PCFWebUI: Data-driven WebUI for holistic decarbonization based on PCF-Tracking*

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Abstract

The pursuit of corporate greenhoue gas neutrality has become increasingly critical due to heightened sustainability expectations, rising energy and CO2e costs, and stricter regulatory requirements. Key drivers, such as the mandated reduction of greenhouse gas emissions by 65% by 2030 compared to 1990 levels and the goal of achieving climate neutrality by 2045, necessitate immediate action toward decarbonization. In this paper, we introduce PcfWebUI, a data-driven tool developed to support companies in their decarbonization journey. PcfWebUI is built on real company data integrated into a knowledge graph, enabling efficient tracking and management of product carbon footprints (PCF), facilitating strategic planning and accurate monitoring to help companies meet stringent climate targets and progress toward climate neutrality. A demo of our system is publicly available at https://climatebowl.demo.dice-research.org/.

Keywords

Knowledge Graphs, PCF Tracking, Energy Efficiency

1. Introduction

Achieving greenhouse gas (GHG) neutrality poses a complex challenge for companies, driven by political pressures, stakeholder demands, and rising energy costs. Essential drivers such as the mandatory reduction of GHG emissions by 65% by 2030 relative to 1990 and the attainment of net zero emissions by 2045 underscore the need for companies to embark on the path to decarbonization promptly [1]. The allocation of GHG emissions to specific sources and the identification of suitable measures are complex due to the intricate interactions within the production systems. Current digital approaches exhibit significant gaps, particularly in the comprehensive aggregation and assessment of GHG emissions. Furthermore, they fall short in sufficiently developing reduction measures across the entire value chain. Addressing these challenges requires a holistic and digital approach. The foundational step towards reducing GHG emissions is achieving transparency in emissions across both specific sites and the entire

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value network. This transparency is starting point for the development of decarbonization measures.

In this paper, we present PcfWebUI[1] Based on real companies' data integrated into knowledge graph (KG), PcfWebUI enables efficient tracking and management of the Product Carbon Footprints (PCF), helping companies to identify potentials to reduce GHG emission as well as derive and assess specific measures. The system's data-driven approach ensures accurate monitoring and strategic planning, supporting companies in meeting stringent climate targets and advancing toward GHG neutrality. PcfWebUI aims to simplify the process of identifying and implementing energy efficiency (EE) measures. This is the focus of our collaborative project *Climate bOWL*[2].

2. PCF-Tracking in context of industrial decarbonization

The holistic decarbonization of corporate activities can be divided into the three phases: *target definition*, *carbon accounting* and *action planning* [2]. Defining reduction targets and translating them into a reduction pathway is the foundation of any decarbonisation strategy. It is necessary to create transparency about the company's product-specific greenhouse gas emissions through carbon accounting. The general methodical procedure is defined in the Greenhouse Gas Protocol (GHGP) or standard DIN EN ISO 14064, the product-specific accounting is specified in standard DIN EN ISO 14067 [3]. The accounting of all input and output flows for the relevant process modules of a product is recorded in a life cycle inventory and then subjected to an impact assessment in order to quantify the GHG potential measured in GHG equivalents [4]. By analyzing the PCF, it becomes clear which process modules in the life cycle inventory have the greatest GHG potential. The aggregation of process modules according to criteria such as scope categories or life cycle phases makes it possible to evaluate the influence of individual or aggregated process modules on the overall PCF. This analysis is important because it defines the starting point for the development of decarbonization measures by identifying the emission-intensive process modules. In the third phase of action planning, measures for GHG reduction are derived for the identified drivers of the PCF. In principle, decarbonization efforts can be strategically implemented following the principles of avoidance, reduction, replacing and offsetting [5]. There is a need to automate the individual steps of PCF tracking and the development of measures in order to ensure a holistic approach and accelerate industrial decarbonization [2]. The *Climate bOWL* research project is therefore investigating the development of a digital support system that automates the PCF accounting and analysis as well as the derivation of reduction measures based on the methodological framework described.

