LOGISTIC SYSTEMS IN CLUSTERS: BIOMASS CASE STUDY

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Abstract: Logistics systems in many sectors of the modern economy have a significant impact on their competitiveness. Having examined the general logistics systems functioning principles, their types and conditions of formation, authors of the article have determined that in order to ensure the competitiveness of each more or less clustered economic sector, a unique logistics system is needed. By researching biomass clusters, authors of the study have developed their logistics system that involves planning, provision, production, resource flow distribution from producer to user, and ensures synergistic effects for cluster participants. Authors' empirical research on hypothetical biomass clusters fully confirmed the theoretical assumptions about the impact of logistics systems on the competitiveness of biomass clusters. The results of empirical research have indicated, that logistics system is effective in case of both large and small intensity of biomass consumption. It has been established that evenly increasing demand for biomass can be based on further biomass deposits, and closer deposits are used to neutralize the sudden jumps in demand.

Keywords: Logistic systems, supply chain, clusters, biomass clusters, competitiveness.

1 Introduction

Logistics systems today are critically important when seeking business efficiency. In a competitive market, rational logistics solutions ensure the ability to profitably operate in the market. Many scientists who investigate the logistics systems indicate that they link production and consumption (Bartolacci, M. R., Leblanc, L. J., Kayikci, Y., Grossman, T. A., 2012), and that logistics is a science that covers production, planning, organization, control and delivery of the final product to the consumer (Bazaras, D., 2005, Christopher, M., 2007, Palšaitis, R., 2010). Logistics includes transportation of goods, warehousing, customs operations and payment systems (Arvis, J.F. et al, 2014). Logistics, therefore, consist of processes involving the planning, implementation and control of the flow of goods, services and related information (Vitasek, K., 2013). Logistics object is movement of material goods and their transformation process (Braškienė, L., 2009); the goal and mission is to deliver high-quality products on time (Palšaitis, R., 2010).

In the context energy market transformation, the use of fossil resources is abandoned moving to the use of renewable resources. At this point biomass is the only renewable resource that allows to ensure uninterrupted production of energy. To achieve this a logistics system adapted to specific activities (energy production) in the region needs to be established. This way, the authors of the study created a medium-sized hypothetical biofuel cluster logistics system. The main axis of the cluster's activity is the use of indigenous biofuels for the production of thermal energy, electricity or natural gas. Biomass cluster is a dynamic structure therefore in different countries it can be formed using different types of entities. It depends on the abundance of biomass, the existing supply and distribution infrastructure, and prevailing type of energy production in particular country. Biomass that is not used for process heating can either be converted into products, thus increasing the conversion efficiency, sold as feedstock or fuel to external customers (Hackl R., Harvey S., 2016). Another advantage of integration into an industrial cluster is that the existing infrastructure (boilers, utility systems, air separation plant, etc.) is already in place. The cluster structure can be influenced by the general state of cluster culture in the country. Other factors, such as financial state of the business, scale of cooperation, and level of corruption, create the conditions for facilitating or complicating the development of clusters. As the Fourth Industrial Revolution is approaching, technological advancement and responsiveness to innovative solutions significantly impact the clustering of biomass. Biomass clusters help to preserve forests, but it requires the involvement of all stakeholders. Stakeholder engagement within the cluster is necessary to ensure efficient and coherent use of forest resources. In forest based rural communities this approach requires tighter coordination between members of the community, existing forest product producers, non-forest business, landowners, and land managers interested in developing cluster benefits (Saah, D., et al., 2014)

The research topic is unique, because authors aim to investigate the processes of logistics system functionality adapting them to biomass clusters. This is achieved by developing the most rational versions of logistics systems based on which the cluster would operate on the given region level. Since biomass cluster is a specific business system (dominated by logistics), it requires a smoothly functioning logistics system. Cost management is one of the key factors determining the success of a logistics system. Authors' research suggests that cost management contains continuous analysis and control seeking to deliver solutions that are relevant to a particular season.

In this study the authors would like to introduce the types of logistics systems and the context of their development. Logistics systems contain different business activities - purchasing, marketing, and distribution. Having evaluated these factors, we can move towards the energy systems. The activity of the biomass energy cluster is shaped by its specific characteristics. Biomass-fired energy projects have also been shown to generate local income, through sales of energy and by providing a market for local wood, agricultural wastes and energy crops (Walker, G., 2008). It lets to compare the different regions and revenue of business subjects in these regions. biomass contributes to the decentralization of the energy market (Grigoras, G., Scarlatache F., 2015, Faße, A., et al., 2014). The decentralized electricity generation is intended to provide small-scale power close to users, using a broad range of renewable technologies. Having considered these important circumstances, we can better understand the components necessary to develop a biomass cluster logistics management system.

