Gazi University Journal of Science
GU J Sci
24(3):647-656 (2011)

GUJS

The Control of Energy Consumption and The Investigation of CO_2 Emissions in The Production of Aggregate

Atac BASCETIN[1], Deniz ADIGUZEL[1♠], Serkan TUYLU[1], Abdulkadir KARADOGAN[1], Mehmet CAGLAYAN[2]

[1] *Istanbul University, Faculty of Engineering, Department of Mining Engineering, 34320 Avcilar/Istanbul TURKEY*

[2]*Nisan Building and Mining Company, Kadikoy/Istanbul, TURKEY*

Received: 28.07.2010 Resubmitted: 06.11.2010 Accepted: 18.04.2011

ABSTRACT

The human requirements have increased rapidly depending on population density and urbanization thus industrialization has grown steadily. As a result of this increase of the greenhouse gas emissions into the atmosphere, the global warming has increased slowly. Therefore, the effects of greenhouse gases in all areas of production must be controlled. The study presents the methods of determination of CO_2 emissions (CO_2-e) and energy consumption in aggregate production. The aggregate constitute approximately 70% by volume of concrete that has widespread use as construction material in the world. One of the most important elements in today's terms is sustainable use of resources and minimum CO_2 emissions (CO_2 + CO + NOx + CH4…) at every stage of production of aggregate. Therefore, these elements must be taken into consideration in the aggregate production standards. The choice of production method of aggregate is very important for optimum use of energy and effects of greenhouse gas emissions. So the properties of the aggregate material must be known well to obtain the target. Within the scope of this study, the unit value of CO_2-e that release when the production of aggregate in different formations is determined for our country. Thus, the effects of green house gas emission can be evaluated according to the characteristics of material in aggregate production planning.In this study, energies consumed during the production of aggregates at a quarry in Istanbul Cendere region were investigated by taking the different formations encountered at the quarry into consideration. The unit CO_2 emission values per ton of produced aggregates were calculated as a result of this investigation. Besides, energy consumption values of previous months at this quarry were taken and the unit CO_2 emission values were also calculated.

Key Words: *Aggregate, CO_2 emission, aggregate production, efficient energy consumption.*

♠Corresponding author, e-mail: deniza@istanbul.edu.tr

1. INTRODUCTION

The emissions of greenhouse gasses occurring from human activities particularly such as fossil fuel usage cause global warming, which is a great danger for our world. In general, global warming is; the return of the sun rays back to the earth instead of the outer space because of the accumulation of greenhouse gasses in the atmosphere resulting from human activities, thus a gradual increase in the earth temperature.

The emission of greenhouse gasses occurring as a result of increasing energy consumption which is a necessity of industrialization - must be taken under control in every stage of production facilities and methods to optimize energy usage should be developed. CO_2 emissions, or in brief CO_2-e value; is the total amount of environmentally harmful gasses such as CO_2, CO, NO_x, CH_4 [1].

In 2008, an increase in CO_2 emissions by 114% in energy sector, 79% in industrial operations was observed compared to 1990 in Turkey. In 2008, 91% of the total CO_2 emissions is energy originated and 9% is industrial process originated. When the energy originated CO_2 emissions in 2008 was observed, it was seen that 36% of them arose from cycle and energy sector, 19% from industry, 16% from transportation sector and the rest of 21% arose from the energy consumption of other sectors [2].

Reducing energy consumption in industry, in general, requires an effective energy management system [3]. A number of researchers including Bush et al. (2002), Dessureault (2007), and Harney (2007) concluded that successful energy saving requires an endeavor to create a Information System (IS) that will be able to provide the answers to the questions of when, where, and how much energy is being used in the mining processes. Authors indicate that an accurate measurement and recording of energy consumption as the key for energy improvements. The IS provides the framework that Harney (2007) considers as vital for efficient utilization and savings of energy in any mining operation. Bush et al. (2002) considers that the management of energy resources requires an integrated information system capable of recording the changes in energy consumption. The changes have to be recorded on a regular basis as either real-time or near real-time [4, 5, 6, 7].

The aim of this study is to determine the energy used and the unit CO_2-e value released during the aggregate production with different formations. Due to this, greenhouse gas effects in the aggregate planning can be evaluated according to the characteristics of the material.

2. CALCULATION OF CO_2 EMISSIONS IN MINING OPERATIONS

Aggregate production in open pit mines and quarries generally starts the use of explosives to blast the rock from the quarry faces into medium size boulders and rocks. Diesel powered excavators and haulers then remove the rubble and dump it into electric crushing and screening plant. Finally diesel powered haulers move the final graded products into stockpiles. Aggregate production is briefly composed of blasting, excavation, hauling and crushing stages.

