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GREENER CEMENT SECTOR AND POTENTIAL CLIMATE STRATEGY DEVELOPMENT BETWEEN 2015-2030 (HUNGARIAN CASE STUDY)

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Abstract: *Advancing the domestic industrial production towards a sustainable, resource-preserving direction can become an important pillar to support competitiveness in the European Union, as well as in Hungary. Reaching the de-carbonization goals for industrial production via lowering the production volume may result in less desirable macro-economic effects, so decisions which concern the industry require a lot of attention from the climate policy as well. In the case of the cement sector, economic actors have to be motivated to make energy-efficiency investments and technology developments, which also show promise in terms of business efficiency. In the more natural-resource-intensive branches of the industry, both innovations and technological developments will be required to reduce the amount of used non-renewable energy resources, keep it in the industrial cycle, and reduce environmental load. The importance of greener cement will be essential in the near future to reduce the sector's CO_2 emission levels. We need to identify more sector branches which relate to sustainability, which can aid the country in establishing long-term competitiveness that points towards the de-carbonization goals. The cost-efficiency aspects of this development process are the most tedious questions in today's business planning.*

Keywords: *emission trading; EU climate policy; cement sector; benchmarking; EU ETS; industrial climate change effects, green cement* (JEL classification: Q55)

Introduction

The role of the cement sector is important for both the European Union (EU) and the Hungarian economy. It affects the construction industry directly and has a strong connection to energy production, due to its energy-intensive nature.

The cement business utilizes 60-130 kilograms (KG) of oil or oil equivalent, and an additional 90-130 kilowatts (KWh) of electricity for each ton of cement produced (Iozia and Jarre, 2011). In the European Union, cement is mainly produced with the dry method, which conserves up to 50% energy when compared to the wet process, a technique commonly used by developing countries. If we want to produce cement in a low carbon way, a range of alternative fuels can be mentioned such waste oil, sewage sludge, used tires and waste derived fuels also. The cement sector's production requires high amounts of capital, approximately 150 million EUR for every million tons of raw materials. Regarding manufacturing costs, consumed fuel and electricity expenditures are usually 35-45% of the total production costs for each ton of cement (Iozia and Jarre, 2011). According to the cement sector, well-prepared scientific processes can go to waste if their limitations have not been evaluated as a result of the absence of information on implementation, theoretic unpreparedness, lack of motivation, or other various reasons (Kovacs and Fogarassy, 2015). The role of the cement sector is important for both the European Union (EU) and the Hungarian economy. It affects the construction industry directly and has a strong connection to energy production, due to its energy-intensive nature.

The importance of the cement industry can be analysed by using other relations as well. The sector can contribute to reducing the usage of fossilized fuels via waste incineration technology. This could result in a global reduction in gas emission, and advance the establishment of real sustainable waste management. (Reid and Huq, 2014) The cement sector aims to reduce its energy-consumption and CO_2 emission by enhancing the effectiveness of cement kilns, discarding the wet process, while also modernising and optimising the technological processes. This research aims to explore the sector's possible routes of low-carbon development in detail using this analysis between 2015-2030.

Experimental section

A. C. Pigou was the first to highlight externalities as outside economic effects, appearing parallel to production activities in his 1920 work, '*The Economics of Welfare*'. These external forces can either be positive or negative macro-economic impacts. If manufacturers are influenced by their own net marginal propensity, which does not match that of society, these damaging outside effects will reduce the welfare of society. The solution Pigou offered for this problem was to levy taxes on polluters, forcing producers to decrease their emission of harmful externalities.

If the manufacturer uses their environment for free understanding that such an activity causes damage to a third party, it can become the source of serious economic malfunctions (Farkas et al., 2008; Kovacs et al., 2014).

Fogarassy (2012) mentions the following economic faults that relate to the existence of externalities:

- The activity causing pollution goes beyond the tolerable level, which leads to an imbalance of the economy,
- Pollution is over-generated due to the manufacturer having no motivation to reduce the activity,
- If the price of the contaminated product is low and does not contain exterior costs, an excessively high demand for said item may appear on the market,
- As long as pollution expenses can be said to be external, there is no motivation to reduce the average pollution level for each product,
- The fact that releasing pollution into the environment is cheaper than handling it makes recycling waste and polluting substances much more challenging.

In order to clearly understand the actual processes currently present in the cement industry, the first priority of this research was to analyse the positive and negative externalities in the sector. Based climate policy goals (increasing renewable energy use, reducing greenhouse gas (GHG) emission, and increasing energy efficiency) and deadlines (2020, 2030, 2050) it was obvious to set the 2015-2020 and 2020-2030 intervals as the spectra of analyses. This examination uses the benchmarking method to include and evaluate externalities.

