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A Low-carbon roadmap for Belgium

Study realised for the FPS Health, Food Chain Safety and Environment

Industry sector – cement document

This document is based on content development by the consultant team as well as expert workshops in April-May 2013, and on 18-05-2011 and 17-06-2011 for Wallonia

vito
vision on technology

CLIMACT

Content – Industry sector - cement

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Executive summary for the cement sector

Construction of different future production trajectories

- 3 trajectories for cement production have been defined, they show **a cement production variation of +25% to -33% by 2050**
  - The stability is historical
  - The demand fundamentals (construction and infrastructure sectors) have stable perspectives
    - There is a limited risk of substitution by other materials (countries using most substitution materials use today <25% concrete)
    - Demand will be supported by renovation caused by the buildings energy efficiency requirements
  - The availability of mineral in Belgium is stable on the long term, yet the current humid process site will close and it's replacement site (Obesco) is uncertain

Estimate of potential and cost for the GHG reduction opportunities

- **The cement GHG emission reduction potential (at constant production) is large (94% in ambition level 3), its applicability is easier than in other industries but strongly depends from CCS**
  - **Metallurgical cement** (e.g. use of steel slag) can reduce emissions by 56% (through access to substitution products and an increase in storage costs and construction time)
  - **Energy efficiency** can still be improved enabling 5% additional reductions (CHP potential is limited)
  - **Coke substitution by biomass and waste** can enable 6% additional reductions
  - **CCS has a large potential** enabling additional emission reductions of 26%. The large size of the installation will enable to amortize the installations on more tons. The cost will be of ~55€/tCO_2e

NOTES Reduction potentials are for an ambition levels 3, expressed as a % of the 2010 GHG emission level except where explicitly mentioned otherwise.
The reduction in each step represents the additional reduction percentage after all the previous levers have been applied.
This is why : (1) The reductions of the actions add up to the total reduction of the sector (levers are applied in the sequential order represented here)
(2) Level 4 ambition can therefore be smaller in cases where more potential has been achieved with the previous levers
There is a double counting between the biomass potentials mentioned here and in the supply section, it is removed in the OPE²RA model

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A detailed analysis is performed for each industrial sector, the methodology is detailed in the general industry document (and not repeated in each sector document)

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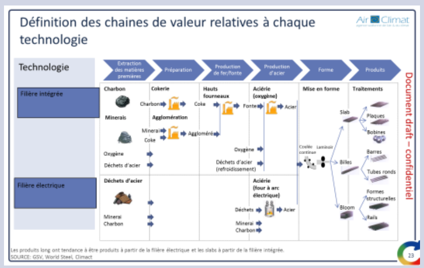
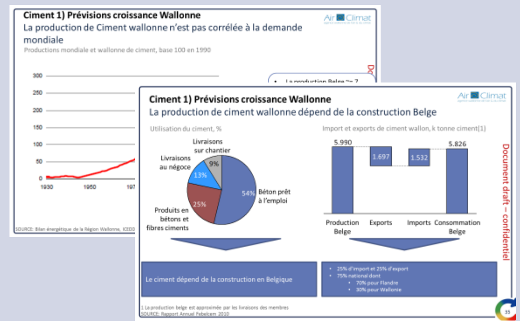
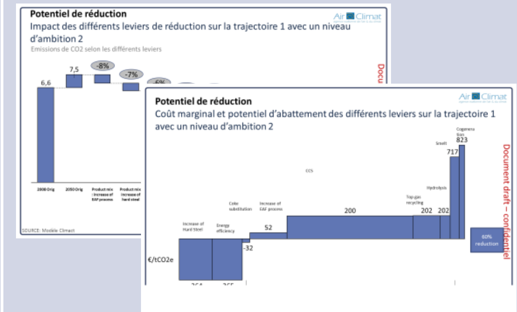
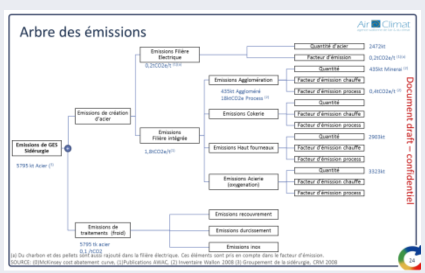
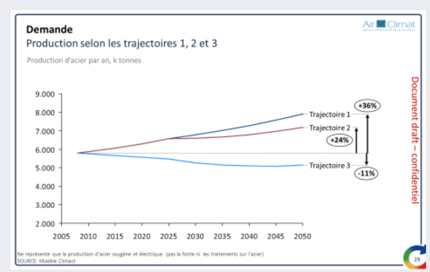
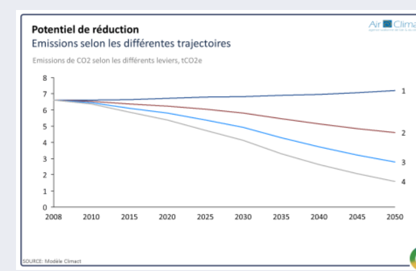
	Understanding the industry	Modelling demand trajectories	Modelling trajectories with intensity levels + CCS
Analyses	Definition of the value chain 	Analyses of growth and competitiveness 	Potential of CO_2 reduction incl. costs 
Results	Modelling the emissions tree 	Demand trajectories 	Trajectories with different intensity levels + CCS 

SOURCE: Climact

Clinker production and energy efficiency are stable, there is an increase in the proportion of the dry process

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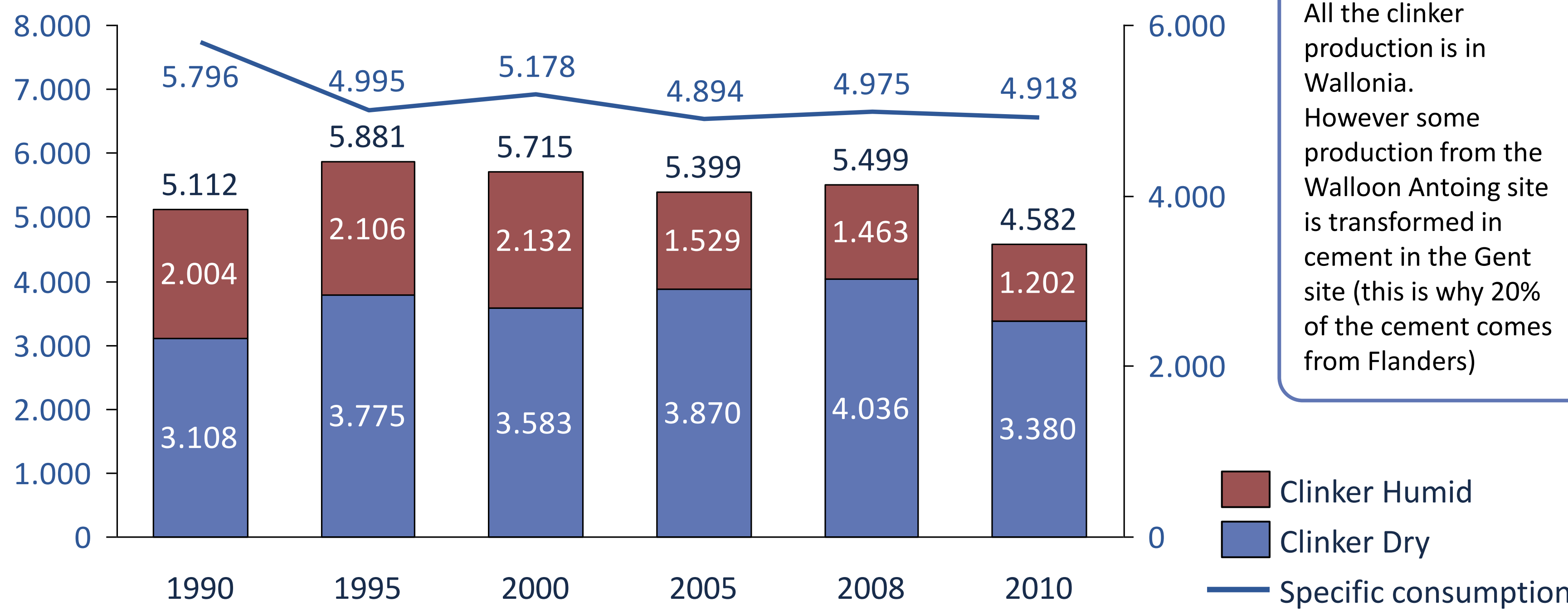
Clinker production and specific consumption evolution in the Belgian cement sector
(kton, Gj/kt)

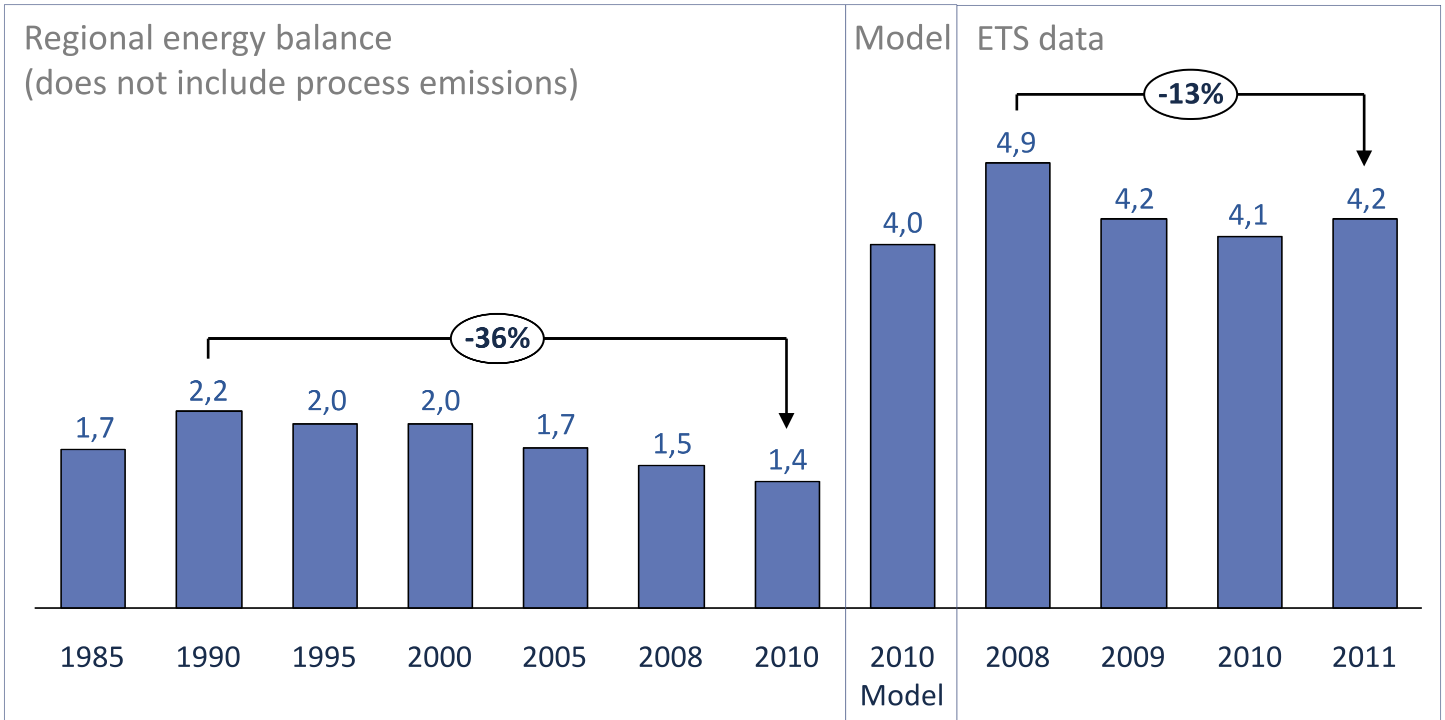


All the clinker production is in Wallonia. However some production from the Walloon Antoing site is transformed in cement in the Gent site (this is why 20% of the cement comes from Flanders)

