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MANAGEMENT OF ENERGY GRASSES FOR BIOGAS PRODUCTION

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ABSTRACT

Global warming from greenhouse gases had caused environmental impact especially from the use of fossil fuel in heating and the electricity sector. Using of biogas was an alternative energy that reduced the amount of greenhouse gases. Thailand has been producing electricity from Napier grass with the target in the years 2012-2021 at 3000 MW. That present was not sufficed for Thailand needs. The objective of this study showed the evaluation of least cost per unit and environmental impact of biogas production from Napier grass, African Star grass and Paragrass by using the Extended Deming and Linear Programming in the management of energy grasses plantations, case study of Nakhon Ratchasima province, Thailand. Simulation management from 7 different scenarios of energy grass plantations was assessed the cost per unit and environmental impact. The result revealed that the scenario 1 simulation of 100 percent of African Star grass plantation that was the most suitable and effective procedure. The results of this study also showed that the energy grasses were highly digestible with relatively high biogas yields, 673 -737 ml/g-VS or 0.673-0.737 m^3/kg-VS.A summary of this research could solve the energy problem that it was the increasing of renewable energy by energy grasses. The economics evaluation of the biogas production from the energy grasses sized 1 MW showed that the internal rate of return of this project (IRR) was 12% per year, PI was 1.69, which was greater than 1, this project should be invested and the payback period was 6.0 years. Calculation of the interest rate was 7.25 baht per year. Feed-in Tariff was 4.5 baht per unit. The results of this study could be used as guide in the preparation of the plan promote and development for the biogas production from the energy grasses. The areas used to simulate of linear programming and extended Deming model to manage agricultural land for energy grasses were one way to manage the areas, maximize the benefits the total costs and minimum environmental impact.

Keywords: grass, energy, biogas.

INTRODUCTION

As well as problem was global climate changing from greenhouse gases emissions for the using of the fossil fuel energy in the industries (Intergovernmental Panel on Climate Change, 1996). Promoting the use of renewable energy in various forms to suit the climate and terrain of Thailand's policy to reduce greenhouse gases emission. The use of biogas as an alternative fuel was one option to reduce the effects of global warming that the use of fossil fuel caused of greenhouse gases increasing. Thailand has been producing electricity from Napier grass with the target in the years 2012-2021 at 3000 MW but was still insufficient for the present. The areas of energy grasses were limited and the amounts of biogas that did not met the target. Therefore the any problems should be studied to find solutions to control air pollutants, renewable energy to fuel production facility of the factories or industries and the economy evaluation of the biogas plants was a renewable fuel. This paper proposed to manage agricultural land use for growing energy grasses on the basis of linear programming(Hillier and Lieberman, 2005)and Inchant (2008) extended Deming model to guide the production of biogas to yield the target to optimize the overall economic and environmental impact. The objectives of research were determination the biogas production potential of the energy grasses and analyzed the feasibility for use as feedstock for anaerobic digestion.

Investment analysis was the planning of value-adding, long-term corporate financial projects relating to investments funded through and affecting the project of capital structure Campbell and Stephen (1997). This project used payback period, PI, and IRR were index for the feasibility study.

The internal rate of return (IRR) of a project was the rate of return which equates the net present value of the projects cash flows to zero; or equivalently the rate of return which equates the present value of inflows to the present value of cash outflows. The internal rate of return (IRR) solves the following equation:

$$\sum_{t=1}^{X} \frac{X_t}{(1+IRR)^t} - I = 0 \tag{1}$$

In determining whether to accept or reject a particular project, the IRR decision rule was

- Accept a project if IRR > r_p
- Reject a project if IRR< r_p
- Indifferent if IRR = r_p
- For Mutually exclusive projects accept the project with highest IRR if IRR > r_p

Where; r_p was the required return on the project.

