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TITLE: CLEAN DEVELOPMENT MECHANISM (CDM) – BASED DEVELOPMENT OF GRID-CONNECTED RICE HUSK-FUELLED BIO-POWER PLANTS IN MEKONG DELTA, VIETNAM

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ABSTRACT

The research is designed for developing the pilot small-scale clean development mechanism bundled project activities in Vietnam electricity/ energy sector. Its overall purpose is to assess the potential of rice husk - fuelled bio-power development projects in Mekong delta. Based on estimating the electricity potential of a bundle of rice husk-fuelled bio-power development projects in Mekong delta with the capacity of 11 MW per project, assessing their CO_2 emission reductions (CERs) and CER credits, calculating and comparing their financial indices (NPV, B/C, IRR) in two cases: W/O CDM and W/CDM, the research expects to establish a rice husk energy balance flowchart for the whole Mekong delta in the year 2021 and recommend policies to use for bio-power generation the unused rice husk that is dumped and discharged from local paddy milling centers into rivers and canals, as well as, to put forward a safe and environmentally friendly solution to minimize thoroughly the current serious pollution of rivers and canals in Mekong delta with the increasing unused rice husk quantity in the context is where the sea level rise phenomenon is the strongest in the world .

Key words: Rice-husk, power plants, CO_2 *emission reductions, Clean Development Mechanism*

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1. INTRODUCTION

Vietnam has an impressive economic growth rate, and success in transforming from command economy to market economy, especially in transforming and developing its agricultural sector.

The importance of the agricultural sector in Vietnam is profound, with a major impact on employment, GDP and export. A continuing agricultural development generally and a rapid paddy production growth particularly are very necessary. The Mekong Delta is the most important agricultural region amongst these regions in the country

Vietnam renewable energy report 2018 of Vietnam Investment Review (2018) planned and highlighted key points including demand of electricity growth rate is 9,1% per year, in in which demand of renewable energy growth rate is 10% per year. This report pointed out that the growth rate of renewable energy supply will be increased fastest 23,2% comparing with hydropower 2,6%, and coal gas fire 7,8%, in the period of 2020 – 2030

The intensive paddy farming and rapid growth of rice production in Mekong delta leads to dumping and discharging a large amount of rice husk from local dense milling center network. The end-uses of rice husk discharged from milling centers are fuelling brick-kilns, porcelain furnaces and rural household cooking (not to be considerable - under 20% of total), open air burning for fertilizing the planted areas (not to be considerable - under 20% of total), and dumping (to be uncontrollable- over 70%) (The Statistical Yearbook, 2020).

Figure 1: Rice husks from rice-milling plants/factories pollute the environment in the Mekong Delta

Because almost all of paddy milling centers in Mekong delta are located on the banks of canals and two major rivers - Tien river and Hau river in order to take advantage of local dense water transport network, unused rice husk dumped by milling centers is discharged into the Mekong delta's dense canal system, that provoke the serious pollution of local canals and rivers with increasing dumped rice husk amount. With Mekong delta's dumped rice husk quantity amounting to 1,4 million tons per year, the uncontrollable dumping of unused rice husk discharged from dense milling center network into canals and rivers provokes serious negative environmental impact to have to be resolved (See figure 1 for rice husk polluting problems). Amongst three rice husk disposal modes - open air burning of rice husk for fertilizing the planted areas, uncontrollable dumping of unused rice husk into rivers and canals, and rice husk-fuelled bio-power generation, the last one is selected as the most economically feasible and environmentally friendly solution in the context of Government and local priorities given to renewable electricity generation technologies and rural electrification in Mekong delta.

P. K. Toan, N. V. Hanh and N. D. Cuong (Institute of Energy) have elaborated in 2005 the quantitative study on the Feasibility of Using the Solar Energy, Mini-hydro power and Biomass Energy in Vietnam. The study provided a comprehensive overview on three main types of renewable energy in Vietnam – Solar, Mini-hydro power and Biomass energy, in that, the using rice husk and bagasse to fuel the bioelectricity generation is first considered in details on not only the qualitative but also the quantitative basis (Chapter 2-2.4 and Chapter 4-4.2). The preliminary data and analysis of the study on the rice husk potential in Mekong Delta (South-Vietnam) are very useful for preparing the CDM-PDD of 11 MW rice husk-fuelled biopower plant and policy recommendations for using the rich rice husk potential of provinces in Mekong Delta (Institute of Energy- EVN-MOI. 2005).

