New Revenue Opportunities Arising from the Waste Streams of the Oil Palm Industry

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ABSTRACT

Pure Power owns an innovative lignocellulosic conversion technology, which enables lignochemicals to be extracted from non-food based feedstocks and biomass. It can be deployed across a broad spectrum of feedstock resources in plantation forests in the Americas, throughout Asia, and more specifically, in Malaysia and New Zealand. Suitable feedstocks include wood chips from eucalyptus, poplar, mesquite and willow, and especially empty fruit bunches from oil palm. The company's technology produces new and profitable products for plantation owners, without disrupting the existing and proven methods for growing, harvesting and processing oil palm. The technology allows for the generation of multiple lignochemicals from oil palm waste, enabling owners and operators to diversify their revenue streams. Pure Power's technology targets the global petrochemical market in providing substitute products based on renewable sources of lignocellulosic biomass, using a proprietary extraction process to produce high value lignochemicals from oil palm waste. Pure Power's approach is founded on the simple principle of processing hardwood gently, leaving the long polymer molecules intact so that they can be used as chemical building blocks for high value applications.

INTRODUCTION

Pure Power's proprietary lignocellulosic technology enables owners and operators of oil palm plantations to generate new revenues from the current waste streams of the palm oil industry by converting them for high value uses.

Any significant advance – whether commercial or military – tends to be non-linear. It confounds expectations and breaks existing boundaries. Henry Ford once said, "If I had asked people what they wanted, they'd have said faster horses." In other words, they would have retained the existing model and wanted more of the same.

The 'horses' driving oil palm plantation revenues can be made to go faster in three ways. One traditional approach is to enlarge the plantation size to increase output through the acquisition of land or industry consolidation. However, this approach requires a large capital investment on which it offers a relatively low rate of return.

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Another traditional approach is to use research and development to increase yields (although the word traditional seems a misnomer in this case as it includes genomic research that aims to identify new oil palm genes that will offer those higher yields) while better plantation management can improve harvests and reduce waste. Again this requires substantial investment, affords only incremental growth and delivers that growth over a relatively long timeframe.

Moreover, neither of these approaches makes use of existing, untapped opportunities.

The third traditional way is to invest in downstream applications. This capitalizes on existing infrastructure and, while it may result in significant new revenue opportunities, it also requires a significant re-engineering of the business model.

NEW REVENUE OPPORTUNITIES FROM OIL PALM WASTE STREAMS

Growth Model

There is a fourth way of increasing revenue, one that changes the model: that is, developing new revenue streams out of existing low value by-products and waste.

This arises out of an opportunity that Pure Power identified in the bio-refining of hardwoods and biomass, an opportunity which it subsequently used to drive environmental and economic innovation, and to create additional value by applying it to plantation waste.

Before examining the technology, it is worth considering factors that might affect its deployment. Introducing innovative technologies and applying them in established industries is seldom easy. Alongside the investment in technology, innovation tends to require a re-engineering of existing practices and the introduction of new supply and distribution chains. However, because Pure Power's technology is relatively low cost and scalable, with a low environmental impact, it is suitable for deployment in plantations and bio-refineries across the Asia Pacific region, where it can be introduced alongside existing collection points.

In terms of Henry Ford's metaphor, that is not just a faster horse; it disrupts current models of plantation economics, without disputing existing and proven mechanisms for growing, harvesting, processing, supply and distribution – and that is positive disruption.

The traditional revenue generator in today's plantations is crude palm oil (CPO). Our studies show that plantation owners can increase revenue by between 50% and 70% if they look within the business and extract value from existing waste streams. A typical 5000-ha plantation, with an average annual production of 21 500 t of CPO (Wahid, 2004) will achieve annual revenues of around USD 12.9 million per year, based on a CPO price of USD 600/t.

The revenue growth opportunity comes from the 21 400 t of mill waste produced per year, which, if treated using Pure Power's proprietary process can produce three high value products which have a total annual potential revenue of USD 9.24 million.