NOTE: The energy consumption of the Gent site is not included in this analysis. It is assumed to be relatively minor.
SOURCE: 2010 Walloon energy balance

Emissions related to the energy consumption for the cement production are in decline since the 1990's

Emissions related to the final energy consumption in the Belgian cement sector ($MtCO_2e$)



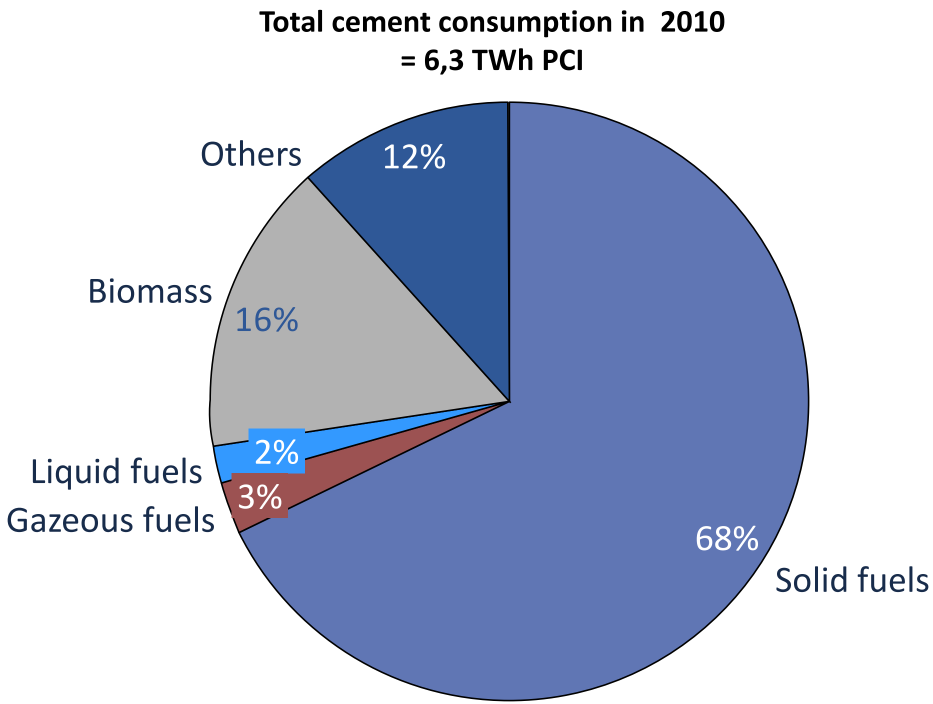
- Process emissions are twice the size of combustion emissions in the cement sector

NOTES: Energy consumption only represents a portion of the emissions, process emissions must still be added, biomass is counted as 0
The energy consumption of the Gent site is not included in the regional energy balance nor in the model. It is assumed to be relatively minor.

SOURCE: 2010 Walloon energy balance, CITL

Cement consumes mainly solid, liquid and biomass fuels

Cement energy sources distribution, 2010
(%)



- Cement consumes mainly solid, liquid, and biomass fuels
- Biomass emits 0tCO_2e/t product

NOTES: The gap with the results in Wallonia Low Carbon 2050 is explained by the fact the category “other fuels” of the energy balance has been reclassified from “Liquid fuels” to “Solid fuels”.
The energy consumption of the Gent site is not included in this analysis. It is assumed to be relatively minor.
SOURCE: 2010 Walloon energy balance

As all large cement installations are in Wallonia, the Walloon data and reasoning of the Walloon analysis can be used for Belgium

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Region	Installations	Emissions per year (tCO_2e)				Process type	Products
		2008	2009	2010	2011		
Wallonia	CBR Cementerie Antoing	695.438	643.163	511.558	633.064	Dry process	Grey clinker (Only clinker)
	CBR Cementerie Harmignies	155.095	199.604	200.364	193.727	Humid process	White clinker
	CBR Cementerie Lixhe	1.139.474	955.732	917.216	894.070	Dry process (humid process stopped in 2002)	Grey clinker
	CCB Cementerie Gaurain	1.425.171	1.313.762	1.272.210	1.333.035	Dry process	Grey clinker
	Holcim Cementerie Obourg	1.433.875	1.126.304	1.157.929	1.190.209	Humid process	Grey clinker
Flanders	CBR Gent	5.850	4.157	-	-	Centre de mouture (not in ETS)	
Grand Total		**4.849.053**	**4.238.565**	**4.059.277**	**4.244.105**	/	/

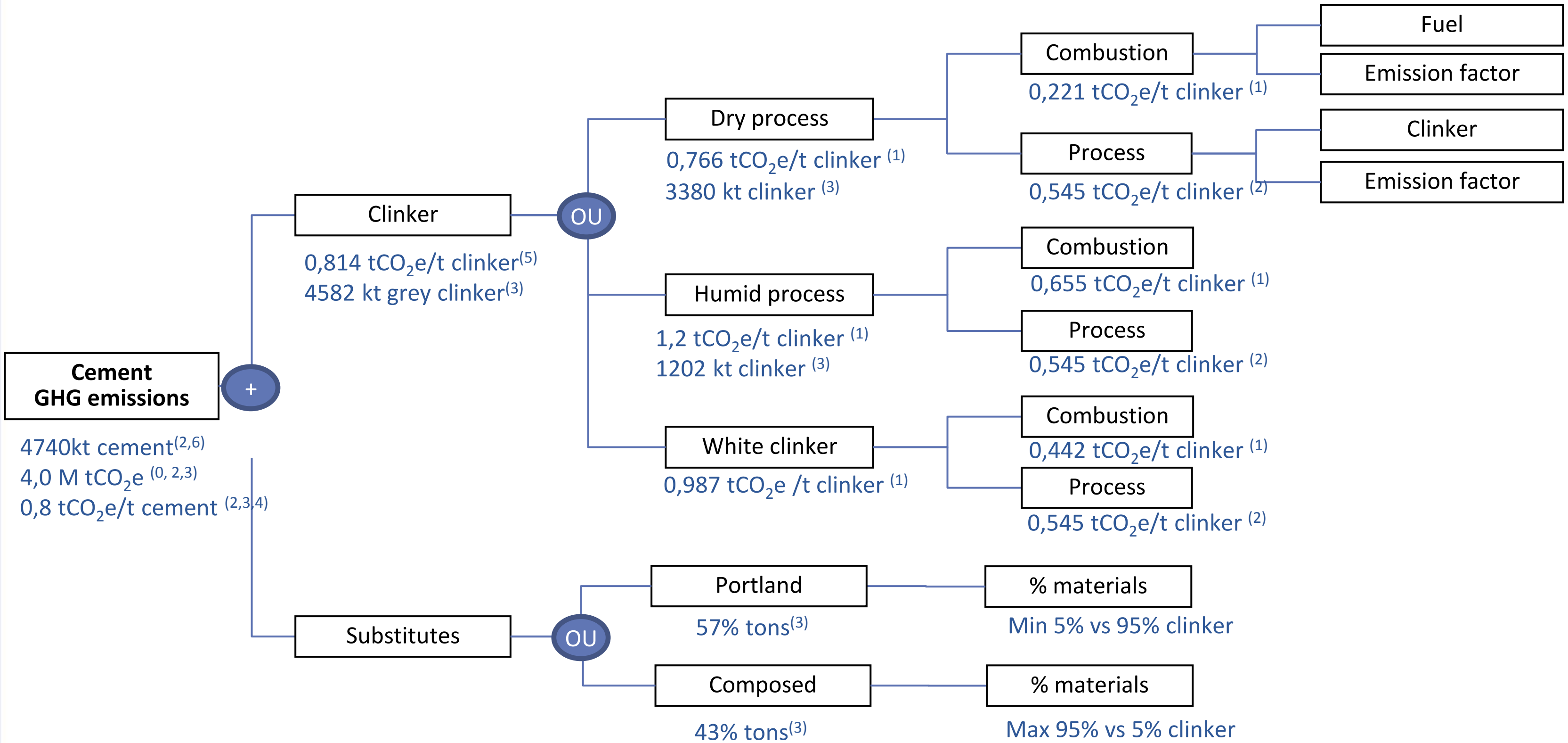
SOURCE: CITL

Supply chain definition for each technology

Technology	Raw materials extraction	Grinding–homogenisation	Heating	Mixing	Cement
Grey clinker • Dry process	**$CaCO_3$** Limestone **SiO_2, Al_2O_3, Fe_2O_3** Clay	**Raw material (powder)** Raw material Substitutes Fuels	**Clinker (and CO_2)**	Clinker Gypsum Other additions	**Portland Cement** (up to 95% clinker) **Composed cement** (up to 95% substitutes)
• Humid process	Idem	No grinding	Drying in a longer rotary kiln		
White clinker	No iron intake		Slower cooking		

SOURCE: Preliminary Climact analysis

Detailed emission tree
(not modelled, used to assess the impact of the reduction levers)



NOTE: (0) Excludes electricity which is included in the energy sector, (6) Simplifying assumption because part of the clinker is exported prior doing cement
SOURCE: (1) CBR & Holcim 2011 interviews, (2) 2010 Belgian GHG inventory (3) 2010 Walloon region energy balance, (4) Climact analysis (5) Febelcem

Emission tree (modelled)

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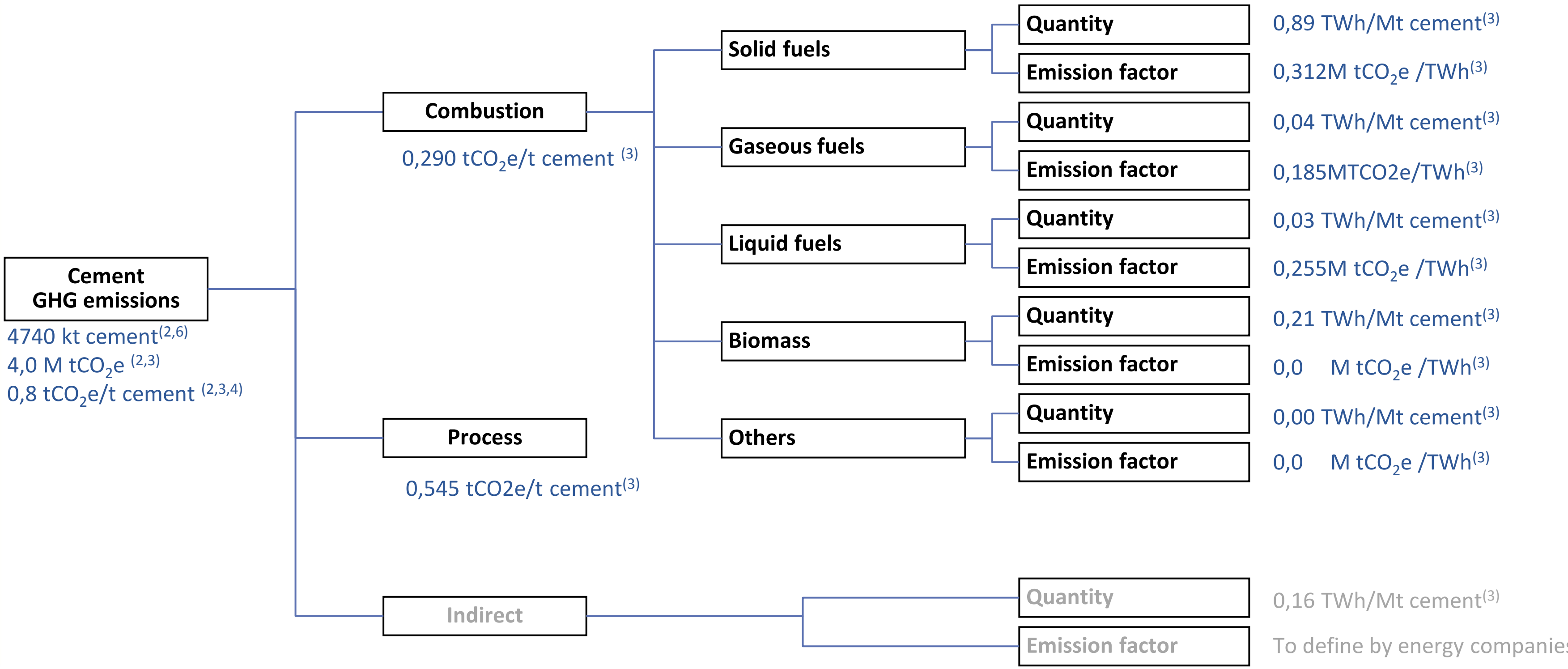

