Potential and method for effective using of biomass from agricultural by-products (paddy, maize, peanut) in Northern Vietnam

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Abstract. Northern Vietnam have natural conditions that are favourable for agricultural development. In this area, arable land is increasingly being narrowed by the industrialization process, however agriculture still has a key role in the region's economy and attracts more labor than other sectors. Through research for the current cultivation status, current collection and use of the harvest by-products (straw, husk), maize (stem, leaves, core); peanut (stem, leaves, shell), analysing and evaluating the potential of biomass energy and environmental performance assessment in provinces in Northern of Vietnam, these results were achieved: the medium value of total biomass (BM) for agricultural products after harvest in recent years across the Northern of Vietnam was 19784.8 million tons (including 1250.4, 9261.6 and 272.8 million tons of paddy, maize and peanut, respectively). BM sources are mainly collected spontaneously and used for different household purposes such as cooking, animal feeding, and fertilizer... This source of BM can generate 9738.3 × 10^6 kWh/year. This will be significant to supplement traditional energy that now is not enough, contributing to reduce environmental pollution, and creating more income for farmers. The results from output energy calculation indicated that economic efficiency from BM will be higher than using coal as fuel for incinerators; If these products are used in ways of heat - electric furnace with fluidized bed combustion (FBC), that will be very active and effective in term of ensuring not only energy security but also reducing the demand for using fossil fuel sources and environmental pollution (BM costs just 10 - 30% compared to coal, CO₂ and SO₂ emissions is less than using coal about 3 - 6 and 18 - 20 times, respectively)

1. Introduction
Due to rapid development of science and technology over the world, many countries nowadays should pay more attention to the production and the use of renewable energy (RE) and acknowledge the importance of the environmental protection. Biomass energy (BE) is one of the most crucial RE sources of energy. RE is the oldest energy source that has been used when people have begun cooking and heating. Development of RE is effective in solving problems of energy demand, contributing to reduce pressure on using fossil fuels and reduce pollution [1, 2].

By using BE, waste and greenhouse gas emission could be reduced, protecting the environment. Many countries in the world are expanding trend of using BM [3]. Unlike other RE, BE not only able
to be controlled but also simultaneously provide both heat and electric generation [4]. Sources of BM vary, thus technologies of BE are also very diverse and can be divided into two categories: changing directly into useful energy and changing into the secondary fuel.

It is very favorable for agricultural development in tropical countries like Vietnam, especially in provinces of red river delta because of natural conditions. Arable lands have increasingly being narrowed by the process of industrialization, but agriculture still has an significant role in the regional economy, and attracts more labors than other sectors [5, 6]. The by-product is produced in enormous amounts and diverse every year. However, to date there is no research that specifies the quantity, composition, particularly the potential use of these BM with an appropriate way.

This paper shows the results of the investigation, survey the current situation of some major agricultural plants (paddy, maize, peanut) in some Northern provinces of Vietnam; collection, using, analyzing and evaluating the potential of BE from the agriculture products, which are farming in provinces of Northern of Vietnam. From that, it will be given the effective plans for using this BE.

2. Materials and methods

2.1. Materials
Agriculture products after harvesting, that includes paddy (straw, husk), maize (stem, leaves, core); peanut (stem, leaves, shell) in Northern provinces of Vietnam: Nam Dinh, Ninh Binh, Thai Binh, Hai Duong

2.2. Methods

2.2.1. On-desk study. Documents and data for the study were collected from the official scientific reports of the Departments of Natural Resources and Environment, General Statistics Offices from these above provinces. Data was also selected from interview and investigation in several communal households in these areas.

2.2.2. Chemical analysis. The following parameters were measured: moisture, ash, total carbon and calorific value. Moisture and ash of the samples were determined by weight analysis method, the total carbon was measured by the Churin method; calorific value is analysed by the calorimetric bomb.

3. Results and discussion

3.1. Cultivation state of some major agricultural plants in Northern provinces of Vietnam Rice cultivation
In Northern Vietnam, rice makes up about 70 - 95% of the annual crops. Rice is cultivated and harvested in two seasons. Planted area, yield and production of paddy in recent years (2012 – 2016) in the studied provinces are shown in Table 1.
Table 1. Planted area, yield and production of paddy [7]

| Year | 2012  | 2013  | 2014  | 2015  | 2016  | Average |
|------|-------|-------|-------|-------|-------|---------|
| Planted area (1000ha) | 1816.7 | 1819.1 | 1811.9 | 1794.7 | 1776.5 | 1803.8 |
| Yield (10000kg/ha) | 54.3 | 53.1 | 54.3 | 54.6 | 109.7 | 65.2 |
| Production (1000 tons) | 10152.4 | 9921.0 | 10100.9 | 10068.9 | 9966.6 | 10042.0 |

Maize cultivation
Planted area, yield and production of maize in recent years in the studied provinces are shown in Table 2.

