CHAPTER 4

COMMUNITY-SCALED ELECTRICITY GENERETION FROM WOODEN RESIDUES WITH TRANSPORT LOGISTICS CONSIDERATION IN CHIANG MAI-LUMPHUN AREA

4.1 Introduction

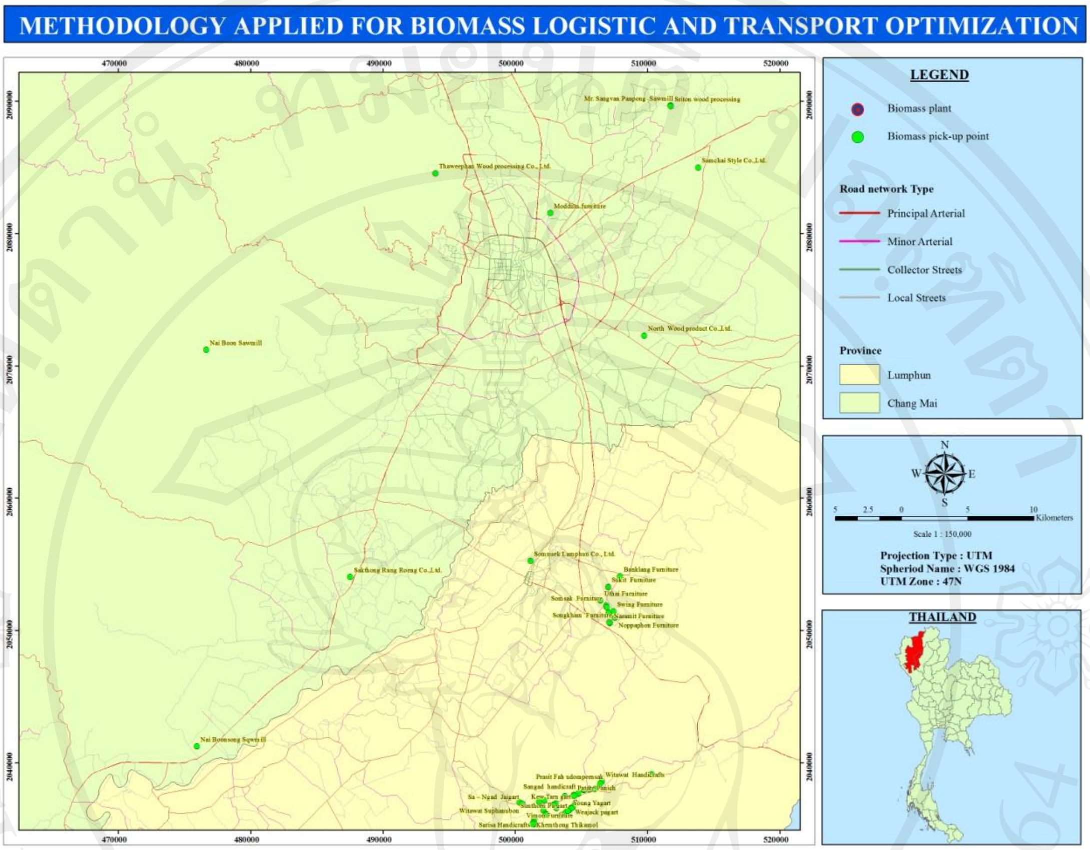
The designed size of the biomass community-scaled power plant will respond to the needs of the community and also the local capacity to supply essential biomass feedstock as fuel for the power plant. Fueled by biomass plantation, the community-scaled size as a main focus of this current work is limited to 100 kW and dealt in Chapter 3. For the sake of sustainability, it is well proposed that the power plant should be managed by the community or at least the local community and profit from others co-products or recovery waste heat should be explored. The environmental impact result from the plantation. If fuel can be obtained from local sites, this will certainly reduce the environmental effects. To explore more local potential, there are a number of local SME or even large industries in Thailand and some of them are abundant with biomass residues from their processes. This are important source for biomass from which the community should benefit. It is intended to explore the potential of the handicraft and wood furniture industry which is one of the strength of northern Thailand to produce the electricity for the community in this chapter. As fuel management is the main essence of current exploration, this work will focus on Chiangmai-Lamphun area such that logistical parameters will be brought into an attention. Selected technology in this chapter is limited to small 400 kW gasification system which is already discussed in previous chapter that it yields more efficiency.

4.2 Study Areas

Some areas of Chiang Mai-Lamphun province are classified as the zone for the production of handicraft. Abundant with biodiversity and plantation of mango wood, teak, timber, and plywood, etc., local products are wooden furniture, home decorations. These craft communities are clustered especially in Maetha district of Lamphun and San Pa Tong district of Chiang Mai.

In generally, these factories will leave woody residues from the production process and have not explored the potential energy for producing local electricity, yet, in spite of the facts that there are a number of wooden residues scattering around the area. To exploit location-based fuel source, transport certainly affect the cost of product unit and should be carefully plan. The site of the power plant has to be carefully chosen such that it can minimize the expense while ensuring the feedstock. From the data of the Energy Research and Development Institute (ERDI), Chiang Mai University (ERDI, 2010) it is found that the location of wood processing industrial factories is within a radius of 30 km and 54 factories are reported. They are shown in positions in the Universal Transverse Mercator as show Figure 4.1. Locations of woody residues sources are given in a form of Geographic coordinate and listed in Table 4.1. If the woody residues are collected to produce electricity from all locations, there will be the amount of wood about 5,000 ton/year. Wooden waste usually has a moisture content of 15% m with the lower heating value of 14.37 MJ/kg (KAPI, 2007**)**. Simple calculation shows that the power plant, if introduced into the area, can generate approximately 400 kWe for the local use.

This study will utilize the data from these industrial factories in order to seek to suitable location of power plant under the logistical constraints to the unit cost of electricity produced, using the principles of Geographic Information System (GIS). The details are as follows.



(The full page available at APPENDIX E)

Figure 4.1 The location of industrial wood processing factories in Chiang Mai and Lamphun provinces (ERDI, 2010).

Table 4.1 List of wood processing industry and wood – furniture, wood-handicrafts in Chiang Mai and Lamphun provinces.

No.	Name	residues-woody (ton)	x (utm)	y (utm)	address
1	Samchai Style Co.,Ltd.	25.7	513821	2084991	4/3 Moo 3 Doisket-Bosang Rd. Amphur Doi Sket Chiangmai 50220
2	Mr. Sangvan Panpong Sawmill	34.27	511712	2089679	62 Moo 7 Tambol Nong Yang Amphur Sansai Chiangmai 50210
3	Sriton wood processing	34.27	511748	2089618	64 Soi 4 Moo 4 Tambol Nong Yang Amphur Sansai Chiangmai 50210
4	Sakthong Rung Roeng Co.,Ltd.	642.6	487516	2054034	2/4-5 Moo 3 Tambol Makhun Warn Amphur Sanpatong Chiangmai 50210
5	Nai Boon Sawmill	1,606.50	476625	2071207	22/1 Moo 4 Tambol Makhun Warn Amphur Sanpatong Chiangmai 50210
6	Nai Boonsong Sqwmill	42.84	475935	2041232	Moo 14 T Chiangmai – Hod road chiang mail 50160
7	North Wood product Co.,Ltd.	274.18	509743	2072288	185 Moo 4 Tambol Chailsman Amphur Sarpee Chiangmai 50140

(Source: ERDI, 2010)

Table 4.1 List of wood processing industry and wood – furniture, wood-handicrafts in Chiang Mai and Lamphun provinces (Cont.)