Different schools and literary sources have different definitions on the principle of benchmarking. This research relies on the simple definition, which states: 'the goal of benchmarking is to measure and compare levels while also exploring the limitations of systems'. According to this structure, benchmarking is an organised leadership process that aids leaders in finding and analysing the best techniques. Seeking the method assisting in the best decisions is not limited to evaluating the direct contenders. Camp (1998) defines benchmarking as the search for, and implementation of unsurpassed practices. Management and surface-survey borrowed the term benchmarking from architecture, where it means a stilt or column, which acts as a reference for all further measurements. The original meaning of the word is: elevation or level of height. According to Evans (1997), benchmarking is a leadership tool, which helps the user find the best business practice that consequently leads to the highest levels of performance.

The goal of the methodology section is to analyse the basic interrelations influencing the implementation of climate policy goals related to the cement sector. This is done by using the characteristics of renewable energy's share and expected changes in it, along with the current trend of raising energy efficiency, and reducing carbon-dioxide equivalence (CO_2e), including its expected aspects as important factors. This study organises the data sets related to sub-sectors into different tables, then evaluates each aspect in three different dimensions (economical, technological and environmental) for nine attributes each, all of which can either be quantified or qualified. After summarizing the results, it was important to draw the appropriate conclusions as to the certain climate policy aspect (renewable, energy-efficiency, CO_2e reduction), and which one of its evaluation dimensions may cumulate negative or positive externalities in a given sector.

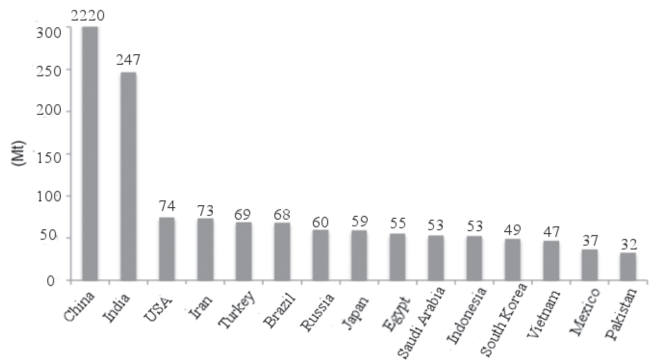
After recording the basic tables, all of the factors received *Status and Performance indicators*. The interrelations of the initial state and 'achievements' compared to the original goals can be evaluated using these indicators. Therefore, *Status indicator* values must be recorded according to the method of this analysis, which becomes the defining parameter for the 2020 period. From this, its related target value for the 2030 period can be determined. The optimum of the *Performance values* (-2, -1, 0, 1, 2) was based on available information results in the *Target indicator* (with a value of '0'), where any other values represent either the under or over performance of the indicator. The results will clearly show what additional climate policy decisions in the sector must be made for the given indicator to achieve the *Target value*. The accumulation of negative externalities and their dominance shows that the framework of the evaluated system is faulty, and leading it towards sustainability can be achieved via re-constructing the framework (Fogarassy, Bakosne, 2014). The amount of positive externalities, and their dominance shows that the system is sustainable, or low-carbon development methods are applicable to it. However to create the balance of welfare indicators, the use of auxiliary resources such as subsidies, tax concessions are required.

Results and discussion

Cement is an exceptionally important material for the construction industry, and its production relates directly to the overall condition of this business. In addition, it is in a tight interrelation with the general state of the economy (Dean et al., 2011). Cement is mainly produced using the dry method in member states of the EU. This technological solution demands an average 50% less energy compared to the wet process, during which clinker, the base material that is ground to powder and mixed with other ingredients to make cement, is incinerated in a kiln. Reducing the heat energy required to cremate clinker is imperative for the manufacturers, as one of the most notable expenses of cement manufacturing is the fuel material (Krzaklewski M. and **Činčera** P., 2007).

Due to the possibility of a carbon leakage (corporations related to this left the area of the EU due to the introduced regulation system, but still relocate their products to its market), the cement sector is of higher importance, since it may affect the emission of related industries beyond that of itself such as construction and transport. (Akashi et al., 2014) The exposure of the cement sector is substantial in countries which are not under the effects of the EU Emission Trading System (ETS) regulation mechanisms, or do not have a strict regulation system targeting hazardous emissions (Figure 1).

