Delivery of sustainable supply of non-food biomass to support a "resource-efficient" Bioeconomy in Europe

S2Biom Project Grant Agreement n°608622

WP8: Pilot (strategic) projects

Slovenian Forestry Institute (SFI)

DISTRICT HEATING SYSTEM ON WOOD CHIPS IN MUNICIPALITY OF MARIBOR– METHODOLOGY FOR ESTIMATION OF BIOMASS POTENTIALS AND INVESTMENT TOOL

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1. STARTING POINT

Town Maribor was selected as pilot project area since there was a concrete idea of switching and upgrading of existing district heating system on heating oil to wood biomass heating system. The project has high political support (from Ministry of environment of R Slovenia) since it should be a case study for promotion of modern district heating systems and has also known investor (Energy company from Maribor – Energetika Maribor)

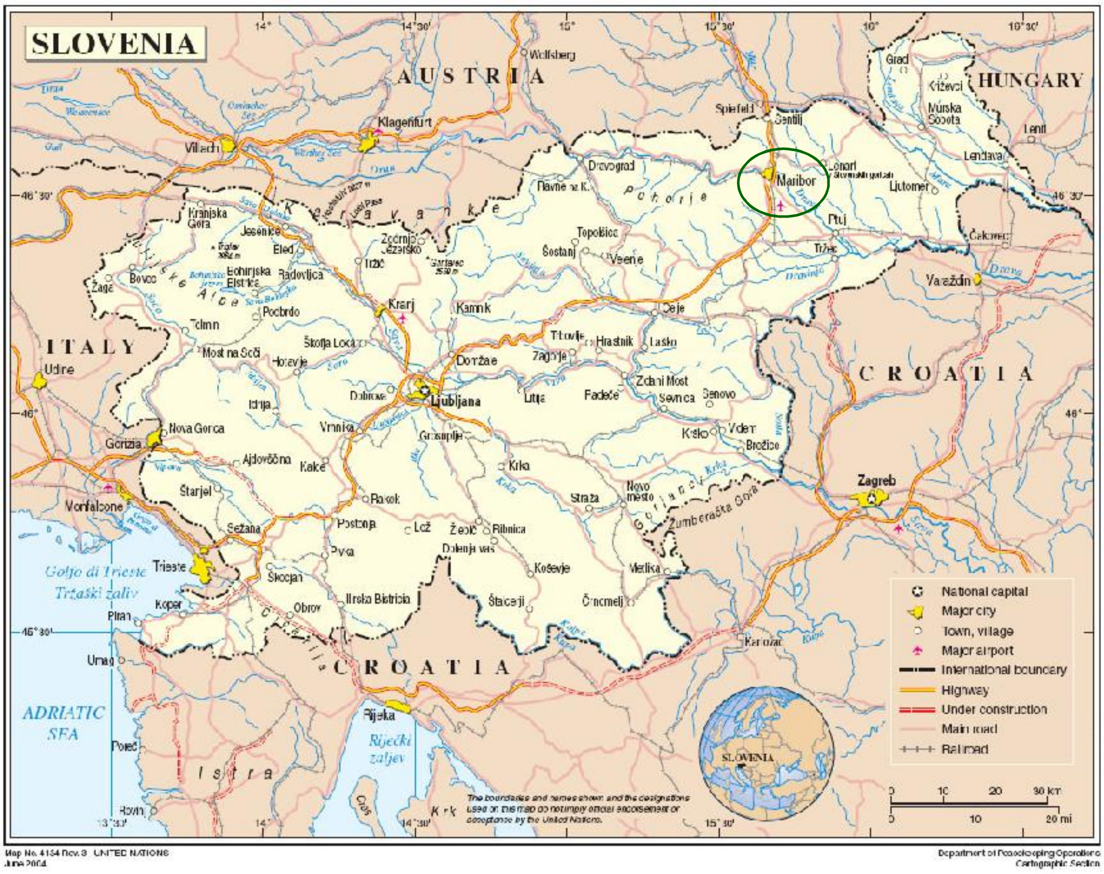

Figure 1 Map of Slovenia and position of Maribor

Maribor is the second-largest city in Slovenia with about 96,000 inhabitants in 2015. It is also the largest city of the traditional region of Lower Styria and the seat of the City Municipality of Maribor. The area of the city is arround 41 km^2. Maribor has a humid continental climate. Average temperatures hover around zero degrees Celsius during the winter. Summers are generally warm. Average temperatures during the city's warmest month (July) exceed 20 degrees Celsius, which is one of the main reasons for the Maribor wine tradition. The city sees on average roughly 900 mm (35.4 in) of precipitation annually and it's one of the sunniest Slovene cities, with an average of 266 sunny days throughout the course of the year. The most recent temperature heatwave record for August is 40.6 °C, measured at the Maribor–Tabor weather station by the Slovenian Environment Agency (ARSO) on 8 August 2013. Heating season usually starts at beginning of October and finish at the beginning of May.

The major part of Maribor is already covered by heating grid (with length of 34 066 m).

Figure 2 Existing heating grid in Maribor

The price of heat for households in March 2016 was 3,59 €/kWh and it was composed by fixed part of the price (1,9197 €/kW/month), price of actually used heat based on data from colorimeter (0,0466 €/kWh), contribution for energy efficiency (0,0008 €/kWh) and contribution for renewable sources of energy (1,2083 €/kWh).

The investor wants to install a modern high-efficiency boiler for combustion of biomass (wood chips) to heat facility, with power of 5.000 kW and all the associated peripheral equipment. The contracting authority wishes to produce and hand over as much heat energy from renewable sources (wood biomass) as possible to the district heating system manager. Since this is a relatively large energy facility, the cost of fuel is an important factor and desire to maximize the optimization of logistics is great. Boiler is designed to allow thermal treatment of wood chips with high water content (up to 65 %), with dimensions 3.15 – 100 mm and up to 6 % ash on a dry basis (Table 1). The investor will pay special attention to the system of cleaning flue gas as the construction of the energy facility is among the measures to reduce air pollution in municipality of Maribor. Also facility is positioned in close proximity to apartment buildings and therefore requires the utmost limitations to any emissions into the environment, especially particulate emissions (PM10 and PAH) and noise.

Table 1 Required (expected) characteristic data device – boiler (source: Energetika Maribor, Annex 1)

Thermal power	5.000 kW
Temperature regime	**110/70 ^{0}C**
Working pressure	**16 bar**
Thermal efficiency	**ηt > 85%**
Operation at partial power	**40 % from the nominal (thermal) power**
Anticipated annual operation	**5.000 operating hours at full power**

Table 2 Annual requirement of biomass to produce thermal energy

Operating hours	Lower calorific value - Hu	Need for biomass – calculation of the investor	MW/year	Need for biomass – calculation of SFI in tonnes of dry substance
1500	1.94	4559 t*	□ 8800	2051.55 t_{wb}**
3000		9118 t*	□17600	4103.10 t_{wb}**
5000		15197 t*	□ 29400	6838.65 t_{wb}**

** the investor assumed for the calculation of tonnes 55 % water content and 40 % of deciduous*

*** tonnes with bark - ton of absolutely dry matter = 0 % water content*

The mains aim of this study are:

- Specify the availability of wood biomass potential and amount of wood biomass available depending on required quality (moisture, type of wood – deciduous/coniferous, …);
- Figure out whether there is enough available feedstock in the nearby forests – distance to feedstock with various forms of ownership (state or private forests);
- Prepare recommendations for the storage of wood biomass as roundwood (brief description of storage);
- Analyse the production cost of wood chips.

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2. METHODOLOGY

There is a lot of different software based on graph theory that provides analysis of different (spatial, social...) networks. These include ArcGIS, Wolfram Mathematica, R! and others. For analysis we used software Network Analyst, which can be found within the ESRI ArcGIS software environment and provides the solution of complex logistic problems. Network Analyst is a research tool as well as an operative tool, with which it is possible to increase efficiency due to reduction of mileage, resulting in reduced vehicle attrition, fuel consumption and time on account of driving. Network Analyst comprehensively provides more efficient strategic and organizational policy. It represents a tool to determine cost- optimal relations between resources (supply side: potential feedstock...) and sinks (primary wood industry, energy use..). Analysis is based on (cost) matrices, which originate from an area of social network analysis or deterministic mathematics area, where are known as graph theory. Matrices generated by the tool "Network Analyst" often lead to more detailed and extensive analysis. For example, they predict distances / travel time / travel cost that we have to do, to ensure the selected feedstock with a pre-planned use of feedstock (e.g. consumption resulting from the investment plan). These distances are based on mathematical operations that help us forecasting the costs.

The model was created as an investment tool, where we are interested in transport costs at a selected location for a predetermined amount of feedstock. By saying model we mean a computer algorithm in which a predetermined sequence connects different mathematical and spatial operations. The model is therefore based on the basis of overlapping different spatial situated data and theoretical interactions between them. Performance analysis is largely dependent on the accuracy or details of the input data.

2.1 Input data

Before analysis, we have to collect specific inputs. The input data is divided into two sets:

i) data on network,
ii) data on resources and sinks (supply and demand side).

The first set of data is defining the network (roads, restrictions, traffic signs, toll stations...). In the second set there is combined data on the supply side (feedstock resources pool) and data on demand side (assessed location, competitive use...). Analyses were performed for three pilot locations with the entire country of Slovenia as the impact area.

2.1.1 Data on network

For the zone of pilot area we need data that represents logistic network, therefore road infrastructure. The states road network represents our starting point, to which we have later added lower class roads according to a specified algorithm (e.g. local roads, forest roads).