Our study develops a logistic system tailored to the biomass cluster. It takes into account the purpose of the supply, the frequency, the main operating costs of the biomass cluster, and the specifics of the activity of the biomass cluster. The cluster's activity ensures that natural waste will be used for the production of energy, which cannot be otherwise recycled. Sustainable use of resources is a prerequisite for the biomass cluster, which distinguishes it from other energy producers. Building on the economic and financial value of unprocessed bio-waste, the cluster is becoming an important economic entity shaping the energy policy of the country's regions.

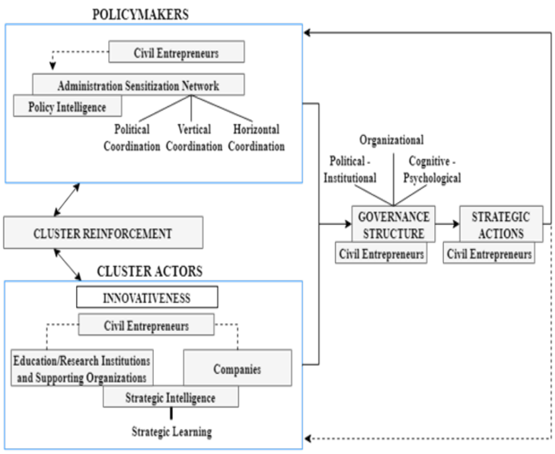
The logistics of biomass energy sector is quite complicated. It is impacted by seasonality and which affects the final energy price. Under more favorable climate conditions, it is possible to obtain the required amount of biomass at a lower cost. However during the winter or prolonged periods of rain biomass price rises at a significant rate. In the spring time, working with heavy machinery in the forest and transporting wood from distant and uninhabited areas is difficult because of the wet soil and missing or poor conditioned roads (Kuula J., et al., 2011). For overcoming seasonal changes and for making all these processes efficient and smooth, one should develop the whole production process in general, and each actor's role separately. In addition, the logistics and infrastructures in this process should be improved nationwide, which is expensive and diminishes the profitability of the whole bioenergy. This necessitates a very accurate assessment of the biomass supply chain by including specific factors that could prolong the supply chain. Therefore, biomass processing quantities and raw material supply must be modeled at least several months ahead. Having a consistent supply chain planning mechanism would make it possible to ensure the continuous supply of required amount of biomass at a similar price range.

2 Theoretical background

2.1 Logistics Systems in Different Clusters

The logistics system is based on the type of business and the type and quantity of products transported. It is an important measure ensuring smooth functioning of the business. State of specific sector that involves both private and public entities has to be taken into account when investigating logistics options. Both sides are pursuing similar goals - to maximize benefits, expand opportunities and business development. Cluster management model (Fig. 1) is presented as a cluster-government interaction. Based on this decision makers and cluster participants strengthen their ties thereby persuading the government to allow the development of their activities.

Figure 1. Cluster governance model



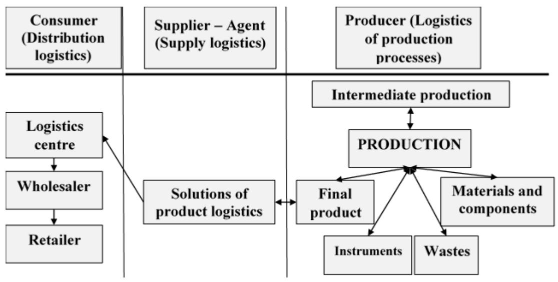
Source: Ebbekink, M., Lagendijk, A., 2013

Thus, cluster activities are based on the promotion of innovation, inclusion of educational institutions, and collaboration with policymakers (Figure 1). The interaction of the above mentioned entities allows the negotiation with the government in order to legitimize its activities in a given region. Under this model, cluster policy and public policy need to be more closely linked and based on co-operation. It would be possible to achieve a positive effect that would be benefit both the business subjects and the society. Presence of civil entrepreneurs is another important aspect. They are one of the main cluster activity catalysts, as theyenable the development of new ideas and the ability to convince those dubious public institutions. The interaction between business and government members can extract relevant social and environmental solutions. If this model is applicable in a biomass cluster, then from a government perspective, consumers are being targeted to help them pay the lowest price for energy. From the point of view of business, the objective is to get the market operating conditions in order to earn profit. Biomass users operating on the market should seek maximum efficiency, they will only be able to compete on the market and persuade the government to allow them to operate.