Figure 1. The 15 most notable cement manufacturing countries in 2012

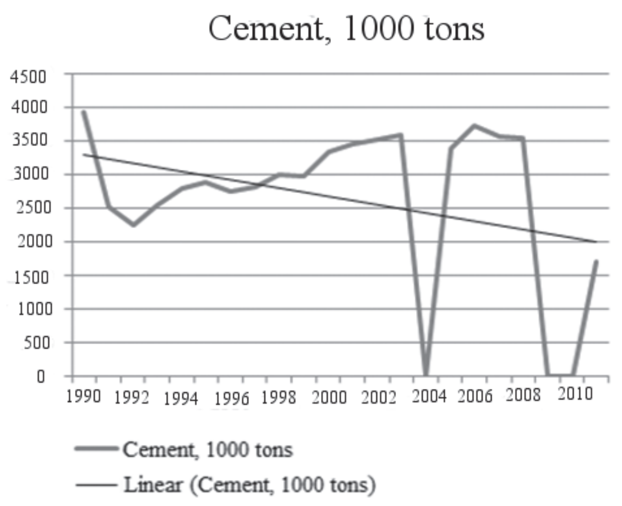


Source: Armstrong (2013)

State of the Hungarian cement sector

The cement sector of Hungary is one of the most endangered and energy intensive sectors, as energy costs make up to 35-40% of the total production expenses (Iozia and Jarre, 2011). The fact that more than 50% of the total emission comes from technological de-carbonisation is a problem. It is not affected by any attempts of cost sparing, or the exchange of fuel materials (Fogarassy et al., 2012; Bakosne and Fogarassy, 2011). Additionally, specific emission-reduction in the national cement sector only has limited opportunities, due to reasons related to technology and the market.

Figure 2. Emissions of Hungarian cement production for the 1990-2011 period



Source: Personally edited, based on the Hungarian Central Statistical Office's data

To reduce the total CO_2 emission by 21% (which is the target of the EU), the use of fuel materials would need to be reduced by 50,5% (based on studies). However, this is highly unlikely due to current technology (Hungarian Cement Concrete and Lime Association, 2008). In this case, factories would have to acquire unavailable carbon-dioxide quotas from the market. The amount of cement production showed a tendency to decrease in recent years, according to the data of the Hungarian Central Statistical Office (Figure 2). This trend (no accessible data for the years of 2004, 2009-2010) to decrease relates to a decline in the demand of the construction industry. If the investments in the construction business start to increase, the amount of available free quota will probably hinder the expansion of corporate emission in the cement sector. In the future, distribution methods of the (free) ETS quotas will determine how the sector's market actors keep or discontinue manufacturing.

Benchmarking analysis of the cement sector

The analysis of the Hungarian cement sector was conducted along three aspects adhering to the climate policy targets. These characteristics are: *'Aspects of renewable energy's share'* (Table 1), *'Aspects of raising energy efficiency'* (Table 2), and *'Aspects of reducing CO_2 emission'* (Table 3). Subsequently, the various indicators in each table had to be defined, which served as the basis of the evaluation. They were selected and defined using the assessment of international literary resources, and the coordination with professionals as the basis.

Tables 1, 2 and 3 which include *attributes of renewable energy's share and its changes, and the current trend of increasing energy efficiency, and decreasing CO_2e (carbon-dioxide equivalence) and their expected aspects*, show the syllabus of the concluded analyses.

Table 1. First indicator group of the cement sector's benchmarking analysis

Dimensions	Code	Status Indicators	Code	Performance Indicators (including the method of establishment)
ASPECTS OF RENEWABLE ENERGY'S SHARE				
TECHNOLOGICAL	RS1	Specific analysis and general characteristics of applied energy mix	RP1	Changes of depleting energy resource use, increase or decrease of fossilized resource usage in the evaluated sector between 2020 and 2030
	RS2	Average quality and development opportunities of machinery and tools	RP2	Development options of engineering level under certain economic circumstances
	RS3	Level and characteristics of renewable energy resource utilisation	RP3	Opportunities to use renewable energy resources in the sector, opportunities to increase share in the sector