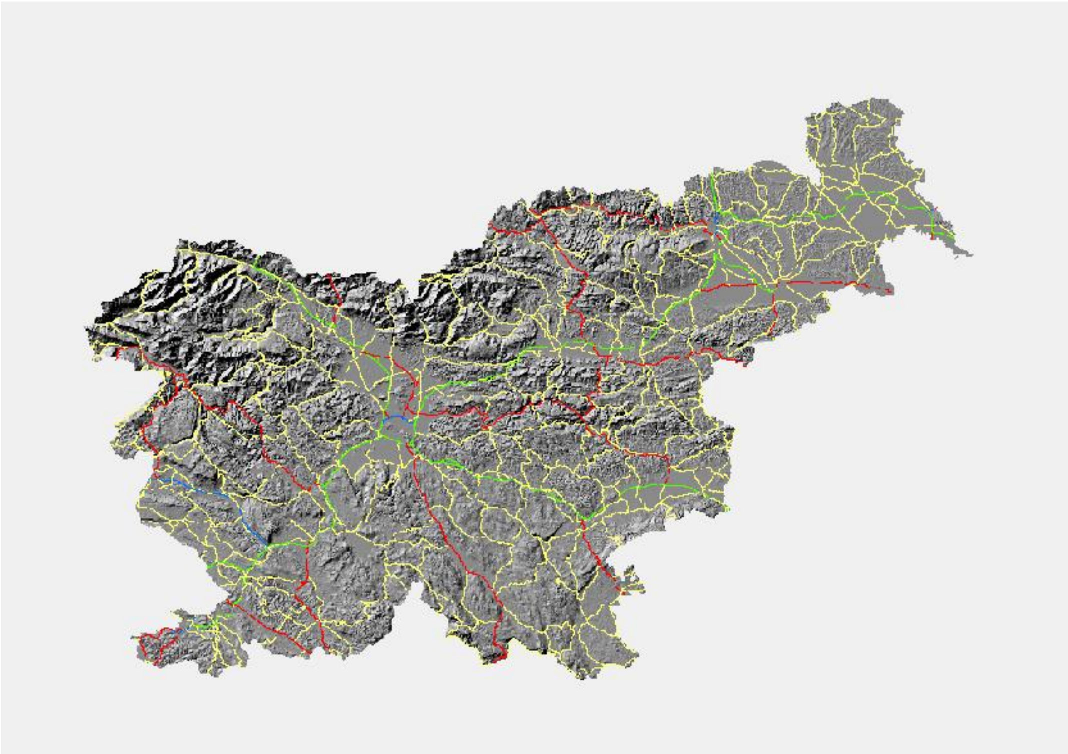

Figure 3 State roads network relevant for freight transport.

If necessary, we supplement the road network with traffic restrictions. In the case of our model this means a restriction of freight transport by a traffic sign with a prohibition of driving too heavy vehicles (over 7.5 tonnes).

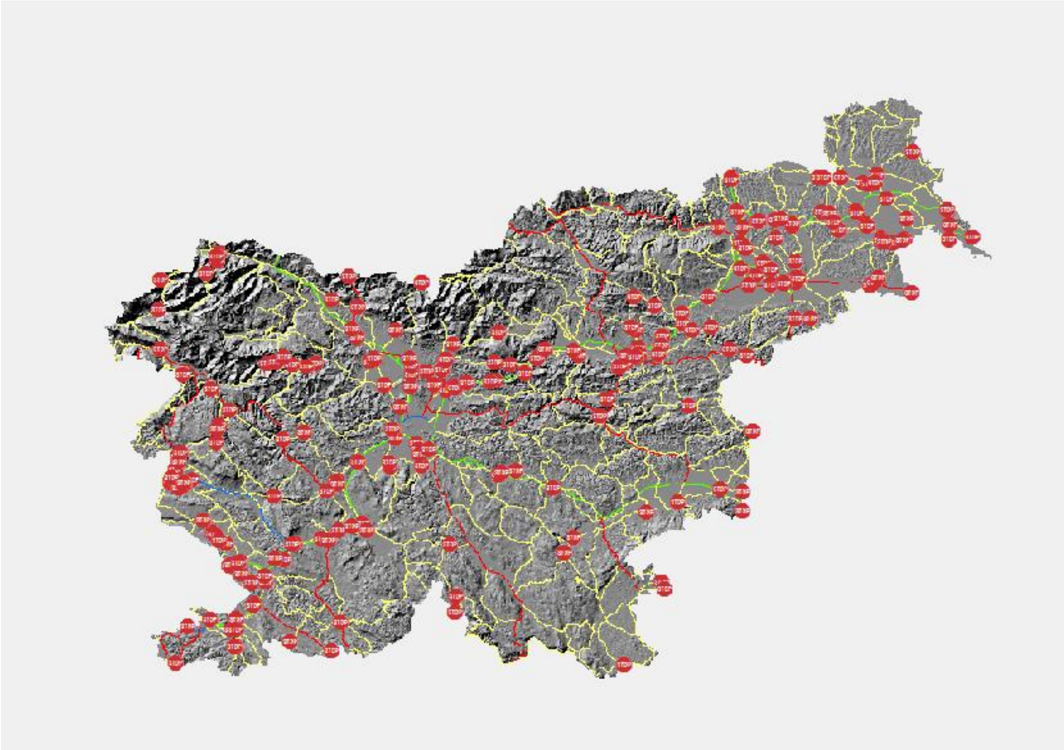

Figure 4 State roads network relevant for freight transport with taking into account the road traffic restrictions in the Republic of Slovenia.

After the transport network is ready, it is necessary to define the particulars of feedstock resources (e.g. biomass potentials) and their sinks (demand locations and their competition, who is also targeting to same feedstock resources).

2.2 Data on resources and sinks

In SFI model the biomass potentials represent the annual quantity of lower quality wood in assortment structure of felling in last five years. In this research lower quality wood includes pulpwood, other lower quality roundwood and energy wood.

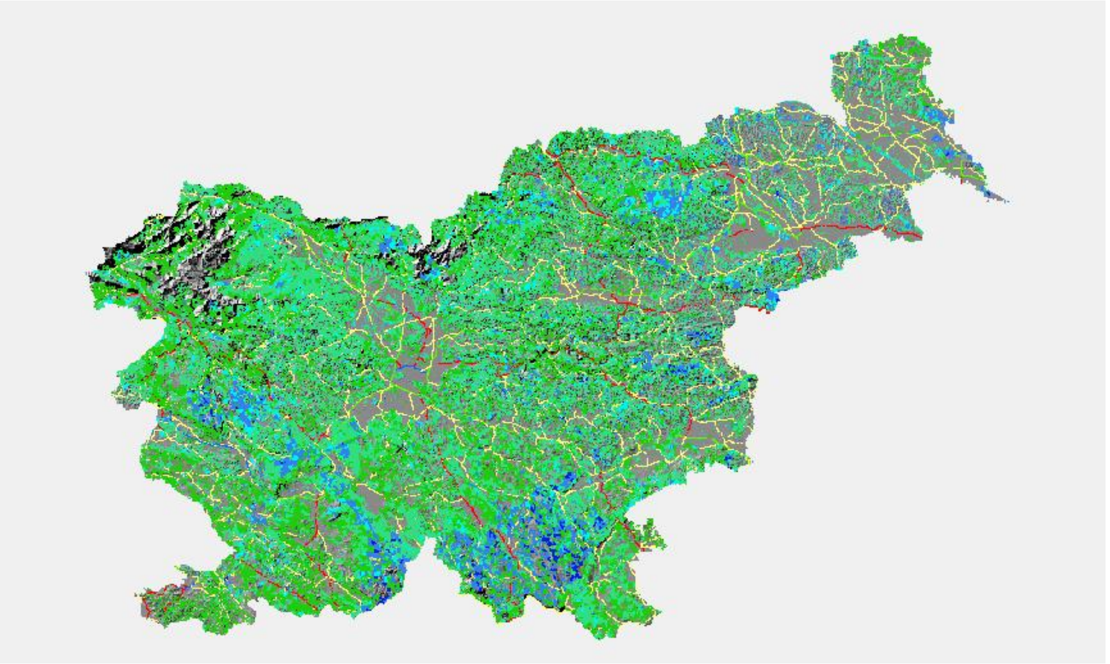

Figure 5 Map of marketable quantities of lower quality wood.

A specified algorithm transformed biomass potentials into points of freight on a forest road. Each such point represents a potential location with 22 tonnes of freight, which means a full drive of forest transport composition (i.e. truck for roundwood transportation).

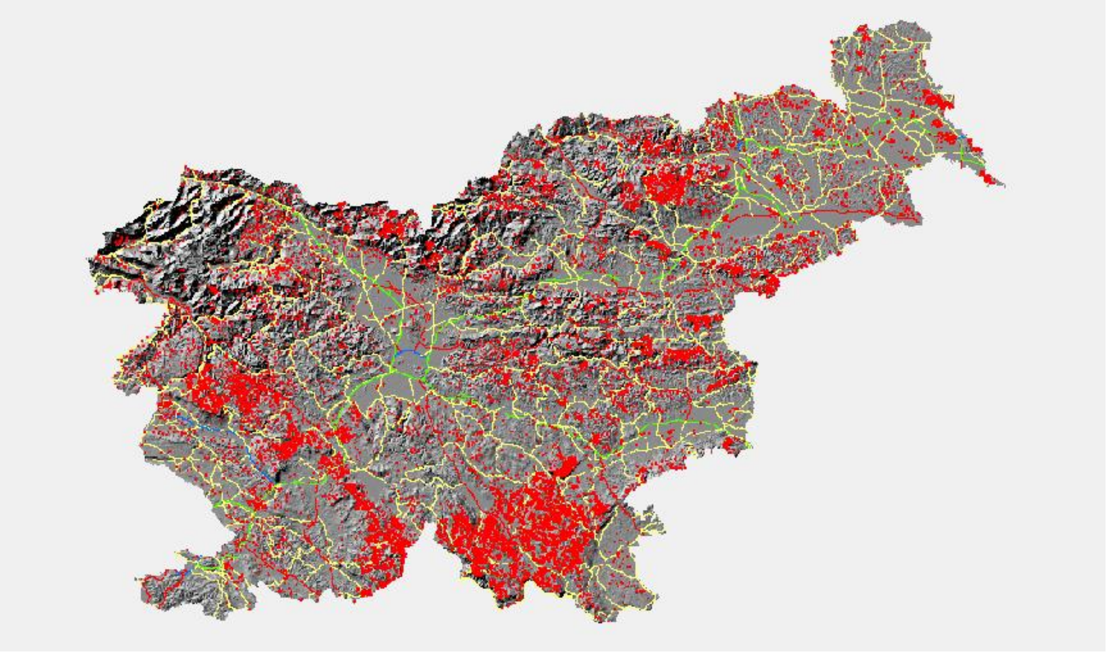

Figure 6 Locations of freight along the road.

