MITIGATION STRATEGIES FOR IMPACTS FROM THE INDUSTRIAL SECTOR IN THE STATE OF CEARA

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Abstract. *Implementing pollution mitigation measures is one of the biggest challenges the industrial sector faces today, given that scientists worldwide have linked the increased concentration of greenhouse gases to industrialization growth. Considering this predicament, this paper proposes mitigation strategies for the pollution-related impacts from industrial activities in the State of Ceara. It should be highlighted that this work can serve as a baseline for future studies in other Brazilian states. Moreover, the strategies presented are focused on proposals to replace carbon-intensive fossil fuels with renewable sources. Since Brazil, particularly the northeast, represents a great potential regarding the use of renewable energy, due to suitable climate and land for growing renewable energy inputs, the strategies presented by the authors of this work are considered viable to be implemented. For the objectives to be fully met, this work proposes an analysis of the structure of energy consumption and the balance of* CO_2 *emissions of the entire industrial sector in the state of Ceara. With this procedure, it will be possible to identify the industrial activity branch with the greatest emission reduction potential and propose mitigation measures. The research method also uses the top-down approach of IPCC (Intergovernmental Panel on Climate Change) to measure the current* CO_2 *emission and to predict that pollutant's future emission with the fuel substitution. A literature exploratory approach was necessary to construct the strategies. With the results, the importance of government incentives was emphasized to develop cheaper technologies in order to reduce the inclusion costs of cleaner energy sources in the energy industry source. In addition, the importance of greater oversight by the agencies responsible for environmental control is stressed, as well as greater consumer demand for environmentally correct products. All of this can contribute to the expansion of cleaner industrial processes. In conclusion, the importance of working with mitigation measures in the cement sector is emphasized, due to the high steam coal consumption, a non-renewable energy source that contributes to high* CO_2 *concentrations in the atmosphere. It was observed that this energy contributes with approximately 42% of all carbon dioxide emissions from the cement sector.*

***Keywords**: mitigation, climatic changes, industry, Ceara.*

1. INTRODUCTION

Throughout history, mankind's approach to natural resources has been purely extractive. Deciding on the mass production process, prompted by the Industrial Revolution, accelerated the level of environmental degradation, which has reached alarming levels (JARDIM, 2006). The prevailing environmental damage, such as floods, acid rain, soil erosion, desertification, among others, demonstrates mankind's endless exploitation of on the environment.

Furthermore, as a way to highlight the influence of human activities on the increased atmospheric emissions of greenhouse gases (GHGs), studies show that the progressive increase of the use of fossil fuels took place in parallel to the increase in industrial activities. Given that the intensification of the greenhouse effect began precisely during the Industrial Revolution, during which fuels were developed based on hydrocarbon deposits (coal, natural gas and oil), this process is significantly correlated to the emissions that result from the increasing use of these energy sources (MAY; LUSTOSA AND VINHA, 2003).

Given the problems generated by the ceaseless exploitation of natural resources, stipulations were established by the *Brundtland* Commission. To comply with these specifications, companies must produce development measures that meet the needs of present generations, without compromising the ability of future generations to meet their needs. The commission disapproves of the excessive use of natural resources, which does not consider the ecosystems' capacity to endure this unrestrained use, pointing towards the incompatibility in sustainable development and production standards and current consumption. (BRAGA, 2007).

The concern with the environment has begun to be a requirement by business in general, since consumers, governments and society at large now give priority to activities that do not affect the quality of life of future generations, that is, activities that ensure sustainable development, which can be considered as the first motivation for studies on this topic.

What led to the present work was the need to propose mitigation measures to climate change in highly polluting sectors, which consume large amounts of fossil fuels, as these sectors may have the capacity and can greatly reduce GHG emissions.

Therefore, the objective of this paper is to *present strategies to mitigate the impacts related to pollution from industrial activities in the state of Ceara, Brazil*. The procedural steps to achieve the objective were: 1. Analyze the structure of energy consumption and the balance of CO_2 emissions from the industrial sector in the state of Ceara; 2. Identify the industrial activity with the greatest emission reduction potential and propose mitigation measures; 3. Prepare a forecast of the cleaner sources that will replace the current fossil fuel volume in use, and 4. Estimate the level of CO_2 to be reduced by the energy replacement.

It should be noted that the article uses data from the Energy Balance of the State of Ceara (BEECE - Balanço Energético do Estado do Ceará in Portuguese) of 2008 to analyze the current energy consumption structure and the CO_2 emission balance from Ceara's industrial sector. Furthermore, the IPCC reports will be used to implement the *top-down* methodology in order to measure the current CO_2 level and anticipate the level of future emissions with the energy replacement.

