Towards a Sustainable Energy Economy – The Role of Palm
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Abstract

This paper reviews the factors which affect the palm industry’s role in the world energy economy. Currently palm’s role as a renewable fuel is small, but if all the world’s palm oil, and palm biomass by-product, were to be used as fuel, then the annual energy supply would be 7.31 exajoules - more than most country’s requirements. Alternatives are evaluated, as are social issues.

Keywords
Palm, Renewable Fuel, Palm Biomass, Energy Economy, Sustainable Energy

1. Introduction

Today the worldwide palm oil industry is sizeable, with an annual production of some 42 million tonnes (as of 2009). Most of this gets consumed in food uses, soaps and cosmetics, but in recent years palm oil has already entered the world’s fuel market too.

To give an idea of the palm industry’s potential for energy, these figures are sizeable also. If all the palm oil produced were combusted as a fuel then that would produce 1.64 exajoules (exa = 10^18) of energy per year. On top of that, there is the palm industry’s biomass by-product (ie palm lumber, fronds, and fruit bunches after processing) which, if combusted, would give an extra 5.67 exajoules, bringing the total for palm to 7.31 exajoules annually.

To give these numbers some perspective: 42 million tonnes of oil per year equals 640,068 barrels per day. That is equivalent to 38% of the UK’s current oil consumption of 1,710,000 barrels per day (crude oil and palm oil have comparable energy densities). An alternative perspective is that 640,068 barrels per day is more than the total daily oil consumption of Argentina. Also, 640,068 barrels per day is greater than the oil consumption of Malaysia, or for that matter The United Arab Emirates or, for that matter, 182 different countries (208 being the total number countries in the world)^1

The above figures refer to palm oil production and fuel oil consumption. If we include the non-oil palm biomass too, then the potential increases considerably. This is because the quantities of energy from non-oil palm biomass equal around 3.5 times the energy value of palm oil alone. When we sum up both the palm oil and the non-oil biomass, we get the above mentioned figure of 7.31 exajoules per year. That means the palm industry could supply more than the total energy consumption of many countries. For example, if we focus on electricity consumption, then 7.31 exajoules of fuel value equates to 2.03 trillion kWh per year. Taking a typical power station efficiency of 30%, the figure for available electricity is then 609 billion kWh per year. For comparison, only a few countries consume more than this (such as: USA, China, Russia, Japan and India). But, there are another 191 countries in the world, where such a number would be more than the national requirement (on an individual country basis - in fact, it would be more than several smaller countries combined). All in all, the potential is large^1. How much of this potential gets reached, depends on a number of factors:

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a. Technology: how palm compares with other energy options.
b. Economic factors: especially pricing in the traditional senses, as well as pricing in the emerging “carbon economy”.
c. Market demand for palm as a fuel, versus its other uses, such as food, soaps and cosmetics.
d. Public opinion / media: energy issues are in the news most days, as are ecological issues. Both affect palm.
e. Political pressures: both in response to public opinion and in response to lobbying from commercially interested parties (energy companies and agricultural groups in particular).

2. The reason why Palm could have a significant role in an energy economy

i. As a fuel, palm oil and biomass are sustainable. Unlike coal, oil and natural gas (all of which will run out at some stage due to technical difficulties or high expense, in terms of money or environmental issues, of extraction) the supply of palm will continue as long as crops can be planted and harvested. Also, they can be planted and harvested all the year round, as palm is mostly grown in tropical climates.

ii. Palm is part of the carbon cycle. Carbon dioxide is generated by combusting palm oil, or other palm biomass, but then carbon dioxide is also absorbed every day the palm trees are productive. Importantly, the amount of carbon dioxide generated by combusting palm products and the amount of carbon dioxide absorbed by palm trees via respiration are comparable in quantity. Whilst there is debate about how close palm is to carbon neutrality (where total neutrality would mean all the carbon dioxide produced by palm oil combustion, is absorbed by the growing of palm trees) there is no debate that palm plantations absorb carbon dioxide by respiration. A claim that fossil fuels cannot make.