Presented biomass potentials are represented by the potential quantity of lower quality wood available on the Slovenian market. This means that while we were preparing the base of feedstock users (demand side) we could not ignore competitive use on the market, which is why we implemented competitive use in the SFI model. This is an industry which deals with the processing of lower quality wood (pulp industry) and the use of lower quality wood for energy purposes, such as co-combustion, biomass power plants and biomass remote heating systems. These companies represent competitive use locations in the model. All of the locations (points of analyses and points of competitive use) were determined by weights. Weight represents the estimated annual production.

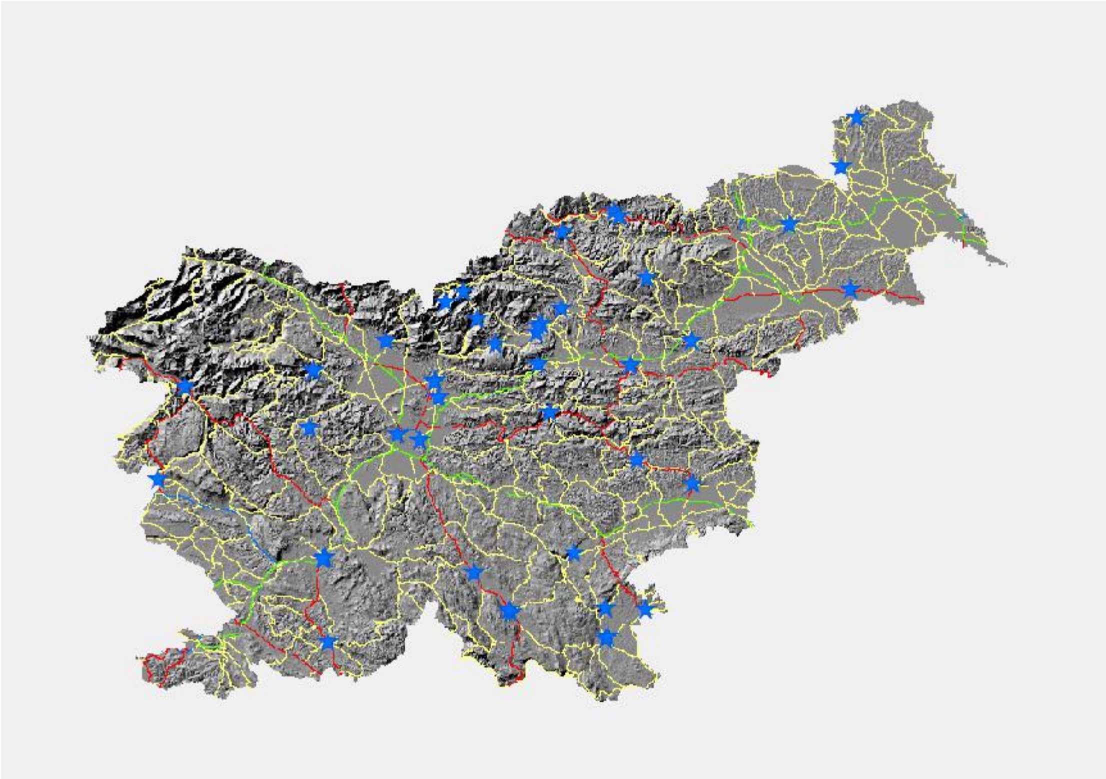

Figure 7 Locations of existing competitive use (Source: Slovenian Forestry Institute and web portal EnGIS).

Last but not least we need to define the particulars of the studied locations (i.e. pilot locations). We can evaluate infinite number of pilot locations, but it needs to be taken into account that each studied locations extends the time needed for aggregation of results. Therefore it is advisable to preselect (up to 5) potential pilot locations and run the model to select the best options.

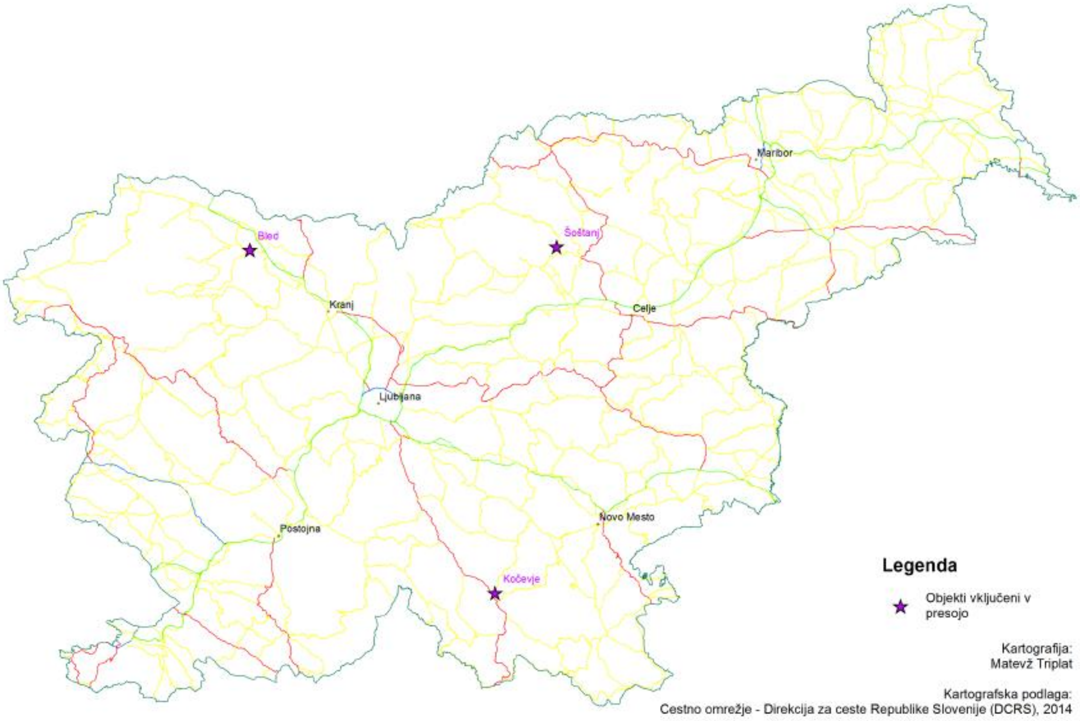

Figure 8 Pilot locations from the first test of methodology (2014)

For transport costs assessment we used the equation and assumptions described below.

Table 3 Basic assumptions related to calculation of transportation costs.

Truck loading time (minutes)	**30**
Truck unloading time (minutes)	15
Truck costs (€/h)	101.9

Equation 1: Calculation of transport costs for each line

$$C_{i=n} = \left(t_p * 2 + (t_n + t_r)\right) * \frac{c_t}{P}$$

Where:

$C_{i=n}$ = transportation cost [€]

t_p = travel times [min]

t_n = time for the loading of truck [min]

t_r = time for the unloading of truck [min]

c_t = truck costs [€/ h]

P = maximum allowable load

2.2 Calculation of potential of lower quality wood

The model which calculates quantity and potential assessment of wood from Slovenian forests is based on detailed and up to date input data. These data were obtained from: the multi-annual censuses of agricultural holdings and sample censuses of agriculture by the Statistical Office Republic of Slovenia (SURS), the annual reports from Farmland and Forest Fund of the Republic of Slovenia (SKZG), the register of spatial units (GURS), the internal data from Slovenian Forestry Institute (GIS; egg. data from recording normative), and different databases of forest inventories from Slovenian Forest Service (ZGS).

The methodology for calculating quantity and potential estimates of wood is based on the market quantities of round wood, which excluded estimated home use. Estimates of actual and theoretical market quantities of wood are calculated. Actual market quantities are actual average annual wood quantities which were harvested in years 2009-2013 and put on the market. Theoretical market potential is maximum quantity of wood which could be harvested and offered on market (including home use) and meanwhile also ensuring sustainable forest management. Analysis was made separately for private forests and other forms of forest ownership. Quantities were calculated for lower quality wood. The entire methodology has been developed on bases of current market conditions and estimated use of wood in Slovenia.

The detailed methodology for calculating the potential quantities of wood in Slovenia is presented in the article "The methodology for wood potential assessment in Slovenia".

2.3 The costs estimate for wood chips production

In our environment chips production chains are generally related to chips production from different types of input feedstock (forest residue, wood residues from wood processing, round lower quality wood). Despite the fact that in practice more and more green chips are produced from forest residue, there is still many unresolved issues that still do not have adequate legal solutions. Main concerns in chip production from forest residues are:

- Majority of nutrients is stored in the leaves/needles. The felling of trees and production of chips from forest residues leads to larger removal of nutrients from forest ecosystems. It is a nutrient limiting further forest production. Long significant nutrient removal leads to deterioration of the site productivity, the decline in increment, difficulty in natural regeneration of demanding tree species, greater susceptibility to pests and diseases, change in tree species composition, etc.;
- Technological limitations when collecting forest residues – in the forest (due to the movement of machinery on pathless terrain) should not increase the proportion of disturbed area or damaged forest soil;
- Restrictions in forest residues use in case of mechanical logging mainly stemming from the fact that forest residues are used to reduce the negative effects for the soil, which is achieved by overlapping skidding tracks with forest residues;
- Economic eligibility of collecting forest residues which are scattered through the forest is questionable.