No.	Name	residues-woody (ton)	x (utm)	y (utm)	address
8	Moddum furniture	3.57	502640	2081547	18/2 Moo 6 Chiangmai – Dosaket Rd. Tambon Sanparnet, Sansai, Chiangmai
9	Thaweephan Wood processing Co., Ltd.	71.4	493958	2084557	115 Moo 2 Chotan Rd. Tambon Donkewq Amphur Mae Rim Chiangmai 50120
10	Banklang Furniture	178.5	507914	2054078	135 Moo 9 T. Umong Amphur Muaeng Lamphun 51000
11	Somnuek Lamphun Co., Ltd.	21.42	501144	2055256	304 Moo 6 Charoenrat Rd. Amphur Mueng Lamphun 50100
12	Sukit Furniture	464.1	507029	2053287	97 Moo 2 Tambon Umong Amphur Mueang Lumphun 51000
13	Uthai Furniture	89.25	506445	2052255	100/1 Moo 7 Tambon Sriburbarn Amphur Mueang Lumphun 51000
14	Somsak Furniture	89.25	506870	2051889	369 Moo 5 Tambon Sribarbarn Amphur Mueang Lumphun 51000
15	Thanaboon Furniture Co., Ltd.	17.14	506921	2051739	97 Moo 6 Tambon Sribourbarn Amphur Mueang Lumphun 51000
16	Jitrcharoen Furniture	3.57	507048	2051350	135 Moo 5 Tambon Sribouban Amphur Mueang Lumphun 51000
17	Swing Furniture	75.68	507433	2051442	119 Moo 6 Tambon Sribouban Amphur Mueang Lumphun 51000
18	Noppaphon Furniture	22.85	507520	2050958	102 Moo 5 BanMa Rd. Tambon Sribouban Amphur Mueang Lumphun 51000
19	Naramit Furniture	21.42	507150	2050546	35 Moo 6 Tambon Sribouban Amphur Mueang Lumphun 51000
20	Songkham Furniture	107.1	507088	2050614	197/2 Moo 5 Tambon Sribouban Amphur Mueang Lumphun 51000
21	Patare Panich	8.21	504416	2037550	117 Moo 4 Thackak – MaeTa Road Tambon Ta Thung Luange Amphur Meata Lumphun 51140
22	Giang Kham Sarakart	34.27	503735	2037461	249 Moo 2 Tambon Tha Thung LuangeAmphur Maeta Lumphun 51170
23	Jianphan Panyagart	8.03	502106	2036400	128 Moo 2 Tambon Thagart Amphur Meata Lumphun 51140
24	Sangad handicraft	85.68	504748	2037669	168 Moo 4 Tambon Tha Thung Luange Amphur Mueang Lumphun 51170
25	Sutep handicraft	299.88	503496	2036029	190 Moo 12 Tambon Thagart Amphur Mueang Lumphun 51140
26	Young Yagart	3.57	504078	2036414	32Moo 1 Tambon Thagart Lumphun 51140
27	Weajack pagart	44.98	504232	2036572	12/1 Moo 1 Tambon Thagart Amphur Metha Lumphun 51140
28	Sriwan Sang-gart	8.93	504349	2036627	8/2 Moo 1 Tambon Thagart Amphur Metha Lumphun 51140
29	Witawat Suphanubon	21.42	500317	2036996	134 Moo 1 Tambon Thathung Luang, meatha Lumphun 51170
30	Sa – Ngad Jaigart	8.93	500540	2036880	171 Moo 1 Thajack – Maeth Rd. Tambon Thatung Lang Amphur Meatha, Lumphun 51170

(Source: ERDI, 2010)

Table 4.1 List of wood processing industry and wood – furniture, wood-handicrafts in Chiang Mai and Lamphun provinces (Cont.)

No.	Name	residues-woody (ton)	x (utm)	y (utm)	address
31	Teeryuth Handicarfts	38.56	501787	2037028	9/2 Moo 2 Thajack – Maeth Rd. Tambon Thatung Lang Amphur Meatha, Lumphun 51170
32	Wanchai Handircrafts	7.14	502182	2037148	182 Moo 1 Thajack – Maeth Rd. Tambon Thatung Lang Amphur Meatha, Lumphun 51170
33	Banprasit shop	88.89	505610	2038004	170 Moo 5, Tabmon Thathungluan, Amphur Meatha, Lumphun 51170
34	Somsak Tangart	34.27	506008	2037994	38 Moo 5 Tambon Thatung Luang Amphur Meatha, Lumphun 51170
35	Sa – Nguansak Chaikeaw	28.56	510308	2039120	168 Moo 10 Tambon Tha Sopsao Amphur Meatha, Lumphun 51170
36	Thamrong Thalong – gart	7.71	501487	2035351	26/2 Moo 1 Tambon Thagart, Amphur Meatha, Lumphun 51140
37	Sarisa Handicrafts	23.56	501429	2035731	158/9 Moo 11 Tampon Thagart Amphur Meatha, Lumphun 51140
38	Vimon Furniture	7.5	501365	2035469	113/1 Moo 11, Tampon Thagart Amphur Meatha, Lumphun 51140
39	Khemthong Thikamol	6	501303	2035359	55 Moo 11, Tampon Thagart Amphur Meatha, Lumphun 51140
40	Thongsri Boonyuen	9.28	502287	2036118	157 Moo 2 Tambon Thagart Amphur Meatha, Lumphun 51140
41	Pacharin Star-ngam	8.28	502380	2036067	291 Moo 2 Tambon Thagart Amphur Meatha, Lumphun 51140
42	Srira Duanggart	67.83	503776	2036166	196 Moo 12, Tambon Thagart Amphur Meatha, Lumphun 51140
43	Sman Keaw gart	7.71	503841	2036261	210 Moo 12, Tambon Thagart Amphur Meatha, Lumphun 51140
44	Kew Tarn gart	25.7	503066	2036902	93 Moo 3, Tambon Thatung Luang Amphur Meatha, Lumphun 51170
45	Pisamai Jitagart	13.71	502879	2036811	75/1 Moo 3, Tambon Thatung Luang Amphur Meatha, Lumphun 51170
46	Boonsap Peng gart	107.1	503103	2036570	311 Moo 3, Tambon Thatung Luang Amphur Meatha, Lumphun 51170
47	Sunthorn Pa gart	42.84	504239	2036566	12 Moo 1, Tambon Thagart Amphur Meatha, Lumphun 51140
48	Boonthong Motharat	64.26	503977	2036345	60 Moo 1, Tambon Thagart Amphur Meatha, Lumphun 51140
49	Thawatchai Sirikwan	2.5	504557	2036966	120 Moo 3, Tambon Thatung Luang Amphur Meatha, Lumphun 51170
50	Lamduan Keawgart	21.42	504455	2037488	111 Moo 4, Tambon Thatung Luang Amphur Meatha, Lumphun 51170
51	Manopporn Saenggart	8.57	505168	2037928	50/4 Moo 5, Tambon Thatung Luang Amphur Meatha, Lumphun 51170
52	Romance Keawgart	17.99	505206	2037967	196 Moo 5, Tambon Thatung Luang Amphur Meatha, Lumphun 51170
53	Witawat Handicrafts	20.56	506534	2038563	206 Moo 5 , Tmbon Thatung Luang Amphur Meatha, Lumphun 51170
54	Prasit Fah udompernsak	51.41	506414	2038411	201 Moo 5 , Tambon Thatung Luang Amphur Meatha, Lumphun 51170

(Source: ERDI, 2010)

4.3 Cartographic spatial analysis and optimal location of power plant

This study will exploit mainly the database of the Energy Research and Development Institute and also randomly (at 85% level of confidence) verified by separated survey based on Yamane's statistical regime (Yamane, 1967) to ensure the coordinates of the sources of fuel. The information for the survey is presented in Appendix. B. The result of the survey shows that the locations of sources are, by average, 17.92 m. different from what is found from all exact location which can be ignored in latter calculation. The locations and their capacity of providing wooden residues will lead to the energy density or cartographic spatial energy density of the area which are eventually used to find the optimum location of the power plant.

Energy density in each area is assigned, as spatial data, on GIS. Various data can closely link to the coordinate system based on the position on the surface of the world (Geo-reference). This investigation combine above-mentioned the Energy Research and Development Institute's data and GIS based software ArcGIS9.2 together as presented in Figure 4.2. To evaluate of the optimum location for electrification from biomass there are four analyses involved, i.e., input database, cartographic spatial analysis, network analysis and result reporting.

4.3.1 Input database

GIS, as the system for referencing position on the global surface, a systematic collection of information relevant or other information can be applied on for variety of applications. Parameters have to be brought into attentions:

- Boundaries. Focusing areas of this study are handicraft area of Sanpatong, Chiang Mai, and Mae Ta, Lamphun. This gives the area of 30 km radius with approximated capacity to produce 5,000 tons of wood fuel per year. (ERDI,2010)
- Road network. This information is essential as it relates directly to energy consumption in transporting biomass residues to the location of power plant.

- Locations of the industrious plants. These are the source of wood fuel material.

4.3.2 Cartographic spatial analysis

On the digital cartographic map, the image resolution is often in the form of a pixel or grid: the smallest, controllable element on the map. The address (location) of a grid corresponds to its physical coordinates and will be assigned with information. Quantification of the available wood fuel is detailed in each area to the exact pixel. Target area of Chiang Mai-Lumphun is, therefore, divided into small areas (Regular Grid) and 1 km x 1 km to the centroid of the rectangle on digital cartographic map. Each grid represents its amount of biomass residues (kg). Grid's potential of energy is calculated from the heating value of the fuel (MJ/kg) and grid size (km^2). The result is the amount of energy per unit area of 1 km^2 (MJ/km^2). However, the relevant details on social and environment constraints are not discussed here in this work and might be listed on the direction of the future work especially those enforced from Factory Act 1992.