In simple companies entrepreneurship is determined by the characteristics of the leader; in planning companies it is defined by explicit and product-market strategies; while in organic companies is is defined by a function of their environment and structure (Gaweł, A., Jankowska, B., 2012). An entrepreneurial company is characterized by three dimensions: pioneering (proactiveness), innovation and risk taking. Such businessmen help the cluster to grow and increase its competitiveness. Renewable energy will not only address the limitations associated with current energy consumption patterns and provide much needed modernization of the energy sector, but will also promote sustainable development objectives (Kaygusuz K., 2007). Constant pursuit of efficiency and the application of innovations are key factors ensuring smooth functioning of the biomass energy sector.

Logistics system should be perceived as a wider structure with essential elements inherent for private business entities. It allows them to achieve full operational performance, including pre-production and post-production processes. In reality, logistics system includes not only the logistics of production, marketing and distribution, but also procurement logistics. This allows creating just-in-time operational procedures where purchases, production and sales are synchronized (Figure 2). Procurement logistics is important in terms of ensuring continuous operation and avoiding situations where user needs cannot be met.

Figure 2. Main chains of the logistics system



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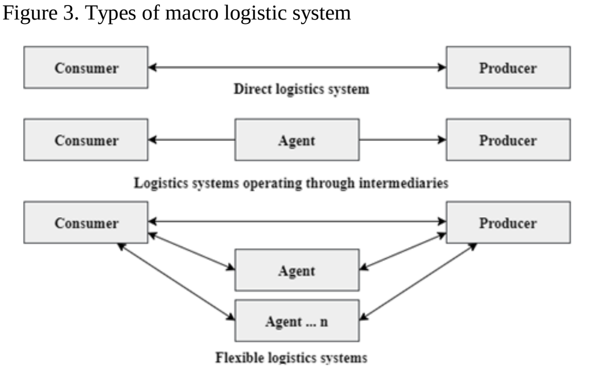
Studies show that marketing or distribution logistics can be seen as an entirety of logistics functions and goals that affects the distribution of goods. Distribution logistics includes activities related to the supply of services and goods from the production warehouse to the outlet market. Production logistics is also a combination of logistic functions and goals that ensure continuous production, including activities related to the movement of materials and raw materials at all stages of the production process, as well as interim storage until the finished product reaches the warehouse. Supply logistics ensures timely provision of material resources to the company, as well as inventory management, supplier selection, reduction of logistics related risks (due to non-compliance with supply parameters).

Logistics systems can also be seen from a generalized perspective taking into account the prevailing environment. It can also be applied to a separate business branch. Usually logistics systems are valued based on the prevailing relationship between the business and the end user. This is considered as macro-level logistics. Macro-level logistics includes direct, intermediary and flexible logistics systems (Figure 3). They are relevant for businesses of different sizes and sectors that operate in both production and in service sectors. Logistics systems may have exceptions however these are currently universally accepted types of systems.

Direct logistics system (A) is a system in which the flow of material goods moves directly from producers to consumers. In this case there is no intermediary structure. This type of system is most common in small and medium-sized businesses that do not have a large storage capacity. In this case it is easier for them to deal with individual manufacturers. It allows developing direct contact with those subjects ensuring continuous supply of goods. This system can function smoothly only if small quantities of goods is delivered to customers because communication with different manufacturers can deprive the consumer of a significant proportion of time and human resources.

Figure 3. Types of macro logistic system



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The most commonly used logistics system is based on intermediaries (B). This way the movement of material goods goes through one or several intermediaries before reaching the end user. In case of industrial products, the role of intermediaries is usually carried out by wholesale distributors or logistics centers that distribute goods closer to end users. In case of services, business entities manage the service packages that are later distributed to consumers. In case of energy, two business parts need to be distinguished - the supply of fuel and the supply of the final product. Power plants can procure fuel supply directly or through intermediaries. The latter is quite common among low power plants. Meanwhile the final energy is usually sold through municipal energy supply companies that, in this case, carry out the role of intermediaries.

