LOGISTICS MODEL OF ARBOREAL BIOMASS SUPPLY

István Réthy
Károly Róbert College, Hungary
Zsolt Tégla
Károly Róbert College, Hungary
Hajnalka Szabóné Pap
Károly Róbert College, Hungary

Our investigation dealt with questions related to the raw material supply of a virtual energy-cluster. We examined those elements of production technology, in which the logistics methods and the optimisation of the flow of materials showed tangible results. The competitiveness of actors in the economic sphere is significantly determined by the effectiveness of their supply chain. The optimal solution to these tasks is provided by that combination of apparatus wherein both the "time factor" (JIT) and the efforts to minimise costs are realised. The supply chain we examined comprised of harvesting, transport and storage process elements; of these, harvesting in particular, due to its exceptionally high operating costs. We sought an answer to the question of whether it is better to transport the raw material directly to the processing plant or indirectly after temporary storage. In the case of indirect delivery, we wanted to know where storage facilities should be established and how many should there be in the interests of minimising total costs. We created and utilised a simulation model to solve the task. We established that in case of short transport distances (1-3 km), direct transport is feasible. In the case of greater distances, indirect transport and the development of micro-logistical storage centres is justified. The number and location of these micro-logistical storage centres can be exactly determined with the help of our model.

1. OBJECTIVES, MATERIAL AND METHOD

In our survey we modelled the supply-logistics system of a virtual energy-cluster. We examined the variation of total costs of the supply system in the case of direct transportation (harvesting to power plant) indirect transportation (harvesting, temporary storage, power plant) or a combination of these. We created a simulation model which allows selecting the optimum solution in each case. As a result of the investigation we calculated the ideal number of temporary storage facilities, and are able to formulate propositions for optimally positioning these facilities based on logistic points of equilibrium. The database for calculation comes from earlier materials plus from already functioning similar systems. Rational land use can be fostered by biomass production as well (10, 13).

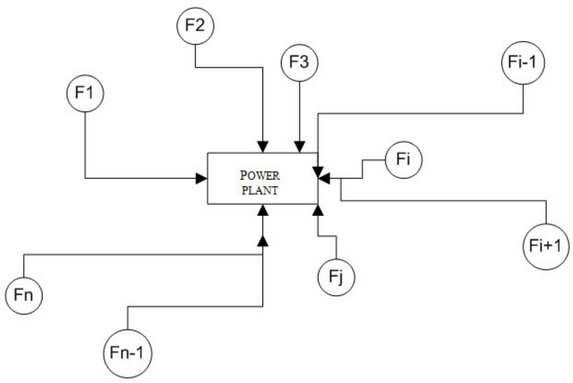
2. THE SUPPLY LOGISTIC SYSTEM OF BIOMASS BASED ENERGY CLUSTER

Raw material supply of the virtual energy cluster we analyse can be realised three ways:

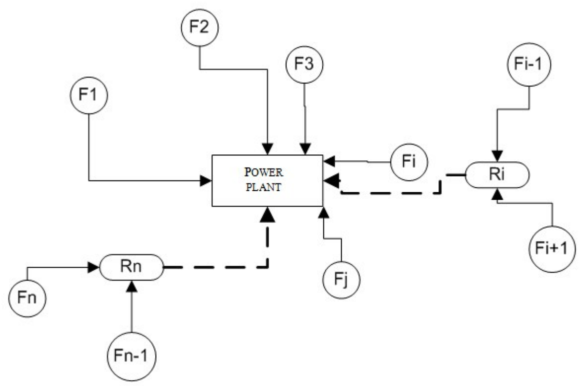
1. At the time of harvesting each production unit transports the high humidity level wood-chips (45-50%) to the central storage facility of the power plant.
2. The harvested amount is stored in temporary storage facilities on the production site, and is transported to the power plant in the rhythm of usage.
3. In the case of large distances micro-regional storage facilities are established for temporary storing the wood-chip output of the given micro-region until the time of usage. Production units nearby still transport directly to the power plant.

Figure 1 shows these variations.

Figure 1: Direct and combined supply systems



Direct supply from the production units



Combined supply with temporary storage facilities (R_i)
Source: own

We tried to find out which solution leads to the lowest total costs. For this we utilised the heuristic simulative method (RECAM) for optimising harvesting-transport. For establishing the number of regional centres we built a simulation model shown in figure 2. The calculation method applies for the model is the one used by Cselényi (1997).

First we calculated total costs in the case when we are not using temporary (regional) storage facilities – everything is transported directly to the power plant (3,4).

In this case total costs:

$K = K_{sz} + K_r$

K_{sz} - cost of transportation

K_r - cost of storage (nonexistent in this case)

Total transportation costs:

$$K_{sz} = \sum_{i=1}^{n} k_i s_i \frac{Q_i}{c_i}$$

k_i specific cost of transport from field i

s_i distance from field i to power plant

Q_i yield on land i

c_i capacity of vehicles transporting from field i

During calculation we assumed one kind of transportation and one kind of vehicle. Our RECAM survey showed that MTZ 82 (tractor) + Fliegel EDK 130 (trailer) is the lowest cost means of transport.