Feedstock

It is now abundantly clear that, for a host of environmental, economic and ethical reasons, the next generation of feedstocks for biofuel will not be based on food crops. The United States Environmental Protection Agency, for example, in its February 2010 proposed regulations, targets the use of biofuels in transport fuel to climb from 13 billion gallons (49 billion litres) in 2010 to 36 billion gallons (136 billion litres) in 2022, requiring by far the largest part of that increase to come from various advanced biofuels, rather than ethanol made from corn (Anon., 2010).

As a result, researchers and governments are looking to a variety of feedstocks in different climatic zones. In the northern temperate zone, wood chips, switch grass and corn waste are targeted in North America and poplar in Europe. In the southern temperate zones in South America, bagasse is targeted, and in Oceania, willow. In the tropics, miscanthus and cotton husk are targeted in Africa, eucalyptus in Australia, and algae, plant waste and oil palm waste in Southeast Asia.

Pure Power focuses on sustainable next generation, non-food feedstocks with low environmental impacts. Comparative research shows that, when it comes to energy crops, oil palm leads the way in many key metrics. For instance, oil palm plantations can produce biodiesel at an energy balance of 1:9.0 (*i.e.* its energy output is nine times greater than its energy input (FAO, 2008; Sumathi, 2008), and each hectare yields 5000 litres of biodiesel (FAO, 2008; Basiron, 2009) at a cost of USD 0.54/litre in 2006 (Anon., 2009). Oil palm achieves a better energy balance than corn, sugar beet, rapeseed, soyabean and sugar-cane, with higher yields of biofuel per hectare than all those crops except sugar beet and sugar-cane, and at a lower cost per litre than all the crops except sugar-cane.

The even better news is that there is a real opportunity today for the oil palm industry to lead other crops in generating additional revenue streams by converting plantation waste into green chemicals. This leadership opportunity is possible because Pure Power's process is able to

deal with the full set of oil palm plantation residues including fronds, empty fruit bunches, trunks, kernels, palm oil effluent and mesocarp fibre. These waste products are readily available on site, are non-food based, low-cost and, most importantly, suitable for the production of high value products. By aggregating these waste streams and treating each appropriately, plantation owners can effectively produce gold from dross.

PURE POWER'S PROCESS

Pure Power's proprietary technology, for which the United States Patent and Trademark Office (USPTO) has now granted a patent, uses a simple, soft-wash process to break down hardwood into cellulose, hemicellulose and lignin. The patented technology can be integrated into a low waste bio-refinery which captures nearly all of the biomass and converts it into bioethanol, xylose and natural lignin. Over 80% of hardwood value is found in non-fuel products, *e.g.* xylose is a natural sweetener and natural lignin is a substitute for phenols, polyols and other feedstocks used in the petrochemical industry.

The commercial value of these two substances is largely ruined by other harsher processes, which destroy or degrade natural lignin, rendering it mostly suitable as a low value boiler fuel. Pure Power's process can be made virtually waste-free, using environmental-friendly, re-usable solvents to convert the total woody biomass into multiple product streams. A set of unique gentle washing processes readily separates woody feedstocks into three distinct intermediate streams: black liquor, yellow liquor and clean pulp. Each of these streams is further processed into high-value natural lignin, xylose and bioethanol, respectively.

Pure Power has patented a five-stage process to convert untreated feedstocks into a stream of high value products. The technology uses next generation approaches in lignocellulosic fractionation which, as a class, utilize a combination of physical and thermal pre-processing, followed by aqueous or solvent extractions, to afford substantially purified fractions of hemicellulose (and C-5 sugars), lignin and cellulose (and C-6 sugars) for further processing specific to each component.

As a class, these fractionation technologies offer the potential for bolt-on pulping processes that can extract higher value from pulpwood feedstocks. Lignocellulose fractionation is a valuable and important component of an integrated biochemical processing platform. While the processes will provide sugars for fermentation, more importantly they will also provide value-added purified lignin products for new market applications as aromatic chemical platform feedstocks. Additionally, unlike the lignin produced as a by-product from kraft pulping, fractionated and purified lignin is unsulphonated and therefore of higher purity and consistency. The complete process can be described as follows:

a) *Pre-treatment process*. This uses ethanol as an organic solvent to produce black liquor and a mixture of cellulose and hemicellulose.
b) *Lignin recovery from the black liquor.* This involves harvesting and drying to produce lignin.
c) *Separation of cellulose and hemicelluloses*. Hot water pre-treatment is used to break down into clean pulp and produce yellow liquor.
d) *Clean pulp (cellulose) processing*. This is used for paper pulp, or digested to sugar and fermented to produce ethanol or specialty chemicals.
e) *Yellow liquor conversion*. This involves crystallization to produce xylose.