3. Climate bOWL Knowledge Graph

The foundation of PcfWebUI's robust functionality lies in its use of real companies' data from the Climate bOWL project, integrated into knowledge graph (KG). For generating our KG, we

[1]Demo: https://climatebowl.demo.dice-research.org. Please be aware that for data protection purposes, our public demo exclusively utilizes synthetic data. This ensures that no real company data is used or exposed.
[2]https://dice-research.org/ClimatebOWL

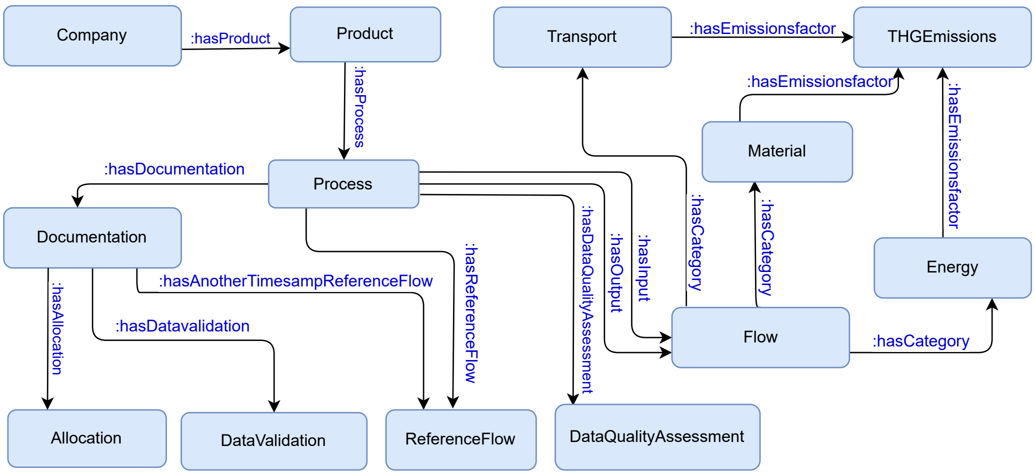

Figure 1: The Climate Bowl Ontology (CLBO)

deployed *Python* scripts to convert data from Excel files into the KG triples. Our KG conversion scripts are available from the project *Github*[3]. The resulted triples is then hosted using *Apache Jena*[4]. To facilitate advanced querying, we also provided a SPARQL endpoint to our KG, allowing users to perform complex queries and extract more specific information.

The *Climate Bowl Ontology* (CLBO), see Figure 1, is designed to facilitate the aggregation, evaluation, and prioritization of GHG emission reduction measures throughout the value chain in industrial settings. CLBO defines key concepts and their relationships relevant to industrial GHG emission reduction. Key entities include companies, products, processes, flows, and documentation standards. Properties describe the relationships between these entities, enabling a structured approach to tracking and analyzing GHG emissions and identifying potential reduction measures. For more details see the climatebowl ontology online resource[5].

4. PcfWebUI

We introduce PcfWebUI, a data-driven tool developed to support companies in their decarbonization journey. The system emphasizes improving material and energy efficiency as the first step, followed by substituting energy sources and compensating for residual emissions. PcfWebUI enables efficient tracking and management of PCF facilitating strategic planning and accurate monitoring to help companies meet stringent climate targets and progress toward climate neutrality. The key components of PcfWebUI are:

1. **Query Component.** The query component is designed to allow users to efficiently search and retrieve specific information related to their PCF data. This component includes a

[3]https://github.com/dice-group/ClimateBowl-KGConverter
[4]https://jena.apache.org/
[5]http://w3id.org/dice-research/climatebowl/ontology

field for SPARQL queries that utilizes our integrated KG to get detailed data for a product. We built the query component using `React`[6] for the front-end and *Apache-Jena* for the back-end. The query component provides instantaneous feedback, displaying results as users refine their queries.

2. **PCF Tracking Component.** The PCF tracking component enables users to monitor and manage PCF comprehensively. This component presents a table with different parameters for a single product, where the data for this table comes from the KG using the SPARQL query in the *query component.* As shown in Figure 2, the `Flow` column (`"fluss"` in German), there is a drop-down feature that allows users to choose for different materials or energy sources. The `Flow` column includes a searchable drop-down that retrieves data from our KG, allowing users to find materials or energy sources quickly. This component dynamically reflects changes in emission factors in real-time, indicated by a green arrow if emissions decrease and a red arrow if emissions increase.
3. **Analytics Component.** The analytics component of PcfWebUI responsible for analyzing PCF data and generating insights. This component uses the updated data from the PCF Tracking table, including all user updates, to display various analytical graphs. One of the key graphs is *the life cycle phases graph*, where emission data is divided into different life-cycle phases of the product and compares old and new emissions (See an example in the lower part of Figure 2). Another important chart is *the scope graph* that shows data grouped by scopes, providing a view of emissions according to different scope categories.

