for CDQ of about 6 kg CO_2 per ton of coke 2. 100% pellet ratio assumed for calculations 3. If credits for slag were to be taken into consideration, this would reduce the effect of 100 percent pellet-operated BFs by 72 kg CO_2 per ton of hot metal (or 65 kg CO_2 per ton of crude steel) because of a lower slag volume of around 130 kg (based on operational plant data). Depending on the grade of pellets, fluxes—which normally are bound into the sinter–may have to be charged directly into the BF, which could increase CO_2 emissions from blast furnace operations. In optimizing the pellet ratio the trade off between operational benefits due to lower slag volumes and less CO_2 savings in the cement industry pertaining to slag, have to be considered

Note: Saving potential per ton of crude steel is calculated on the basis of respective material-input amounts as well as yield factors for each process step

Source: BFI; Steel Institute VDEh; Project team analysis

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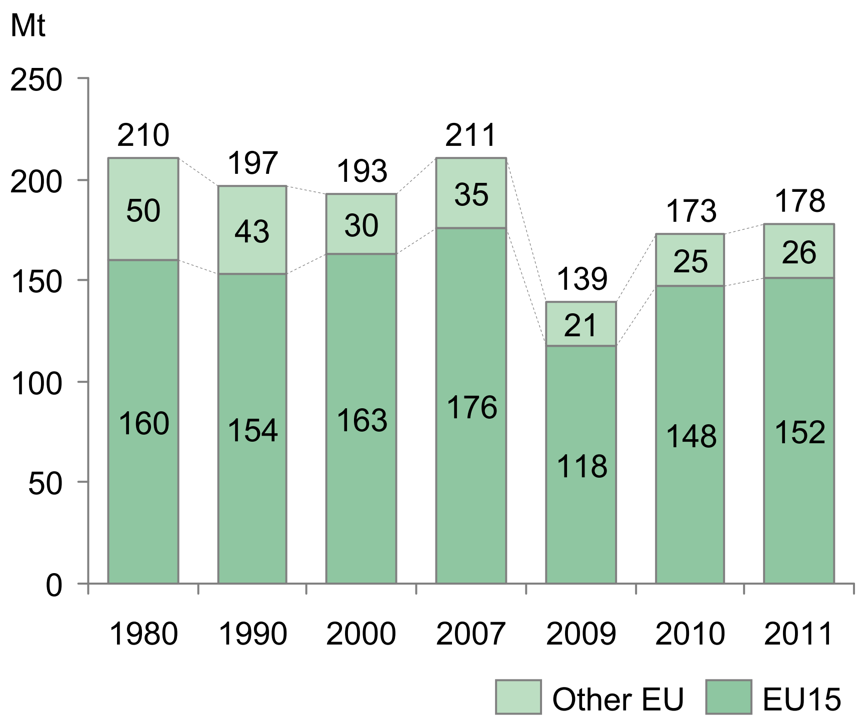
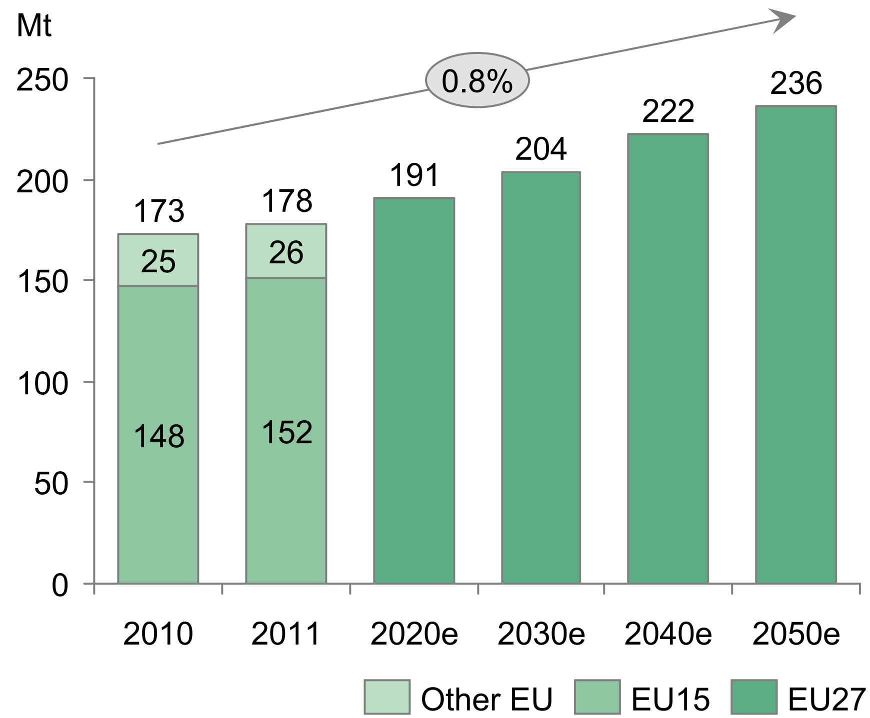
The baseline forward: Moderate annual growth of crude steel production expected (0.8 percent from 2010 until 2050)

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



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



Note: e = estimate
Source: World Steel Association; Project team analysis

Scrap availability forecasted to grow by 0.9 percent 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

Crude steel production × Scrap rate (%)