NOTES: (6) Simplifying assumption because part of the clinker is exported prior doing cement
SOURCE: (2) 2010 Belgium GHG inventory (3) 2010 Walloon region energy balance, (4) Climact analysis

Content – Industry sector - cement

Growth forecasts : World

Walloon cement production is not correlated to worldwide demand

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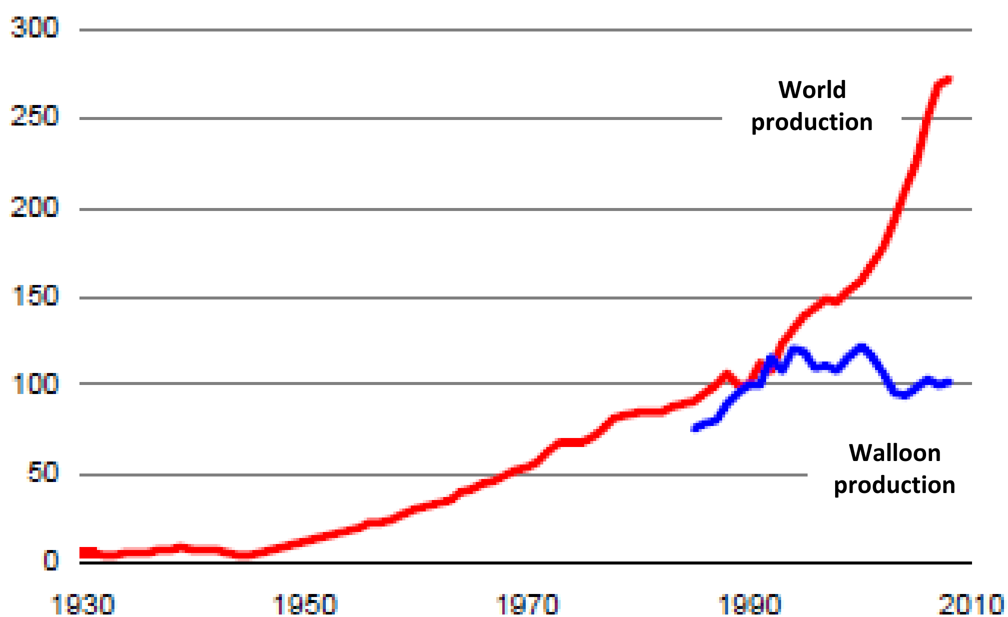
World and Walloon cement productions
(base 100 in 1990)



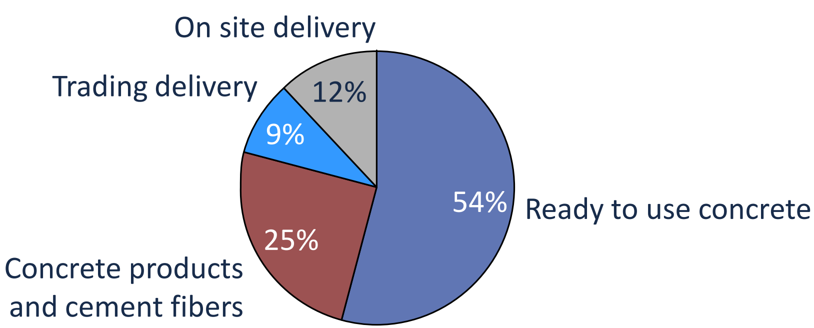
- Belgian production ~= 6 M tons of cement(1) for a 10M ton capacity
- Walloon production represents 80% of the national production and 0.2% of the world production

NOTE: For 5 M ton production of clinker
SOURCE: Walloon energy balance, ICEDD, Minerals.usgs.gov

Growth forecasts: Belgium

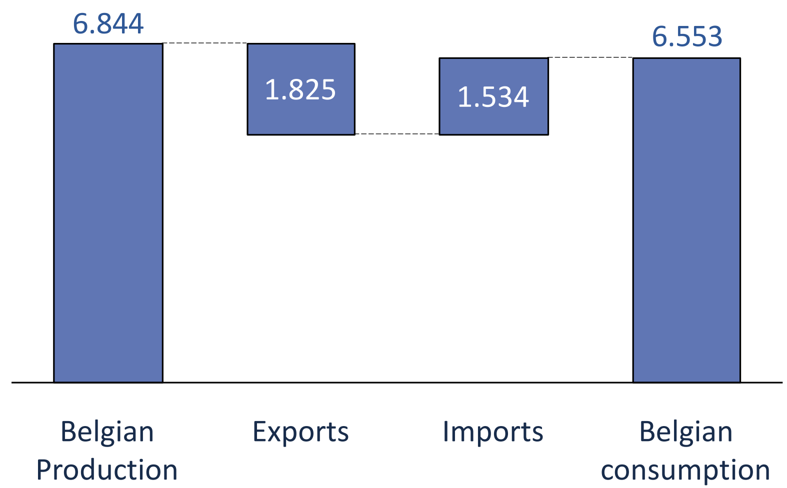
Cement production depends on the Belgian construction sector

Cement use
(%)



Walloon cement is completely dependant of the Belgian construction and infrastructure sectors

Belgium cement imports and exports
(k tons cement)(1)



- Imports and exports are balanced
- Amongst national sales:
  - 70% is for Flanders
  - 30% is for Wallonia

NOTE: (1) Belgian production is estimated through the deliveries of the federation members
SOURCE: 2011 Febelcem Annual report

Growth forecasts: Belgium

Several parameters have been taken into account to assess future demand

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Growth forecast parameters

Expected growth type definition (CAGR)	• GDP: 1,6% [1] • Federal planning bureau using Primes non-metallic minerals : 1,3%(05-20) 1,4% (20-30) [2] • GEM E3 projections: 0,8%[6] • 2030 projections: 0,6% (10-15), -4,7% (15-20), 0% (2020-2030) • PMDE Wallonia (10-20) Clinker: 2,5% [3] • Construction: 0% [4]
Probability to create new infrastructures	• Competitive sector sensible to carbon leakage • No additional installation (stable market), the quarries will tend to be located in the Tournaisis on the 2050 horizon. There are no quarries expected in Flanders by 2050. • Humid process (Obourg)expected to close by 2020, new installation Obesco project is currently blocked (because of a risk to affect water reserves)
Competitiveness	• Possesses minerals (Vs France) • Expensive labour costs • Industry sensible to carbon leakage towards other materials (however, the countries using the most substitution materials substitute today <25% of the concrete)
Import and export proportion	• 25% imports and 25% export • 75% national of which 70% for Flanders and 30% for Wallonia
Indicators to correlate the production	• Construction in Belgium • Infrastructures in Belgium • Renovation can be strongly supported by energy efficiency regulation [5]
Product mix expected modifications	• This analysis is covered in a later analysis (in the « product mix » section)

SOURCE: (1) Belgian Federal planning bureau Belgian long term tendency, (2) Belgian federal planning Bureau, (3)Plan pour la Maîtrise Durable de l'Energie, (4) Climact analysis: Hypothesis of a 1% annual growth for the park (5) CBR, Holcim Consultation s (6) GEM-E3 projection, physical production output (kton) (used in TUMATIM study)

Growth forecast: Belgium cement

3 trajectories influencing future energy demand are modelled

Possible growth scenarios

- Recovery of historical production by 2015
- Obesco project takes over in trajectory 1
- No Obesco project in Trajectories 2 and 3

Possible closures scenarios

- Closure of humid process by 2025
- If no free quota allocation after 2020 (scenario not modelled because excluded)

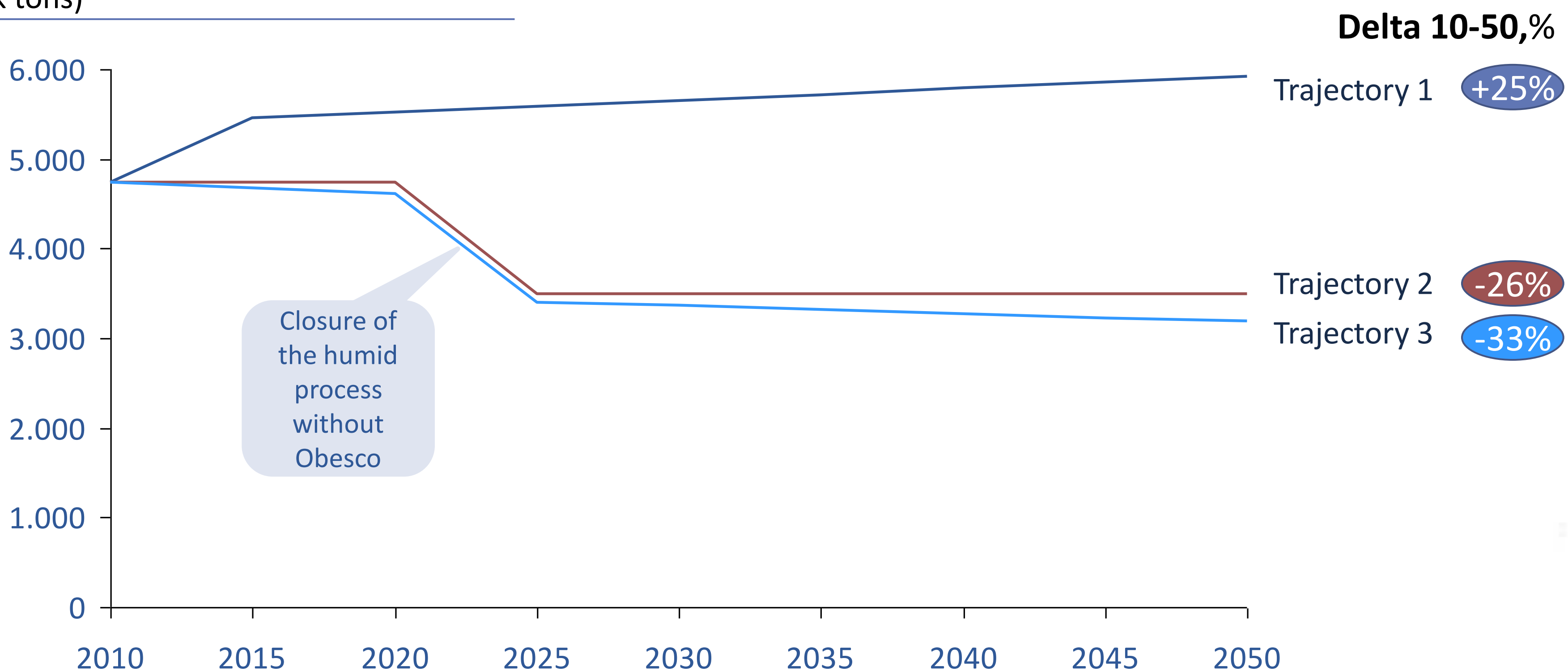
	Cement
Trajectory 1	+25% in 2050 via a continuous progression (optimist scenario) • Recovery of historical levels (+15%=2,83% CAGR from 2010 to 2015) • Obesco implemented (flat) • + 0,24% CAGR other years
Trajectory 2	-26% in 2050 with Clinker production is maintained at its current level • Obesco not implemented (-5,9% CAGR from 2020-2025) • 0% CAGR for the rest
Trajectory 3	-33% in 2050 via a continuous progression (pessimist scenario) • Obesco not implemented (-5,9% CAGR from 2020-2025) • Then -0,26% CAGR for the rest