Dimensions	Code	Status Indicators	Code	Performance Indicators (including the method of establishment)
ENVIRONMENTAL	RS4	Characteristics of recycling in waste energetics system	RP4	Evaluated by assisting role in renewable energy systems
	RS5	Results/connections of emission/injection value benchmarking	RP5	Possibility of decreasing emission levels using renewable energy resources
	RS6	Level of corporate environmental management, general sector attributes of environmental management systems	RP6	Evaluating ISO 14001 systems in the process
ECONOMICAL	RS7	Is the sector a participant in the renewable emission market (CDM, JI, VER), green electricity production, trade	RP7	Evaluation of activity (description of carbon financing)
	RS8	Intensity/activity of Environmental policy - Climate policy regulation	RP8	Effect regulation has on production output
	RS9	Complexity of resource efficiency - labour market effects, effects on employment	RP9	Analysing workplace-establishing effect, and describing its importance

Abbreviations: *'RS (Renewable status) 1 - 9:' status indicators of the ratio of renewable energy, according to dimensions; 'RP (Renewable performance) 1 - 9:' performance indicators of the ratio of renewable energy, according to dimensions*

Table 2. Second indicator group of the cement sector's benchmarking analysis

Dimensions	Code	Status indicators	Code	Performance Indicators (including the method of establishment)
		ASPECTS OF INCREASING ENERGY EFFICIENCY		
TECHNOLOGICAL	ES1	Share of nuclear energy in total consumption	EP1	Evaluating quality of nuclear energy usage, with scaling in the EU
	ES2	Opportunities and levels of system interconnections in energetics	EP2	Connectivity to local and international networks, for optimal supply and cost reduction
	ES3	Opportunity and level/rate of clean tech usage	EP3	Opportunities to introduce clean tech solutions
ENVIRONMENTAL	ES4	Opportunity of industrial ecology usage	EP4	What system attributes that assist circular processes are like
	ES5	Level of waste lifecycle optimisation	EP5	Based on the practice of waste usage in energetics
	ES6	Level of energetic losses	EP6	Level of decisions made to avoid losses
ECONOMICAL	ES7	Cost-efficiency parameters of increasing energy efficiency	EP7	Cost-efficiency analysis based on general technological levels
	ES8	Usual costs of increasing eco-efficiency	EP8	Eco-efficiency analyses based on general sector attributes
	ES9	Importance of regulation elements in the manufacturing process	EP9	Effect regulation has on the increase of technological quality

Abbreviations: *'ES (Energy status) 1 - 9:' status indicators of the energy efficiency aspect, according to dimensions; 'EP (Energy performance) 1 - 9:' performance indicators of the energy efficiency aspect, according to dimensions*

The attributes of different characteristics and measurement units compared to each other in the *economical, environmental and technological indicator groups* properly define the positive and negative interrelations, along with the specifics of the non-market attributes for a given evaluation area.

Table 3. Third indicator group of the cement sector's benchmarking analysis

Dimensions	Code	Status indicators	Code	Performance Indicators (including the method of establishment)
		ASPECTS OF REDUCING CO_2 EMISSION		
TECHNOLOGICAL	CS1	Intensity of GHG emission, in relation to technology	CP1	GHG emission based on evaluating obtainable technological variations
	CS2	Opportunities to introduce low-carbon technologies in the sector	CP2	Level of applicability for known low-carbon technologies
	CS3	Constitution / volume index of specific GHG	CP3	General characteristics of GHG emission for the area
ENVIRONMENTAL	CS4	Environmental characteristics of emission gases	CP4	Description of environmental attributes of harmful emission, and evaluation in regards to foreseeable decisions
	CS5	Border values / consistency of environmental regulations / norms	CP5	Does the regulation aid or hinder the completion of environmental policy targets
	CS6	Level of environmental risks for emission	CP6	Attributes and quality of adaptation decisions

Dimensions	Code	Status indicators	Code	Performance Indicators (including the method of establishment)
ECONOMICAL	CS7	Attributes and levels of GHG market share	CP7	Activity in the EU ETS system, practice of carbon management
	CS8	Usual costs of avoiding GHG emission for each unit of CO_2e	CP8	Cost index of CO_2e in the analysed sector
	CS9	Nature of contributions to completing GHG climate policy targets	CP9	Volume, cost and efficiency calculations

Abbreviations: *'CS (CO_2 status) 1 - 9:' status indicators of the aspect of reducing CO_2 emissions, according to dimensions; 'CP (CO_2 performance) 1 - 9:' performance indicators of the aspect of reducing CO_2 emissions, according to dimensions*

The evaluation of various indicators (1-9) was done by first naming the value used to describe the attribute and then its selection was explained to define the performance indicator, which can imply the change (estimated performance). The method of evaluating performance for the chosen indicator happens via categorisation on a scale of (-2); (-1); (0); (1); (2). The research uses the data sets of international and Hungarian databases to determine performance levels. The analyses are mainly based on forecasts, for which 2020 is the first milestone, and 2030 is the final planned time of the performance results and changes. The benchmarking provides a clear description of what prognosis the data describing the current (2010-2015) state of affairs generates in the various sectors. Moreover, what development trends Hungary can expect in 2020 and 2030, based on the 2015 plans, meaning what criteria are needed for the national EU climate targets to be achieved was determined.

