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Logistics, Supply Chain, Sustainability and Global Challenges
Vol. 14, iss. 1, December 2023
doi: 10.2478/jlst-2023-0007

Supply chain management mitigation to climate change in three selected industrial sectors

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Abstract **- As the world economy is growing and globalisation is on the rise, climate change and its effects on the planet Earth are also increasing. But climate changes do not disturb only nature; they also affect businesses and their supply chains. Many companies have recently recognised the positive impacts of green and circular supply chain management practices. Supply chains that deliver products from around the world are increasingly exposed to the impacts of a changing climate and scarce resources. In this research, it was determined how climate change impacts supply chains in the food, automobile, and energy industry sectors. Furthermore, we wanted to find out if and how the management of supply chains is altered to adapt to the business environment which is more and more affected by environmental changes.**

Keywords **- climate change adaptation and mittigation, circular economy, sustainable developement, supply chain management**

I. INTRODUCTION

As world economy is growing and globalisation is on the rise, climate change and its effects on the planet Earth are also increasing. But climate changes do not disturb only the nature; they also affect businesses and their supply chains (SC), spread all over the world. In 2012 emissions grew for 2.5% and in 2013 concentrations of carbon dioxide (CO_2) had already reached values high above "safe limit", also The Intergovernmental Panel on Climate Change (IPCC) had recently reported on rising of the estimated anthropogenic global waring for approximately 1.0°C (±0.2°C) since the pre-industrial levels. They are also predicting even bigger warming rate which is supposed to reach 1.5°C between 2030 and 2052 (Wijesiri, Liu & Goonetilleke, 2020). Schor (2014) said some moderate emission reductions have been made but were too minor to balance out enormous increases in other countries, such as India or China. Many companies has recently recognize the positive impacts of green supply chain management, yet relatively little research has been conducted in the field of linkages between climate changes and changes in supply chain circularity (Chiou, Chan, Lettice & Chung, 2011). However, Lim-Camacho et al. (2017) proved, that supply chains that deliver products from around the world are increasingly exposed to the impacts of a changing climate. According to authors Lim-Camacho et al. (2017), risk management should be implemented into the context of supply chain adaptation to climate change. They also claim in their study that climate change presents risk as well as opportunities for circular use of resources through rising of the reconfiguration of global SC design.

In this research, we wanted to find out how climate change and supply chains interact iwth one another in different economy sectors. Focus was on food, automobile, and energetics industries. Furthermore, we wanted to discover how management of SC is altered in order to adapt to business environment which is more and more affected by environmental changes while we were also curious how activities throughout SC affect environmental changes.

II. METHODS

Due to the nature of our study, our work was more theoretically focused. We wanted to include three as diverse areas as possible into our study, but still staying within the lines of everyday lives of people. To identify the topics to be addressed, we executed a short brainstorming session, during which we tried to list as many different areas as possible to choose from for our research. After the reflection was completed, we selected three sectors to suit our wishes and requirements, while being broad enough to enable us finding

Article History: Received September 2023; Revised October 2023; Accepted October 2023

studies that have already been carried out in that field. The final selection thus consisted of the food, automotive and energy sectors.

As mentioned before, we got acquainted with the topic of climate change and supply chain management before we began, by looking for appropriate literature and studies that were more general and focused mainly on the relationship between climate change and adjustments in supply chain management (SCM). We used two online databases for this – Scopus and Science Direct.

A general overview of the researched field was followed by a more detailed browsing through databases and finding suitable articles. At this stage of our work, we focused on finding studies surveying the impact of climate change on the SCM in the food, automotive and energy sector. We entered keywords in the search engine of the online databases, which provided us with a selection of articles that researched the mentioned topic in any aspect. We executed our search by adding more and more keywords to our search terms, which enabled us to narrow our search area. We ended the search after we had a handful of potentially interesting articles. The search for useful content was followed by a review of the texts found to ensure that the topics of the articles were relevant and that studies contained information that was relevant to us. After careful review and elimination of inappropriate articles, we were left documents that we have read and worked with. The main findings of the authors were noted promptly, and any similarities, differences, or other information that we considered relevant was logged. In Table 1, there are used key words presented for each studied sector. The number of potentially engaging articles and the actual number of altered articles for our research is also presented in this table.

Table 1: Key words and number of articles used in the process of creating a review

Sector type	Keywords used for searching the literature	Number of potentially interesting articles	Number of articles actually used
Food sector	climate change, food supply chain, food sector, green food production	18	6
Automotive sector	climate change, supply chain, automotive sector, car industry	25	11
Energy sector	climate change, supply chain, management, impact, energy, energy sector	32	20

III. RESULTS

In the following subchapters, an effect of climate change on each sector (food, automotive and energetics) will be described and a short literature review will be written.

A. Food sector

Supply chains in food sector are complex networks. They include lots of different activities, which are related to transferring the food from farms to the plate of customers. One part of these activities includes food production, food processing, distribution of food and sales. If at least one of these activities is affected, then all of them will be, because of the nature and vulnerability of the food supply chain (FSC) through which perishable goods are transit. Other part of activities determines where and when food reaches the customers, also consumption and finally food disposal are included in FSC. (Gomes, Pinto-Varela & Barbosa-Povoa, 2016)

Climate change has enormous impact on the food supply chain, but it is important to emphasize that environment is also affected by it. In other words, food sector further contributes to overall climate change. (Paeajuli, Thoma & Matlock, 2019)

FSC is fighting numerous climate changes which cause several responses of the environment. One of them are global warming and temperature rising which can cause not only forest and field fires, heat stress, massive rainfalls or sudden leap from drought to flood (Paeajuli et al., 2019), but can also affect growth rate of animals and plants, the quality of produced food and the density of deaths or illnesses outbreak. (Liverpool-Tasie, Pummel, Tambo, Schmitt Olabisi & Osuntade, 2020)

Animal and plant waterborne illnesses are second response of environment on climate change that mark FSC. A major influence on the development of these diseases have high rainfalls, floods, temperature rising, humidity and wind carrying the droplets. (Jacxsens, Luning, van der Vorst, Devlieghere, Leemans & Uyttendaele, 2010)

Next environmental response is caused by using chemical pesticides and inorganic fertilizers in phase of food production. It has negative impact on ambiance in general by affecting global warming and also human health. (Sazvar, Rahmani & Govindan, 2018)

Furthermore, the FSC contributes to greenhouse gasses (GHG) emissions. One of the major reasons for GHG formation in FSC are livestock production, industrialization, manure handling, use of fertilizers, food processing, biomass burning and transportation of food. (Liverpool-Tasie et al., 2020)

Liverpool-Tasie et al. (2020) also discovered that economic activity of FSC can add negative impact on climate change. There are many direct and indirect activities affecting climate change because of encouraging economic growth in food sector. One of them is increased food production and/or transportation which cause emissions of GHG and air pollution.

