Carbon Footprint and Emission Trading

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Abstract— Carbon Footprints aim to bring a proper definition and structure to monitoring pollutant emissions. This is done by formulating a method to calculate their negative ecological impact. This will lead to a proper scale, where comparative measurements will help us understand and estimate our carbon emissions.

A carbon market, in analogy to share market, can be set up on an international level. We are using financial methods to curb pollution. In this concept, a company has to buy carbon credits or certificates (equivalent to shares). A single carbon certificate is equivalent to a metric ton of carbon dioxide being emitted into the atmosphere and correspondingly that many trees have to be planted by that company in order to make up for the damage caused. The revenue thus generated would be utilized to encourage green solutions. Despite the frequent use of the term 'Carbon Footprint' nowadays, there is still a lack of clear academic definitions as to what exactly does it mean. This report aims at exploring and suggesting a scientific approach towards carbon footprints, and throw light on its calculation, significance and setting up a system on an international level to control carbon emissions into the atmosphere. The awareness regarding climate change and its possible effect on our lives has already raised serious concerns throughout the world, and governments are already implementing control measures. Carbon footprint promises wide applications in the form of Ecological Economics, wherein Carbon credits and Emission trading will revolutionize the way our industries will function in the future.

Keywords: global warming, greenhouse gas emission, carbon footprint, carbon credits, emission trading

1. INTRODUCTION

DURING the last decade, there has been a large focus on global warming. The rising concern about humans' contribution to global warming has put pressure on the commercial world, politicians and nations on the whole. Climate change is high on their agenda, and there is a huge demand for methods to calculate carbon release in the environment.

As a reaction, Carbon Footprint has come up as one attempt to control the emissions of greenhouse gases from industries to offices to even households. Carbon footprinting helps us in determining

the amount of greenhouse emissions by considering every activity carried out throughout the process individually, in a particular time frame, the summation of which is the total carbon output. This data is very useful, since it gives us a definite idea and easily understandable statistics about our greenhouse gas emissions, and accordingly necessary actions can be taken to curb the output.

The problem of carbon emissions is at a much larger scale when it comes to industries and the commercial sector. Thus, the solutions also ought to be big. Emission Trading provides a great way to impose restrictions on companies and enables officials to monitor their emissions.

Many of these questions have been discussed in the disciplines of ecological economics and life-cycle assessment for many years and therefore some answers are at hand. So far, however, they have not been applied to the term carbon footprint and thus a clear definition is currently missing.

This report addresses the questions above and attempts a clarification. We provide a literature overview, propose a working definition of the term 'carbon footprint' and discuss methodological implications and applications to emission trading.

2. *CARBON* FOOTPRINT

A. Definition

The following definition of the term 'carbon footprint' has been proposed:

"The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product."[1]

This includes activities of individuals, populations, governments, companies, organizations, processes, industry sectors etc. Products include goods and services. In any case, all direct (on-site, internal) and indirect emissions (off-site, external, embodied, upstream and downstream) need to be taken into account.

We include only CO_2 in the analysis, being well aware that there are other substances with greenhouse warming potential. However, many of those are either not based on carbon or are more difficult to quantify because of data availability. Methane could easily be included, but what information is gained from a partially aggregated indicator, that includes just two of a number of relevant greenhouse gases? A comprehensive greenhouse gas indicator should include all these gases and could for example be termed 'climate footprint'. In the case of 'carbon footprint' we opt for the most practical and clear solution and include only CO_2. Also, carbon footprint is measured only in mass units (kg, ton etc), and does not consider area, because the conversion into a land area

would have to be based on a variety of different assumptions and increases the uncertainties and errors associated with a particular footprint estimate.

Whilst it is important for the concept of 'carbon footprint' to be all-encompassing and to include all possible causes that give rise to carbon emissions, it is equally important to make clear what this includes. The correct measurement of carbon footprints gains a particular importance and precariousness when it comes to carbon offsetting. It is obvious that a clear definition of scope and boundaries is essential when projects to reduce or sequester CO_2 emissions are sponsored. When accounting for indirect emissions, methodologies need to be applied that avoid under-counting as well as double-counting of emissions, therefore the word 'exclusive' in the definition. Furthermore, a full life-cycle assessment of products means that all the stages of this life cycle need to be evaluated correctly.[2]

B. Calculation of Carbon Footprint

When you drive a car, the engine burns fuel which creates a certain amount of CO_2, depending on its fuel consumption and the driving distance. When you heat your house with oil, gas or coal, then you also generate CO_2. Even if you heat your house with electricity, the generation of the electrical power may also have emitted a certain amount of CO_2. When you buy food and goods, the production of the food and goods also emitted some quantities of CO_2. Your carbon footprint is the sum of all emissions of CO_2, which was induced by your activities in a given time frame.

