Bioindustry development based on citronella essential oil to meet the needs for renewable energy: A review

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Abstract. In 2015, national domestic fuel consumption is already above 1.5 million barrels per day, while production is under 800,000 barrels per day. The gap between production and consumption will be considerably widened, serious efforts is needed to save the use of petroleum and also look for alternative replacement with renewable natural energy. Two approaches that can be taken: First, save the use of fossil fuel directly by using citronella essential oil-based bioadditive by 20 percents, equal to at least Rp. 55.2 trillions of national petroleum subsidies. Second, encourage increased utilization of biofuel mixed with that bioaditives that gradually reduce dependence on fossil fuels while developing machines which will fully operated with biofuels. Development of Sustainable Agricultural Bioindustry (SAB) system by integrating crops (candle nut, citronella) with livestock (dairy cattle) in a specific region. could contribute to: a) production of biodiesel and bioadditive feedstocks, b) production foodstuffs like beef and/or milk, c) utilization of non-productive land, d) employment, by absorbing large number of farmer, e) increase the farmers income, f), biogas that can be used to meet daily household energy needs, and g) environmental conservation and sequestration of carbon emissions.

1. Introduction

Increasing need in energy demand which parallel with the development of the human population with all their needs are faced with the facts for depletion of the world's energy reserves, especially fossil energy. This conditions globally, sooner or later, have sparked increasingly fierce competition for dominance and the search for foddil energy resources. For Indonesia, which is located in the equator with a tropical climate, the problem can not be ignored, because it has been stated that Indonesia's oil proven reserve is 3.7 milyard barrels that will be exhausted in 10 years [1].

In 2015, domestic fuel consumption is already above 1.5 million barrels per day, while production is under 800,000 barrels per day. Indonesia ranks as 24th producer of petroleum in the world. To meet these needs, the Government of Indonesia has to import 350,000 - 500,000 barrels per day [2]. The gap between production and consumption of the national fuel are considerably widened so that serious efforts is needed to fulfill most of the fuel demand through utilization of renewable energy. This effort is hoped could help ease the burden of fuel subsidies in the state budget by reducing the consumption of domestic and imported fuel.

Realizing this, before emerging energy crisis which will have a wide impact politically, economically and socially, the Government through the Directorate General of New, Renewable Energy and Energy
Conservation (EBTKE), Ministry of Energy and Mineral Resources, has established policies and facilitated various parties to carry out research and development efforts for utilization energy of biomass (bioenergy), whose raw materials are available in abundance in the sheer number continuously in the archipelago, especially biofuels. Biofuel can be determined as a fuel from organic resources including plants and animals [3]. Biofuel has a specific characteristic that is renewable, whereas it can be produced by using raw material which can be grown or developed. There are a variety of biofuels potentially available, but the main biofuels being considered globally are biodiesel and bioethanol. Bioethanol could be used as a substitute for gasoline and biodiesel as a substitute for diesel oil.

On the other side, applications of biofuel nowadays still facing some problems because it is not fully compatible with recently available machinery technologies as they were designed to work with petroleum fuels. Nevertheless, by adding a small number of bioadditive which was derived from citronella essential oils into the fuel tank then the effect of clogging, heating and knocking in the engine can be minimized.

This paper examines the ideas how to couple the upstream-downstream production and utilization of biofuels in an integrated manner in order to fulfill part of the national needs for renewable energy.

2. Citronella Based Additive: Prospect and Contribution in the Utilization of Renewable Energy

Citronella (Cymbopogon nardus L, family Gramineae) is one kind of essential oil producing plants that can grow in Indonesia (Figure 1). Citronella oil was obtained from distillation of citronella grass leaves, and Indonesian citronella oil in world trade has known as "Java Citronella Oil". Citronella crop acreage in 2014 was 18,660 ha [4]. Citronella production centers area in Indonesia were located in Aceh, West Sumatra, West Java, Central Java, East Java and East Kalimantan [5].