The result of quantification is shown in Table 4.2 in unit of GJ/km^2 shown as Fig. 4.3. Only 30 grid promises the potential energy as some other area does not have factories. The total energy potential is 70,000 GJ/year. The grid position No. 7 has the highest energy density which 22,924.76 GJ/km^2 but the grid position No. 21 has the lowest energy density which 35.66 GJ/km^2. In the Cartographic spatial, energy density might be divided into 7 levels includes to 0-100, 100-1000, 1,000-2,000, 2,000-3,000, 3,000-4,000, 4000-5000, and more than 5000 GJ/km^2. As many as 13 out of 54 sources are listed under 100-1,000 GJ/km^2. Locations in Nai Boon Sawmill, Sakthong Rung Roeng Co.,Ltd. and Sukit Furniture are listed with highest energy density (5,000 MJ/km^2) and these locations are the prominent candidate for constructing the power plant. Cost of collecting should be factored in addition to plant location, which is related to the distance of transportation. It is obvious from this selected case that for the main candidate locations are in zones A and B due to their high energy density.

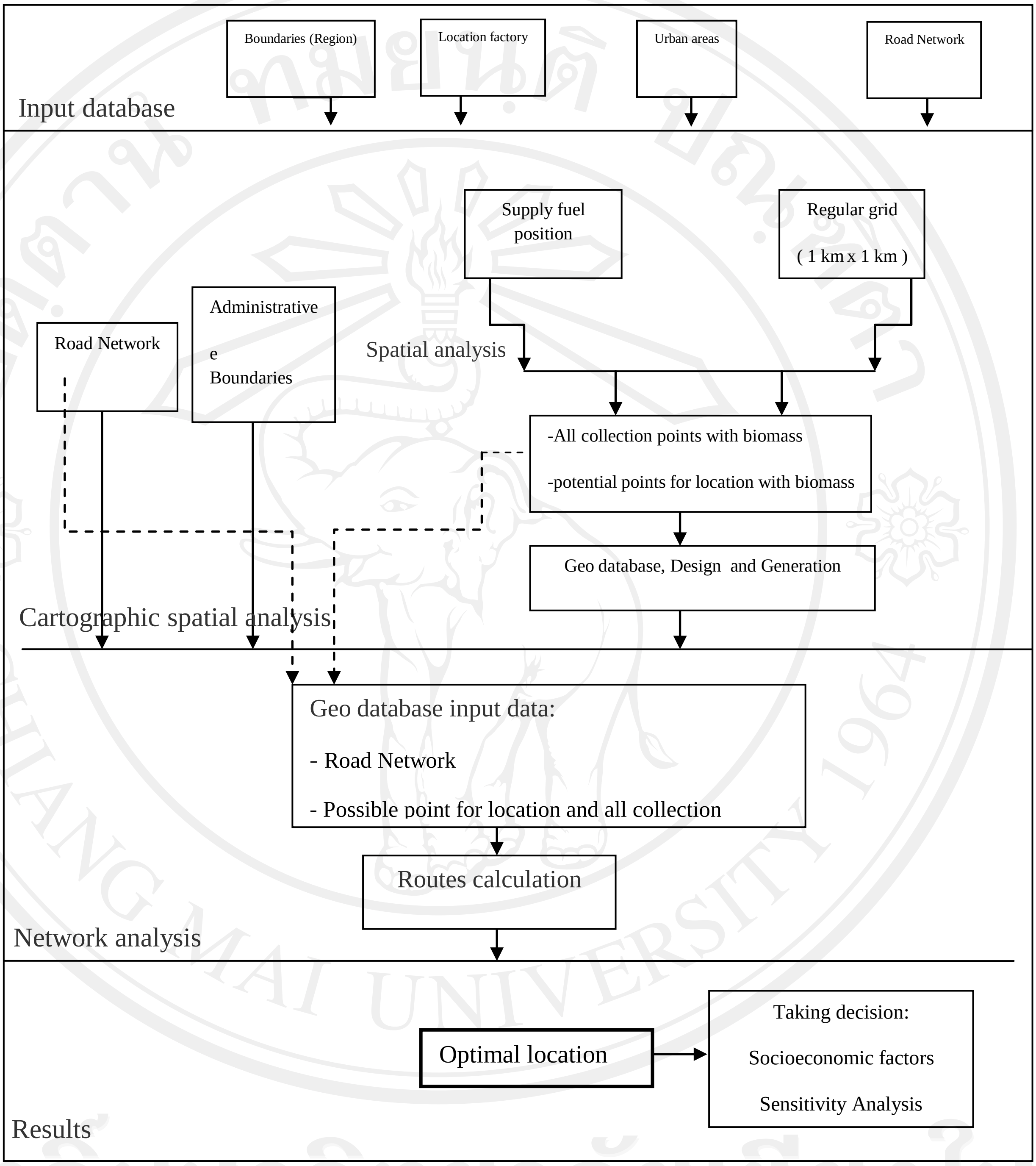


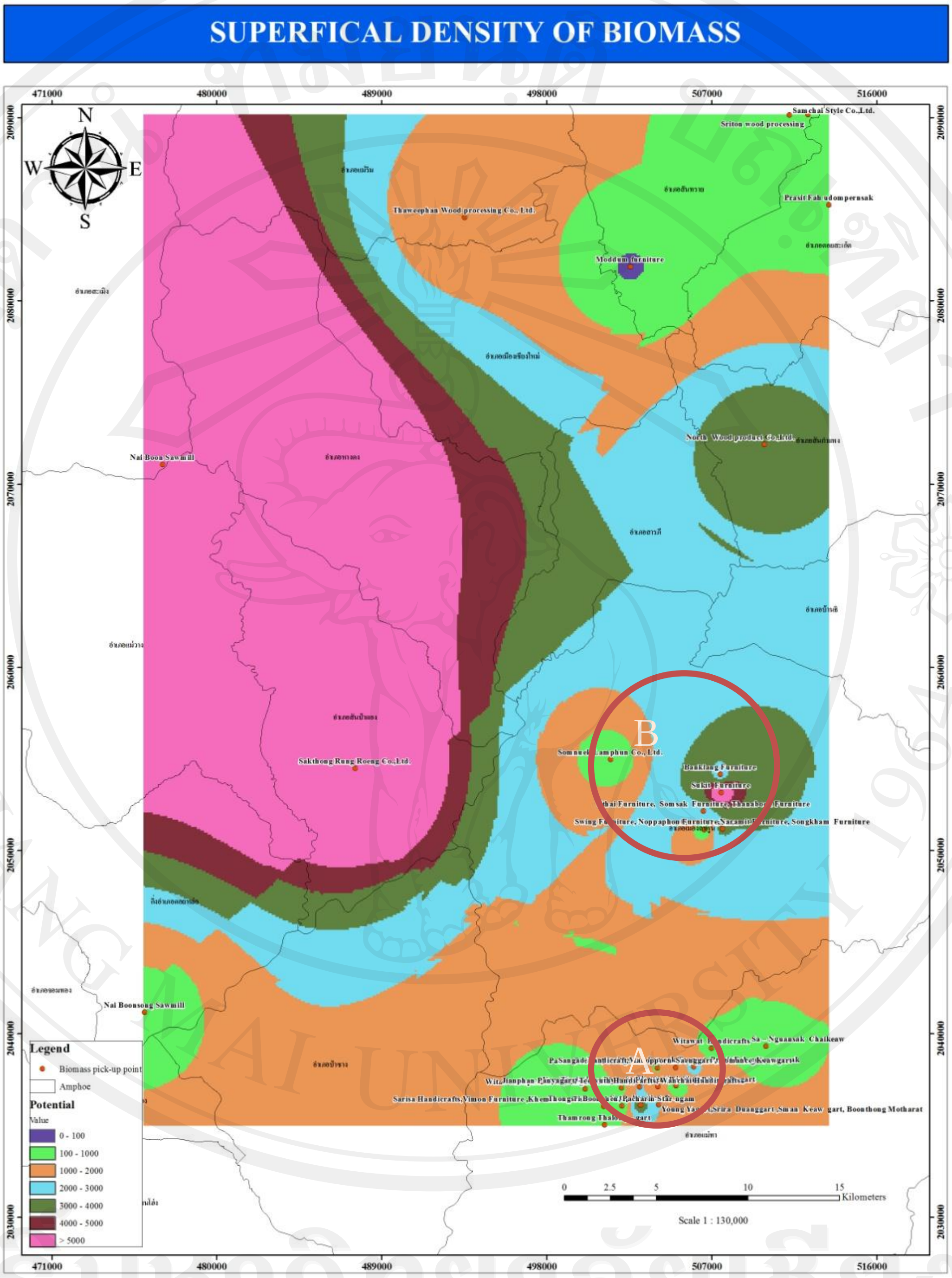
Figure 4.2 The work flow diagram layers and spatial operations connected.