In summary, Pure Power's patented process reclaims waste streams of the oil palm, or other woody or herbaceous matter, and converts them into three high value lignochemicals at a relatively low cost. The first two steps are benign treatments of hardwood biomass that produce lignin and xylose, both of which have significant potential.

There is still today a very limited number of such biomass fractionation technologies which are able to maximize the utilization of all the major components of biomass. Most firms seeking to produce cellulosic-based ethanol are set to derive all revenues from this single product, whereas the ethanol that Pure Power produces represents approximately 20% of the projected process revenues. In essence, Pure Power is a specialty chemical firm with 80% of its product revenue coming from the production of lignin and xylose. Pure Power estimates that adding lignochemicals to a plantation's current CPO production can increase revenues by between 50% and 70%.

Products

Pure Power's approach enables the setting up of an integrated business model that extends from plantation to feedstock, to refinery, and to industrial markets.

The model aims to substitute a new lignochemical economy, based on the lignocellulosic fractionation of renewable biomass resources, for the 100-year-old oil economy, based on the fluid catalytic cracking fractionation of fossil fuels – which were themselves originally biomass. In the oil economy, fossil fuels are converted into a

number of high value products including LPG, transport fuels, industrial fuels and chemicals. In the new lignochemical economy, plant biomass, in the form of oil palm waste, is used as a direct feedstock and converted, by a biochemical fractionation process, into a comparable range of high value products: xylose; natural lignin, a feedstock for the chemical industry; and ethanol, as a fuel source.

The unique processes allow Pure Power to capture the full value of oil palm that is processed (other feedstocks being evaluated include hardwood shrubs and forest residue in other plantations). Other lignocellulosic processes aim primarily to extract cellulose for conversion to bioethanol – this targets only the tip of the iceberg. Pure Power targets the whole iceberg and all its value, in particular natural lignin and xylose.

Pure Power's products based on lignin, xylose and ethanol can leverage existing industries, markets, distribution channels and transportation networks; they are subject to little or no adoption or acceptance cycle.

PRODUCT APPLICATIONS, MARKETS AND REVENUE STREAMS

Using Pure Power's patented technologies, high value lignochemical products can be extracted from renewable feedstocks – they are carbon-neutral and their cost of production is competitive with those from fossil fuel feedstocks.

Lignin, the second most abundant polymer found in nature, is what gives rigidity to plants. It is durable and biodegradable in nature. Natural lignin, derived from woody biomass, competes effectively with fossil fuel feedstocks in an addressable global petrochemical market estimated at USD 8.4 billion per annum. Replacing fossil fuel feedstocks with natural lignin will allow the chemical industry to reformulate the way it makes plastics, paints, resins, adhesives, insulation and barrier coatings – and even carbon fibre.

Natural lignin gives rise to four distinct lines of product applications:

- polyols, which are mainly used in the production of polyurethane for the manufacture of rigid and semi-rigid foams, flexible plastics, structural materials, elastomers, adhesives and coatings;
- phenols, which are used to produce adhesives and coating agents in the manufacture of fibre composites;
- PVC, which produces a very wide range of plastics products. Lignin can be incorporated by blending with existing raw materials; and
- carbon fibre, which has appli-cations in aircraft, automobiles, consumer products, furnishings and the sports industry. Lignin can substitute polyacrylonitrile (PAN) that is currently used in the production of carbon fibre.

International chemical companies form the primary customer group for lignin-based products. Industry demand for petrochemicals is currently growing at about 2.5% above the world GDP, and the industry's average growth rate of 5% to 6% is about triple the expected growth rate for energy. Well over 90% of the industry's feedstock currently comes from compounds in oil and natural gas.