SOURCE: (1) Belgian Federal planning Bureau, long term Belgian tendency (2) Belgian Federal planning bureau, (3)Plan pour la Maîtrise Durable de l'Energie, (4) Climact analysis: Hypothesis of a 1% annual growth for the park

Belgium growth forecasts

Production according to trajectories 1, 2 and 3

Cement production per year
(k tons)



SOURCE: Climact model

Reduction potential

Reduction levers are additional and applied in the following order

Methodology

Product mix
- Increase the proportion of products which require less CO_2

Energy efficiency
- Reduce mechanical and thermal losses
- Recover thermal losses (e.g. CHP)

Process improvements
- Improve the way the products are made

Alternative fuels
- Increase the proportion of fuels which emit less CO_2

End of pipe
- Capture the CO_2 emitted by the production (e.g. CCS)

Examples

- Product mix: Steel/composed cement
- Energy efficiency: Insulation; Preheating; CHP/ heat recovery
- Process improvements: Dry process; Steel/composed cement
- Alternative fuels: Biomass; Waste
- End of pipe: CCS

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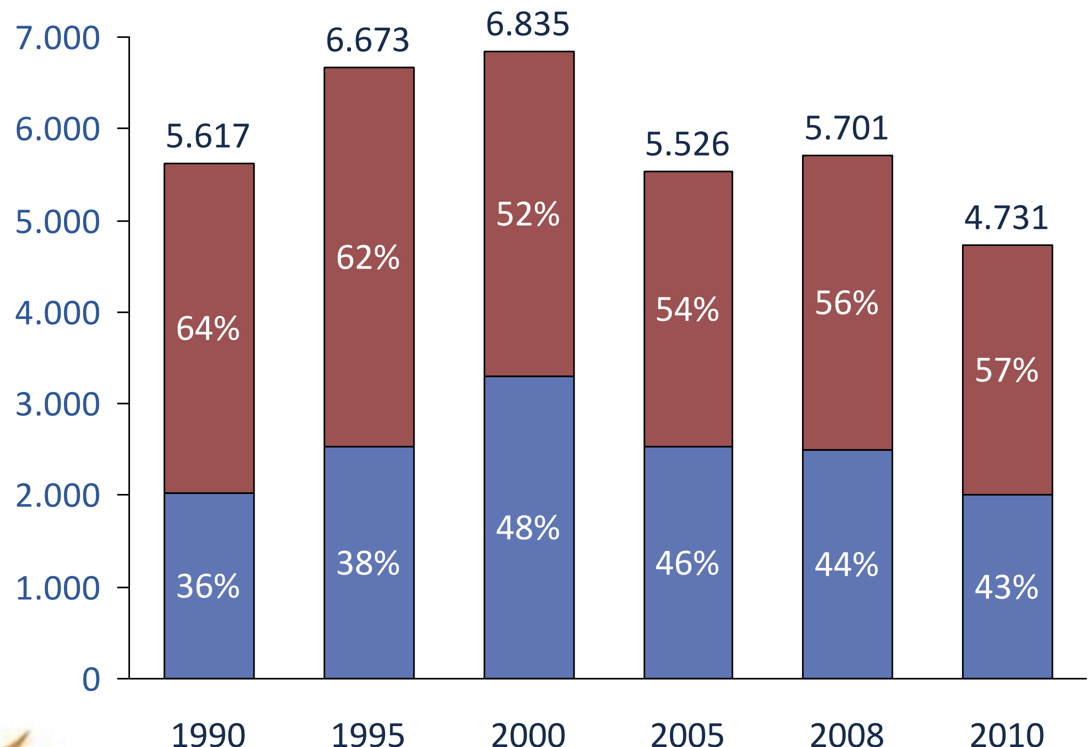
Reduction potential: product mix (1/4)

Composed cement market share has increased historically…

Walloon cement production and product mix evolution
(ktons and % of the annual total)



- Mineral components can be added to the clinker to obtain de cement (flying ashes, blast furnace slag, others), if those are superior to 5%, we get composed cement. Steel cement is a type of composed cement
- Steel cement share has slightly increased in recent years

NOTE: Composed cement includes steel cement
SOURCE: Walloon region energy balance

Reduction potential: product mix (2/4)

...Wallonia already has an important clinker substitution

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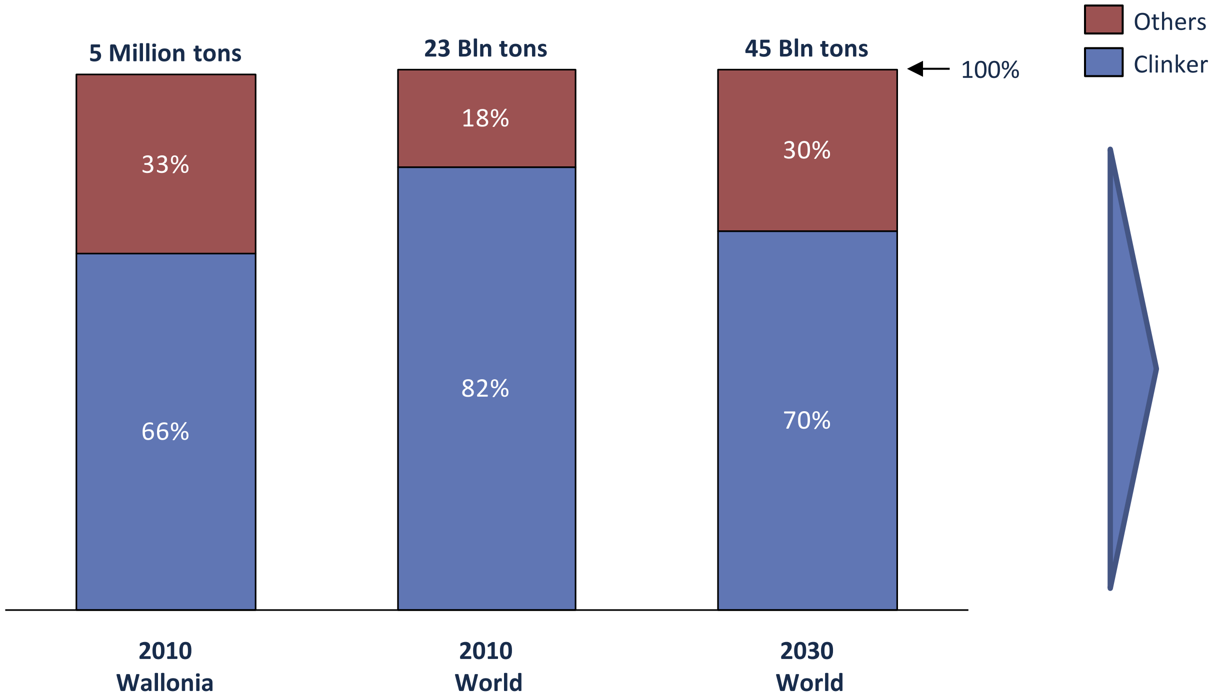
Actual and potential cement composition
(%)



- Wallonia has surpassed the worldwide ambition level for clinker substitution by 2030 and is getting closer to the 2050 level [(1)]
- Prefabricated sector requires Portland cement (95% clinker) to dry faster
- Other applications can be satisfied with CEM III C cement (10% clinker and 90% steel slag). This cement can reach higher solidity levels than Portland cement but takes longer to dry
- The access to substitution mineral components is getting harder. The decline of the steel industry oxygen phase and the reduction of coal power plants in western Europe
- If the cement industry were to use significantly more steel slag, its price would be expected to increase

NOTES: IEA 2009 report data provides similar results
Major hypothesis: no emissions are allocated to the steel slag, considering it as a waste from the steel sector
Substitution potential is not applicable to white cement

SOURCE: (1)McKinsey GHG abatement model 2.0, (2) Fortea CBR and Holcim consultations, Febelcem annual report

Reduction potential: product mix (3/4)

…a reduction of 63% to 93% of the clinker proportion is possible before 2050

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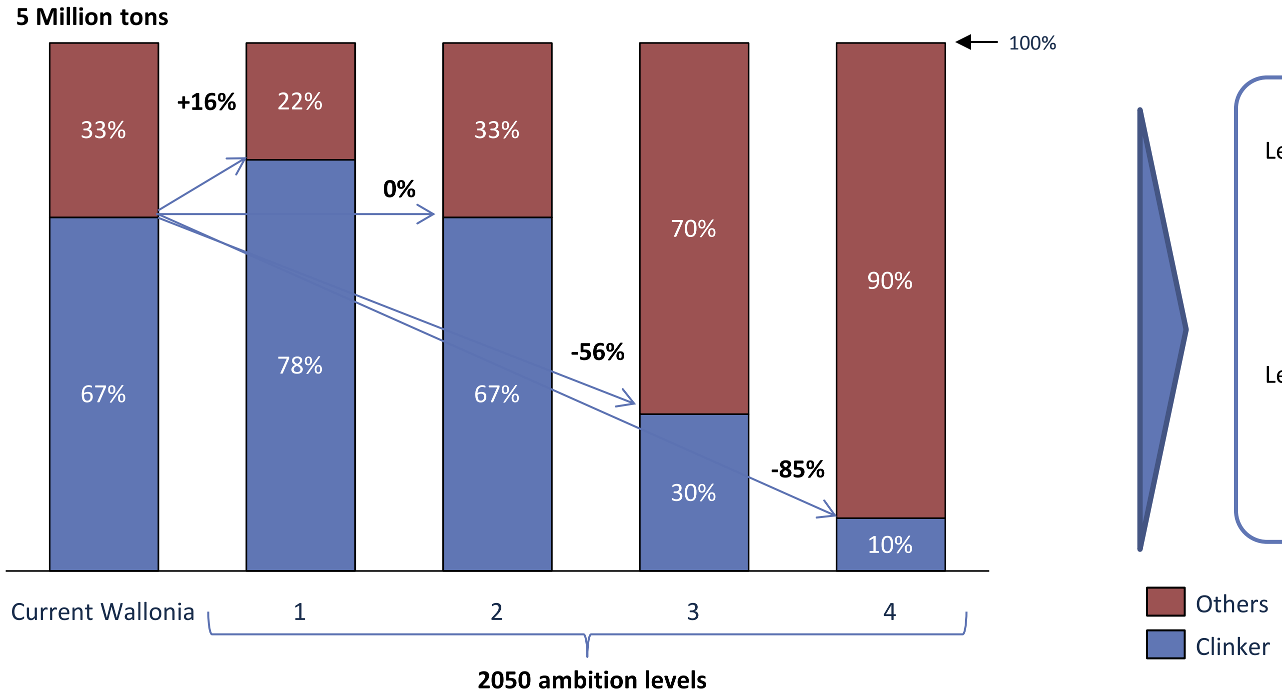
Actual and potential cement composition
(%)



Level 3 hypothesis(2) of
- 23% of the market currently requires « Portland » with 95% clinker (prefabricated+ ethernit)
- The rest can use CEM III C with 10% clinker

Level 4 hypothesis
- 100% transition to CEM III C, which is possible but will imply higher storage costs

NOTE: IEA 2009 report data provides similar results
Major hypothesis: no emissions are allocated to the steel slag, considering it as a waste from the steel sector
Substitution potential is not applicable to white cement

SOURCE: (1) McKinsey GHG abatement model 2.0, (2) Fortea CBR and Holcim consultations, Febelcem annual report

Reduction potential: product mix (4/4)