Table 4.2 List of grid to quantification of the available wood fuel from the factories.

Number of grid	Factory in the grid	Quantity (ton)	Potential (GJ/km^2)
1	Samchai Style Co.,Ltd.	25.70	366.80
2	Sriton wood processing	34.27	489.06
3	Prasit Fah udompernsak	51.41	733.59
4	Thaweephan Wood processing Co., Ltd.	71.40	1,018.88

Table 4.2 List of grid to quantification of the available wood fuel from the factories (Cont.)

Number of grid	Factory in the grid	Quantity (ton)	Potential (GJ/km^2)
5	Moddum furniture	3.57	50.94
6	North Wood product Co.,Ltd.	274.18	3,912.49
7	Nai Boon Sawmill	1,606.50	22,924.76
8	Somnuek Lamphun Co., Ltd.	21.42	305.66
9	Sakthong Rung Roeng Co.,Ltd.	642.60	9,169.90
10	Banklang Furniture	178.50	2,547.20
11	Sukit Furniture	464.10	6,622.71
12	Uthai Furniture, Somsak Furniture, Thanaboon Furniture	195.64	2,791.73
13	Swing Furniture, Noppaphon Furniture,Naramit Furniture, Songkham Furniture	227.05	3,240.03
14	Jitrcharoen Furniture	3.57	50.94
15	Nai Boonsong Sawmill	42.84	611.33
16	Sa – Nguansak Chaikeaw	28.56	407.55
17	Witawat Handicrafts	20.56	293.44
18	Banprasit shop, Somsak Tangart ,Prasit Fah udompernsak	174.57	2,491.16
19	Sangad handicraft,Manopporn Saenggart , Romance Keawgart	112.24	1,601.68
20	Patare Panich , Giang Kham Sarakart , Lamduan Keawgart	63.90	911.90
21	Thawatchai Sirikwan	2.50	35.66
22	Weajack pagart , Sriwan Sang-gart ,Sunthorn Pa gart	96.75	1,380.58
23	Kew Tarn gart , Pisamai Jitagart, Boonsap Peng gart	146.51	2,090.74
24	Jianphan Panyagart, Teeryuth Handicarfts, Wanchai Handircrafts	53.73	766.71
25	Witawat Suphanubon,Sangad handicraft	30.35	433.02
26	Young Yagart,Srira Duanggart ,Sman Keaw gart, Boonthong Motharat	143.37	2,045.90
27	Sutep handicraft	299.88	4,279.29
28	Thongsri Boonyuen, Pacharin Star-ngam	17.56	250.64
29	Sarisa Handicrafts,Vimon Furniture ,Khemthong Thikamol	37.06	528.80
30	Thamrong Thalong – gart	7.71	110.04
	Total	**5,078.00**	**72,463.12**



(The full page available at APPENDIX E)

Figure 4.3 Cartographic spatial of energy density (GJ/m^2) in the study area

4.3.3 Network analysis

Network analysis is to analyze the informative database to achieve the desired objectives. Grid is represented by its centroid. Those centroids with high energy density are expected to be the location for the powerhouse. Example of one location linked to other supply grids is shown Figure 4.4. The energy potential on the centroid of 30 grid is needed such that network analysis (ESRI, 2005) is necessary as a tool for this work to provide network-based spatial model from which the optimal route, travel directions, shortest path and origin-destination analysis, and eventually criteria to select the location of the power plant are addressed. The problem of finding the optimal route is similar to the problem in planning of goods delivery, and communication, etc. Edsger Dijkstra (Sniedovich, 2009) a computer programmer, had a concept of Dijkstra's algorithm to solve route optimization problem. It requires assigning informative nodes or centroid of the grid representing location and determining the shortest route by the distance. The results from different routes will be compared to determine the appropriate location.

In this chapter the lowest woody residues collection cost is expected and its corresponding mathematical model is shown in Equation (2.1) (Perpina et al., 2009).

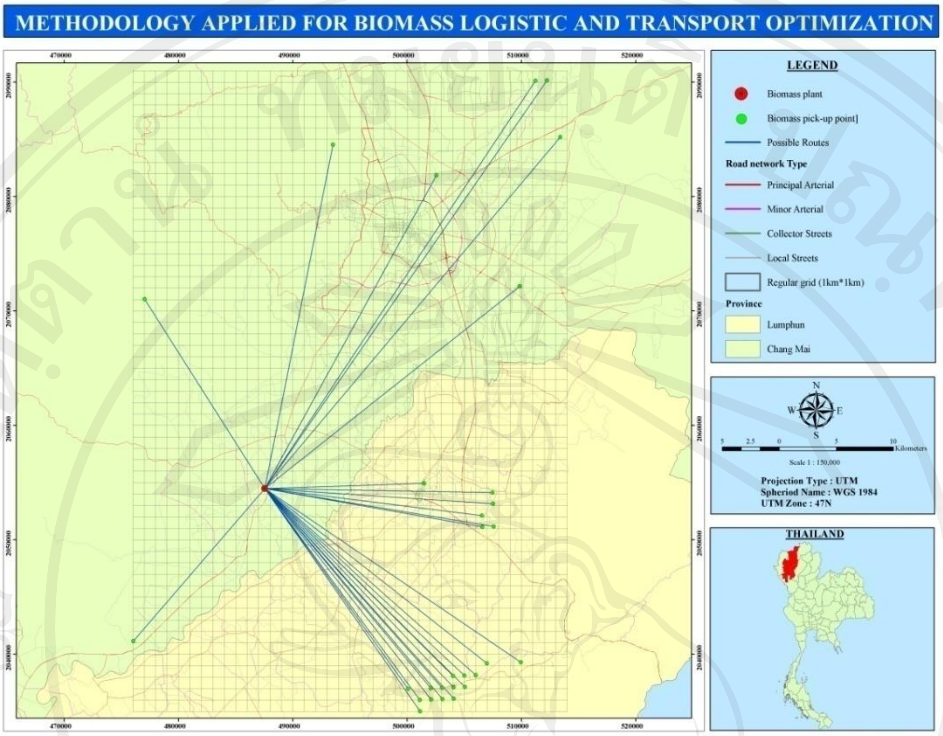


Figure 4.4 An example of collection and transportation of biomass to optimum location of power plant.

This research has developed a model based on a ArcGIS program with Microsoft Visual Basic 6.0 to analyze the route of collecting wood fuel based on network analysis applied fast shortest path Theory and multi seed point Theory. The flow work diagram shows as Figure 4.5. Attributes on each grid include fix location, fix capacity and fix number of power plant. The functional objective is minimum collection cost and woody residues capacity as high as possible. The fuel consumption cost is estimated from the route distance, fuel consumption rate of transportation vehicle selected and unit cost of fuel. The GIS database used in this work will provide road information, vehicle information and target radius. The input page is shown at Figure 4.6 while its source code is available in Appendix. C. Operating conditions of the system are also to be carefully designed. There are as operating conditions of the system for Network analysis

A) Speed of the truck

Speed of the vehicles is determined by the types of road and suggested by the Department of Land Transport. Speed of 45 km/hr or lower and 80 km/hr are prescribed in the urban area and highway, respectively. A list of other roads is shown as Table 4.3.

Table 4.3 The estimate velocity classification depending on type of road. (TLRC, 2012)

Type of road	Estimate velocity (km/h.)	Source
Municipal area	Inside, Not exceed 45 km/h.	Land transportation Act. (BE 2551)
	Outside, Not exceed 60 km/h.	
Rural highway	Not exceed 80 km/h.	Highways Act. (BE 2535)

B) Fuel consumption

National Metal and Materials Technology Center (MTEC) is presented in a list of the country's transport capacity of the freight cars, and the fuel consumption presented in Table 4.4. The difference of fuel consumption of the truck depends on types of truck and loading. For example, 6-wheel trucks that can carry a maximum weight of 11 ton consume fuel at 0.1775 liter/ton when no loading and 0.0207 liter/ton.km when carrying maximum loading. From the Table, the rate of fuel consumption of the truck with no load is proportional to the size of the truck. On the contrary, the fuel consumption of the trucking with loading will be inversely proportional to the size of the truck. So, the approximate of transport cost is associated with the ability to fill a load which, in turn, affecting to the rate of fuel consumption. In spite of the fact that wooden residues are not uniform in size and uneven, its density is approximated 375 kg/m^3 (KAPI. 2007). By estimating the volume of the truck, the weight of the woody fuel in various trucks can be determined. For example 6-wheel truck with 23.44 m^3 loading capacity can carry 6.15 ton/time of woody fuel on the assumption that woody fuel is 70%. Calculation shows that relating fuel consumption is at 0.0365 liter/ton.km. Complete inventory is shown in Table 4.5.