Climate change has enormous impact on food supply chain. In their study Franzo, Davis, McLaren and Choufani (2018) talk about how climate change affect FSC. If one of FSC steps is affected, the whole FSC will be distressed. But it is important to emphasize that each step of FSC is vulnerable and is constantly dependant on climate. If is it too cold the plants will not grow or if the environment is too dry the animals can suffer from dehydration. All the negative climate change impacts can have a harmful effect on quality of food which is bad for the whole FSC. (Franzo et al., 2018) The following Table (Table 2) shows a summary of the above-mentioned findings.

Table 2: A summary of the main findings on the impact of climate change on the food sector

Study	Focus of the study	Impact on the environment	Impact on the SC	Impact on production/growth
Gomes, Pinto-Varela & Barbosa-Povoa (2016)	The nature and vulnerability of FSC	Food production, processing and distribution have a negative impact on the environment	If one activity in FSC is affected, then all of them will be	Poor production and quality of food, less possibilities of providing food
Paeajuli, Thoma & Matlock (2019)	Consequences of GW, such as fires, heat, massive rainfalls, or drought	Rising of temperatures, fires, heat stress, massive rainfalls, drought, or floods	CC impact FSC and vice versa	When CC worsen, production and growth deteriorate
Liverpool-Tasie, Pummel, Tambo, Schmitt Olabisi & Osuntade (2020)	Effect of CC on growth rate, quality of products and illnesses outbreaks	Illnesses outbreaks, death of animals, bad quality of crops, contribution to GHGs	Affecting growth rate, encouraging of economic growth	Poor production and quality of food
Jacxsens, Luning, van der Vorst, Devlieghere, Leemans & Uyttendaele (2010)	Consequences of CC, such as diseases, rainfalls, floods, winds, temperature rising	Animal and plant ilnesses development	Worsening of growth rate, dying of farm animals	Poor production and quality of food

Sazvar, Rahmani & Govindan (2018)	Negative impact of chemical pesticides and inorganic fertilizers	Negative impact on ambiance, affecting human health	Augmentation in use of chemicals at the stage of food production	Better growth of crops, increased food production
Franzo, Davis, McLaren and Choufani (2018)	The effect of CC overall FSC	Bad harvest if temperatures are too low, dehydration of animals in case of extreme heat, bad quality of food	If one step of FSC is affected, the whole SC will be distressed	Lower food production, bad quality of food

B. Automotive sector

The whole automotive industry and all the activities related to car production, distribution and usage have major impact on climate change and are ranked as first CO_2 pollutant. De Stefano, Montes-Sancho & Busch (2016) state that »emissions occur at nearly every stage of a vehicle's life cycle« and efforts to reduce emissions from processes have been made. Still, the use of automobiles accounts for approximately 80% of the total energy consumption through the life cycle of an automobile, authors say. Therefore, SCs of automotive industry must become more sustainable in order to prevent the negative environmental influences. Only strong and stable SC will be able to introduce new technology that is sustainable and more environmentally friendly. (Sovacool & Axsen, 2018)

One way of making the automotive sector greener and reduce global warming effects from this sector's activities is deployment of low carbon technologies, such as electric vehicles (EV). But in their study, Ballinger, Schmeda-Lopez, Kefford, Parkinson, Stringer, Greig & Smart (2020) expose vulnerability of electric-vehicle SCs which stems from significant quantities of rare earth elements required for manufacturing critical components in many low carbon energy technologies. Namely, the supply of before-mentioned rare earth elements have been unstable over the last decade, authors add. Nevertheless, Canada is one of the first countries who recognized the possibility of underpinning new low-carbon technologies (such as EV) with hydroelectricity, as current Canadian economic policy's goal is »maximizing inudstrial linkages from natural resources, such as waterpower«. (Haley, 2015)

The supply chain of automotive sector has been widely known for trying out new types of biofuels to decrease potential impacts on the environment but also because of social and economic interests. Biofuels have lesser impact on climate change in the phase of production as well as while being used or burned in the car engine. The exploitation of biofuels should decrease air pollution, noise pollution, GHG and other emissions while also minimize other negative impacts on the environment. (Li, Kesharwani, Sun, Qin, Dagli, Zhang & Wang, 2019) Rivera & Reyes-Carillo (2014) also expose the most energy intensive process within the automobile manufacturing stages – the painting process. Not only a lot of energy is consumed in this process, but also many chemicals are used. The authors therefore presented a collaborative project which »seeks to establish an integrated and strategic approach to improve the overall performance of the painting shops«.

Some authors further discuss which activities in SCs can make automotive sector greener. Simpson, Power and Samson (2014) state that some of these activities might be getting penalties for not being green enough, using of products or production process that are not sustainable, also consumer backlash and other is possible in that case. The automotive supply chains which use more sustainable products and have greener productions are considered to have higher environmental performance standards, have skillful supply chain management and being better with responding to customers' sustainable requirements. Some authors are focusing on introducing closed loops into the SCs of the automotive industry. The centre of Chavez & Sharma's (2018) study for example was recycling products, based on thermoplastic polymer materials, such as nylon or polyethylene terephthalate (PET), which are widely used in Mexican automotive industry.