For the purposes of the study we focused on the production of wood chips from lower-quality roundwood. We assume the traditional way of logging which is environmentally acceptable. The process starts in the forest stand with felling and pollarding with chainsaw. Skidding to forest road is provided by adapted farm tractor. Transport from the forest road to roundwood storage is made by forestry transport composition. Grinding of roundwood is provided to a covered intermediate storage directly from a wood storage. Transport of wood chips is provided to the boiler room from there depending on the weekly needs.

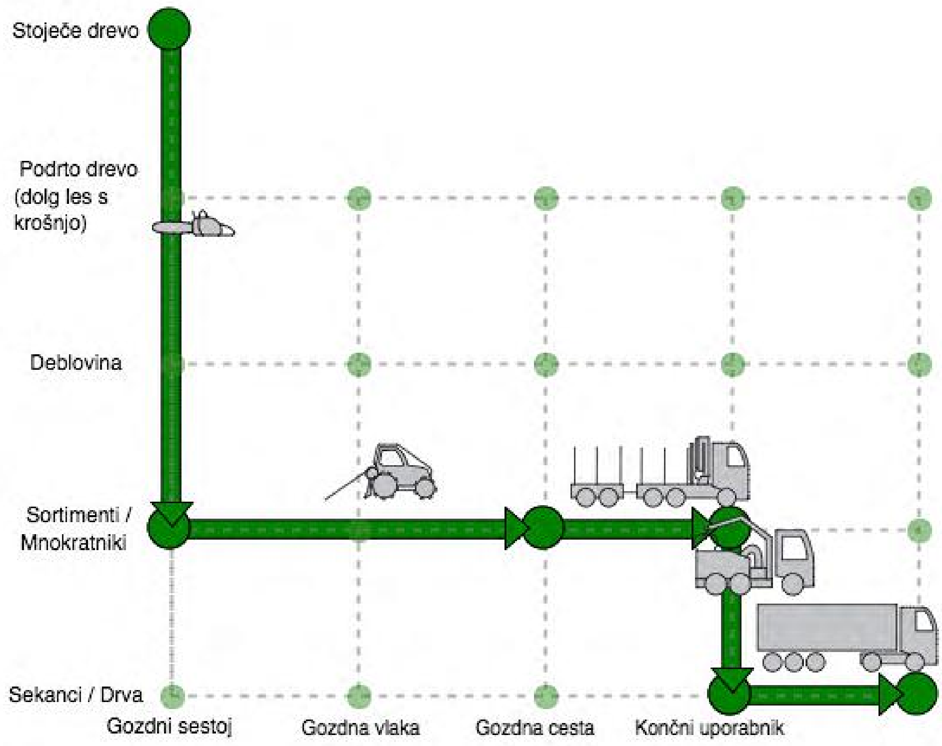

Figure 9 Technological model of presented production of wood chips.

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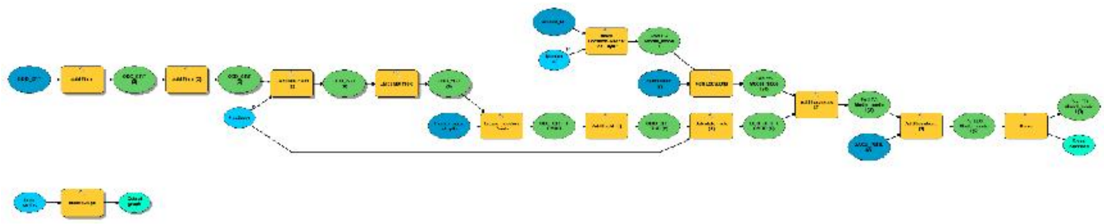

Figure 10 Model defines the type and sequence of tools or computer operations.

2.4 Modelling for pilot area of Maribor and its surroundings

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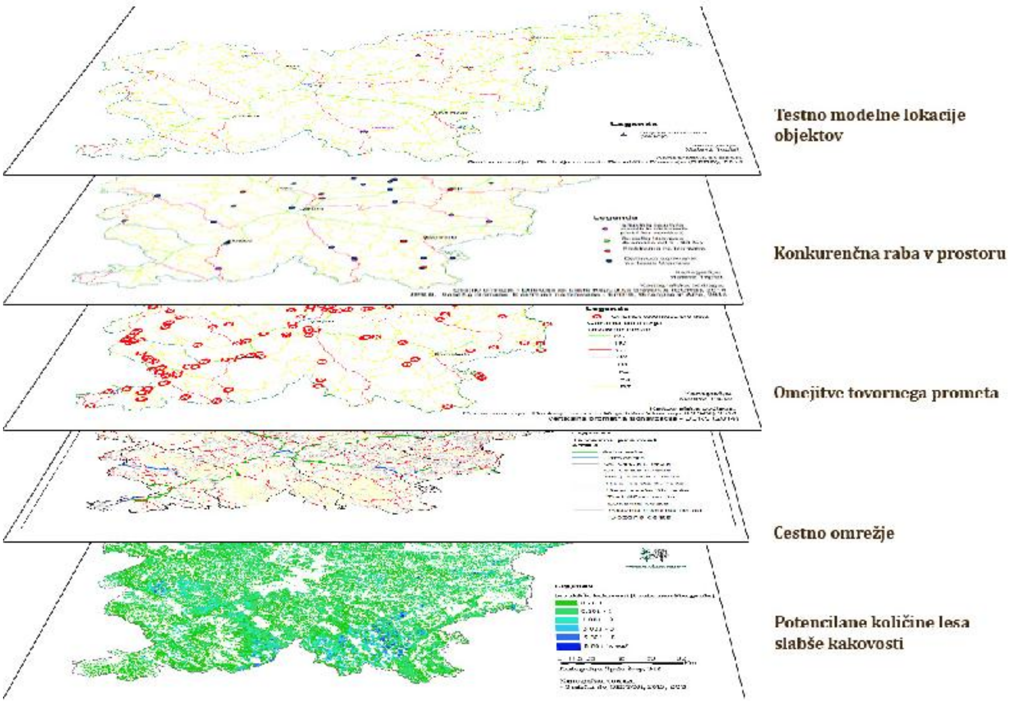

Figure 11 Overlapping layers according to an algorithm determined by the designed model.

Simulation model is looking for the most favourable routes by time (eg. if we have two routes of same distance, the model will choose the one, which can truck faster transports). Time from a point on the forest road to the chosen location (eg. wood storage) is calculated based on slope distance and average speed (average speeds of various categorised roads are hypothetical). The detailed methodology of placement for assessment of transport costs was first introduced in 2014.

2.4.1 Transportation of roundwood

In concrete case the model suggests n- routes (from forest road to the selected wood storage in Maribor (Figure 4)) needed to ensure sufficient quantities of lower quality wood suitable for wood chips.

Figure 12 Location selected for transport costs simulation.

The process of timber transportation includes the phase of preparation on transport, the phase of transport and the phase of the end of transport. In this study we focused only on a limited part of processes. To calculate total time of each moved freight we considered time of full load transportation (from location on forest road to client wood storage), time of no-load transportation and estimated time needed for timber loading and unloading.

$$\begin{aligned} Total\ transport\ time &= time\ of\ no\ load\ transportation + time\ for\ timber\ loading \\ &+ time\ of\ full\ load\ transportation + time\ for\ timber\ unloading \end{aligned}$$

Transport costs are calculate on the basis of forestry transport composition (FTC) calculation – truck, determined by an online tool WoodChainManager and defined in Table 3.

$$Transport\ costs = Total\ transport\ time \times (Costs\ FTC + Driver\ costs)$$

Worker costs (in selected case the driver of the truck) covers the minimum base of gross salary which is determined by the collective agreement for forestry. The work of forestry truck driver is classified after collective agreement as a typical work in the fare class V. The minimum base of gross salary for fare class V. is 969.18 €.

Worker is after collective agreement entitled to:

- Vacation bonus in the amount of 850 € for a full-time,
- Reimbursement of costs for meals during work in the amount of 6.12 €/day
- Reimbursement of travel expenses to and from work (estimate – 10 km/day)

Table 4 Basic assumptions used to simulate the transport costs.

Time needed for timber loading	30	min
Time needed for timber unloading	15	min
Material truck costs	84.96	€/ h
Work costs (driver)	7.83	€/ h

2.4.2 Costs of wood chips production and competitive use

To calculate costs of wood chips production we must take market price of the service in the region into account. Slovenian Forestry Institute monitors the market of service of wood fuel production – on the basis of interviewing the machine owners we perform researches about production and wood chips selling. In 2015 research we included the majority of chipper owners in Slovenia. We included 186 chippers owned by 179 individuals or enterprises (Figure 5). Based on the collected data we found that the price of services in the enlarged region is 3 – 7.32 €/bulk m^3 (with VAT). The contracting authority wants to produce larger amount of wood chips therefore we took the lowest price of the service into account, amounting to 3 €/bulk m^3.