The following summary will describe the indicator of '*Aspects of renewable energy's share*'.

The evaluation score shows what changes can be expected for 2020 and 2030 respectively, in relation to accumulation of externalities. According to the results if no change happens by the end of 2020, the EU targets will still remain reachable. However developments based on EU resources must be made until 2030 for their completion.

The next session shows a detailed description of the '*Share of electricity in total energy consumption*' State indicator from the '*Aspects of increasing energy efficiency*' indicator group's analysis.

Aspects of renewable energy's share (indicator group 1)

State indicator: level and attributes of renewable energy resource utilisation (Table 1, indicator 3).

Reason for choosing the indicator: The indicator was chosen because renewable energy usage / utilisation may differ in the evaluated sector.

Performance indicator: Opportunities for using renewable energy resources, and increasing its share in the sector.

Method of evaluating performance:

(-2) the renewable energy resource usage of the sector can be increased by 0%

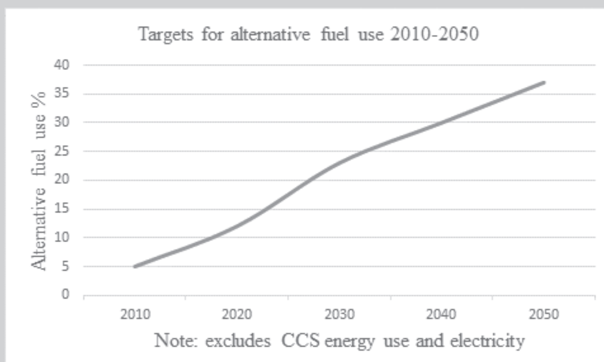
(-1) the renewable energy resource usage of the sector can be increased by 1-3 %

(0) the renewable energy resource usage of the sector can be increased by 5-10% (low)

(+1) the renewable energy resource usage of the sector can be increased by 15-20% (moderate)

(+2) the renewable energy resource usage of the sector can be increased by 25-30% (substantial)

Figure 3. Graph of cement sector's renewable energy resource usage



Source: IEA *(2009)*

	Results for 2010-2020 period	Results for 2020-2030 period
Evaluation score	0	+1

Reason: *The share of renewable energy can be increased by approx. 7% in the 2010-2020 period. The share of renewable energy resources for the 2020-2030 period can be increased by approx. 10-11%. (Figure 3).*

Aspects of increasing energy efficiency (Indicator group 2)

1. Status indicator: Share of electricity in total energy consumption.

Reason for choosing the indicator: The indicator was chosen because the end product's energy efficiency indicators are determined by the share of electricity in the analysed sector.

Performance indicator: Evaluating quality of energy consumption, with scaling in the EU.

Method of evaluating performance:

(-2) electricity consumption of industry/sector is substantial more 15 Million ton equivalence
(-1) electricity consumption of industry/sector is notable; 10-15 Million ton equivalence
(0) electricity consumption of industry/sector is optimal; 5-10 Million ton equivalence
(+1) electricity consumption of industry/sector is moderate; 1-5 Million ton equivalence
(+2) electricity consumption of industry/sector is trivial.

	Results for 2010-2020 period	Results for 2020-2030 period
Evaluation score	0	+1

Reason: *The electricity consumption of the sector in the EU will be approximately 15 million ton equivalence by 2020.*

The electricity consumption of the sector in the EU will be approximately 13-15 million ton equivalence by 2020. It will show a tendency to decrease, but stay substantial. (Table 4.)

Table 4. Energy consumption of the cement sector

Sum of EU 25	BLUE low demand			BLUE high demand		
Technology	2015	2030	2050	2015	2030	2050
Energy consumption (Mtoe)	15.5	13.3	13.7	16.5	15.7	19.0

Source: IEA (2009)

Note: the Mtoe measurement used by OECD and IEA indicates oil equivalence value: 1TWh = 0.086 Mtoe.

Aspects of reducing CO_2 emission (indicator group 3)

9. State indicator: Opportunity to capture and store CO_2 in the sector.

Reason for choosing the indicator: The indicator was chosen because by making the CO_2 detachment and storage possible for the sector, up to 95% of CO_2 can be saved in the long-term.

