A METHOD FOR IMPLEMENTING QUALITY 5.0 WITHIN A SUSTAINABLE FRAMEWORK

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Abstract: *The quality of the products and services provided is essential in order to stay on the market in a competitive framework, and nowadays it has become a necessity to implement modern measures for permanent monitoring. For the continuous improvement of business processes and for the creation of products and services to meet the market demands, it is necessary to redirect the management at the highest level towards the new concepts of Industry 5.0: IoT, Big Data, Cloud Computing, as well as the adoption of modern methods and techniques of measuring quality in compliance with the principles of sustainability. In our study we proposed a methodology to implement the newest technologies on the market but, at the same time evaluating them with the traditional statistical methods such as 6 Sigma. The proposed model was based on the measurement of the performance indicators of the processes, evaluating them in relation to the proposed target and the company's digital transition was made according to the 8 new principles proposed by CQI (Chartered Quality Institute).*

Keywords: *Quality 5.0, 6 Sigma, Carbon Neutral policy, GHG inventory, ISO 14067*

1. Introduction

The need for continuous improvement is based on the demand for quality products and services. In engineering, the quality term is similar with the reduction of non-conformities and getting the planned results, products and services that comply with the client's requirements. [1] This study evaluates to what extent the previously developed methodology, manages to cope and become a tool for analysis, measurement, and transition of a small and medium-sized company in Romania to the status of a smart, digital company, using appropriate latest tools such as Microsoft BI together with the traditional statistical methods in a sustainable framework based on the Carbon Neutral policy.

2. Literature review

Starting from the methodology proposed in our previous studies, that demonstrates that the measures used in two different companies to improve their processes and integrate the Quality 4.0 concept are successful [2, 3], a model was drawn to be used as an effective and ready instrument, to be implemented in similar companies for self-evaluation and transformation. In our vision, this model should contain the sustainable approach in accordance with the European Union's integrated strategy regarding the environmental policy. Adopted in November 1997, the Kyoto protocol foresees the reduction of greenhouse gases by each country that signed the treaty.

Carbon dioxide (CO2), methane (CH4), nitrogen oxide (N2O), fluorocarbons (F-gases), the gases with the greatest impact in global warming, are generated as a result of human activity and are retained by the ozone layer in the atmosphere, generating heating and negative chain effects on the environment.

Later, in order to combat the negative effects of global warming generated mostly by new technologies (pollution, very high temperatures, greenhouse gases), the European

Union undertook, through the Paris Agreement in 2015, to reduce emissions by 2030 of gas by 40%. This agreement was revised in 2021 to 55% for the year 2030 [4] having a bold target until 2050, namely the achievement of climate neutrality [5]. Studies for the calculation of the carbon footprint in order to raise awareness of the impact of activities on the environment took place in relevant fields such as construction [6] or agriculture [7].

3. Materials and Methods

The proof that our methodology was efficient, and the proposed target was achieved was supported by the fact that the results of the evaluations could be measured and evaluated with the help of specific Quality 5.0 tools. The implementation methodology of the proposed model follows the 6 Sigma DMAIC steps (Define, Measure, Analyze, Improve, Control). In both cases studied, the results obtained were positive and next the proposed model was implemented through an App model. It will also try to achieve the objectives related to the environmental component and establish to what extent the model is sustainable for companies. The development of an application that ensures efficiency in use and a physical interface of the project will be pursued.

Simultaneously with the development of their own products, the analyzed companies are concerned with the impact of their activities on the environment and closely follow the Carbon Neutral policy in accordance with the regulations and aspirations of the European Union. This way, it carefully monitors its own activities that generate emissions. The present study is limited to the data of the company Electrotehnica Electric devices SA, whose data was available. The routes used to achieve the proposed goal were: European Directive 2003/87/CE [8], Implementing regulation no 2066/2018 [9]. To begin with, the necessary steps were made to establish the inventory of the sources of greenhouse gas emissions (GHG emissions) within the system according to Fig.1. To establish the inventory of carbon emissions, they were classified as to their purpose according to the GHG Guide protocol that belongs to World Resource Institute and World Business Council for Sustainable Development [10], as follows: emissions that belong to the Scope 1, 2 and 3. Fig.2. According to WRI and WBC, Scope 1 means everything that is owned by the company and that generates greenhouse gas emissions through the direct use of fuel (gas, petrol, diesel), the Scope 2 everything related to purchased electricity, that connects to electricity and generate indirect emissions (steam, heating, cooling) and Scope 3 means indirect emissions, which are related to the preceding activities together with those after the product is made.