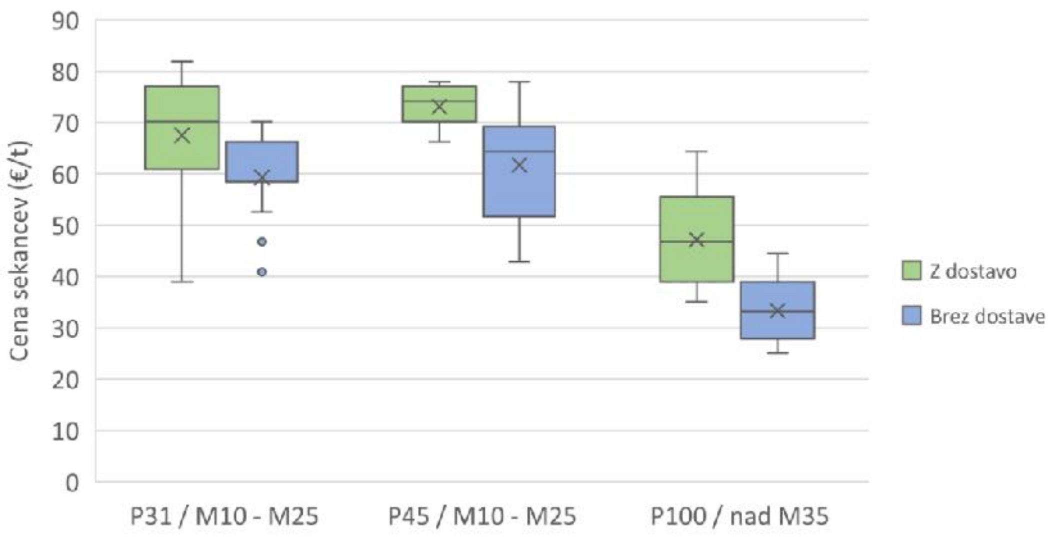

Figure 13 Prices of wood chips (€/t) per type of wood chips and with delivery costs (green bars) and without delivery costs (blue bars) in Slovenian market at the beginning of 2016

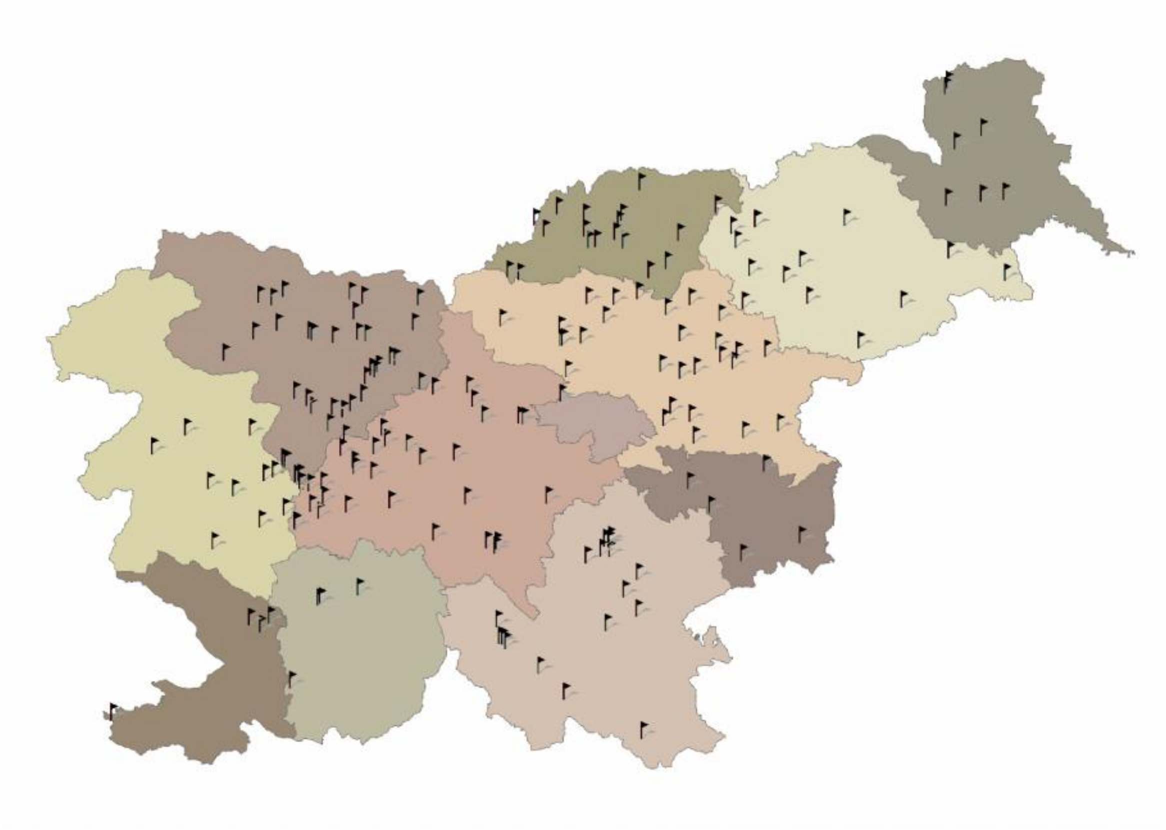

Figure 14 Chipper locations by statistical regions of Slovenia (Source: Slovenian Forestry Institute)

Competitive use in space represents an important consideration in the assessment of selected locations. Chips producers represent the greatest competition therefore we defined them as a spatially distributed point objects with a specific need for lower quality wood, which represents the competition on a market of lower quality wood.

The use of wood in households is excluded at the level of resources, while import and export are not taken into account in the analysis.

2.5 Storage (roundwood and wood chips)

Wood fuel storage method has a significant impact on its quality. Wood can be stored as roundwood or in any form of wood fuel. Wood can be stored at intermediate storages or in the immediate vicinity of the boiler room. The most important characteristic for wood is to be dried in a convenient location, whatever the form of fuel or storage duration are (ventilated and dry area). The best place for storage and drying of wood chips is a covered fortified surface (concrete or asphalt) on a sunny and ventilated location. The architectural structure of the cover should allow maximum ventilation of stored material and facilitate handling with wood chips (the height of storage and height of chips).

Figure 15 Example of an adequately regulated space for production and intermediate storing of wood chips in a suitable facility (biomass logistic centre in Pölstalu)

The investor is recommended to:

- Feedstock for wood chips should be stored at least one summer on ventilated and sunny area (natural drying);
- Stored wood contains 25 – 30 % of water at the time of chips production during summer;
- In a rainy summer it is recommended to cover the wood (commercially available paper, fabric or plastic sheet);
- Only materials that allow air to circulate freely are used for covering;
- Removing chips from storage should be controlled and planned ("first come – first go");
- Caution when working with long stored chips (exposure to fine wood particles and micro-organisms);
- Try to avoid the storage of chips with a high proportion of leaves and needles otherwise the chips could be heated due to very intense activity of micro-organisms and then the process of decay starts within a few weeks. Chips with a high proportion of leaves and needles should therefore be stored in piles with a maximum height of 7 m and for the shortest period of time possible.

Adequately regulated space as defined in figure 6 (roundwood is stacked next to covered space) allows optimal production. For all other cases of storage, it is necessary to take costs of clamp loader (5 €/m^3) into account, which either delivers feedstock to Chipper or drives chips away to a storage house.

The investor will store feedstock on two locations. At one location 11.000 m^2 of area is provided for storing roundwood and other alternative sources of feedstock (forest residues, residues from wood processing, green cut, …) for wood chips production and for intermediate storage of wood chips in storage house (covered part is 400 m^2). The other location (at the energy facility) is provided for weekly storage of wood chips in a container with a volume of 1.500 m^3.

Recommended area for storage of lower quality roundwood depends on a number of factors. These are: the length of roundwood (determines the width of the stack), the length of the stack, the required distance between the stacks, the required distance between the stacks and other facilities as well as conversion factors and planned quantity of wood for storage. Table 4 shows a variant calculation of the necessary areas for roundwood storage with the following assumptions: the width of the stack and intermediate distance between the stacks as well as distance to other objects is 4 m, height of stacks is 4 m and the conversion factor is 0.60 m^3_{wb}/stacked m^3.

Table 5 Variant calculation of areas for lower quality roundwood storage areas

m^3_{wb}	Stacked m^3	Number of stacks	1	2	3	4	5	6	7
500	833,3	Area (m^2)	769	761	822	901	986	1075	1166
1000	1666,7	Area (m^2)	1394	1282	1308	1370	1445	1527	1613
1500	2500,0	Area (m^2)	2019	1803	1794	1838	1903	1978	2059
2000	3333,3	Area (m^2)	2644	2323	2280	2307	2361	2430	2506
2500	4166,7	Area (m^2)	3269	2844	2767	2776	2820	2881	2952
3000	5000,0	Area (m^2)	3894	3365	3253	3245	3278	3332	3399
3500	5833,3	Area (m^2)	4519	3886	3739	3713	3736	3784	3845
4000	6666,7	Area (m^2)	5144	4407	4225	4182	4195	4235	4291
4500	7500,0	Area (m^2)	5769	4928	4711	4651	4653	4687	4738
5000	8333,3	Area (m^2)	6394	5448	5197	5120	5111	5138	5184

m^3_{wb} – cubic meter of wood with bark
Stacked m^3 – stacked cubic meter

2.5.1 Transport of wood chips from storage to boiler

There are additional transport costs at two (dislocated) storages because the shortest possible route between the storages is 4.8 km. For the transportation of wood chips traditional bulk transport can be used, but from technological point of view the following solutions are more appropriate:

- Hook loaders with a container up to 40 m^3. It is possible to defer it at any place where chip production will be and later loaded on the truck. In this mode wood chips can be put in a container directly;
- Semitrailers with movable bottom of volume 90 m^3;
- Trailers that blow wood chips in storage.

For the purposes of the study a semitrailer truck with a movable bottom and bulk storage space of 90 m^3 of wood chips was selected, which is then filled with a small construction loader. Table 5 represents the basic assumptions used to estimate the transport costs of wood chips from intermediate storage to boiler.

Table 6 Basic assumptions used to simulate transport costs for the transport of wood chips.

Time needed for timber loading	10	min
Time needed for timber unloading	20	min
Material costs of truck for bulk	70.56	€/ h
Material cost for wheel and combined loader	90	€/ h
The cost of worker	7.83	€/ h

All prices used in the study include VAT.

4 RESULTS

Basicly SFI model provide most appropriate locations and detailed information's on routes, travel times, travelled distances, transport cost etc. The model can be used by investors or local decision makers when deciding to start with biomass projects.