Home scrap

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

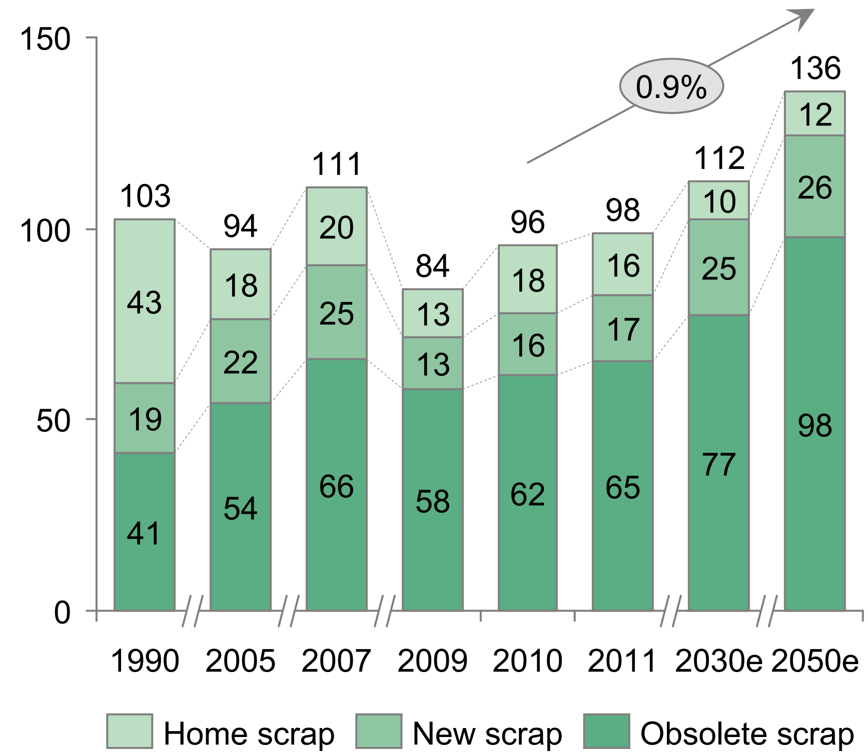
Finished steel consumption per sector × Scrap rate (%)

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: Project team analysis

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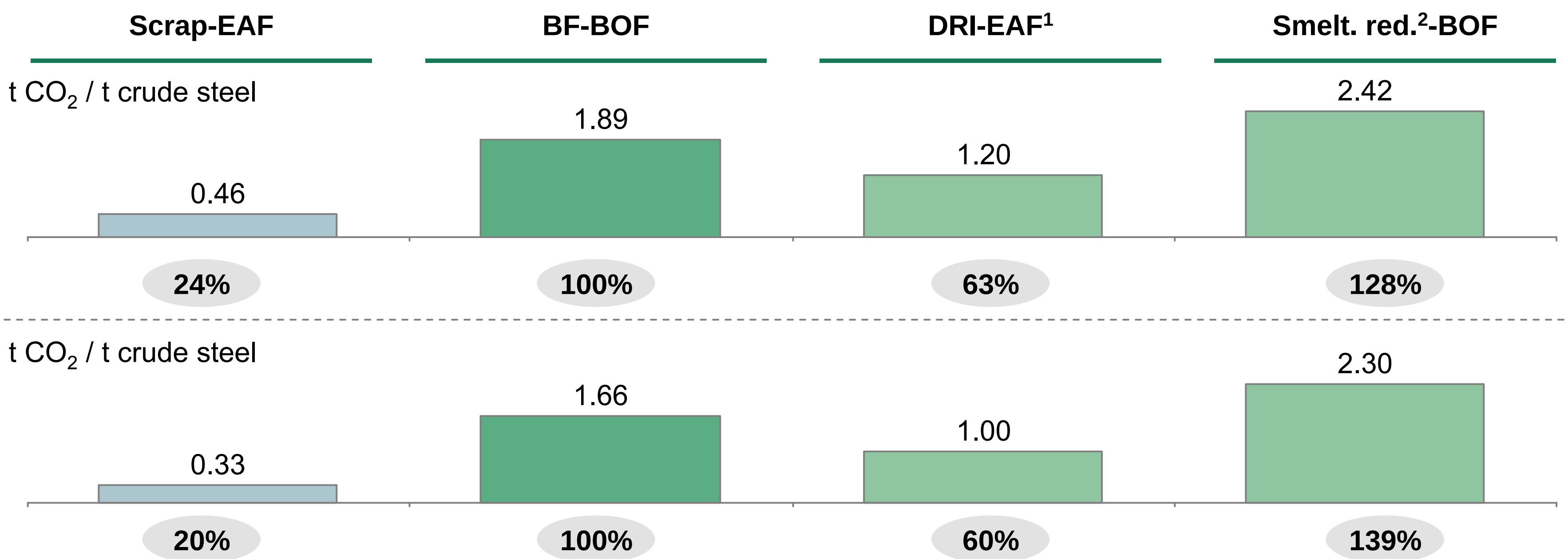
Overview of CO_2 intensity per route for 2010 and 2050