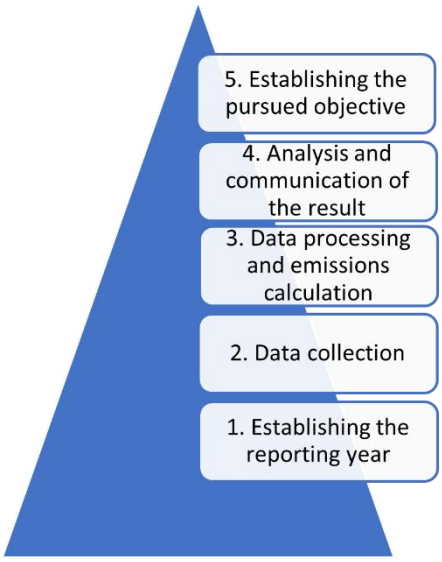

Figure 1: *Steps for identifying the sources of greenhouse gas emissions (own elaboration)*

Carbon dioxide emissions even if they have a global warming potential (GWP) more than 28 times lower than methane gas emissions **[11]** remain in the atmosphere for at least 150 years, while other emissions remain in the atmosphere for 10 times less time, therefore only the emissions of CO_2 of all anthropogenic gases were considered. These are obtained when we convert greenhouse gas units into units CO_{2e} by multiplying with the global warming factor GWP (global warming potential), the latter representing the amount of radiation that a greenhouse gas can absorb, for example: CO_2 , CH_4 , N_2O, fluorocarbons, -gases-F. Moreover, according to the EU report, in 2021 CO_2 constituted 80% of the total greenhouse gases

in the atmosphere, therefore the calculations will only contain this gas. The studied company carefully monitors the sources with an overwhelming role in the emission of GHG.

