



CHAPTER 5: CEMENT SECTOR






5 CEMENT SECTOR

GENERAL OVERVIEW

The cement industry is responsible for about 5% of global anthropogenic carbon emissions, not only caused by combustion related emissions but also a result of process emissions (Mikulcic et al. 2013). The transition risk story for the sector articulates itself along a few trends:

- Increasing demand for cement.** The demand for cement is largely influenced by economic developments and population growth as it is mostly used in form of concrete by the building industry. Demand is expected to remain stable in developed countries until 2030 and set to continue to increase in emerging economies.
- Fade out of wet cement production routes.** Cement can be manufactured through four different routes: dry, semi-dry, semi-wet and wet process. The dry or wet state of its raw materials determines the use of the routes. Wet processes consume more energy and are therefore expected to fade out stepwise until 2030. Wet cement routes only play a minor role for the six countries in scope, therefore, this trend won't be considered in detail.
- Declining clinker-to-cement-ratio.** The production of clinker is highly carbon-intensive. It emits on average about 60% of total CO₂ emissions in the production process (Moya et al. 2010). The demand for specialised cement has risen continuously during the last decades with more composite materials and additives currently being used. Thus, the clinker-to-cement-ratio is declining. This trend is expected to increase further in the future.
- Shift from coal to less carbon-intensive fuels for cement kilns.** The shift from coal to secondary raw materials (e.g. biomass, waste and waste-related materials such as tyres, sludge and slag) could allow a substitution rate of about 80% from a technical point of view. In addition, the share of renewables in the electricity supply can cause a significant emission reduction.

The scenario involves the following parameters:

	PRODUCTION & TECHNOLOGY	
	Cement production (Mt)	CCS deployment (%)
	Clinker to cement ratio (%)	CO ₂ Intensity (t CO ₂ / t cement)
	Energy intensity clinker production (GJ/t clinker)	Share of Alternative fuel use (%)
	MARKET PRICING	
	Secondary fuel prices (USD/ton)	
	POLICY MANDATES, INCENTIVES & TAXES	
	Allocation of free CO ₂ allowances (%)	

5 THINGS BEFORE GETTING STARTED

1. **Demand vs. population growth.** Cement is one of the major building blocks of modern society and is general, correlated with population growth. Over the last 25 years, the global cement production has increased by roughly 400%, in particularly in emerging countries like China, Brazil and India. In industrialized countries like Germany and France cement production is stagnating or decreasing. With increasing global population, the demand for cement is expected to continue to increase unevenly across the globe. This relationship is also known as the cement frown or scowl, as demand increases and then decreases with GDP per capita growth.
2. **Abatement potential.** The production of cement is one of the largest CO₂ sources of all industries. Global cement production is responsible for more than 3% of all anthropogenic CO₂ emissions. Besides the utilization of a range of fossil fuels such as coal and lignite, further process-related CO₂ emissions occur during the calcination from limestone to clinker which is the main ingredient in cement. Calcination is responsible for 50 to 75% of the total CO₂ emissions of cement production. Abating process-related CO₂ emissions is generally perceived as more challenging compared to energy-related CO₂ emissions, as major process changes or CCS retrofitting is required.
3. **Efficiency gains.** A comparatively high energy use combined with low prices for raw materials (e.g. limestone) and products result in one of the highest energy cost intensities in industry. Energy costs compose one third of the total production cost. Increasing the energy efficiency is often a viable option for cement producers to gain a competitive advantage as most of the production inputs like coal are commodities for which main competitors are likely to have similar raw material prices.
4. **Market size.** Cement is among the bulk commodities with the lowest value per weight or volume ratio. With the exception of some high-value white clinker cements, individual transportation of cement over distances longer than 200 km is usually not economically viable. Thus, the supply and demand for cement is regional and international trade intensity is very low.
5. **Carbon leakage risks.** Although cement is considered to be a regional product due to low value per weight ratio, making it unfavorable for imports, cement producers can be exposed to carbon leakage risks. In particular, in areas in close proximity to the sea or major rivers, transportation of the carbon-intensive clinker in bulk carrier ships from countries with no emission trading scheme or similar CO₂ taxes can be become economically viable. Thus, the imported clinker can be ground and mixed with additives in the destination country to produce the desired type of cement with no direct CO₂ emissions involved.

5.1 CEMENT PRODUCTION



Overview. Cement is one of the major building blocks of modern society. It is needed for buildings and infrastructure. Thus, cement demand can be correlated with population growth. Over the last 25 years, the global cement production has increased by roughly 400%. With increasing global population, the demand for cement is expected to continue to increase which implies more ambitious CO₂ intensity reductions to meet climate targets.