Dri-vers

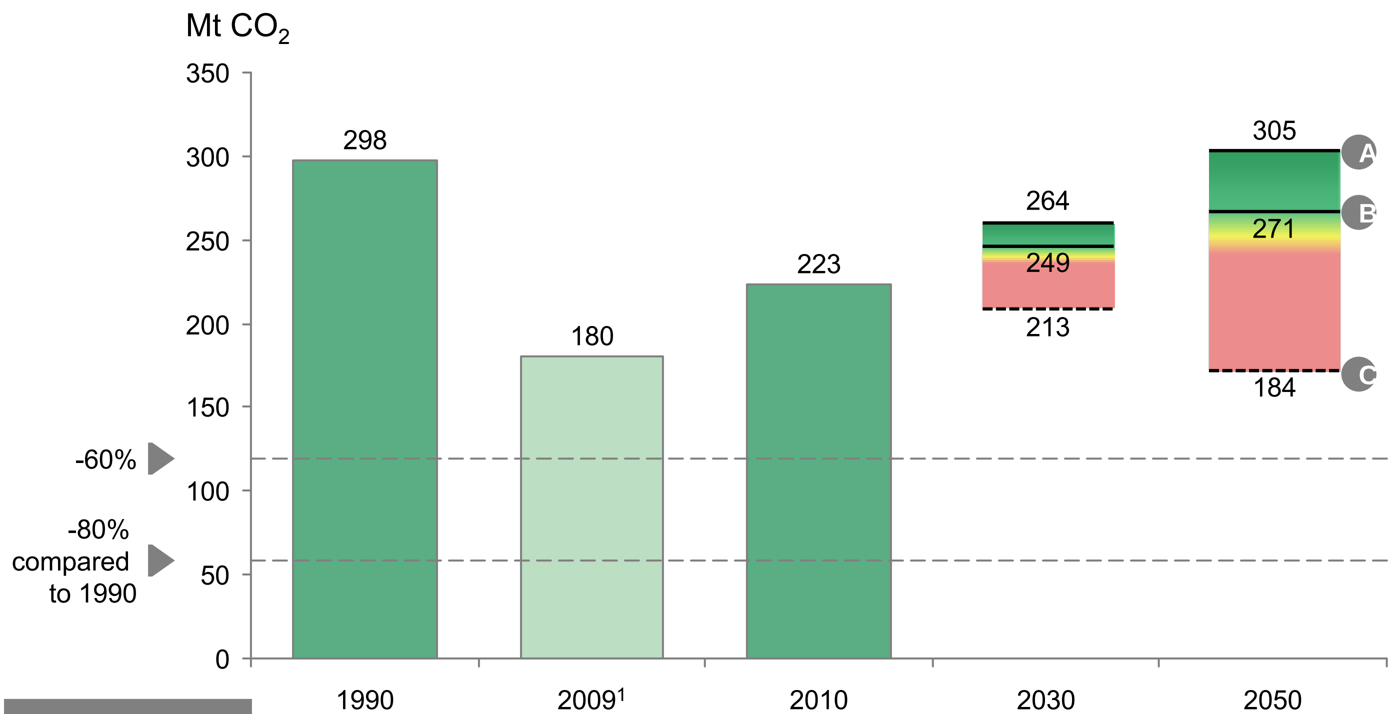
- Best-practice sharing + incremental technologies (Scrap-EAF, BF-BOF)
- Hot charging in 2050 (DRI-EAF)
- 5% efficiency gain (Smelt. red.-BOF)
- CO_2 intensity of purchased electricity (**429 g CO_2 / kWh** in 2010 and **221 g CO_2 / kWh** in 2050)

Notes

	Scrap-EAF	BF-BOF	DRI-EAF	Smelt. red.-BOF
Notes		Only pellets produced in EU27 are included	All pellets (1,120 kg) w/ 105 g CO_2 / t pellet rucksack	
		Self sufficiency in terms of electricity		Self sufficiency in terms of electricity

1. Based on Midrex direct reduction technology 2. Based on Finex smelting reduction technology
Note: Differences between routes in production of the by-product slag not considered in analysis
Sources: VDEh; Project team analysis

The option space for possible CO_2 abatement until 2050



	1990	2009[1]	2010	2030	2050	
Crude steel production [Mt crude steel]	197.4	139.3	172.8	204	236	
Specific CO_2 intensity [kg CO_2/t crude steel]	1,508	1,293				A
				1,219	1,145	B
				1,046	778	C

Upper boundary

- A: CSP forecast + CO_2 intensity on 2010 level
- B: Increased EAF-share based on scrap availability + best-practice sharing

Lower theoretical boundary without CCUS

- C: 44% Scrap-EAF, 45% DRI-EAF, 11% BF-BOF; incremental improvements esp. for BF-BOF

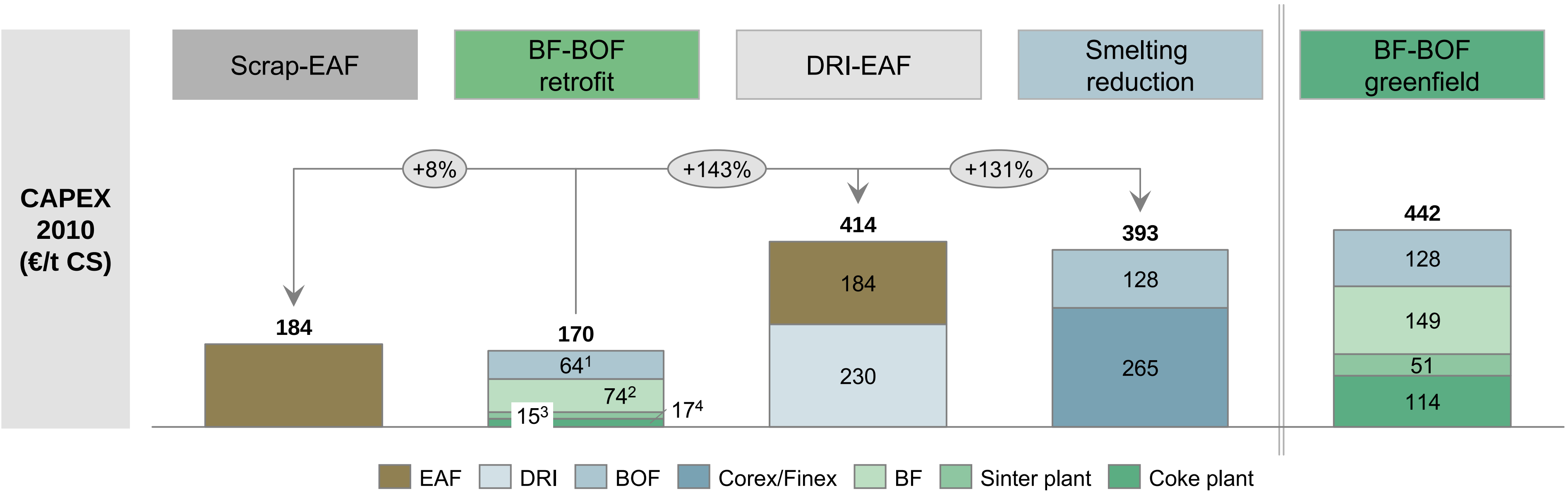
Economically viable
Not economically viable

