CHAPTER V

DATA & RESULTS OF AN ANALYSIS OF GASIFICATION TECHNOLOGY INTRODUCTION TO NONGWANG VILLAGE BASED ON RCDM

Gasification systems in Nongwang could be used for electricity generation for self use, water pumping for irrigation, and shaft power for rice milling. Simulation of such technology introduction was analysed using the RCDM under 4 hypotheses as follows :

1. Hypothesis 0, for basic activities in Nongwang prior to technology introduction.

2. Hypothesis 1, for charcoal gasifier introduction in the capacity of 600W, 2KW operated with gasoline engine ; and 5, 10KW operated with dual-fuel diesel engine (gas : diesel = 70 : 30).

3. Hypothesis 2, for wood gasifier introduction in the capacity of 5, 10, 25 and 50KW operated with dual-fuel diesel engine (gas : diesel = 70 : 30).

4. Hypothesis 3, for rice husk gasifier introduction in the capacity of 10, 25 and 50KW operated with gasoline engines.

Table 5.1, presents the main parameters used in the model for charcoal, wood, and rice husk gasification. These are the values used in the baseline cases and are listed from Chapter II.

Table 5.1 Parameters used in the baseline cases for charcoal, wood+rice husk gasifiers

Technology	Capacity (KW)	Heating Value of Gas Produced (MCAL/KG)	Efficiency (KWH/MCAL)	Investment Cost (BT85/KW)	Life Time (YRS)	Labor (HRS/OP.HR)	Maintenance Cost (BT85/KWH)	Lubricant Cost (BT85/KWH)
Gasif 1, Charcoal, with Gasoline Eng	0.6	5.33	0.1860 (0.2493 HPH/MCAL)	16,000 (11,936 BT/HP)	6	0.2000 (0.2487 HRS/HPH)	0.7200 (0.5370 BT/HPH)	0.2128 (0.1587 BT/HPH)
Gasif 2, Charcoal, with Gasoline Eng	2	5.33	0.1860 (0.2493)	14,500 (10,817)	6	0.2000 (0.0746)	0.7200 (0.5370)	0.2128 (0.1587)
Gasif 6/1 Charcoal, with Diesel Eng	5	5.33	0.2342 (0.3139)	13,500 (10,071)	6	0.2000 (0.0300)	0.7200 (0.5370)	0.2128 (0.1587)
Gasif 6/2 Wood, with Diesel Eng	5	3.05	0.2342 (0.3139)	23,400 (17,456)	6	0.2000 (0.0300)	0.7200 (0.5370)	0.2128 (0.1587)
Gasif 7/1 Charcoal, with Diesel Eng	10	5.33	0.2342 (0.3139)	12,635 (9,425)	6	0.2000 (0.0150)	0.7200 (0.5370)	0.2128 (0.1587)
Gasif 7/2 Wood, with Diesel Eng	10	3.05	0.2342 (0.3139)	20,615 (15,379)	6	0.2000 (0.0150)	0.7200 (0.5370)	0.2128 (0.1587)
Gasif 3, Rice Husk, with Gasoline Eng	10	2.02	0.1860 (0.2493)	20.615 (15,379)	6	0.2000 (0.0150)	0.7200 (0.5370)	0.2128 (0.1587)
Gasif 8, Wood, with Diesel Eng	25	3.05	0.2342 (0.3139)	16,900 (12,607)	8	0.2500 (0.0075)	0.7200 (0.5370)	0.1596 (0.1191)
Gasif 4, Rice Husk, with Gasoline Eng	25	2.02	0.1860 (0.2493)	16,900 (12,607)	8	0.2500 (0.0075)	0.7200 (0.5370)	0.1596 (0.1191)
Gasif 9, Wood, with Diesel Eng	50	3.05	0.2342 (0.3139)	13,965 (10,418)	8	0.3500 (0.0052)	0.7200 (0.5370)	0.1596 (0.1191)
Gasif 5, Rice Husk, with Gasoline Eng	50	2.02	0.1860 (0.2493)	13,965 (10,418)	8	0.3500 (0.0052)	0.7200 (0.5370)	0.1596 (0.1191)