Risk pass-through mechanism. Due to a low share of product value to weight, cement is a locally traded product. Cement producers' revenues depend on local demand and supply. While in developing countries like India the demand for cement is steadily increasing, in developed countries like Germany, France and Italy demand has slightly decreased over the last 25 years. Here, overcapacities have put a lot of stress on revenue margins and sales volumes of cement producers. In areas with cement overcapacity, the utilization rate tends to be lower which has a negative effect on the energy intensity and on the specific production costs.

Sources. Scenarios generally present inputs around cement demand at macro-level (e.g. IEA 2016a, Green peace 2015). As an example, IEA (2016a, 2015) give cement production on a highly regional level for the OECD and non-OECD as a whole. The low demand scenario is comparable with IEA 2016a global cement production until 2050. Most sources correlate future cement demand with population growth.

Method. In line with the IEA Energy Technology Perspectives, it is assumed the same global cement demand and production under both climate scenarios. Historic crude steel production on a global level and for the countries in scope is taken from (WBSCD 2014). Country-specific demand for cement is forecasted by computing per capita production multiplied with the future population growth according to the United Nations (UN 2016). Historic per capita production is calculated similarly using UN data 2015, as well as information from the World Business Council on Sustainable Development 2014.

Results. Cement production is expected to increase steadily by 0.3% per on average over the next 35 years at global level. This is a significant reduction in growth compared to the more than 10% average cement production over the last 25 years. The countries in focus cover only about 5% of the global cement production in 2015. For the developed countries in focus, cement production is stagnating or will continue to slightly decrease over time. The USA, with an increase of more than 18% until 2040 in comparison to 2015, is an exception due to anticipated population growth. In contrast, Brazil and Mexico will roughly double their production during the same period, a trend driven by stronger population growth.

TABLE 5.1 GLOBAL AND COUNTRY-SPECIFIC CEMENT PRODUCTION (MT) FOR BOTH SCENARIOS (SOURCE: AUTHORS, BASED ON IEA ETP 2016a, WBSCD 2014, UN 2015)

Country	2015	2020	2025	2030	2035	2040
World	4 074	4 318	4 357	4 387	4 394	4 520
Brazil	53	59	65	71	76	80
France	17	17	18	18	18	18
Germany	34	33	33	32	32	31
Italy	18	18	17	17	17	17
Mexico	40	45	51	56	61	65
USA	56	58	61	64	65	66

5.2 CLINKER TO CEMENT RATIO



Overview. Standard cements like Portland Cement consists of more than 90% clinker. In any kind of cement type, clinker is the major ingredient. The production of clinker is energy and carbon intensive. Over time, cement producers substitute some part of the clinker with cheap by-products like fly ash and granulated blast furnace slag to improve cement properties, but also to reduce production costs. These clinker substitutes are generally accounted as carbon neutral for cement producers, as their CO₂ emissions have already occurred elsewhere during their production e.g. in coal fired power plants and blast furnaces for steel production. Thus, a higher share could reduce the direct CO₂ emissions. However, some of the clinker substitutes require a higher grinding effort, which increases electricity intensity and indirect CO₂ emissions.

Risk pass-through mechanism. The production of cement is regarded as the industrial process with the highest CO₂-intensity, when referencing intensity to product value. In the light of rising CO₂ certificates, failing to increase clinker to cement ratio could lead to higher production cost in comparison to competitors and loss in margins and sales volumes. Furthermore, cement types with a lower clinker ratio tend to be of higher quality (e.g. acid-resistance, quicker drying) and value. Having access to clinker substitutes and the knowledge as well as the machinery to produce high quality cements can be a competitive advantage.

Sources. Scenarios generally report the clinker to cement ratios at macro level (e.g. IEA 2016, Greenpeace 2015). As an example, the IEA's Global Cement Roadmap 2050 gives clinker to cement ratios on a regional level (e.g. Latin America, USA and Canada, EU25) for 2030 and 2050 in a low and high demand scenario.

Method. In line with the IEA (2016a, 2015), the same clinker to cement ratio is assumed under different climate targets. World estimates are taken from IEA 2016e. Country estimates are computed as follows:

- Historic ratios are taken from WBSCD 2014. Mexico's ratio is derived from Latin America.
- Ratios are forecasted following their respective regional estimates (e.g. North America for USA) of the IEA 2009 for the low demand scenario in 2030 and 2040. These estimates are comparable to ETP 2DS and 4DS estimates.
- Data between 2015 and 2040 is linearly interpolated.

