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# Analyzing the Impacts of Carbon Regulatory Mechanisms on Supplier and Mode Selection Decisions: An Application to a Biofuel Supply Chain

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**Abstract**

This article analyzes the impacts of carbon regulatory mechanisms on replenishment decisions in a biofuel supply chain. We employ mathematical models for operations which integrate replenishment and supplier/transportation mode selection decisions. These models explicitly account for carbon emissions that may result from transportation and inventory storage activities. This research is motivated by observations indicating that nearly 19% of the energy consumption and 25% of the energy-related carbon dioxide emissions worldwide arise from transportation. Because freight transportation is expected to continue to grow, we consider the impacts of different carbon regulatory mechanisms on transportation and inventory replenishment decisions in a biofuel supply chain. A set of extensive numerical experiments uses the biofuel supply chain context to analyze the impacts of different regulatory mechanisms, including carbon cap, carbon tax, carbon cap and trade, and carbon offset, on performance. We use existing methodologies to calculate emissions as a function of distance traveled, load weight, and transportation mode used. We also use publicly available data to derive representative biomass transportation costs. As a consequence, our numerical results are meaningful, and give a realistic representation of the relationships between emissions from different transportation modes and the resulting costs. The results of our computational experiments indicate that carbon regulatory mechanisms have a non-trivial impact on replenishment schedules, and as a consequence, costs and emissions in the supply chain.

*Keywords:* Carbon Emissions, Biomass Supply Chain Operations, Economic Lot-Sizing, Supplier Selection, Transportation, Forest Residues



## 1. Introduction

Global climate change is an important contemporary issue that is being investigated from numerous perspectives. Many prominent world leaders and scientists have raised concerns in recent years regarding increased levels of greenhouse gas (GHG) emissions and the impacts these emissions have on climate change.The Intergovernmental Panel on Climate Change (IPCC) estimates an increase of 1.8° to 4° Celsius in Earth's temperature by the end of this century because of increased GHGs, such as carbon dioxide ($CO_2$), methane and nitrous oxide (Solomon et al., 2007). Of major concern is the burning of fossil fuels, since their extensive usage in areas ranging from power generation to transportation yields significant GHG emissions levels.

These concerns have inspired a worldwide debate about GHG emission reduction targets and regulations. Rogner et al. (2007) argue that in order to prevent global warming and climate change, GHG emissions should be reduced by 50% of their 1990 levels by 2050. Many countries and governments have accepted the premise that an urgent need exists to put policies into action, and have already set reduction targets. For example, through its European Climate Change Programme, the European Union aims to reduce its GHG emissions by at least 20% by 2020 compared to 1990 levels ( European Commission, 2008). While the media has chronicled a fair amount of controversy regarding GHGs and climate change, our study does not weigh in on this debate; instead, our research assumes that reducing fossil fuel consumption will provide economic benefits and improve quality of life.

Transportation and other supply chain related activities are a major contributor to GHG emissions (International Transport Forum, 2010). The International Energy Agency (IEA) states that 19% of the energy consumption, and almost a quarter of the energy-related $CO_2$ emissions worldwide result from transportation (International Energy Agency, 2009). The US Environmental Protection Agency (EPA) estimates that during the period from 1990 to 2010, transportation-related emissions rose by 18% (Environmental Protection Agency, 2012). This is mainly due to the increased demand for travel, and the US vehicle fleet's stagnant fuel efficiency. Considering current

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