First we would let the model choose the gasification system acceptable by the villagers and tell us how much investment and variable costs the remaining systems should be decreased by in order to be compatible with the system selected. Second, a sensitivity analysis of some parameters as shown in Table 5.2 was performed to see whether it would influence the introduction of gasification. The model would show the optimum operating hours to run the gasifier economically and also arrange some activities to maximize income of the community.

Table 5.2 Variations of baseline assumptions for sensitivity analysis

Variable	Value Used for Baseline Cases	Values Used in Sensitivity Analysis
Charcoal cost	1.3 BT85/KG	1.5 BT85/KG 2.0
Wood Cost	509 BT85/TON	288 BT85/TON 797
Rice Husk Cost	139 BT85/TON	415 BT85/TON 515 615
DIESEL COST	6.7 BT85/LIT	6.5 BT85/LIT 6.3
Premium Gasoline, Cost	10.2 BT85/LIT	9.5 BT85/LIT 8.9
Availability, Factor	2880 HPH/HP	2000 HPH/HP

The model simulation was performed corresponding to the node-link diagram in Figure 4.1-4.12 with an assumption of 3 percent real discount rate and was used to forecast the development projects'impact on the community in the year 1985-1989.

The computer data base and parts of outputs for charcoal gasifier, wood gasifier and rice husk gasifier are shown in the Appendix D, page 126, 169, 181 and 192 respectively.

The results obtained from the outputs of RCDM are summarized in Tables 5.3, 5.4, 5.5 and described below :

1. For charcoal gasifiers, the system which is economically acceptable by the community in a condition of premium-gasoline price of 10.2 BT/LIT, of 6.7 BT/LIT for diesel and charcoal prices of 1.3, 1.5 BT/KG for Gasifier System 7/1 operated with diesel engine. The minimum operating hours should be 2880 HRS/YEAR, meaning that, the gasifier should be fully utilized in both wet and dry seasons. If the charcoal price is increased up to 2.0 BT/KG, all the gasification systems are not economically acceptable by the villagers and the system driven with diesel engine only is selected. For a normal charcoal price of 1.3 BT/KG, Gasifier System 7/1 is still attractive even though the present prices of premium-gasoline are down to 8.9 BT/LIT and diesel prices are down to 6.3 BT/LIT. Gasifier System 2, operated with a gasoline engine is considered to be the second most favourable system, and can be accepted if the variable costs of the system are slightty decreased.

2. For wood gasifiers, Gasifier System 9 operated with a diesel engine is the system selected by the model for a premium-gasoline price of 10.2 BT/LIT and a diesel price of 6.7 BT/LIT. At the estimated wood price of 797 BT/TON, (which is a shadow price based on the labor and transportation involved) the system should be fully utilized during 2880 HRS/YEAR to make the system economically acceptable. But for wood prices of 509 and 288 BT/TON, it

Table 5.3 Maximum investment & variable costs, and minimum operating hours of charcoal gasifiers permissible in Nongwang suggested by RCDM.