Objectives of the study: To assess the CDM-based potential of rice husk - fuelled bio - power development projects and to recommend a regional strategy to develop a bundle of rice husk - fuelled bio-power development projects of 11 MW installed capacity per project for minimizing the uncontrollable dumping of unused rice husk discharged from local dense paddy milling centers to rivers and canals in Mekong delta.

2. LITERATURE REVIEW

Cheewaphongphan et al. (2018) show that rice straw has the potential to serve as a fuel supply for VSPPs at 14.2%, 21.6%, 26.3%, and 29.0% for the radii of compilation at 24, 36, 48 km and 60 km, respectively. The study results of Ji & Nananukul (2019) assist decision making on the location of biomass plants as well as in the distribution plan. Weldekidan et al. (2020) concluded that “gases produced from solar assisted biomass pyrolysis have a high concentration of combustible products that could be directly used as fuels in engines or power plants.” The most promising residues are rice husk, bagasse, oil palm residue and rubber wood residue, merely due to their availability at the mills, which heat–power cogeneration is feasible. Biogas resources are from industrial wastewater and live stocks manure, which have potential of 7800 and 13,000TJ/y, respectively (Prasertsan & Sajjakulnukit 2006). Kinoshita et al. (2010) found that biomass production of 15Â PJ that is the numeric target of Japanese government is possible. The study of Beagle & Belmont (2016) assessed beetle kill biomass availability in national forests in Wyoming and Colorado through Geographic Information System (GIS) analysis of U.S. Forest Service (USFS) data. Power plants near beetle kill mortality were identified as candidates for co-firing. The various barriers to biomass utilization are highlighted in study of Tzelepi et al. (2020) such as the stranded asset risk of a future coal phase-out scenario, biomass supply chain challenges, biomass availability in main lignite-producer EU countries, the existing full conversion technologies, and biomass cost. Jasiulewicz (2019) stated “when taking a decision on replacing hard coal with local biomass, it is necessary to adequately handle logistics and replace boilers in thermal power plants with special boilers for the combustion of solid biomass” Bioelectricity potential from sugarcane biomass is estimated to be in the range of 209–313 GWh for Nepal and 62–93 TWh for Brazil. In Nepal, the grid connected bioelectricity can provide power for operating industries, and support local development through rural electrification. In Brazil, the biomass potential can be further enhanced through a better utilization of the biomass in the sugar-ethanol industry to balance hydropower availability (Khatiwada et al. 2012)

Biomass power plants could achieve net emission reductions in a shorter time (0.39 year) after operation. The life cycle GHG emissions of biomass power projects are between 42 and 85 g CO2-e/kWh (He et al. 2018). The results of study of Luk et al.

(2013) show that with proper drying and heat integration, the overall efficiency can be improved by more than 5%, when compared to process without drying. The simulation incorporates the county-level biomass market of corn stover, wheat straw, switchgrass, and forest residues as well as endogenous crop prices (Dumortier 2013) The results of Botelho et al. (2016) study stress the importance of performing an equity analysis of the welfare effects on different groups of stakeholders from the installation of forest biomass power plants, as their effects on welfare are location and impact specific. While the biomass sulphur content is between 0 and approximately 1%, the sulphur content of coal can reach 4%. Using coal in power plants requires important investments in installations of flue gas desulfurization (Tîrtea & Mărculescu 2017). The most widespread method of producing electricity from renewable sources in power plants involves the co-firing of biomass with fossil fuels, utilizing the existing infrastructure (Tokarski 2015). Cereals (rice, wheat, maize and barley) have major contribution (74.67%) in the surplus biomass, followed by cotton (25.01%) and sugarcane (0.2%). The estimated annual bio-energy potential of unused crop residues is 0.35EJ (8.43% of India’s potential), which is equivalent to 1.43% India’s annual primary energy consumption. It has been revealed that a power potential of 2000–3000MW can be exploited from these resources depending upon thermal efficiency (Singh 2015). The results of Zhang et al. (2016) show that the proposed feedstock supply pattern can significantly increase the profits of biomass plants, biomass supply amounts, and farmers' participation, and in contrast with the broker pattern, it can lower feedstock prices through disintermediation. the average nominal and the average real LCOE for the proposed power plants are 10.55 and 6.33 ¢/kWh respectively, which is very competitive, compared with LCOE of other renewable energy technologies in Egypt Abdelhady (2018). The study of Gao et al. (2019) suggests that wind power plants should be built in desert areas when possible. Study of Moretti et al. (2020) is to identify the main sources of environmental impacts and to assess the potential environmental performance compared to benchmark of Biomass-fueled combined heat and power systems (CHPs) and conventional separate production technologies. The novel high-efficiency bio-based power (HBP) technology shows better environmental performance than heat from natural gas and electricity from the German/European grid.