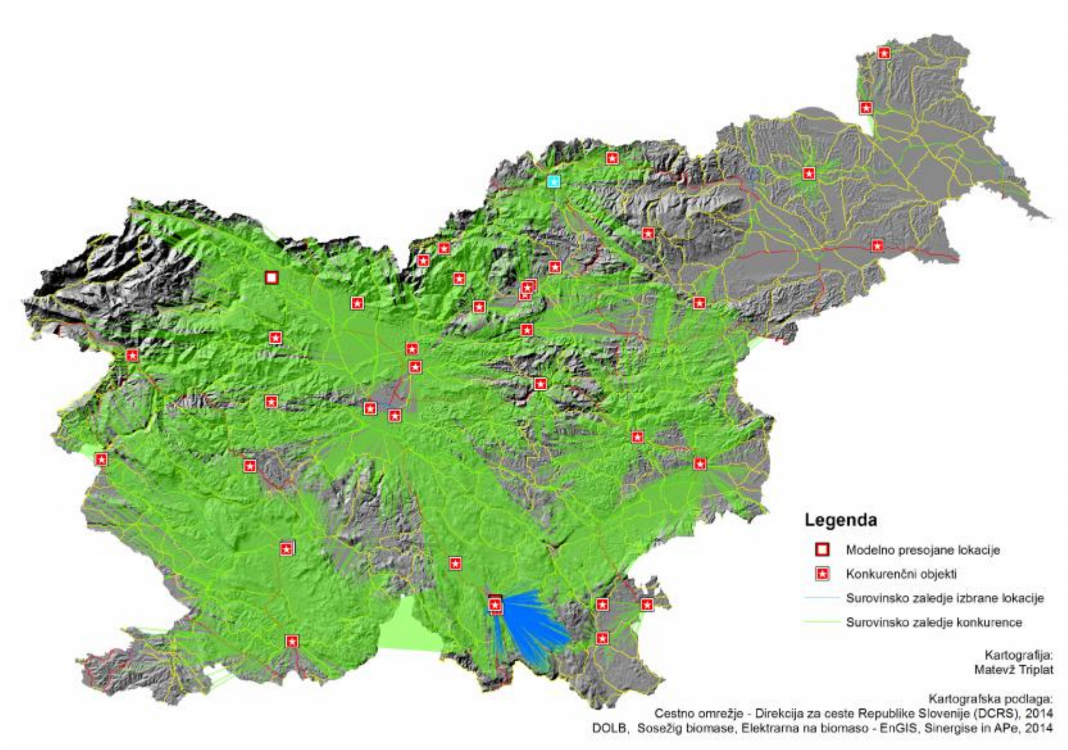

Figure 16 Feedstock polls for studied locations (blue spot is the feedstock area for locations selected by SFI model as the most appropriate locations for CHP).

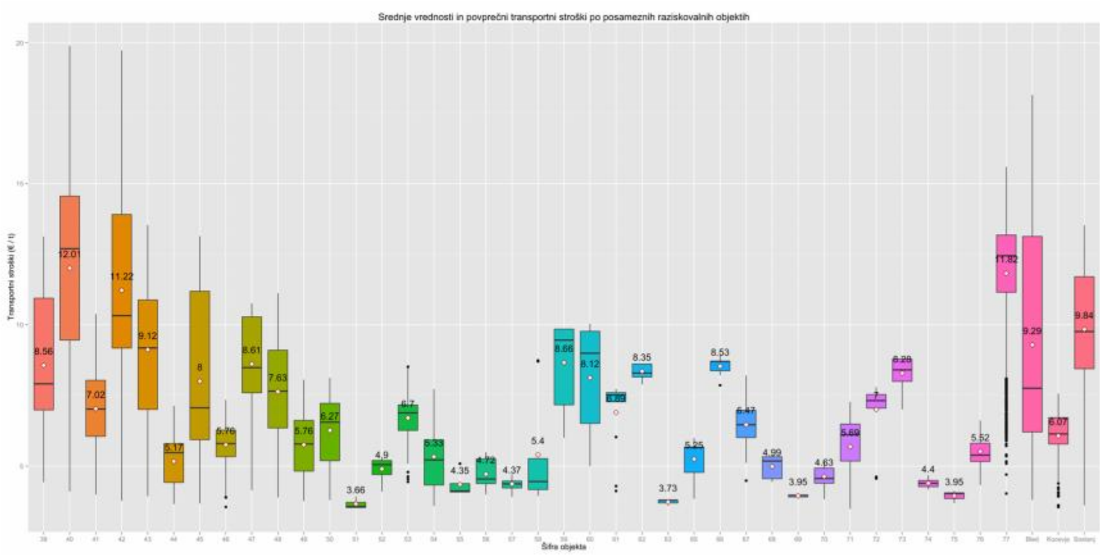

Figure 17 Transport cost for theoretical locations – an example of possible result from the model

2.6 Estimates of actual market volumes or actual market potential of lower quality wood in Slovenia

Quantity assessment of lower quality wood in Slovenia which is coming to market per year is 470.000 tones (Table 7) and this is an actual market quantity. Calculation based on a total forest area the actual market quantity of lower quality wood is 0.4 tones/ha per year.

Table 7 Actual market quantity assessment of lower quality wood per year in Slovenian forest

Lower quality wood	Coniferous [t_{wb}]	Deciduous [t_{wb}]	Total [t_{wb}]
State and municipal forests and forests of other legal entities	60.000	260.000	320.000
Private forests	50.000	100.000	150.000
TOTAL	110.000	360.000	470.000

Figure 18 shows the spatial distribution of actual market quantities where it is evident that the greater quantities of actual harvested timber per year entering the market (more than 5 t/ha) are on areas of Kočevje, Suha Krajina, Snežnik, Trnovski gozd and in Posavje region, especially in Kozjansko and Bohor surroundings.

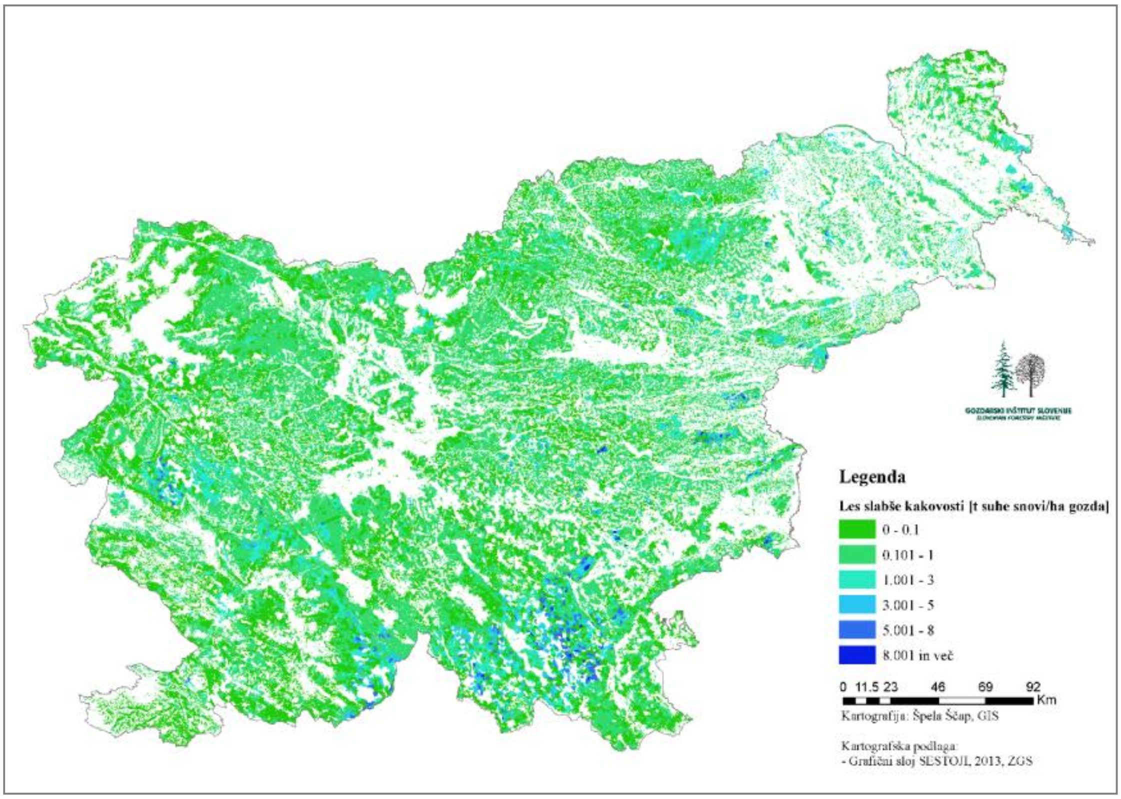

Figure 18 : Map of actual market quantities of lower quality wood (in tonnes of absolute dry matter per hectare of forest per year).

2.6.1 Assessment of lower quality wood potential in enlarged region of Styria overview

Quantity assessment of lower quality wood which is entering the market per year in the enlarged region of Styria (statistical regions Podravska, Pomurska, Savinjska, Koroška in Zasavska) amounts to 135.400 t (table 8) and this is an actual market potential for the foreseen plant in Maribor. Actual market potential of lower quality wood is 0.39 t/ha per year, which is calculated from the total area of forest and does not deviate significantly from the Slovenian average (0.4 t/ha).

Table 8 Actual and theoretical quantity assessment of lower quality wood on market in the enlarged region of Styria.

		Actual potential				Theoretical potential			
		State forest and other forms		Private forests		State forest and other forms		Private forests	
Region	Forest area (ha)	Deciduous (dry tonnes)	Coniferous (dry tonnes)	Deciduous (dry tonnes)	Coniferous (dry tonnes)	Deciduous (dry tonnes)	Coniferous (dry tonnes)	Deciduous (dry tonnes)	Coniferous (dry tonnes)
Koroška	72400	4900	7800	2100	4600	6800	8400	25300	4900
Podravska	84946	22700	7100	8100	3000	29800	7500	140800	22700
Pomurska	39739	14000	2000	3900	600	20700	2400	59100	14000
Savinjska	134915	25300	5800	14300	6500	27800	6900	161300	25300
Zasavska	17070	900	300	1200	300	2500	300	24300	900
Total	349070	67800	23000	29600	15000	87600	25500	410800	67800

Figure 19 shows that the most actual market quantity of lower quality wood is located in Podravska region in the heart of Pohorje where the biggest areas of state forests are. Bigger amounts of actual market potentials of lower quality wood (over 5 t/ha) can also be found on the eastern part of Pomurska region and on southern part of Savinjska region.