In this section, we will see how the carbon footprint is calculated in various walks of life. Usually a carbon footprint is calculated for the time period of a year. The best way is to calculate the carbon dioxide emissions based on the fuel consumption.

B.1. Car emissions

Car emissions are calculated by dividing the miles driven by the fuel efficiency of the vehicle. This number is then multiplied by the CO_2 emissions coefficient, 19.36 lbs CO_2/gallon of gasoline, and then divided by 2204.6 lbs/metric ton to obtain the tonnes of CO_2 emitted from car travel (*Equation 1*).

Equation 1:

$$\left(\frac{MilesDriven}{FuelEfficiency}\times 19.36\left(\frac{lbsCO_2}{gallon}\right)\right)\div 2204.6 = CO_2Emissions(tonnes)$$

Combustion of Fossil Fuels is the major contributor of CO_2 in the atmosphere. For example, the combustion reaction of Petrol is given as,

$2C_8H_{18} + 25O_2 => 16CO_2 + 18H_2O$

Thus, it can be seen that combustion of fuel releases large amounts of CO_2. The Transportation industry is the largest consumer of fossil fuels, and forms an integral part of the industrial world. Thus, it is all the more essential for the Transportation industry to calculate its carbon footprint.

Table 1 provides the carbon footprint (in kg) per unit for the various fuels.

TABLE I: Carbon Footprint per unit Fuel

Fuel type	Unit	CO_2 emitted per unit
Petrol	1 gallon (UK)	10.4 kg
Petrol	1 litre	2.3 kg
Gasoline	1 gallon (USA)	8.7 kg
Gasoline	1 litre	2.3 kg
Diesel	1 gallon (UK)	12.2 kg
Diesel	1 gallon (USA)	9.95 kg
Diesel	1 litre	2.7 kg
Oil (heating)	1 gallon (UK)	13.6 kg
Oil (heating)	1 gallon (USA)	11.26 kg
Oil (heating)	1 litre	3 kg

For example, if your car consumes 7.5 litres of diesel per 100 km, then a drive of 300 km distance consumes 3 x 7.5 = 22.5 litres of diesel, which adds 22.5 x 2.7 kg = 60.75 kg CO_2 to your personal carbon footprint.

Using the above formula and data, carbon footprint of most of the vehicles can be found out. [3]

B.2. CO_2 emissions due to Appliance use

Equation 2:

$$\left(\frac{Electricit\ yConsumpti\ on\left(\frac{Kwh}{day} \right)}{Use\left(Family\ /Individual \right)} \right) \times 365\ days \times \left(1.486\ \frac{lbsCO_2}{Kwh} \right) \div 2204.6 = CO_2 Emissions\ \ (tonnes)$$

In *Equation 2*, "Electricity Consumption" is the daily consumption by the given appliance, "Use (Family/Individual)" is the number of people using that appliance (1 for an individual; 2, 3, 4, or 5 etc. for family use), and "1.486 lbs CO_2/Kwh" is the weighted carbon emissions coefficient for electricity.

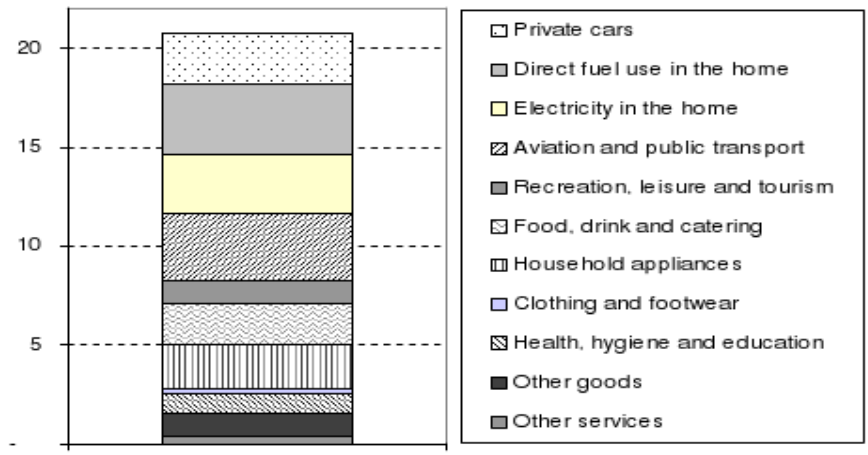


Figure 1

Direct emissions occur through heating and car use. Indirect emissions are the emissions that occur during the generation of electricity and the production of goods and services. They make up 70% of the almost 21 tons of CO_2 per household. Transport (private cars, aviation and public transport) accounts for 28% of total emissions. Electricity use in the home and use of fuels for space and water heating in the home account for almost one third of the emissions. [4]

Figure 1 gives a rough idea of the breakdown of carbon footprint of an average household, associated with several day to day activities:

3. EMISSION TRADING

A. Objective of Emission Trading Scheme

To tackle climate change effectively, a limit must be placed on rights to emit greenhouse gases to the atmosphere, and this must be reduced over time to the level that prevents any net accumulation in the atmosphere. Governments, with their coercive powers, are the only bodies able to impose such a restriction.