5. Conclusions and Future Work

Corporate climate neutrality is imperative due to strict regulations, rising energy and CO2e costs, and increased sustainability expectations. PcfWebUI is a pivotal tool, enabling efficient tracking and management of product carbon footprints with a data-driven approach. By integrating real company data into a KG, PcfWebUI enhances material and energy efficiency, energy source substitution, and residual emissions compensation. Despite challenges in data availability, secure exchange, and PCF tracking complexity, PcfWebUI offers a robust foundation for companies to meet decarbonization targets and achieve GHG neutrality.

In future work, we will enhance PcfWebUI by developing advanced features for EE benchmarking, measure derivation, and prioritization to guide companies in decarbonization. We will also integrate a recommendation system for energy reduction and decarbonization based on PCF and energy efficiency benchmarking data. Finally, We will integrate our novel SPARQL query generation approach into PcfWebUI for a more user-friendly experience [6].

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[6] https://react.dev/

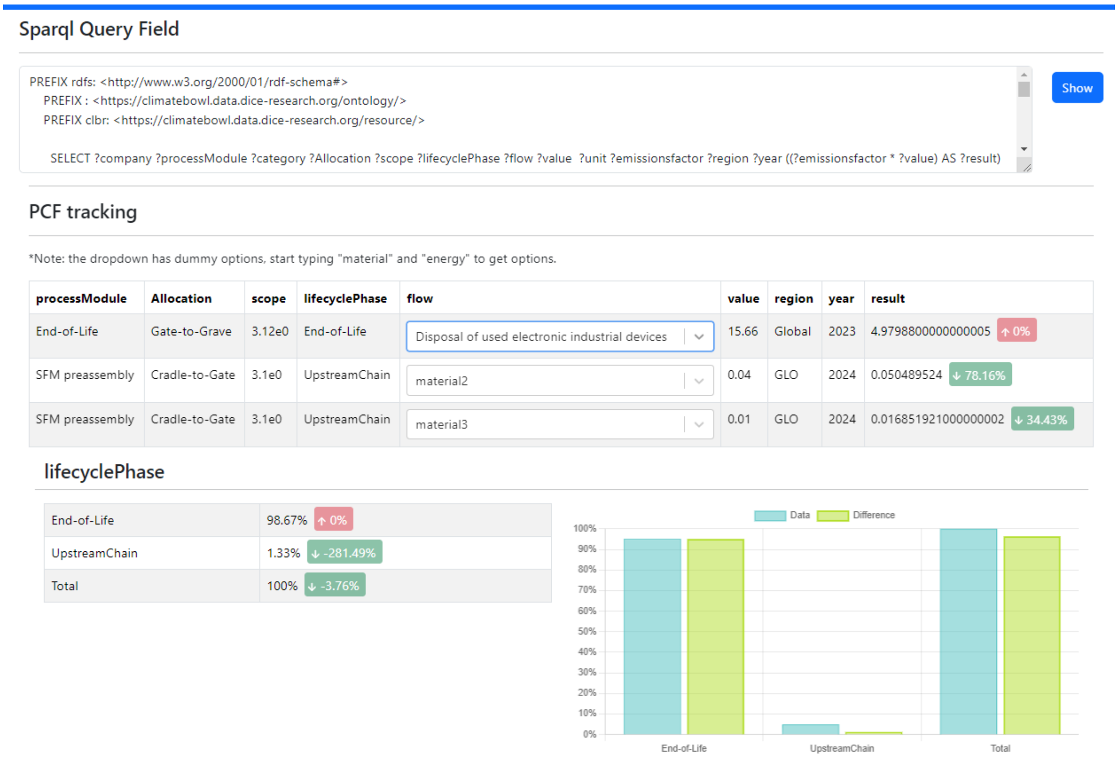

Figure 2: PCF-tracking UI overview

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