Table 4.4 Inventory of trucks transportation (VC).

Truck	fuel consumption rate (liter/ ton.km)				Maximum load weight (ton)
	no load	50%	75%	100%	
4 wheels	0.1145	0.0961	0.0656	0.0503	7
6 wheels	0.1775	0.0365	0.0259	0.0207	11
10 wheels	0.2133	0.0328	0.0233	0.018	16
18 wheels	0.3193	0.022	0.0153	0.0119	32

Source: MTEC (2012)

Table 4.5 Characteristics truck loading.

Truck	**Volume (WxLxH)**	**Volume (cu.m)**	**density (kg/cu.m)**	**actual load (Ton)**	**70% loading**	**fuel consumption (liter/ton.km)**
4 wheels	2.1x1.3x2	5.46	375.00	2.05	1.43	0.0075
6 wheels	6.2x2.1x1.8	23.44	375.00	8.79	6.15	0.0365
10 wheels	7.2x2.5x1.8	32.40	375.00	12.15	8.51	0.0328
18 wheels	10x2.5x2.5	62.50	375.00	23.44	16.41	0.0220

C) Fix operation cost will based on Equation 2.5 and 2.6 where these considerations are applied.

- Loading cost (FC1+FC2) is 10.71 Baht/ton
- Trucks are purchased and owned by community and maintenance cost has to regular during the 7-year life service. Driver is hired and is additional cost for the community.
- Other economic conditions are as given in section 3.3.1

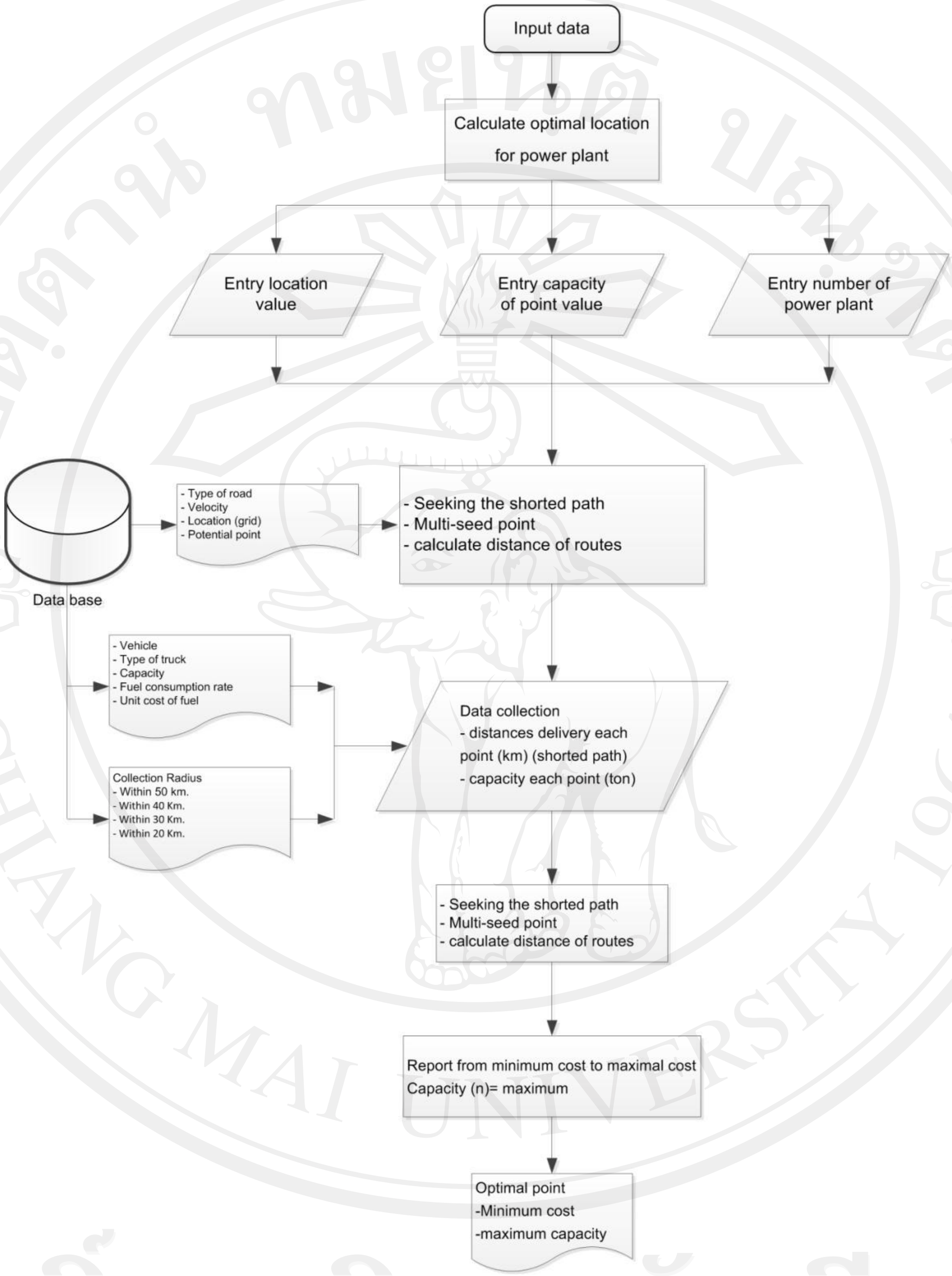


Figure 4.5 The flow work diagram for location optimal point**.**

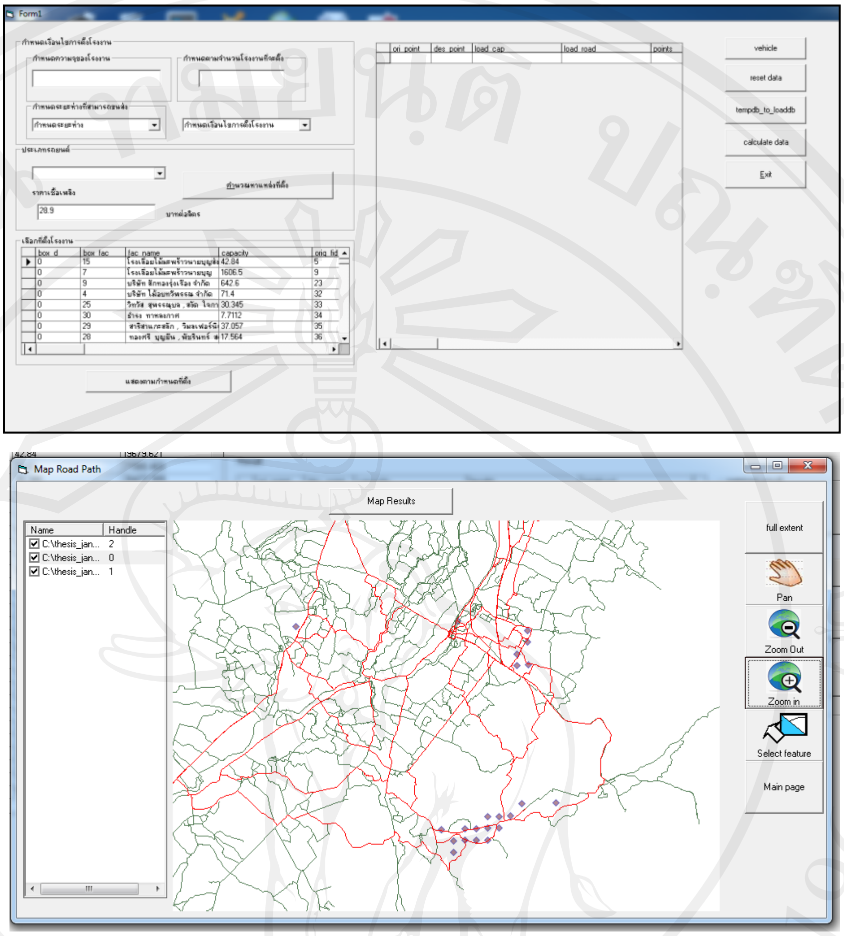


Figure 4.6 The developed program feature.

4.3.4 Optimal location of power plant result

Candidate locations for power plant are often at the locations of the source itself so the calculation will be based on the power plant based on the centroids of 30 potential points. The results of the network analysis as a cost of fuel transportation to these points are shown in Table 4.6 where the largest and lowest amount of candidates are indicated.