The key findings of Yan et al. (2020) are under the optimum conditions, the power generation efficiency, the levelized cost of electricity, the CO2 capture rate, the annual power generation and the annual CO2 mitigation of the proposed system (or the conventional system) are 35.7% (31.5%), 0.0522$/kWh (0.0601$/kWh), 100% (98%), 1443.7 × 109 kWh/year (1241.81 × 109 kWh/year) and 1.191 × 109 t/year (1.159 × 109 t/year), respectively. A detailed cost analysis of Delivand et al. (2011) about a typical rice straw logistics process for two baling options in three regions of Thailand shows that the costs for all logistics operations vary from a minimum of 18.75USD/t for small rectangular bales in the Northern region of Thailand to maximum 19.89USD/t for large rectangular bales in the North-eastern region. Study results of Wang & Watanabe (2020) about the Development of Straw-Based Biomass Power Generation showed that: (1) risk transfer in the biomass supply chain is one of the reasons why farmers are unwilling to supply straw; (2) middlemen are vital intermediaries between biomass power plant managers and farmers as a middleman-based biomass supply system is necessary to guarantee the quantity of straw supply, and; (3) the institutional structure that underlies the Chinese biomass energy industry is immature. The study results of Visser et al. (2019) show that the WC, MLC and BC LCOE for biomass power plants in South Africa are 3.53 ZAR/kWh (0.235 USD/kWh), 1.30 ZAR/kWh (0.086 USD/kWh) and 0.78 ZAR/kWh (0.052 USD/kWh), respectively. The study results of Yang et al. (2019) indicated that a pulverized biomass/coal co-firing power plant with CCS can achieve near-zero emissions at a co-firing ratio of 25% and negative emissions of 877 kg CO2-e/MWh from a life-cycle perspective when coal is totally replaced. For the life-cycle GHG emissions, the forest residues ranges from 14.71 to 19.51g-CO2eq/kWh depending on the power plant size. The bundled and chipped at the power plant ranges from 21.42 to 20.90g-CO2eq/kWh (Thakur et al. 2014). The optimum size of ORC for a DH system of approximately 30 MW peak heating output is within the range of electric power of 1–2 MW (Świerzewski & Kalina 2020). The results of Cheewaphongphan et al. (2018) about very small power plants in Thailand, rice straw has the potential to serve as a fuel supply for VSPPs at 14.2%, 21.6%, 26.3%, and 29.0% for the radii of compilation at 24, 36, 48 km and 60 km, respectively. The current status of biomass resources of Portugal shows that the total potential estimated for various sectors of the country is of 42,489.7GWh/ye (Ferreira et al. 2017). Economic and environmental results of Mohamed et al. (2020) show that the efficiencies of the CCS and Non-CCS plants are equal to 36% and 41%, respectively, with a COE (including government renewable energy subsidies) for both CCS and Non-CCS equal to 15.9 ¢/kWh and 12.8 ¢/kWh, both of which are lower than the average COE in the UK (approximately 17.7 ¢/kWh). Singh (2016) concluded that "the cereal crops have major contribution (64.60%) in production of surplus biomass followed by sugarcane (24.60%) and cotton (10.68%). The energy potential of these resources is of the order of 3.72EJ, which represents a significant proportion of the primary energy consumption in India". The 60% biomass co-combustion supply chain scenarios show possibilities to reduce emissions up to 48%. The low co-combustion levels are effective toreduce GHG emissions, but the margins are small (Miedema et al. 2017).The results show that a better efficiency is obtained for the syngas 1 (up to 54%), in respect to the others. Concerning pollutant emissions, the syngas with a GHG impact and lower carbon dioxide (CO2) percentage is syngas 2 (Marseglia et al. 2020). The environmental analysis of the study of Roy et al. (2020) predicts that the proposed system has a maximum CO2 emission reduction potential of about 2867 tCO2/year compared to a coal-fired sub-critical steam power plant of similar capacity, resulting in an environmental benefit value of about 430014 $/year. The ash from the bubbling fluidized bed (BFB) was richer in potassium, phosphorus, CaO, and micronutrients than the ash from the circulating fluidized bed (CFB) and contained cumulatively less contaminants. However, the BFB ash exceeded the threshold values of Cd to be considered as a liming amendment (Jarosz-Krzemińska & Poluszyńska 2020). The optimum scenario is a 40 MW solar PV power plant, complemented with a 10 MW biomass power plant and with a substantial energy storage system (ESS). This configuration has the highest generation capacity, at over 1,200 PWh/yr, the lowest the levelized cost of energy (LCOE), at 11.2 US cents/kWh, and avoiding CO2eq emissions of nearly 38 ktonnes per year (Waewsak et al. 2020).