Performance indicator: CO_2 reduction reachable in the sector on the EU level by introducing a Carbon Capture and Storage (CCS) project.

Method of evaluating performance:

(-2) CO_2 emission decrease using CCS is 0 Million tons
(-1) CO_2 emission decrease using CCS is 1-2 Million tons
(0) CO_2 emission decrease using CCS is 2-3 Million tons
(+1) CO_2 emission decrease using CCS is 4-8 Million tons
(+2) CO_2 emission decrease using CCS is over 10 Million tons.

	Results for 2010-2020 period	Results for 2020-2030 period
Evaluation score	-1	+1

Reason: *Using CCS projects, substantial emission decrease can be achieved in the long term.*

A CO_2 emission decrease of about 4-9 million tons can be achieved using CCS projects by 2030, and even more after that. (Table 5)

Table 5. Amount of captured CO_2 in the cement sector

Sum of EU 25	BLUE low demand			BLUE high demand		
Technology	2015	2030	2050	2015	2030	2050
Captured CO_2 (Mt)	0	4.3	20.7	0	9.4	69.8

Source: IEA (2009) (BLUE scenario of IEA)

After comparing the results, the evaluation score for 2020 is '0', which forecasts no changes. For 2030, the score is '+1', that suggests development and subsidy needs for the decision makers of the sector.

Eventually the evaluation the '*Opportunity to capture and storage CO_2 in the sector*' indicator for the *GHG, or 'Aspects of reducing CO_2 emission*' indicator group's analysis:

Carbon Capture and Storage (CCS) technological solutions will not be mainstream for the cement sector until 2020, and regulatory or normative redesign of the sector will be required for them to be implemented. Therefore the sector's greenhouse gas (GHG) reduction targets of 2030 are not achievable in the 2020-2030 period without at least partially introducing the usage of CCS.

The results of indicators related to the respective GHG reduction aspects were summarized in Table 6.

Table 6. Summarising the benchmarking analysis of the cement sector

Numbers and dimensions		ASPECTS OF RENEWABLE ENERGY'S SHARE		ASPECTS OF INCREASING ENERGY EFFICIENCY		ASPECTS OF REDUCING CO_2 EMISSION	
		2010/2020	2020/2030	2010/2020	2020/2030	2010/2020	2020/2030
technological	1	1	1	0	-1	1	1
	2	1	1	-1	1	0	1
	3	0	1	-1	1	1	2
environmental	4	-1	1	0	1	-1	2
	5	1	1	1	2	1	1
	6	0	0	0	1	0	1
economical	7	-1	0	-1	0	1	2
	8	1	1	-1	0	0	-1
	9	0	-1	1	1	-1	1
A: Net positive externality ∑(1;9)		**2**	**5**	**-2**	**6**	**2**	**10**
B: Total externality ABS (1;9)		**6**	**7**	**6**	**8**	**6**	**12**
C: Share of net positive external effects in total external effects		**33%**	**71 %**	**0 %**	**75 %**	**33 %**	**83 %**

Explanation: **A:** *Net positive externalities ∑ (1;9): the number of positive externalities within the various aspects in 2020 and 2030, respectively, if no directed climate policy developments take place outside of BAU;* **B:** *Total externalities ABS (1;9): the absolute value of the total number of externalities;* **C:** *The ratio of net positive external effects within total external effects; expressed as a percentage, it indicates the dimension of improvability in the studied area.*

The examination includes 3×9 State indicators, 3 each for economical, environmental and technological groups respectively, for each reduction system. The function of the sector is not influenced by the high amount of indicators by the same measurements or effect mechanisms. The five categories of [(-2); (-1); (0); (+1); (+2)] based on the benchmarking analysis created one of the most honest analytical frameworks for evaluating the accumulation of externalities.

Table 6 illustrates the summarised 'Net positive externality quantity' of all present externalities for the evaluation (A) and the absolute values of all externalities (B), which helps to determine the amount of all positive effects within all externalities (C).