Results. The clinker to cement ratio does not vary much among the countries in focus (67% to 75%) with the exception of the USA. The USA has a traditional high demand for standard cement. One of the reasons is that customers are not willing to pay the surcharge for high quality cement with lower clinker content. Increasing prices for CO₂ allowances will have a higher impact in standard cements with a higher carbon-intensive clinker content compared to cements with lower carbon-intensive clinker content reducing the surcharge and bringing the average clinker to cement ratio from 84% to 74%. In other countries, the clinker to cement ratio drops by less than seven percentage points due to already low ratios in the starting year.

TABLE 5.2 GLOBAL AND COUNTRY-SPECIFIC RATIO OF CLINKER TO CEMENT FOR BOTH SCENARIOS (SOURCE: AUTHORS, BASED ON IEA 2016A, 2016E, 2015, 2009, WBSCD 2014)

Country	2015	2020	2025	2030	2035	2040
World	65%	67%	68%	68%	68%	67%
Brazil	67%	66%	66%	65%	65%	65%
France	73%	72%	71%	70%	69%	68%
Germany	70%	69%	68%	67%	66%	65%
Italy	75%	74%	73%	72%	71%	70%
Mexico	69%	68%	68%	67%	67%	67%
USA	84%	82%	81%	79%	78%	77%

5.3 ENERGY INTENSITY FOR CLINKER PRODUCTION



Overview. For clinker production, the main ingredient of cement, temperatures of over 1350°C are required over a long period. These temperatures are reached by burning a range of solid fossil fuels like coal and lignite. The high energy use makes the production of cement one of most energy-intensive industries in the world. Energy intensity has improved significantly over time (e.g. change from wet processes to the use of semi-dry and dry kilns). A dry kiln with high heat integration can reach less than half the energy intensity of older semi-wet or wet kilns. The recent trend of bigger cement plants with ten times more the capacity of a typical European plant affects thermal energy intensity positively due to reduced thermal losses.

Risk pass-through mechanism. The high energy use combined with comparatively low raw materials prices (e.g. limestone) and products, results in one of the highest energy cost in industry. Energy costs usually account for one third of the total production cost. Increasing energy efficiency is often a viable option for cement producers to gain a competitive advantage. Failing to decrease energy intensity in relation to local competitors could lead to lower market volumes and revenues.

Sources. Scenarios generally present total final energy consumption and total crude steel production at macro level. For instance, the IEA's Global Cement Road Map 2050 reports thermal energy intensity at regional level (e.g. Latin America, USA and Canada, EU25) for 2030 and 2050 in a low and high demand scenario. Sector specific studies show cost-effective and technical energy efficiency potentials considering mutual interaction with energy efficiency measures in specific geographies (e.g. Brunke & Blesl 2014b).

Method. The ACT and LCT scenarios take as basis ETP's global aggregated energy intensity data built from the ratio of total final energy consumption and total cement production and weighting it with the respective clinker to cement ratio until 2040. In the ACT scenario, the ratio of the regional forecast of energy consumption (e.g. Latin America, EU25 and USA and Canada), and 2015's population-production forecast of UN's World Population Prospects for each region is applied to the current energy intensity of the countries in scope. Mexico's energy intensity corresponds to the average intensity of Latin America due to lack of country data. For the LCT, the relationship of 4DS and 2DS energy intensities of IEA is calculated and applied to the country-specific energy intensities of the ACT scenario.

Results. In both scenarios, the energy intensity in clinker production is reduced by 6% until 2040 compared to 2015 levels. While in the ACT scenario, energy intensity steadily decreases by 10% until 2025 compared to 2015, it increases after 2025 due to higher energy requirements of low carbon technologies. In the LCT scenario, energy intensity declines steadily until it reaches the same level of the ACT in 2040. The countries in focus have a consistent higher energy intensity than the global average figures. This can be explained by the vast majority of high capacity greenfield cement plants in India and China which have been installed over the last decade. Plant operators in Germany and France need to reduce energy by 10% and Italy in until 2040 and require additional capital due to higher energy intensity reductions and the high cost of brownfield plants retrofit.

TABLE 5.3 GLOBAL AND COUNTRY-SPECIFIC ENERGY INTENSITY FOR CLINKER PRODUCTION (GJ/T CLINKER) FOR ACT AND LCT SCENARIOS (SOURCE: AUTHORS, BASED ON IEA 2016A, 2015, 2009)