3. RESEARCH METHODS

3.1. Data collection

The rice husk availability on the basis of estimating the rice husk potential of milling centers located alongside Tien Giang river in Mekong delta.

The capability to transport in most economic manner (water way) the rice husk needed by not only the considered pilot rice husk-fuelled bio-power plant but also the future similar ones planned at Mekong delta;

The current local rice husk using and pricing.

Interviewing the relevant companies and stakeholders:

The willingness to participate in the pilot Project of current local milling centers in capacity of Project developers.

The willingness to sell the stored rice husk, the rice husk selling capability and the acceptable rice husk pricing level of current rice milling centers.

The steady rice husk availability and procurement for bioelectricity generation in provinces of Mekong delta (South - Vietnam).

3.2. Calculation of GHG emissions by sources

3.2.1. Project emissions

CO_2 from on - and off-site transportation.

CO_2 from start-up/auxiliary fuel use.

a) Biomass electricity generation

Annual CH_4 released	=	Heat value of rice husk used by Project	×	Methane emission factor for rice husk combustion	×	GWP of CH_4
(tCO_2e/yr)		(TJ/yr)		(tCH_4/TJ)		(tCO_2e/tCH_4)

b) Transportation of biomass

Distance traveled	=	Total rice husk consumed by project	÷	Truck capacity	×	Return trip distance to supply site
(km/yr)		(t/yr)		(t)		(km)

Emission factor	=	CO_2 emission factor	÷	CH_4 emission factor	×	GWP of CH_4	+	N_2O emission factor	×	GWP of N_2O
(tCO_2e/km)		(tCO_2/km)		(tCH_4/km)		(tCO_2e/tCH_4)		(tN_2O/km)		(tCO_2e/tN_2O)

Annual emission	=	Emission factor	×	Distance traveled
(tCO$_2$e/yr)		(tCO$_2$e/km)		(Km/yr)

c) Start-up/auxiliary fuel use

- For residual oil:

CO$_2$ emission factor	=	C emission factor	×	Fraction of C oxidized	×	Mass conversion factor
(tCO$_2$/TJ)		(tC/TJ)		–		(tCO$_2$/tC)

- For CH$_4$ and N$_2$O

Emission factor	=	CO$_2$ emission factor	+	CH$_4$ emission factor	×	GWP of CH$_4$	+	CO$_2$ emission factor	+	N$_2$O emission factor	×	GWP of N$_2$O
(tCO$_2$e/TJ)		(tCO$_2$/TJ)		(tCH$_4$/TJ)		(tCO$_2$e/tCH4)		(tCO$_2$/TJ)		(tN$_2$O/TJ)		(tCO$_2$e/tN$_2$O)

- For fuel consumption in energy equivalent

Fuel consumption in energy equivalent	=	Fuel oil (FO) consumption	×	Net calorific value of FO	×	Density of FO
(TJ/yr)		(L/yr)		(TJ/10^{3}t)		(t/L)

Annual Emission	=	Emission factor	×	Fuel consumption in energy
(tCO$_2$e/yr)		(tCO$_2$e/TJ)		(TJ/yr)

d) Describe the formulae used to estimate anthropogenic emissions by sources of greenhouse gas in the baseline using the baseline methodology for the applicable project category in appendix B of M & P:

$$\mathbf{E\ (ton\ CO_2/yr) = \textstyle\sum_j E_j\ (ton\ CO_2/yr)} \qquad \mathbf{(1)}$$