During the evaluation of the scores in the results table, it can be concluded that there are developments or GHG decreasing alternatives for augmenting the share of renewable energy. This mainly describes using more waste as fuel material. The 33% value related to the 2020 period may signify a mid-level development priority, which is optional since it is also tied to changes in regulation. The 71% change value related to the 2030 period can be attributed to the intensification of climate policy regulations on the sector. Increasing energy efficiency can change due to criteria from economic policy, however the current structure does not necessarily lead the sector towards a sustainable low-carbon strategy (0%). The area's opportunities until 2030 are defined and affected either positively or negatively by the constitution of Hungary's energy production (energy mix). This may create exceptional opportunities (75%) under certain circumstances, but then may stay unchanged as well. Regarding the development areas of CO_2 reducing aspects, the remaining elements of the technological system may offer efficient development options for the GHG decrease target system until 2020. CCS development may prove to be a substantial step forward for the sector. This changes the system-wide emission in its entirety (83%), but economic influences of this possibility are the least definitive.

The importance of the cement sector nationally, and on the EU level is substantial, since it has both direct and indirect influences on employment and the increase of Gross Domestic Product (GDP) (Schneider et al, 2011). The Hungarian cement industry currently manufactures using quite modern technological solutions, with the exception of one factory. It is only by implementing the CCS solution that more substantial decreases in emissions are possible on the current technological level. However, this can only be a realistic alternative for production in 2030. The environment-centred control systems used in domestic factories adhere to both the EU's and Hungary's requirements, which can assure the professional development of the situation, along with it's monitoring.

The production of the cement sector is very energy-intensive; it has high requirements both for fossilized energy resources, and electricity. Any modernisation or structural interventions shake the entirety of the sector, which makes handling an important factor. The manufacturing process requires high amounts of capital, and investment, which are basically dependent on EU resources. Developments made by owners to assure an increase in profit and the climate policy targets are not expected in the next few years. However, due to adhering to changes in regulation policy and climate goals, improvements targeting GHG reduction have a realistic chance of being implemented.

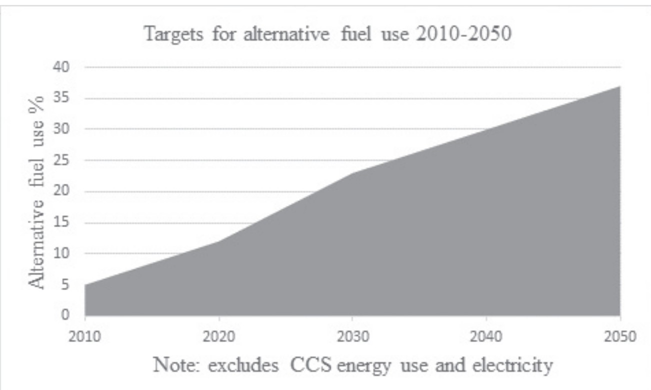
Presently, cement production technology utilises waste effectively. Nevertheless, there is a potential for development in this area until 2030. Hungary has the capacity to incinerate hundreds of thousands of waste annually, which can be consumed by the cement sector. However, extending the development of selective waste collection systems to consumption may hinder this. There are additional opportunities in terms of alternative energy resources, and by utilising the CCS projects by 2030, the CO_2 reduction potential can become substantial as well.

With alternative fuel use at the cement industry conventional fuels like coal and/or petcoke can be replaced during the cement kiln heating process. These alternative fuel sources can be alternative fossil fuel sources like natural gas and some kind of biomass fuels. According to IEA studies with this kind of fuel mix the process can be 20-25 % less carbon intensive than with the use of coal. Practically cement kilns are suitable for alternative fuels since the energy component of them can replace the fossil energy components and the other inorganic byproducts integrated into the clinker product. Alternative fuels could be used by the cement industry like biomass forms, discarded tyres, waste oil, plastics, textiles and paper residues, and pre-treated industrial and municipal solid wastes.

Biomass commodities such recycled wood and paper; sewage sludge; biomass crops; animal meal, wood chips and residues can be used as well.

Even though the energy need of cement production could be satisfied entirely with alternative fuels, in practice we must face some limitations. The problem is the major difference between alternative and conventional fuels regarding their physical and chemical attributes. So we must distinguish the ones that are suitable for industrial production from the others which lead us to technical challenges. According to IEA in the next few decades the share of alternative fuel use can be raised up to 37% until 2050 (Figure 4).