iii. In comparison to the major biofuel: ethanol, palm avoids the energy-consuming steps of fermentation and distillation. Both of these steps apply to ethanol production, whether it is from corn or sugar cane crops. Distillation, in particular is an energy-intensive process (an average of around 4 J/g/K for heating to boiling point, or 300 kJ/kg to heat from 25° C to 100° C, and on top of that around 2000 kJ/kg to cover the enthalpy of vaporisation). By comparison,棕榈油 production avoids these energy costs totally as no fermentation and no distillation is involved. Instead, palm oil production uses a small amount of steam and then pressing of the fruit. A full study really requires a paper of its own, but initial calculations indicate palm to be the “front runner” of a low-energy contender.

iv. Land usage: in comparison to other crops which can be used as a fuel, palm has the big advantage of an extremely high yield per hectare.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Yield (tonnes oil / ha/year)</th>
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<tbody>
<tr>
<td>Palm</td>
<td>3.80</td>
</tr>
<tr>
<td>Soybean</td>
<td>0.41</td>
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<tr>
<td>Sunflower</td>
<td>0.50</td>
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<tr>
<td>Rapeseed (Canola)</td>
<td>0.65</td>
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Table 1: Oil Crop Yields

From the above figures, palm has a more than five times the land efficiency of its next closest competitor: rapeseed (and ten times better that olive oil). This is particularly interesting in terms of public opinion; because the palm industry has had a lot of negative publicity due to rain forests being chopped down to make way for plantations. However the same point works in favour of palm, because had it been any other oil crop then deforestation would have been much worse. And people aren’t about to stop consuming edible oils.

3. Palm’s role in the wider economy

The above areas cover factors concerning fuel in the traditional sense. However, when looking at the role of palm as a player in the worldwide energy economy there are secondary factors too, namely:

Palm Oil as Food

The future of palm as an energy source is intertwined with its role as a food. There are several reasons for this. Firstly, consumption
of palm, as edible oil, has grown steadily over recent years. Mainly this is because of its acceptability as a food product combined with a low cost of production which is partly due to its land efficiency.

Additionally, palm oil consumption as a food is likely to grow further, for the following reasons:

- **Population growth:** The number of people on the planet is growing, and people need food. Oils or fats are an essential part of a diet both for survival (World Health Organisation guidelines being 20kg per person per year for optimum health). In a modern society, where there is so much emphasis on reducing dietary fat intake, it’s easy to forget that people do need oil to live.
- **There is a trend away from fats containing trans fats and cholesterol (such as butter and lard) and more to fats and oils containing zero trans fats and zero cholesterol (which is the case for the vegetable oils such as: olive oil, palm oil, soy oil, and rapeseed oil)**
- **The percentage of people living in cities is growing (meaning more food consumed via supermarkets and restaurants).**
- **More people (and countries) moving from being economically “lesser developed” to “developed”**

Combine these above four factors with the above figures on crop yield and there are two things we can say about worldwide palm oil industry, with a high level of certainty:

**It’s big, and, it’s not about to go away.**

**Non-oil biomass from palm production**

Every tonne of palm oil produced, also produces 9 tonnes of non-oil biomass. This non-oil biomass consists of:

- palm lumber (the vertical trunk)
- fronds (large leaf-like branches from the top of the palm tree)
- empty fruit bunches (the harvested fruit after the oil has been squeezed out)

Apart from the drawback that they are low in density, the above three items are all good fuels. This is because they are, for the most part, a mixture of cellulose and lignin; consequently they more or less have the same fuel value as most woods, at 15 MJ/kg (which is also the figure for low grade coals, such as some lignite which have been reported in the 15 to 28 MJ/kg range). Also the issue of density has already been addressed with proven approaches of compaction and densification to make briquettes or pellets.