1. 2009 crude -steel production with 2010 CO_2 intensity and 2010 Scrap-EAF share
Source: EUROFER Benchmark 2007/2008; VDEh data exchange 1990/2010; Project team analysis

Economic feasibility assessment of the technologies

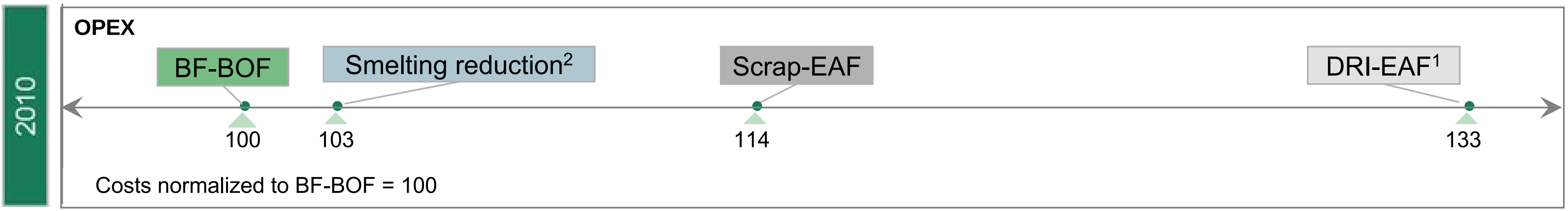
- Economic feasibility was computed by comparing costs (CAPEX et OPEX) with the potential savings over considered investment period, depending on different price scenarios
- The price scenarios included a reference-price scenario (inflation only), medium-price scenario (doubling of real input factor costs) and high-price scenario (fivefold increase of input factor costs)
- The economically feasible technologies were gradually implemented based on varying adaptation curves for the different scenarios

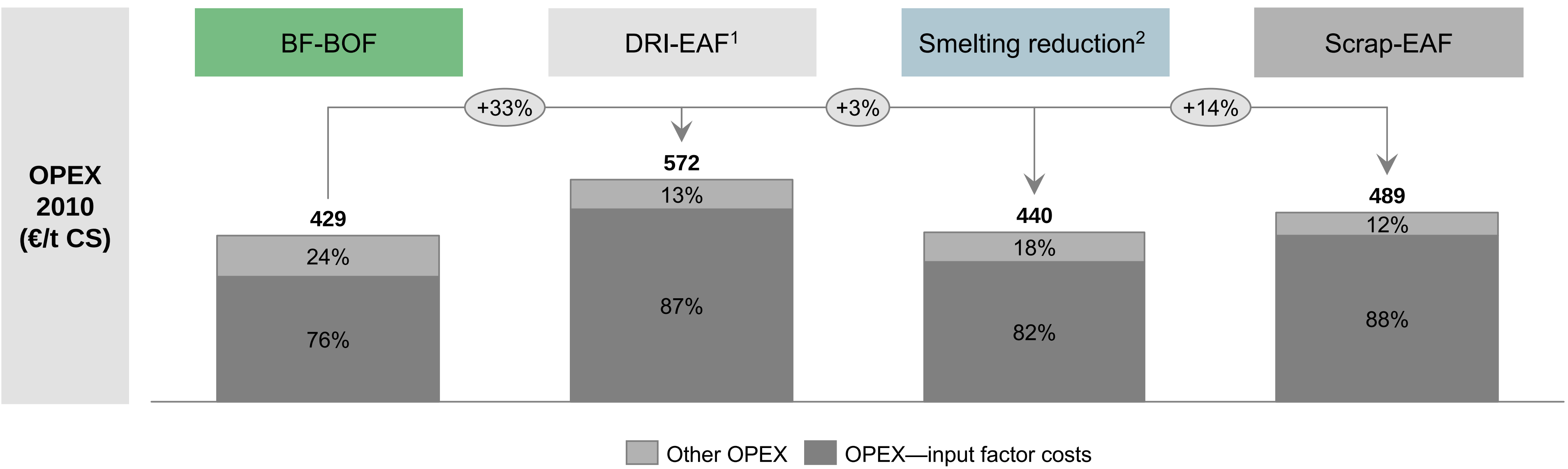
A comparison of capital expenditures for alternative steel-making technologies



1. BOF: 50 percent of Greenfield investment 2. BF: 50 percent of Greenfield investment 3. Sinter: 30 percent of Greenfield investment 4. Coke: 15 percent of Greenfield investment
Note: CS = crude steel
Source: Diemer et. al., 2011; Steel Institute VDEh; Project team analysis