Payback Period was the period of time required for the return on an investment to "repay" the sum of the original investment. Payback period intuitively measures how long something takes to "pay for itself." All else being equal, shorter payback periods are preferable to longer payback periods. To calculate a more exact payback period (Williams, *et al*, 2012):

Payback period = Amount to be invested / Annual net cash flow (2)

Campbell and Stephen (1997) according to apply the payback period criterion, it was necessary for management to establish a maximum acceptable payback value PP*. In practice, PP* was usually between 2 and 4 years. In determining whether to accept or reject a particular project, the payback period decision rule was:

- Accept if PP < PP*
- Reject if PP > PP*
- Indifferent where PP = PP*
- For mutually exclusive alternatives accept the project with the lowest PP if PP<PP*

The profitability index, was used when projects had only a limited supply of capital with which to invest in positive NPV projects. This type of problem was referred to as a capital rationing problem. Given that the objective was to maximize shareholder wealth, the objective in the capital rationing problem was to identify that subset of projects that collectively had the highest aggregate net present value. To assist in that evaluation, this method required that we computed each projects profitability index PI.

$$PI = \frac{NPV}{I} \quad (3)$$

Then ranked the projects PI from highest to lowest, and then selected from the top of the list until the capital budget was exhausted. The idea behind the profitability index method was that this would provide the subset of projects that maximize the aggregate net present value (Campbell and Stephen, 1997).

RESEARCH METHOD

The methodology of research to manage agricultural crop use that were 3 types of energy grassesin Nakhon Ratchasima province, Thailand on the basis of linear programmingand extended Deming model to guide the production of biogas yield to the target with optimize the overall economic and environmental impact. Perform batch anaerobic digestion tests to determine the rate of digestion and biogas yields of energy grasses samples.

Equipment used in operations research

The high rate anaerobic digestion reactor was attempted to achieve contact between microorganism and nutrients or sewage sludge by circulate of wastewater sludge in system (Keeratiurai, 2015). The high rate anaerobic digestion includereactor has 880 liters in a cylindrical shape, 75 cm in diameter, and 2 meters highas shown in Figure-1. The components of the high rate anaerobic digestion reactorwere as follows.

- Circulation pumps to the sewage sludge of the high rate anaerobic digestion reactor
- Section for exhaust biogas of the high rate anaerobic digestion reactor

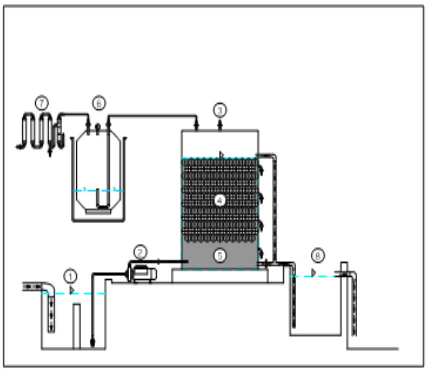

Figure-1. Section of the high rate anaerobic digestion reactor (Keeratiurai, 2015).

METHODOLOGY

This study took the grasses as Napier grass (*Pennisetum purpureum*), African Star grass (*Cynodon plectostachyus*) and Paragrass (*Brachiaria mutica*) were digested in the liquid state.The grasses were minced and crushed into small pieces. Then, they were put into the primary tank and mixed with manure in a ratio of 50:50 and flowed into the high rate anaerobic digestion reactors, respectively. This study had the four conditions of hydraulic retention times were 3 days, 5 days, 7 days, and 9 days. The all batch conditions were controlled system in the range of pH 7.5 ± 0.5, thermophilic digestion temperature in slurry as 45 - 55 °C and desirable moisture content of feed as 50-60%. The influence of temperature, nutrients and pH upon process performance was evaluated. The start-up process consisted of a long acclimatization phase followed by a low loaded growth phase at which total COD removal efficiencies of 80-90% were achieved. The system went into steady state. The percentage average of COD removal in 10 days had standard deviation less than 10%.The wastewater samples were collected at inlet and outlet of the high rate anaerobic digestion reactor. The parameters were analyzed with the Standard method (APHA, AWWA, WEF, 1992).

The study found the right proportion of area management energy grasses in order to obtain the highest amount of biogas. The results of this study also showed

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the lowest costs of 3 energy grasses that were Napier grass, African Star grass and Paragrass. The scopes of this study were cultivation, transportation, processing and biogas production using the extended Deming model (Inchant, 2008) as shown in Figure-2.