As mentioned earlier, automobile industry must become greener in the production section as well as in the segment of vehicle usage. Many authors state that numerous industries are becoming more sustainable and efficient with reducing water and energy consumption which are becoming considered as rare sources, and it is important how we manage them. (Babel, Oo, Shinde, Kamalamma & Haarstick, 2019) China is even

an example of a country, where economic development policies do not follow the changes in the market. In their study He, Zhou & Liu (2017) present the effort and trouble of China to unify economic and environmental benefits by fully considering environmentally friendly policies in the economic development policy making. As the authors state, in China current market share of the new energy vehicles stands at only 0.4%, while worldwide percentage is much higher and totals at 3%. Similarly, India has some challenges in the field of waste management practices as there is no real regulations for this segment of the industry. Nevertheless, Kulkarni, Rao & Patil (2014) found out that even though Indian automobile manufacturing is responsible for creating 42.6% of hazardous waste, they are trying to adapt to global waste management trends and are focusing on sustainable principles such as reduce, reuse and recycle.

Sovacool & Axsen (2018) entitle people's behavior as irresponsible for owning and/or using a vehicle individually instead of practicing shared mobility. This causes congestions which make people dissatisfied, noise pollution, GHG, air pollution etc. are also common. The authors also mention that people are increasingly searching for more sustainable transportations but are not ready to share their cars with others.

To summarize, automotive sector has to start with making the entire SCs more sustainable, while also focus on production of more environmentally friendly vehicles and use alternative fuels as biofuels, electricity, etc.

Table 3: A summary of the main findings on the impact of climate change on the automotive sector

Study	Focus of the study	Impact on the environment	Impact on the SC	Impact on production/growth
De Stefano, Montes-Sancho & Busch (2016)	Emissions caused by automotive industry	CO_2 pollution	The occurrence of emissions at all stages of the vehicle life cycle	The need to become more sustainable
Sovacool & Axsen (2018)	Becoming sustainable to prevent bad impact on climate changes	Worsening of the CC	Strong and stable SC will survive	Introducing new technology
Ballinger, Schmeda-Lopez, Kefford, Parkinson, Stringer, Greig & Smart (2020)	Vulnerability of electric-vehicle SCs	Unstable supply of rare earth elements	Vulnerable electric-vehicle SC	Deployment of low carbon technologies
Haley (2015)	The possibility of underpinning new low-carbon technologies (such as EV)	»Maximizing industrial linkages from natural resources, such as waterpower«	Usage of renewable resources	Greener production
Li, Kesharwani, Sun, Qin, Dagli, Zhang & Wang (2019)	New types of biofuels	Reduce of air pollution, noise pollution, GHG and other emissions	Trying out new types of biofuel	Impact on social and economic interests, greener production phase
Rivera & Reyes-Carillo (2014)	The painting process - the most energy intensive process within the automobile manufacturing stages	Negative impact on climate	Exploiting an integrated and strategic approach for greener performance through whole SC	A lot of energy is consumed, and many chemicals are used
Simpson, Power and Samson (2014)	Activities which makes SCs greener	Good effect on environment	Becoming more sustainable and having higher environmental performance standards	Getting penalties for not having enough green production
Chavez & Sharma (2018)	Recycling products	Less waste finish in the environment	Change in SC	Being more sustainable

Babel, Oo, Shinde, Kamalamma & Haarstick (2019)	Becoming greener in whole automobile industry	Reducing usage of water in energy consumption in vehicle production	Importance of energy and water management	Becoming more sustainable and efficient
He, Zhou & Liu (2017)	China and India having troubles with becoming sustainable	China has trouble to unify environmental benefits by fully considering environmentally friendly policies, India has troubles with waste	Current market share of sustainable vehicles is bad	Environment unfriendly production
Kulkarni, Rao & Patil (2014)	Irresponsible people behaviour	Congestions, air pollution, noise pollution, GHG	SCs cannot introduce sharing economy	It effects production of sustainable vehicles

C. Energetics sector

Climate change and energy production are simultaneously affecting one another. To mitigate the impact of the energy sector and its SCs on the environment, some authors have begun to explore the potential shown by alternative and renewable energy sources. One of those sources is biomass and according to De Meyer, Cattrysse, Rasinmäki & Van Orshoven (2014) bioenergy is expected to play a dominant role in the transition to alternative fuels and reduction of society's dependency on fossil fuels. But even though biomass is one of the main sources for bioenergy production and is as such perceived as environmentally friendly, climate changes have a negative effect on the sector of bioenergy production which is kind of contradictory. As De Meyer et al. (2014) and Sharma, Ingalls, Jones & Khanchi (2013) state, few of the negative consequences of climate change on biomass production is its discontinuous availability, connection to the condition of the environment, such as weather and seasonal uncertainty, geographical distribution or low bulk density of biomass feedstocks. They also acknowledged some solutions such as optimization of utilization of biomass and its residue.

Similar findings have been presented by Klein, Wolf, Schulz & Weber-Blaschke (2016), who stated that even though wood biomass is considered as renewable source, providing of wood and its conversion processes demand some non-renewable inputs which, again, have contradictory effect on climate change mitigation by changing to energy from biomass. Authors also state that raw wood therefore should not be declared as “climate neutral” and at the same time sustainable forest management should be established. Furthermore, Klein et al. (2016) recommend implementation of environmental impact calculations throughout the whole wood production chain to mitigate environmental impacts and thus improve the profitability of wood biomass industry. Szarka, Len & Thrän (2019) emphasized the influence countries have on the future provision of exploiting biomass for heat by implementing and accepting different climate policy goals, like Energy Saving Ordinance (EnEV), the Renewable Energy Heat Act, the Heat and Power Cogeneration Act, etc. They also mention new possible technology concepts which could be implemented in wood biomass SCs to cut back emissions, while also strive towards smart use of bioenergy.

As stated before, demands for biomass can only be fulfilled, if wood is available in sufficient quantities. Präger, Paczkowski, Sailer, Derkyi & Pelz (2019) stated in their study that total removal of off-cuts after the timber processes is bad for the soil and forests renewal as they present an important nutrition and fertilizer source for forest soil. The authors also state that negative environmental effects such as deforestation, global warming, smog, eutrophication, etc. can be reduced by minimizing the wood waste through modern and efficient biomass conversion systems or even by using kitchen waste as a source of energy. Potential of wood waste was also recognized by Raychaudhuri & Ghosh (2016) who said that to mitigate the effect of residue, a mature industry chain is necessary. Olofsson & Börjesson (2018) agree on the idea of circular bio-based economy and reusing biomass waste. Mafakheri & Nasiri (2014) emphasized the importance of relying on a local biomass supply as long-distance transport by trucks can lead to the fact that raw wood does not necessarily have only positive effects on climate change. Local biomass does not necessarily have to come from native forests, but can be harvested from cultivated groves, say Simioni, Buschinelli, Moreira, dos Passos, Sandy Bernardi & Girotto (2018). In their article, Ng & Maravelias (2017) introduced the concept of regional biomass processing depot where biomass is pre-treated into stable and dense intermediate which

is more durable and has reduced volume what eases the transportation and indirectly diminishes bad environmental impacts.

