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# A literature review on reducing carbon emission from supply chain system: drivers, barriers, performance indicators, and practices

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**Abstract.** This study aims to review the literature in reducing carbon emission from supply chain system for the past few years and presenting drivers, barrier, performance indicator, and practice. The issue of reducing carbon emission become frequently discussed since unplanned and irresponsible actions by industries are potential threats to sustainability. Companies are now trying to minimize environmental impacts by integrating environmental concerns into their supply chain operations. In the aim of reducing carbon emissions, the industry is faced with different drivers, barriers, and performance indicator. With a variety of problems faced, the practices taken to reduce carbon emissions are very diverse. Thirty papers were collected from previous studies and linked to discussion points. The result showed that good coordination with various media in the supply chain system would be able to achieve common goals in reducing gas emissions.

## 1. Introduction

Supply chain management is strategically positioned for sustainability, performance, and organizational sustainability [1]. Furthermore, the supply chain is an essential branch of operations management, and it has an essential impact on the environment, including emissions, pollutions, and the health hazard of the community. However, unconsciously, inefficient supply chain management activities from upstream to downstream can cause excessive carbon gas emissions.

The increase of global warming and changing biodiversity has brought the world's sustainability towards immediate danger. People from different areas, including researchers, academicians, practitioners, and scientists got all together to suggest ways to maintain the environmental sustainability.

According to King and Lenox [2] claimed that unplanned and irresponsible actions by industries are potential threats to sustainability. Companies are now trying to minimize environmental impacts by integrating environmental concerns into their supply chain operations. According to Sarkis and Dou [3], the integration of supply chain elements with corporate environmental management that referred to as "Green Supply Chain."



In today's globalized supply chains, environmental issues are of critical importance. During the past decade, carbon emissions and pollution associated with economic development have caused severe issues such as the greenhouse effect, abnormal climate, and environmental degradation [4]. Based on this background, the handling of gas emission in the company must be better and carefully planned. Many previous studies have tried to find strategies and scenarios in minimizing gas emissions.

This paper presents a review of reducing carbon emission problem, which classifies the study in terms of driver, barrier, and performance indicator. The remainder of this paper is organized as follows: Section 2, is for presenting the literature review. Section 3 is for drivers and barriers and performance indicators in Section 4. Section 5 is for presenting the practice. Section 6, which is, for the conclusion.

## 2. Literature Review

Tapia Granados and Spash [5] suggest that annual costs in emissions are highly correlated with economic growth. In California, the cap-and-trade scheme has been implemented since 2013, and it did not have a significant impact because the energy supply was minimal. When making decisions about cap-and-trade allowance allocations or carbon tax designs, policymakers should consider that industries may be concentrated and thus already limit output below socially optimal levels [6]. Carbon cap-and-trade regulation and green technology investment is an effective method of reducing carbon emissions however carbon cap-and-trade regulation and green technology investment is an effective method of reducing carbon emissions Bai, et al. [7].

Waltho, et al. [8] and Elhedhli and Merrick [9] try to build network design with the aim to reduce carbon emission. Four policies are recommended by Waltho, et al. [8] that successfully reduce emissions effectively without increasing high costs, i.e. carbon offset, carbon cap, carbon tax, and cap-and-trade. Cap-and-trade is the most preferred policy because it has high flexibility. Peng, et al. [10] utilize structural decomposition analysis and structural path decomposition analysis method to identify air pollution emission. Adjusting the energy consumption structure as soon as make some guiding consumption will reduce emissions gradually.

According to Valadkhani, et al. [11], the country's economic conditions are an essential part of the transition to renewable energy. They study energy consumption portfolio by utilizing data from 79 countries from 1965 to 2017 and investigate the contribution of consumption of primary energy (i.e., coal, gas, oil) to changes in CO<sub>2</sub> emission per capita. The result of the study suggests that only high-income countries are eligible to switch to renewable energy. On the other hand, in low-income countries, natural gas remains a potential solution.