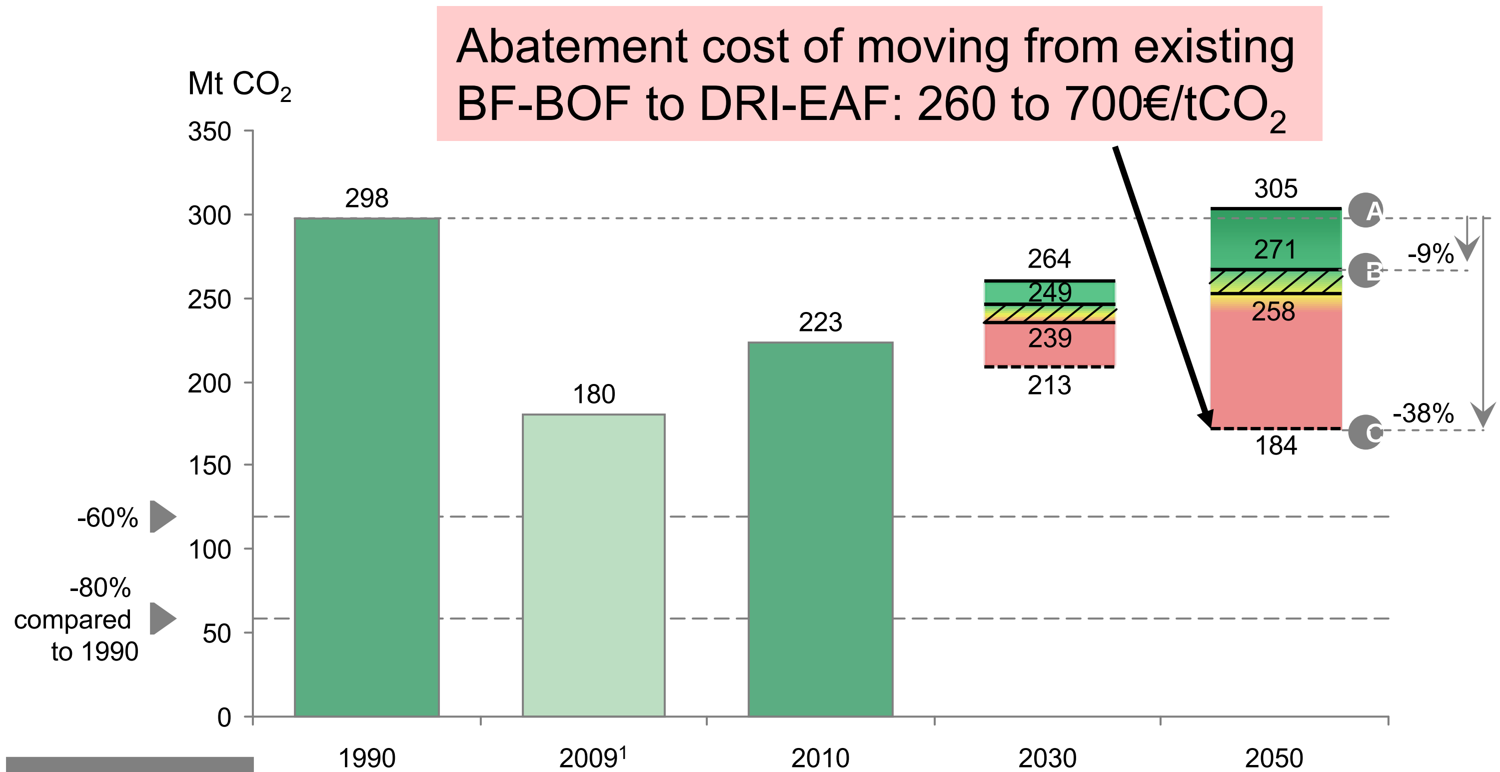
A comparison of the operating expenses of alternative steel-making technologies





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

CO_2 Abatement Economic Scenarios for 2050: Around 10-13 Percent as Compared with 1990 (Close to Point B)



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Specific CO_2 intensity [kg CO_2/t crude steel]	1,508	1,293				A
				1,219	1,145	B
				1,046	778	C

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 CCUS

- (C) 44% Scrap-EAF, 45% DRI-EAF, 11% BF-BOF; increased improvements, especially for BF-BOF