Country	2015	2020		2025		2030		2035		2040	
		ACT	LCT	ACT	LCT	ACT	LCT	ACT	LCT	ACT	LCT
World	3.5	3.3	3.5	3.1	3.4	3.2	3.4	3.2	3.4	3.3	3.3
Brazil	3.5	3.4	3.5	3.3	3.5	3.2	3.4	3.3	3.4	3.4	3.5
France	3.9	3.7	3.9	3.5	3.8	3.4	3.6	3.4	3.5	3.4	3.5
Germany	3.8	3.6	3.8	3.4	3.7	3.3	3.5	3.3	3.4	3.3	3.4
Italy	3.6	3.5	3.6	3.3	3.5	3.1	3.3	3.1	3.3	3.2	3.3
Mexico	4.2	4.1	4.3	4.0	4.2	3.9	4.1	4.0	4.1	4.1	4.2
USA	3.8	3.6	3.7	3.3	3.5	3.1	3.3	3.1	3.2	3.1	3.2

5.4 SHARE OF ALTERNATIVE FUEL



Overview. The production of cement is associated with a high energy usage to reach and maintain high process temperatures required for the calcination of lime to clinker. Cement operators utilize a wide range of solid fossil fuels like coal and lignite. Fossil fuels are responsible for more than 30% of the total CO₂ emissions of cement production. With rising coal prices, cement producers sought for cheaper energy carriers and started to use alternative fuel mixes. The process temperatures of above 1350°C allow the use of a wide range of alternative fuels from wastes (e.g. waste tyres, waste oil and solvents, pre-treated industrial and domestic wastes, plastic, textile and paper wastes) to biomass (e.g. animal meal, waste wood, sawdust and sewage sludge) with a, in general, lower calorific value (CSI 2009).

Risk pass-through mechanism. A higher share of alternative fuel use can reduce production costs for cement operators nowadays and will even more in the future. Alternative fuels tend to have lower specific costs in relation to their calorific value and a lower CO₂ intensity depending on the share of carbon neutral biomass in the fuel mix. However, the use of alternative fuels is limited to the local situation (i.e. prices and availability), additional preparation time to burn the fuel (e.g. drying and homogenization) and the retrofit of clinker kilns to allow for higher shares of alternative fuels. Cement producers, who are not able to utilize higher shares of alternative fuels due to technical or market-related restrictions, can thus lose competitiveness.

Sources. Scenarios generally present alternative fuels share of macro-level (e.g. ETP). IEA's Global Cement Roadmap 2050 reports the share of alternative fuels at regional level (e.g. Latin-America, EU25, USA and Canada) for 2030 and 2050. Sector specific studies consider an increase in the share of alternative fuels in specific geographies (e.g Brunke & Blesl 2014b).

Method. It is assumed that both scenarios have the same development of alternative fuel shares, since an increase of alternative fuels can be economically beneficial even with lower CO₂ certificate prices. World estimates are taken from IEA 2016e. Country estimates are then computed as follows:

- Country-specific historic data on alternative fuel use is taken from of WBSCD 2014. The Latin American average is applied to Mexico. These shares are compared to the global average provided in IEA's Global Cement Roadmap 2050 and it is assumed that countries with a current higher share need to achieve less relative growth.
- Country-specific alternative fuel use is forecasted using the regional shares from IEA's Global Cement Roadmap 2050 for 2030 and 2040.

Results. The share of alternative fuels increases globally from 10% in 2015 to 32% in 2040. Germany and France will have the highest share of alternative fuels in 2040, partly helped by the well-established infrastructure for collection industrial and households wastes in place. Although some cement plants in Germany claimed the possibility to use 100% alternative fuels, the alternative fuel share is limited to 90% as some fossil fuels are required for process control.

TABLE 5.4 GLOBAL AND COUNTRY-SPECIFIC SHARE OF ALTERNATIVE FUELS IN THE PRODUCTION OF CLINKER IN BOTH SCENARIOS (SOURCE: AUTHORS, BASED ON IEA 2016A, 2016E, 2015, 2009, WBSCD 2014)

Country	2015	2020	2025	2030	2035	2040
World	19%	22%	25%	28%	32%	36%
Brazil	19%	23%	27%	30%	35%	39%
France	37%	41%	44%	47%	49%	51%
Germany	65%	68%	72%	76%	80%	83%
Italy	13%	16%	19%	22%	24%	26%
Mexico	15%	18%	21%	23%	27%	30%
USA	15%	19%	23%	26%	29%	31%

5.5 CCS DEPLOYMENT



Overview. Besides the utilization of a range of fossil fuels such as coal and lignite, further process-related CO₂ emissions occur during the calcination from limestone to clinker. Calcination is responsible for 50 to 75% of the total CO₂ emissions of cement production, depending on the clinker to cement ratio. By extension, CO₂ reduction through increased shares of alternative fuels with lower carbon intensity are limited. One option for the cement sector to contribute to climate targets would therefore be CCS.

Risk pass-through mechanism. With the expected increase of CO₂ certificates, cement producers would need to pay 30% of the total production costs for CO₂ certificates in 2050, when continuing to produce with the same carbon intensity (Brunke & Blesl 2014a). Cement producers failing to deploy CCS would therefore risk losing competitiveness which could lead to lower market volumes and revenues.