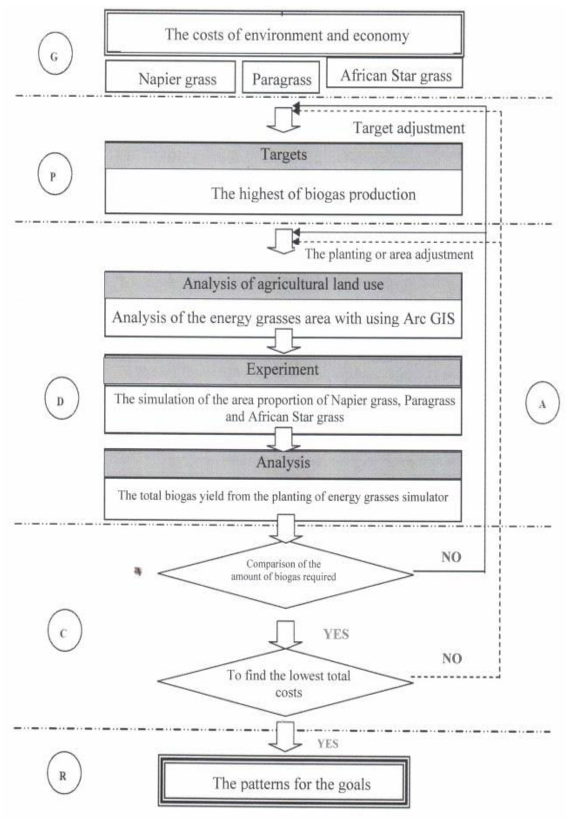

Figure-2. Diagram of the study.

Step 1 (G: General) was a part of the basic information about the economic and environmental costs of energy grasses. The environmental costs from the effects of greenhouse gases, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxides (N_2O) (Spadaro and Rabl, 2002).The environmental costs were equivalent to the costs of pollution treatment. The data in stage of cultivation, transportation, processing and the biogas production from Napier grass, African Star grass and Paragrass obtained from the literature, the pilot scale in laboratory and estimated the actual data of the Arc GIS.

Step 2 (P: Plan) was a part of the goal that was set by the research that was based on the lowest costs and the production of biogas up to the demand of electricity for Thailand was 1 MW (Department of Alternative Energy Development and Efficiency, 2015).The investment did not exceed 100 million baht per property. The system of biogas production from energy grasses size 1 MW per property need areas for planting was 800-1000 rais that it produced biogas to 100 m^3/ton.grasses/day. There were produced 35-40 tons per rais per year.

Step 3 (D: Do) was analysis of energy grasses considering on the Arc GIS that was found in Nakhon Ratchasima province was grown Napier grass, African Star grass and Paragrass spread throughout the areas. The areas for energy grasses planting 180,655.10 rais of estimates of area planted and yield by considering demand and supply of various crops that were grown in the areas of Napier grass, African Star grass and Paragrass in order to avoid the problems of food and energy crops. The remaining areas for the management of energy grasses wererainless areas, wetland and the areas could not planted to rice. Later, the areas for energy grasses and then the simulation for 7 crop management models.

scenario 1: African Star grass area was 100%

scenario 2: Napier grassarea was 100%

scenario 3: Paragrass area was 100%

scenario 4: Napier grass area was 50% and : African Star grass area was 50%

scenario 5: Napier grass area was 50% and Paragrass area was 50%

scenario 6: African Star grass area was 50% and Paragrass area was 50%

scenario 7: Napier grass area was 33.33%, African Star grass area was 33.33% and Paragrass area was 33.33%

Step 4 (C: Check) were the results of them growing energy grasses of the model that assumed the proportions of the 3 types of energy grasses on target. The research was based on the lowest costs and the maximum yield of biogas.

Step 5 (A: Act) If the results did not meet the targets set, would had to reverse back in step D by adjusting grasses plantation/area. If it did not meet the goal might be to reverse the process P by the new target to accomplish this objective.

Step 6 (R: Result) was the proportion of energy grasses that were the targets.

Statistical data analysis

The data were analyzed with descriptive statistics and statistical analysis as follows: To describe the characteristics of the wastewater, performance of the high rate anaerobic digestion reactor, and the daily biogasyield (ml/gVS.day) and the cumulative biogas yield (ml/gVS) in

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mean, standard deviation, that they were tested at 95% confidence level (Cavana *et al*., 2001, Yamane, 1973).

RESULTS AND DISCUSSIONS

This research proposed to manage agricultural land use for growing energy grasses on the basis of linear programming and extended Deming model in Nakhon Ratchasima province, Thailand. Analysis of agricultural land use was divided into 2 parts: the areas used in the simulations and the distance used in transportation. The areas used in simulations to find the areas that were used to simulate different scenarios for the biogas production using real data. The distances used to transport evaluated from the field to the plants of biogas production in districts, primarily in this section applied the breadth of the district / 2 was the average distance shipping. Productivity of the field to the processing plants and the distance originally used to transport raw materials were calculated from the ArcGIS. The results of this study showed that agricultural land use in the simulation, the economic and environmental costs of energy grasses were shown in Table-1.