Arévalo, Quispe & Raymundo (2017) have gone into even greater detail and researched a sustainable bioenergy model based on briquettes, made from agricultural waste. This kind of biomass SC adjustment could increase efficiency in some domestic sectors, potentially replace firewood and give an opportunity for cleaner energy. In her article Lewandowski (2015) represents envisioned "ideal" bio economy where, amongst other, biomass production takes ecological aspects in consideration. She stated that the realization of sustainable biomass production depends on greatly defined meaning of what is considered "sustainable". In words of Lewandowski (2015), the next big challenge in the field of biomass energy production is to achieve optimal combination of ensuring quality and environmentally beneficial biomass production.

Some authors have already discussed usage of agricultural and other waste as the energy source since waste poses an increasing challenge to people and environment. Aracil, Haro, Giuntoli & Ollero (2017) did a similar thing in their study as they researched the production of biofuels from municipal solid waste (MSW). Non-recyclable MSW represents over half of the total MSW and has a great potential for energy production. Authors also stated that mitigation of climate change in Europe could be achieved by production of biofuels from MSW. Zabaniotou (2018) was thinking similarly when he conducted his research on redesigning a bioenergy sector in the EU. He believes that bioenergy can incorporate agricultural traditions and offer waste management solutions. Waste-to-energy technologies were also considered as an option in a study, conducted by Menikpura, Sang-Arun & Bengtsson (2016). In Asia, most cities practice open dumping which is a method, proven to have adverse impacts on climate change and environment. Energy recovery from waste could therefore pose a solution for greenhouse gas mitigation and minimizing the need for long-distance transportation of waste.

As many authors before, Mastrocinque, Javier Ramírez, Honrubia-Escribano & Pham (2020) stated the use of fossil fuels is one of the main reasons for global warming and also one of the main reason for many efforts to promote renewable energy have been made in the last decade. Their work focused on modelling a sustainable supply chain in the renewable energy sector, more precisely, in the photovoltaic energy sector.

As many times mentioned, greenhouse gasses are the primary reason for global warming. In China, which is world's biggest polluter, the biggest problems are caused by CO_2 emissions as China burns immense quantities of coal to meet the needs of surging electrification, say Cao, Zhao, Wen, Li, Ii, Wang, Liu, Shi & Weng (2019). The solution for decarbonisation in China is hidden in using and managing the entire supply chain and life cycle of "green" coal. This means that CO_2 emissions mitigation is made in four subsystems of "electric-coal" supply chain, including production, transportation, storage, and consumption subsystem.

Coal has been dealt with by World Bank also, who launched its Climate-Smart Mining (CSM) Facility in May 2019, as stated by Phadke (2019). They wanted to "explore and analyse the implications of the rapid uptake of climate-friendly technologies for commodity demand and the mineral resources required to manufacture these new technologies". According to World Bank (2016) CSM is »a method of low-carbon extraction that develops sustainable and green value chains while respecting communities, ecosystems and the environment.«

Vance, Heckl, Bertok, Cabezas & Friedler (2015) made a P-graph framework in their study which showed that alternatives throughout supply chains can be found, heat and electricity could be supplied by using renewable feedstock and that structures with far lesser impact on the environment than structures currently used exist. Authors also say that opportunities to improve environmental performance are out there, but they are dependent on market conditions for electricity.

Table 4: A summary of the main findings on the impact of climate change on the eneregetics sector

Study	Focus of the study	Impact on the environment	Impact on the SC	Impact on production/business growth
De Meyer, Cattrysse, Rasinmäki & Van Orshoven (2014)	Exploiting of biomass as an alternative energy source	Becoming more environmentally friendly	Discontinuous availability, connection to the condition of the environment, low bulk	Optimization of biomass and residue utilization in SCs

			density of biomass feedstocks	
Sharma, Ingalls, Jones & Khanchi (2013)	Exploiting of biomass as an alternative energy source	Becoming more environmentally friendly	Discontinuous availability, connection to the condition of the environment, low bulk density of biomass feedstocks	Optimization of biomass and residue utilization in SCs
Klein, Wolf, Schulz & Weber-Blaschke (2016)	Exploiting of biomass as an alternative energy source	More environmentally friendly, but demand for some non-renewable inputs	Demand for non-renewable inputs has contradictory effect on CC mitigation	The need for sustainable forest management, implementation of environmental impact calculations throughout the whole SC, improvement in profitability
Szarka, Len & Thrän (2019)	The influence of countries on exploiting biomass by accepting climate policy goals	Mitigation of CC and GW by cutting back emissions	Changes in SC because of implementation of climate policy goals	mplementation of new technology concepts and use of bioenergy
Präger, Paczkowski, Sailer, Derkyi & Pelz (2019)	Prompting of forests renewal by not removing off-cuts after the timber processes	Better forest renewal, fertilizing the forest soil	Enabling the fulfilment of biomass demand	Easily and quickly fulfilled demands for biomass
Raychaudhuri & Ghosh (2016)	Diminishing the effect of wood residue	Mitigation of environmental impact by reusing biomass waste	The need for a mature industry chain	Enforcing bio-based circular economy
Olofsson & Börjesson (2018)	Reusing biomass waste	Mitigation of environmental impact by reusing biomass waste	The need for a mature industry chain	Enforcing bio-based circular economy
Mafakheri & Nasiri (2014)	The importance of a local biomass supply	Long-distance transport of wood has negative impacts on the environment	The need for changing the supplier and transportation routes	New business opportunities (cultivated groves), supporting local businesses
Simioni, Buschinelli, Moreira, dos Passos, Sandy Bernardi & Girotto (2018)	Harvesting biomass from local cultivated groves	Less CC impacts that stem from long-distance transportation	Less need for long-distance transportation	New business opportunities (cultivated groves), supporting local businesses
Ng & Maravelias (2017)	Introduction of new concept of regional biomass processing depot	Indirect diminishing of bad environmental impacts	New processes in the SC (pre-treating biomass into stable and dense intermediate),	More durable materials with reduced volumes, eased transportation
Arévalo, Quispe & Raymundo (2017)	Research on a sustainable bioenergy model based on briquettes, made from agricultural waste	Opportunity for cleaner energy	Integration of domestic sectors into the SC	Increased efficiency, new business opportunities for domestic sectors, production of cleaner energy
Lewandowski (2015)	"Ideal" bio economy, where ecological aspects are taken into consideration	Becoming more environmentally friendly	The need for greatly defined meaning of what is "sustainable" in the whole SC	The challenge of achieving optimal combination of ensuring quality and environmentally beneficial biomass production