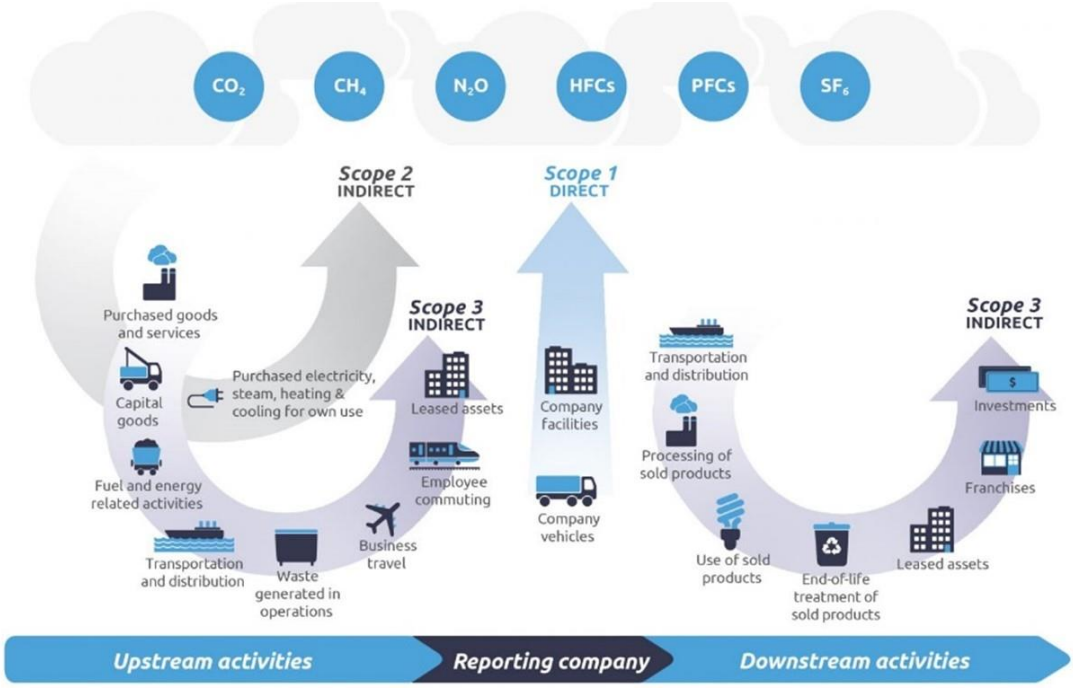

Figure 2: *Overview of scopes and emissions across a value chain. Source: The Greenhouse Gas Protocol.*

The reporting year was set: 2019. The following data were collected: the activity carried out is in the electrical field, it is not franchised, it has no equipment, cars, machinery rented but only the property of the company, it has no offices in other countries. The building was thermally rehabilitated between 2010-2020 in order to increase energy efficiency, located on the ground floor and having a height of 3m, with nearly 1000 m2, the main heating source is natural gas with a central heating plant. The company does not have water treatment equipment, it is not a biomass producer, it carries out locally commercial activities. Some of the components that go into the production of commercial goods are imported from non-EU countries, but the data on the emissions generated by them upstream is not available. Under the incidence of emissions that fall under Scope 1: the building, the cars owned by the company that use gasoline as fuel from a refinery whose gasoline types are made in Romania. Emissions related to Scope 2 were: 2 lathes, 2 milling machines, 5 soldering machines, 30 desktop PCs, 30 monitors. 10 printers, 2 refrigerators and 10 air conditioners. Scope 3 emissions data was not available. The following data related to Scope 1 and 2 were centralized in Table 1, evidence of energy consumption for the years 2019-2022. It can be seen that company has an evolutionary tendency towards reducing consumption, being aware of the impact of its activities on the environment.

Table 1: *Evidence of energy consumption*

	Scope 1		Scope 2
Year	Petrol (l)	Gas (m3)	Electrical Energy (kWh)
2019	11461	11925.98	116700
2020	11488	11644.95	106800
2021	13338	169739.9	81900
2022	11362	7267	62100

Next, in the third stage of processing and calculating emissions, the step-by-step approach was used to process the data collected according to chapter 5.4 of the ISO 14067:2018 standard **[12],** respectively: the purpose and target pursued, the analysis of the LCI life cycle, the assessment of the impact on the life

cycle, in order to determine the environmental footprint. To this approach, the other principles must also be considered, respectively: the relevant scientific approach, completeness, consistency, coherence with the rest of the standards, accuracy, and the avoidance of double measurement. In order to see the data evolution in time, the annual measurements were analyzed as in **Fig. 3** and conclusions about the annual consumption were drawn. Where data was not available, the standard, reference or zero value was used. Since the data were available in different measurement units, they were converted so to calculate the consumption of CO_{2e}. Conversion factor of equivalent carbon dioxide emissions CO_{2e} converts data from activities into emissions of CO_{2e}, as in **Table 2.** Here, emissions of CO2 were calculated as well as the consumption in kW in order to establish the GHG inventory based on the available data.

