Segmentation of Industrial Sectors Based on the Characteristics of their Greenhouse Gases Emissions

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Abstract. This paper analyses the characteristics of sectoral contributions to Greenhouse gases emissions based on economic data of industrial energy consumption in Spain and gives some insights about public programmes for emissions reduction. It departs from the total amount of Greenhouse gases emissions due to the energy mix deployed per industrial sector, the percentage of electrification of its activities and the indirect emissions due to generation mix behind electricity consumption. Separately, it examines the dispersion of emissions across firms (tCO2-eq/firm) per industrial sector. By segmenting the industrial sectors into quadrants, the authors identify in quadrant iv four industrial sectors with a low level of electrification, high level of emissions and a strong concentration of emissions at the level of individual firms. Due to their characteristics, it is suggested that specific public programmes for Greenhouse gases reduction should target these four industrial sectors.

Keywords: Circular Economy, Green Deal, Sustainability, Greenhouse gases

1 Introduction

The Green Deal [2] seeks to reduce the footprint caused by economic activities on the environment. In 2020, industrial direct Greenhouse gases (GHG) emissions accounted for 20% of total emissions in Spain [7]. In addition, part of the indirect emissions related to the electricity generation mix is due to electricity consumption in industrial processes.

European and state regulations associated with the promotion of sustainability affect industrial sectors differently. Some authors [1] state that climate-neutral energy infrastructure or the housing sector and materials used in its value chain,

such as cement or metals (steel, copper, aluminium, nickel, zinc, manganese or lead), account for 9% and 7% of total emissions, respectively. Thirteen sectors [3], especially those involved in the Industrial Emissions Directive, are analysed, including Energy, Refineries, Iron and steel, Non-ferrous Metals, Chemicals, Food and drink, Cement, Lime and magnesium oxide, Surface treatment with solvents, Pulp and paper, Rendering, Ceramics, Glass, and textiles.

To implement effective emissions reduction policies, it is necessary to understand the characteristics of the emitting sectors, such as the energy consumption mix, the percentage of electrification, the total amount and the direct or indirect nature of emissions and their concentration (amount of tCO2-eq/firm).

Considering that each one of the energy sources emits a different amount of GHG during its use, the energy consumption variables per energy source are necessary to obtain the estimation of the emissions and prioritise the most emitting sectors. The percentage of electrification is necessary to estimate the amount of indirect emissions and the degree to which the projects to reduce the GHG footprint are mainly related to a change in energy source or to a reduction in the consumption of electricity. The generation mix is necessary to account for the GHG emissions in electricity production companies' facilities due to the consumption of electricity in industrial companies.

2 Methodology

In this article, the analysis of data obtained has been made within the following framework: the total Tier I and Tier II [6] emissions (tCO2-eq) attributed to the industrial system of a country or region can be expressed as follows:

$$E = \sum_{i=1}^{n} \sum_{j=1}^{m} \left(1000.\, C_{ij}.\, K_j\right) \text{ and } K_j = \left(EF_j/1000\right)/AP_j$$

where E is the total amount of CO2-eq (tCO2-eq) emitted due to the industrial activity of a country or region for the period of analysis, Cij is the consumption (m€) of energy source j on behalf of sector I, Kj is the emission factor (tCO2-eq/€) of energy source j, EFj is the emission factor of energy source j (tCO2-eq/MWh), and APj is the average price for the year of reference of energy source j (€/KWh). Average prices have been obtained mainly from the Eurostat Data Browser. The values for emission factors have been obtained from [4], [5] and [7]. Data related to the Survey of Energy Consumption and for the year 2019 was obtained from the National Institute of Statistics (INE).

The activities of extractive industries corresponding to the statistical classification of economic activities in the European Community (NACE) codes 051 to 099 and '19. Manufacture of coke and refined petroleum products' are not considered, as they are not included in the official data obtained from INE.

3 Results

According to the results, the energy consumption of the manufacturing sectors amounted to EUR 10,117 million, of which EUR 5,948 million was in the form of electricity and EUR 2,887 million was in the form of gas. In addition, EUR 789 million were consumed in petroleum products (diesel, fuel oil, gasoline, butane, propane and others) and EUR 491 million in others (coal and coke, solid or liquid biofuels, heat and other products). Electricity (58%) and gas (28%) accounted for a high percentage of the energy consumption of companies in most manufacturing sectors.

The sectors that consume the most energy are the following: Manufacturers of food products, Manufacturing of basic metals, Manufacturing of chemicals and chemical products, and Manufacturers of other non-metallic mineral products. Together, they account for 64% of the total consumption of the entire manufacturing sector.