Table-1. Agricultural land use in the simulation, the economic and environmental costs of energy grasses.

Simulation areas	**Economic costs** (baht x 10^3 per rai per day)			**Environmental costs** (baht x 10^3 per rai per day)		
(rais)	**African Star grass**	**Napier grass**	**Paragrass**	**African Star grass**	**Napier grass**	**Paragrass**
180654 ± 6205.00	2036 ± 1.13	3529 ± 0.85	7511 ± 1.08	130.64 ± 0.12	226.7 ± 0.11	322.76 ± 0.09

Management of renewable energy from grasses in various proportions to obtain the maximum amount of biogas and the lowest total costs compared to the targets set. Calculated using the following by

$$\text{Min } Z = \sum_{l=1}^{2} . \sum_{k=1}^{5} . \sum_{j=1}^{32} . \sum_{i=1}^{3} .(CP_i + CPP_i + CT_{ijkl} + CB_i)\, x_{ij}$$

$CP_i = ECP_i + ENP_i$
$CPP_i = ECPP_i + ENPP_i$
$CT_{ijkl} = ECT_{ijkl} + ENT_{ijkl}$
$CB_i = ECB_i + ENB_i$
The following functional constraints

1. Constrained by areas for agriculture
$x_{1j} + x_{2j} + x_{3j} \leq X_j$

2. Restrictions on the amount of biogas
$\sum_{k=1}^{5} . \sum_{j=1}^{32} . \sum_{i=1}^{3} .\ A_{ij}V_i x_{ij} y_{ijk} \geq 0$

3. Restrictions on the transport routes
$y_{1j1}+y_{1j2}+y_{1j5}= 1$
$y_{2j3}+y_{2j4}+y_{2j5}= 1$
$y_{3j3}+y_{3j4}+y_{3j5}= 1$

4. Constrained by the capacity of the biogas plants
$\sum_{j=1}^{3} .A_{1j}V_1 x_{1j} y_{1j1} \leq 547272$
$\sum_{j=1}^{3} .A_{1j}V_1 x_{1j} y_{1j2} \leq 331044$
$\sum_{j=1}^{3} . \sum_{i=2}^{3} .A_{ij}V_i x_{ij} y_{ij3} \leq 373536$
$\sum_{j=1}^{3} . \sum_{i=2}^{3} .A_{ij}V_i x_{ij} y_{ij4} \leq 479880$
$\sum_{j=1}^{3} . \sum_{i=1}^{3} .A_{ij}V_i x_{ij} y_{ij5} \leq 436116$

Where; Z = Total costs (baht per rai per day)
C = Costs of each step (baht per rai per day)
P = Cultivation
PP = Processing
T = Transportation
B = Biogas production
EC = Economic costs (baht per rai per day)
EN = Environmental costs (baht per rai per day)
x = Area (rai)
y = Routes to transport raw material to plant
Napier grass = 1, 2, 5
African Star grass = 3, 4, 5
Paragrass = 3, 4, 5
X = Cultivated areas in each districts (rai)
A = Average yield per unit area (tons per rai per day)
V = Conversion ratio of biogas (m^3 per ton)

Simulation management from 7 different scenarios of energy grass plantations was to assess the cost per unit and environmental impact. The result revealed that the scenario 1 simulation of 100 percent of African Star grass plantation that was the most suitable and effective procedure.This study also took the grasses that were Napier grass, African Star grass and Paragrass, were digested in the liquid state. They were put into the primary tank and mixed with manure in a ratio of 50:50 and flowed into the high rate anaerobic digestion reactors, respectively. This study had the four conditions of hydraulic retention times were 3 days, 5 days, 7 days, and 9 days. The all batch conditions were controlled system in the range of pH 7.5 ± 0.5, thermophilic digestion temperature in slurry as 45 - 55 ºC and desirable moisture content of feed as 50-60%. The results of this study showed that the energy grasses were digestible with relatively daily biogas production (ml/g-VS/day) and the batch digestion times (25 days) as showed in Figure-3.

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The results of this study also showed that the energy grasses were highly digestible with relatively high biogas yields, 673 -737 ml/g-VS or 0.673-0.737 m^3/kg-VS as showed in Figure-4.