Reduce the portion of clinker in the cement mix

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Level 1	Level 2	Level 3	Level 4
• **Minimum effort** (following current regulation)	• **Moderate effort** easily reached according to most experts	• **Significant effort** requiring cultural change and/or important financial investments	• **Maximum effort** to reach results close to technical and physical constraints
• **Substitutes reduced by 33%** **(+16% clinker per ton of cement, directly impacting energy and processes)**	• **Constant use of substitutes** **(+0% clinker per ton of cement, directly impacting energy and processes)**	• **Switch for all except prefabricated industry** **(-56% clinker per ton of cement, directly impacting energy and processes)**	• **Switch for all industry** **(-85% clinker per ton of cement, directly impacting energy and processes)**

SOURCE: Cement consultation, Climact analysis

Reduction potential: energy efficiency (1/2)

Cement energy efficiency can increase by more than 30%

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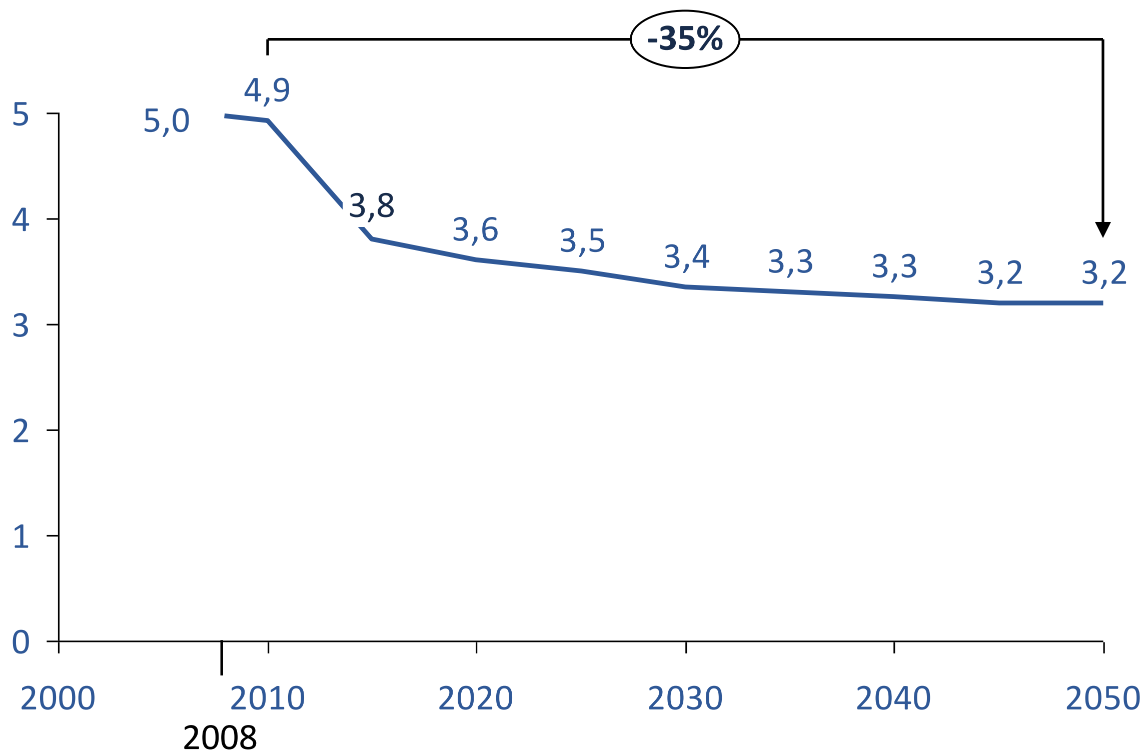
Specific consumption evolution forecast
(Gj/t)



- IEA 2050 specific consumption objective is 35% lower than the Walloon 2010 one

NOTES: Energy efficiency improvements are expected to be lower in white cement
The later only represents 2% of the production

SOURCE: 2010 Walloon energy balance and GHG inventory, IEA objective for the other years, Climact analysis

Reduction potential : process improvement

The dry process share has increased and will replace the humid process

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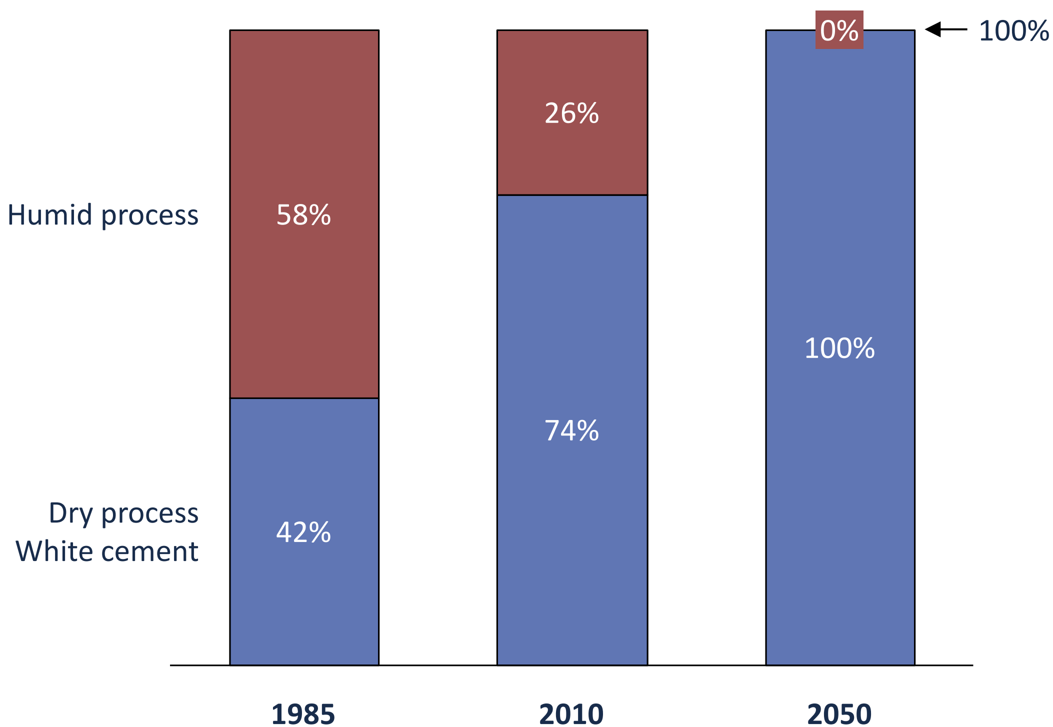
Proportion of grey clinker obtained through the humid process
(%)



- The choice of using a dry or humid choice is linked to the exploited quarry type
- Historically, the dry process proportion increase in grey clinker is explained by the conversion of the Lixhe site (humid towards dry)
- The last remaining humid process site is Obourg. It will close in 2015.
- The new Obesco project in Obourg will be based on the dry process. Its implementation is currently uncertain yet does not affect the lever.
- We assume this improvement is included in the IEA specific consumption projections (previous slide)

NOTE: Grey clinker does not include white clinker
SOURCE: 2010 Walloon region energy balance

Reduction potential: energy efficiency (2/2)

Improve energy efficiency (including process improvements)

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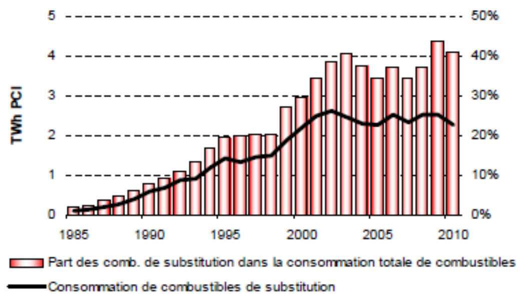
Level 1	Level 2	Level 3	Level 4
• **Minimum effort** (following current regulation)	• **Moderate effort** easily reached according to most experts	• **Significant effort** requiring cultural change and/or important financial investments	• **Maximum effort** to reach results close to technical and physical constraints
• **-14% specific consumption**	• **-18% specific consumption**	• **-35% specific consumption**	• **-42% specific consumption**

SOURCE: Cement consultation, Climact analysis

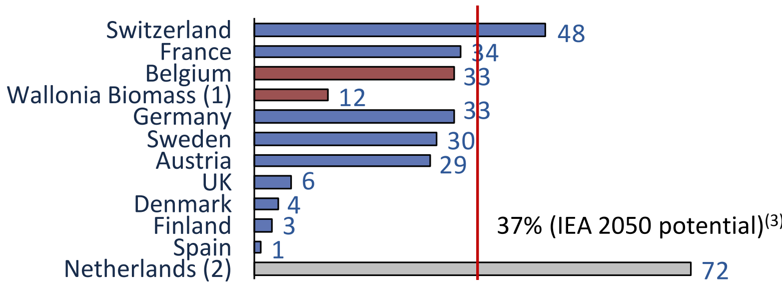
Reduction potential: alternative fuels

The alternative fuels proportion has strongly increased and reaches one the highest European levels

Alternative fuel consumption in the Walloon cement sector (%)



Alternative fuel consumption in the European cement sector in 2002 (%)



Current situation

- 41% currently assumption mostly biomass and not waste

Potential evolution

- 0% risk (waste and biomass could become inaccessible)
- 100% potential (contrarily to some industries, cement does not absorb the biomass and waste impurities)

Barriers:

- There are access problems to alternative fuels (biomass and waste)
- There are currently no financial incentives for waste incineration

NOTE: We assumed waste combustion emissions at 0 (because otherwise, waste would go to incinerators)
(2) The Netherlands use a different nomenclature for the waste, their results are therefore not comparable
SOURCE: CBR, CCB, Holcim, ICEDD, Cembureau, (1) 2010 Walloon energy balance, (3)IEA Cement Technology RoadMap

Reduction potential: alternative fuels

Portion of alternative fuels in 2050

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Level 1	Level 2	Level 3	Level 4
• **Minimum effort** (following current regulation)	• **Moderate effort** easily reached according to most experts	• **Significant effort** requiring cultural change and/or important financial investments	• **Maximum effort** to reach results close to technical and physical constraints
• **Biomass is too expensive or inaccessible (0%)**	• **Constant use of substitutes (41 %)**	• **Strong increase (70%)**	• **Entire mix (100%)**

SOURCE: Cement consultation, Climact analysis

Reduction potential: CCS (1/3)