Aracil, Haro, Giuntoli & Ollero (2017)	Production of biofuels from municipal solid waste	Mitigation of climate change in Europe	The need for changes in SC in order to include usage of non-recyclable municipal solid waste	A lot of available energy-source materials
Zabaniotou (2018)	Incorporating agricultural traditions and waste management solutions into bioenergy	Mitigation of waste-related challenges, opportunity for cleaner energy	The need for redesigning a bioenergy sector in the EU	Combining two different sectors into one SC, while they mitigate bad effects of each other
Menikpura, Sang-Arun & Bengtsson (2016)	Waste-to-energy technologies	Open dumping is proven to have adverse impacts on CC and environment, greenhouse gas mitigation	Introducing processes of energy recovery from waste	Minimizing the need for long-distance transportation of waste
Mastrocinque, Javier Ramírez, Honrubia-Escribano & Pham (2020)	Modelling a sustainable SC in the renewable energy sector	Use of fossil fuels is one of the main reasons for global warming	Redesigning the photovoltaic energy sector	Producing energy from sun
Cao, Zhao, Wen, Li, Ii, Wang, Liu, Shi & Weng (2019)	Solutions for decarbonisation in China	Greenhouse gasses are the primary reason for global warming, CO_2 emissions from coal burning	The need for entire SC and life cycle of coal to become "green coal"	CO_2 emissions mitigation in four subsystems of "electric-coal" SC – production, transportation, storage, consumption
Phadke (2019)	Exploring and analysing the implications of the rapid uptake of climate-friendly technologies	Extraction of coal burdens the environment	Launch of Climate-Smart Mining (CSM) Facility	Developing sustainable and green value chains while respecting communities, ecosystems and the environment
World Bank (2016)	Exploring and analysing the implications of the rapid uptake of climate-friendly technologies	Extraction of coal burdens the environment	Launch of Climate-Smart Mining (CSM) Facility	Developing sustainable and green value chains while respecting communities, ecosystems and the environment
Vance, Heckl, Bertok, Cabezas & Friedler (2015)	Making of a P-graph framework which showed alternatives throughout supply chains	Structures with far lesser impact on the environment exist than structures currently used	Finding alternatives for heat and electricity throughout supply chains	Defining opportunities to improve environmental performance

IV. DISCUSSION

In this paper impact of climate change on different sector supply chains are examined and their adaptation strategies are identified. It was found out that the food sector has most vulnerable SC, because if one step of food SC is affected the whole SC is compromised. In food SC there are many negative effects of climate change that affect food production (e.g. droughts, frost, temperature rising,). Climate change can affect animals and plants with different diseases which are carried by water or air and this can also have negative impact on consumers if not discovered on time. Food sector is one of biggest producer of greenhouse gasses and as such causes climate change which later adversely affect the food supply chain.

Along with food sector as one of the biggest GHG producers in general, automotive industry is perceived as first biggest CO_2 polluter. The contamination of nature is caused throughout the whole SC – including

production, distribution, and car use. The biggest challenge of automotive sector therefore represents a total redesigning of the SCs. Some changes in perspective have already been achieved as some proposals for the use of biofuels had been made, increased recycling rates are implemented etc. Automotive sector is also greatly dependant on customers which should request more sustainable transport modes and technologies but is already more circular than the rest.

Energetics sector, similarly, as automotive one, has an impact on the environment throughout the entire SC. Energy industry itself is the biggest produces of GHG and in the EU also challenging because of lacking fossil fuel supply. Climate change can also affect continuous availability, bulk density, or geographical distribution of e.g. bioenergy sources. This leads us to one of the suggested solutions of optimizing the utilization of biomass and its residue while also focus on sustainable supply chain management in energy sector (production and distribution especially). Energy related SC are also greatly afflicted by different climate policy goals which suggest new cleaner technologies and can therefore impact on energy supply network flexibility. Waste-to-energy technologies have been debated and considered as an potential for improving sustainability of energy supply network as wel.

As it can be seen from this review that SC in all sectors need a shift towards sustainability and circularity since circular use of resources enables reuse and recycling of existing materials. Especially the EU, which is very import dependent, can become more resilient by lovering its import dependency by more efficient (re)use of resources already imported in the past and currently considered as waste. This paper had just begun to uncover the numerous questions concerning the mitigation and adaptation on climate change consequences. In future research, focus should be directed also towards sollutions that allow innovative improvements like de-growth strategies. Even though it might be out of scope of current global economic orientation it might be the only strategy towards sustainable future and as seen through the review, all the studies are related to production/business growth and creation of added value without considering de-growth even as a distant possibility.

ACKNOWLEDGMENTS

Matevz Obrecht and Marijana Pecarevic received funding for research cooperation between Slovenia and Croatia from Slovenian Research and Innovation Agency (ARIS): Circular Economy for Sustainable and Resilient Supply Chains, proj. no. BI-HR/23-24-042.

REFERENCES

Aracil, C., Haro, P., Giuntoli, J. & Ollero, P. (2017). Proving the climate benefit in the production of biofuels from municipal solid waste refuse in Europe. *Journal of Cleaner Production*, 142 (4), pp. 2887-2900, doi: 10.1016/j.jclepro.2016.10.181.

Arévalo, J., Quispe, G. & Raymundo, C. (2017). Sustainable Energy Model for the production of biomass briquettes based on rice husk in low-income agricultural areas in Peru. *Energy Procedia*, 141, pp. 138-145, doi: 10.1016/j.egypro.2017.11.026.