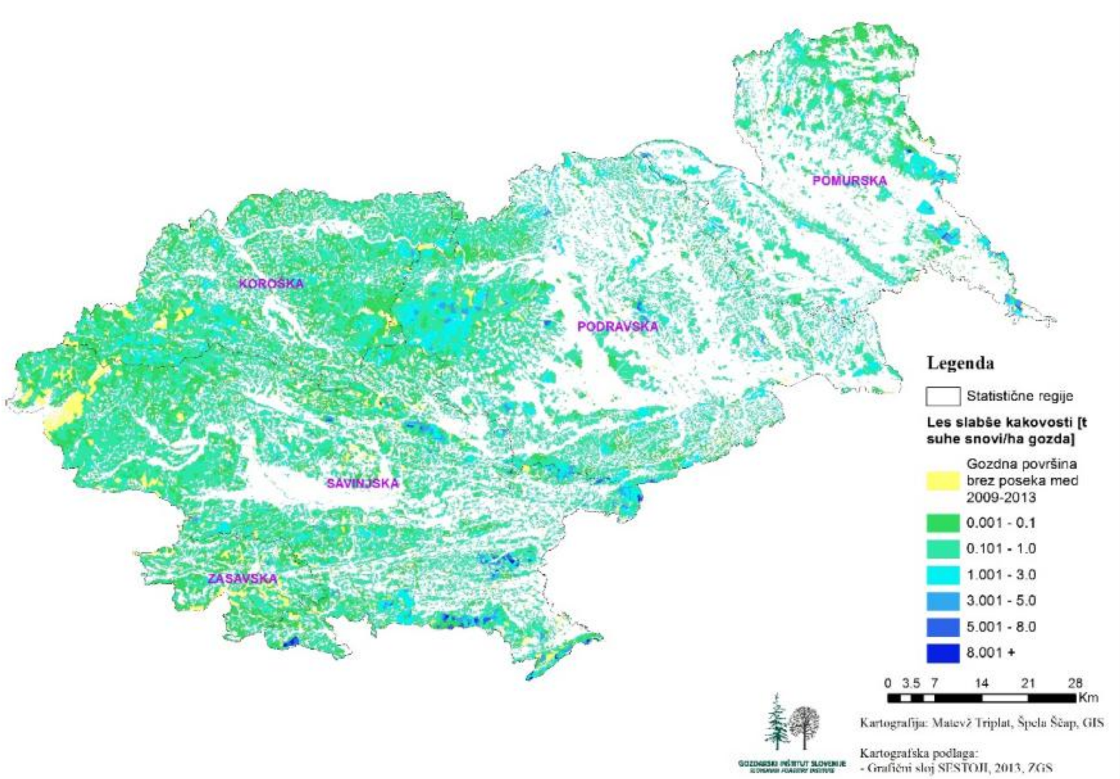

Figure 19 Map of actual market quantity of lower quality wood in statistical regions of Podravska, Pomurska, Savinjska, Koroška and Zasavska.

Figure 20 clearly shows that these are the areas where the annual level reached (in some cases even exceeded) the theoretical potential of lower quality wood (the one that represents maximum quantity of wood, which can be harvested and offered on market while also ensuring sustainable forest management). Figure 20 gives the information to the investor that there is still a large part of untapped potential in Podravska region. This is already reflected in table 8 which shows that almost the entire area of untapped potential is located in private forests.

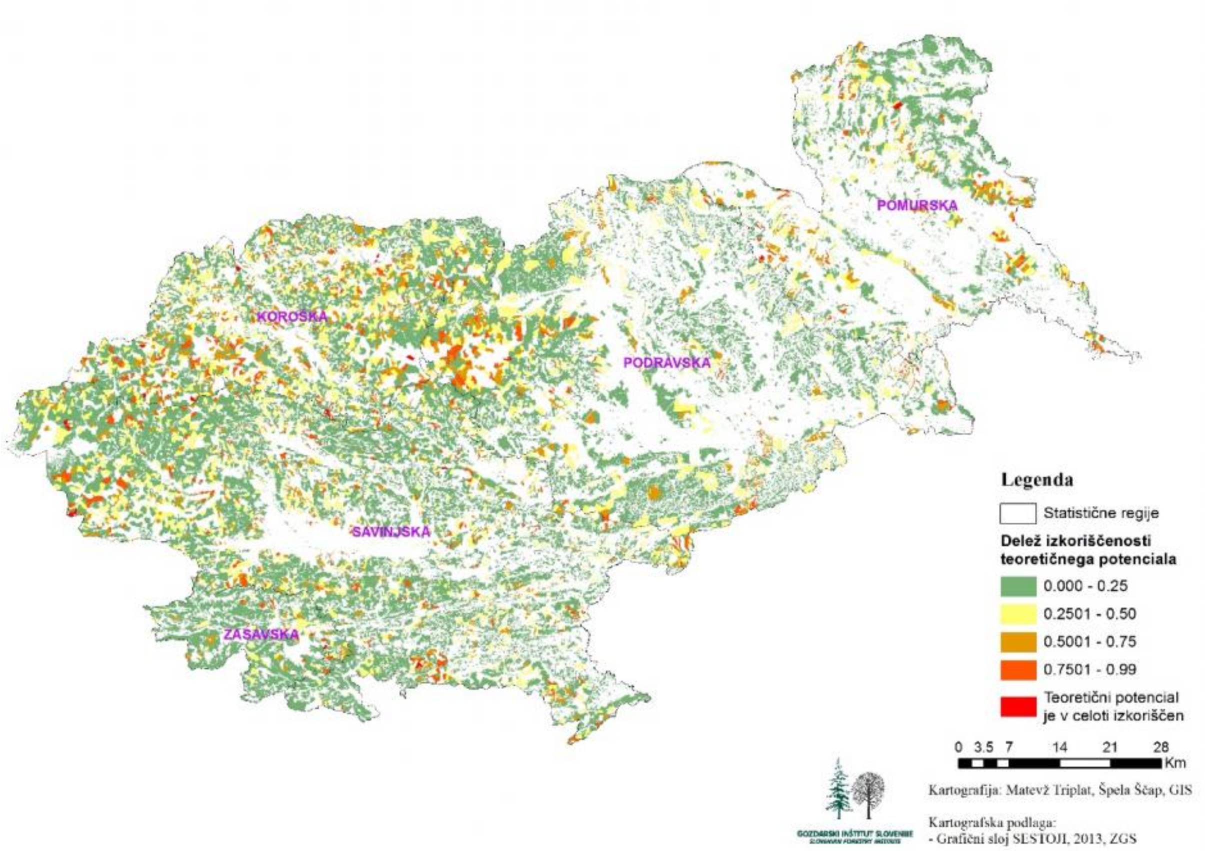

Figure 20 Utilization map showing proportions of theoretical potential market quantities of lower quality wood by statistical regions (Podravska, Pomurska, Savinjska, Koroška and Zasavska).

2.7 Simulation of production and supply of wood chips

Expected results of the model are different general maps (egg. an impact (feedstock) area, distance from feedstock), assessed theoretical transport costs and the demand curve which illustrates the relationship between transportation costs and availability of feedstock.

Simulation of transport costs for Maribor municipality was performed in different scenarios in which forest ownership and competitive use in area (chippers) play the main role. Table 9 defines all predefined scenarios.

Table 9 Predefined scenarios for transport cost simulations.

Scenarios 1	State forest (SF) taking competing use into account
Scenarios 2	State forest (SF) without taking competing use into account
Scenarios 3	Private forest (PF) taking competing use into account
Scenarios 4	Private forest (PF) without taking competing use into account
Scenarios 5	Total SF + PF taking competing use into account
Scenarios 6	Total SF + PF without taking competing use into account

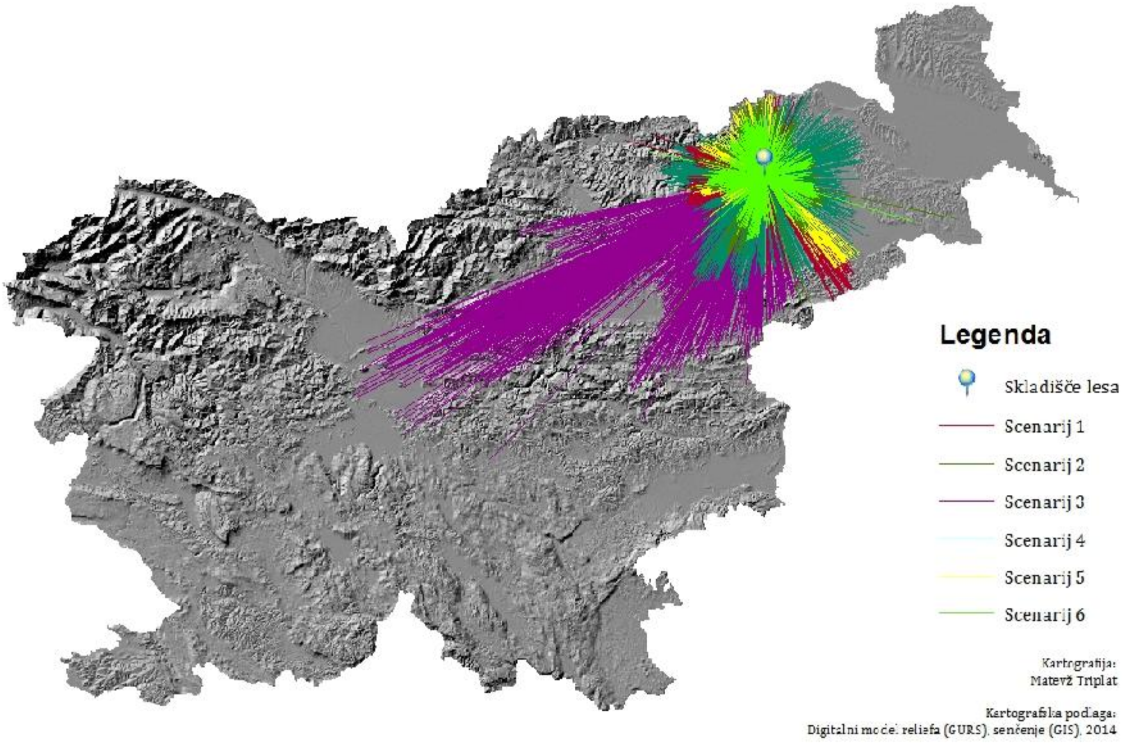

Figure 21 Feedstock hinterland in case of different scenarios.