2. BIBLIOGRAPHIC REVISION

According to Cavalcanti (2004), all human activity, whatever its form, affects the ecosystem, either by resource exploitation (where nature works as a source) or by discarding waste.

Due to the accumulation of waste (solid, liquid and gaseous) from the economic development in our *habitat*, a proactive stance regarding the environment is required by the economic stakeholders, in order to promote sustainable development. If the industrial sector does not commit to comply with the appropriate initiatives that can reduce the amount of waste, it will be impossible to provide future generations a better quality of life.

Thus, one of the greatest concerns currently is the level of greenhouse gas emissions that cause global warming. Among the greenhouse gases (GHGs), the main one is CO_2. Therefore, the main focus of this paper is on the CO_2 level. Carbon dioxide was selected as it is the highest GHG concentration in our planet.

To reduce the level of GHG emissions in the atmosphere, mitigation measures are proposed in the industrial sector by implementing energy efficiency projects and expanding the use of renewable resources in the production processes. With these measures, the objective of the study herein is to develop strategies to mitigate the impacts associated with pollution from the industrial activities in the state of Ceara, Brazil.

According to Goldemberg and Villanueva (2003, p.119), "The industrial production, worldwide, accounts for approximately 20% of all air pollution." In Ceara, it was found that the industrial sector is among the largest CO_2 emitters (Figure 1).

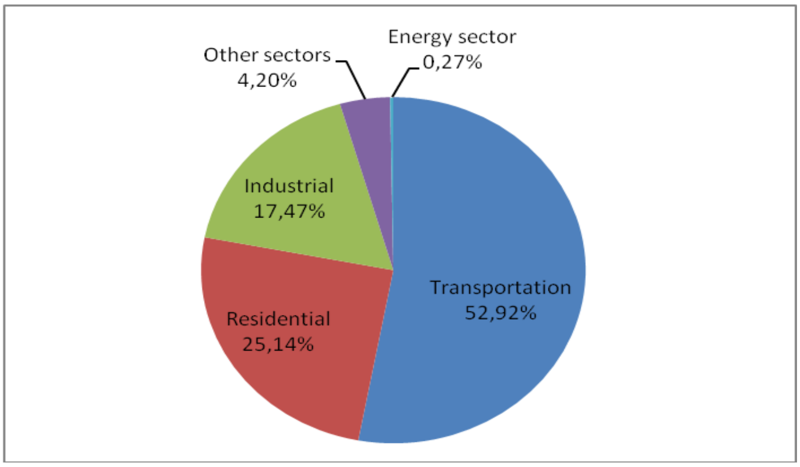

Figure 1. Level of CO_2 emission by sector in the State of Ceara. Values obtained by BEECE (2008).

Figure 1 shows that the industrial sector is the State's third largest CO_2 emitter, accounting for 17.47% of the total value emitted. Mass use of alternative sources will only be feasible with the commitment by government, business, society and other stakeholders. Moreover, many of the technologies that use cleaner energy sources are already available in the market and ensure a relatively quickly recovery of the investment made. This arouses the entrepreneurs' interest in using these sources in their production processes.

It should be noted that the reduction of GHG emissions by industrial activities is possible because, according to the Ministry of Mines and Energy (2006), the ingress of new and renewable sources will avoid the emission of 2.5 million tons of carbon dioxide per year.

To instantiate a greater feasibility for the use of renewable sources, it is important to remember that fossil fuels will soon end. According to the National Petroleum Agency (ANP), it is estimated that if the current rate of global oil production is maintained, taking into account the current reserves, it will have a lifespan of approximately 40 years.

One can identify instruments that promote the diversification of the Brazilian energy matrix, given that the financial sector funds R&D projects in the energy area. One example of such funding is the CT-ENERG, that funds programs and projects in the energy area, especially in the end-use of the energy efficiency area. The emphasis of the project is organizing the companies' direct expenditure in R&D and defining a comprehensive program to address the long-term challenges in the energy sector, such as alternative energy sources with lower costs, better quality and reduced waste, in addition to stimulating the increased competitiveness of Brazil's industrial technology (FINEP, 2006).

Figure 2 illustrates the numerous possibilities of energy substitution in the various energy consumer sectors (industrial, transportation, energy, residential, services and agricultural) in Brazil. The fossil fuels that emit greenhouse gases are at the top line, with the exception of nuclear energy, and renewable energy sources that do not emit gases or emit very little are at the bottom line. There are some applications that were not considered, as they are widely diffused in the Brazilian market. Some examples of such applications are the use of solar and hydrogen energy (fuel cell) in transport.