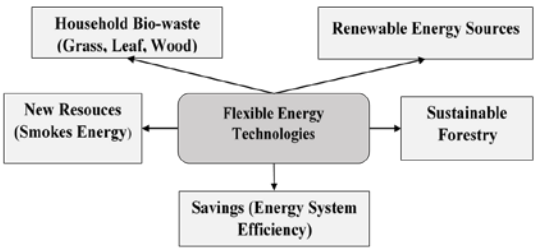
Flexible logistics system (C) is characterized by its flexibility and ability to adapt to the emerging situation. A flexible logistics system is based on the fact that intermediary services are not mandatory - they can be used or not. This can be adjusted based on the response to changes in demand. This system is considered to be the best reflection of the biomass cluster case because intermediate suppliers able to provide greater quantities of biomass are needed when weather conditions and energy supply change. In this case it is considered that biomass manufacturer is a provider and heat, energy or natural gas producing power plant is a consumer. In normal cases direct communication is used however, the possibility to rely on the services of intermediaries remains.

Logistics systems are applied in almost all sectors of the economy. They help to control the growth of the costs and effectively fill the needs of consumers. One of the key competitive advantages of a biomass cluster is a balanced fuel supply to the power plants. It helps to manage the costs and win a competitive battle against fossil-based power plants. The logistics system in the cluster occurs through both direct links and cooperation with the intermediaries.

2.2 Features of Logistics Systems in Biomass Cluster

Sustainable development of the biomass energy sector makes it possible to reform the energy structure and increase its efficiency in different countries and regions. As fossil-fuel equipment installations are more often replaced with equipment suitable for burning biomass it creates conditions for the joint review of the local energy grid. This results in reduced amounts of wasted energy and increased efficiency of energy production and supply. Controlling the growth of potential biomass helps cultivating the flexibility. The success of a bio-based industry depends on an accurate forecast of the raw material flow coming from the forests for the entire biomass supply chain up to the industrial processing stage (Husmann, K., et al, 2018). This ensures the sustainable use of biomass based on economic logic. Cluster developments encourage a highly specific territorial process, which performs as an intermediate system between the micro-economy of the commodity-producing society and the structure of the modern space–economy (Yang, Z., et al., 2015). Increasing efficiency and ensuring supply flow dynamics are the key components ensuring sustainable development of the biomass sector (Figure 4). The development of biomass energetics allows obtaining various types of fuel from different sources, making it possible to ensure long-term price stability. At the same time it is possible to generate different volumes of energy production based on demand.

Figure 4. Components ensuring sustainable development of the biomass sector



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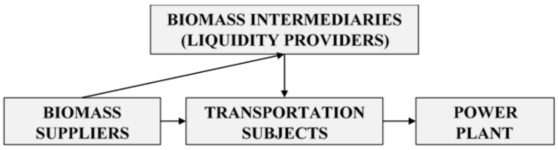
Biomass energy sector has favorable clustering possibilities as it uses local renewable resources. Such resources are usually managed by small entities that are not able to supply regional biomass processing facilities all by themselves. In case of cooperation they would not only satisfy the demand for biomass but at the same time would also receive tangible financial benefits. It is more favorable for biomass processors to cooperate with a larger number of suppliers as this allows them to obtain the required quantities of renewable fuels faster and at a lower cost. It is therefore extremely important to involve residents who would generate different types of bio-waste. By handing over their bio-waste to be recycled they would help to increase the competitiveness and flexibility of the cluster. At the same time, biomass energy structure can be community-based, where members of the community contribute to the production of the resources they need.

A result it can be argued that biomass cluster structure can be favorable to logistics system development. Moreover, it is essential for this sector to have a smoothly functioning logistics system as it helps maintaining high competitiveness level in the energy market. Logistics system covers the planning, provision, production and distribution of goods from manufacturer to customer. All these elements interact and affect each other. System efficiency is also influenced by marketing. An efficient logistics system can only exist if all elements interact with each other. When evaluating the efficiency of the biomass cluster logistics system, marketing does not play a vital role as it only acts in the local market where the all products are the same. In this situation, energy producers need to compete for the market share but not for consumers. The main instrument for securing the market share is the effective operation leading to lower final energy prices. For this reason biomass cluster logistics system plays a vital role in optimizing the fuel costs and transportation costs.

The biomass cluster and its logistics system require a specific structure. Since biomass energy requires high quantities of raw materials, it is necessary to ensure a smooth material processing and supply flow. In case of biomass cluster, intermediary services are required on several occasions - when fuel is supplied and when it is burned. Business in biomass cluster is highly seasonal because during the winter the demand for thermal energy is significantly higher compared to the summer time. This influences the volumes of cluster logistics at the same time affecting the entire logistics system (Figure 5). Subjects providing transportation services are also required. In this case, they shall be called service staff.

Figure 5. Simplified biomass cluster logistics system



Source: created by the authors.