The energy consumptions in the observed quarry are gathered in 3 groups by means of CO_2 (CO_2-e) emissions.

- 1st Group; CO_2-e occurring during the explosive material disposal ,
- 2nd Group; CO_2-e occurring by diesel fuel operating vehicles,
- 3rd Group is the CO_2-e occurring as the result of electricity consumption.

Among the 1st energy consumption group are the ANFO and Dynamite type explosives used during the blasting processes in the quarry. 2nd energy consumption group comprises the fuel used in the vehicles and the 3rd energy consumption group comprises the 2 crushing and screening plants, the pump used for the water disposal in the quarry and the electricity used in the administrative buildings.

In this study, firstly the 2009 energy consumption values of the mentioned quarry and aggregate production values were evaluated in terms of CO_2-e. Methods used in the calculations were explained in details for each energy group. Furthermore, it was also calculated how the energy consumption values with different formations had changed by the measurements and observations made on site. During 7 days of observation on site, it was determined that the productions were made with 3 different formations and in order to identify these different formations, density and point loading tests had been made in Istanbul University Faculty of Engineering, Department of Mining Engineering, Laboratory of Rock Mechanics. The electricity amount consumed, explosive material consumption and diesel fuel consumption during the production of different formations were observed.

The CO_2 emissions occurring during the blasting is directly related to the explosive material. The emission factors vary depending on the types of explosive materials. Emission factors depending on the explosive types were given in Table 1 [8]. The emission factors of CO, CH_4 and NO_X in Table 1 were calculated separately for each type of gas by multiplying the explosive material amount, the CO_2–e value was found by the addition of the values calculated.

Table 1. CO_2 –e factors for explosives [8].

Explsv. Type	Composite	CO kg/ton	NO_X kg/ton	CH_4 kg/ton	Other gasses kg/ton
Black Powder	Potassium nitrate / sulphur	85	-	21	12 (H_2S)
Dynamite	Nitroglycerin/ sodiumnitratecalcium carbonate	141	-	1.3	3 (H_2S)
Gelatinide Dynamite	Nitroglycerin composite	52	26	0.3	2 (H_2S)
Anfo	Ammonium nitrate/ fuel oil	34	8	-	1 (SO_2)

In order to determine the CO_2-e values released by vehicles operating by diesel fuels. 1996 IPCC Guide, methods and parameters in the highway emission account were examined. Here, 3 different methods were mentioned as Tier 1, 2, 3. Tier 1 method is generally a facile method comprising less data, whereas Tier 3 is a more complicated and specialist method. Generally, it is possible to discriminate as Tier 1 and other Tier methods. Because, Tier 2 and Tier 3, which can also be described as higher stages-are being used basically with the same logic. It can also be thought as; we pass to a new Tier stage as the categories become more detailed. The main difference between Tier 1 and Tier 2 and 3 is the disposal of the fuel consumption and distribution values which can be obtained without the necessity of any knowledge about the combustion technology of the fuel. Whereas, it is more difficult to determine the difference between Tier 2 and 3. Because, as a result of the betterment of emission calculation operations, from one approach to another approach has been passed. In general, with Tier 2 approach, it is aimed to separate the energy consumption groups in the way that the suitable emission factors could be used. That is why Tier 2 method was preferred in this study. In the emission accounts of the diesel fuel operating vehicles, the formula below which was determined in Tier 2 approach will be used (Equation 1) [9].

CO_2-e = Emission factor (g/kg) x Fuel consumed (lt) (1)

When the engine powers of the vehicles operating with diesel fuel were observed, it was seen that all were above 200Hp. This is the reason why the emission factor values determined by the European Union standard heavy diesel vehicles were used in the calculations. Table 2 shows the emission factors of heavy diesel vehicles (with 200Hp or more engine power).

Table 2. Emission factors of Heavy Diesel Vehicles [9].

Units	NO_x	CH_4	CO	N_2O	CO_2
g/kg fuel	42	0.2	36	0.1	3140

The equipment operating with electricity was evaluated in 3 categories in the working site. 1st group crushing and screening plant, 2nd group inside quarry water pumps and third group were administrative buildings.