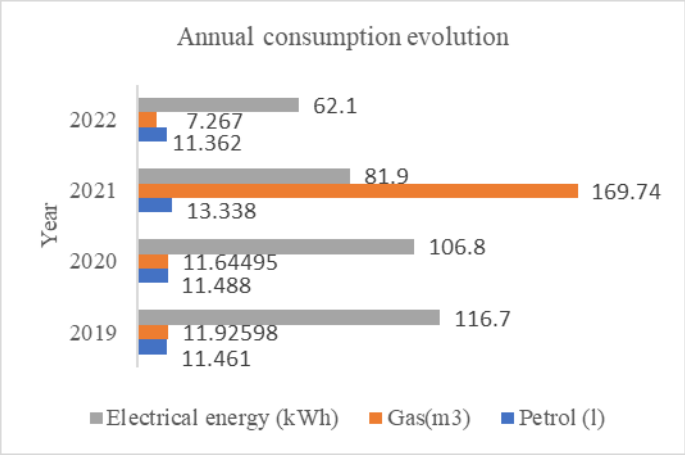

Figure 3: ***Consumption evolution between 2019-2022.***

The following conversions were used:

1 kWh = 3,6 MJ
1l Petrol = 13.13 kWh= 47.3 MJ
1m3 Gas =10.7kW

For Romania in the public system, the conversion factors are provided in law no 2.057 **[13]**. The coefficients used in this study regarding emissions and emission factors are those reported by the UK government, cross-sector **[14]** aligned with the standards established by the Intergovernmental Climate Change Guide (IPCC, Fifth Assessment), International body in which Romania also participates and the reporting is done voluntarily by the member states.

Table 2: *GHG Inventory*

	Petrol consumption	*)conversion factor CO_2	Emissions	Consum-ption	Gas	*)conversion factor CO_2	Emissions	Electrical energy consumption	Electrical Energy	***)conversion factor CO_2	kg CO2e	Consum-ption
UM	L/year	Kg Co2 / l	kg CO2e	kWh	m3/year	m3/Kg	kg CO2e		kWh	kg		kWh
2019	11461	2.30	26360.3	120087.78	11926	2.026	24162	127608	116700	0.00061	71.2	127608
2020	11488	2.3	26422.4	120370.57	11645	2.018	23499.5	124601	106800	0.00061	65.1	124601
2021	13338	2.33	31077.5	124142.34	169740	2.017	342365	2E+06	81900	0.00061	50	1816217
2022	11362	2.32	26359.8	105750.99	7267.01	2.011	14614	77757	62100	0.00061	37.9	77757

*) established based on UK annual report data
**) established based on UK annual report data
***) established based on the invoice data issued by the supplier

These data are centralized, and a report is issued annually in which the conversion factors are included. At the same time, the data provided by the utility providers with whom the company has signed contracts as well as the official EIA converter were considered **[15]**

The carbon footprint represents all the greenhouse effect emissions that an entity (company, person) generates in a certain period of time. The carbon footprint is measured in units (tons) of equivalent carbon dioxide CO_{2e}.

Carbon Footprint = Activity Data x Emission Factor (tons of emissions per unit/year) (1)

Mass of equivalent carbon dioxide CO_{2e} = *Mass of CO2 x corresponding GWP of the gas* (2)

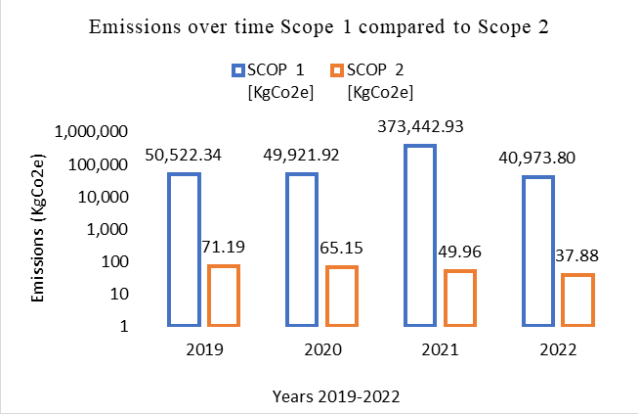

Figure 4: *Emissions analysis over time*

During the studied period, it was also analyzed how the emissions related to Scope 1, as well as the emissions related to Scope 2 evolved, in order to see the changes regarding the main types of consumption. **Fig. 4.** From the analysis of the figure above, it can be seen that for the year 2020 the emissions related to Scope 1 recorded the lowest level compared to the previous year and the following year, and for the year 2021 the highest level of emissions for Scope 1 was recorded. The explanation is the activity breaking in the year 2020 as a result of the COVID 19 pandemic situation, followed by a strong resumption of activities in 2021 when it gradually returned to the previous situation. However, for the year 2022, although it gradually recovered, a lower consumption is found than in all the previous three years analyzed, against the background of the increase in the turnover of the company and implicitly the increase in the number of orders and activities, resulting in an active involvement of the staff in what regarding its role in reducing emissions. An annual inventory of total emissions can be calculated as in **Fig. 5** to obtain the carbon footprint of the company.