Azevedo, S. G., Carvalho, H. & Cruz Machado, V. (2011). The influence of green practices on supply chain performance: A case study approach. *Transportation Research Part E: Logistics and Transportation Review*, 47 (6), pp. 850-871, doi: 10.1016/j.tre.2011.05.017.

Babel, M. S., Oo, E., Shinde, V. R., Kamalamma, A. G. & Haarstrick, A. (2020). Comparative study of water and energy use in selected automobile manufacturing industries. *Journal of Cleaner Production*, 246, doi: 10.1016/j.jclepro.2019.118970.

Ballinger, B., Schmeda-Lopez, D., Kefford, B., Parkinson, B., Stringer, M., Greig, C. & Smart, S. (2020). The vulnerability of electric-vehicle and wind-turbine supply chains to the supply of rare-earth elements in a 2-degree scenario. *Sustainable Production and Consumption*, 22, pp. 68-76, doi: 10.1016/j.spc.2020.02.005.

Cagliano, R., Worley, C. & Caniato, F. (2016). The Challenge of Sustainable Innovation in Agri-Food Supply Chains. *Organizing Supply Chain Processes for Sustainable Innovation in the Agri-Food Industry (Organizing for Sustainable Effectiveness)*, *Emerald Group Publishing Limited*, 5, pp. 1-30, doi: 10.1108/S2045-060520160000005009.

Cao, Y., Zhao, Y., Wen, L., Li, Y., li, H., Wang, S., Liu, Y., Shi, Q. & Weng, J. (2019). System dynamics simulation for CO2 emission mitigation in green electric-coal supply chain. *Journal of Cleaner Production*, 232, pp. 759-773, doi: 10.1016/j.jclepro.2019.06.029.

Chavez, R. & Sharma, M. (2018). Profitability and environmental friendliness of a closed-loop supply chain for PET components: A case study of the Mexican automobile market. *Resources, Conservation and Recycling*, 135, pp. 172-189, doi: 10.1016/j.resconrec.2017.10.038.

Chiou, T.-Y., Chan, H. K., Lettice, F. & Chung, S. H. (2011). The influence of greening the suppliers and green innovation on environmental performance and competitive advantage in Taiwan. *Transportation Research Part E: Logistics and Transportation Review*, 47 (6), pp. 822-836, doi: 10.1016/j.tre.2011.05.016.

Cristina De Stefano, M., Montes-Sancho, M. J. & Busch, T. (2016). A natural resource-based view of climate change: Innovation challenges in the automobile industry. *Journal of Cleaner Production*, 139, pp. 1436-1448, doi: 10.1016/j.jclepro.2016.08.023.

De Meyer, A., Cattrysse, D., Rasinmäki, D. & Van Orshoven, J. (2014). Methods to optimise the design and management of biomass-for-bioenergy supply chains: A review. *Renewable and Sustainable Energy Reviews*, 31, pp. 657-670, doi: 10.1016/j.rser.2013.12.036.

Edgeman, R. & Wu, Z. (2016). Supply chain criticality in sustainable and resilient enterprises. *Journal of Modelling in Management*, 11 (4), pp. 869-888, doi: 10.1108/JM2-10-2014-0078.

Fleming, A. Hobday, A. J., Farmery, A., van Putten, E. I., Pecl, G. T., Green, B. S. & Lim-Camacho, L. (2014). Climate change risks and adaptation options across Australian seafood supply chains – A preliminary assessment. *Climate Risk Management*, 1, pp. 39-50, doi: 10.1016/j.crm.2013.12.003.

Gomes, A. C., Pinto-Varela, T. &Barbosa-Póvoa, A. P. (2016). Multimodal Green Food Supply Chain Design and Planning under Uncertainty. *Computer Aided Chemical Engineering*, 38, str. 181-186, doi: 10.1016/B978-0-444-63428-3.50035-7.

Gruda, N., Bisbis, M. & Tanny, J. (2019). Impacts of protected vegetable cultivation on climate change and adaptation strategies for cleaner production – A review. *Journal of Cleaner Production*, 225, pp. 324-339, doi: 10.1016/j.jclepro.2019.03.295.

Haley, B. (2015). Low-carbon innovation from a hydroelectric base: The case of electric vehicles in Québec. *Environmental Innovation and Societal Transitions*, 14, pp. 5-25, doi: 10.1016/j.eist.2014.05.003.

Halldórsson, Á., Kovács, G., Halldórsson, Á. & Kovács, G. (2010). The sustainable agenda and energy efficiency: Logistics solutions and supply chains in times of climate change. *International Journal of Physical Distribution & Logistics Management*, 40 (1/2), pp. 5-13, doi: 10.1108/09600031011018019.

He, M., Zhou, J. & Liu, L. (2017). A study of supporting legal policies for improving China's new energy automobile industry based on environmental benefits equilibrium-enlightenment from the environmental subsidies of Germany legal system. *International Journal of Hydrogen Energy*, 42 (29), pp. 18699-18708, doi: 10.1016/j.ijhydene.2017.04.184.

Ivascu, L., Mocan, M., Draghici, A., Turi, A. & Rus, S. (2015). Modeling the Green Supply Chain in the Context of Sustainable Development. *Procedia Economics and Finance*, 26, pp. 702-708, doi: 10.1016/S2212-5671(15)00819-9.

Jacxsesns, L., Luning, P. A., van der Vorst, J. G. A. J., Devlieghere, F., Leemans, R. & Uyttendaele, M. (2010). Simulation modelling and risk assessment as tools to identify the impact of climate change on microbiological food safety – The case study of fresh produce supply chain. *Food Research International*, 43 (7), pp. 1925-1935, doi: 10.1016/j.foodres.2009.07.009.

Jawad, H., Jaber, M. Y. & Nuwayhid, R. Y. (2018). Improving supply chain sustainability using exergy analysis. *European Journal of Operational Research*, 269 (1), pp. 258-271, doi: 10.1016/j.ejor.2017.10.007.

Jawid, A. (2020). A Ricardian analysis of the economic impact of climate change on agriculture: Evidence from the farms in the central highlands of Afghanistan. *Journal of Asian Economics*, doi: 10.1016/j.asieco.2020.101177.