Figure 21 shows that by taking actual use of lower quality wood into account, a larger part of required quantities can be obtained within the region, no matter by which scenario the investor is acting (except in the case of scenario 3). Figure 21 also reveals the role of competitive sector which is very strong in Savinjska region. Therefore, the model is taking competitive use into account and providing missing quantities from northern, eastern or southern regions from the analysis point (located in Maribor municipality).

The exception is scenario 3, which indicates the fact that there are not enough quantities for all needs (investors and competitive) in private forests in the region (taking current trends of logging into account). Moreover, competition in surrounding regions is among the strongest in Slovenia. This is also the main reason that the model provides required quantities from the distanced regions which is very evident with transport costs represented in table 10.

Table 10 Calculation of average transport cost from the forest road to the wood storage in Maribor.

	Scenario	Average transport costs (€/ t)
1	State forest (SF) taking competing use into account	7.20
2	State forest (SF) without taking competing use into account	6.21
3	Private forest (PF) taking competing use into account	17.28
4	Private forest (PF) without taking competing use into account	9.53
5	Total SF + PF taking competing use into account	6.40
6	Total SF + PF without taking competing use into account	**6.12**

It is evident from table 10 how important quantities of wood from state forests are for a selected location in Maribor. Theoretically it would be possible to provide required quantity with lower transport costs from immediate vicinity but only by increasing the mobilization of wood from private forests, since the table 8 points to a large unutilized potential in private sector. The current situation shows that an investor would have difficulties to achieve optimal costs of production only by operating with private owners. We anticipate the private sector would be motivated by higher price of wood on the road, but then the question of competitiveness arises.

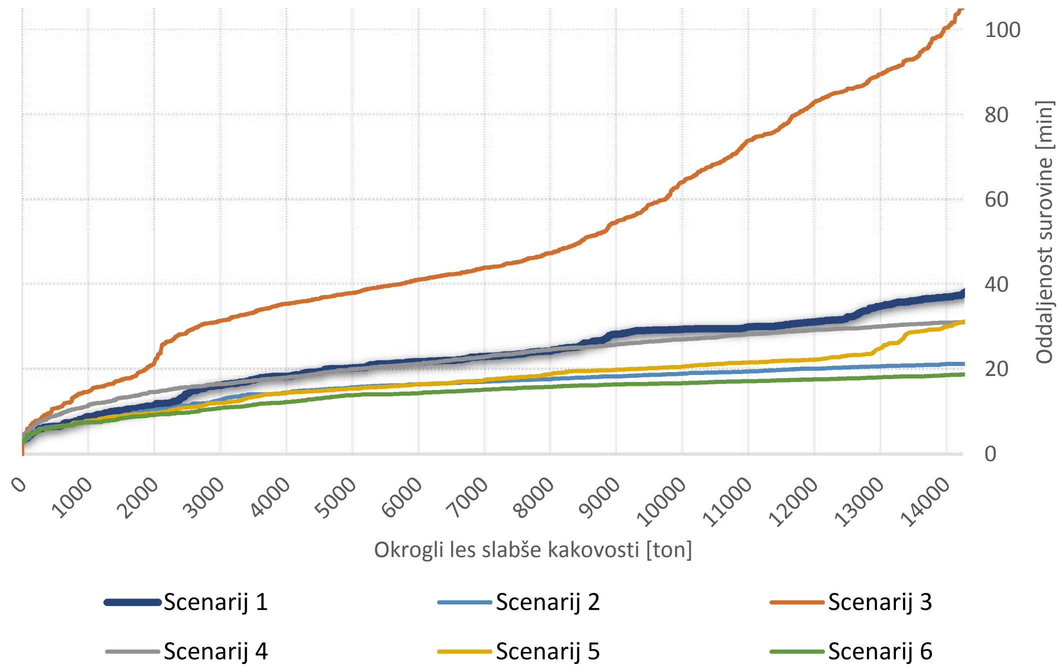

Figure 22 Available quantities ratio of feedstock depending on the distance.

Figure 22 shows a ratio between availability and distance of feedstock (expressed in minutes of full drive). It is evident that the impact of competitive use is not significant on the total costs of woodchips production. Scenario 3 is the exception as already mentioned. Taking competitive needs on the market into account, the investor should also obtain feedstock from remote regions which significantly increases transportation costs.

As shown on figure 23, the investor should provide 600.000 – 900.000 € for production (15.000 tonnes of absolutely dry matter) of wood chips used for heat production (depending on the business performance of the market).

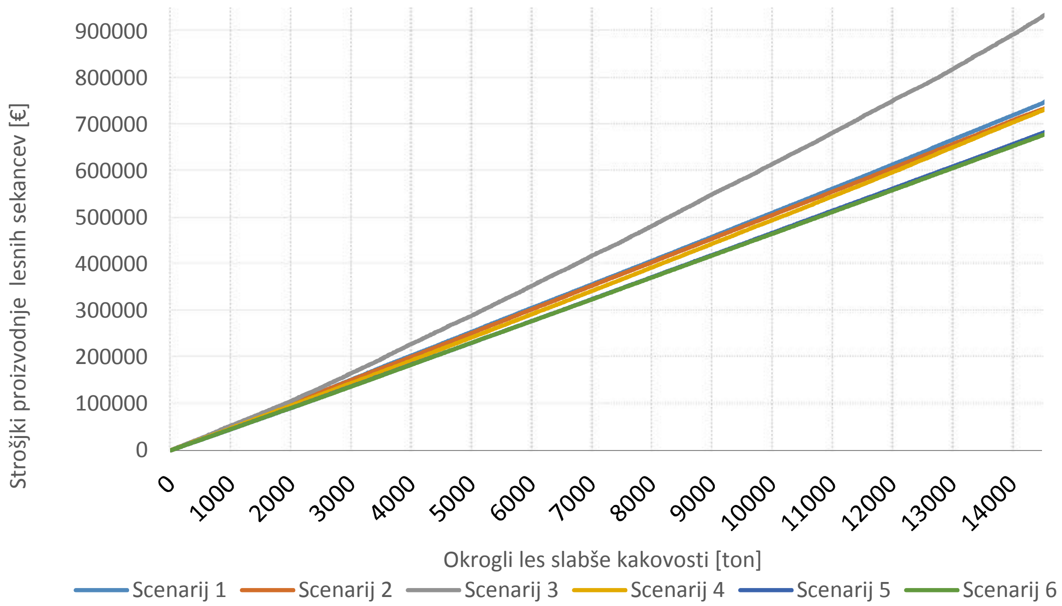

Figure 23 Ratio of available quantities of feedstock and transportation costs.

Figure 24 presents ratio of costs arising in the production of wood chips (15.000 tonnes of absolutely dry matter). Included in the total costs are:

- Costs of purchasing wood on the truck road (assuming that the price of coniferous lower quality wood is 25 €/m^3 and 36 €/m^3 in the case of deciduous),
- Costs of hiring the service for wood grinding,
- Transport costs.

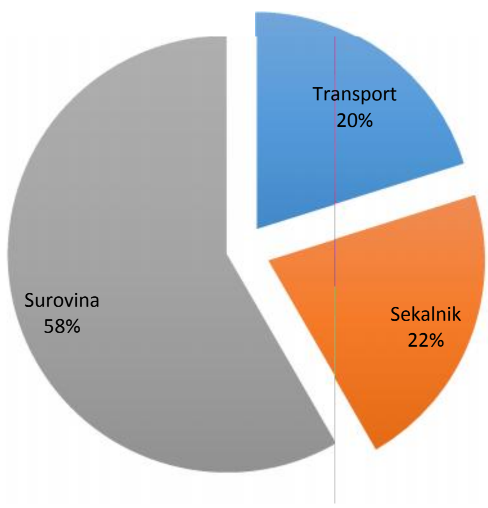

Figure 24 Ratio of costs in wood chips production.

3. CONCLUSIONS

We can conclude that in the case of considered location in municipality Maribor it is possible to confirm a sufficient quantity of lower quality wood for heat production which is evident from the results of analysed scenarios.

Nevertheless, we emphasize:

4. The model covers only quantities of recorded felling (for which Slovenian Forestry Service issue permit for felling) and according to our quantity assessment there is more on the market. We need to take the fact that according to the owners of chippers around 40 % of production is exported into account.
5. Provided maximum possible felling of 10 years is not reached in bigger part of the region which means that there are more theoretically available quantities.
6. The investor foresees a boiler which will allow burning wet chips and will provide a certain proportion from green cut and forest residue. The model is taking only round lower quality wood into account.
7. The investor may optimize transport costs by increasing purchase prices of wood for surrounding forest owners, who could deliver feedstock by their own means of transport taking appropriate equipment into account (egg. 8-tonnes forestry semitrailer for tractors).
8. Appropriate regulation of storage space in terms of process optimization cannot be neglected. It is estimated that each additional movement of feedstock at the storage brings extra costs up to 5 €/m^3.

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