Capacity		Original	Availability Factor 2880 KWH/KW Gasoline Price 10.2 BT/LIT, Diesel Price 6.7 BT/LIT Charcoal Price (BT85/KG) 1.3	 1.5	 2.0	 Gasoline 9.5 Diesel 6.5 Charcoal Prc 1.3	 Gasoline 8.9 Diesel 6.3 Charcoal Prc 1.3	Avai Fac 2000 KWH/KW Gasoline 10.2 Diesel 6.7 Charcoal Prc. 1.3
Gasif 1, 600W Life Time 6 Yrs. Gasoline Eng.	Max. Investment Cost (BT/KW) (BT/MWH) Max. Variable Cost (BT/MWH)	16,000 2,505.78	5,441 (348.74) 1,789.96	1,692 (108.43) 1,906.58	2221 (142.39) 1,482.99	3684 (236.11) 1,476.29	9387 (601.66) 1,202.83	- -
Gasif 2, 2KW Life 6 Yrs. Gasoline Eng.	Max. Investment cost (BT/KW) (BT/MWH) Max. Variable Cost (BT/MWH)	14,500 1,404.48	14,500 (929.40) 1,211.45	14,500 (929.40) 1153.14	14,303 (916.74) 	14,500 (929.40) 738.43	14,500 (929.40) 681.96	14,500 (1,338.34) 966.14
Gasif 6/1, 5KW Life 6 Yrs. Diesel Eng.	Max. Investment Cost (BT/KW) (BT/MWH) Max. Variable Cost (BT/MWH)	13,500 1,122.35	11,113 (712.28) 899.16	12,504 (801.47) 842.86	12,495 (800.84) 850.23	11,113 (712.28) 867.65	11,113 (712.28) 822.75	10,453 (964.81) 653.85
Gasif 7/1, 10KW Life 6 Yrs. Diesel Eng.	Max. Investment Cost (BT/KW) (BT/MWH) Max. Variable cost (BT/MWH)	12,635 1,027.45	12,635 (809.80) 756.68	12,635 (809.80) 701.04	12,134 (777.75) 707.75	12,635 (809.80) 725.84	12,635 (809.80) 680.27	12,167 (1123.11) 512.04
	System Selected (based on original cost) Min. Operating Hours/Year		Gasif 7/1 2880	Gasif 7/1 2880	Not Acceptable	Gasif 7/1 2880	Gasif 7/1 2880	Not Acceptable

Investment cost = Investment cost of gasifier system only, not including diesel engine or gasoline engine.

Variable cost = Labor cost, maintenance cost and lubricant cost.

Table 5.4 The Maximum Investment + variable costs and minimum operating hours of wood gasifiers permissible in Nongwang as suggested by RCDM.

Capacity		Original	Availability Factor 2880 KWH/KW Gasoline Price 10.2 Diesel Price 6.7 BT/LIT Wood Price (BT85/TON) 288	509	797	Gasoline 9.5 Diesel 6.5 Wood Prc 509	Gasoline 8.9 Diesel 6.3 Wood Prc 509	Avai Fac 2000 KWH/KW Gasoline 10.2 Diesel 6.7 Wood Prc 509
Gasif 6/2,5KW Life Time 6 Yrs Diesel Eng	Max. Investment Cost (BT/KW) (BT/MWH) Max. Variable Cost (BT/MWH)	23,400 1,122.35	9,087 (664.60) 1,122.35	 1,122.35	7,399 (531.29) 1,103.58	- - 968.19	8,142 (521.85) 1,029.85	
Gasif 7/2,10KW Life Time 6 Yrs Diesel Eng	Max. Investment Cost (BT/KW) (BT/MWH) Max. Variable Cost (BT/MWH)	20,615 1,027.45	9,855 (720.84) 1,027.45	9317 (668.97) 1,027.45	8,931 (572.49) 961.10	9,405 (602.87) 968.47	9,673 (620.00) 938.11	9,497 (876.61) 807.61
Gasif 8,25KW Life 8 Yrs Diesel Eng	Max. Investment Cost (BT/KW) (BT/MWH) Max. Variable Cost (BT/MWH)	16,900 926.68	13,809 (778.53) 926.68	13,809 (764.30) 926.68	14,904 (736.43) 810.05	13,666 (675.23) 905.90	13,666 (675.23) 875.07	13,756 (978.77) 655.90
Gasif 9,50KW Life 8 yrs Diesel Eng	Max. Investment Cost (BT/KW) (BT/MWH) Max. Variable Cost (BT/MWH)	13,965 912.39	13,965 (787.33) 912.39	13,965 (772.95) 912.39	13,965 (690.03) 788.39	13,965 (690.03) 884.23	13,965 (690.03) 853.40	13,965 (993.63) 628.20
	System Selected (based on original cost) Min. Operating Hours/Year		Gasif 9 2524	Gasif 9 2571	Gasif 9 2880	Gasif 9 2880	Gasif 9 2880	Gasif 9 2000

Table 5.5 Maximum investment + variable costs, and Minimum operating hours of rice husk gasifiers permissible in Nongwang suggested by RCDM.