Sources. Scenarios generally present CCS deployment for cement production at macro-level. In some cases, the amount of CO₂ captured through CCS is listed for the industry as whole, but not for cement individually (IEA 2016a). Furthermore, the cement sector is rather skeptical of CCS and the topic is hardly covered. For instance, CSI 2009 excludes CCS as a CO₂ reduction mechanism due to barriers, such as technological challenges (e.g. availability of the full CCS chain including infrastructure), settlement of legal requirements and public acceptance. In a questionnaire conducted by the authors among experts on industrial efficiency during the Industrial Summer Study 2016 of the European Council for Energy Efficient Economy (ECEEE) in Berlin, 6 out of 9 participants stated that CCS deployment in Europe will develop similar to the IEA's 4DS scenario.

Method. In both, the ACT and LCT scenarios, the assumptions are based on ETP 2016 global aggregated CO₂ captured emissions data for the total industry from 2015 until 2040. The aggregate figures are broken down to regions (i.e. Latin-America, USA and Canada, and EU25) using the Global Cement Roadmap 2050 data on CO₂ captured for the years 2030 and 2040. Country-specific CO₂ emissions estimates under the ACT and LCT scenarios (see next section) are then used to further break-down regional data (e. g. USA and Canada) to country data (e. g. USA).

Results. CCS deployment differs significantly between the scenarios. While in the ACT scenario, 18% of the global CO₂ emissions occurring from cement production are captured by CCS by 2040, in the LCT scenario only 7% are captured. Countries with a higher CO₂-intensity like Mexico, Brazil and the USA should deploy CCS at a higher rate compared to Germany, France and Italy in both scenarios. CCS deployment has, among the CO₂ abatement options, the highest CO₂ abatement costs and can be regarded as a last resort for cement producers. Countries with higher CCS deployment can have less access to cheap and low carbon alternative fuels or to clinker substitutes, or are required to produce cement types with a higher clinker to cement ratio.

TABLE 5.5 GLOBAL AND COUNTRY-SPECIFIC SHARE OF CO₂ CAPTURED IN THE ACT AND LCT SCENARIO (SOURCE: AUTHORS, BASED ON IEA 2016A, 2015, 2009 AND WBSCD 2014)

Country	2015	2020		2025		2030		2035		2040	
		ACT	LCT	ACT	LCT	ACT	LCT	ACT	LCT	ACT	LCT
World	0%	0%	0%	3%	1%	5%	2%	11%	5%	18%	7%
Brazil	0%	0%	0%	3%	1%	7%	3%	15%	6%	24%	8%
France	0%	0%	0%	2%	1%	4%	1%	9%	3%	15%	5%
Germany	0%	0%	0%	2%	1%	4%	1%	9%	3%	15%	5%
Italy	0%	0%	0%	2%	1%	4%	1%	9%	3%	15%	5%
Mexico	0%	0%	0%	3%	1%	7%	3%	15%	6%	24%	8%
USA	0%	0%	0%	3%	1%	5%	2%	11%	4%	17%	6%

5.6 CO₂ INTENSITY



Overview. The production of cement is one of the largest CO₂ sources of all industry. The CO₂-intensity depends on a wide range of factors including thermal energy intensity, capacity, alternative fuel use, clinker to cement ratio and CCS.

Risk pass-through mechanism. Without disruptive adaptive measures, CO₂ certificate costs can make up for 30% of the total production costs in the in 2050. Thus, reducing the CO₂ intensity is a necessary option for cement producers to gain a competitive advantage. Failing to decrease CO₂ intensity in relation to local competitors could lead to lower market volumes and revenues.

Sources. Scenarios generally present CO₂ intensity at macro-level. For instance, the IEA's Global Cement Roadmap 2050 discloses CO₂ intensity of a regional level (i.e. Latin-America, USA and Canada, EU25) for 2030 and 2050 in low and high demand scenario. Sector specific studies show the cost-effective reduction potential of CO₂ intensity when considering mutual interaction with CO₂ reduction measures and no disruptive innovations for some specific geographies (e.g Brunke & Blesl 2014b).

Method. Both the ACT and LCT scenarios are based on data of ETP 2DS and 4DS scenarios. The global aggregated CO₂ intensity is computed by building the ratio of total cement CO₂ emissions and total cement production for 2010 until 2040. For country-specific data, WBSCD 2014 data is used for each country, except for Mexico, where Latin America data is used. Country-specific CO₂-intensity is forecasted using an carbon intensity factor developed by the authors. This factor has a positive linear relation with energy intensity and the clinker to cement ratio, and a negative relation to share of alternative fuels in the fuel mix and share of CO₂ captured to total CO₂ emissions.