Table 2. Planted area, yield and production of maize [7]

| Year | 2012 | 2013 | 2014 | 2015 | 2016 | Average |
|------|------|------|------|------|------|---------|
| Area (1000ha) | 588.4 | 592.8 | 603.4 | 596.2 | 599.3 | 596.0 |
| Yield (100kg/ha) | 83.4 | 83.7 | 83.8 | 86.0 | 86.2 | 84.6 |
| Production (1000 tons) | 2247.7 | 2306.2 | 2305.9 | 2351.3 | 2365.9 | 2315.4 |

Peanut cultivation
Planted area, yield and production of peanut in the studied provinces are shown in Table 3.

Table 3. Planted area, yield and production of peanut [7]

| Year | 2012 | 2013 | 2014 | 2015 | 2016 | Average |
|------|------|------|------|------|------|---------|
| Area (1000ha) | 108.2 | 108.0 | 103.0 | 103.0 | 103.0 | 105.04 |
| Yield (100kg/ha) | 21.4 | 22.7 | 21.7 | 22.7 | 23.1 | 22.32 |
| Production (1000 tons) | 229.4 | 246.9 | 220.4 | 220.0 | 220.0 | 227.34 |

3.2 Current status of collection and using agricultural by-products after harvesting from cultivated rice, maize, peanuts in Northern provinces of Vietnam
The by-products after rice harvesting and processing are straw, thatch, and rice husks. Stubble burning is used to supply the ashes as fertilizer or thrown away or face plowing to increase soil humus. Straw is used for cooking (ash muck) or as feed for cattle and buffaloes, and raw materials are used to grow mushrooms (straw mushrooms, scallops mushrooms, wood-ear mushroom with a yield of 285kg/1 ton of straw). Besides, straw is also used to mix with the manure of animal to compost as organic fertilizers; straw is used to cover the soil when planting vegetables, to avoid high temperatures or heavy rainfall, reserve soil moisture, prevent erosion washes soil, etc. However, the burning straw creates enormous smoke and dust that is harmful to human health, flora, and affects the safety of traffic. Plowing will face with CH₄ emission into the atmosphere. The mushroom sample also has its advantages and
disadvantages. Rice husks are also produced in high amounts, which are used for cooking, compost, etc., while the remaining part is dumped that cause environmental pollution.

After harvesting, maize by-products including stem, leaves, kelp and corncobs are cut and dried in the field (90%) then are taken home to pile in dry place. Dried corn stalks and leaves are used for burning or animal feeding, because they have higher values fiber content (31.5%), crude protein (7.6%) and starch sugar than straw. Leaves and sheath are separated and then dried for burning or animal feeding. Cobs obtained after separation from corn grain are often discarded or dried for cooking.

By-products from peanut including body, leaves and shell, which would be dried for burning or composting. Peanut is dried for preservation. Leaves containing high protein content should be used as food for livestock. Shell mostly used for cooking burning.

3.3 Estimation of agricultural by-products amounts after harvesting

Based on the results of field studies, the amounts of BM-products from agricultural cultivation including rice, maize, and peanuts and other data collected through the questionnaire from farmers in the studied provinces (Nam Dinh, Ninh Binh, Thai Binh and Hai Duong), it was given the ratio between by-product and product [8, 9].

There is not much change when comparing BM annually with average values of 5 years recently. That value was achieved 19784.8 million tons (Table 4). This is a great potential BM.

Table 4. Ratio of by-product to product and average values of by-product amounts in Northern the provinces of Vietnam within 5 year recently (*)

| Plant | By-product         | Ratio of by-product to product | By-product amounts (1000 tons) |
|-------|--------------------|-------------------------------|-----------------------------|
| Paddy | Straw              | 1/1                           | 10042.0                     |
|       | Husk               | 1/5                           | 208.4                       |
| Maize | Stem, leaves, core | 4/1                           | 9261.6                      |
| Peanut| Stem, leaves, shell| 1.2/1                         | 272.8                       |
| Total |                    |                               | 19784.8                     |

(*)- BM value = (Production) x (Ratio of by-product to product)

The amounts of by-products calculated (Table 4) were not much different to the survey data from the farmers. For example, corresponding to 100 kg of rice, there is about 70 to 80 kg of straw and 25 kg of rice husk. Although area for growing rice will be reduced in the coming years, the rice production still ensure at a certain level in recent years.

3.4. Proposing technological schemes for using BE from rice by-products

Principally, BM-products could be used for ethanol production, growing mushrooms or making construction materials, manufacture of pulp, insulation, etc. However, thus far ethanol production from cellulose still has limitation, i.e., the yeast is expensive and ineffective, furthermore cellulose is only partially converted into ethanol and lignin, and the fermentation process could be easily damaged from infection, making the cost still high [10, 11]. The plan of using husk as building materials, pulp manufacturing, insulation, etc. has been tested on a small scale but not highly efficient. The use of straw for growing mushrooms has its advantages but there are some difficulties, for example, mushroom seed production is not active, waste, produced not enough, not meeting the requirements; using them as fertilizer will emit greenhouse gas, that not be suitable for the environment; therefore caking this biomass to produce solid fuel can be feasible to use these resources for BM energy.