CCS potential is based on size of installations

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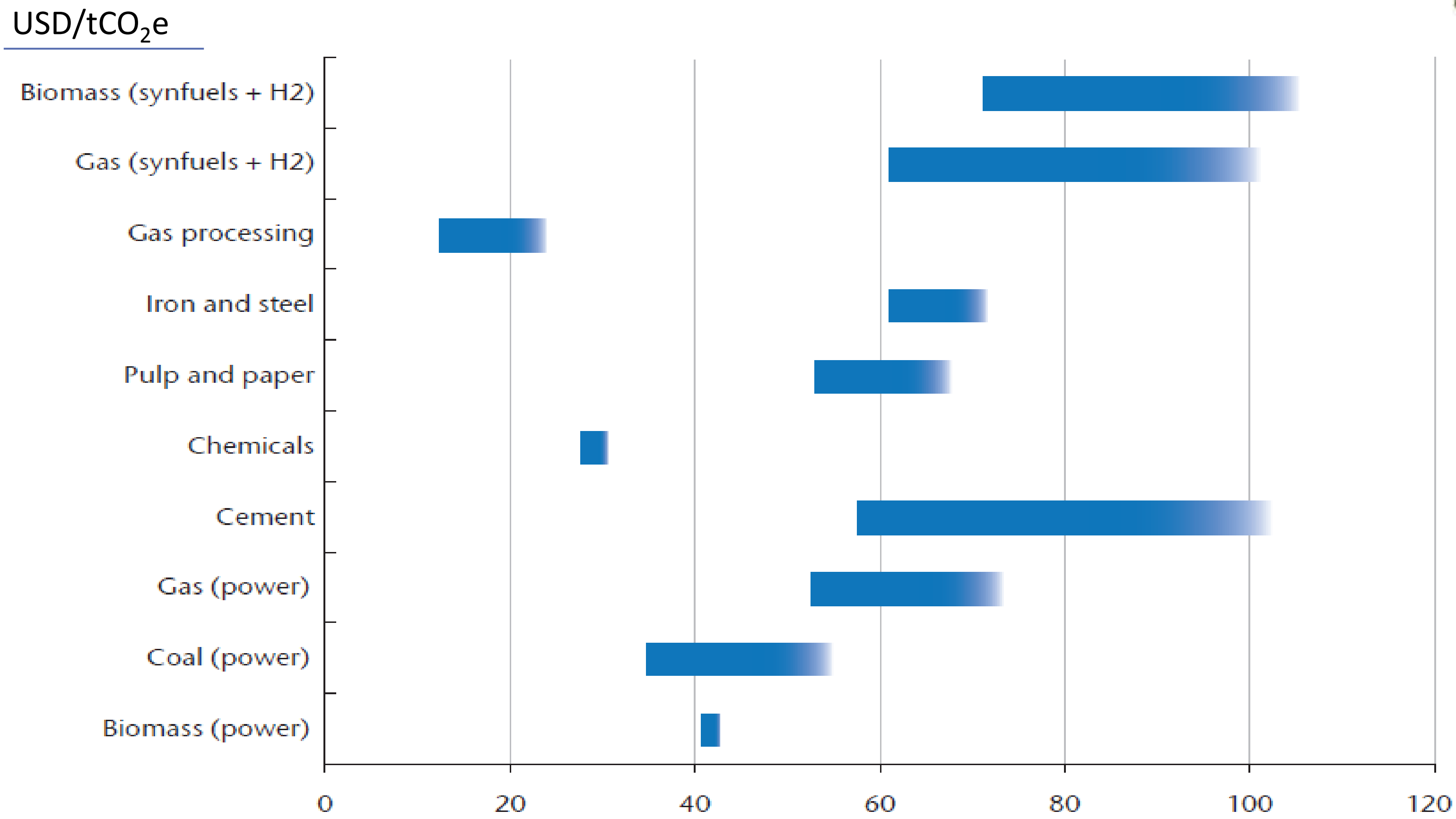
Industry	ton CO_2eq by production site category			Total	Level 1	Level 2	Level 3	Level 4
	<0,3 M	0,3-1 M	>1 M					
Iron & steel	1.291.469	787.034	4.386.583	6.465.086	0%	68%	80%	85%
Non ferrous metals	349.098	-	-	349.098	0%	0%	0%	85%
Chemical	1.777.925	1.185.959	3.088.691	6.052.575	0%	51%	71%	85%
Refineries	54.765	521.974	5.784.870	6.361.609	0%	85%	85%	85%
Lime	613.101	943.472	1.146.381	2.702.954	0%	36%	66%	85%
Glass	537.388	551.237	-	1.059.785	0%	0%	43%	85%
Cement	200.364	1.482.774	2.230.139	4.059.277	0%	51%	81%	85%
Food	981.850	-	-	981.850	0%	0%	0%	85%
Pulp & paper	768.785	-	-	768.785	0%	0%	0%	85%
Bricks & ceramics	567.888	-	-	567.888	0%	0%	0%	85%
Total	6.729.570	5.309.780	18.498.687	30.538.037	0%	59%	73%	85%
Coverage level 1	/	/	/					
Coverage level 2	/	/						
Coverage level 3	/							
Coverage level 4								

SOURCE: ETS registry (Belgium), analyse VITO&Climact

Reduction potential: CCS (2/3)

Cost per industry



SOURCE: IEA

Reduction potential: CCS (3/3)

CCS implementation by 2050

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Level 1	Level 2	Level 3	Level 4
• **Minimum effort** (following current regulation)	• **Moderate effort** easily reached according to most experts	• **Significant effort** requiring cultural change and/or important financial investments	• **Maximum effort** to reach results close to technical and physical constraints
• **No implementation** **(0%, starting after 2025)**	• **Only largest sites** **(51 %, starting after 2025)**	• **Only large and medium sites (81%, starting after 2025)**	• **All sites** **(85%, starting after 2025)**

SOURCE: Cement consultation, Climact analysis

Additional information on the levers

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Lever type	Lever description	Description
Product mix	Portland and Composed product mix	See specific slide Hypothesis the imports and export proportion is constant
Energy efficiency	Energy efficiency	See specific slide
	CHP	Currently not used because there are no green certificates 300° c smokes are available and lead to electricity production potential Assumption that for each electricity KWh, there is a 0,85 KWh consumption of the other fuels (same proportion)
Process improvements	Dry process	See specific slide (included in energy efficiency)
	Clinker substitution	The process can be improved by placing the steel slag in the raw (cru) This technology is not technologically mature and is therefore not modelled
Alternative fuels	Biomass and Waste	Biomass potential is limited by supply, it is therefore modelled in another section of the tool (at once across all the sectors) to avoid any double count See specific slide for what would be modelled
End of pipe	CCS	See specific slide (there are CCS pilots with algae on some cement installations)

SOURCE: (1) Interviews

Reduction potential

Potential of the reduction levers, per ambition and per technology, on the 2050 time horizon

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Cement levers

Lever type	Improvement levers	Potential (%) in 2050 by level				Cost	Description	Applicability		
		1	2	3	4			Dry	Humid	White
Product mix	Portland & Composed product mix	+16% energy & process	+0% energy & process	-56% energy & process	-85% energy & process	0 To refine	25% precast industry which requires Portland 75% other applications on CEM III C	✓	✓	✓
Energy efficiency	Energy efficiency	-14% energy	-18% energy	-35% energy	-42% energy	0 To refine	From 4,9 to 3,2 Gj/ton of cement	✓	✓	✓
	CHP	N/A	N/A	N/A	N/A	/	No potential in 2050, following energy efficiency	✓	✓	✓
Process improvements	Product mix: Dry process	100%	100%	100%	100%	/	From 27% to 0% humid (included in energy efficiency)	✓	✓	
Alternative fuels	Alternative fuels	0%	41%	70%	100%	€15/kt cement	Not applied in this sector, else 100% potential for alternative fuels	✓	✓	✓
End of pipe	CCS	0%	51%	81%	85%	€57/t CO_2e	40-75€/tCO_2 Includes the additional consumption (0,3MWh/tCO_2e)	✓	✓	✓

SOURCE: Interviews

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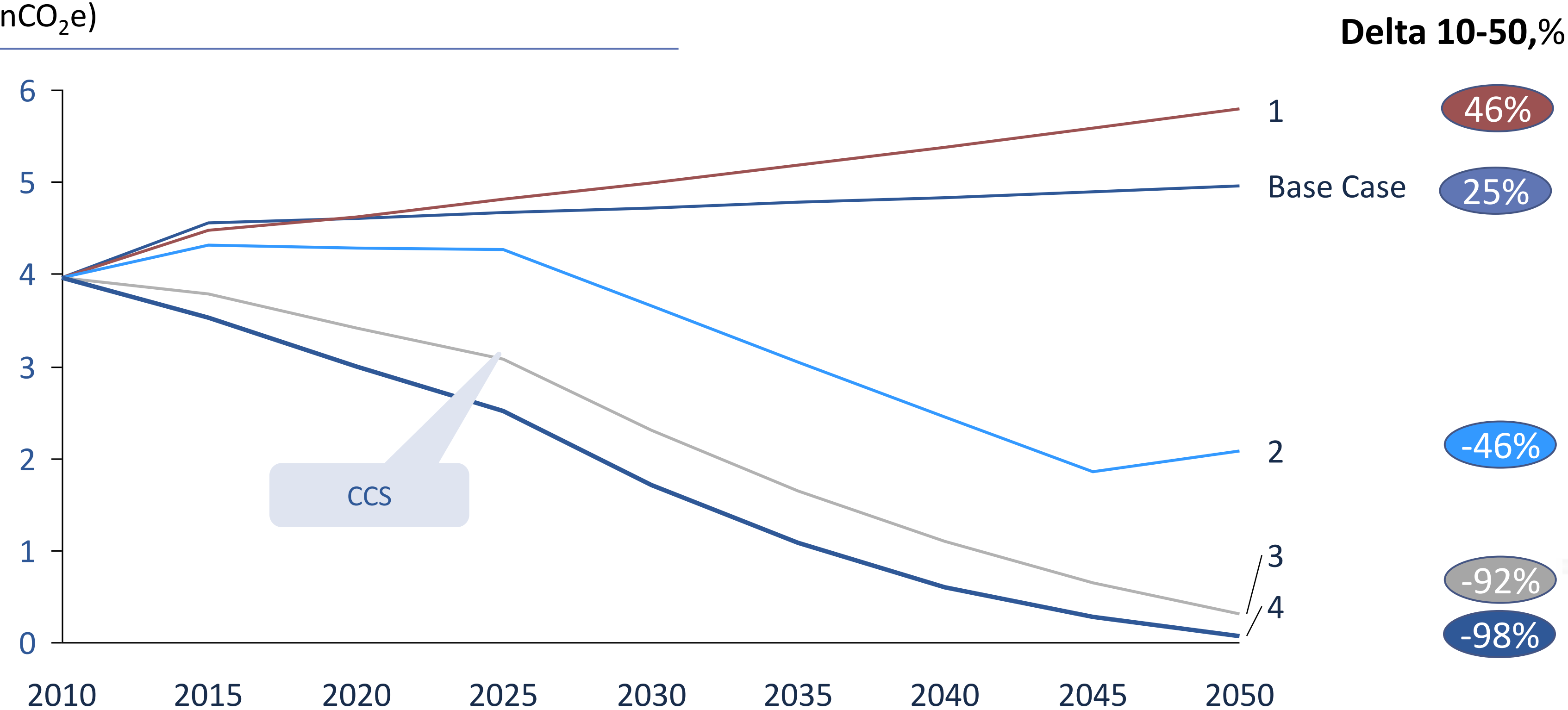
Reduction potential

Emissions according to different trajectories

Trajectory 1 (high growth) GHG emissions for different ambition levels
($MtonCO_2e$)



