Product and corporate carbon footprint using the compound method based on financial accounts. The case of Osorio wind farms

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HIGHLIGHTS

- We applied novel organization-product-based-life-cycle assessment to Osorio Wind Farms.
- This study includes sources, phases and areas previously unreported for the wind power sector.
- MC3 assess carbon footprint in a practical and comprehensive manner.
- MC3 is suitable for its application in major international projects.

GRAPHICAL ABSTRACT

Purchases, Wastes and Land-uses

ABSTRACT

The challenge of developing clean and renewable energy sources is becoming ever more urgent. Over the last decade, the concept of carbon footprint has been used to report direct and indirect greenhouse gas emissions and as a support for sustainable consumption decisions. However, the discrepancies in the approaches based on either the product or corporate carbon footprint can seriously hinder its successful implementation. The so-called compound method based on financial accounts is a tiered hybrid method which enables the calculation of both the product and corporate carbon footprint. This work aims to assess this method as a tool for carbon footprint through its implementation in a comprehensive life-cycle assessment of the Osorio Wind Farms in Brazil. The total cumulative life-cycle emissions are 362.455 t CO2eq, representing 18.33 gr CO2eq per kW h delivered to the Brazilian national power grid. The difference with regard to previous works derives from its broader scope and different assumptions. In this study the comparable value from wind turbine manufacture, transport and construction is 8.42 gr CO2eq per kW h, 56% lower than the mean figure reported by Arvesen and Hertwich (2012). This study includes sources, phases and areas previously unreported in the carbon footprint reviews for the wind power sector. We conclude that the compound method based on financial accounts is a practical method that allows the definition of a more comprehensive goal and scope. Its implementation at Osorio Wind Farms demonstrates the method’s suitability for application in major international projects and institutions interested in closely monitoring their carbon footprint.

1. Introduction

Sustainable developmental science promotes management solutions and tools which integrate the fundamentals of sustainability (i.e. environmental quality, economic prosperity, and social...
One of the latest advances in hybrid methods is the compound method based on financial accounts (MC3, from its Spanish acronym “Método Compuesto de las Cuentas Contables”) [24]. This is an organisation-product-based-life-cycle assessment able to calculate both product CF and corporate CF in an updated and comprehensive assessment [25]. The method is one of the most widely accepted approaches in Spain [26,27]; MC3 is now supported by the Technical Committee of the Carbonfeel Initiative [28] and was approved as a valid approach for assessing corporate CF within the framework of the Spanish Voluntary Reduction Agreement [29]. A large number of pilot experiences have been developed under the MC3 approach. However, few are discussed in detail in the scientific literature, and none are applied to renewable energy production. Wind power is the fastest-growing energy technology of all the renewable sources. Despite the worldwide financial crisis, annual installed wind capacity has grown exponentially from 3760 MW in 2000 to 35,467 MW in 2013, and the world’s installed wind capacity reached a total of 318,137 MW at the end of 2013 [30]. In the current world scenario, Brazil is considered to be one of the more promising markets for wind power in the long term [31]. The wind power capacity in this country has grown significantly in recent years. Annual installed wind capacity was 583 MW, 1077 MW and 948 MW in years 2011, 2012 and 2013, respectively. Moreover, this rapid growth is only the start; the 6.7 GW of new power already contracted ensures a potential market investment of around 15 billion US dollars in the coming years. Brazil has managed to attract several wind turbine manufacturers who have set up factories in the country, and 15,000 new jobs were created by the wind industry in 2012 [30,32].

Lenzen and Munksgaard [33] developed one of the first comprehensive reviews to assess the environmental impacts of wind turbines, highlighting the need to reduce uncertainties by using hybrid methods for CF. Kubiszewski et al. [34] further extended this wide-ranging study by reviewing 119 wind turbines from fifty different analyses published between 1977 and 2007. Their findings place wind power in a favourable position compared to fossil fuel, nuclear and solar power generation technologies. Subsequent reviews were conducted under the Intergovernmental Panel on Climate Change (IPCC) with a high level of consensus [35,36]. Finally, Arvesen and Hertwich [23] reviewed 44 selected studies and identified weaknesses and knowledge gaps to be addressed by future research. The results of the analyses of wind power CF reveal significant differences; their spread is due to discrepancies in the energy contents of materials and the methodology and scope of the analysis. Despite these advances there are still areas without environmental assessment. For example, environmental impacts from wastes and land use are not commonly assessed and environmental impacts from the promotion phase or processes related to office activity, access roads and drainage have not previously been assessed.

This work aims to assess MC3 as a tool for CF through its implementation in the comprehensive life-cycle assessment of a Brazilian wind farm. To our knowledge, this paper is the first CF analysis in a wind farm under this novel approach. MC3 was built under the

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<thead>
<tr>
<th>Nomenclature</th>
<th>Description</th>
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<tbody>
<tr>
<td>CF</td>
<td>carbon footprint</td>
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<tr>
<td>CO₂</td>
<td>carbon dioxide</td>
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<tr>
<td>CO₂eq</td>
<td>carbon dioxide equivalent</td>
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<tr>
<td>EEIO</td>
<td>environmentally extended input-output</td>
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<td>GHG</td>
<td>greenhouse gases</td>
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<td>ISO</td>
<td>international organization for standardization</td>
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<td>MC3</td>
<td>compound method based on financial accounts</td>
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<td>LCA</td>
<td>life-cycle assessment</td>
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