First of all, the total electricity consumption is determined in order to find the CO_2-e value released from electric energy. Due to the fact that the electricity used in the site is produced by natural gas, it is essential to determine the natural gas amount that the power unit consumes to produce 1 kWh of electricity. According to the information obtained from the related electricity company, 0.175 m^3 of natural gas is consumed to produce 1 kWh of electricity (this is the standard value determined according to the type of the power source producing electricity). [10]. Table 3 shows the emission and energy factors as the result of the combustion of fuels.

Table 3. The emission factors as the result of the combustion of fuels [11].

Fuel type	Energy Factor (Gj/m^3)	Emission Factor kg CO_2 – e / Gj		
		CO_2	CH_4	N_2O
Natural Gas	$39.3*10^{-3}$	51.2	0.1	0.03
Coal	$37.7*10^{-3}$	51.1	0.2	0.03
Biogas	$37.7*10^{-3}$	0	4.8	0.03

CO_2-e released from the combustion of natural gasses is calculated by using equation 2 [11].

$E_{ij}=(Q_i x EC_i :x Efi)/1000$ (2)

E_{ij}: The emission of gas type (CO_2-e ton).

Q_i : Quantity of the fuel type (m^3)

EC_i: Energy content factor of fuel type (gigajoules per m^3)

Efi : Emission factor (kg CO_2 – e / Gj)

If Q_i is measured in gigajoules, then EC_i is "1".

3. CASE STUDY

A quarry in Istanbul Cendere region producing aggregate material for concrete production was chosen as the working site. Cendere region and its immediate surrounding remain as a whole within the Istanbul Paleozoic area. This area comprises the sedimentary rocks occurred in the period between ordovician and carboniferaus.

In the basis of Istanbul Paleozoic area remains the old Kurtkoy Formation of Middle and pre-Ordovician. Kurtkoy Formation is composed of purple; mostly chaotic inner structured, indefinitely stratified pebble stones and crosswise stratified sandstone-mudstone intercalation. The crosswise stratified shale-siltstone intermediate layer pink-mottled and white quartz arenite on the Kurtkoy formation which are rich in feldspar compose the Aydos Formation. Aydos Formation which is Middle Ordovician aged, with a compatible relation from above, passes to Gözdag Formation which is middle Ordovician – Landoverian aged. In the sub-cut, Gözdağ Formation comprises thin laminal and greeny-dark grey shales, feldspathic sandstone layers seen within them and chamosite intercalations. The unit which is interdigitated with qaurz arenite lenticular shales of Gözdag Formation and which dark blue – bluish dark grey is colored and composed of carbonate facies is called the Dolayoba Formation. Within the Dolayoba formation, grey-dark grey reefy limestones, thin intermediate layered, dark bluish, grey pinkish and grey colored lenticular and laminal limestones, laminal, dark bluish grey micritic and pinkish laminal mudstone intercalations take place. It is Sub Silurian – Sub Devonian aged. The sub-middle Devonian aged Kartal Formation composed of yellowish, brown-grey colored, well leaved, rich in fossils, micaceous, feldspared siltsone and sandstone intercalated shales comes over Dolayoba Formation. With the increasing in number and thickening of clastic limestone intermediate layers within Kartal Formaton and gradually vanishing of shails, the unit passes to yellowish-bluish-grey colored massive limestones. The same limestones become an intercalation of micritic limestone and yellowish brown stone and this unit is described as Tuzla Formation within the Istanbul Paleozoic area. Following Tuzla Formation, Trakya Formation occurring from the intercalation of greeny grey coloured, thin layered and parallel laminated stone, dioptrically pebble stone and turbidic sandstone takes place [12].

The main rock in the mentioned quarry has been described as the sandstone. The site also comprises a significant amount of dolerite intrusions.

Because of the hard and strong structure of the rock units in the mentioned working site, excavation processes are carried out by drilling and blasting method. The shredded material loaded on the trucks by the excavators after the blasting process, is brought to the crushing-screening plant in order to be reduced to the dimensions suitable for the disposal of the industry. 2 crushing-screening plants exist in the mentioned quarry. The general flow scheme regarding these plants was shown in Figure 1 [13]. The material produced from the quarry is firstly feeded to Jaw Crusher to reduce the dimensions of the material under to 150 mm. Then ıt is crushed under to 40 mm by Cone Crusher. The crushed material is screened to obtain desired final product. The Molder is used between the two Units for giving the best shape to the material.