Kanger, L., Geels, F. W., Sovacool, B. & Schot, J. (2019). Technological diffusion as a process of societal embedding: Lessons from historical automobile transitions for future electric mobility. *Transportation Research Part D: Transport and Environment*, 71, pp. 47-66, doi: 10.1016/j.trd.2018.11.012.

Kayikci, Y., Ozbiltekin, M. & Kazancoglu, Y. (2019). Minimizing losses at red meat supply chain with circular and central slaughterhouse model. *Journal of Enterprise Information Management*, doi: 10.1108/JEIM-01-2019-0025.

Klein, D., Wolf, C., Schulz, C. & Weber-Blaschke, G. (2016). Environmental impacts of various biomass supply chains for the provision of raw wood in Bavaria, Germany, with focus on climate change. *Science of The Total Environment*, 539, pp. 45-60, doi: 10.1016/j.scitotenv.2015.08.087.

Kulkarni, S., Rao, P. & Patil, Y. (2014). Are the Non-renewable Resource Utilization and Waste Management Practices Employed in Indian Automobile Sector Sustainable?. *Procedia - Social and Behavioral Sciences*, 133, pp. 364-371, doi: 10.1016/j.sbspro.2014.04.202.

Lewandowski, I. (2015). Securing a sustainable biomass supply in a growing bioeconomy. *Global Food Security*, 6, pp. 34-42, doi: 10.1016/j.gfs.2015.10.001.

Li, Y., Kesharwani, R., Sun, Z., Qin, R., Dagli, C., Zhang, M. & Wang, D. (2020). Economic viability and environmental impact investigation for the biofuel supply chain using co-fermentation technology. *Applied Energy*, 259, doi: 10.1016/j.apenergy.2019.114235.

Lim-Camacho, L., Plagányi, E. E., Crimp, S., Hodkinson, J. H., Hobday, A. J., Howden, S. M. & Loechel, B. (2017). Complex resource supply chains display higher resilience to simulated climate shocks. *Global Environmental change*, 46, pp. 126-138, doi: 10.1016/j.gloenvcha.2017.08.011.

Liverpool-Tasie, L. S. O., Pummel, H., Tambo, J. A., Schmitt Olabisi, L. & Osuntade, O. (2020). Perceptions and exposure to climate events along agricultural value chains: Evidence from Nigeria. *Journal of Environmental Management*, 264, doi: 10.1016/j.jenvman.2020.110430.

Lodorfos, G., Konstantopoulou, A., Kostopoulos, I. & Essien, E. (2018). Food and Drink Industry in Europe and Sustainability Issues. *The Sustainable Marketing Concept in European SMEs, Emerald Publishing Limited*, pp. 121-140, doi: 10.1108/978-1-78754-038-520180006.

Lytos, A., Lagkas, T., Sarigiannidis, P., Zervakis, M. & Livanos, G. (2020). Towards smart farming: Systems, frameworks and exploitation of multiple sources. *Computer Networks*, 172, doi: 10.1016/j.comnet.2020.107147.

Mafakheri, F. & NAsiri, F. (2014). Modeling of biomass-to-energy supply chain operations: Applications, challenges and research directions. *Energy Policy*, 67, pp. 116-126, doi: 10.1016/j.enpol.2013.11.071.

Mastrocinque, E., Javier Ramírez, F., Honrubia-Escribano, A. & Pham, D. T. (2020). An AHP-based multi-criteria model for sustainable supply chain development in the renewable energy sector. *Expert Systems with Applications*, 150, doi: 10.1016/j.eswa.2020.113321.

Meinel, U. & Abegg, B. (2017). A multi-level perspective on climate risks and drivers of entrepreneurial robustness – Findings from sectoral comparison in alpine Austria. *Global Environmental Change*, 44, pp. 68-82, doi: 10.1016/j.gloenvcha.2017.03.006.

Menikpura, S. N. M., Sang-Arun, J. & Bengtsson, M. (2016). Assessment of environmental and economic performance of Waste-to-Energy facilities in Thai cities. *Renewable Energy*, 86, pp. 576-584, doi: 10.1016/j.renene.2015.08.054.

Musgrave, J., Beer, S. & Lemmer, C. (2011). A critical review of "green" procurement: Life cycle analysis of food products within the supply chain. *Worldwide Hospitality and Tourism Themes*, 3 (3), pp. 229-244, doi: 10.1108/17554211111142194.

Ng, R. T. L. & Maravelias, C. T. (2017). Economic and energetic analysis of biofuel supply chains. *Applied Energy*, 205, pp. 1571-1582, doi: 10.1016/j.apenergy.2017.08.161.

Olofsson, J. & Börjesson, P. (2018). Residual biomass as resource – Life-cycle environmental impact of wastes in circular resource systems. *Journal of Cleaner Production*, 196, pp. 997-1006, doi: 10.1016/j.jclepro.2018.06.115.

Parajuli, R., Thoma, G. & Matlock, M. D. (2019). Environmental sustainability of fruit and vegetable production supply chains in the face of climate change: A review. *Science of The Total Environment*, 650 (2), pp. 2863-2879, doi: 10.1016/j.scitotenv.2018.10.019.

Payen, S., Falconer, S., Carlson, B., Yang, W. & Ledgard, S. (2020). Eutrophication and climate change impacts of a case study of New Zealand beef to the European market. *Science of The Total Environment*, 710, doi: 10.1016/j.scitotenv.2019.136120.

Phadke, R. (2019). Climate-smart mining: A conference report on the World Bank's facility launch. *The Extractive Industries and Society*, 6 (4), pp. 1373-1375, doi: 10.1016/j.exis.2019.10.004.

Pineda, R. (2016). Making the climate change issue "real" for managers. *Journal of Global Responsibility*, 7 (1), pp. 84-97, doi: 10.1108/JGR-12-2015-0022.

Pires, J. C. M. (2019). Negative emissions technologies: A complementary solution for climate change mitigation. *Science of The Total Environment*, 672, pp. 502-514, doi: 10.1016/j.scitotenv.2019.04.004.

Präger, F., Paczkowski, S., Sailer, G., Derkyi, N. S. A. & Pelz, S. (2019). Biomass sources for a sustainable energy supply in Ghana – A case study for Sunyani. *Renewable and Sustainable Energy Reviews*, 107, pp. 413-424, doi: 10.1016/j.rser.2019.03.016.