Results. In contrast to energy intensity, the CO₂ intensity in the ACT and the LCT scenario decreases by more than 15% until 2040 in comparison to 2015. New quality cement types and higher alternative fuels shares increase the energy intensity and analogously the CO₂ intensity but at a lower rate until 2020. After 2020, the CO₂ intensity decreases steadily until 2040 at a global and country level. Although countries like Brazil, Germany, France and Italy have a higher energy intensity compared to the global average, the actual CO₂ intensity is less or close to the average due to higher shares of alternative fuels and lower clinker to cement ratios. These countries reduce their CO₂-intensity mainly due to higher shares of alternative fuels in the fuel mix.

TABLE 5.6 GLOBAL AND COUNTRY-SPECIFIC RATIO OF CO₂ INTENSITY FOR BOTH SCENARIOS (SOURCE: AUTHORS, BASED ON IEA 2016A, 2015, 2009, WBSCD 2014)

Country	2015	2020		2025		2030		2035		2040	
		ACT	LCT	ACT	LCT	ACT	LCT	ACT	LCT	ACT	LCT
World	0.6	0.6	0.7	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5
Brazil	0.6	0.5	0.6	0.5	0.5	0.5	0.5	0.4	0.5	0.4	0.5
France	0.6	0.6	0.6	0.5	0.6	0.5	0.5	0.4	0.5	0.4	0.5
Germany	0.6	0.5	0.6	0.5	0.5	0.4	0.5	0.4	0.5	0.4	0.4
Italy	0.7	0.6	0.7	0.6	0.6	0.5	0.6	0.5	0.5	0.5	0.5
Mexico	0.6	0.6	0.6	0.5	0.6	0.5	0.5	0.4	0.5	0.4	0.5
USA	0.7	0.7	0.7	0.6	0.7	0.5	0.6	0.5	0.5	0.4	0.5

5.7 SECONDARY FUEL PRICES



Overview. Secondary fuel prices vary between the regional markets. Differences are primarily due to transportation costs, infrastructure constraints, local demand, fossil fuel prices and composition of secondary fuels. Secondary fuel for the cement industry comprises wastes (e.g. waste tyres, waste oil and solvents, pre-treated industrial and domestic wastes, plastic, textile and paper wastes) and biomasses (e.g. animal meat, waste wood, sawdust and sewage sludge). The types of wastes and biomasses vary greatly regarding caloric heating value, CO₂ emissions and price. Depending on the type of fuels, transportation costs make a significant share of the total price. Due to the increasing demand for waste fuels, e.g. cement plants and district heating, industrial and domestic waste is traded internationally. The burning of some types of wastes, e.g. hazardous waste from hospitals or industry, can provide additional monetary benefits for cement producers.

Risk pass-through mechanism. Secondary fuel usage provides a significant reduction of operating costs for cement producers in comparison to fossil fuel usage. Even more important in the future, secondary fuels can have significantly lower CO₂ intensity compared to fossil fuels which reduces costs for CO₂ allowances.

Sources. To derive one secondary fuel price for a nation is generally a challenging task. First, prices vary significantly depending on the composition as high caloric wastes such as waste oil or waste tyres as they tend to be of more value than low caloric wastes such as municipality waste. Second, a significant part of the price depends on regional infrastructure for collecting, transporting and sorting. Third, the competition for secondary fuels or wastes depend on local district heating and cement plants. To the knowledge of the authors, there is no comprehensive listing of regional secondary fuel prices available. McKinsey 2008 states a global long-term price for secondary fuels in relation the primary fuel costs in their report on the impact of emissions trading in Germany.

Method. From an economic perspective, the price of secondary fuel should relate to the respective caloric value of the secondary fuel in relation to the displaced fossil fuel, i.e. coal. The caloric value of secondary fuel ranges widely from 25% to 125% of the caloric value of coal. Additionally, solid waste has on average less than a half of the caloric value of coal (EC 2013). Thus, for achieving the same energy content, twice the amount of secondary fuel compared to coal is required. Additionally, some retrofitting is required to use the inhomogeneous fuel type in cement kiln which increases opportunity costs. McKinsey 2008 states a price of 7% for 2010, 15% for 2015 and a long-term price of 40% in relation to the primary fuel, which is coal. A gradual increase from 40% to 50% until 2040 is expected due to an increasing demand together with increasing CO₂ allowance prices.

Results. With increasing demand of secondary fuels, the secondary fuel price in relation to the coal price increases from 25% in 2015, to 40% in 2020 and 46% in 2040. The secondary fuel share in the energy mix is identical for both scenarios since CO₂-induced incentives through reduced CO₂-intensity are considerably lower than the incentive from the lower energy carrier price.