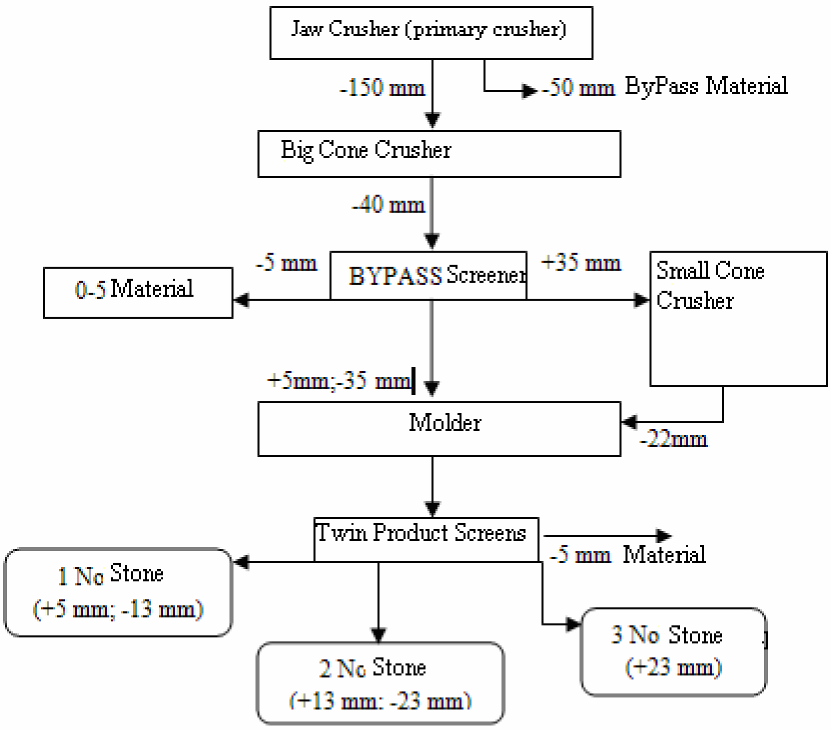

Figure 1. Plant flow scheme.

The energy consumption values of the prior years and the values obtained during the observations and examinations on site have been separately calculated and compared. However, as only the energy consumption and aggregate material production values exist in the records of the company, energy consumption changes due to the different formations will not be evaluated according to the 2009 data obtained from the company.

During 7 days of observation on site, it was determined that productions were made with 3 different formations and in order to identify these different formations, density and point loading tests had been made in Istanbul University Faculty of Engineering, Department of Mining Engineering, Laboratory of Rock Mechanics.

It was observed on site that most of the production was in sandstone formation. Along with the sandstone formation, dolerite intrusions were used in the production. Laboratory experiments regarding these formations are given below.

As the result of the density experiments made on the ten samples of each three formations observed on site, the densities of the materials have been determined and average results have been given in Table 4.

Table 4. Density experiment results of different formations.

Formation Name	Average Dry Density (gr/cm^3)
Gray Sandstone	2.87
Dolerite	3.14
Light Gray Sandstone	2.92

As the result of the point loading experiments made on the ten samples of each three formations observed on site, the uniaxial compressive strength and uniaxial pulling strength values of the material have been indirectly calculated and the average values have been given in Table 5.

Table 5. Point loading experiment results of different formations.

Formation Name	Average Point Load Index $I_{s\,(50)}$ (Mpa)	Average Uniaxial compressive strength (Mpa)	Average Uniaxial pulling strength (Mpa)
Gray Sandstone	4.4	96.9	5.51
Dolerite	8.15	179.36	10.19
Light Gray Sandstone	5.45	119.99	6.82

The places of the compressive and pulling strength values obtained as the results of the experiments in the hardness scale proposed by the International Society for Rock Mechanics (ISRM) had been determined and rock-hardness descriptions were made. Accordingly, dolerite and light gray sandstone formations were described as highly competent and the gray sandstone formation was described as normally competent.

3.1. CO_2-e Value Released from the Blasting Operations

During the explosive excavation processes on site, formation differences were not taken into consideration. As the same range pattern was used for each 3 different formation types, same amount of explosive was used during the production of each formation. The emission factor values shown in Table 1 during the blasting originated CO_2-e emission calculations.

CO_2-e value released from the disposal of explosive material during the observation period:

The total material amount excavated by blasting during the period of excavation, the explosive consumption and the CO_2-e values calculated by using this amount were given in Table 6.

Table 6. Explosive material consumption during the observation process and the amount of material excavated.

	Explosive material consumption (kg)	CO_2-e values (kg)	Material amount excavated by blasting (ton)
Dynamite (kg)	155	12	
Anfo (kg)	10600	445.2	
Total	459000	457.33	51273

CO_2-e values obtained as the result of explosive material consumption have been proportioned with the corresponding total material amount and unit CO_2-e (kg) values per ton were found.