When demand for biomass is rapidly rising biomass supply intermediaries are needed the most. Intermediaries are able to quickly supply themselves with biomass usually obtaining it from their managed biomass areas and forest massifs. In terms of the latter, forests are also cleaned by removing poor-quality wood. This also carries out a specific market-forming function because when possibility is presented stable quantities of biomass are produced and increase in prices is stabilized. In most cases such entrepreneurs diversify their risks by producing biomass in winter while shifting their businesses to other activities during the summer. This ensures some sort of synergy taking into account seasonal changes.

Clarity and goal to fulfil consumer needs are key characteristics of a logistics system. Similar phenomenon is present in the case of biomass clusters. It focuses on the supply of sustainable energy resources ensuring continuous production of thermal energy and electricity. The cluster is oriented to a local area, and its extent is easily controlled. Following a biomass cluster logistics system analysis it is estimated that different quantities of biomass are supplied during different seasons. It creates conditions for a dynamically managed logistics system that ensures continuity and competitiveness of biomass cluster activities.

2.3 Methodology and research findings

The research analyses the hypothetical supply chain system in areas where all of the thermal energy is produced using biomass. The study uses data from two cities (A and B). Creating this model it is assumed that the first city consumes approximately 18,618 TOE (Tonnes of Oil Equivalent) of biomass per year. The second city consumes about 1850 TOE of biomass per year. The model examines the situation where the first city can be supplied from seven biomass production sites located in different areas meanwhile the second city is supplied from five sites. Different supply proportions are determined depending on the size of the biomass production site in the area. The difference between the least and most exploited production sites is almost twice as high. Data provided in Table 1 shows that the differences between biomass production sites are not significant allowing to maintain balanced supply quantities. The areas are selected based on the potentially available biomass, annual forest harvesting volumes, quality of transportation services and potential to supply large quantities of biomass in the short period of time.

The map of biomass supply sites and cities (Figure 6) shows that biomass supply sites are located in different areas. Their exploitation mostly depends on seasons and unexpectedly increased demand for biomass. During the warm season when demand for energy is lower, supply sites that are closer to the cities are exploited the most. During the cold season when demand for biomass is higher, the exploitation level of further supply sites is increased. Biomass extraction is viewed from a broader perspective as different size supply sites are exploited taking into account the planned forest harvesting volumes and the scale of cleaning in small forests. For the most part, large arrays are utilized because of the planned forest harvests. The conditions for this situation are the ongoing forest harvestings. Waste gathered during the harvest is used for energy production. In all cases, the waste is then shredded locally and afterwards transported to the incineration point. Waste gathered cleaning less woody areas is also used for energy production. Forest cleaning can be done in order to increase the sustainable use of the forest resources.

In the first area the incineration facilities are located in the middle (city A), this enables smooth supply of required biomass quantities. Forest areas are located in the southern part of the area. Since distances are optimal (up to 30 km), biomass is delivered to power plants within 1 hour using trucks. This enables quick response time in situations when demand for biomass increases significantly. In the second area, the power plants are located in the northern part. This changes the logistics system, since all biomass supply sites are located south of the city B. The prolonged supply distance helps to better express how significant is the efficiency of the logistics supply chain. Basic operating costs are related to biomass processing and transportation. Unlike in the case of fossil fuels here a supply chain based on human resources is needed and high automation level cannot be ensured. Therefore, it is necessary to anticipate a weekly biomass sourcing strategy that would be adjusted based on the changing seasons. Depending on the weather, the number of trucks entering the power plant can differ 2-3 times.

Table 1 Demand for biomass in the area distributed among the biomass supply sites.

Supply site ID (First area)	Required quantity of biomass (TOE)	Supply ID (Second area)	Required quantity of biomass (TOE)
1	2243	1	515
2	2984	2	245
3	2123	3	215
4	2759	4	335
5	3450	5	540
6	3235		
7	1824		
Total	18618		1850

Source: created by the authors

The map of biomass supply sites and cities (Figures 6 & 7) shows that biomass supply sites are located in different areas. Their exploitation mostly depends on seasons and unexpectedly increased demand for biomass. During the warm season when demand for energy is lower, supply sites that are closer to the cities are exploited the most. During the cold season when demand for biomass is higher, the exploitation level of further supply sites is increased. Biomass extraction is viewed from a broader perspective as different size supply sites are exploited taking into account the planned forest harvesting volumes and the scale of cleaning in small forests. For the most part, large arrays are utilized because of the planned forest harvests. The conditions for this situation are the ongoing forest harvestings. Waste gathered during the harvest is used for energy production. In all cases, the waste is then shredded locally and afterwards transported to the incineration point. Waste gathered cleaning less woody areas is also used for energy production. Forest cleaning can be done in order to increase the sustainable use of the forest resources.