This raises the key question: why use palm biomass (which is only grown in hot tropical countries) when local forests could supply timber instead? One important response is that non-oil palm biomass is a by-product. So long as there is consumption of palm oil, which looks highly likely, there will be an automatic production of a supply of related palm biomass. This is not the case with, say, European forests, where lumber is produced for as a fabrication material, or for wood as a fuel. Either way, ecological negatives are incurred for the timber as a single primary product. By contrast, non-oil palm biomass is a kind of “eco-neutral, extra bite of the cherry”. By using the palm biomass, especially if it is from the processing mill, can gain a fuel with zero extra ecological impact.

**Geo-political issues**

Palm oil is grown in humid, tropical climates, which are close to, or on, the equator. Palm cannot be grown efficiently in cooler climates such as Europe or the northern parts of America. Furthermore there is a big concentration of supply as currently the majority of the world’s palm oil comes from just two countries: Malaysia and Indonesia. Both of which are developing countries, and as such, many national and political factors can come in to play such as:

- **Corporate and social responsibility.** The palm industry provides a lot of jobs to people in developing countries. This is especially the case for palm because it is so labour intensive (Malaysian plantations alone have 580,000 workers directly employed in harvesting. Add support services and that figure rises to 1.4 million, or 3.5 million worldwide). In other words: the feeding, housing and education for many families, in some of the poorer countries, rely totally on palm.
- **The role of lobbying.** Particularly the USA and EU have a long and widely discussed history of the role of agriculture in formulating policy. Preferences will generally go to where the skill base and the climate of their constituents lie.
c. The role of media. Publicity campaigns have affected palm’s development as a fuel, with one example being RWE in the UK. In January 2007, RWE abandoned plans to build a palm-oil-fired power station in Kent in the south of England. They cited the concerns about media articles about deforestation by the palm industry as being the main reason for their change of plans.12

Currently over 90% of energy consumption is from non-sustainable sources, with almost all of that production being from the main three fossil fuels: coal, oil and natural gas. A smaller amount (around 6%) is nuclear. In all four cases, there is a fixed amount of material (be it coal, oil, natural gas or uranium) under the ground which can be recovered.

4. The role of sustainable energy

Currently, and for the foreseeable future, sustainable energy is generated from the following:

a. Hydroelectric plant
b. Wind turbines
c. Biomass
d. Solar

All of the above four ways of generating electricity are proven to work, and with most of them there is a considerable history (examples being the burning of wood as an early biomass, to windmills as an early form of wind turbine – both have been around for thousands of years).

On the downside, all of the above four have ecological negatives too.

For example, the construction of dams for hydroelectricity involves flooding of large areas with the consequent disruption of the natural ecology. The biggest example of this is China’s Three Gorges Dam. The scale of this dam is phenomenal. Its surface area is 1045 km² and its height (or, if you prefer, depth) is 185 m. But despite the ecological negatives, it is estimated that electricity from the dam would have required the burning of 84 million tonnes of coal, in the period 2003 to 2007 3.

When it comes to wind turbines, there is a parallel story. Although small, there will be disruption to wildlife due to the construction and maintenance of wind turbines. The same applies to their operation. Additionally there are the concerns of homeowners that the negatives of noise and spoiling of views may negatively affect property prices. With wind turbines, the issue of predictability has an especially large role because wind is one of the more notoriously variable entities. This point was poignantly illustrated in the UK during January 2010 with the coldest winter for 29 years 4, 5. Along with the cold weather came another effect: no wind. As a consequence many wind turbines stayed static for the whole month (not to mention the fact that a thick cake of frost seizes up the turbine also). At the time climate change experts highlighted this as more evidence of climate change. Logically, as wind is part of climate, and climate is changing, wind patterns will change. What was a good location for a wind farm five years ago might not be a good location today.

By contrast, while January 2010 caused the UK to experience a massive degree of variability to its climate, the climate of palm producing countries reported no change. If climate change becomes a growing phenomenon (as most people think it will be) then non-linear phenomena need to be looked at more carefully. Given recent events, it appears wind in temperate climates might be more non-linear than crops in tropical ones.