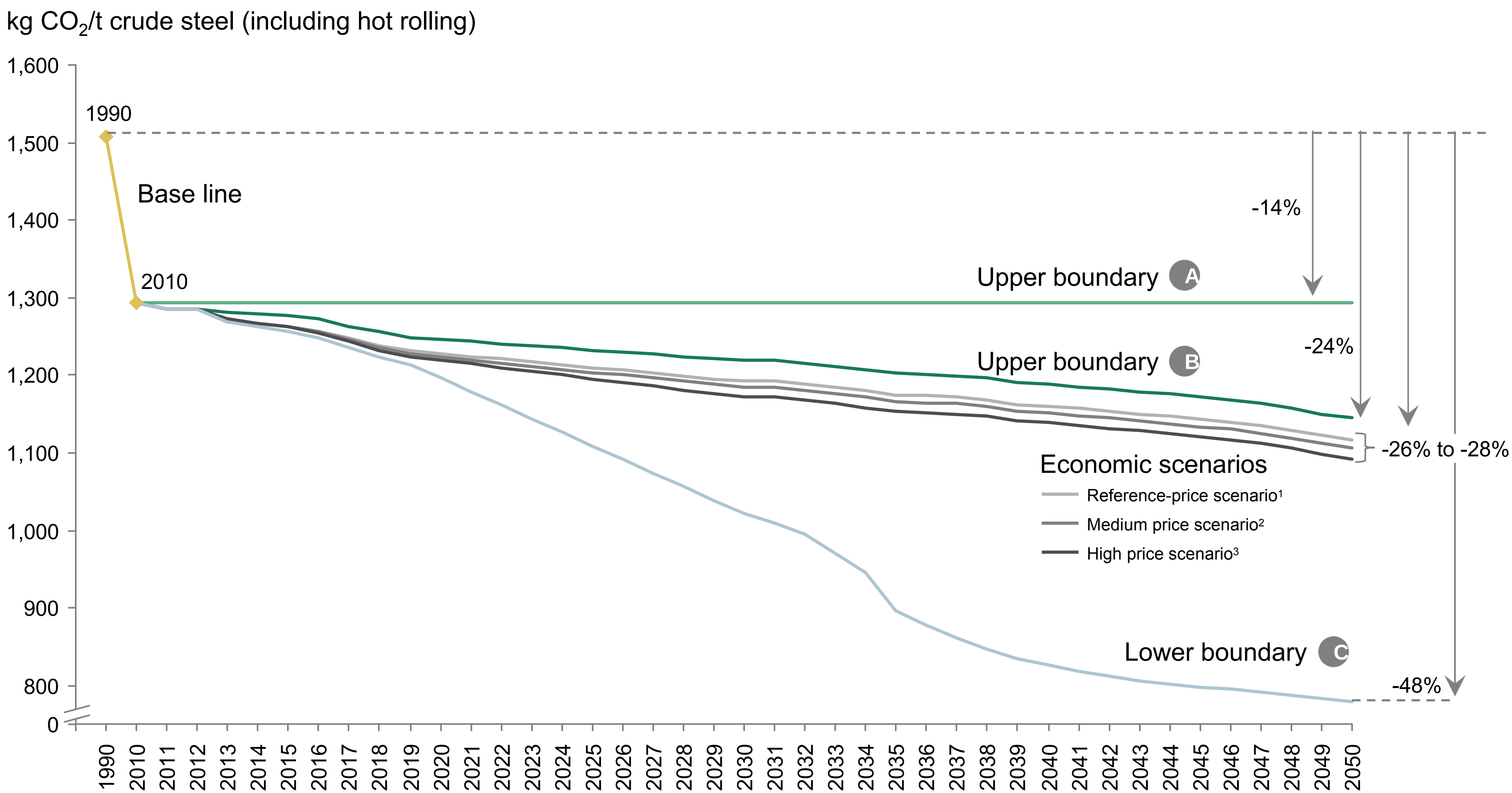
Economically viable

Not economically viable

1. 2009 crude -steel production with 2010 CO_2 intensity and 2010 Scrap-EAF share

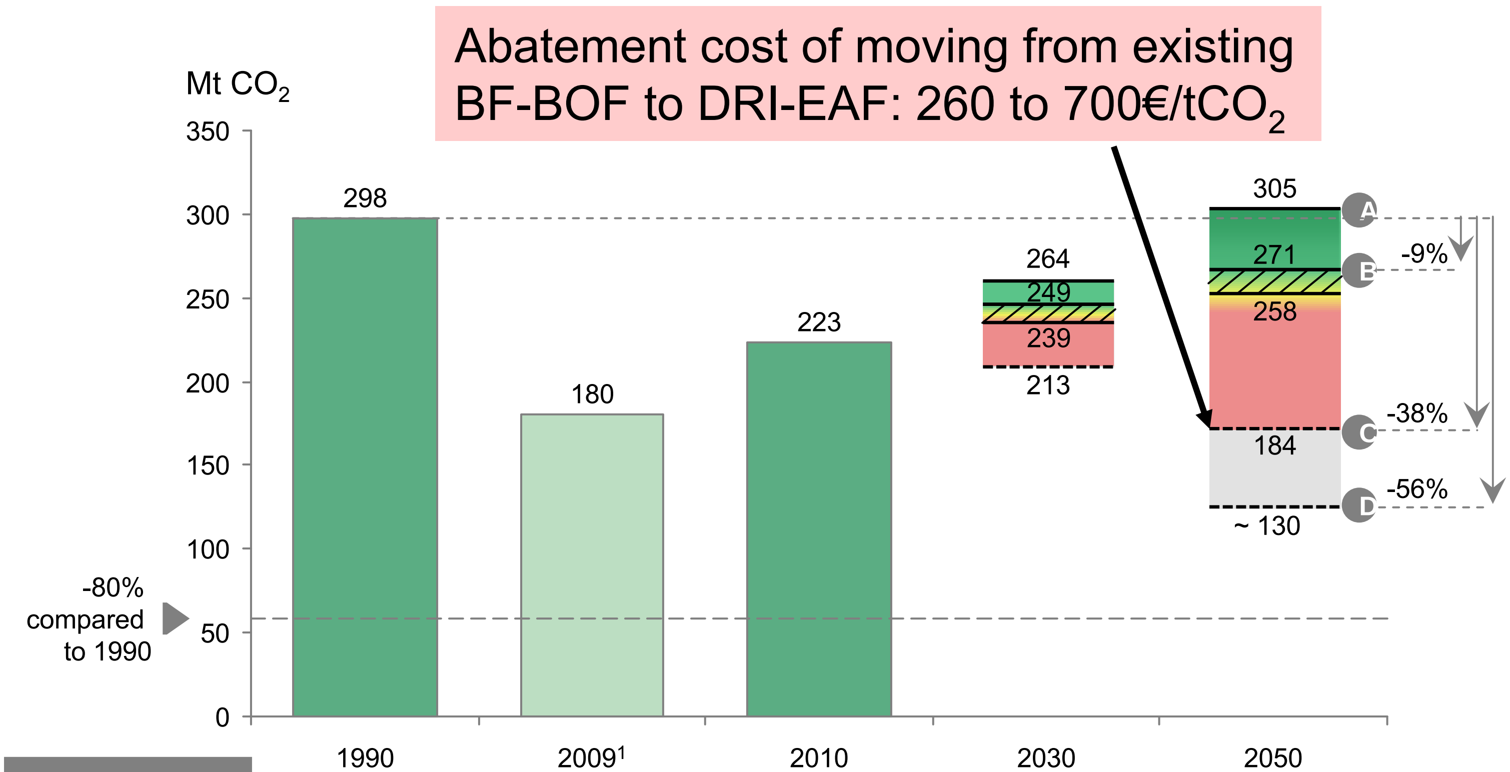
Source: EUROFER Benchmark 2007/2008; VDEh data exchange 1990/2010; Project team analysis