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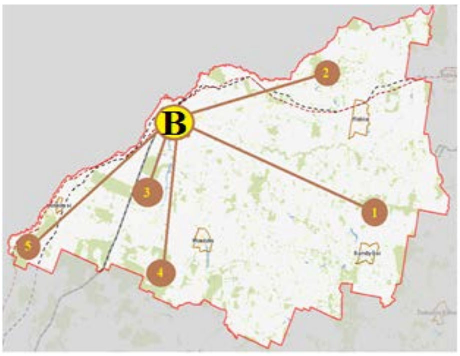
Figure 6. Layout of biomass supply sites (1-7), in first area

Source: created by the authors

Figure 7. Layout of biomass supply sites (1-5), in second area



Source: created by the authors

Distances between biomass mines are different based on the quantity of available biomass resources. The highest quantity of biomass is extracted from areas that are located further from the power plants in the cities. In operational terms, if demand for biomass has increased significantly, it can be satisfied by bringing supplies from the nearby areas. In other cases, sustainable circulation of biomass supply is being developed, taking into account established demand and fuel resources in the area. Table 2 indicates the distances between biomass supply sites and central consumption point in city A or B. Each supply site is assigned a separate number. Supply sites are located at a sufficiently optimal distance, which allows to sustain balance in the supply chain processes.

Table 2 Distances between supply sites to power plants

Supply site ID (First area)	Distance from supply site to power plant, km.	Supply site ID (Second area)	Distance from supply site to power plant, km.
1	26	1	34
2	12	2	25
3	4	3	9
4	22	4	19
5	23	5	23
6	24		
7	20		

Source: created by the authors

To assess the supply chain functionality and costs, formulas determining these components were selected and adapted to the simulated case. Primary supply chain costs are related to biomass processing and transportation. In each case they vary because of the different distances between biomass supply sites. Characteristics of processed fuels are also different. Whereas Just-in-Time (JIT) system is used storage need is not being considered.

In this simulated situation thermal energy is produced using four biomass power plants in city A and two in city B. The demand for biomass varies based on the changing weather. During the warm season biomass is used to provide hot water and during the cold season it is also used in thermal energy production. Data in Table 3 shows how required biomass quantities are distributed based on seasons. There are three periods - warm, intermittent and cold. The intermittent period is exceptional because at that time biomass power plants operate in a capacity that is just slightly higher than average. The intermittent period partially covers spring and autumn seasons.

Table 3 Distribution of biomass quantities based on seasons.

Month names and group ID	Biomass demand in city A, toe	Biomass demand in city B, toe
November - December - January - February (1)	8058	820
March - April - October (2)	5760	570
May - June - July - August - September (3)	4800	460

Source: created by the authors

The selected formulas help to assess biomass supply quantities and the efficiency of logistics system. They are related to biomass processing and transportation cost analysis. The logistics system is based on the biomass supply chain. Despite the fact that only two hypothetical areas were used for this research, this research instrument can be applied in more extensive research of other similar areas. Indicator values can change significantly depending on the distances between the biomass supply sites and power plants, fuel price and conversion ratio. It is generally accepted that efficient transportation distance is between 50 and 100 km. If distances are longer, the logistics system needs to be rearranged to include other means for transportation such as trains and water transport. In this research diesel powered trucks were used for transportation.

Transportation costs play a vital role in the logistics system. Optimal transportation plan enables competitive activities. If biomass supply transportation distance is greater than 100 km there is a risk to lose competitive advantage against subjects that are using fossil fuels. For this reason when developing a supply chain scheme it is important to estimate the transportation costs from each biomass supply site. Alongside the estimation of transportation distance it is important to include the transportation costs per kilometer. In this case it is estimated based on fuel consumption. The following formula is used to estimate the transportation costs.

$$TC=\sum(TD*2)*TP \quad (1)$$

TC – Transportation Costs (EUR); TD – Transportation Distance (km); TP – Transportation Price (EUR/km).