TABLE 5.7 SECONDARY FUEL PRICE AS A PERCENTAGE OF COAL PRICES (USD/TON) FOR LCT AND ACT (SOURCE: AUTHORS, BASED ON MCKINSEY 2008)

	2010	2015	2020	2025	2030	2035	2040
World	7%	25%	40%	40%	42%	44%	46%

5.8 ALLOCATION OF FREE CO₂ ALLOWANCES



Overview. The combination of high production volumes and high carbon intensity groups the cement industry among the highest CO₂ emitters of all industries. In addition, cement is a bulk commodity with the lowest value added in relation to its CO₂ emissions. Energy costs are close to 50% of the value-added which indicates a carbon leakage risk (Brunke & Blesl 2014b). As for the steel sector, in Europe, cement producers are granted a volume of free CO₂ allowances which are allocated according to CO₂ intensity benchmarks to minimize carbon leakage risk and their negative impact on the national economics.

Risk pass-through mechanism. Cement production emits 0.5 to 0.8 ton CO₂ per ton of cement nowadays. An increase of CO₂ allowance price to 50 EUR/t CO₂ could lead to more than 30% of CO₂ costs in relation to the sector's typical value-added (Brunke & Blesl 2014b).

Sources. Neither IEA's Energy Technology Perspective nor its World Energy Outlook give detailed information on future CO₂ emission trading schemes or free CO₂ allowances. No source on how free CO₂ allowances for the cement sector could evolve was found during the literature review carried out in this study.

Method. The forecast of the cement sector is aligned to that of the steel sector due to the lack of information of free CO₂ allowances post-2020 for the cement industry. This assumption is based on the similar share the steel and cement sectors have in the overall EU ETS emissions from and allocations allowances to the industrial sector in 2015 (Sandbag 2016). The estimates of free CO₂ allocation allowances from Ecofys 2016 (see page 51) are taken as base and it is assumed that future emissions trading schemes in USA, Mexico and Brazil will follow the EU trend. Ecofys 2016 suggest that the European steel industry will face an annual shortage of free CO₂ allowances for direct emissions increasing from 32% in 2020 to 49% in 2030 based on the proposed ETS revision. Thus, in the LCT scenario a similar shortage of free CO₂ allowances across the regions will occur. Values until 2040 are extrapolated. In the ACT scenario, CO₂ certificates are significantly increased beginning of 2030 and emission trading schemes or similar policies are implemented in all region in scope, including Brazil.

Results. In the LCT scenario, the annual shortage of free CO₂ allowances for direct emissions increases linearly from 32% in 2020 to 66% in 2040. Brazil with no emissions trading scheme in place according to IEA 2016 is an exception and has thus no shortage. In ACT scenario, the emission trading scheme is rolled out to all regions in focus with no free CO₂ allowances after 2030.

TABLE 5.8 ANNUAL SHORTAGE OF FREE CO₂ ALLOWANCES FOR DIRECT EMISSIONS IN CEMENT PRODUCTION (% OF TOTAL CO₂ DIRECT EMISSIONS) (SOURCE: AUTHORS, BASED ON IEA ETP 2016, 2015, ECOFYS 2016)

Year	Brazil		EU		Mexico		USA	
	ACT	LCT	ACT	LCT	ACT	LCT	ACT	LCT
2020	32%	0%	32%	32%	32%	32%	32%	32%
2025	66%	0%	66%	41%	66%	41%	66%	41%
2030	100%	0%	100%	49%	100%	49%	100%	49%
2035	100%	0%	100%	58%	100%	58%	100%	58%
2040	100%	0%	100%	66%	100%	66%	100%	66%



MEET THE BUILDERS - ET RISK CONSORTIUM

The ET Risk consortium, funded by the European Commission, is working to develop the key analytical building blocks (Fig. 0.1) needed for Energy Transition risk assessment and bring them to market over the coming two years.



1. TRANSITION SCENARIOS

The consortium will develop and publicly release two transition risk scenarios, the first representing a 'soft' transition extending current and planned policies and technological trends (e.g. an IEA NPS trajectory), and the second representing an ambitious scenario that expands on the data from the IEA 450S /2DS, the project's asset level data work (see Number 2), and relevant third-party literature. The project will also explore more accelerated decarbonization scenarios.