Table 4.6 fuel consumption cost results of net work analysis

Number	Number of grid	factory	fuel consumption cost (Baht/ton)
1	8	Somnuek Lamphun Co., Ltd.	39.25
2	14	Jitrcharoen Furniture	39.64
3	12	Uthai Furniture, Somsak Furniture, Thanaboon Furniture	40.33
4	11	Sukit Furniture	41.62

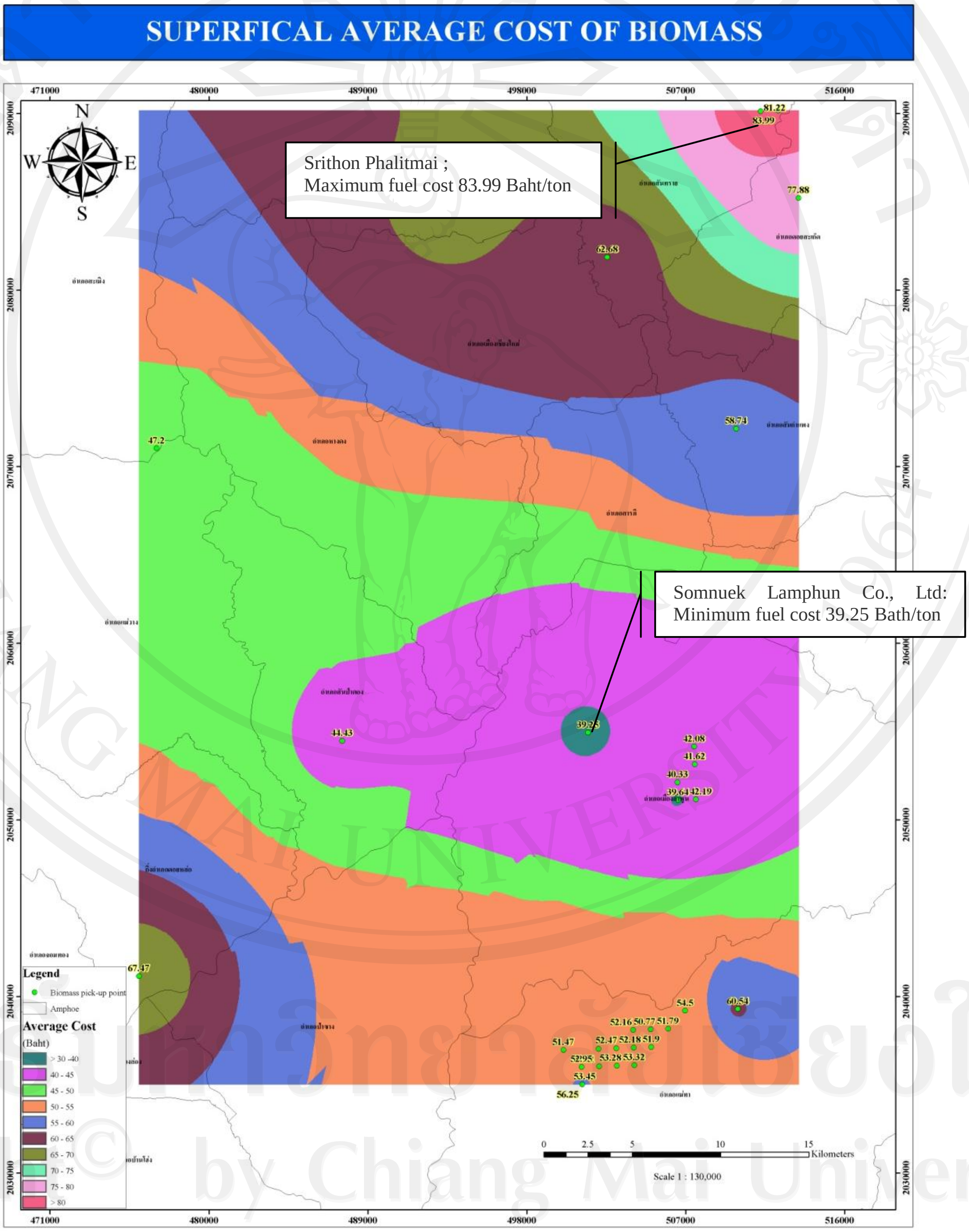
Table 4.6 fuel consumption cost results of net work analysis (Cont.)

Number	Number of grid	factory	fuel consumption cost (Baht/ton)
5	10	Banklang Furniture	42.08
6	13	Swing Furniture, Noppaphon Furniture,Naramit Furniture, Songkham Furniture	42.19
7	9	Sakthong Rung Roeng Co.,Ltd.	44.43
8	7	Nai Boon Sawmill	47.20
9	19	Sangad handicraft,Manopporn Saenggart , Romance Keawgart	50.77
10	25	Witawat Suphanubon,Sangad handicraft	51.47
11	18	Banprasit shop, Somsak Tangart ,Prasit Fah udompernsak	51.79
12	21	Thawatchai Sirikwan	51.90
13	20	Patare Panich , Giang Kham Sarakart , Lamduan Keawgart	52.16
14	22	Weajack pagart , Sriwan Sang-gart ,Sunthorn Pa gart	52.18
15	24	Jianphan Panyagart, Teeryuth Handicarfts, Wanchai Handircrafts	52.31
16	23	Kew Tarn gart , Pisamai Jitagart, Boonsap Peng gart	52.47
17	29	Sarisa Handicrafts,Vimon Furniture ,Khemthong Thikamol	52.95
18	27	Sutep handicraft	53.28
19	26	Young Yagart,Srira Duanggart ,Sman Keaw gart, Boonthong Motharat	53.32
20	28	Thongsri Boonyuen, Pacharin Star-ngam	53.45
21	17	Witawat Handicrafts	54.50
22	30	Thamrong Thalong – gart	56.25
23	6	North Wood product Co.,Ltd.	58.74
24	16	Sa – Nguansak Chaikeaw	60.54
25	5	Moddum furniture	62.68
26	4	Thaweephan Wood processing Co., Ltd.	66.01
27	15	Nai Boonsong Sawmill	67.47
28	3	Prasit Fah udompernsak	77.88
29	1	Samchai Style Co.,Ltd.	81.22
30	2	Sriton wood processing	83.99

Note:
the result under constrain .
Truck: six-wheels truck containing up to 8.79 ton.
Fuel consumption rate: no-load 0.1775 liter/km full load 0.0365 liter/ton.km
Diesel fuel cost 29.83 baht/liter

The position of Grid 8 is Somnuek Lamphun Co., Ltd. and its average fuel consumption cost is found as the lowest of 39.25 Bath/ton. Grid 2 is Srithon Phalitmai, and its cost is found to be the highest 83.99 Baht/ton, i.e. 2.14 times of Somnuek Lamphun Co., Ltd. Seven Grid positions (8, 14, 12, 11, 10, 13 and 9) reported average fuel consumption cost lower than 45 baht/ton. Shade of intensity corresponding to the fuel used are illustrated in Figure 4.7. It is also confirmed that Zone B is the right location as its energy density is a fairly reasonable. In spite of the fact that a location of Nai Boon

Sawmill in Grid 8 shows the highest energy density but it is far from the all other factories. Other candidate locations the areas with low energy density have high cost of collecting fuel.



(The full page available at APPENDIX E)

Figure 4.7 Average fuel consumption cost results each gird.

For the case of 6-wheel trucks to be used, the network analysis results is found that the power plant should be built in areas are the density of concentrated energy sources and economical investment with roads which not only reduce operative transportation cost but also initial establishment cost. Same trend with different number is obtained for the case of all other trucks.

Based on above transport logistics cost, unit cost of electricity produced from biomass community-based power plant can be calculated for 30 candidate points. For the sake of the example, the case of 400 kW power plant (shows at Table. 4.7) is selected and also, in this case, the maximum-benefit scenario is applied such that woody residues charges is not imposed as factory owners are co-owner of power plants. Results are tabulated in Table 4.8.

Table 4.7 System performance

Power capacity (kW)	**400**
Technology	Downdraft
Fuel Type	Biomass
Fuel consumption (kg/kWh)	1.88
Efficiency system	15.00%
Investment cost (baht)	17,200,000
Data reference	The Energy and Environmental Engineering Center (EEEC), KU

The unit cost of produced electricity results from transport logistics cost, fuel preparation cost and electrification cost. The analysis shows that the LCC of transport logistics to Somnuek Lamphun Co., Ltd, (grid No. 8) is optimal at 16.2 million baht while the LCC of transport logistics of Sriton wood processing (grid No. 2) costs at maximum at 27 million baht for the life span of the power plant. 67% difference indicated that the transport logistics affects the cost. From all calculation at this 400 kW capacity, transport logistics cost is responsible for 14% -21% of the average unit cost which is not so high in comparison with some other costs, i.e. fuel preparation, or electricification.

Table 4.8 The result of economic analysis of the community-base power plant collected of the lowest and highest transport logistics cost.