Where: E$_j$ = CO$_2$ emissions per year of the generation mode j, calculated as:

$$\mathbf{E_j\ (ton\ CO_2/yr)\ =\ PG_j\ (MWh/yr)\ x\ EF_j\ (ton\ C/TJ)\ x\ OF_j\ x\ CF/TE_j\ (\%)} \quad \mathbf{(2)}$$

Where: PG$_j$ = electricity generation of power plant j;

EF$_j$ = emission capacity of the fuel-fired power plant j;

OF_j = oxidation factor

CF = unit conversion factor: 44/12 (C – CO_2) x 0.36 (TJ – MWh);

TE_j = thermal efficiency of the electric generation mode j

Weighted average emission (E), representing the emission intensity, is given

$$\textbf{(E) (ton CO}_2\textbf{/MWh) = E(ton CO}_2\textbf{/yr)/PG (MWh/yr)} \qquad \textbf{(3)}$$

by:

Where: E is given by equation (1); PG (MWh/yr) = $\sum_j PG_j$ (MWh/yr)

The emission intensity coefficient, $(E)_{baseline}$, is thus obtained as:

$$\textbf{(E)}_{\textbf{baseline}} \textbf{ (ton CO}_2\textbf{/MWh) = \{(E)}_{\textbf{operating margin}} \textbf{ (ton CO}_2\textbf{/MWh) +\{(E)}_{\textbf{build margin}} \textbf{ / (ton CO}_2\textbf{/MWh)\}/2} \qquad \textbf{(4)}$$

Finally, baseline emissions are given by:

$$\textbf{E}_{\textbf{baseline}} \textbf{ (ton CO}_2\textbf{/MWh) = (E)}_{\textbf{baseline}} \textbf{ (ton CO}_2\textbf{/MWh) x CG (MWh/yr) (5)}$$

3.2.2. Estimating the anthropogenic emissions by GHG sources of baseline.

a) Grid electricity generation.

CO_2 emission from grid	=	Grid fuel consumption	×	Net calorific value	×	C emission factor	×	Fraction of C oxidized	×	Mass conversion factor
(tCO_2)		(10^3t)		(TJ/10^3t)		(tC/TJ)		–		(tCO_2/tC)

CO_2 emission factor	=	Sum of all CO_2 emission from grid	÷	Grid Electricity generated
(tCO_2/MWh)		(tCO_2)		(MWh)

CO_2 emission displaced by Project	=	Electricity exported by Project	×	CO_2 emission factor
(tCO_2/yr)		(MWh/yr)		(tCO_2/MWh)

b) Open air burning for biomass disposal

Carbon released	=	Rice husk use as fuel by the bio-power plant	×	Carbon fraction of biomass
(tC/yr)		(t biomass/yr)		(tC/t biomass)

Annual CH_4 released	=	Carbon released in total	×	Carbon released as CH_4 in open-air	×	Mass conversion factor	×	GWP of CH_4
(tCO_2e/yr)		(tC/yr)		(%)		(tCH_4/tC)		($tCO_2e/tCH4$)

c) Baseline emissions summary

CO_2 emission from grid electricity	+	CH_4 emission from open air burning of rice husk	=	Total baseline emissions
(tCO_2/yr)		(tCO_2e/yr)		(tCO_2e/yr)

3.2.3 Difference between 3.2.1 and 3.2.2 representing the emission reductions of project activity.

Emission reduction	=	Emission from grid electricity generation	+	Emission from open air burning for rice husk disposal	–	Emission from biomass fuelled electricity generation	–	Emission from transportation of rice husk for the Project	–	Emission from fuel oil use for the Project (start-up)

3.2.4. Emission reductions of Project activity.

Total baseline emissions	–	Total Project emissions	=	Emission reductions
(tCO_2/yr)		(tCO_2e/yr)		(tCO_2e/yr)

3.3 Benefit cost analysis

3.3.1 Total cost including:

$$C_t = C_{t\ inv.} + C_{t\ O\ \&\ M} + C_{t\ fuel\ (RH)}$$

$C_{t\ inv.}$ = investment cost

$C_{t\ O\ \&\ M}$ = operation and maintenance cost

$C_{t\ fuel\ (RH)}$ = fuel rice husk cost (including rice husk transport and storage costs).