Du, et al. [12] utilize a system dynamic method to investigate carbon reduction technology policies to the level of economic growth. According to the study, emissions could be reduced by promoting the development of carbon reduction technology. One of the policies that can be implemented is promoting the use of renewable energy in related industries so that it can reduce carbon emissions. Recovery supply chain model with consideration of safety stock and carbon emission has been developed by Darom, et al. [13]. In this model, safety stock is used as an essential mitigation strategy in overcoming supply disruptions, and the cost of carbon emissions is also considered for its relationship with the environment.

Tseng and Hung [14] developed a strategic decision-making model considering social costs and operational cost costs incurred due to carbon dioxide emissions during the process in the supply chain system. Evaluation is carried out through several different scenarios with case studies on industrial apparels. The results of the study suggested that the government make strict regulations on companies to bear the social costs of carbon emissions produced. This needs to be done because, from the experimental results, it can be concluded that the higher the level of social costs can reduce carbon emissions effectively.

According to Wang, et al. [15], the retailer can achieve the goal of jointly reducing carbon emission with the manufacturer. In their study, numerical experiment and analysis successfully were done to get the optimal cost-sharing rate and the optimal premium rate of the wholesale price. Incentive

mechanism policy from the government to work collaboratively among supply chain member to reduce carbon emission has been investigated by Ding, et al. [4]. The results show that collaboration between supply chain members plays a crucial role in improving their environmental performance. Ji, et al. [16] has been compared two emission reduction strategies, i.e., production strategy and joint emission reduction strategy, the result is joined emission reduction strategy is more profitable for manufacturer and retailer.

In recent years, the business and scientists communities have a significant interest to discuss the danger of gas emissions that always increases [17]. According to Chen, et al. [17], the main goal of emission reduction will not succeed if companies often choose actions to reduce emissions without coordination with other business partners. This kind of event results in an increase in emissions for other partners which will not cause emissions reductions in the supply chain system

Daryanto, et al. [18], Zissis, et al. [19], Peng, et al. [20], Bai, et al. [21], Liu [22], Xu, et al. [23], Ding, et al. [24], [25] in their research they found that integration in the supply chain system can be an essential way to reduce total costs and carbon emissions. Contracts are needed that are designed in such a way as to create the coordination of the entire supply chain system to make perfect coordination between players in the supply chain [26]. Coordination between players in the supply chain system has succeeded in creating optimal costs, especially in transportation costs and carbon emissions [27]. Improving performance and obtaining the benefits of an overall supply chain system will be achieved if the supply chain can be appropriately coordinated [28].

According to Zissis, et al. [19], just the right environmentally friendly policies can save the total cost of the supply chain system. They suggest a quantity discount mechanism to coordinate players along the supply chain. Daryanto, et al. [18] develop three-echelon supply chain models to determine the optimal number and size of the delivery. Delivery starts from supplier to third-party logistic (3PL) and from 3PL to buyers to reduce carbon emissions. Zhou and Ye [26] analyzed shared emission reduction strategies and contract design in multiple channel supply chains under a low carbon environment. Cooperative advertising contract and emission reduction cost-sharing contract successfully to make more supply chain improvements.

Utilizing quantity discount contracts as a medium of coordination between players in the supply chain system has been done by Peng, et al. [20]. The result show, that quantity discount contracts, and revenue sharing contract can coordinate the low-carbon supply chain perfectly with some several combinations.

According to Dash Wu, et al. [29], the win-win solution achieved when manufacturer invests more in reducing emissions. They design a contract to coordinate the supply chain under optimal order quantity, the optimal wholesale price of the manufacturer, and optimal carbon emission level to be the focus for exploration.

Bai, et al. [21] analyze coordination effect on emission reduction, revenue-and investment-sharing (RIS) contract successfully coordinating the supply chain system perfectly. RIS can make supplier and manufacturer gain more profit and not negatively affected by carbon cap. In other studies Liu [22] and Xu, et al. [30] also succeeded in creating a low-carbon supply chain through revenue sharing contract.