Process	lowest transport logistics cost	Highest transport logistics cost	Unit
Transportation phase	16	27	Million Baht
Preparation phase	34	34	Million Baht
Electrification phase	65	65	Million Baht
Total	115	126	Million Baht
Electricity breakeven price	1.37	1.50	Baht/kWh
Plantation phase	-	-	Baht/kWh
Transportation phase	0.19	0.32	Baht/kWh
Preparation phase	0.41	0.41	Baht/kWh
Electrification phase	0.77	0.77	Baht/kWh
Payback period	3.21	3.31	Years
NPV	57	54	Million Baht
IRR	32.21	31.11	%

The result of economic analysis is found among the 30 candidacy centroids. There are all worth for the investment with different intensity. The unit costs are in the range of 1.37 to 1.50 baht/kWh. The IRR of the project is within the range of 31.11% -32.21%, higher the rate of current interest of 8.7% (Date of July, 2012). The payback period is within 3.21 to 3.31 years, complete detail is in Table 4.8.

4.4 Sensitivity Analysis

Transport logistics cost tends to be sensitive to several key parameters including type of trucks, woody residues costs, the cost of the investment of gasification system. The details of the study are as follows.

4.4.1 Sensitivity to Type of Trucks

Example shown in Section 4.2 is dealt with an assumption of using a six-wheel truck, a vehicle for collecting woody residues from the source to the destination. However, common transportations are 4-wheel, 6-wheel, 10-

wheel, and 18- wheel trucks. Transport logistics cost is dependent of (1) the initial cost, basically, a purchase of a truck. (2) operating cost, such as driver wage, insurance, taxes, car expenses, office rent, depreciation, and (3) running cost, the cost of transport such as fuel, maintenance costs and the tires. Operating costs are normally fixed with insignificant effect on the cost of collecting wood fuel. The unit cost therefore relies on initial cost and running cost only Cost of trucks in various size is shown in Table 4.9. These prices are for well-known and respectable manufacturers in Thailand. The Big trucks usually are more expensive than small ones.

Table 4.9 The truck commercial price

Truck	Truck price (Baht/Truck)		Volume (m^3) [1] (WxLxH)	Volume[2] (m^3)
	Brand A	Brand B		
4-wheel	860,000	720,000	2.1x1.3x2	5.46
6 -wheel	1,320,000	1,475,000	6.2x2.1x1.8	23.44
10- wheel	2,295,000	2,225,000	7.2x2.5x1.8	32.40
18 -wheel	2,595,000	2,260,000	10x2.5x2.5	62.50

[1,2] estimation

Source: vendor market price, (2012)

Table 4.10 Total of fuel collection cost.

Truck	Brand A			Brand B		
	fix cost of truck (Baht/ton)	running cost (Baht/Ton)	Total (cost)	fix cost of truck (Baht/ton)	running cost (Baht/Ton)	Total (cost)
4 -wheel	24.06	60.72	84.78	20.14	60.72	80.86
<u>6- wheel</u>	<u>36.92</u>	<u>39.25</u>	<u>76.17</u>	<u>41.26</u>	<u>39.25</u>	<u>80.51</u>
10 -wheel	64.20	39.96	104.16	62.24	39.96	102.20
18 -wheel	72.59	28.77	101.36	63.22	28.77	91.99

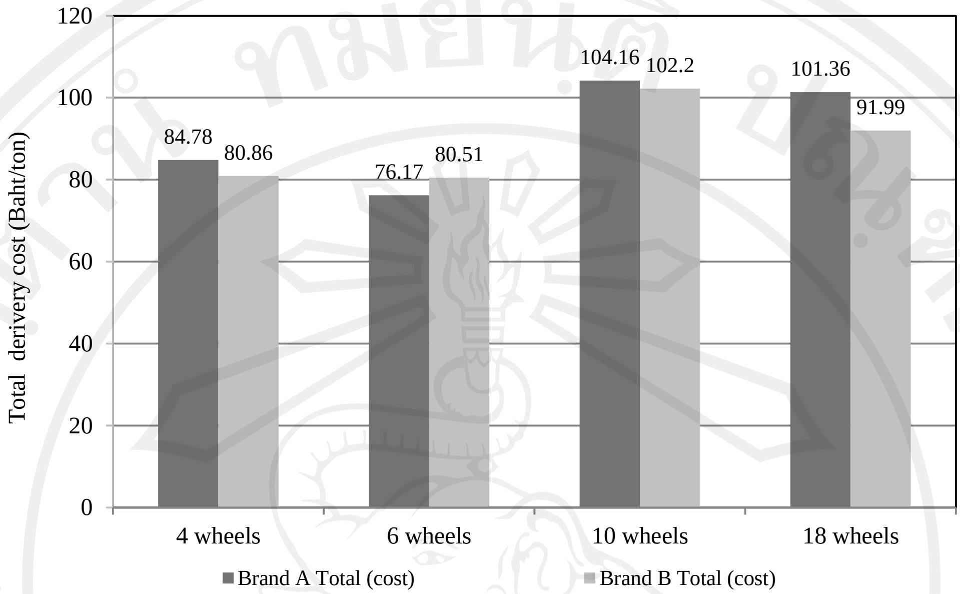


Figure 4.8 The comparative cost of each vehicle transporting wood fuel.

Network analysis shows the comparison of the transport logistics cost when four different types of trucks are used when the life span of the truck is considered as 7 years. Results are shown in Table 4.10. It is found that the 10- wheel truck has a maximum cost of 102.20 to 101.36 baht/ton as a result of the initial cost of 2,225,000 baht which is 64.64% of the total cost. The 18-wheel truck has a minimum running cost, but initial cost is the highest since the price of the truck is the most expensive. Similarly, the 4- wheel truck has a maximum running, but the initial cost was the lowest in only 720,000 baht. The 6-wheel truck has an average cost of transport as lowest at of 76.17 - 80.51 baht/ton. However, the cost of collecting woody residues should be considered in combination with the initial cost and running cost. In Figure 4.8 Comparison of the cost of truck types was found that 6-wheel trucks had the lowest and were suitable to be used in power production systems for this community. Besides, those trucks could also be used to carry timber by-product, carbon bar for sale etc. when by-products and co-products are in consideration.

However, big trucks were appropriate to be used as well if more wooden fuel is available, or larger power plants were is installed.

4.4.2 Price of wooden fuel

The previous example is the case when there is no charge of a wooden fuel. This is according the scenario that the power plant is community owned and wooden industries are parts of community. Wooden fuel is given without extra charge except for the transport logistics cost. Monetary benefit will only be shared after payback period is reached. IRR of this benefit-maximized case is therefore as high as 32.2%. However, in more common scenario the fuel supply may be purchased to ensure the continuous operation. The woody residues price is anticipated as less than 1,200 Baht/ton according to the market price of biomass (EforE, 2012).

Based on the set up shown in section 4.2.4., analysis shows the results available in Figure 4.9 and Table 4.11. It can be seen that the community should not pay for fuel supply more than 1,105 baht/ton at IRR is equal to the present (Date of July, 2012) interest rate of 8.7%. Unit cost of electricity produced in this case is 3.46 baht/kWh.

Table 4.11 The economic evaluation of the cost of fuel at different price.

Woody fuel price	0	100	200	300	400	500	600	700	800	900	1,000	1,100	1200	baht/Ton
Electricity Cost	1.37	1.56	1.74	1.93	2.12	2.31	2.50	2.68	2.87	3.06	3.25	3.44	3.62	baht/kWh
NPV (M Baht)	56.89	51.73	46.57	41.41	36.26	31.10	25.94	20.78	15.62	10.46	5.31	0.15	(5.01)	Years
IRR	32.2	29.86	27.54	25.26	23.0	20.8	18.7	16.6	14.5	12.6	10.6	8.75	6.92	%
Payback period	3.21	3.47	3.76	4.11	4.53	5.04	5.67	6.49	7.57	9.09	11.34	15.05	22	%

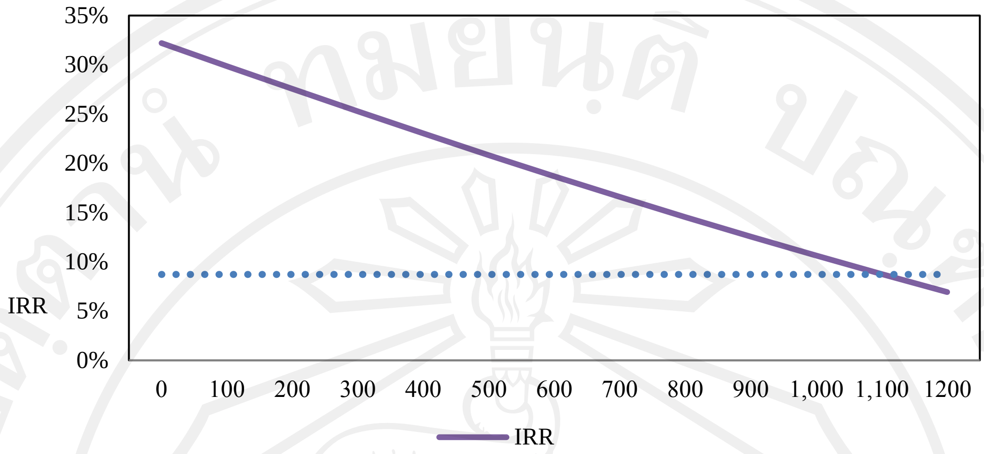


Figure 4.9 The comparison of the IRR as the cost of fuel supply.