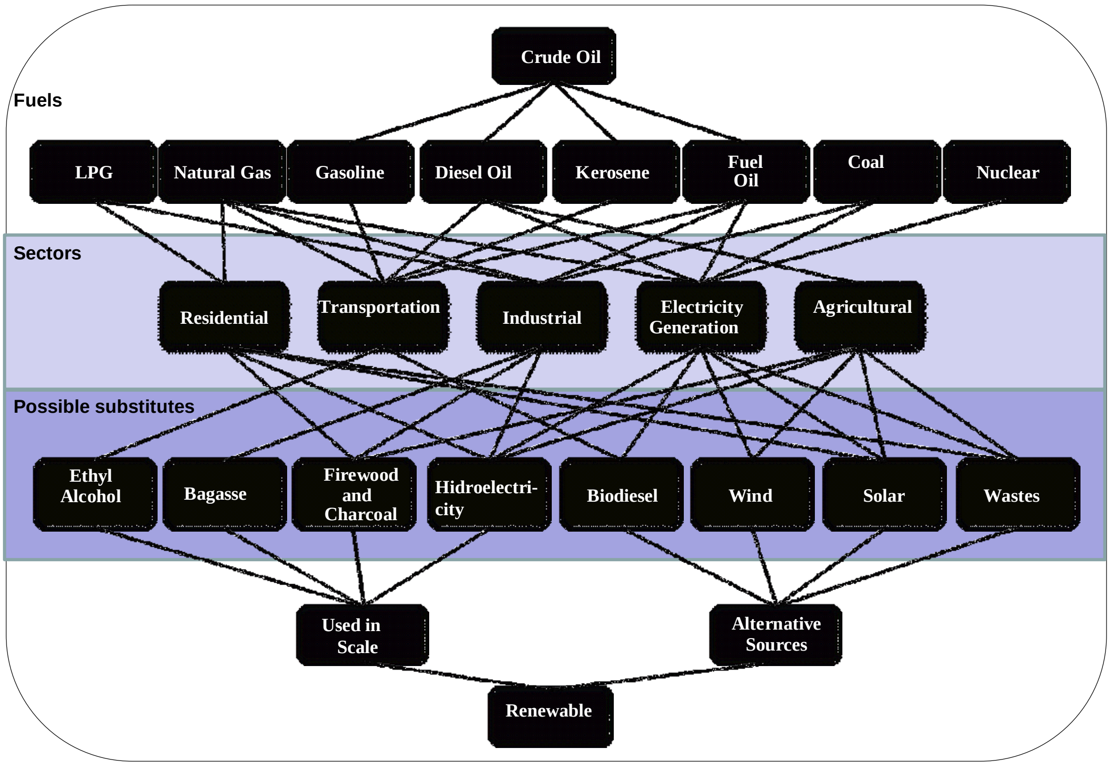

Figure 2. Multiple energy substitution possibilities for Brazil's energy consumers. Adapted by Rosa (2005).

Although renewable sources are environmentally friendly, they may have negative aspects in relation to other sources already consolidated in the market, these are: investment to introduce new equipment, supply risks, lack of qualified personnel to operate the new energy and new equipment and the lack of companies providing maintenance services for the equipment. These negative factors are being addressed, because as the production of such equipment increases, the product value decreases.

In addition, more technical assistance companies and more fuel providers enter the market, thereby ensuring the development of these new technologies. Moreover, the positive aspects related to the use of these technologies go beyond economic benefits, as there are environmental and social benefits that are not measured and therefore are left out of the feasibility analysis studies.

3. CASE STUDY IN THE STATE OF CEARA

From the data published in Ceara's Energy Balance (BEECE, 2008), a study was conducted on the energy consumption structure of various industrial segments and the emission balance to identify an industrial consumer that exhibits a high energy consumption reduction potential and high greenhouse gas emission reduction potential.

To select the industrial sector to be studied, the following steps were followed:

a) Identification of the largest energy consumers;

b) Analysis of the energy consumption structure of major customers;

c) Analysis of the CO_2 emissions balance of the industrial sector and identification of the major industrial CO_2 emitters;

d) Identification of a sector with emission reduction potential after changing the energy consumption structure.

After identifying this industrial consumer, an analysis of its consumption structure was carried out in order to find alternatives to reduce GHG emissions. In this last step, mitigation measures based on changes in the industrial energy sector that was studied were also proposed.

The results of each step mentioned earlier will be presented to follow.

a) Identification of the largest industrial energy consumers in the State of Ceara

As reported by BEECE (2008), the largest energy consumers in the industrial sector are foods and beverages, which appear in first place, with a consumption of 41.2%; next is the ceramics industry that consumes 17.1%; and in third place is textiles, consuming 13.0%; followed by cement with 8.6%. Note that these percentages represent the proportion of energy consumption of the sector mentioned in relation to the total amount consumed by the entire industry.