Total CO_2-e (kg) / Total amount excavated (ton) = 457.33/51273 = 0.0089 kg/ton CO_2-e

This calculation gives the value of kg CO_2-e occurring during the blasting and excavation of 1 ton material.

CO_2-e value released from 2009 explosive consumption:

The explosive material consumption value in 2009 and the excavated material amount in the same period were obtained from the records of the company. The CO_2-e values calculated by the total amount of excavated material and the explosive amount used were given in Table 7.

Table 7. 2009 explosive material consumption, CO_2-e values and the excavated material amount.

	Explosive material consumption (kg)	CO_2-e values (kg)	Material amount excavated by blasting (ton)
Dynamite (kg)	9000	704	
Anfo(kg)	450000	18900	
Total	459000	19605	2602093

2009 CO_2-e values obtained as the result of explosive material consumption have been proportioned with the corresponding total material amount and unit CO_2-e (kg) values per ton were found.

Total CO_2-e (kg) / Total amount excavated (ton) = 19605/2602093 = 0.007534 kg/ton CO_2-e

It was observed that this value matches the unit kg CO_2-e value reached in the observation period

3.2. CO_2-e Value Released from Diesel Fuel Operating Vehicles

In finding out the CO_2-e value released from diesel fuel operating vehicles, the operation durations and the fuel consumed by particularly the excavators and drillers change according to the formation type. During calculations, the fuel consumptions according to the formation types were recorded in the observation periods. In the calculations of 2009 obtained from the company, it was observed that the formation effects had not been taken into consideration as no such record had existed.

In the calculations of CO_2-e value, the emission factors of heavy diesel vehicles shown in Table 2 were used.

CO_2-e value released from diesel fuel operating vehicles during the observation period:

Diesel fuel consumption values of the formation types in the observation period, CO_2-e values calculated by using these consumption values and material production amounts were shown in Table 8.

Table 8. Fuel consumption and material production values according to the formation types of the observation period.

Formation	Diesel fuel consumption values (7 days of total, lt)	CO_2-e value (kg)	Material amount produced (ton)
Gray Sandstone	7353.371	19996	13844
Dolerite	16050.05	43647	19911
Light Gray Sandstone	4634.58	12601	8244

The CO_2-e values released from diesel fuel consumption have been proportioned with the corresponding total material amount and unit CO_2-e (kg) values per ton were found. Furthermore, in order to make the formation differences clearer, the unit CO_2-e (kg)/ton values occurring from diesel fuel consumptions for 3 different formation types were calculated (Table 9).

Table 9. CO_2-e (kg) /ton units of 3 different formations observed.

Formation	Unit CO_2-e value kg/ton
Gray Sandstone	1.44
Dolerite	2.19
Light Gray Sandstone	1.52

As seen in Table 9, while the CO_2-e values of gray sandstone and light gray sandstone formations are close to each other, this value is higher in dolerite formation which of compressive and pulling strength values are comparatively bigger.

2009 CO_2-e values released from the fuel consumption of diesel fuel operating vehicles:

The records obtained from the company showed that the total fuel consumption of the machines in the equipment park was 1.376.460 lt in 2009. According to the calculation made regarding this value, 3.743.232 kg CO_2-e value was found in order to produce a total of 2.602.093 tons of material.

According to these values, the unit CO_2-e value released by vehicles operating by diesel fuel during 1 ton of aggregate production was found as;

Total CO_2-e value (kg) / Material amount produced (ton) = 3743232 / 2602093 = 1.438 kg/ton.

It can be said that the unit CO_2-e value calculated by using the 2009 data and the unit CO_2-e value calculated as the result of the observations made in the sandstone which appears to be the main formation in the site are slightly compatible.

3.3. CO_2-e Value Released from Electricity Consumption

Among the devices consuming electricity, 2 crushing-screening machines, a pump unit used to release the water in the quarry and the electricity consumption in the administrative buildings take place. The electricity consumption examined during the observation period and the consumption values obtained from the 2009 electricity bills of the company were separately evaluated and the CO_2-e calculations were made.

Formation differences lead to changes only in the crushing-screening plants. These amounts of changes were calculated by reading the general counter, the counters on the crushers in the periods of measurement, and by the determination of the formation of the material fed in the crusher. As no any data regarding the formation differences was found in 2009 records of the company, general calculations could not have been made.