4.4.3 Investment of Gasification system

The unit cost of electricity is directly sensitive to the price of the technology from the 400 kW pilot Gasification plant system which costs 17.2 million baht. The information is available from project carried out by renowned university in Thailand and supported by the governmental agency (EEEC, 2011). This is relatively low. In practice, the cost of these technologies is subjected to change depending on several factors such as the manufacturer's pricing policy, inflation, competitive and market etc. The sensitivity study in this case is determined by allowing the system to cost 4 times of above-mentioned base case and is reported when the expense on fuel is exempt (as source provider, i.e. wood industry, is a co-owner). The results are shown in Table 4.12 and Figure 4.10. As the power plant operates without fuel cost, it is worth for investment when cost of system is below 3.8 times of base case.

Table 4.12 Economic results and the rate of economic growth levels of investments

Time of gasification cost	1	1.5	2	2.5	3	3.5	4
Electricity Cost (Baht/kWh)	1.37	1.44	1.51	1.58	1.65	1.73	1.80
NPV (M Baht)	5.69	4.67	3.65	2.64	1.62	0.60	-0.42
IRR (%)	32.2%	22.4%	17.1%	13.7%	11.3%	9.6%	8.2%
Payback period (years)	3.21	4.68	6.40	8.45	10.94	14.03	17.95
IRR base	8.70%	8.70%	8.70%	8.70%	8.70%	8.70%	8.70%

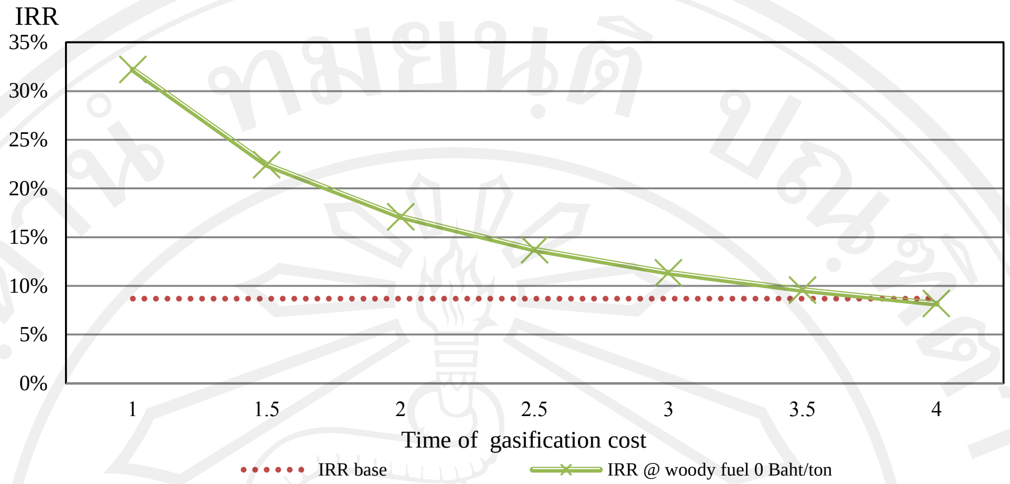


Figure 4.10 The relationship between the technology and net cost to produce 400 kW.

4.4.4 Scenario case

Some of the assumptions posed on above calculations are based purely from anticipation, for examples, the cost from the feedstock is free as it is given by the industries who are members of the community, or the price of small gasifier is based on pilot project. It will be interesting to use model developed in this work with more reasonable parameter, i.e.

- Wooden feedstock is sold to the power plant at 500 baht/ton.
- Gasification system construction costs 1.5 times more than the investment figure of the proposed pilot project. The cost is then 25.8 million baths
- Wooden chips are 85% usable as it might be loss to some other appropriate use in the community

Other than those, the assumptions are the same. However, the power plant should still be in the optimized location where the transport logistics cost is the lowest.

All results are suggested in Table 4.13 and the environment impacts are shown in Figure 4.11. From this calculation, a unit cost of electricity is 2.09 baht/kWh and IRR of the project is 11.96% which is higher current interest of 8.7% (Date of July, 2012). The payback period is approximately 9.8 years. SimaPro shows that the mid-point environment impact is found to be 4.11E-04 Pt/kWh . Externality cost is 0.19 baht/kWh. It points out that main impacts are Ecotoxicity water chronic, Ecotoxicity water acute, Human toxicity soil, Global warming and Ozone depletion at 1.17E-04 Pt, 1.16E-04 Pt, 1.06E-04 Pt, 3.10E-05 Pt and 2.15E-05 Pt, respectively. The impacts results from processes in reactors, fossil fuel used, and grid-line electricity used.

Table 4.13 Economic results in scenario case

Analysis	Value
Economic analysis	
Electricity Cost (Baht/kWh)	2.09
NPV (M Baht)	11.34
IRR (%)	11.96%
Payback period (years)	9.79
Life cycle assessment	
LCA by EDIP method (Pt/kWh)	4.11E-04
Externality cost (Baht/kWh)	0.19

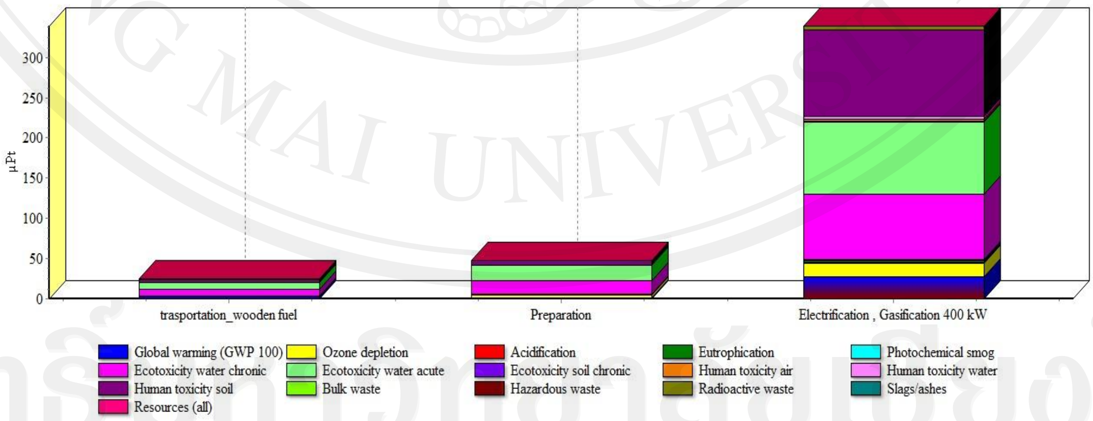


Figure 4.11 Environmental impact results in 400 kW gasification system by EDIP method (Pt/kWh)

4.5 Conclusions

Main objective of this work is to determine the feasibility of producing electricity from woody residues in local community with the demand below 400 kWe. Renowned as handicraft promoted area, case study of Sanpatong and Mae Ta in Chiang Mai and Lamphun, respectively, is chosen where its spatial information as energy density from woody residues is utilized. 400 kWe is based on Gasification system and assumed to be built at one location of biomass sources. It is designated that the plant is community-based and should be owned by the community such that, as wooden industry is local's, the cost of wooden residues is irrelevant. Benefit can be shared among the stakeholders after the payback period is reached.

Using dedicated GIS software and network analysis, optimum locations which yield the lowest transport logistics cost in terms of fuel consumption is reported along with analyses of effecting variables. A mathematic model set up by fast shortest path Theory and multi-seed point Theory can reveal the optimum paths for biomass transport logistics for specific optimum location of electrification power plant.

Somnuek Lamphun Co., Ltd. is found to be the most appropriate site for power plant location with the lowest average fuel consumption at 39.25 Baht/ton with the unit cost of electricity is about 1.37 baht/kWh. The corresponding IRR of the project is 31.11% with the payback period of 3.21 years.

At 400kWe capacity, sensitivity of several relevant is studied. It reveals that a local 6-wheel truck is the most effective as it yields highest in comparison the other kinds to tucks. Additionally, if fuel supply is relevant this community-based power plant can afford up to 1,105 baht/ton where IRR is breaking even with the current interest rate. Cost sensitivity of power plant is also in discussion.