To assess the efficiency of the supply chain it is important to evaluate the extent of preparations required at each biomass supply site. Production of biomass depends on the distance to the biomass supply site, its potential and season. When developing the supply chain system It is important to include the extent to which different biomass supply sites will be exploited. The exploitation extent is defined based on the quantity of unrefined wood and its availability in particular site. Subsequently biomass supply demand is calculated based on the time of year. This indicator can be calculated using the formula below.

$$BPC=FPR*DBP*RPC \quad (2)$$

BPC – Biomass Processing Coefficient; FPR – Feedstock Production Ratio; DBP – Daily Biomass Production (TOE/Day); RPC – Relative Production Capacity (depending on the season).

FPR is a percentage of biomass feedstock production per site compared to overall production in the area. APB is daily feedstock production capacity within the supply site. Relative production capacity is calculated based on the biomass demand during particular time of year. In winter, when the demand for biomass is highest, the relative production capacity is 1 and this coefficient is lower in warm seasons.

Another indicator shows the changes in biomass processing costs. Costs are calculated based on one conditional unit, in this case it is equal to tonnes of oil equivalent. It is assumed that a certain amount of fuel is needed to process one biomass unit. In this case it is estimated that this amount equals to 8 liters per unit. The price of fuels varies depending on the time of therefore companies have to plan fuel costs otherwise their logistics system can result in higher supply costs. This should be considered during fuel purchases If there is a tendency for rising fuel costs. Fuel prices might differ from one region to another and that also influences the final energy price.

$$DBPC=\sum FN*FP \quad (3)$$

DBPC – Daily Biomass Production Cost; FN – Fuel Needs (L/TOE); FP – Fuel Price.

In the empirical study transportation costs are calculated first. The are estimated based on the cost of bringing one biomass unit to power plant. Due to changing fuel prices cost estimates might differ. In this case two optimal transportation prices are selected to reflect fuel price volatility. This indicates how important it is for businesses to evaluate how fuel price will change and its effects on the price of the final product. Data provided in Table 4 shows that transportation costs can vary significantly depending on the distance and fuel price.

Table 4 Simulation of transportation costs.

Supply site ID (First area)	Distance from supply site to power plant, km.	TC (TP = 0,55)	TC (TP = 0,75)
1	26	28,6	39
2	12	13,2	18
3	4	4,4	6
4	22	24,2	33
5	23	25,3	34,5
6	24	26,4	36
7	20	22	30
Supply site ID (Second area)	Distance from supply site to power plant, km.	TC (TP = 0,55)	TC (TP = 0,75)
1	34	37,4	51
2	25	27,5	37,5
3	9	9,9	13,5
4	19	20,9	28,5
5	23	25,3	34,5

Source: created by the authors

In Table 4 two transportation prices are selected. Based on that transportation costs of one biomass unit are calculated and expressed in amount of trucks needed. Transportation costs are calculated estimating the distance of a round trip therefor the volatility of transportation costs is financially more significant. It can be seen that average costs in the second area are slightly higher compared to the first area. This is related to the distribution of supply sites in the second area where the plant is located in the northern side of the region and there are no conditions to bring supplies from areas that are located to the north from the plant. Transporting biomass from the supply sited located in the southern part results in increased transportation costs. In the first area transportation costs are distributed evenly. Feedstock supply sites located closest to the power plant generate lowest distribution costs. However the feedstock production capacity is not high enough for them to fully cover demand for biomass. For this reason the logistics system should help manage the costs and balance the biomass transportation from separate supply sites.

Another indicator is biomass processing coefficient that is calculated for three different seasons lasting for different period of time. The highest amount of biomass is used during the winter months. The consumption of biomass is lower in other months and the amount is calculated using the adopted coefficient. In summertime coefficient is 0.2, during the interim period before and during the end of the heating season the coefficient is 0.6.

Data in Table 5 show that indicators the first area vary considerably when seasons change. The highest coefficient value is generated in the 5th supply site because it supplies the power plant with largest amount of biomass. In the event of an unexpected jump in energy demand precisely this supply site can quickly provide required amount of biomass to the power plant. Meanwhile during the tactical period resources are supplied form sites 3 and 7, as they are relatively close to the power plant and can meet the lower energy needs.

Table 5 Biomass processing coefficient in the first area

Supply site ID (First area	FPR	DBP	DBPC (1)	DBPC (2)	DBPC (3)
1	12,05	6,15	74,03	44,42	14,81
2	16,03	8,18	131,03	78,62	26,21
3	11,40	5,82	66,32	39,79	13,26
4	14,82	7,56	112,02	67,21	22,40
5	18,53	9,45	175,15	105,09	35,03
6	17,38	8,86	154,00	92,40	30,80
7	9,80	5,00	48,96	29,37	9,79

Source: created by the authors

Same actions were taken in the second area. As Table 6 shows the highest coefficient value is calculated in the 5th supply site. Indicators in the table vary significantly and this variation is related to season changes. Following the values calculated for the warm season it can be seen that supply site exploitation is symbolic and it is only used to fulfil the hot water needs for that period of time. This allows maintaining the efficiency of the logistics system in both active and passive operating periods.