CO_2-e value released from electricity consumption during the observation period:

The electricity consumption was measured in the work site examined. During the measurements, the electric energy formation differences of the electricity consumed by the crushing-screening machine were also taken into consideration. Table 10 shows these measurements. As the electricity amount consumed by the pump and the administrative buildings were not affected by the formation differences, only the electricity consumption values were given (Table 11).

Table 10. Electricity consumption values of the crushing-screening machine in different formations during the observation period and the amount of material produced in the same period.

Formation	Electricity consumption values (7 days of total) (kWh)	Amount of material produced(ton)	Electricity consumption values a per ton material produced (kWh)
Gray Sandstone	6216.598	2670	2.33
Dolerite	10373.33	3840	2.7
Light Gray Sandstone	3948.074	1590	2.48

Table 11. The pump and administrative buildings' electricity consumption values in the observation period and the amount of material produced in the same period.

	Electricity consumption values (7 days of total) (kWh)	Amount of material produced(ton)	Electricity consumption values a per ton material produced (kWh)
Pump	621		
Admin. Buildings	558		
Total	1179	8100	0.145

By using this data, the total electricity consumption originated CO_2-e values were calculated and shown in Table 12.

Example calculating for dolerite formations can be seen in below.

First of all natural gas consumption values per ton material produced was calculated.

$(2.7+0.145) * 0.175 = 0.498\ m^3$ natural gas

In the second stage, the values of CO_2, CH_4 and N_2O released from the natural gas were calculated. The values of emission factor used for the calculations can be seen in Table 3.

For CO_2 ;

$E_{ij} = (0.498 * 39.3.10^{-3} * 51.2) = 1.002$kg

For CH_4 ;

$E_{ij} = (0.498 * 39.3.10^{-3} * 0.1) = 0.00196$ kg

For N_2O ;

$E_{ij} = (0.498 * 39.3.10^{-3} * 0.03) = 0.00059$ kg

Total CO_2 –e = 1.005 kg CO_2 –e

Table 12. Emission values of electricity consumption during the observation period.

	CO_2-e value kg			Total (kg)
	Crushing-Screening	Pump Unit	Admin. Building	
Gray Sandstone	2194.596	72.26	64.93	2331.786
Dolerite	3662.014	103.92	93.38	3859.314
Light Gray Sandstone	1393.75	43.03	38.66	1475,44

CO_2-e value released from electricity consumption during the observation period was proportioned with the corresponding total amount of material excavated and the unit CO_2-e (kg) values were found. Furthermore, in order to make the formation differences clearer, the unit CO_2-e (kg) /ton values of 3 different formations released from electricity consumption were calculated (Table 13).

Table 13. Unit CO_2-e (kg)/ton values of 3 different formations released from electricity consumption.

Formation	Unit CO_2-e value kg/ton
Gray Sandstone	0.873
Dolerite	1.005
Light Gray Sandstone	0.927

CO_2-e value as the result of electricity consumption in 2009:

The total electricity consumption values of 2009 and the total value of the amount of material produced in the same period were obtained from the records of the company (Table 14).

Table 14. The total electricity consumption values of 2009 and the total value of the amount of material produced in the same period.

Period (01/01/2009-31/12/2009)	Electricity consumption values (kWh)			Amount of material produced (ton)
	Crushing-Screening	Pump Unit	Admin. Building	
12 months of Total	7001898	316800	256320	2602093

CO_2-e value was calculated by using this data. During the calculations, the emission factor values shown in Table 3 were used. The emission values occurred as the result of electricity consumption in 2009 were calculated and given in Table 15.

Table 15. CO_2-e values of the total electricity consumed in 2009.

Period (01/01/2009-31/12/2009)	CO_2-e value kg			Total (kg)
	Crushing-Screening	Pump Unit	Admin. Building	
12 monthly Total	2471824	111837	90486	2674147

The total CO_2-e values found as the result of the electricity consumption in 2009 were proportioned to the corresponding amount of excavated material and CO_2-e values per ton were found.

Total CO_2-e (kg) / Total excavated amount (ton) = 2674147/2602093 = **1.027 kg/ton CO_2-e**

It is seen that this value is higher than the unit kg CO_2-e value during the observation period. While the company was making production with only one crushing-screening machine in 2009, later on, another plant was included in the company. It was observed that the new plant consumed less electricity by means of the electricity consumption values. Thus, the unit CO_2-e values of 2009 released by electricity are higher than the unit CO_2-e values of the observation period.