Table 1 shows a detailed energy consumption by sector.

Table 1 – Evolution of energy consumption by segment, represented by %. Values obtained by BEECE (2008).

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Final Consumption	100	100	100,1	100,1	100	100	100	100	100	100
Final non-energy consumption	4,6	3,6	3	3,1	2,5	2,3	2,1	2	2,1	2,2
Final Energy Consumption	95,4	96,4	97,1	96,9	97,6	97,7	97,9	98	98	97,8
Energy Sector	2,5	2,8	2,5	2,6	2,9	5,7	13,3	4,4	2,5	0,5
Residential	23,7	25,4	25,6	24,7	23,3	23	21	22,6	23,2	22,8
Commercial	3,9	4,4	4,3	3,9	4	4,4	4,4	4,7	5	5,1
Public	2,7	3,9	3,3	3,2	3,2	3,2	3	3,4	3,4	3,3
Agricultural	2,2	2,1	2,1	2,2	2,4	2,7	2,3	2,9	2,9	3,1
Transportation	33,4	33,8	34,3	35,8	36,5	34,6	32	36,2	37,1	41,1
Road transportation	95,5	96,2	96,1	94,6	94,7	94,2	93,4	93,1	91,2	89,8
Railroad transportation	0,4	0,5	0,6	0,7	0,6	0,7	0,7	0,7	0,4	0,4
Air transport	4,2	3,1	3,2	4,7	4,7	5,1	5,8	6,1	8,3	9,8
Water transportation	0	0,1	0	0,1	0	0	0,1	0,1	0	0
Industrial	26,9	24	23	22,4	23,3	23	20,8	22,6	22,5	21,8
Cement	24,7	12,3	9,3	9,4	8,8	8,5	8,3	8,5	8,6	8,6
Mettalurgical	2,6	3,1	2,4	2,4	2,5	3	3,3	3,9	4,3	4,6
Chemical	3	3,1	2,8	2,5	2,3	1,9	2,3	2,4	2,7	2,8
Food and Beverages	32,3	39,8	40,7	41,4	37,9	42,4	43,4	41,8	42,1	41,2
Textile	10,6	12	13,9	13,7	14,4	13,4	13,1	13,1	12,8	13
Paper	0,5	1,5	1,1	1,5	1,2	1,4	1,4	1,3	0,9	0,7
Ceramic	18,2	18,3	18,7	17,8	16,5	16,3	16	16,3	17,1	17,1
Others	8,2	9,8	11	11,4	16,5	13,2	12,2	12,5	11,5	12,1
Unidentified Consumption	0	0	2,1	2,1	2	1,2	1,2	1,2	1,4	0,3

b) Analysis of the consumption structure of the largest industrial consumers

Table 2 shows the participation (in %) of each energy in the food and drinks consumption structure.

Table 2. Consumption Structure of the food and beverage industry, represented in%. Values obtained by BEECE in 2008.

Fuel	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Natural Gas	11,7	7,4	8,3	7,1	1,6	7,8	9	9,4	9,9	9,6
Firewood	11,9	11,6	13	14,5	16,1	16,3	17,4	17,4	17,5	17,7
Cane products	6,5	5,6	5,8	5,6	5,6	5,2	5	5,1	5,1	5,3
Other primary	58,8	63,7	61,5	61	64,5	59,5	57,3	55,6	54,2	53,1
Diesel Oil	1,4	1	0,7	0,9	0,5	0,5	0,7	2,1	2,6	3,2
Fuel Oil	0,9	1,3	0,7	1,4	1,1	1	1	0,7	0,6	0,6
LPG	0	0,8	1	1	0,9	0,4	0,5	0,5	0,5	0,5
Electricity	8,9	8,6	8,9	8,6	9,6	9,3	9,2	9,1	9,4	10
Total	100	100	100	100	100	100	100	100	100	100

According to Table 2, we see that the food and beverage sector mainly uses other primary energy sources (not specified) with a 53.1% participation in the consumption structure. Additionally, there is a large share of firewood (17.7% of total consumption), electricity (with 10% of total consumption) and natural gas (9.6% of total consumption). Because the two main energy sources are renewable, there is a tradeoff in much of the CO_2 emitted during the combustion absorbed by the sugarcane cultivation stage, resulting in a low impact on global warming (greenhouse effect). Thus, this sector has little emission reduction potential.

Table 3 shows the participation, in percentage, of each energy source in the consumption structure of the ceramic industry.

Table 3. Consumption structure of the ceramics sector, represented in%. Values obtained by BEECE (2008).