![Figure 1. Citronella plantation at Manoko Experimental Garden, Lembang, West Java [6]](image)

Citronella oil containing about 35-45% citronella compounds, 85-90% geraniol, 11-15% citronellal, 3-8% geraniol acetate, 2-4% citronellal acetate and slightly contains sesquiterpenes as well as other compounds. Citronella oil is widely used as an industrial raw material of soap, toothpaste and medicines. Citronellal and geraniol are generally used for the manufacture of esters, such as hydroxy citronellal, geraniol acetate, and synthetic menthol which have the nature of a more stable and widely used in the perfume and other fragrance industries. Hydroxy citronellal is important for high-quality soaps and perfumes, while menthol flavors to the basic ingredients of cough medicine, toothpaste and as dessert. Citronella oil is also used as a plant-based pesticides such as fungicides, bactericides,
insecticides and nematicides [7]. At lately, citronella oil also developed as bioadditive for petroleum based fuel oil [8, 6].

Citronella oil-based industry is very potential to be developed as Indonesia has a comparative advantage in the supply of raw material. The development of this essential oils industry will create a multiplier effect by increasing the income of essential oil crop farmers, and creating employment in the field of agroindustry [6]. If a few years ago, Indonesia ranks as the second largest citronella oil producing countries after China, then Indonesia is currently the largest producer in the world because of declining acreage and production in China.

One of the benefits of citronella oil which is highly prospective for development in the future is utilization of this oil as a main component for fuel additive (bioadditive). Bioadditive is made of a mixture of several essential oils, main component is citronella oil, which are native to Indonesia, easy to cultivate in the country and does not interfere with human food needs.

Bioadditive can be used easily by added to the fuel tank, it can be mixed with any composition of gasoline and diesel oil, at 1 ppm concentration, have the physical and chemical properties similar to gasoline or diesel fuel, it can be degraded easily (biodegradable). Bioadditive serves as a catalyst, enhance the combustion process in the engine, so that the resulting combustion emissions environmentally friendly and does not add to the accumulation of carbon dioxide in the atmosphere that can further reduce the effects of global warming or known with zero CO2 emission [8].

Two approaches that can be taken in implementing citronella essential oil-based bioadditive for lowering national fossil fuel consumption: First, save the use of fossil fuel directly by using bioadditive on commercial machines. If the use of citronella-based bioadditive simply able to economize on the use of fuel by 20%, then if the quota of national fuel subsidies in 2015 is estimated to reach 46-47 million KL [9], equal to Rp. 276 Trillion, there will be a saving of fuel subsidy by Rp. 55.2 trillion. Laboratory test results on the Lemigas Laboratory and the vehicles that use bio fuel additive products showed a decrease in exhaust emissions/opacity of the vehicle are quite significant, this means that they would help in the global warming reduction program. Second, encourage increased use of biofuel mixed with bioadditive that can reduce fossil fuels usage while developing machines which will fully operated with biofuels. It was considered that biofuel produced today were not optimum working on gasoline and diesel machines used by today’s society and industry. Some of the problems faced is the clots of biofuel in the engine combustion chamber, the crust of dirt that interfere with engine performance and increased engine temperature. Utilization of citronella bioadditive will improve biofuel engine performance whiles maintaining machines and extend engine life.

There are some advantages in using citronella based bioadditive, among other things: 1) It is a renewable energy, 2) cultivation of the raw material is not difficult because the plants easily adapt to the climate and local soil, 3) Use of raw materials for the additive does not conflict with the interests of provision of food or products vital in community life, 4) reduce exhaust emissions (especially reducing black smoke) in comparing with fossil fuels without the addition of these additives, and 5) environmentally friendly [8].

A series of tests in the field using a variety of gasoline and diesel fuelled engines show that citronella-based bioadditive is able to save petroleum consumption: Gasoline 10-30%, Solar 10-40%. These figures show that bioadditive utilization will obtain a significant decrease in petroleum based fuel consumption. Sucipto stated that in addition to the more complete combustion in the engine it will obtain better power and exhaust emissions are more environmentally friendly [8]. Further assessment is technically and economically necessary to provide opportunities of additive use as a blending
component of gasoline and diesel oil for supporting fuel consumption efficiency in the transportation sector, power plant generators, military equipments and other industries.