3.4. RESULTS AND DISCUSSION

According to the results achieved in the sections above, total unit CO_2-e values according to the formation types observed on site were calculated. This value gives the CO_2-e value released from energy consumed (blasting + electricity + diesel fuel) during 1 ton of aggregate production. According to this, 2.3219 kg/ton of CO_2-e for gray sandstone, 3.2039 kg/ton of CO_2-e for dolerite and 2.4559 kg/ton of CO_2-e value for light gray sandstone were found. The distribution of these values according to the energy sources for gray sandstone, dolerite and light gray sandstone were given in Figure 2. The values were obtained by the studies for 3 months in the mine site.

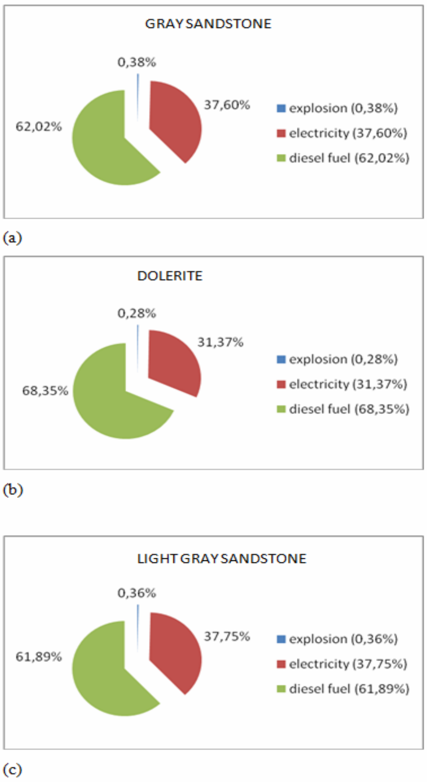

Figure 2. The distribution of unit CO_2-e values per ton aggregate (observations, 2010).

When the Figure 3 a, b and c are observed, it is seen that the most important reason of CO_2-e values is the fuel consumption. Furthermore, it is also seen that the CO_2-e percentage distribution values according to the energy types of gray sandstone and Light gray sandstone formations are slightly close to each other. However, CO_2-e percentage value released from fuel consumption in dolerite formation is higher than the other formations. This is because the dolerite's uniaxial compressive strength in the rock mechanics tests was higher than the other formations. This leads to a higher fuel and time consumption of diesel fuel operating devices for dolerite.

When these values are compared to the CO_2-e value released during the production of 1 to of aggregate, it is seen that they remain in a low level. The electricity in the observed site being obtained by natural gas can be shown as the most important reason for this result. Furthermore, in addition to the observation period, the general unit CO_2-e value for the mentioned site was calculated without taking into consideration the 2009 data obtained from the company and the formation types. The percentage distribution of these values according to the energy sources are given in Figure 3.

According to this, the unit CO_2-e value released during 1 ton of aggregate production in the site was calculated as 2.4725 kg/ton.

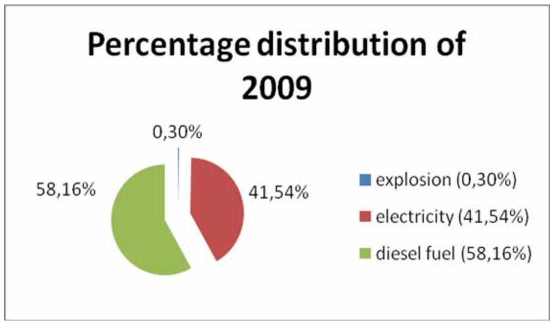

Figure 3. The distribution unit CO_2-e values per ton aggregate (2009).

As seen in Figure 3, the most important reason for the release of CO_2-e for all formations is the fuel consumption. Furthermore, when the distribution value of CO_2-e released from the electricity consumption is compared to percentage distribution made in the observation period, it is seen that this value remains in a high level. The first plant operating more actively in 2009 and the other plant which consumed less electricity starting to operate quite after can be shown as the reason for this result.

4. CONCLUSION

In this study, the energy consumed during the aggregate production operations in a stone quarry and the different formations in the quarry in Istanbul Cendere region was observed and the unit CO_2-e emission values released during 1 ton of aggregate production for 3 formations having different compressive, pulling strengths was calculated. Accordingly, the dolerite formation having a high value of compressive and pulling strength has given the highest unit CO_2 emission value. Furthermore, the energy consumption amounts regarding the prior months of the mentioned quarry were taken and the unit CO_2 emission values according to these values were also calculated. When the percentage distribution of CO_2 emissions during the aggregate production was observed; it was understood that the diesel fuel consumption had been the most important CO_2 emission reason by a rate of 60-70%. CO_2 Emissions of electricity consumption by the rate of 30-40%. The main reason why the CO_2