Cost-sharing and wholesale price contract is some contract that can coordinate supply chain Xu, et al. [23]. They focus on the problem of coordinating supply chain systems under cap-and-trade regulation. With proper coordination, carbon emissions can be reduced without affecting the profit of each player in the supply chain system. One example, although the retailer shares the manufacturer's total cost, the manufacturer may increase the wholesale price, which indicates that the manufacturer can charge a high price for the low-carbon product.

Ding, et al. [24] developed an optimal pricing strategy model for environmentally friendly supply chain system. In this supply chain model, government and manufacturing have mutually integrated with strong coordination relationships. The results of this study suggest that the performance of an environmentally friendly supply chain system can be improved by the existence of good cooperation between manufacturers and suppliers, regardless of the role of the government.

**Table 1.** Paper Classification According to Source of Drivers, Barriers and Performance Indicator

No.	Authors	Drivers Source		Barriers Source		Performance Indicator			Practices
		IN	EX	IN	EX	EC	EN	OP	
1.	Tapia Granados and Spash (2019)		X		X	X			Policies (must be balanced with renewable material and energy supply)
2.	Valadkhani, Nguyen, and Bowden (2019)	X		X		X			Renewables energy policies (only eligible to high-income countries)
3.	Di Filippo, Karpman, and DeShazo (2019)		X	X		X			Carbon-pricing policies (limit output and optimal level)
4.	Du et al. (2019)	X		X			X		Low carbon development policy (technology need)
5.	Chen, Benjaafar, and Elomri (2019)	X		X	X				Penalties in the decentralized supply chain (buyer-vendor supply chain framework)
6.	Daryanto, Wee, and Astanti (2019)	X			X	X	X		Optimizes the number of deliveries and delivery size (SCM contract)
7.	Bai, Gong, Jin, and Xu (2019)	X		X	X	X			Carbon cap-and-trade regulation and green technology investment
8.	Liu (2019)		X			X	X		Revenue sharing contract, pricing, and targeted advertisement policy
9.	Zissis, Saharidis, Aktas, and Ioannou (2018)	X			X	X			Supply chain coordination with quantity discount
10.	J. Peng, Zhang, Xie, and Liu (2018)	X			X		X		Coordinate the relationship between household consumption by adjusting energy consumption structure
11.	Darom, Hishamuddin, Ramli, and Mat Nopiah (2018)	X				X			a recovery model with safety stock as the mitigation strategy to respond to environmental issues
12.	Zhou and Ye (2018)	X			X	X			Shared emission reduction strategies and contract design under a low-carbon environment
13.	H. Peng, Pang, and Cong (2018)		X		X		X		quantity discount contracts as a medium of coordination between players in the supply chain system
14.	Dash Wu, Yang, and Olson (2018)	X			X	X			contract to coordinate supply chain under optimal order quantity, the optimal wholesale price of the manufacturer, and optimal carbon emission level
15.	Bai, Xu, and Zhang (2018)	X	X		X	X			coordination with emission reduction, revenue-and investment-sharing (RIS) contract
16.	L. Xu, Wang, and Zhao (2018)	X	X		X	X			Revenue sharing contract
17.	Aljazzar, Gurtu, and Jaber (2018)		X		X	X			Delay in payment to improve economic performance
18.	X. Xu, He, Xu, and Zhang (2017)		X	X	X	X			Coordinate by Wholesale price and cost-sharing contract
19.	Ji, Zhang, and Yang (2017)	X		X		X			Production strategy and join emission reduction strategy
20.	Yang, Zhang, and Ji (2017)	X	X	X	X	X			Profit-sharing contracts
21.	Bai, Xu, Xu, and Wang (2016)	X	X		X	X			Revised revenue sharing contract
22.	Wang, Zhao, and He (2016)	X		X	X		X		Retailer and manufacturer join carbon reduction contract
23.	Ding, Zhao, An, and Tang (2016)		X	X	X	X			Incentive mechanism policy
24.	Zhou, Bao, Chen, and Xu (2016)		X	X	X	X			co-op advertising contract and the co-op advertising & emission reduction cost-sharing contracts
25.	Sarkar, Ganguly, Sarkar, and Pareek (2016)	X		X		X			Coordination between players
26.	Ding, Zhao, An, Xu, and Liu (2015)	X			X	X			Coordination with optimal pricing strategies
27.	Tseng and Hung (2014)		X	X		X			Government regulation, level of social costs effectively reduce carbon emissions
28.	Zhang, Wang, and Ren (2014)	X	X	X	X	X			Pricing and coordination strategy
29.	Liu, Kasturiratne, and Moizer (2012)		X	X	X	X	X		Multi-dimensional integration strategy
30.	Elhedhli and Merrick (2012)		X	X	X	X	X		Network design