Development of average specific CO_2 intensity for different scenarios (without CCUS)



1. Input factor prices adjusted for inflation 2. Doubling of (real) input-factor prices from 2010 until 2050 3. Fivefold increase of (real) input-factor prices from 2010 to 2050
Note: All scenarios are without CCUS
Source: EUROFER Benchmark 2007/2008; VDEh data exchange 1990/2010; Project team analysis

Absolute CO_2 emissions in 2050 could be almost 60% lower than in the 1990s with the full implementation of CCUS



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Specific CO_2 intensity [kg CO_2/t crude steel]	1,508	1,293 (A)	1,293 (A)	1,293 (A)	1,293 (A)
				1,219	1,145 (B)
				1,046	778 (C)
					~ 550 (D)

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 CCUS

(C) 44% Scrap-EAF, 45% DRI-EAF, 11% BF-BOF; increased improvements, especially for BF-BOF

Lower theoretical boundary with CCUS

(D) 44% Scrap-EAF, 56% BF-BOF+TGR, DRI-EAF, or SR-BOF

Economically viable

Not economically viable

1. 2009 crude-steel production with 2010 CO_2 intensity and 2010 Scrap-EAF share

Source: EUROFER Benchmark 2007/2008; VDEh data exchange 1990/2010; Project team analysis

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Stringent four-step logic applied to isolate the case studies for evaluating steel's own mitigation potential

Initial list

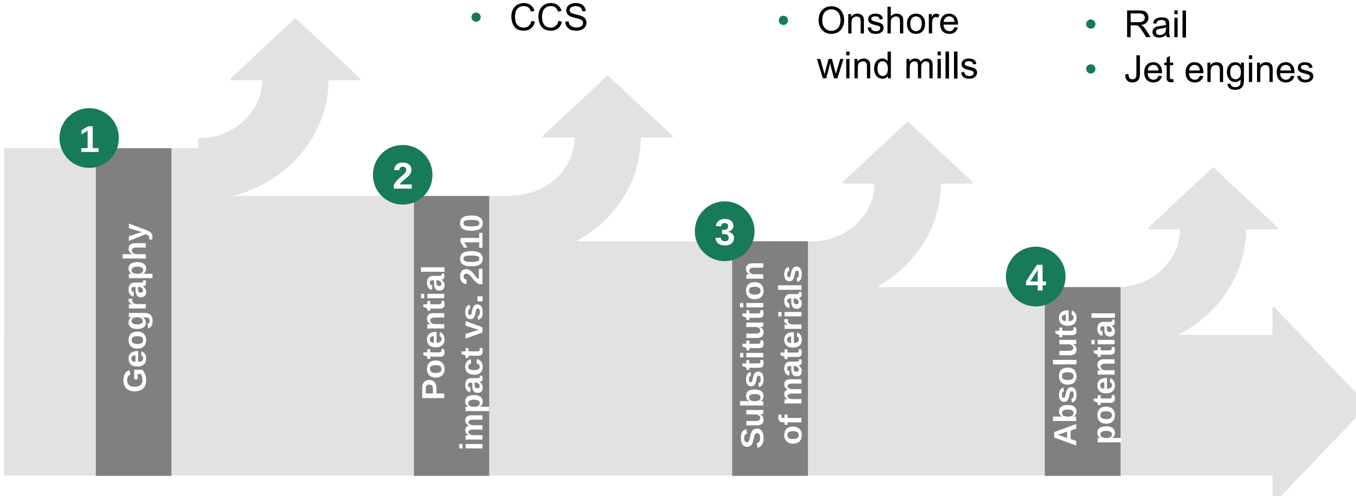
- Weight reduction cars
- Onshore/offshore wind power
- Leaf springs
- Rubber-enforcing steel structures for tires
- Motor systems
- Assembled camshafts
- CCS
- Structural steel
- …

Excluded at step 1:
- Nuclear power plants
- Solar power

Excluded at step 2:
- Inland water transport
- CCS

Excluded at step 3:
- Bridges
- Onshore wind mills

Excluded at step 4:
- Rail
- Jet engines



1. Focus on EU-27
2. Relevant potential by 2030
3. No comparative examination of alternatives
4. Cases with abatement ≥ 5 $MtCO_2$ / year

8 case studies with distinct potential

Selection: Only savings that are 100% attributable to steel are taken into account

Sources: VDEh; BCG/VDEh analysis.