Capacity		Original	Availability Factor 2880 KWH/KW						Avai Fac 2000 KWH/KW
			Gasoline Price 10.2 BT/LIT Diesel Price 6.7 " Rice Husk Price (BT85/TON)			Gasoline 9.5 Diesel 6.5 Rice Husk Prc	Gasoline 8.9 BT/LIT Diesel 6.3 BT/LIT Rice husk Price		Gasoline 10.2 Diesel 6.7 Rice Husk Prc
			139	415	515	139	139	615	139
Gasif 3, 10KW Life Time 6 Yrs Gasoline Eng.	Max. Investment Cost (BT/KW) (BT/MWH) Max. Variable Cost (BT/MWH)	20,615 1,027.45	9,856 (758.09) 1,027.45	9,856 (758.09) 1027.45	9,856 (757.46) 1,027.45	9,856 (758.09) 1,027.45	9,856 (758.09) 1,027.45	9,317 (597.17) 1,027.45	10,138 (1,090.64) 1,027.45
Gasif 4, 25KW Life 8 Yrs., Gasoline Eng	Max. Investment Cost (BT/KW) (BT/MWH) Max. Variable Cost (BT/MWH)	16,900 926.68	13,814 (819.06) 926.68	13,814 (819.06) 926.68	13,814 (818.37) 926.68	13,814 (819.06) 926.68	13,814 (819.06) 926.68	13,730 (678.38) 926.68	15,024 (1,245.88) 926.68
Gasif 5, 50KW Life 8 Yrs., Gasoline Eng	Max. Investment Cost (BT/KW) (BT/MWH) Max. Variable Cost (BT/MWH)	13,965 912.39	13,965 (828.01) 912.39	13,965 (828.01) 912.39	13,965 (827.33) 912.39	13,965 (828.01) 912.39	13,965 (828.01) 912.39	13,965 (690.01) 912.39	13,965 (1,158.10) 912.39
	System Selected (based on original cost) Min. Operating Hours/Year		Gasif 5 2,400	Gasif 5 2,400	Gasif 5 2,402	Gasif 5 2,400	Gasif 5 2,400	Gasif 5 2,880	Gasif 5 1,716

can be economic for operating times of only 2571 and 2524 HRS/YEAR respectively. For normal wood prices of 509 BT/TON, if the availability factor of the system is decreased to 2000 KWH/KW, it can be accepted by decreasing the original variable cost to about 284 BT/MWH. In the competitive condition of premium-gasoline prices down to 9.5, 8.9 BT/LIT and diesel prices down to 6.5, 6.3 BT/LIT, Gasifier System 9 at normal wood prices is acceptable with minimum operating hours of 2880 HRS/YEAR with a slight decrease in variable costs.

3. For rice husk gasifiers with conditions of gasoline prices of 10.2 BT/LIT and diesel prices of 6.7 BT/LIT, Gasifier System 5 operated with a gasoline engine is the most appropriate system for the community at rice husk prices below 515 BT/TON. The optimum operating hours are only about 2400 HRS/YEAR, that is, the ratio of operating hours in both wet and dry seasons is 3:2. The model shows that importing glutinous paddy for the rice mill using the rice husk gasifier-gasoline engine system and converting to glutinous rice, then exporting it in excess of domestic consumption in any one season, will increase income of the community. At one point the investment cost of the gasification system due to the increased capacity will be higher than the gain from export of glutinous rice. Under the present conditions where premium-gasoline and diesel prices have decreased to 8.9 and 6.3 BT/LIT respectively, if the cost of rice husk is increased up to 615 BT/TON due to lack of local process residue and the rice husk must be imported from elsewhere, the gasification system would be economically acceptable only in the case of running at a maximum yearly operating hours of 2880 HRS/YEAR.