emissions originated from electricity consumption remain comparatively low is the electricity being produced by natural gas. Furthermore, when the percentage distribution of CO_2 emissions according to the formations is observed, it was seen that the CO_2-e distribution rates of sandstone and greywacke remain closer to each than the other formations. However, CO_2-e release rate value as the result of fuel consumption in the dolerite formation remains higher. It can be said that as the result of the increase in the strength of the formation, the increase in the fuel consumption becomes more than the other formations. As not much explosive material was used, CO_2 emissions occurred remained in low levels. It was seen that the 2009 unit CO_2-e distribution value remained in high levels when compared to the distribution rate in the observation period. The first plant operating more actively in 2009 and the other plant which consumed less electricity starting to operate quite after can be shown as the reason for this result.

The figures for the emissions for aggregates have been developed based on large number of records obtained from the quarry. Although the data presented above was collected from the location around Cendere, Istanbul, it can be used as a guide to estimate the emissions due to mining of minerals in other parts of the world with similar production methods. The recommended approach is required to develop for more accurate measurement the CO_2 emissions and innovative production methods should be take consideration for less CO_2 emissions.

ACKNOWLEDGEMENT

This work was supported by the Executive Secretariat of Scientific Research Projects of Istanbul University Project Numbers: (UDP-5144/14012010, T-864 / 02062006). The authors are grateful to the Executive Secretariat of Scientific Research Projects of Istanbul University.

REFERENCES

[1] Flower, D.J.M., Sanjayan, J.G., "Green House Gas Emissions due to Concrete Manufacture", ***Int J LCA 2007***, 12: 282-288 (2008).

[2] Turkish Statistical Institute (TÜİK), 2010, GHG EMISSIONS INVENTORY 2008, Newsletter Number 113, 25 June 2010.

[3] Van der Merwe, C., "Mining industry challenged to cut energy consumption 15 % by 2015", C***reamer Media's Mining Weekly Magazine, Energy Conservation***, South Africa(2007).

[4] Bogunovic, D., Kecojevic, V., Lund, V., Heger, M., Mongeon, P., "Analysis and control of energy consumption in surface coal mining", ***2009 SME Annual Meeting and Exhibit & CMA 111th National Western Mining Conference***, February 22-25, 2009 Denver, Colorado, USA(2009).

[5] Bush, V., Killingsworth, T.G., Ruffel, E.P., "Leveraging your energy management reduces: application for the mining industry", ***SME Annual Meeting 2002***, SME, Preprint 02-042(2002).

[6] Dessureault, S., "Data mining, mining data: energy consumption modeling", ***Proceedings of 33rd International Symposium on Application of Computers and Operations Research in the Mineral Industry***, Magri (editor), 2007, Santiago, Chile: Gecamin Ltda., 2007, (Santiago : Quebecor World), 451-457(2007).

[7] Harney, D., "Measuring and controlling energy utilization", ***2007 SME Annual Meeting and Exhibit***, preprint 07-110, Denver, CO, Feb.26-28, 2007, preprint 07-110(2007).

[8] AP-42 Section 13.3, "Explosives Detonation", EPA Contract No. 69-D0-0123, Midwest Research Institute, Kansas City, MO(1993).

[9] IPCC/UNEP/OECD/IEA, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories Volume III: Reference Manual, Intergovernmental Panel on Climate Change, United Nations Environment Prog., ***International Energy Agency***, Paris, Chapter 1, 4-44, 62-98(1997).

[10] Turkey Electricity Transmission Company General Directorate of Research Planning and Coordination Department, (2004), Turkey Electricity Production Planning Study, (2005 – 2020).

[11] Australian Government Department of Climate Change, National Greenhouse Accounts (NGA) Factors (2009).

[12] Uz, B., "Mineralogical-Petrographic and Physico-Mechanical Properties Investigation and Evaluation Report of Ayazaga Village Cendere Region", I.T.U. Mining Faculty, Istanbul, (2007).

[13] Bascetin, A., Adiguzel, D., Tuylu, S., Karadogan, A., Caglayan, M., "The Control of Energy Consumption and The Investigation of CO_2 Emissions in the Production of Aggregate", I***nternational Sustainable Building Symposium***, Ankara-Turkey, 796-801, 26-28 May (2010).

[14] Bascetin, A., Sertabipoglu, Z., "Strategic Mine Planning and Design for Quarrying" 2010 SME Annual Meeting & Exhibit, Phoenix Convention Center, Phoenix, Arizona, America, 28 February-03 March 2010.