Raychaudhuri, A. & Ghosh, S. K. (2016). Biomass Supply Chain in Asian and European Countries. *Procedia Environmental Sciences*, 35, pp. 914-924, doi: 10.1016/j.proenv.2016.07.062.

Rivera, J. L. & Reyes-Carrillo, T. (2014). A Framework for Environmental and Energy Analysis of the Automobile Painting Process. *Procedia CIRP*, 15, pp. 171-175, doi: 10.1016/j.procir.2014.06.022.

Sazvar, Z., Rahmani, M. & Govindan, K. (2018). A sustainable supply chain for organic, conventional agro-food products: The role of demand substitution, climate change and public health. *Journal of Cleaner Production*, 194 (1), pp. 564-583, doi: 10.1016/j.jclepro.2018.04.118.

Schor, J. B. (2014). Climate discourse and economic downturns: The case of the United States, 2008–2013. *Environmental Innovation and Societal Transitions*, 13, pp. 6-20, doi: 10.1016/j.eist.2014.04.006.

Shankar Sankaran, P., Andreoni, V. & Miola, A. (2015). Climate change and supply-chain vulnerability: Methodologies for resilience and impacts quantification. *International Journal of Emergency Services*, 4 (1), pp. 6-26, doi: 10.1108/IJES-09-2014-0012.

Sharma, B., Ingalls, R. G., Jones, C. L. & Khanchi, A. (2013). Biomass supply chain design and analysis: Basis, overview, modeling, challenges, and future. *Renewable and Sustainable Energy Reviews*, 24, pp. 608-627, doi: 10.1016/j.rser.2013.03.049.

Shokri, A., Oglethorpe, D. & Nabhani, F. (2014). Evaluating sustainability in the UK fast food supply chain: Review of dimensions, awareness and practice. *Journal of Manufacturing Technology Management*, 25 (8), pp. 1224-1244, doi: 10.1108/JMTM-04-2013-0031.

Simioni, F. J., Buschinelli, C. C. de A., Moreira, J. M. M. A. P., dos Passos, Sandy Bernardi, B. M. & Girotto, F. T. (2018). Forest biomass chain of production: Challenges of small-scale forest production in southern Brazil. *Journal of Cleaner Production*, 174, pp. 889-898, doi: 10.1016/j.jclepro.2017.10.330.

Simpson, D., Power, D. & Samson, D. (2007). Greening the automotive supply chain: a relationship perspective. *International Journal of Operations & Production Management*, 27 (1), pp. 28-48, doi: 10.1108/01443570710714529.

Sovacool, B. K. & Axsen, J. (2018). Functional, symbolic and societal frames for automobility: Implications for sustainability transitions. *Transportation Research Part A: Policy and Practice*, 118, pp. 730-746, doi: 10.1016/j.tra.2018.10.008.

Szarka, N., Len, V. & Thrän, D. (2019). The crucial role of biomass-based heat in a climate-friendly Germany–A scenario analysis. *Energy*, 186, doi: 10.1016/j.energy.2019.115859.

Touboulic, A., Matthews, L. & Marques, L. (2018). On the road to carbon reduction in a food supply network: a complex adaptive systems perspective. *Supply Chain Management*, 23 (4), pp. 313-335, doi: 10.1108/SCM-06-2017-0214.

Vance, L., Heckl, I., Bertok, B., Cabezas, H. & Friedler, F. (2015). Designing sustainable energy supply chains by the P-graph method for minimal cost, environmental burden, energy resources input. *Journal of Cleaner Production*, 94, pp. 144-154, doi: 10.1016/j.jclepro.2015.02.011.

Ward, H., Steckel, J. C. & Jakob, M. (2019). How global climate policy could affect competitiveness. *Energy Economics*, 84 (1), doi: 10.1016/j.eneco.2019.104549.

Wijesiri, B., Liu, A. & Goonetilleke, A. (2020). Impact of global warming on urban stormwater quality: From the perspective of an alternative water resource. *Journal of Cleaner Production*, 262, doi: 10.1016/j.jclepro.2020.121330.

World Bank, 2016. Climate Action Plan 2016-2020. Najdeno 3. maja 2020 na spletnem naslovu https://openknowledge.worldbank.org/bitstream/handle/10986/24451/K8860. pdf?sequence=2&isAllowed=y.

Yang, L., Feng, Q., Adamowski, J. F., Deo, R. C., Yin, Z., Wen, X., Tang, X. & Wu, M. (2020). Causality of climate, food production and conflict over the last two millennia in the Hexi Corridor, China. *Science of The Total Environment*, 713, doi: 10.1016/j.scitotenv.2020.136587.

Zabaniotou, A. (2018). Redesigning a bioenergy sector in EU in the transition to circular waste-based Bioeconomy-A multidisciplinary review. *Journal of Cleaner Production*, 177, pp. 197-206, doi: 10.1016/j.jclepro.2017.12.172.

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Manuscript received by 28 September 2023.

The authors alone are responsible for the content and writing of this article.

doi: 10.2478/jlst-2023-0007

Blažitev podnebnih sprememb pri upravljanju dobavne verige v treh izbranih industrijskih sektorjih

Povzetek - Z rastjo svetovnega gospodarstva in globalizacijo se povečujejo tudi podnebne spremembe in njihovi učinki na planet Zemljo. Podnebne spremembe pa ne motijo le narave, temveč vplivajo tudi na podjetja in njihove dobavne verige. Številna podjetja so v zadnjem času prepoznala pozitivne učinke zelenih in krožnih praks upravljanja dobavnih verig. Oskrbovalne verige, ki dobavljajo izdelke z vsega sveta, so vse bolj izpostavljene vplivom spreminjajočega se podnebja in omejenih virov. V tej raziskavi je bilo ugotovljeno, kako podnebne spremembe vplivajo na dobavne verige v živilskem, avtomobilskem in energetskem sektorju. Poleg tega smo želeli ugotoviti, ali in kako se spreminja upravljanje oskrbovalnih verig, da bi se prilagodile poslovnemu okolju, na katerega vse bolj vplivajo okoljske spremembe.

Ključne besede - prilagajanje podnebnim spremembam, krožno gospodarstvo, trajnostni razvoj, upravljanje dobavne verige