Other informations obtained from the output of RCDM are as follows :

1. The dual value of "X", which represents the capacity variable, indicates that reduced costs or the investment cost which must be lowered to let one unit of capacity (1HP) be introduced in that link. The yearly cost, which equals the Dual value $x(1+a)^t$, tells us the value by which the investment cost should be decreased per 1 HP for the gasification system not selected by the model to be acceptable at that year.

<u>Example</u>

From the Dynamic Cost Table

The yearly cost of "X" for Gasifier System 8 at wood prices of 288 BT/TON in the year 1985 is 1502 BT/1HP

Original investment cost = 16,900 BT/1KW
= 12,607 BT/1HP

$$\text{Annual capital charge (A)} = I \times \frac{a}{1-(1+a)^{-DV}}$$

I = Initial equipment cost

DV = Life time (in years)

a = Real discount rate = 3%

$$\frac{a}{1-(1+a)^{-DV}} = 0.2184 \text{ for 5 years}$$

$$= 0.1423 \text{ for 8 years}$$

"A" for Gasifier System 8 (Life time 8 years)

$$= 12,607 \times 0.1423 = 1793.98 \text{ BT/HP.YEAR.}$$

Investment cost in 5 years period (1985-1989)

$$= \frac{1,793.98}{0.2184} = 8214.19 \text{ BT/HP}$$

Max. Investment cost in 1985 for Gasif 8 to be acceptable

$$= (8214.19 - 1502) \times \frac{.2184}{.1423} \quad \text{BT/HP}$$

$$= 10301.78 \quad \text{BT/HP}$$

$$= 13809 \quad \text{BT/KW}$$

$$= 13809 \times 0.1423 \times \frac{1000}{2524} \quad \text{BT/MWH}$$

$$= 778.53 \quad \text{BT/MWH}$$

2. The yearly cost corresponds to the dual value of "E", the flow variable, which indicates how much less the variable cost would be if the link not selected by the model has one unit flow (such as 1 KHPH) in that year.

From the results suggested by the model, we could select suitable gasification systems for specific activities in Nongwang as follows :

1. In case of lighting in the community, 34.34 MWH in 1985, we would introduce charcoal gasifiers in the capacity of 10 KW operated with dual-fuel diesel engines, Gasifier System 7/1, for shaft power of about 15 KHPH/SEASON to generate electricity by amounts of 10.14 and 10.07 MWH in the dry and wet season respectively in 1985 and a little more generation for the following years (gross-efficiency of

the generator = 0.6716 KWH/HPH). Nearly all of the electricity would be used for lighting for an electricity consumption of 0.5 KWH/KWH, to replace 90% of all kerosenc lamps.

2. If the villagers would like to have more water to increase the yield of rice and glutinous rice by about 66% of the original low land crops, shaft power of the order 36.6 KHPH to pump about 920 kilo-cubic meter of water from natural sources and unelevated reservoirs during the wet season irrigation will be required. The 20 KW wood gasifier operated with a dual-fuel diesel engine, Gasifier System 8, was selected to serve this activity and would be compared to the pump operated with the diesel engine.

3. The existing rice mill receives a local-production of rice paddy and glutinous paddy of 90 and 700 tons respectively in the wet season as the inputs when there is irrigation, the rice husk gasifier in the capacity of 50 KW operated with gasoline engine, Gasifier System 5, should be introduced for shaft power of 118.86 HPH/TON of paddy by using the mill residue and some imported from other villages nearby as the source of fuel. In the dry season, paddy should be imported and supplied to the mill by the same amount as local paddy production. The reason is for full utilization of the invested gasification system during the year and increasing in community income.