Eight case studies for EU27 show annual CO_2 savings of about 440 Mt attributed to steel and only 70 Mt of extra CO_2 Emissions

		Case study	Net CO_2 reduction potential[2] (Mt CO_2 / yr.)	Emissions in the steel production (Mt CO_2 / yr.)	Ratio between CO_2 reduction / emission
Energy industry	1	Efficient fossil fuel PPs	103.0	0.7	~ 155:1
	2	Offshore wind power	69.7	3.0	~ 23:1
	3	Other renewables[1]	22.2	0.16	~ 148:1
	4	Efficient transformers	19.6	1.2	~ 17:1
	5	Efficient e-motors	6.9	3.2	~ 2:1
Traffic	6	Weight reduction cars	165.9	42.1	~ 4:1
	7	Weight reduction trucks	6.3	14.0	< 1
Household / industry	8	Combined heat / power	49.6	5.3	~ 9:1
			Σ ~ 443	Σ ~ 70	~ 6:1

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

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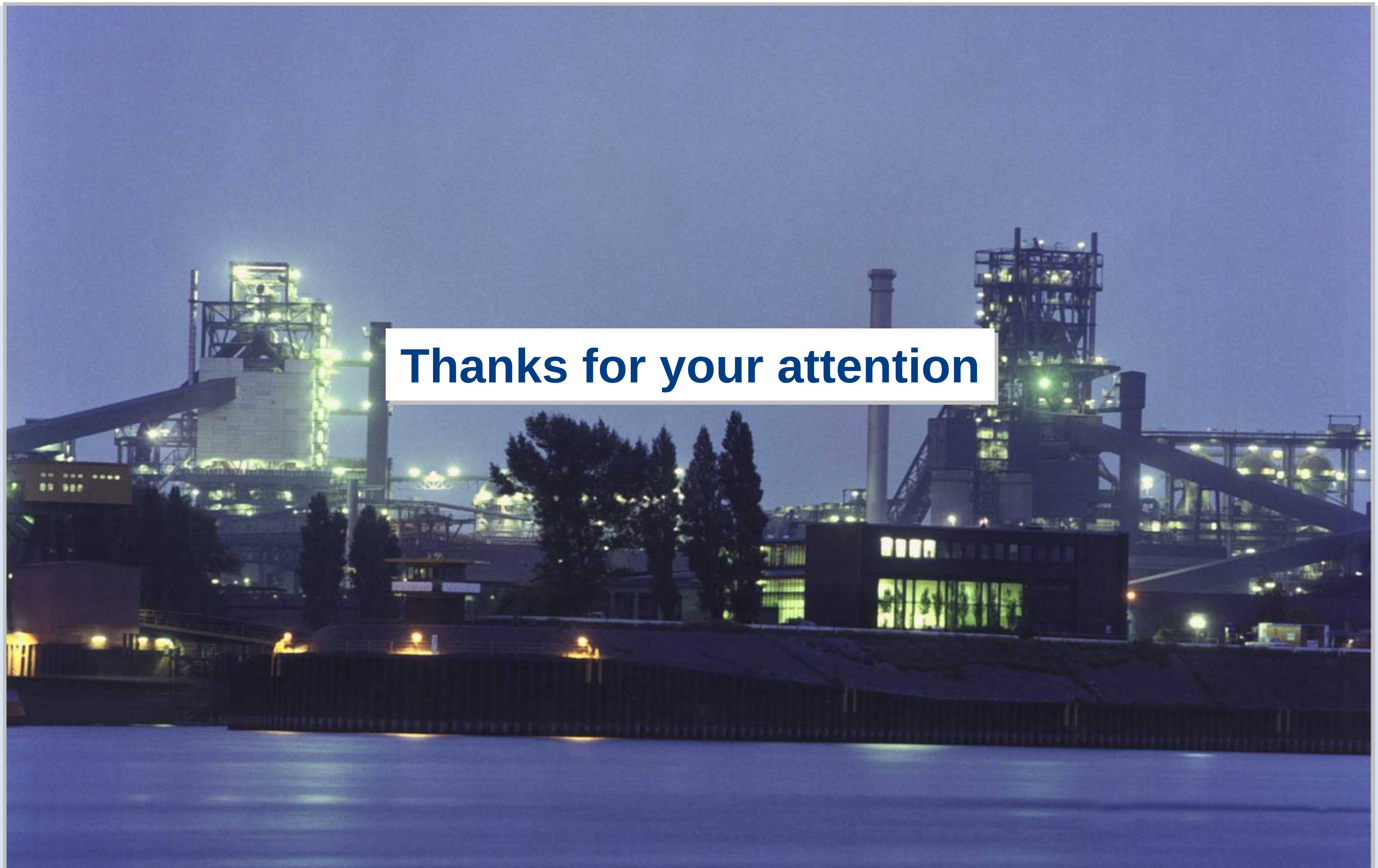
Conclusion to CO_2 Reduction Potential of the EU 27 Iron and Steel Industry until 2050

- The equipment of the European iron and steel industry are already operated at very high efficiency level
- Existing potentials of energy and heat recovery provide only small contributions to increase efficiency and reduce CO_2 emissions but request high investment and operating costs.
- Steel will not be able to come anywhere near the requested CO_2 reduction of about 80% for the ETS sector between 1990 and 2050.
- A reduction of 38% seems possible with a transition from coal-based to gas based reduction method. However, this would require access to raw material, scrap and energy at competitive prices, incentives for further investment and full offset of distortive CO_2 costs.
- A CO_2 reduction of 56% seems possible with the implementation of CCS
- The use of steel makes a significant contribution to CO_2 emission reduction


Thanks for your attention