3.3.2 Total benefit including:

$$B_t = B_{te} + B_{tCER} + B_{ash}$$

B_{te} = Benefit given by rice husk electricity sale = p_eWt;

B_{tCER} = Benefit given by CER sale = $p_{CO2}CER$;

$B_{t\ ask}$ = Benefit given by rice husk ash sale = $p_{ash}W_t$;

P_e = rice husk electricity sale price;

p_{CO2} = CER sale price;

p_{ash} = rice husk ash sale price;

W_t = rice husk electricity sale to EVN grid in year "t";

4. RESULTS AND DISCUSSIONS

4.1 Assessment of the CO_2 emission reductions (CERs) and CER credits determined by different assumed CO_2 prices

Assessment of the CO_2 emission reductions (CERs) and CER credits determined by different assumed CO_2 prices is realized for a bundle of five *similar pilot grid connected rice husk-fuelled bio-power development projects 5 × 11 MW installed capacity*. As presented in previous part 3, these five identified and recommended power projects are *similar* regarding their size and employed technology. And although they are originally presented as *a single CDM project*, this comprises five *similar rice husk power projects* with the installed capacity of 11 MW per project. The assessment of their CERs and CER credits will be carried out only for an individual rice husk power project then its assessed CER and CER credit will be multiplied with 5 to make the CER and CER credit of the whole CDM project.

4.2 IRR, NPV, BCR project of the rice husk – Fueled Bio – Power Projects in two cases: With CDM and Without CDM

4.2.1 Calculation and comparison of IRR, NPV and B/C in two cases - W/O CDM and W CDM (Table 1):

Unit investment costs of proposed rice husk power project, namely 1,350; 1,570; and 1,700 US$/Kw ;

Electricity sale prices of proposed rice husk power project, namely 0.04; 0.05; 0.06; and 0.07 US$/KWh;

CO_2 sale prices of proposed rice husk power project namely O (W/O CDM); 3 (W CDM); 9 (W CDM); and 15 (W CDM) US$/ton of CO_{2e}.

Rice husk ash price of proposed rice husk power project to be assumed as at constant pricing level of US$ 0.02/t of ash.

4.2.2 Calculation and comparing of IRR, NPV and B/C ratios are carried out for 2 cases.

With maximal running day number(332 days/year)(as above), and average running day number(200 days/year)(realistic case) based on realistic input parameters, namely 1350 and 1579US$/KW;0.04,0.045 and 0.05US$/KWh; 0,3,9 and 15US$/TCO2 (Table 1)

Table 1. Benefit cost analysis of the rice husk-rueled bio-power projects W/ & W/O CDM

Unit investment cost (US$/KW)	Electricity sale price (US$/KWh)	IRR (%) By CO_2 prices (US$/t$CO_2$) of:				NPV (US$ 1000) By CO_2 prices (US$/t$CO_2$) of:			
		0 (W/O CDM)	3 (W CDM)	9 (W CDM)	15 (W CDM)	0 (W/O CDM)	3 (W CDM)	9 (W CDM)	15 (W CDM)
1350	0.040	<12 (8.99)	<12 (10)	<12 (10.63)	<12 (11.67)	-874.23	-395.82	561.00	1517.81
	0.045	<12	<12	=12	>12	716.82	-	2152.05	-
	0.050	<12 (8.47)	<12 (9.04)	>12 (13.95)	>12 (14.88)	-130.14	-826.73	3743.10	4699.24
1570	0.040	<12 (6.52)	<12 (7.06)	<12 (8.09)	<12 (9.08)	-3318.66	-2840.25	-1883.43	-926.61
	0.045	<12	<12	<12	<12 (10.64)	-	-	-	-
	0.050	<12 (6.53)	<12 (10.33)	<12 (11.24)	>12 (12.11)	-3312.03	341.85	1298.67	2255.49

Consideration of current serious pollution of Mekong delta's rivers and canals with unused rice husk dumped and discharged from local paddy milling centers shown great region-wide environmental threat to the health of local communities and their livelihood, especially their traditional aquaculture and pisciculture. This region-wide environmental threat will be rapidly increasing with following context:

- Increasing paddy production and rice export is the most important long term economic development orientation of Mekong delta, that lead to rapidly increase the local rice husk generation.
- Basic change in traditional rice husk end-uses of local communities from using the rice husk fuel to using the commercial energy types for rural household cooking, fuelling their brick-kilns, pottery and porcelain furnaces, food processing etc., that leads to rapidly reduce the local rice husk consumption and increase the local unused rice husk dumping.
- Without a region-wide cooperation in looking for an environmentally friendly and effective solution to thoroughly minimize the pollution of Mekong delta's rivers and canals with unused rice husk dumped and discharged by paddy milling centers.