NOTE: Including biomass potential
SOURCE: OPE²RA model

Reduction potential

Emissions according to different trajectories

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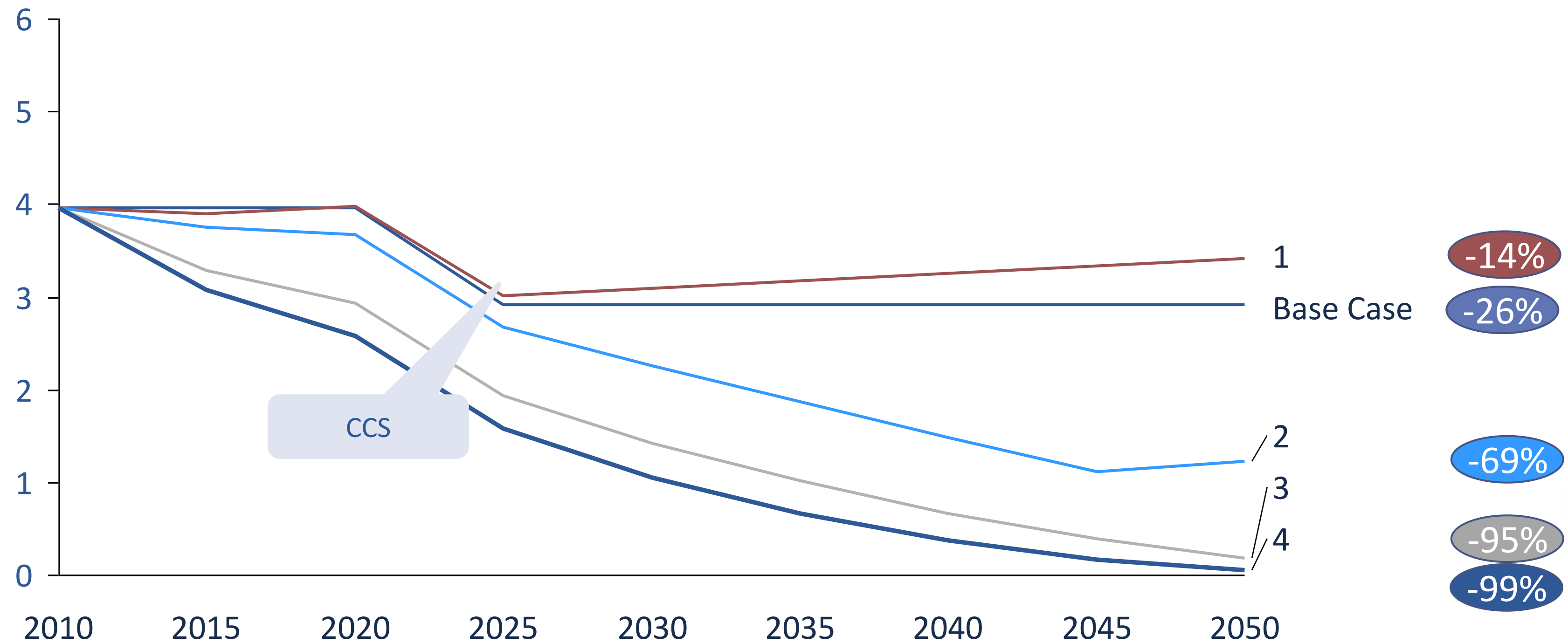
Trajectory 2 (medium growth) GHG emissions for different ambition levels
(MtonCO_2e)

Delta 10-50,%

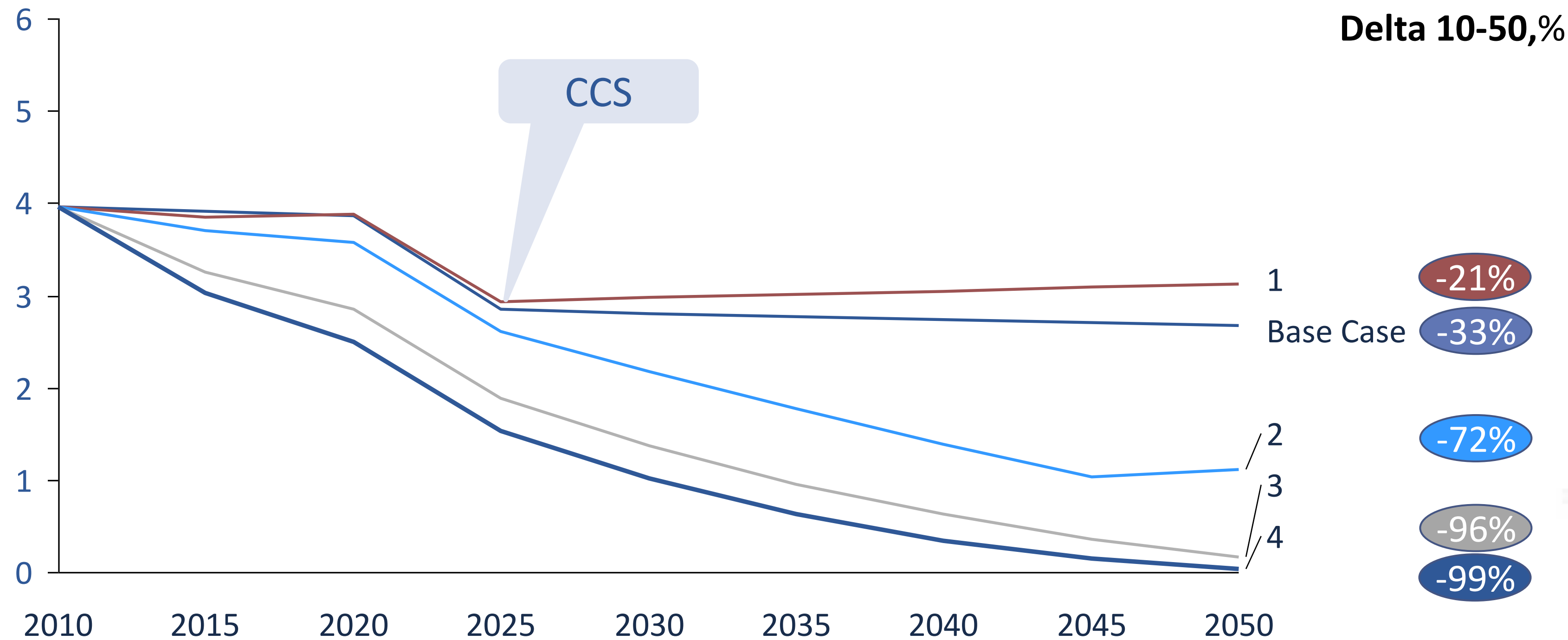


NOTE: Including biomass potential
SOURCE: OPE²RA model

Reduction potential

Emissions according to different trajectories

Trajectory 3 (low growth) GHG emissions for different ambition levels
($MtonCO_2e$)



NOTE: Including biomass potential
SOURCE: OPE²RA model

Reduction potential

As of level 2,5 (which includes CCS) the reductions are in line with the European objectives for the industry

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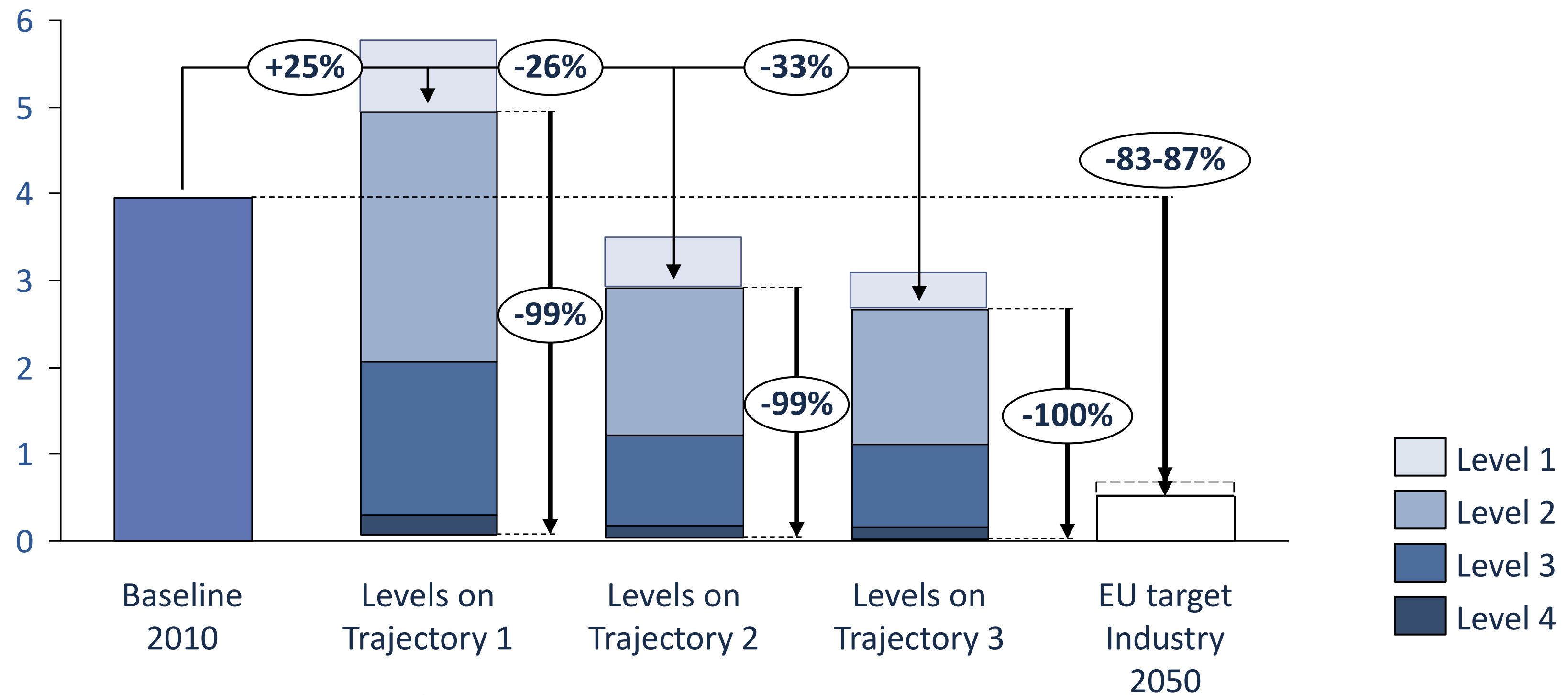
GHG emissions for different trajectories and ambition levels
(MtonCO_2e and % change in % of 2010 level)



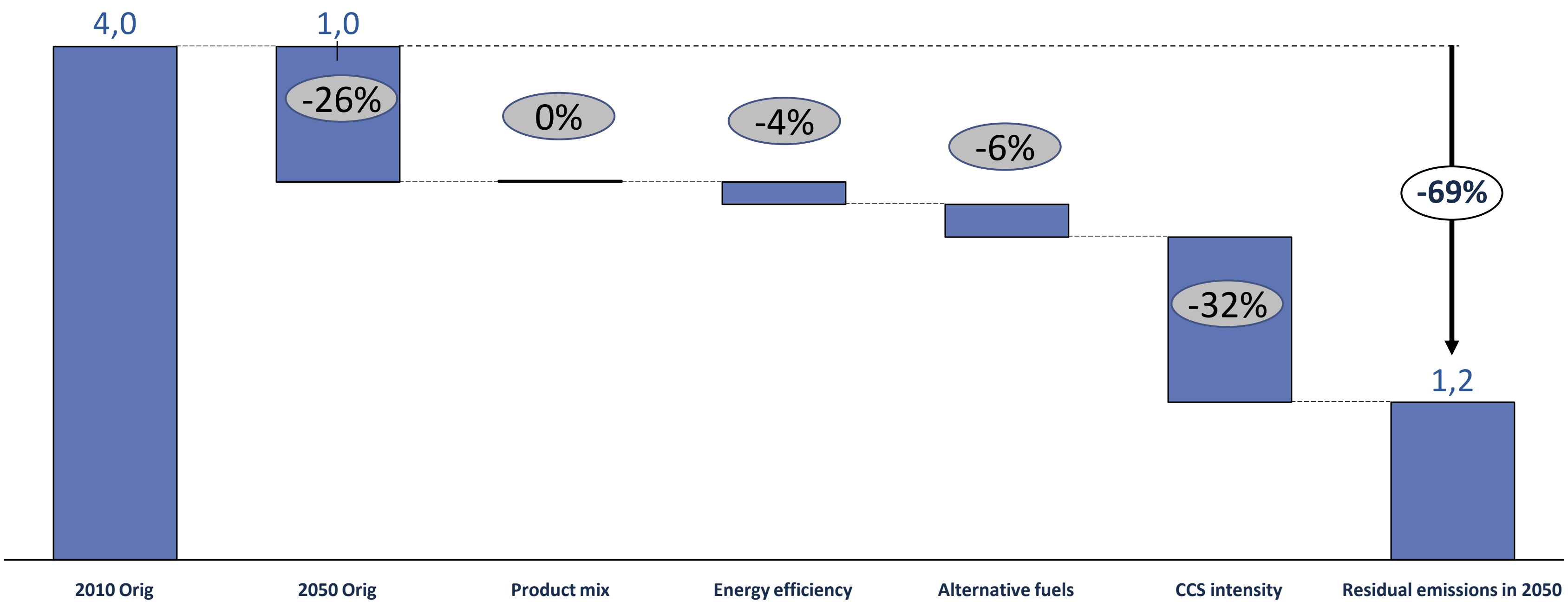
NOTE: Level 1 has a negative impact (because assuming more clinker and less alternative fuels than today)
For more consistency with the rest of the analysis, reductions should be assessed vs 1990