Under the Emissions Trading Scheme (ETS), this supply-side constraint is imposed by governments creating "permits" that allow the holder of the permit to emit a specified volume of

greenhouse gases to the atmosphere. The demand side of the market is established by the government requiring emitters to acquit permits if they wish to release greenhouse gases to the atmosphere. In so doing, the government must have the administrative machinery to enforce such a requirement credibly, as the requirement only exists by virtue of government decree.

A permit represents a tradable instrument with inherent value that can be exchanged between sellers and buyers in an "emissions market". [5]

B. Setting Emission Targets

The government has to set such emission caps or targets such that is should neither be too high, nor too low. If the cap is too high, there won't be any significant reduction in emissions. If the target is set too low, then it can affect the profitability of the companies more than they can handle.

Thus, in order to set appropriate cap, the historical emission data of the company is checked. Accordingly, an arbitrary limit (say, 25% lesser than the current emission) is set as an immediate goal. As the goals are met, the targets are slowly reduced with time until the optimum emission levels are achieved.

C. Carbon Credits

A carbon credit is a generic term for any tradable certificate or permit representing the right to emit one ton of carbon dioxide or the mass of another greenhouse gas with a carbon dioxide equivalent (tCO_2e) equivalent to one ton of carbon dioxide.

Thus, calculation of carbon footprints is essential and the most basic step in ETS, since it estimates the amount of carbon credits that have to be purchased. An industry has to figure out how much its carbon output is when it is manufacturing its products. This can be done using the various formulae, which includes a detailed background study and behind-the-scenes or indirect carbon emissions. Even the government bodies that will monitor the carbon output after the credits have been purchased; need to have the comparative data of the carbon footprint to check whether the limits set by the credit purchase are not breached.

The concept of carbon credits came into existence as a result of increasing awareness of the need for controlling emissions. The IPCC (Intergovernmental Panel on Climate Change) has observed that:

"Policies that provide a real or implicit price of carbon could create incentives for producers and consumers to significantly invest in low-GHG products, technologies and processes. Such policies could include economic instruments, government funding and regulation"

while noting that a tradable permit system is one of the policy instruments that has been shown to be environmentally effective in the industrial sector, as long as there are reasonable levels of predictability over the initial allocation mechanism and long-term price. The mechanism was formalized in the Kyoto Protocol, an international agreement between more than 170 countries.

D. Setting the cost of carbon credit

The price of carbon credit needs to be high enough to motivate the changes in behavior and changes in economic production systems necessary to effectively limit emissions of greenhouse gases.

Keeping high price of the carbon credit will in turn, increase the cost of the final product which reaches the consumer. This will encourage the consumer to check which product is made by high carbon emissions, and would opt for products with lower carbon emissions, since they would cost lesser. This will in turn encourage the manufacturers to opt for processed which have low carbon output, so that the final market price of their product in controlled.

The market system can also be designed to ensure industries that the shares will not be overly costly. The regulator accomplishes this goal by committing to sell additional permits, raising the overall cap, if the price of a permit rises above a fixed ceiling. This ceiling can be raised over time when it becomes clear that the cap has set a reasonable overall pollution target and the market is functioning well.

According to Prof. William Nordhaus of Yale University, the optimum price for a carbon credit is around $30 per share. Which means, for every ton of CO_2 the company wants to emit, it will have to buy a carbon share costing $30.

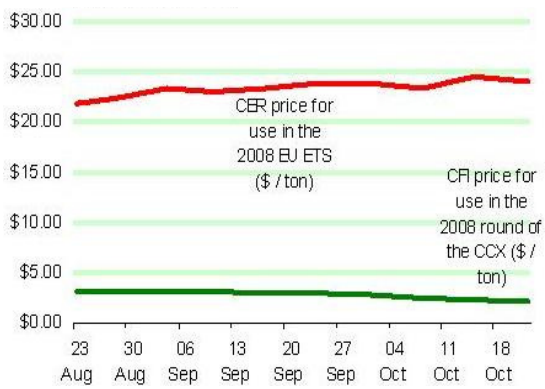


Figure 2 compares the rate of carbon shares in European Union and the Unites States. Due to liberal rules regarding ETS in the Unites States, the carbon credit rates are low. This is because the market there is still highly competitive and the pressure from the industries has forced a control over the share rates. But, the government plans to make stringent rules.