An additional, and recently reported, “eco-negative” for wind turbines is the fact that they are causing bats to die 6, 7. This is because bats are particularly vulnerable to the sharp pressure changes large wind turbines create, causing their lungs to haemorrhage (a condition called barotrauma). A problem that will get worse as wind turbines get bigger. However, the size of this negative has not yet been quantified.

For palm, the most widely reported eco-negatives are largely about deforestation in general and the loss of habitat of orangutans in particular. Both of which have widely reported in the media, especially in Europe (a Google search on “deforestation guilty parties” and the first page of hits mentions only one crop: palm, and the resultant lobby against it in the EU 8). In fairness to palm, every cultivated crop involves disruption of natural habitat. Obviously this is undesirable, but it is equally undesirable in Europe, where natural forests have been chopped and replaced with intensive agricultural crops for centuries. Additionally, there is initial evidence that biodiversity in a palm plantation is wider than was previously assumed 9, 10. There are a
handful of agreed facts that indicate plantations could be the home to more species than thought previously:

- The world’s palm plantations have millions of trees
- In those plantations are even more millions of insects (because without the insects to do the pollination, there’d be no commercial crop).

Consequently, where there are insects, there will also be the wildlife that eat insects: birds, bats, and squirrels and other mammals. Then there will be the species that eat these animals. Initial studies suggest there are many types of flora and fauna in a plantation, more than previously thought, including some rare ones.

Moving on to solar, it probably has the fewest eco negatives for the reason that solar panels are usually put on roofs of buildings, or in desert locations where disturbances to wildlife are close to zero. However, in the area of “knowns versus unknowns” solar panels don’t score so well in terms of availability of carbon footprint information. In published data, it is easy to get data showing how efficient solar panels are, namely 15% to 20% on a standard test of 1000 W/m² incident light. But when it comes to carbon footprint, the author didn’t find anything published after several searches. The production of solar panels (the main ones being photovoltaic) requires monocrystalline silicon, polycrystalline silicon, cadmium telluride, and copper, indium and selenium. Most of them, in term of energy, are expensive to mine and ship. All of them, in terms of energy (because of high processing temperatures and highly specialized plant) are expensive to process.

5. Predictability and knowledge management

One of the biggest plus factors of the palm industry is that it is well known. Part of this is because they have been around for a long time (many being 2nd and sometimes 3rd generation family concerns). Also part is because they are commercial operations with the consequent accumulated knowledge and data. On the production side, this includes crop yields and productivity per hectare. On the consumption side, as a fuel, this includes: flammability, fuel values, viscosity and pumpability – all of which put palm on a par with petroleum derived liquid fuels.

Hence palm oil can be used as a fuel where diesel is used. There is one exception though: the role of weather. When the temperature drops, as it does in, say a Northern European climate, palm oil goes thickens and can even go solid, thus making pumping sometimes impossible.

There are two remedies to prevent palm oil being a solid in cold environments; one would be to chemically modify the palm oil to lower its melting point (as is done in biodiesel manufacture via esterification) and the other would be to use part of the energy generated from combustion to keep the palm oil warm.

6. Palm as a fuel – palm oil

In terms of basic combustion science, palm oil is a versatile fuel. The key factor in this regard is that its fuel value (or calorific value) is 39 MJ/kg, which is 90% of the value for regular diesel (typically in the 40 to 44 MJ/kg range). And the two have almost the same density (around 900 kg/m³).

Although mostly it is talked about as a fuel in terms of biodiesel (where it is esterified and mixed with petroleum diesel) it can also be combusted as refined palm oil, or crude palm oil (CPO). Out of the three the latter being the cheapest and the former being the most expensive (both financially and in terms of carbon footprint). Worldwide, and certainly in Europe, diesel engine cars run on biodiesel, it has been shown at MPOB that running them on just palm oil works just fine.