The two sectors in which petroleum products and others (coal and coke, solid or liquid biofuels, heat and other products) account for the highest percentage in their production are Repair and installation of machinery and equipment (49.4%) and Manufacturing of furniture (29.9%), although both sectors together account for only 1.14% of the total consumption of the manufacturing sector.

Based on estimations using economic data and the previously presented formula, the total emissions of industrial companies in Spain during 2019 accounted for 53.85 MTCO2-eq (NACE codes 10 to 33, excluding ‘19. Manufacturing of coke and refined petroleum products’). The CO2-eq emitted in industrial facilities (MTCO2-eq) were as follows: gas 34.46 Mt; gasoil 3.59 Mt; fuel oil 2.45 Mt; coal and coke 1.85 Mt; others 3.49 Mt. The indirect emissions linked to electricity consumption and generation mix and heat accounted for 10.51 MtCO2-eq. During 2020, 16% of electrical energy was produced from gas in combined-cycle plants, 2% from coal, 0.8% from non-renewable waste, and 1.9% from other renewables [8].

The industrial sectors emitting the biggest amount of CO2-eq are as follows: Manufacturing of other non-metallic mineral products, Manufacturing of chemicals and chemical products, Manufacturing of food products, and Manufacturing of basic metals. The level of consumption of electricity (€) over the total energy consumption of the three most emitting sectors is lower than 60%.

4 Discussion

In Figure 1, the emissions per sector (size of the bubble) are represented with their concentration levels (emissions per firm in x axis) and the electrification percentage (y axis). Considering that the article aims to give some insights that could guide GHG emission reduction public programmes, the percentage of electrification was

selected to assess whether the investments should be executed in the industrial company or in the electricity supplier company.

For the same reason, it was necessary to know if the emissions were concentrated in companies with a high amount of emissions or dispersed in many sites and locations with few emissions. Depending on the case, the size of the projects and financing needs can be a lot different.

Based on the figure, the sectors can be segmented depending on the quadrant where they are located. The industrial sectors have been segmented using the averages for the x and y axes, which are represented with dotted lines.

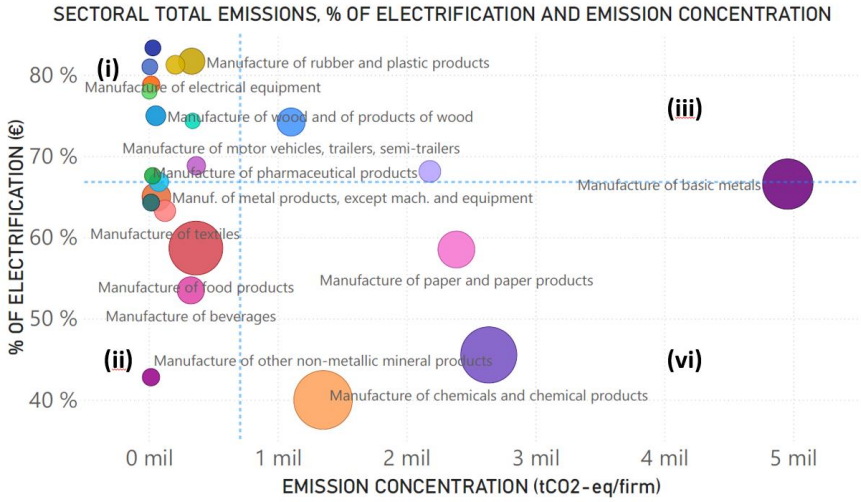

Figure 1. Sectoral total emissions, % of electrification and emission concentration

Quadrant i) Top-left. It includes 11 sectors (48%) that emit 7% of the total emissions. The emissions are widely dispersed in firms with a high level of electrification. On average, cost-oriented, energy efficiency projects with low emission reductions per firm can be addressed.

Quadrant ii) Bottom left. It includes six sectors (26%) that emit 26% of total emissions. The emissions are very dispersed in firms with a low level of electrification. 'Manufacture of food products' is included in this quadrant and represents 65% of the emissions of this quadrant. Projects for energy efficiency, electrification or low emission alternative energy sources with relatively low levels of investment can be suitable for companies represented in this quadrant.

Quadrant iii) Top-right. It includes two sectors (9%) that emit 5% of the total emissions. The emissions are concentrated with a high level of electrification. Manufacture of pharmaceutical products and Manufacture of motor vehicles, trailers and semi-trailers are included in this quadrant. Cost-oriented energy

efficiency projects with a relatively high level of investment per firm can be applied.