All these projects were tested with the model to see the effects to the community income, and the outputs are presented in the Appendix D, page 213-281.

Table 5.6 and Figure 5.1 indicate the incomes in Nongwang focasted by the model between 1985-1989 after gasification systems have been introduced compared to the original conditions in the community using gasoline and diesel prices of 8.9 and 6.3 BT/LIT respectively.

Figure 5.2 tells us the increase in wealth of Nongwang due to introduction of the technology for the five years period 1985-1989.

When the diesel engine driven pump was introduced to Nongwang for irrigation (Case 2) in 1985, the income of the Community decreased in the first year when compared to the original case of no water pumping (Case 1) because of the investment and variable costs of the equipment, and income would be higher in the following years from 1986 onward because of the increase in yield of paddy and the export of excess rice and glutinous rice after the milling process. The total income in the 5 years period would be increased by 835,000 Baht.

If the pump driven with dual-fuel diesel engine were operated with producer gas from wood gasifiers (Case 4), the income of Nongwang would decrease in 1985 compared to the system driven with diesel engine only (Case 2) due to the higher investment and higher variable costs for operation and maintenance of the gasification system. In subsequent years such income would increase slightly because of the cheaper cost of fuel (wood) compared to diesel for the same heating value. The total income in the 5 years period for this case would be no more than Case 2, but would be greater after 1989.

Table 5.6 Incomes in Nongwang focasted by RCDM when gasifiers are introduced during the years of 1985-1989.

Case	Activities	Income (BT85 x 10^6)					
		1985	1986	1987	1988	1989	Accumulation
1	Lighting - Kerosene lamps Irrigation - No water pumping for agriculture Rice mill - Diesel engine	7.213	9.408	11.570	12.740	12.890	53.821
2	Lighting - Kerosene lamps Irrigation - Water pumping with diesel engine Rice mill - Diesel engine	6.257	9.839	12.570	12.960	13.030	54.656
3	Lighting - Self electricity generat^{n} with Gasif 7/1, Dual-fuel engine Irrigation - Water pumping with diesel engine Rice mill - Diesel engine	6.033	9.837	12.570	12.960	13.010	54.410
4	Lighting - Kerosene lamps Irrigation - Water pumping with Gasif 8, Dual-fuel engine Rice mill - Diesel engine	6.080	9.870	12.600	12.990	13.060	54.600
5	Lighting - Kerosene lamps Irrigation - Water pumping with diesel engine Rice mill - Gasif 5, gasoline engine	5.918	10.250	12.960	13.340	13.340	55.808