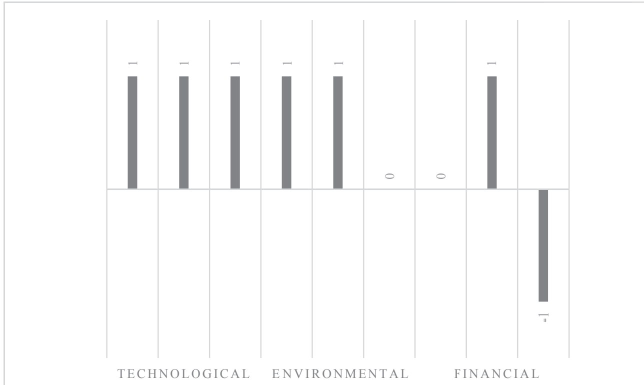
Figure 4. Graph of cement sector's renewable energy resource usage



Source: IEA (2009)

It seems that alternative fuel costs will be increasing and this tendency will be there for the CO_2 costs also. If it happens it can be much more difficult for the cement industry to reach the sufficient amount of biomass resource on acceptable prices. According to IEA studies for the cement industry the use of alternative fuels can be economically viable until 2030. Based our research results this point is the most sensitive among the different dimensions. On the next figure we can see the negative externality aggregation problems connected to renewable fuel use (Figure 5). It shows that for 2030 there will be a major positive externality accumulation regarding renewables in the cement sector. Most of these unused potentials are observed in the case of the technological and the environmental dimensions which means there is still room for technological development and stricter regulations for the optimal long-term operation. Considering that these indicators are kind of related to each other it is obvious that policy makers should drive this sector to spread clean technologies within their production.

Figure 5. The number of externalities within the aspect of renewable energy's share in 2030



By this time the prices will reach about the 30% of conventional fuel costs and by 2050 it will rise up to 70%. This can be the obstacle for the growth of alternative fuel use in the sector on long term, however technically higher substitution rates could be possible.

Conclusions

The cement sector is highly dependent on the EU's policies and decisions related to carbon-dioxide-emission, and other pollutants. As it was already mentioned, this sector is the most sensitive to changes in quota distribution. The dispersion of EU's rations requires a high level of foresight for the sector's future. The market players have to be motivated to reduce emission rates, as well as using energy efficient technology, while also fixing the effects of CO_2 emission decreases that distort the market. The result of the benchmarking analysis showed that the potential of CO_2 decrease and energy efficiency optimisations is limited until 2020 in the sector, and more substantial changes will only be apparent in 2030. The industry is to be handled with higher priority due to the chance of a carbon leakage. This can defined as the migration of the sector's actors into other, non-EU countries, and the relocation of their products back to the EU market may easily happen due to the unfavourable climate policy regulations. This may have further impacts beyond the cement sector in the related industries like construction and transport. The prognosis of this research for emissions may increase by 5-25% due to the increase of transport demands. The exposure of the domestic and EU cement sector is high, unlike in countries which are not subject to the ETS regulation mechanisms, or do not have a strict regulation system targeting pollutant emission. This may result in an edge for them on the market, due to the changes in the regulation environment. Therefore, changes in the global market trends have to be handled carefully. Heavily influenced by Asian markets, the international marketplace usually operates with lower prices along with a strictly regulated environment, thereby also becoming a potential cause for market failure in Hungary.

This study showed that the European ETS's rising quota prices and the increase of energy prices put together could cause a rise in manufacturing costs. This cannot be resolved later, neither by technological innovation, nor market policy tools. It may lead to the sector losing its competitiveness in Europe. Quota prices cannot be determined prior to their change and the cement sector is one of the high-risk sectors for the climate policy interventions because of its high sensitivity for allocations. Still, according to the benchmarking results it was clear that positive externality accumulation will occur in the long-term operation of the sector meaning a lot of unused potentials. While the financial dimension of the several aspects stays balanced even until 2030, the technological and environmental sides follow this underperforming trend. Even though the point of this research was mostly to examine the changes within the renewable energy aspect, the similar tendencies to the other aspects show that they are highly connected. Therefore the optimal operation of the sector cannot be achieved without a bit more serious environmental regulations – even if there is a risk for carbon leakage.

For a sustainable cement industry, the requirement of reaching climate policy goals is that the energy resources derived from waste increases substantially by 2030. Based on the positive externalities of the technological dimension, new alternative solutions will be also necessary to reduce the CO_2 emission levels of the sector. There are opportunities in alternative fuel use and alternative clinker producing methods during the manufacturing process. In the future the greener cement will be priority since the producers have to fulfil the market's demand in parallel with the low carbon emission requirements. Considering the return indicators, it is clear that further technological development of the sector aimed at CO_2 reduction is moderate at best, and currently there are no technological changes ahead. CCS technological solutions would be able to achieve a substantial decrease in CO_2 emission, however this may require hard investment decisions from national actors, as it will not bring short-term profitability. Therefore, this option cannot be foreseen until 2020 or even until 2030. Only theoretical opportunities are present based on the required investments.

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