If full transport is done by the same machines:

$$k_1 \approx k_2 \approx \ldots \approx k_n \qquad and \qquad c_1 \approx c_2 \approx \ldots \approx c_n$$

The total storage costs:

$$K_r = r_e \overline{R}_e \overline{T}_e$$

r_e specific maintenance costs of the power plant storage

$\overline{R}_e$ average stock at the power plant storage

$\overline{T}_e$ average storage time at the power plant storage

Cost K resulted will be the base – algorithm cycle starts from here. **After this we analyse total costs in case of 1,2,…,m storage facilities.** The same formula applies:

$K = K_{sz} + K_r$

K_{sz} - cost of transportation

K_r - cost of storage (nonexistent in this case)

This time the transportation costs consist of two factors:

$$K_{sz} = K_{sz}^{r} + K_{sz}^{f}$$

K_{sz}^{r} cost of transportation from storage to power plant

K_{sz}^{f} cost of transportation form fields to storage

Detailed calculation is as follows:

$$K_{sz}^{r} = \sum_{j=1}^{m} k_{(r)j} s_{(r)j} \frac{Q_{(r)j}}{c_{(r)j}}$$

$k_{(r)j}$ specific cost of transport from storage j

$s_{(r)j}$ distance from storage j to power plant

$Q_{(r)j}$ yield on fields belonging to storage j

$c_{(r)j}$ capacity of vehicles transporting from storage j

This is one of the key factors in calculation since total costs can be reduced significantly if we minimise transportation cost from storage to power plant.

When transporting biomass from filed to storage the following costs arise:

Assuming that storage facilities $R_1, R_2, \ldots, R_m$ are associated with territories $t_1, t_2, \ldots, t_m$

$$K_{sz}^{f} = \sum_{j=1}^{m} \sum_{p_j=1}^{t_j} k_{jp_j} s_{jp_j} \frac{Q_{jp_j}}{c_{jp_j}}$$

k_{jpj} specific cost of transport from field p_j to storage R_j

S_{jpj} distance from field p_j to storage R_j

Q_{jpj} yield on fields p_j belonging to storage R_j

c_{jpj} capacity of vehicles transporting from field p_j to storage R_j

Storage costs are to calculated here too, of course:

Storage costs are to calculated here too, of course:

$$K_r = K_r^e + K_r^r$$

K_r^r storage costs of storage facilities

K_r^e storage costs of power plant

$$K_r^r = \sum_{j=1}^{m} r_j \overline{R}_j \overline{T}_j$$

r_j specific maintenance costs of storage R_j

$\overline{R}_j$ average stock at storage R_j

$\overline{T}_j$ average storage time at storage R_j

$$K = \sum_{j=1}^{m} k_{(r)j} s_{(r)j} \frac{Q_{(r)j}}{c_{(r)j}} + \sum_{j=1}^{m} \sum_{p_j=1}^{t_j} k_{jp_j} s_{jp_j} \frac{Q_{jp_j}}{c_{jp_j}} + \sum_{j=1}^{m} r_j \overline{R}_j \overline{T}$$

In this case total costs are:

We should notice that there are going to be fields from which transportation is directly to the power plant. In our calculation in such cases the power plant functions as storage facility but no further transportation is needed.[3,4]

The following in equation demonstrates things

$$k_i s_i \frac{Q_i}{c_i} + K_{r_i} < k_{jp_j} s_{jp_j} \frac{Q_{jp_j}}{c_{jp_j}} + k_{(r)j} s_{(r)j} \frac{Q_{(r)j}}{c_{(r)j}} + r_j \overline{R}_j \overline{T}_j$$

stated above:

Thus, if transportation and storage costs of field i directly to the power plant are lower than total transportation costs to any storage R_j it is better to transport directly to power plant. This calculation should be performed for all fields and storage facilities. As a result we will be able to see the limits of the area around the power plant within which fields belong directly to the power plant. These fields will transport directly to the plant, the rest to allocated storage facilities. (see Figure 1. Combined supply).

Planning the supply system of the virtual energy cluster we established

The task: designing the supply system for a 1 MW biomass based hot water and heating plant based on the methodology presented earlier.

Starting data:

Raw material need:

1.100 t/year (18-20% humidity level wood-chips)

2.500 t/year (45% humidity level wood-chips)

Need of land:

110-120 ha (energy poplar /AF 2/, 45 t/ha yield, 2 year cutting cycle)

Analysing the distance features (1-10 km) of the virtual cluster based upon the RECAM method the MTZ 82 (tractor) + Fliegel EDK 130 (trailer) proved to be the lowest cost means of transport. Following RECAM simulative model methodology we calculated total costs in the case of various scenarios. Data and results of direct, indirect and combined supply are shown in table 1-3.