Zhang, et al. [31], has investigated the issue of pricing and coordination of players in the green supply chain system. System performance in cooperative games is better than non-cooperative games.

Deteriorating item in inventory management is the challenging issues [28]. Research conducted by [28] proposes a revised revenue-sharing (RRS) contract to coordinate the decentralized system. They constructed two models with multivariate decisions for both decentralized and centralized systems. Then proposed the use of the RS contract and RRS contract to coordinate the system. The result show RSS contract successfully coordinates the supply chain system perfectly and give a higher profit than RS contract.

Yang, et al. [32] has analyzed two competitive supply chains under the cap and trade scheme. The win-win solution between manufacturers and retailers could be achieved effectively with profit-sharing contracts provided by retailers, while also benefiting the environment with a higher level of emission reduction. Members in the supply chain system could accept the cap and trade mechanism only if consumers had strong low carbon preferences Ji, et al. [16].

According to studies by Zhou, et al. [33] Co-op advertising and emission reduction cost-sharing contracts can achieve channel coordination and achieve win-win situations under certain conditions. On another research by Aljazzar, et al. [34], delay in payment has successfully improved the economic performance of the supply chain system and environmental performance.

### **3. Source of Drivers and Barriers to Reducing Carbon Emission from Supply Chain System**

To reduce carbon emission from a supply chain system, there are various drivers and barriers in the process of implementation. Drivers in this study are factors that can encourage companies to reduce carbon emissions, for example, the target of company image or competitive pressure. While the barrier is factors that inhibit some process from reducing carbon emission. According to Tseng, et al. [35], drivers on reducing carbon emission can be classified into internal and external sources.

#### *A. Internal Source of Drivers on Reducing Carbon Emission*

The drivers come from internal organizational, for example, company green image, the requirement of ISO 14000, internal environmental awareness, resource efficiency by way of reducing waste.

#### *B. External Source of Drivers on Reducing Carbon Emission*

The drivers come from external organizational, for example, a regulator from government, a regulator from an environmental group, awareness-raising of business partners, competitive pressure because of competitors, requirements of business partners.

On the other hand, barriers to reducing carbon emission are also classified into internal and external sources.

#### *A. Internal Source of Barriers to Reducing Carbon Emission*

The barriers come from internal organizational, for example, lack of environmental knowledge, lack of environmental awareness, new system switching cost, environmentally friendly design costs, financial problem, lack of top management involvement, lack of collaboration between departments, afraid of failure, lack and high cost of eco-technology.

#### *B. External Source of Barriers to Reducing Carbon Emission*

The barriers come from external organizational, for example, lack of government support, lack of eco-friendly training, no eco-friendly appreciation from partners or government, lack of awareness between partners, market uncertainty, lack of commitment between partners, lack of support from related parties.

#### 4. Performance Indicator

Performance Indicator is a unit of measurement that can describe how successful the implementation of policies in reducing carbon emissions. In general, economic factors are the most frequently used performance indicators. According to Huang, et al. [36] refined by Tseng, et al. [35], in general, performance indicators are divided into three major groups. Performance can be seen through environmental performance, economic performance, and operational performance.