The better prospects for the future is the use of this citronella bioadditive in supporting the above mentioned machines to be operated with biofuels, i.e bioethanol as a substitute for gasoline and biodiesel as a substitute for diesel oil. There is also an important need to develop and mass production of machines and vehicle that could be fully operate with biofuel. Collaboration among academicians and industrialists were needed to bring the dream into reality. Indonesia then could play an important role by producing these machines as well as their renewable biofuel for energy independence and energy security.

3. **Sustainable Agricultural Bioindustry: Components and Products for Production of Bioenergy**

Bioindustry term is used for integrated system where from single bio raw material through multiple process to produce multiple valuable products [10]. The bioindustry term used in this paper is intended to applied on Sustainable Agricultural Bioindustry (SAB), the new paradigm to accommodate transformation of the development orientation from fossil-based raw materials into renewable resources (biological resources). Thus, the role of agriculture is not only a major producer of materials food, but a producer of biomass feedstock biorefinery to produce food, feed, fertilizer, fiber, energy, pharmaceutical products, chemical and other bioproduct. SAB systems in principle how to manage and/or make an optimum use of all biological resources including biomass and/or waste organic farming, for the welfare of the community in an ecosystem in harmony. In this scheme, agricultural waste and biomass utilized by applying bio-technology and genetic engineering process to produce tangible output of agricultural products for final consumption as stock feed, processed food, feed, energy, bioproduct. It also includes environmental services to public and private and also has economic value added. It was expected that from agricultural bioindustry will occur economic participation and distribution of added value, which will be beneficial socially and politically [11].

SAB can be developed in a farmer level, farmer’s group, or by large agricultural companies in a specific region. The development area can be tangible ecological region with a particular landscape, or in a village-level administrative region, district or a wider area. The SAB systems designed so that a sustainable way of bioprocess which took place in the region are able to produce range of products such as biomass, nutrients, water, gas and energy independently with minimum external input. The type of raw material used is the entire biomass, agricultural waste and the results derived from the use of crop, animal, other organism. Besides aiming to reduce yield loss, agriculture bioindustry characterized by reprocessing and recycling of waste and the waste processed, biorefinery where an integration processing with multi input multi output as well as the joint input-joint output, the agricultural bioindustry can also be utilized for the expansion of the product and industry (Product / industry widening). From this SAB system, we could have produced the main products or by-products of high economic value or strategic value, including citronella oil based bioadditive which became the topic of discussion in this paper.

SAB components developed for the production of biofuels and bioadditive consists of: candle nut pant (*Reutealis trisperma*, family Euphorbiaceae) cultivated in strip farming with citronella plant, cattle, biogas fermentor, candlenut oil processor, and citronella oil distillator. Candlenut tree is able to produce 5 ton of oil / ha and its use as a biofuel is not a conflict as foodstuffs such as palmoil (Figure 2). Pranowo *et al.*, that productivity level of candle nut can reach 8-9 tons of crude oil, equivalent to 6-8 tons of biodiesel/ha/year, make as a strategic commodity associated with government programs to find alternative sources of renewable energy [12]. Besides as a biofuel feedstock, candlenut also useful as conservation plants because it has deep and broad roots [13, 14], even in degraded land [12]. This plant has a good adaptability to grow in various regions in Indonesia. Meanwhile citronella oil production obtained is 480 kg /ha/yr [6].
Each of these plants are cultivated following their Good Agricultural Practices (GAP) procedures and processed into candle nut oil and citronella oil in accordance with their Good Manufacturing Practices (GMP), the dregs material from citronella distillation waste is used as feed for cattle (beef or dairy cattle) (Figure 3), while livestock manures are used for the biogas production process and further processed into compost which is returned to the plantation to fertilize candle nut and citronella plants. Biogas produced in this bioindustry system can be used for domestic use (cooking and lighting) or used as a fuel for the distillation of citronella. Other benefit of this SAB system are production of foodstuffs such as meat or dairy milk. Analysis of the citronella grass residual distillates indicate that the nutritional content are balanced with grass and a little much of better than rice straw (Sukamto and Syukur, 2015) [6]. Meanwhile, fresh milk produced 12 litres/cow/day, the quality still meet the required standards SNI-3141.1.:2011 about fresh milk [15] and are safe for public consumption as complied with Indonesian National Standard on Testing for Microbial Contamination on dairy Products [16, 17].