Besides its use in cars other fuel applications would be:

- Lorries
- Buses
- Trains
- Planes
- Ships
- Power stations
- Domestic heating in people’s homes

The important point being: all of the above applications are not limited by science. They are limited by political and social will.

The role of finance is large, but it is not massive. At the time of writing, the price of crude oil is around US$80/barrel. By comparison, Malaysian palm oil is around RM2000 per tonne, or in equivalent units: US$110 per barrel. So, at first glance, palm oil
appears less workable. But it wasn’t all that long ago crude oil peaked at US$147.30 per barrel (during July 2008). At that time both production and consumption patterns of oil continued as normal.

A key element in the area of “social will” is how palm oil stacks up in the “food versus fuel” debate. Palm oil can be used for either (as is the case for all vegetable oils). The fact is: human beings need both. This is especially the case in colder climates, where a person, in a survival situation, will die of lack of fuel before he will die of a lack of food. It’s not as if one matters and the other doesn’t, because they are both important. Also, the debate is complicated by societal factors (such as: there is general agreement that we have more than enough food to feed everyone today, but the people who need it don’t get it because of political and social issues). Then there are the additional complications from related areas such as the widespread concern in the West with obesity being “an epidemic” because of too much food. Consequently, the argument becomes very philosophical very quickly. Also, it is compounded by the emotional issues of world hunger. The more media attention it gets, the more fossil fuels stand to gain, and the palm oil stand to lose.

7. Palm as a fuel – non-oil biomass

There are a number of significant advantages to exploring the possible roles of non-oil palm biomass:

a. We sidestep the “food versus fuel debate” because palm lumber and fronds are not edible. These two items also constitute 85% by weight of non-oil biomass produced. The remaining 15% of the biomass are the empty fruit bunches, which so far have only found a limited application in animal feed. Consequently, for the most part, the non-oil products from a palm plantation have two options: fuel or compost.

b. Palm biomass is a by-product. Plantations have no option but to produce it, and produce it in large quantities at that. The only choice they have is: what to do with it.

Despite these two significant reasons in favour of using palm biomass for fuel, there could also be the following drawbacks:

a. Its density is low. Palm biomass is mostly fronds (72% by weight). And as they are the “large leafy part” of the palm tree, not only do they tend to make biomass into a low density fuel, but also the density will vary depending on how they are packed. A likely estimate is 100 to 200 kg/m³ as compared with fuel oils at 900 kg/m³. As a result, more equipment will be needed for transportation.

b. Logistics of collection. Unlike fossil fuel production, such as the case for an oil rig where all of the fuel comes from one location (the drilling hole) palm biomass is evenly spread out over the surface of the plantations (to the tune of 36 tonnes per hectare for a year’s production). Also, there are many plantations and they are quite a few kilometres apart. Hence collection mechanisms will be needed.

c. Composting. Growing palm trees requires fertilizers, with the main ones being: NPK (nitrogen, phosphorous and potassium). Currently much of this is supplied by “recycling” biomass as compost. Removing biomass also means removing compost.

However, all of the above negatives can be addressed, and with current technologies too.

a. Density issues of handling palm biomass can be addressed by densification plant (such as compacting or pelletization) or by conversion to more easily handled fuels (via gasification or pyrolysis).

b. Collection issues are no more complex than have already been addressed by other industries (such as supermarkets and parcel delivery services).

c. Composting issues could be dealt with by a variety of alternatives, from using animal waste to domestic waste to co-planting with nitrogen-fixing crops (such as mucuria bracteata). Additionally, fertilizer production, though a traditional crop with a long history, is at the early stages of finding ways of being produced with a lower carbon footprint.

Overall, the palm industry has an opportunity to play a significant role in the worldwide energy economy. As with every other energy option, it has its drawbacks, with the main one being the one it shares with all other forms of renewable energy: that of being eco-friendly (and being seen to be). There is every reason that this can be addressed at the same time as
contributing to the livelihoods of people in developing countries, as well as its growing role in energy, if there is the will to do it.

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