Fuel	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Natural Gas	2,6	4,4	4,8	5,1	5,3	5,5	5,2	7,9	9,6	9,4
Firewood	92,4	89,7	85,3	85	85,2	87,2	87,3	83,4	81,9	81,9
Fuel Oil	0	0	2,4	1,9	1,7	0	0	0	0	0
Electricity	5,1	5,9	7,5	7,9	7,8	7,3	7,5	8,7	8,5	8,7
Total	100	100	100	100	100	100	100	100	100	100

The ceramics industry consumes much firewood, totaling a 81.9% participation in the consumption structure in 2007. Because this energy source is considered a renewable energy source, this sector also has no significant potential to mitigate greenhouse gas emissions, since the reforestation of this input is a form of compensation of the gases emitted during their use. This greatly reduces the global warming impact.

Table 4 shows the participation, in percentage, in each energy consumption structure of Ceara's textile sector.

Table 4. Consumption structure of the textile sector, represented in %. Values obtained by BEECE (2008).

Fuel	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Natural Gas	7,9	8,3	14,3	13,5	22,9	25,7	25,9	26,8	26,8	25,6
Firewood	2,8	2,8	2,7	2,6	2,5	2,8	3,1	3	3,1	3
Other Primary	0	0	0	0	0	0	0	0	0	0
Fuel Oil	14,1	5,6	3,7	4,2	2,3	0	0,1	0,1	0,1	0,1
Electricity	75,3	83,3	79,3	79,7	72,3	71,5	71	70,2	70	71,3
Total	100	100	100	100	100	100	100	100	100	100

As Table 4 depicts, there is a significant participation of electricity (71.3%) in the textile sector. In addition to electricity, natural gas is an important energy source for this sector, as its participation in the consumption structure is of 25.6%. The remaining energy sources consumed by the sector (firewood and fuel oil) have little participation. Since NG is a fossil fuel considered "environmentally friendly", it does not seem possible to find effective emission reduction proposals for this sector.

Table 5 shows the shows the participation, in percentage, in each energy consumption structure of Ceara's cement industry.

Table 5. Consumption structure of the cement sector, represented in %. Values obtained by BEECE (2008).

Fuel	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Natural Gas	2,2	0	0	0	0	0	0	0	0	0
Steam Coal	8,9	21,9	30,9	32,3	32,6	34,4	34,7	33,2	33,5	33,4
Fuel Oil	73,9	47,3	2	0	1,5	0	0	0	0	0
Electricity	6,1	14,3	25,6	25,7	24,6	23,6	24,2	28,3	28,6	29,5
Charcoal	8,9	16,4	41,5	42	41,3	42	41,1	38,5	38	37,1
Total	100	100	100	100	100	100	100	100	100	100

Out of the four sectors analyzed, the cement sector is the one with the greatest potential to reduce and mitigate the emission of greenhouse gases, since its energy system is based on the use of fossil fuels, such as steam coal (33.4%). Nevertheless, this sector uses two renewable energy sources, charcoal (37.1%) and electricity (29.5%).

It was observed that the cement industry has a high emission level of carbon dioxide (CO_2), due to the high fossil fuel consumption (steam coal), a non-renewable energy source that is polluting and non-exchangeable. This type of coal is primarily used in the process of heating boilers.

c) Analysis of the balance of CO_2 emissions from the industrial sector and identification of its main CO_2 emitters

According to the Energy Balance of the State of Ceara, 2008, base year 2007, the industrial sector of the state ranks third in CO_2 emissions. The three main sectors responsible for CO_2 emissions in the state are: transport, residential and industrial.

In agreement with BEECE (2008) data, it can be seen that the largest CO_2 emitters in the industrial sector are: in first place the ceramic sector, with 430.3 x 10^3 t/year; in second place the food and beverages sector with 306.1 x 10^3 t/year of carbon dioxide emissions; third place goes to the cement sector with 168.9 x 10^3 t/year of carbon dioxide emissions; followed by the textile sector with 61.9 x 10^3 t/year of CO_2.

As observed, the ceramic industry's emission level is high, when compared with other industries that also have high emission levels. The ceramic industry's high emission level is so significant that, when compared to the cement industry, which ranks third, there is more than twice the emission volume of the latter. Although the ceramic sector ranks first place, this sector does not use a significant percentage of fossil fuel, eliminating any fuel substitution possibility.

Figure 3 below, published in BEECE (2008), has the highest CO_2 emitters in the industrial sector.