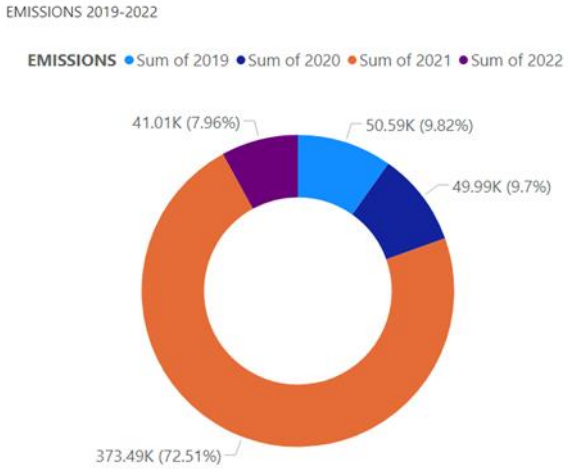

Figure 5: *Annual emissions 2019-2022*

Following the conversions carried out in the 4 years analyzed, a total of 4,762,717.67 KWh was calculated and a total of 515085.15 kg of CO2e resulted, which means an annual average of 128,771.28 Kg CO2e (128 t Co2) resulting from an average consumption annually of 4,762,717.67kW related to SCOPE 1 and SCOPE 2.

According to Regulation (EU) no. 601/2012 of the consolidated European Commission, within the document General Guidelines regarding installations at company level depending on the amount of emissions generated, they fall into category A (average annual emissions are less than or equal to 50,000 tons of CO_{2e}, Category B (average annual emissions are greater than 50,000 tons of CO2e but less than or equal to 500,000 tons of CO2 CO2e or Category C (average annual emissions are greater than 500,000 tons of CO2. The analyzed company having an average annual consumption below 50,000 t falls into category A.

4. Results

The company falls into category A, up to 50,000 tCO_{2e}/year. In order to reduce carbon emissions, the company has proposed to implement a series of measures in its policy, as well as the establishment within the organizational culture of a chapter that encourages staff to carry out activities that lead to the reduction of its CO_2 footprint, such as: using the bicycle , public transport, recycling, the use of economical lighting solutions, the use of local products, the heating/cooling systems should not be used excessively.

The data provided by the company was not fully available at the time of the study, therefore the analysis does not fully reflect al the company's activities. However, the data collected and used represent a starting point to define the company's strategy for the coming years in terms of sustainability and social responsibility.

5. Conclusions (Future directions)

The conducted study proved to be a useful tool for the presented companies, so that, first of all, it helped to implement a method of improving processes and ensuring their transition to the status of a digital company, all in a sustainable framework by reducing their carbon footprint. In this sense, measures have been taken into consideration for the future implementation of measures such as: reducing the use of paper in the company's activities until its elimination.

Similarly, the use of natural gas has major disadvantages, as it is known that during the extraction, incidents with the effect negative on the environment, at the same time it is a limited resource and through use, during combustion, greenhouse gases are released into the atmosphere that contribute to global warming. In our country, at the national level, P.A.E.D. guides were drawn up at the level of local authorities (sustainable development and action plan) for raising awareness of GHG effects. They help us to be aware of the impact that each of us has on the environment in which we live when we make certain choices. However, these actions should not be exacerbated at the expense of other actions related to sustainability, because in the desire to obtain an economy with zero carbon emissions, it is possible to affect other sectors and pollute in another way.

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