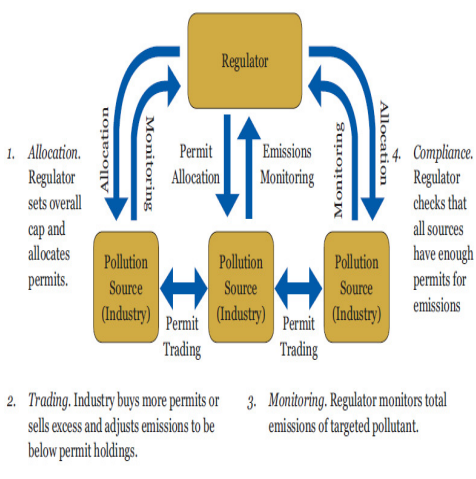
Figure 2

E. Trading

The nature of the permit itself can be very important. The permit should be a commodity with a value that industry can easily measure to encourage trading.

Permits also have time duration. Allowing a longer duration, such as a whole year, may reduce uncertainly by letting units adjust to their emissions. Allowing permits to be used over longer periods generally lowers the total costs of compliance, because firms can choose to emit more in periods when the costs of abatement are low and less when they are higher (e.g., during an economic boom). On the other hand, the greater the time duration of a permit, the greater the chance that firms will lobby to be granted extra permits that ultimately break the cap.

At the beginning of a trading scheme, when the right level of the emissions cap is uncertain, permits should have limited validity so that a cap that is too high does not allow high emissions to spill-over into the future. Set up a permit market. Create an exchange system that sets clear prices and enables easy trading. The liquidity of the market refers to how easy permits are to buy and sell. Units looking to buy or sell permits should be able to easily and inexpensively determine the market price and be able to conduct transactions at that price at a low cost.



The design of the permit itself, as discussed, will affect the liquidity of the market, as will the size of the market itself. If a greater number of units is participating it is more likely that buyers and sellers can promptly find one another so that each may hold permits in accordance with their needs. In a small market, the pollution authority may want to guarantee some measure of liquidity by offering to sell permits at a high price. With this offer units can know that their costs for emissions will never exceed a certain limit. [6] Figure 3 represents the functioning of an Emission Trade market.

Figure 3

F. Monitoring

Monitoring is the foundation for any trading system. The accurate, comprehensive monitoring of total emissions helps ensure the transparency and success of the permit market.

This monitoring should cover not only pollutant concentrations but also the volume of gas flow, so that trading can be based on aggregate pollutant emissions rather than concentrations. Monitoring is not only a technology but also a system for filling gaps in that technology and recording emissions levels. The monitoring protocol should specify how frequently continuous emissions monitoring equipment will be inspected and what the consequences are in case of tampering or incomplete data.[7,8]

4. CONCLUSION

Carbon footprint calculation is becoming more and more essential as the focus is strengthening on global warming and pollution control. Having definite numerical data about the carbon outputs helps us to understand and compare where we stand with our emissions and how much we need to control. The figures help us to analyze the trends of our emissions and purchase our carbon credits accordingly. Emissions trading schemes have great potential to lower pollution while minimizing costs for industries. An emissions trading scheme, once established, will provide a self regulating system that that makes pollution control more efficient.

A. Advantages of Emission Trading scheme

1. ETS brings a great mechanism with a market based approach for the control of carbon emissions in the industrial sector.

2. The revenue which the governments will generate from the ETS scheme can be utilized to encourage green solutions and adoption of green processes in industries.

3. It will help raise awareness among the public regarding carbon emissions, since products which had higher carbon emissions will cost more. This will make people look for products manufactured with lower carbon outputs.

4. Competition in the market will force the companies to move over to green technologies to cut down their carbon footprint in order to control the prices of their products.

B. Disadvantages of Emission Trading Scheme

1. The implementation of the scheme may become an administrative or financial burden for regulating authorities or participating sources.

2. Governments may be reluctant to adopt this scheme since it results in imposition of another tax, which may not go well with the general public in the initial stages.

These innovative systems leverage technology and harness markets to ensure better compliance with environmental laws and regulations. Carbon footprint promises wide applications in the form of Ecological Economics, wherein Carbon credits and Emission trading will revolutionize the way our industries will function in the future.

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