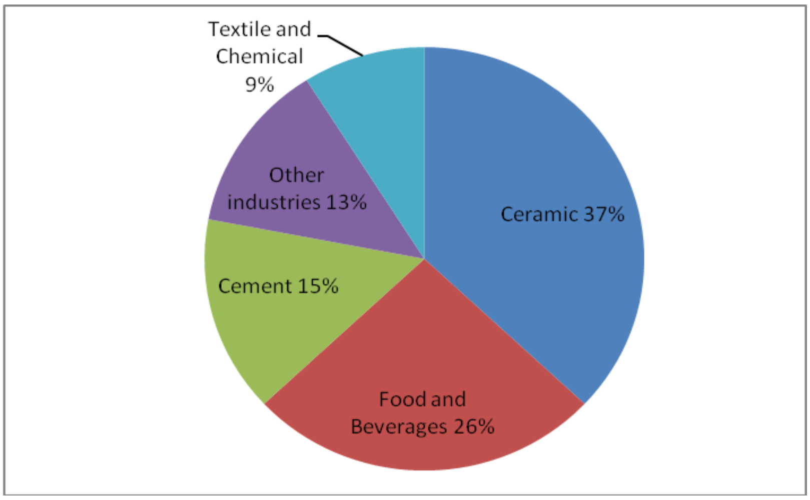

Figure 3. CO_2 emissions by sectors in 2007. Values obtained by BEECE (2008).

d) Identification of a sector with emission reduction potential after changes in the energy consumption structure

To identify the industry with emission reduction potential, first, the industry that uses a significant amount of fossil fuel considered as polluting will be identified, and then the CO_2 emissions from the use of fossil fuels will be quantified.

To quantify the CO_2 emission levels from energy consumed, the IPCC *top-down* approach will be used. This methodology was selected due to the lower complexity in obtaining the data and due to its reliability.

It should be noted that the IPCC methodology proposes quantifying the volume of emission without considering the nature of capturing CO_2 from the renewable energy sources, during the development stage. Therefore, the results should be cautiously interpreted to avoid precipitated conclusions.

Furthermore, the methodology assumes that, once introduced into the national economy in a given year, the carbon contained in a fuel is either released into the atmosphere or is trapped in some way (as for instance, by increasing the fuel stock, incorporating to non-energy products or its partially non-oxidized retention). The great advantage of the *top-down* methodology is that it does not need detailed information on how the fuel is used by the end user or what intermediate transformations it undergoes before being consumed.

The values will be calculated on an annual scale for each non-renewable energy source used by the sector with the greatest mitigating emission potential in the state of Ceara.

According to the MCT (2006), the calculation of carbon dioxide emissions per burning fossil fuels using IPCC's *top-down* approach includes the following steps:

i) Determination of apparent consumption in tons of crude oil equivalent (toe);

The apparent consumption represents the amount of fuel consumed. This value can be given in toe, m^3, liters, kilograms, tons or some other unit to represent the amount consumed. The ton equivalent to crude oil (toe) is a unit of energy defined as heat released in the combustion of one ton of crude oil, about 42 gigajoules.

If the consumption is not informed in toe, the gross calorific value is considered to identify the amount in Mcal (megacalories) contained in a certain amount of fuel. This information enables to calculate, by a simple ratio of three, the amount of toe, as it is known that 1 toe = 10800 Mcal.

For this study, the apparent consumption, in toe, will be found in the Energy Balance of the State of Ceara, 2008.

ii) Conversion of apparent consumption for a common energy unit, terajoules (TJ);

To obtain the consumption in TJ, multiply the consumption in toe by the conversion factor. It is known that the conversion factor is obtained by multiplying 45.217×10^{-3} by the correction factor. The correction factor is equal to 0.95, when it is the case of solid and liquid fuels and 0.90, when the fuel is gaseous.

iii) Transformation of the apparent consumption of each fuel carbon content, through its multiplication by the fuel's emission carbon factor;

To obtain the carbon content inserted into the fuel, multiply the apparent consumption given by TJ by the emission carbon factor given in tons of carbon per terajoule.

Table 6 shows the emission factor of C and CO_2 for each fuel.

Table 6. Emission factor of C and CO_2 of each energy source. Values obtained by MCT (2006).

Energy	(t of C/TJ)	(t of CO_2/TJ)
Crude Oil	20	69,7
Steam Coal	26,8	93,4
Natural gas	15,3	53,3
Diesel oil	20,2	70,4
Fuel Oil	21,1	73,5
Gasoline	18,9	65,8
LPG	17,2	59,9
Kerosene	19,6	68,3
Other energy sources of crude oil	18,4	64,1
Firewood/Charcoal/ Bagasse	29,9	104,2
Ethyl alcohol	16,8	58,5

iv) Determining carbon quantity in each fuel intended for non-energy purposes and deducting that amount from the carbon contained in the apparent consumption, to compute the actual carbon content that can be emitted;

Not all fuel supplied to a country is destined for energy purposes. Part of it is used as raw material in the manufacture of non-energy products, where carbon becomes fixed, such as plastics, asphalt, and etc. In the IPCC methodology, this carbon is called "stored", and it should be subtracted from the carbon content of the apparent consumption of fuels.

