Enhancing Carbon Emission Tracing in European Electricity Markets through Temporal Carbon Tracking in Power Storage

Konstantin Pelz
Information Systems Management M.Sc.
Technische Universität Berlin
konstantin.pelz@campus.tu-berlin.de

I. Introduction

Electric power generation emits carbon. Some types of generation emit more carbon than others, such as coal and gas, while others emit less, such as wind, solar, and nuclear. In most areas, multiple sources are used to generate the power needed, and the resulting mix of generation sources determines the carbon intensity of the power generated. In addition, the power consumed consists not only of power produced in one zone, such as Germany, but also of power imported from other zones, such as France, the Netherlands, or Austria. As a result, the carbon intensity of the consumed power may differ from that of the produced power due to a combination of self-produced, imported, and exported power. To determine the respective shares, recent reseach has focused on utilizing the flow tracing methodology [1] to track carbon emissions and calculate the carbon intensity of consumption [2]–[6]. Often the focus is on the largest interconnected electricity market, the European one, which will also be the focus of my work. This essay provides an outlook on the contribution of my master thesis, which addresses a methodological gap in carbon emissions tracing through power storage systems. The following two sections introduce the problem and outline the proposed solution.

II. Problem

The current methodology for computing carbon intensity has a gap as it does not account for power storage systems, such as batteries and pumped hydro. These systems consume power by converting electrical energy into another form in order to store it. Later, the stored power is converted back to electrical power and supplied to the power grid. During this process, the carbon emissions from the consumption are accounted for at the storage facility but not given back to the grid. To the end consumer, it may appear that the power coming from such a storage facility is clean. To ensure accurate accounting of emissions to the end consumer, the emissions should be tracked and returned to the grid for the end consumer.

Carbon emissions are produced during the generation of electric power, including those resulting from power plant construction [7], [8]. These emissions are considered embodied emissions and can be converted to operational emissions. For instance, a wind turbine has a projected lifespan during which it is expected to generate a specific amount of energy. The embodied emissions are then allocated to the energy to be produced. The carbon intensity of a production type is determined by its actual operational emissions and the embodied emissions, also known as lifetime emissions. The Intergovernmental Panel on Climate Change provides intensities for most production types[1]. It is important to note that carbon emissions during power generation are accounted for by the entity that consumes the power, allowing for tracking of emissions caused by each entity. The carbon intensity is used increasingly for greenhouse gas accounting [9].

Currently, power storage facilities are accounted for based on the power they consume to store energy. Although this approach is technically correct, it overlooks the fact that they are temporarily storing energy for later release to the grid. As a result, when they dispatch energy, it is considered clean and has a low carbon intensity, ignoring the emissions the storage is accounted for. One reason why this issue has been overlooked is that storage facilities mainly consume power when the price is low and produce power when the price is high. The cost of electric power is highly correlated with wind and solar production [10], and falls when the share of these two low-carbon sources is high. However, it is important to note that power storage does not exclusively consume low-carbon sources. In fact, the introduction of storage into a grid can actually increase the carbon intensity on average, as demonstrated in the case of the US [11], [12]. Nevertheless, strategic storage installation can help reduce the import of power with high carbon intensity [13] and lower the average carbon intensity in a zone [14], [15]. Therefore, accurate accounting of the carbon intensity used to charge a storage facility should be tracked and reported back to the grid. This

[1] https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_annex-iii.pdf#page=7 [Accessed 2024-02-17]

is especially crucial because of the expected growth of wind and solar power in the future to achieve carbon neutral electricity system [16]. With the anticipated increase, storage capacities are required to increase in order to ensure flexibility.

III. Solution

The objective of my master thesis is to monitor the carbon emissions and intensities of power storage in the European electricity market during the time the energy is stored, which can range from several hours to weeks and months. To accomplish this objective, several steps must be taken.

To begin, it is essential to monitor the inflows and outflows of various power storage facilities to determine the amount of power stored. Energy Quantified[2] and ENTSO-E[3] provide this data for pumped storage in several European zones up to a frequency of 15 minutes. Although data on battery storage and other options is not yet available in Europe, the methodology can be easily adapted to other storage solutions once data becomes available. One potential aspect for the future is the use of electric vehicle batteries as a form of energy storage [17], [18].

Further, it is necessary to have knowledge of the carbon intensity of power produced and consumed in Europe. This data is provided by Energy Quantified. Production-based carbon intensity measures the carbon intensity of a single zone's production, while consumption-based carbon intensity takes into account imported and exported power to calculate the carbon intensity that is consumed.

Additonally, power storage plants cannot produce as much energy as they consume due to losses in the conversion processes. To determine the necessary power to store to produce a given amount of energy, detailed knowledge of efficiency is required. For pumped storage systems, the efficiency is typically around 70% [19]. The model enhancement must either account for emissions from the conversion losses to the storage facility or pass them on to the grid later. The first option engages to use more efficient systems to minimize the emissions from the plant. The other option includes emissions from the facility to the end consumer. A decision in this case influences the emissions that are accounted for and is therefore important. However, both options will be evaluated to ensure comparability and provide a basis for decision-making.

Finally, it is important to compare multiple strategies for tracking emissions and intensity over time. The most straightforward approach is to monitor the average carbon intensity in storage. Two alternative strategies for energy storage are FIFO and LIFO [20], which are commonly used in inventory management. In this case the inventory is the stored energy and carbon. It is important to note that these are only three strategies, and exploring and evaluating more strategies is an essential aspect of my master thesis as they form the core of the temporal carbon emission tracking within stored energy.

[2]https://www.energyquantified.com/ [Accessed 2024-02-16]
[3]https://www.entsoe.eu/ [Accessed 2024-02-16]

IV. Summary

This essay presents my master thesis, which aims to address the issue of missing temporal tracking of carbon emissions from stored power in the European electricity markets. The solution will be designed and implemented. The result will be evaluated including the simulation of future scenarios, and critically assessed.

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