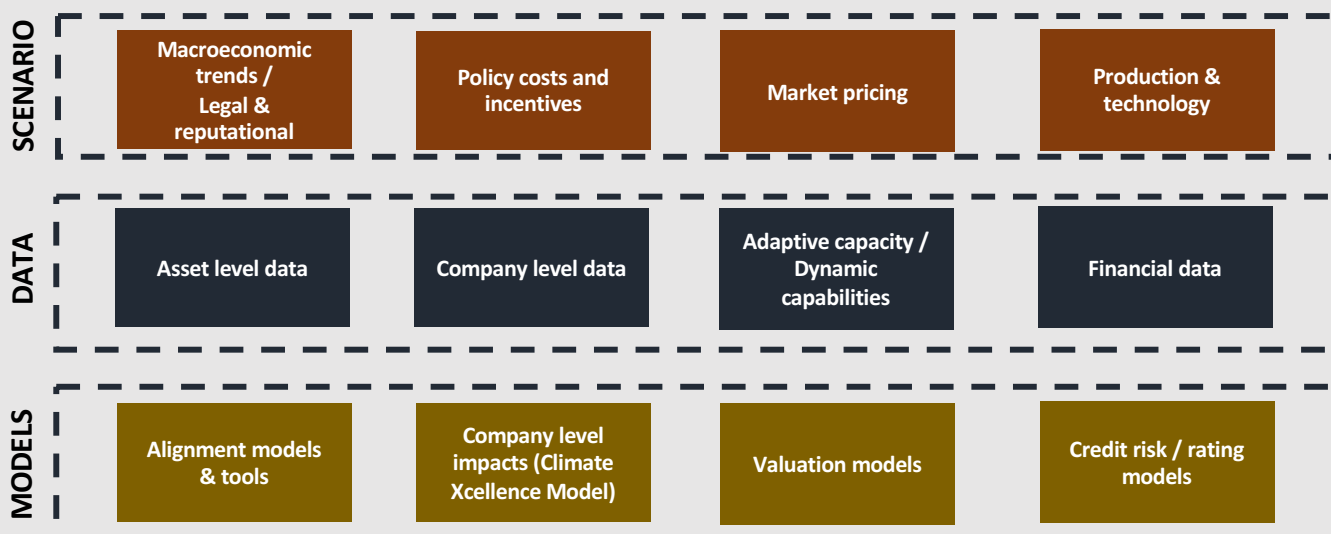
2. COMPANY & FINANCIAL DATA

Oxford Smith School and 2° Investing Initiative will jointly consolidate and analyze asset level information across six energy-relevant sectors (power, automotive, steel, cement, aircraft, shipping), including an assessment of committed emissions and the ability to potentially 'unlock' such emissions (e.g. reducing load factors).

3. VALUATION AND RISK MODELS

- a) **2°C portfolio assessment – 2° Investing Initiative.** 2° Investing Initiative will seek to integrate the project results into their 2°C alignment model and portfolio tool and analytics developed as part of the SEI metrics project.
- b) **ClimateXcellence Model – The CO-Firm.** This company risk model comprises detailed modeling steps to assess how risk factors impact margins and capital expenditure viability at the company level.
- c) **Valuation models – Kepler Cheuvreux.** The above impact on climate- and energy-related changes to company margins and cash flows can be used to feed discounted cash flow and other valuation models of financial analysts. Kepler Cheuvreux will pilot this application as part of their equity research.
- d) **Credit risk rating models – S&P Global.** The results of the project will be used by S&P Global to determine if there is a material impact on a company's creditworthiness. S&P Dow Jones Indices, a S&P Global Division, will explore the potential for developing indices integrating transition risk.

FIG. 0.0: ASSESSING TRANSITION RISK ACROSS THE INVESTMENT CHAIN (SOURCE: AUTHORS)





ABOUT 2° INVESTING INITIATIVE

The 2° Investing Initiative [2° ii] is a multi-stakeholder think tank working to align the financial sector with 2° C climate goals. Our research work seeks to align investment processes of financial institutions with climate goals; develop the metrics and tools to measure the climate friendliness of financial institutions; and mobilize regulatory and policy incentives to shift capital to energy transition financing. The association was founded in 2012 and has offices in Paris, London, Berlin, and New York City.

ABOUT THE CO-FIRM

The CO-Firm GmbH is a boutique consultancy specialized in developing climate and energy strategies for financial services providers, industry, and utilities. Based on financial risk modelling under a range of climate and energy scenarios, the proprietary ClimateXcellence Toolset, and a dataset of more than 200.000 assets and more than 15.000 different technical mitigation measures, The CO-Firm supports its clients in identifying, evaluating and realizing their specific economic opportunities in the national and global climate transition. Specifically, the CO-Firm serves its clients in adjusting their strategies, setting Science Based Targets, creating new business models, and identifying cost savings in their operations and their supply chain. Additionally, the consultancy provides regulatory monitoring services.

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