SOURCE: OPE²RA model

Reduction potential

Details for trajectory 2 with ambition level 2

GHG emissions in 2050 using different levers
(% of 2010)



SOURCE: OPE²RA model

Reduction potential

Details for trajectory 2 with ambition level 4

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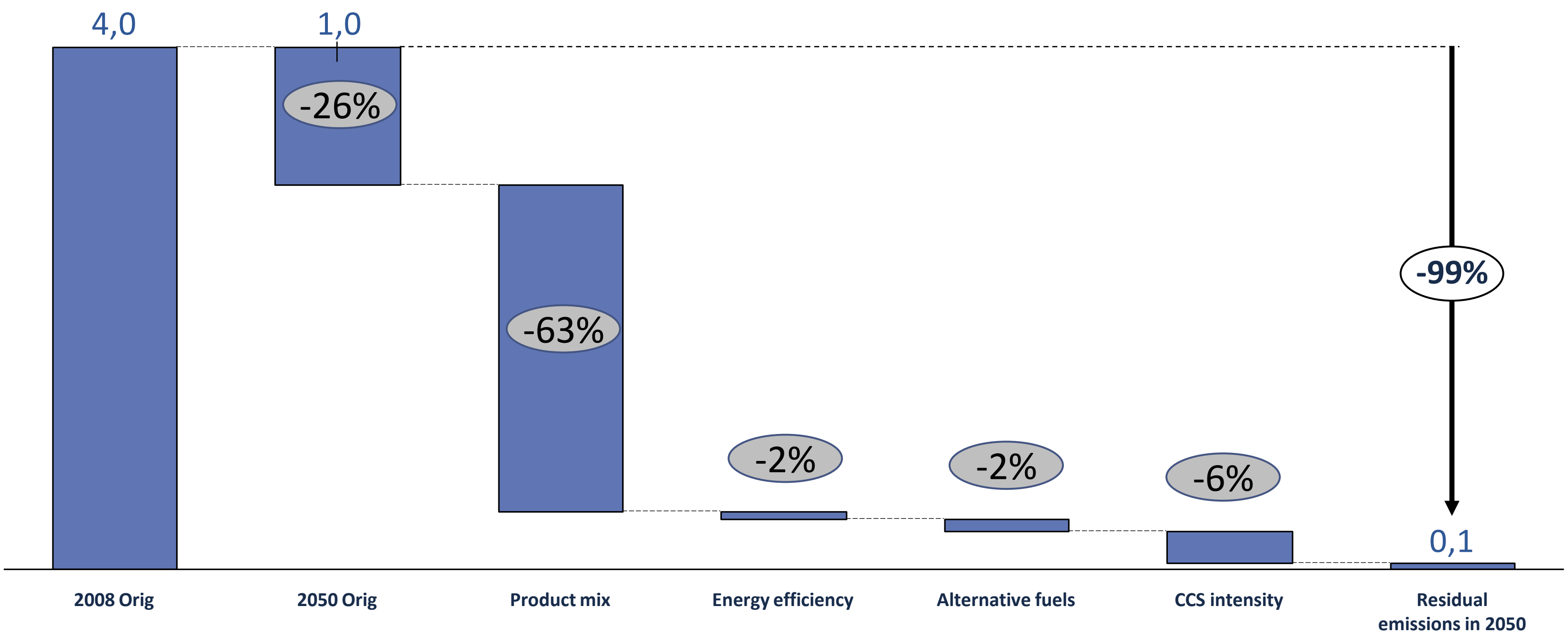
GHG emissions in 2050 using different levers
(% of 2010)



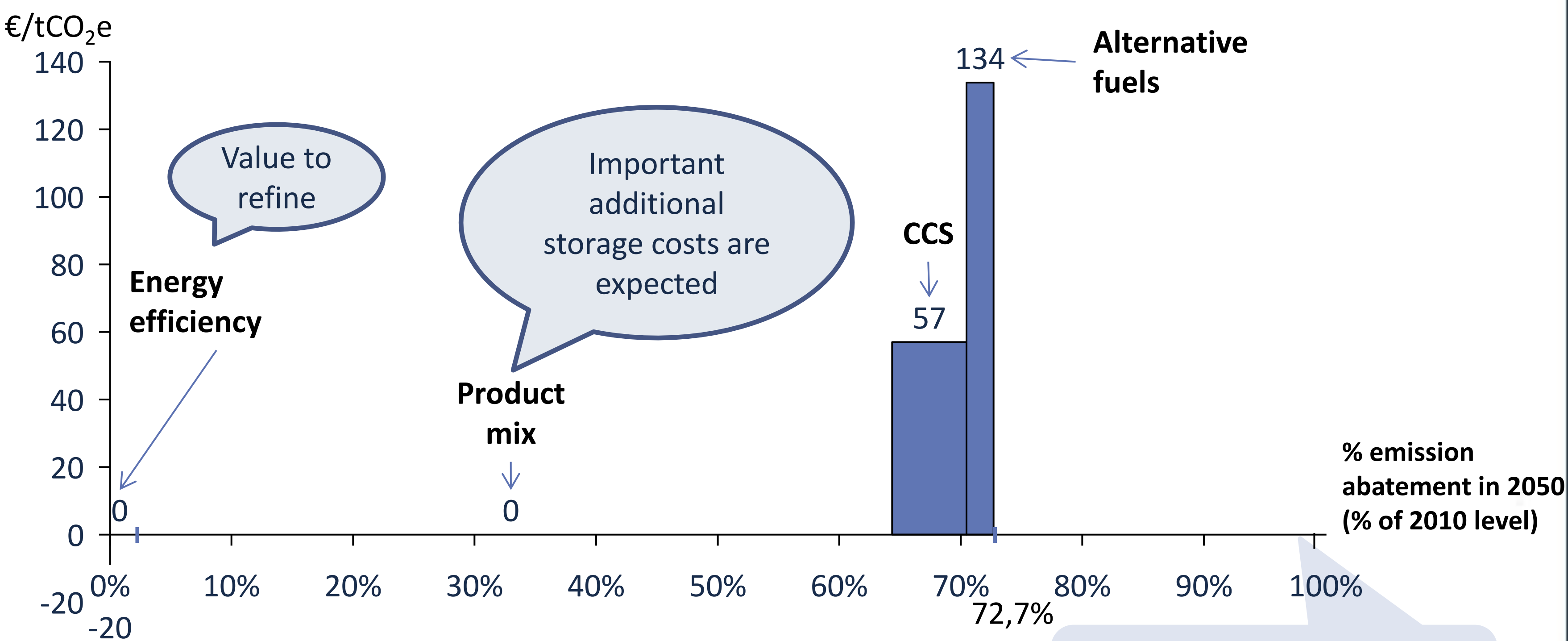
NOTE: CHPs have a positive GHG impact, however, energy production related emissions are not shown here (they are allocated to the supply section)
SOURCE: OPE²RA model

Costs

In cement, most of the potential comes from the use of composed cement

GHG abatement curve for the year 2050 (trajectory 2, ambition 4)

€/tCO_2e, % emission abatement in 2050 (% of 2008 level)



To obtain the-99% evolution of ambition 4, add the 2010-2050 21% reduction

NOTE: Including biomass potential
SOURCE: OPE²RA model

Content – Industry sector - cement

Classical illustration of the cement supply chain

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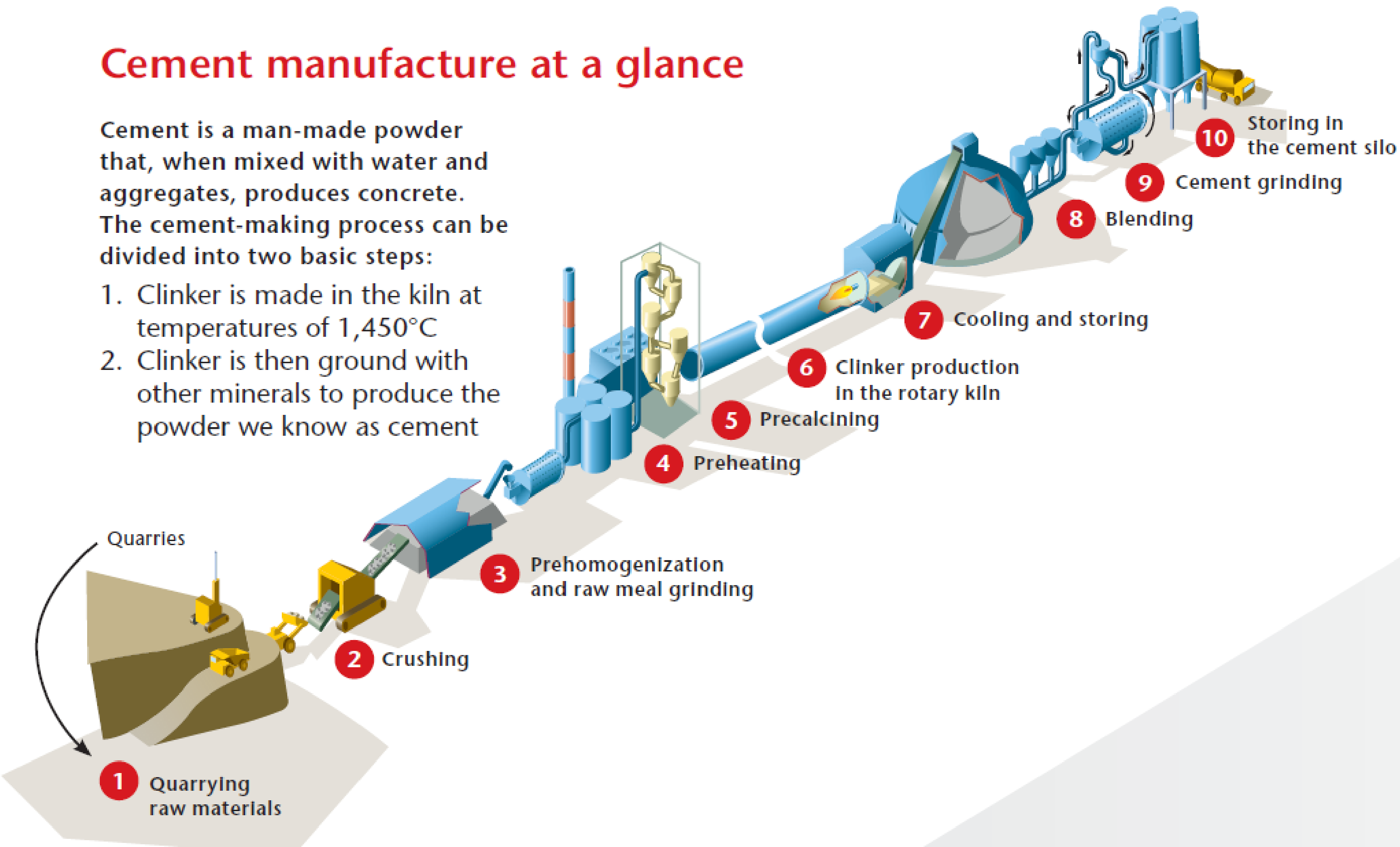
Cement manufacture at a glance

Cement is a man-made powder that, when mixed with water and aggregates, produces concrete. The cement-making process can be divided into two basic steps:

1. Clinker is made in the kiln at temperatures of 1,450°C
2. Clinker is then ground with other minerals to produce the powder we know as cement



Thank you.

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