Quadrant iv) Bottom-right. It includes four sectors (17%) that emit 61% of the total emissions. The emissions are very concentrated in firms with a low level of electrification. The sectors that comprise this quadrant are as follows: manufacture of basic metals, manufacture of chemicals and chemical products, manufacture of paper and paper products and manufacture of other non-metallic mineral products. Alternative energy source projects (electricity or other non-GHG-emitting sources) can contribute strongly to the reduction of emissions.

5 Conclusions

In this paper, the energy-related emissions of industrial sectors have been analysed based on economic consumption data obtained from official sources. The estimates based on energy consumption in firms allow for estimates of GHG emissions up to a NACE 3-digit level using publicly available data.

The results confirm that the four sectors that emit the most GHG account for 71% of the total emissions. The electrification level of all sectors is 59% on average. Three of the four most emitting sectors have an equal or lower level of electrification than average.

Considering the concentration of emissions in firms, manufacturing of other non-metallic mineral products (1,351 tCO2-eq/firm), manufacturing of chemicals and chemical products (2,636 tCO2-eq/firm) and manufacturing of basic metals (4,956 tCO2-eq/firm) comprise a high level of emissions per firm. Manufacturing of paper and paper products has a lower level of emissions (3.92 MtCO2-eq), but they are heavily concentrated emissions (2,385 tCO2-eq/firm).

As mentioned in the introduction, this paper aims to give some insights into public programmes for GHG emission reduction. These programmes should be adapted to the characteristics of the emitting sectors as much as possible. In this research, we have segmented industrial sectors depending on their percentage of electrification and the emissions concentration.

The percentage of electrification allowed us to know if the projects to reduce the GHG footprint for industrial companies were mainly related to a change from a non-electricity energy source to electricity or other non-GHG-emitting sources or to a reduction of the consumption of electricity.

The concentration of emissions in the companies allowed us to know if the emissions were concentrated in companies with a high amount of emissions or dispersed in many sites and locations with few emissions. Depending on the case, the size of the projects and the financing needs could be completely different.

Considering this, a short description of the kind of GHG emissions reduction projects has been presented for the sector included in each quadrant.

The sectors located in the bottom-right quadrant in Figure 1 should be prioritized to reduce the total amount of emissions. They require intense sources of heat for

their processes, and electrification does not seem to be a solution.

The reduction of emissions for these sectors requires a major technological transformation and reconversion that could come from the use of alternative sources of energy, such as hydrogen, if the technology is available at suitable costs. The execution of these projects could include consideration of the industrial footprints of the companies.

The types of projects to be developed in these sectors (investment level, technology development, skills and experience) are distinctive from, for instance, energy efficiency projects in highly electrified and low-consumption companies; thus, the supporting public programmes to foster investment should be different as well.

References

1. Elkerbout, M., Egenhofer, C., Núñez Ferrer, J., Cătuţi, M., Kustova, I., Rizos, V., 2020. 'The European Green Deal After Corona: Implications for EU Climate Policy'. *Policy Insights*. Nº 2020–06. March 2020.
2. European Commission, 2019. 'The European Green Deal'. Communication from the Commission to the European Parliament, The European Council, The Council, The European Economic and Social Committee and the Committee of the Regions. Brussels, 11.12.2019. COM (2019) 640 final.
3. European Commission, 2021. *Wider Environmental Impacts of Industry Decarbonisation Final Report*. Wood E&IS GmbH – February 2021.
4. Krey, V., Masera, O, Blanford, G., Bruckner, T., Cooke, R., Fisher-Vanden, K. Haberl, H., Hertwich, E., Kriegler, E., Mueller, D., Paltsev, S., Price, L, Schlömer, S., Ürge-Vorsatz, E., van Vuuren, D., and Zwickel, T., 2014. *Annex II: Metrics & Methodology. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
5. López Martínez, J.M., Flores, N., Lumbreras, J., Villimar R., Pascual, C., 2010. *Análisis de las Emisiones de CO2 en la Producción de las Fuentes Energéticas Utilizadas en el Transporte por Carretera*. Actas del IX Congreso de Ingeniería del Transporte, CIT 2010.
6. Pandey, D., Agrawal, M., Pandey, J.S., 2010. 'Carbon Footprint: Current Methods of Estimation'. *Environmental Monitoring and Assessment*. 178:135–160.
7. REE, 2021. Red Eléctrica Española.: *Emisiones de CO2 Asociadas a la Generación de Electricidad en España*. https://www.ree.es/es/sala-de-prensa/
8. REE, 2021.: *Red Eléctrica Española*. El Sistema Eléctrico Español 2020. https://www.ree.es/es/datos/publicaciones/