The following equation is used to calculate the carbon stored for each fuel, according to the IPCC methodology:

$$\eta = 10^{-3} \text{ x } \rho \text{ x } \Phi \text{ x } \gamma \text{ x } \varphi$$

where:

η = carbon stored (in Gg C)
ρ = amount of fuel with non-energy use (toe)
Φ = conversion factor from toe to TJ (TJ/toe)
γ = carbon emission factor (tC / TJ)
φ = fraction of carbon stored

As the data used in this work refer to the final energy consumption of fuel, the amount of fuel intended for the non-energy sector was not determined. Thus, it was not necessary to use the share of carbon stored for each fuel in the CO_2 emission calculation,

v) Correction of values to consider the incomplete combustion of fuel;

The difference between the carbon in the apparent consumption of fuel and the one stored in non-energy products represents the carbon available to be emitted during combustion. However, not all of that carbon will be oxidized, since, in practice, the combustion never occurs completely, leaving a small amount of carbon contained in ash and other non-oxidized byproducts (MCT, 2006).

In order to compute only the amount of carbon actually oxidized during combustion, a correction of the values was done to subtract the fuel's incomplete combustion.

Then, to obtain the actual emissions, multiply the carbon available for the emission (in this study, equal to the carbon content inserted into the fuel) by the oxidized carbon fraction during combustion.

Table 7 shows the oxidized carbon fraction in combustion for each energy source.

Table 7. Oxidized carbon fraction during combustion. Values obtained by MCT (2006).

Fuel	IPCC	RTD
Liquid fossil fuels		
Primary fuels		
Crude Oil	0,990	0,990
Natural Gas Liquids	0,990	0,990
Secondary fuels		0,990
Gasoline		0,990
Kerosene		0,990
Diesel oil		0,990
Fuel Oil		0,990
LPG		0,990
Lubricants		0,990
Petroleum coke		0,990
Oils and byproducts	0,990	
Others		0,990
Solid fossil fuels		
Primary fuels		
Cooking coal		0,980
Anthracite		0,980
Bituminous Coal		0,980
Secondary fuels		
Coke		0,990
Gaseous fossil fuels		
Dry Natural Gas		0,995
Refinery Gas		0,995
Solid Biomass		
Charcoal		0,995

vi) Conversion of the oxidized carbon amount in CO_2 emissions.

The conversion of the oxidized carbon amount for the total amount of emitted carbon dioxide is achieved by multiplying the carbon content (after correction) by 44/12. Where 44 is the molecular weight of carbon dioxide (CO_2) and 12 is the molecular weight of carbon (C).

Board 1 is a summary of the step by step to obtain the level of CO_2 emissions from the consumption of a determined energy source.

Consumption in toe (1) i	**Conversion to TJ** (2) = (1) x conversion factor ii	**Consumption in TJ** (2)	**Carbon Content (tC)** = Carbon Emission factor in t of C/TJ x (2) iii	**Deduction of carbon quantity for non-energy p/ purpose** iv	**Correction of the values to consider incomplete combustion = Carbon content** (tC) x oxidized carbon fraction v	**CO_2 Emission** = carbon content (after correction) x 44/12 vi

Board 1. Summary of step by step to obtain the level of CO_2 emissions from the consumption of a determined energy source.

According to Tables 2, 3, 4 and 5, the textile and cement industries are two sectors that use fossil fuels. As the textile industry uses plenty of natural gas (a less polluting fossil fuel) and the cement industry uses much steam coal (a highly polluting fuel and carbon-intensive), we decided to focus the study on the cement sector to propose replacing the steam coal for another source of cleaner energy.

To justify our choice, it should be noted that the cement sector ranks fourth among Ceara's largest energy consumers. Furthermore, it is one of the largest CO_2 emitters (168.9 x 10^3 t/year), thus this sector can have a significant emission reduction potential, if steam coal (non-renewable source) is replaced by a renewable source.

According to Table 5, the cement sector uses only steam coal as a non-renewable source, accounting for 33.4% of the entire consumption structure. As it has a significant percentage when compared to the total, it is no less important than the sectors that consume many non-renewable sources.

The following item will show the energy sources that can replace the use of steam coal in the cement sector.

e) Mitigation measures based on changes in the energy basis of the industrial sectors.

Figure 2 shows the possible renewable energy sources that have the potential to replace steam coal. It is then concluded that bagasse, firewood, charcoal and hydro energy are the energy sources indicated as possible replacements.