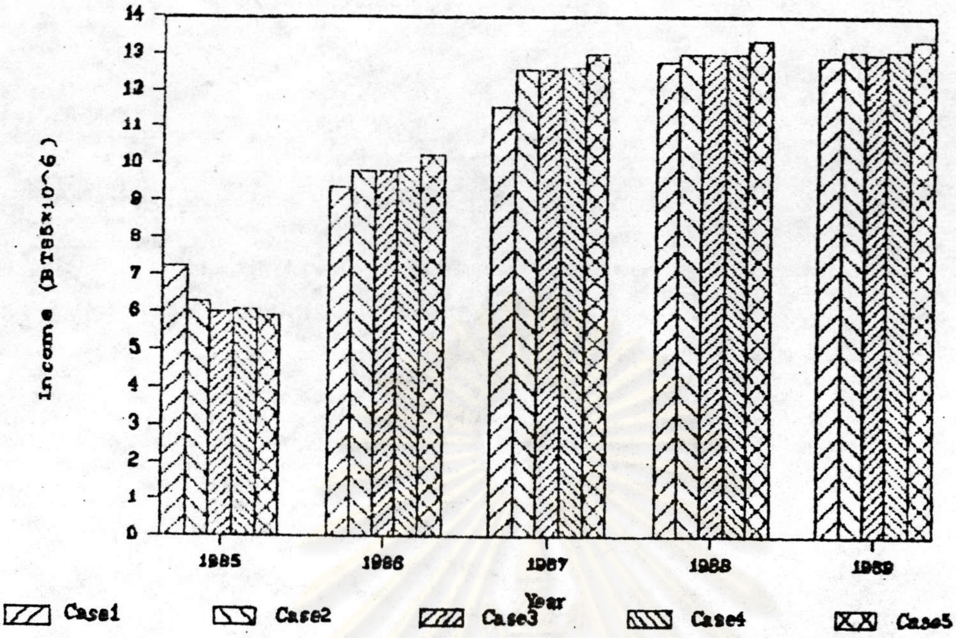

Fig . 5.1 Incomes in Nongwang focasted by RCDM between 1985–1989 after gasification systems have been introduced and, compared to the original conditions.

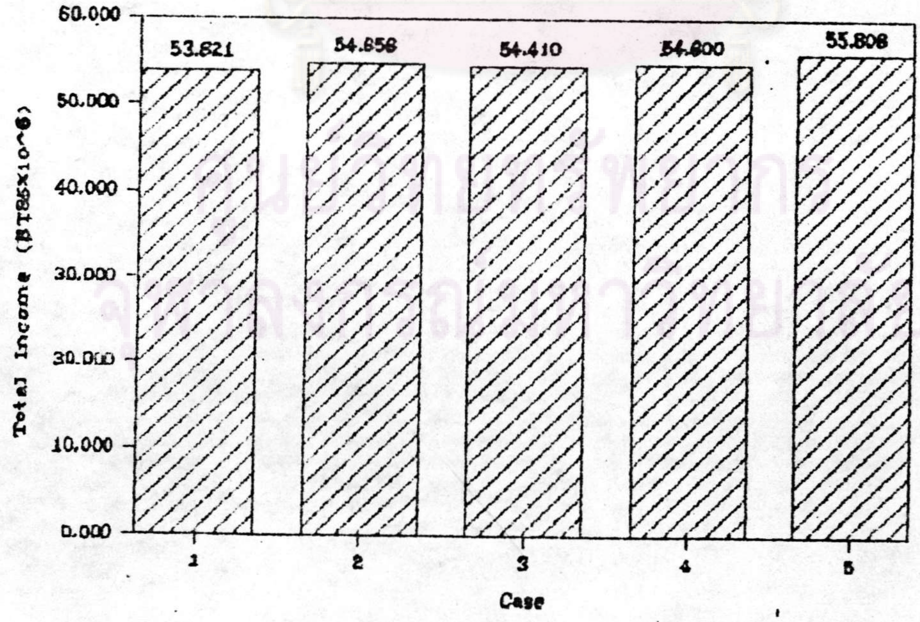

Fig. 5.2 The increase in wealth of Nongwang due to introduction of the technology in 1985–1989.

The introduction of a dual-fuel diesel engine driven generator operated with charcoal gasifiers (Case 3) would reduce the income of the villagers through the whole 5 years period studied (Case 3 minus Case 2) by 246,000 Baht. The model indicates that the cost of electricity generated is at 4.38 BT/KWH which is more expensive compared to the old system of using kerosene lamps. The self electricity generation is attractive only for offering convenience in lighting to the villagers.

Finally, the income of the Community would decrease substantially in the first year upon introducing a 50 KW rice husk gasifier-gasoline engine for shaft power to the existing mill (Case 5) due to the high investment cost of the equipment to replace the old diesel engine system, but income would increase in the following years due to very much cheaper cost of rice husk obtainable from the mill itself or imported from the nearby villages, when compared to diesel cost. In addition, the import of glutinous paddy for the mill to convert into glutinous rice for export in excess of household consumption is also a positive factor in enhancing income in subsequent years. The total income increase from this project in the 5 years period, 1985-1989, is 1,152,000 Baht (Case 5 minus Case 2).