Table 6 Biomass processing coefficient in the second area.

Supply site ID (Second area	FPR	DBP	DBPC (1)	DBPC (2)	DBPC (3)
1	27,84	1,41	39,28	23,57	7,86
2	13,24	0,67	8,89	5,33	1,78
3	11,62	0,59	6,85	4,11	1,37
4	18,11	0,92	16,62	9,97	3,32
5	29,19	1,48	43,18	25,91	8,64

Source: created by the authors

Finally, the costs of biomass production for each site and the entire area are estimated. It is assumed that there are 2 fuel price rates that can change the overall costs of the logistics system. In the case of the first area, estimation of supply site operating costs show that most distant sites and those supplying largest amounts of biomass generate highest processing costs (Table 7). As diesel is used for biomass processing it amounts to the largest part of the processing costs.

Table 7 Daily biomass preparation cost in the first area

Supply site ID (First area	Required quantity of biomass, toe	Sum (NF)	DBPC, (FP = 1,10)	DBPC (FP = 1,20)
1	2243	17944	19738,4	21532,8
2	2984	23872	26259,2	28646,4
3	2123	16984	18682,4	20380,8
4	2759	22072	24279,2	26486,4
5	3450	27600	30360	33120
6	3235	25880	28468	31056
7	1824	14592	16051,2	17510,4
Total:	18618	148944	163838,4	178732,8

Source: created by the authors

Similar trends are also apparent in the second area. Data provided in Table 8 shows that changes in costs are relatively small when production output is low. This enables a more stable logistics system management process as it can quickly adapt to relatively small changes. Assessing the fact that the price may rise or fall gradually makes the logistics system even more resilient. If the prices rise cluster subjects in the area can provide themselves with the required amount of cheap fuel, which would enable cost-effective operations over a long period of time.

Table 8 Daily biomass preparation cost in the second area.

Supply site ID (Second area	Required quantity of biomass, toe	Sum (NF)	DBPC, (FP = 1,10)	DBPC (FP = 1,20)
1	515	4120	4532	4944
2	245	1960	2156	2352
3	215	1720	1892	2064
4	335	2680	2948	3216
5	540	4320	4752	5184
Total:	1850	14800	16280	17760

Source: created by the authors

The results obtained in the empirical study show that the logistics system can be effective in areas with both high and low demand for biomass. Transportation and biomass processing costs are heavily influenced by fuel costs. Changing operational costs also change the final biomass price. Generally speaking it can result in increased or decreased energy prices for end users.

In the second area, due to the relatively unfavourable distribution of the mines, biomass cannot be supplied from the northern part of the area, but the logistics system helps maintaining region's competitiveness in terms of energy. In the case of the first area, a more even distribution of biomass processing sites enables a balanced distribution of biomass flows, and the logistics supply chain is key in achieving this goal.

3 Conclusion

Logistics system is a universal tool that helps balancing the supply of resources in required directions. This is especially relevant for a biomass cluster as its activities are based on smooth biomass supply to power plant. In the case of biomass clusters flexible logistics system is used and depending on demand intermediary services may or may not be used to fulfil it. There are several types of logistics systems, but it is generally acknowledged that the main elements of the logistics system are the manufacturer, the intermediary (if necessary) and the user. All trading operations are carried out between these entities.

In this research we used data related to the amount of biomass consumed and seasonality in two hypothetical areas. Areas have different energetic capacities, which allows us to reveal the flexibility of the logistics system. In the first area there are seven biomass supply sites and the power plant is located almost in the middle of the geographical region. In the second area there are five biomass supply sites but the combustion point is located in the northern part of the region. The latter complicates the biomass supply process and emphasizes the need for a logistics system. Seasionality changes the demand for biomass, which affects the intensity of the logistics chain. To analyze the impact of the logistics system costs of fuel used for biomass transportation and processing are examined.

The obtained empirical research results show that the logistics system works in both high and low intensities of biomass usage. It has been established that more distant supply sites can be used when demand for biomass is increasing evenly and closed sites can be utilized to neutralize sudden jumps in demand. Fuel price volatilities significantly increase the costs therefore when the fuel price rises, logistics system enables a more responsible management of the costs associated with biomass transportation and processing.

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