Calorific values of by-products from rice, maize, and peanuts
Calorific values of by-products indicate the value of heat that generated from by-products. The calculation was based on the approximate percentage of by-products analyzed by calorimetric bomb [12].

- Maize: 25% core and shell + 75% stem and leaves;
- Peanut: 15% shell + 85% stem;
- Husk: 100% husk;
- Straw and thatch: 35% straw + 65% thatch.

It is quite similar when comparing the actual values obtained from analysis in calorimetric bomb 3000 kPa and data from references [7, 12] (Table 5):

| By-products | Calorific values from analysis (kcal/kg) | Calorific values from references (kcal/kg) |
|-------------|------------------------------------------|--------------------------------------------|
| Maize       | 4008                                      | 3595                                       |
| Peanut      | 3752                                      | 3415                                       |
| Husk        | 3719                                      | 3440                                       |
| Straw       | 3488                                      | 3583                                       |

The flow chart of thermoelectricity

The agricultural by-products from rice, maize, and peanuts can be used as fuel for the electric generation which is shown in Figure 1. The principal equipments are the incinerator, boiler, turbine, generator, heat exchanger parts, dryers and other auxiliary parts.

Water is delivered to boiler by pumping systems and fuel (agricultural by-products) are loaded into the incinerator. Combustion in a burner can create heat for boilers, which provide steam; the turbine is pulled back generating electricity and provided the dryer (or milling) with it. Source steam (heat) from the turbine (secondary steam) is used for drying agricultural products.

Estimate the potential supply of electricity from BM-products

Based on the data analysis, electrical energy from agricultural by-products of rice, maize and peanuts was calculated. There were 475.2, 474.1, 512.6 and 479.6 kWh per ton of by-product of husk, straw, maize and peanut, respectively. Theoretically, if all these sources of livelihoods will be collected and
used as fuel to replace fossil fuels which are gradually depleted, power can be obtained relatively large annually. Specific estimates are given in Table 6.

Table 6. Electric potential from by-products in Northern provinces in Vietnam

| From                  | Electric potential (10^6 kWh/year) |
|-----------------------|-----------------------------------|
| Straw, Husk           |                                   |
| From stem, leaves,    |                                   |
| core of maize         | 4760.9                            |
| From stem, leaves,    | 99.0                              |
| shell of peanut       | 4747.5                            |
| Total                 | 130.8                             |
| Total                 | 9738.3                            |

In practice, other factors should be considered and calculated as: collection capabilities, the ability to make solid fuel (bar or pill shaping can reduce fuel transportation costs or storage or burning, etc.) increased performance capabilities and investment in equipment, select the location, etc.

3.5 Selection of incinerators

In fact, there are four common types of incinerator for by-products such as a fixed oven, stove moving, fluidized bed boiler, and furnace rotation. The selected incinerator is burning fluidized sand (called FBC - Fluidized bed combustion) that has more advantages than other kilns by high-intensity fire, stable carbon remaining in the small content of ash; burn the fuel containing high moisture, high ash, and low calorific value.

SiO₂ content in the ash is more than 90% after incinerating by using FBC. This is a very vital component that can be used as additives for the cement industry and construction materials. The gas emitted is mainly CO₂, only an insignificant the amount of SO₂ gas is assumed to be insignificant (Table 7).

Table 7. Emissions from burning rice-products and coal

| Emissions (kg/ton) | Husk  | Straw, thatch | Coal             |
|--------------------|-------|---------------|------------------|
| CO₂                | 40 - 82| 30 - 77       | 200 - 220        |
| SO₂                | 0.5 - 1.5| 0.3 - 1.8   | 28 - 30          |
| NOₓ                | -     | -             | 9 - 11           |

Using the rice husk by-products and straw as fuel for FBC incinerators, it can reduce the CO₂ about 3 - 6 times and SO₂ about 18 - 20 times comparing with using coal. This point gives an ability to apply the Clean Development Mechanism (CDM) according to Kyoto Protocol [13].

4. Conclusion

In theory, agricultural by-products could be used to generate electric. There are 475.2, 474.1, 512.6 and 479.6 kWh per ton of husk, straw and by-products of maize and peanut, respectively. If all the by-products from rice, maize, and peanuts are collected and used to generate electricity, the potential for energy supply would be highly significant, achieving approximately 9738.3 × 10⁶ kWh/year.

The use of these by-products as fuel electric generation is promising and can significantly contribute to energy security, reducing the pressure of using fossil fuel. Prices of BM were assumed to be only 10 - 30% compared to coal, the emissions less than coal 3 - 6 times for CO₂ and 18 - 20 times for SO₂. Furthermore, it also reduce the volume of solid waste and create jobs for local people. Ash formed after
using the FBC technology with high SiO₂ content can make additives for the industrial production of cement and construction materials.

To conclude, it is essential to collect by-products after harvesting to limit the greenhouse gas emissions. Feasible plans should be prioritized and optimized for processing of by-products in several forms that the performance is the highest with lowest emissions.

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