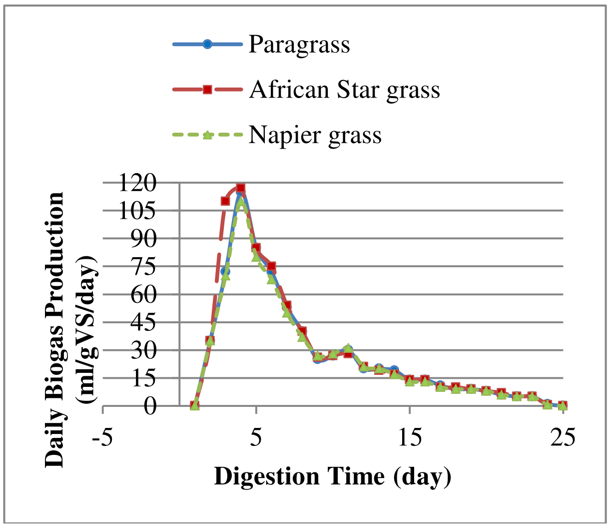

Figure-3. Daily biogas production during batch digestion times (25 days).

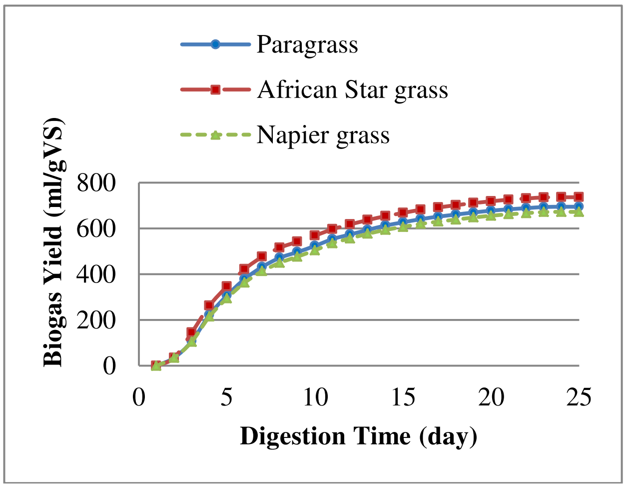

Figure-4. Biogas yield during batch digestion time (25 days).

Analysis of the economic values

This research also studied the economic values of the biogas production from the digestion of the African Star grass with the high rate anaerobic digestion reactor. The results indicated that this high rate anaerobic digestion system was less expensive when the cost of this system was compared to the commercially available wastewater treatment tanks. The economic values were the costs of construction and energy used per unit. Theeconomics evaluation of the biogas production from the energygrasses sized 1 MW showed that the internal rate of return of this project (IRR) was 12% per year, PI was 1.69, which was greater than 1, this project should be invest and the payback period was 6.0 yearsas shown in Table-2. Calculation of the interest rate was 7.25 baht per year. Feed-in Tariff was 4.5 baht per unit.

Table-2. The economic values of the biogas production from the digestion of the African Star grass sized 1 MW.

The economic values	Performance of the high rate anaerobic digestion reactor
Internal rate of return(IRR)	12% per year
PI	1.69
Payback Period	6.0 years

SUMMARY AND CONCLUDING REMARKS

Simulation management from 7 different scenarios of energy grassplantations was to assess the cost per unit and environmental impact. The result revealed that the scenario 1 simulation of 100 percent of African Star grass plantation that was the most suitable and effective procedure. A summary of this research could to solve the energy problem that it was the increasing of renewable energy by energy crops. The results of this study also showed that the energy grasses were highly digestible with relatively high biogas yields, 673 -737 ml/g-VS or 0.673-0.737 m^3/kg-VS. The high rate anaerobic digestion technology could to produce biogas and reduced air pollution such as dust, smoke and greenhouse gases (Keeratiurai, 2015). Therefore, the industries or factories should reduce emissions from energy consumption such as reduced the use of fossil fuels for the heating and electricity in production. It was suggested that the use of fossil fuels for electricity production should be reduced because it creates the highest carbon emission (Keeratiurai, 2012). The economics evaluation of biogas production sized 1 MWshowed that the internal rate of return of this project (IRR) was 12% per year, PI was 1.69, which was greater than 1 this project should invest and the payback period was 6.0 years. The results of this study could be used as guide in the preparation of the plan promote and development for the biogas production from the energy grasses. The areas used to simulate of linear programming and extended Demingmodel to manage agricultural land for energy grasses were one way to manage the areas, maximize the benefits the total costs and minimum environmental impact.

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