In terms of the environment, citronella-based SAB have positive impacts as one way to use marginal lands, also for post-mining and post-disaster land reclamation activity. Combination of annual with perennial plants like citronella and candle nut stands in which the harvesting activities does not damage the land must also contribute as a carbon sink to the surrounding environment.

Indonesia as the third largest forest area in the world, can play an important role to reduce world carbon emissions through carbon sinks [19]. Development of biofuel and essential oil crops that are integrated with cattle in SAB system is expected to be one of the efforts to preserve the forest, through the planting (afforestation) in the non-forest area (degraded land). As well as doing repairs the damaged forest areas (degraded forest) by way of reforestation with both types of plants.
4. Implementation and Benefits for the National Energy Requirements

The implementation of technological innovations and products that have been reinvented by the best sons and daughters of this nation have a great potential to combine in an inclusive SAB system in a region expected to fulfill the need for a national energy by producing and utilizing renewable energy. Development of citronella-based SAB system has the following benefits [8]:

a. Saving national fuel subsidies through utilization of citronella bioadditive

b. Increased use of Biofuel (BBN) combined with citronella bioadditive on commercial machines

c. Utilization of non-productive land

   Use of biofuel additives widely and continuous direct need input source sustainable raw materials as feed stock, for it takes the availability of land for cultivation. The utilization of marginal land (non-productive) become a great potential for growing essential so that it can be a source of raw materials to meet the needs of this bio-fuel additive. Assuming national fuel consumption in 2015 reached 46 million kiloliters, it need 46,000 litres bioadditive (applied at 1 ppm concentration), then it can be use non-productive land as much as 95,833 ha for citronella plantation to cover this need.

d. Employment

   The need of land used to meet the needs of raw materials related to cause a major impact on employment. The positive impacts that occur after the non-productive land is developed for planting effort citronella is absorbed a large number of farmers. As an illustration is in 1 ha of citronella plantation takes at least 4 farmers who can work from planting to harvesting. With as many as 95,883 ha of land use is needed additional workforce of 383,532 farmers.

e. Increasing farmers’ income

   The positive impact that followed as a result of land use is increasing farmer incomes. For comparison farmer per day minimum wage of Rp 50,000, - then in one month (25 days) pay farmers to Rp 1,500,000, -. By cultivating citronella in 1 ha, farmers get as much as 150 kg lemongrass oil, with lemongrass oil price per kg Rp 150,000, - then the farmers’ income to Rp 22,500,000, - / month. After deducting the production cost by 30% the number of farmers’ income to Rp 15,750,000, - / month. If in 1 ha of citronella takes at least four farmers to make the cultivation of citronella then every farmer would get additional income of Rp 3,937,500, - / person, meaning that there is an additional income of farmers amounted to 262.5%, which means there is an increased level of life of farmers [8]. This scheme were calculated based on 10 hectares citronella plantation, in order to get adequate number of citronella grass to be distillated every day. Considering that citronella plants were best distilled after 6 months, and then should be cutted for distillation at every 3 consecutive months, so we propose for each one hectare of citronella farm there shoul be installed 1 distillation unit with capacity of 300 kgs citronella grass.

f. Food source

   In integration with cattle, SAB acting as a source of food, such as milk and/or beef in a program of self-sufficiency and food security. The results of the research in Lembang, West Java show that the integration of planting citronella minimum area of 9 hectares is able to provide supplies forage for 30 dairy cows continuously [6]. Rizal et al. reported that dairy milk produced on that system were proven have suitable quality and safe [17].

g. Biogas

   Livestock manures generated in SAB area could be processed further to into biogas that can be used to meet daily household energy needs.
h. Environmental conservation and carbon sink
In addition to functioning as a plant conservation, candlenut also has a very big role in environmental conservation. Since candlenut produce a large number of leaves, it also play a role in supplying oxygen to the environment in the sheer number is quite large, as well as absorption of CO₂ from the environment and water uptake by the roots (Jurnalasia, 2015) [20].

5. Conclusion
Sustainable Agricultural Bioindustry approaches can be used to produce bioadditive and biofuel, as well as foodstuffs, in a specific region to meet a portion of national renewable energy needs.

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