##### *A. Economic Performance Indicator*

Performance valuation indicators related to economic impacts, for example, minimizing costs, new market opportunities, profit margin, sales increase, market share, net income, cost of goods sold (COGS), overall business performance, cost to the customer.

##### *B. Environmental Performance Indicator*

Performance valuation indicators related to environmental impacts, for example environmental performance, waste minimization, environmental impact analysis, pollution level.

##### *C. Operational Performance Indicator*

Performance valuation indicators related to operational impacts, for example efficiency improvement, quality improvement, productivity improvement, delivery accuracy and speed, level of flexibility, operational performance, minimize lead time.

#### 5. Practice

In the literature, this review found a variety of practices that had been submitted by previous researchers. Various policies from the government have a good impact on reducing gas emissions. These policies include renewables energy, carbon-pricing, low carbon development, and incentive mechanism policy. To produce the best output, these policies must be supported by all stakeholders. According to Tapia Granados and Spash [5], policies that have been made will run smoothly if balanced with the availability of renewable material and energy supply. Thus, the policy to reduce gas emissions will not succeed if it is not balanced with the supply of renewable energy. Renewables energy policies were only eligible for high-income countries [11]. Supporting technology is very important for the success of policy [12].

Green supply chains will be challenging to achieve in the decentralized supply chain. According to Chen, et al. [17], the use of penalties in the decentralization supply chain is quite influential on low-carbon policies. Coordination can be the best way to achieve common goals in a supply chain system. In the literature review, several media in the coordinated contract were found for coordinating the supply chain and achieve the goal of reducing gas emissions. The coordination media include quantity discount, energy consumption structure, optimal safety stock, optimal order quantity, optimal wholesale price, optimal carbon emission level, revenue-and-investment sharing, pricing, delay in payment, production strategy, deliveries, deliveries size, and profit-sharing.

Zissis, et al. [19] and Peng, et al. [20] use quantity discount as a medium in coordinating the supply chain to reduce carbon emission. Energy consumption structure successfully used by Peng, et al. [10]. Darom, et al. [13] succeeded in using safety stock with consideration of emissions. According to past research optimal order quantity [29], optimal wholesale price [29];[23], optimal carbon emission level [29] under a coordinated supply chain can reduce carbon emission effectively. In another side, revenue sharing is used by [22] [30] [28] and investment sharing used by [21] to coordinate the supply chain to reduce carbon emission. Other than that, Liu [22], Ding, et al. [24], and Zhang, et al. [31] utilize a pricing strategy to coordinated supply chain and reduce carbon emission. Moreover, coordination has also been carried out with other media, among others delay in payment [34], production strategy [16], deliveries [18], deliveries size [18], and profit sharing [32].

Based on the practices that have been carried out in previous studies, it can be concluded that coordinated supply chains can reduce gas emissions more effectively.

Through proper coordination with any media, the common goal of becoming a green supply chain will be easier to achieve.

## 6. Conclusion

Reduce carbon emission has recently become a company goal. The emergence of concern about carbon emissions can come from internal and external companies. Many companies are directly aware of the awareness of reducing carbon emissions. However, it is not uncommon for companies that actually do not have awareness but must do so because of government policies related to carbon emissions. In this paper, 30 papers relating to the practice of reducing carbon emissions were reviewed. The author tries to explore drivers, barriers, performance indicators, and practices in reducing carbon emissions from each paper.

Some papers suggest that drivers of reducing gas emissions originate from the company's internal awareness. On the other hand, some papers also say that consciousness occurs due to coercion or the terms requested by external parties. Regarding performance indicators, most papers use economic value as a performance indicator

Most of the papers suggest that coordination must be done with various media. With proper coordination in the supply chain system, a common goal will be achieved in reducing gas emissions. For future research work, it is essential to combine approaches that can more effectively and efficiently coordinate every player in the supply chain system to reducing carbon emission. As we know, based on this literature review coordination is very important in achieving the common goal of reducing carbon emissions.

This review concludes that there is a relationship between approaches in the aim of reducing carbon emissions related to drivers, barriers, performance indicators, and practices.

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