Abstract

With the ongoing digital transformation in the global energy industry, measuring carbon footprints has become more complicated and is now more important than ever. This paper looks at the existing literature on carbon accounting with a specific focus on the application of AI, blockchain, IoT, and even satellite imagery. It takes a more profound look into the critique of traditional lifecycle assessment (LCA) practices and strives to understand how new technologies enable more dynamic, real-time, and transparent emissions tracking. Major systemic changes like the electrification of transport and industry, as well as centralized energy systems, have been looked into regarding their carbon responsibility and hidden emission impact. Ethically, the paper examines equity issues for cross-border emissions blame and some behavioral and institutional guardrails for measuring emissions at this granularity. The survey utilizes over 40 peer-reviewed academic publications, regulatory documentation, and case studies. It maps out a process for blending technological solutions alongside policy redirections and cultural shifts to create robust, fair, and verifiable carbon footprint management policies.

Keywords: *Carbon footprint, energy sector, digital tools, AI, blockchain, lifecycle assessment (LCA), Scope 3 emissions, renewable energy supply chains, decentralized energy systems.*

Introduction:

The inadequacies of carbon footprint accounting due to increasing demand for climate action have become the focal point of global decarbonization schemes. The level of detail and reliability associated with emissions data becomes increasingly important as countries and industries work towards net-zero goals. However, reliance on static lifecycle assessment (LCA) models still leaves gaping silos. Without the ability to capture dynamic, granular, non-transparent emissions, these models lag behind the digitization of energy systems. Further, they miss indirect emissions, lagged emissions, and real-time emissions.

AI, blockchain technology, satellite and drone imagery, and IoT sensors pave the way for better capturing these features. AI algorithms improve the accuracy of emissions estimation algorithms built on ever-changing datasets. Blockchain provides an immutable ledger of emissions data. Real-time IoT systems allow, for the first time, emissions to be monitored at minute levels, even Scope 3 emissions across supply chains.

This paper investigates the following research questions:

1. How do AI and blockchain challenge traditional carbon accounting?
2. What hidden emissions exist in renewable energy supply chains?
3. How does electrification shift carbon burdens to electricity grids?

The accompanying questions are approached in the following key themes: firstly, a review of methods and practices is conducted, which is accompanied by an examination of different digital instruments and new technologies. Then, the focus is placed on structural changes regarding energy consumption, attending to the issues of openness and organizational constraints, discussing policy and equity matters, and finally elaborating on the innovations that may impact the future accounting of carbon footprints.