Table 1: Costs in the case of direct supply

Name	Distance (km)	Area (ha)	Yield (t)	Specific cost (Euro/ha)	Cost (Euro)
Field 1	7	10	450	130,2	1 302,3
Field 2	4	4	180	115,4	461,5
Field 3	10	10	450	160,9	1 608,9
Field 4	5	4	180	118,9	475,8
Field 5	4	6	270	115,4	692,3
Field 6	5	3	135	118,9	356,8
Field 7	8	5	225	140,1	700,6
Field 8	10	6	270	160,9	965,4
Field 9	8	8	360	140,1	1 120,9
Field 10	5	6	270	118,9	713,7
Total:	**66**	**62**	**2 790**	**1 319,9**	**8 398,3**

Source: own calculation

Table 2: Costs in the case of indirect supply

Name	Distance (km)	Area (ha)	Yield (t)	Harvest and transportation cost (Euro)	Loading cost (Euro)	Number of rounds	Transportation cost (Euro)	Total cost (Euro)
Field 1	6	10	450	818,9	76,1	22,50	182,7	1077,7
Field 2	3	4	180	368,2	30,4	9,00	36,5	435,2
Field 3	9	10	450	818,9	76,1	22,50	274,0	1169,1
Field 4	4	4	180	368,2	30,4	9,00	48,7	447,3
Field 5	3	6	270	552,3	45,7	13,50	54,8	652,7
Field 6	4	3	135	276,1	22,8	6,75	36,5	335,5
Field 7	7	5	225	460,2	38,1	11,25	106,6	604,8
Field 8	9	6	270	552,3	45,7	13,50	164,4	762,3
Field 9	7	8	360	726,2	60,9	18,00	170,5	957,6
Field 10	4	6	270	552,3	45,7	13,50	73,1	671,0
Total:	**56**	**62**	**2 790**	**5 493,6**	**471,9**	**140**	**1147,8**	**7113,3**

Source: own calculation

Table 3: Costs in the case of combined supply

Name	Distance (km)	Area (ha)	Yield (t)	Harvest and transportation cost (Euro)	Loading cost (Euro)	Number of rounds	Transportation cost (Euro)	Total cost (Euro)
Field 1	3	10	450	818,9				
Field 2	1	4	180	368,2				
Storage 1	3		630		106,6	31,50	127,9	1 421,6
Field 3	5	10	450	818,9				
Field 4	1	4	180	368,2				
Storage 2	4		630		106,6	31,50	170,5	1 464,2
Field 5	3	6	270	552,3	45,7	13,50	54,8	652,7

Field 6	4	3	135	276,1	22,8	6,75	36,5	335,5
Field 7	7	8	360	726,2	60,9	18,00	170,5	957,6
Field 8	3	5	225	460,2				
Field 9	5	6	270	552,3				
Field 10	1	6	270	423,7				
Storage 3	4		765		129,4	38,25	207	1 772,6
Total:	**44**	**62**	**2 790**	**5 365,0**	**471,9**	**101**	**767,3**	**6 604,2**

Source: own calculation

Basing on the results we can draw the following conclusions:

- Total logistic costs are the highest in the case of direct supply (8 398,3 Euro). Base logistic cost amounts to 3,01 Euro/t.
- Total logistic costs in the case of indirect supply are 7 113,3 Euro, leading to a base logistic cost of 2,55 Euro/t.
- Combined supply results in considerable savings – total logistic costs in this case are 6 604,2 Euro with a base logistic cost of 2,36 Ft/t.
- Savings amount to 1 794,1 Euro compared to direct supply and 509,1 Euro compared to indirect supply.
- Direct supply is justified for shorter distances (1-3 km) – for distances larger than this storage facilities are to be built.
- In line fields must chose the nearest storage facility.

Positioning micro-regional storage facilities – in the case of a geometrical arrangement – is to be based on GPS coordinates, production/yield data and logistic points of equilibrium.

3. SUMMARY

The competitiveness of any company is significantly determined by the effectiveness of its supply chain. The keys of success are fast evaluation of information, immediate analysis and efficient support of decision making – these should be based on fast and reliable logistic procedures. In our survey we modelled the supply-logistics system of a virtual energy-cluster. The supply chain we examined comprised of harvesting, transport and storage process elements. We sought for the answer to the question of whether it is better to transport the raw material directly to the power plant or indirectly after temporary storage. In the case of indirect delivery, we wanted to know where storage facilities should be established and how many should there be in the interests of minimising total costs. In our survey we modelled the supply-logistics system of a virtual energy-cluster.

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István Réthy
Károly Róbert College, Hungary
rethy@karolyrobert.hu