Navigating the Road to Trucking Decarbonization

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I. INTRODUCTION

It is estimated road freight transportation accounts for over 7% [1] of global carbon dioxide (CO_2) emissions. Across the transportation sector, trucking has been recognized as an area that faces many decarbonization challenges [2]. Large payloads necessitate dense energy carriers, thus restricting the available space of diesel alternatives [2]. Transitioning the industry to alternative carriers will also require significant infrastructure investment and build-out [3]. Compounding these factors, the industry's tight profit margins [4] make trucking fleets especially vulnerable to transition risk.

We develop a geospatial mapping tool that complements and extends prior research by enabling the regional identification and assessment of fleet decarbonization opportunities. Leveraging this mapping tool, we implement a methodology to rigorously compare a range of factors that can impact fleet decarbonization decisions at the corridor level. This specific research focuses on the routing aspect of the aforementioned mapping tool.

II. LITERATURE REVIEW

Prior work assessing trucking decarbonization opportunities is found to cover two distinct categories. One category delves into case studies concerning emissions along freight corridors, while the other analyzes cost-effectiveness and coverage. Within the former category, various works quantify and forecast emissions along specific corridors throughout the United States [5], [6]. A subset of these works develop modal choice models based on distance, load, accessibility, emissions, cost, and time [7], [8]. Sources in the latter category compare the cost-effectiveness of alternative energy carriers based on factors such as trip distance and cargo constraints [9]. These sources highlight a lack of one-size-fits-all decarbonization solutions [10], emphasizing the importance of considering the context in which a given fleet operates, and regional aspects such as the local electricity grid.

III. METHODS

Building on prior work, we develop and leverage a geospatial mapping tool to implement a methodology for multivariate identification and assessment of corridor-level fleet decarbonization opportunities. The Freight Analysis Framework Version 5 (FAF5) [11] database, which comprehensively captures freight flows across most corridors throughout the continental United States, provides the core layers for the geospatial mapping tool. The FAF5 data is combined with the Department of Energy's (DOE's) Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model [12] and the U.S. Census Bureau's Vehicle Inventory and Use Survey (VIUS) [13] to evaluate associated lifecycle emissions. These layers are complemented with data from other public sources including the Environmental Protection Agency's Emissions & Generation Resource Integrated Database (eGRID) [14], and the DOE's Alternative Fuels Data Center [15].

The datasets are integrated into a range of "decision support" layers and visualized with a custom-designed interface. Building on this core tool, we develop an algorithm to perform corridor-level routing between regions, and efficiently quantify a range of decision support layers along the corridors. The aim is to enable rapid multivariate identification and comparison of fleet transition opportunities on inter-regional corridors and to embed this functionality within a web-based interactive environment.

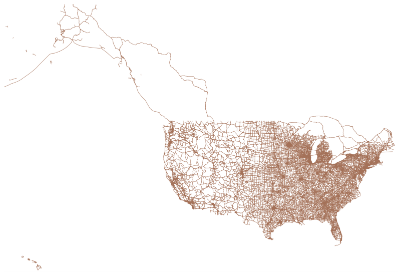

Fig. 1. U.S. road network from FAF5 database.

The highway network contained in the FAF5 database, shown in Fig. 1, is represented as a simple weighted undirected graph. This is used by the routing tool in conjunction with the A* algorithm to find the shortest route along the graph between two given nodes.

IV. PRELIMINARY RESULTS

The routing procedure begins by extracting specific corridor segments, filtering them based on desired geographic origindestination (O-D) pairs with an initial definition of “weight” as distance for testing and validation. Fig. 2 visualizes the extraction of corridor segments for the routing procedure.

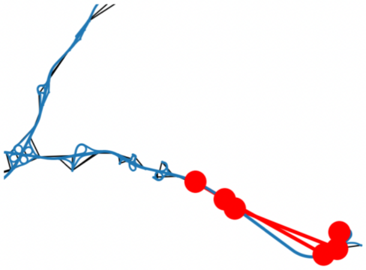

Fig. 2. Corridor segment extraction proof of concept.

Corridors connecting different O-D pairs will be selected by integrating freight flow densities along individual corridor segments into the edge weights within the graph. Once all possible routes connecting an O-D pair are established, the selected corridor will jointly optimize for minimum routed distance and maximum integrated freight flow.

Moving forward, we intend to add functionality to quantitatively compare different decision support layers, such as state-level electricity rates, between corridors connecting different O-D pairs. For a given corridor, this will initially be accomplished by averaging the value of each layer along the length of the corridor.

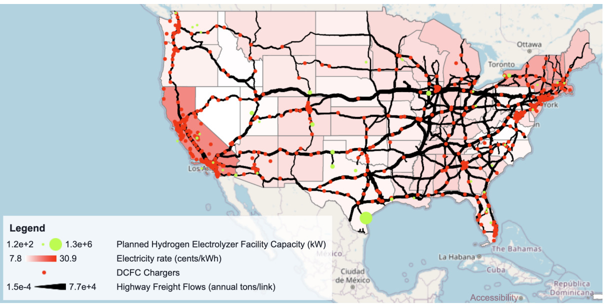

Fig. 3. Sample decision support layers visualized with the core geospatial mapping tool [16].

By quantifying these decision support layers in an integrated manner, we aim to establish a rigorous quantitative foundation upon which standardized corridor-level comparisons of fleet transition opportunities can be further developed. Fig. 3 depicts some of the decision support layers we plan to utilize from the core geospatial mapping tool.

The current version of this tool is available on the MIT Climate & Sustainability Consortium’s Datahub webpage [16].

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