From the year 2004, the seeking for a thorough solution to minimize the increasing pollution of rivers and canals with rice husk discharged from paddy milling centers in Mekong delta became an urgent task faced by local authorities, administrators, agriculture and energy development planners. *Safe and environmentally friendly disposal of 3.7 million tons of rice husk per year with over 70% of that (2.5 millions tons per year) to be dumped is one of major problems of Mekong delta's sustainable development*.

In this context, the development of a *bundle* of 5 rice husk-fuelled bio-power projects with an installed capacity of 5 × 11 MW has been selected as the most through and sustainable solution to solve this problem.

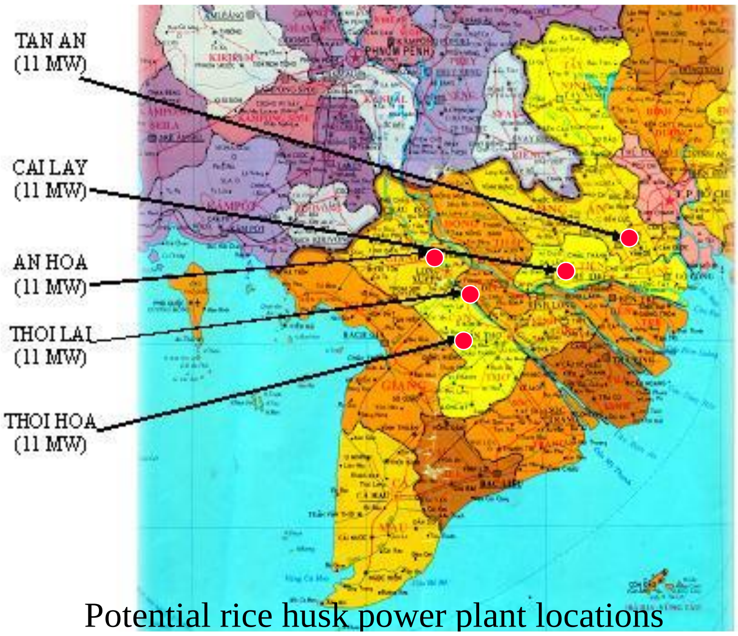
5. CONCLUSIONS AND RECOMENDATIONS

Prices of electricity generated by rice husk power plants and sold to EVN through national power grids should be considered by the government and EVN with the *concession* of electricity pricing to small renewable (rice husk) power producers, so that EVN could agree to purchase the rice husk electricity with the electricity pricing level from US$ 0.045 to US$ 0.050 per KWh.

During the plant life of 20 years (2020 - 2040), the *average annual CER* of a proposed rice husk power project will be of 26,700 *ton of* CO_{2e} with TOU=4,800 hours/yr(or 200 operating days per year), and its *average annual CER credits* by CO_2

prices of US$ 9 and 15 per ton of CO_{2e} will be from 240 to 400 thousand US$ respectively. For the *whole bundle* of *five (5) similar rice husk power projects of 5 × 11 MW installed capacity*, these figures will be of 5 × 26,700= 133,500 *tons of* CO_{2e} *per year; and 1,200-2000 thousand US$ per year*, *respectively*.

The research recommends to develop in Mekong delta a *bundle of five (5) similar pilot rice husk-fuelled bio-power projects having a total installed capacity of 5 × 11 MW at five* locations, namely: *AN HOA* (An Giang province), *THOI HOA* (limitrophe area of 3 provinces - An Giang, Dong Thap and Can Tho), *THOI LAI* (Can Tho province), *CAI LAY* (Tien Giang province) and *TAN AN* (Long An province). Besides these five locations, a reserved location in TAN CHAU (limitrophe area of 2 provinces - An Giang and Dong Thap, and the Kingdom of Cambodia) is selected for the future development of paddy milling center network as well as, of rice husk power centers (See figure 2 for located 11 MW rice husk power plants in Mekong river Delta) .



Potential rice husk power plant locations

Figure 2. Rice-Huck power plants should be located in Mekong river Delta

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