To further substantiate these replacement proposals, the CO_2 emission levels will be calculated when steam coal is the fuel in use and when the appointed substitutes (bagasse, firewood, charcoal and hydroelectricity) replace the use of steam coal.

Table 8 shows the emission level calculation related to the steam coal volume used by the cement sector in the state of Ceara in 2007.

Table 8. Emission level due to the use of steam coal in the cement sector in Ceara in 2007.

Fuel	**Consumption in toe** (1)	**Conversion to TJ** (2) = (1) x conversion factor	**Consumption in TJ** (2)	**Carbon content (tC)** = Carbon emission factor in t of C/TJ x (2)	**Correction of values to consider incomplete combustion** = Carbon content (tC) x fraction of oxidized carbon	**CO_2 Emission (t CO_2)** = Carbon content (after correction) x 44/12
Steam Coal	17.000	730,25455	730,25455	19570,82194	19179,4055	**7.0324,48684**

If the consumption of steam coal is replaced by the use of bagasse, firewood, charcoal and hydroelectricity, the level of CO_2 would change. Table 9 presents the emission level of carbon dioxide for each energy source.

Table 9. Emission level due to the use of bagasse, firewood and charcoal in the cement sector in Ceara in 2007.

Fuel	Consumption in toe (1)	Converting to TJ (2) = (1) x conversion factor	Consumption in TJ (2)	Carbon content (tC) = Conversion factor of carbon emission in t C/TJ x (2)	Correction of values to consider incomplete combustion = Carbon content (tC) x oxidized carbon fraction	CO_2 Emission = carbon content x 44/12
Bagasse	17.000	730,25455	730,25455	21834,61105	21725,43799	**7.9659,9393**
Firewood	17.000	730,25455	730,25455	21834,61105	21725,43799	**7.9659,9393**
Charcoal	17.000	730,25455	730,25455	21834,61105	21725,43799	**7.9659,9393**

It is observed that for any type of solid biomass (bagasse, firewood or charcoal), the CO_2 emission level is the same, therefore regarding emission, the use of any of the three (3) energy sources is irrelevant. This is because the conversion factor, carbon emission factor and the oxidized carbon fraction are the same. Although the levels of carbon dioxide emissions related to the use of the three types of biomass are greater than the steam coal emission levels, they are compensated by the carbon sequestration in the photosynthesis of the crops of these inputs, therefore it is more advantageous, environmentally, to use biomass in the cement sector in place of steam coal.

When we use hydroelectricity as an energy source, the emission level is considered void; therefore the calculation, as well as other steam coal substitutes, is not presented. All of this brings positive expectations to mitigate climate changes.

4. FINAL CONSIDERATIONS

This work may be an important tool to assist in developing plans and programs that will comprise the energy policies of the State of Ceara. The work herein enables analyzing the consumption structure of the state's industrial sector, in order to better view the indicative trends to introduce new technologies, environmental conservation and the rational use of energy, in addition to providing an important information base for the State's sustainable development.

The State of Ceara was chosen because of the effortless manner to obtain data by consulting the BEECE. It should be noted that this same study can be generated for any location, provided that the energy balance information is available for consultation.

The comparison of the emission level of steam coal with its potential replacements enabled to conclude that, due to the compensation of the high emission level generated by the biomass with the CO_2 capture in photosynthesis, the removal of steam coal in the cement industry in the State of Ceara is environmentally feasible for introducing firewood, charcoal and bagasse.

In addition, to further expand the mitigation strategy options, there is the possibility of replacing steam coal by hydroelectricity. As was verified, this last source of energy in the sector does not emit CO_2.

It is also important to remember that energy efficiency measures are feasible. To achieve this, all it takes is to introduce any technology that can reduce energy consumption in the process while maintaining the same level of production.

The mitigating measures for climate change highlighted here, such as projects to generate energy from renewable sources and energy efficiency projects, can be divulged to the other industries in Ceara. If mitigation measures were applied to all sectors, it would reduce the pollution that is currently generated by the industrial activities, hence contributing to a better future for present and future generations.

In conclusion, it is important to underscore that Brazil has the conditions to meet the increasing demand for renewable sources due to its climatic conditions and vegetation diversity that provides the raw materials that could, in fact, be the energy sources that substitute fossil fuels. Moreover, there are numerous scientific research studies on alternative energy sources and development of advanced technologies to expand the use of such sources in various consumer sectors.

For actual changes in the energy consumption structure, more government incentives are needed to reduce the conversion costs of the new energy sources, as well as greater demands from the environmental control agencies and from consumers, in order to encourage the practice of less polluting industrial processes.

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6. RESPONSIBILITY NOTICE

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