Xylose gives rise to three lines of product applications:

- xylose, which is used in personal care products, flavouring agents and pet food additives;
- xylitol, which is used as a food sweetener that is safe for diabetics and individuals with hyperglycemia, as a low calorie alternative to sugar in foods, in pharmaceuticals and oral hygiene products; and
- furfural, an aromatic aldehyde, is used in intermediate commodity chemicals, in resins and fuels, and in solvents used in the production of petroleum lubricants.

The demand for xylose is over 300 000 t per annum. Values range from USD 800 to USD 3500/t, meaning that xylose adds significantly to the income of a bio-refinery. Currently the limited supply curtails opportunities to grow the market.

Finally, cellulose also gives rise to three lines of product applications:

- traditional pulp and paper industries, where cellulose is a source of fibre for pulp mills, a feedstock for paper mills and for specialty cellulose products;
- as a sugar platform chemical, following its conversion to glucose, which then becomes the building block for a multitude of secondary chemicals such as citric/aconitic acid, 5-hydroxy-methyl furfural, lysine, gluconic acid, glucaric acid and sorbitol, all based on C-6 sugars; and
- in the production of ethanol which is used as a blend in transport fuels, as a fuel additive and in solvents.

Opportunities

The commercial opportunity unfolds in two stages. The first is to recognize the value inherent

in what are currently regarded as waste streams; the second is to realize the highest possible value of those waste streams by unlocking their full potential.

Current oil palm plantation practice produces around 51.2 dry tonnes of total waste per hectare each year: 15.8 dry tonnes of empty fruit bunches, 8.2 dry tonnes in the form of trunks, 12.9 dry tonnes in palm fronds, 9.6 t of mesocarp fibre and 4.7 t of shell (Sumathi, 2008).

Currently, these waste streams return little or no value to the plantation owner as they are used in a number of low value applications. They are burnt or converted into charcoal, and used as an energy feedstock. They are composted for fertilizer or used as a planting medium or mulch. They become raw pulping material for paper production. They are used in making insulation materials or as animal feed.

It is possible to release more value by converting these into bio-based transportation fuels. However, like fossil-derived fuels, bio-based liquid transportation fuels such as ethanol are interchangeable commodity products. As such they reflect the lowest unit pricing of all chemical products, and are most influenced by the market fluctuations in crude oil supply.

A more profitable approach is to capture even more value by shifting production away from commodities and into high value products. Chemical products – often categorized as intermediate, specialty and fine chemicals – generally command a price premium relative to liquid fuels.

Pure Power recognizes the value of specialty chemical products (including xylitol, furfural and potentially xylose fermentation) which are derived from lignocellulosic fractionation and downstream processing, in addition to commodity chemical and fuel products. It is by targeting these specialty markets that we are able to derive such a high proportion of revenues from the lignin and xylose streams. Purified lignin products, xylitol and furfural derivatives can all be considered to be value-added chemical products, as opposed to ethanol, which is a commodity liquid fuel.

When it comes to utilization of waste and unlocking its value, not all waste is created equal. Empty fruit bunches and mesocarp fibre, in particular, represent the best opportunity for capturing golden value. Empty fruit bunches are composed of 39% cellulose, 22% hemicellulose and 29% lignin, while mesocarp fibre are 21% cellulose, 16% hemicellulose and 43% lignin. Fronds are almost as valuable, comprising 42% cellulose, 21% hemicellulose and 23% lignin, while trunks are less valuable, comprising 59% cellulose, and only 10% hemicellulose and 11% lignin.

Empty fruit bunches, mesocarp fibre and fronds also compare favourably with designated energy crops such as willow (37% cellulose, 12% hemicellulose, 28% lignin) and eucalyptus (48% cellulose, 11% hemicellulose, 27% lignin).

This analysis of the relative composition of oil palm waste streams paves the way to a business model based on diversified revenue streams.

The oil palm plantation owner enters into a feedstock supply partnership with a bio-refinery utilizing low value waste streams as feedstocks for Pure Power's lignochemical process, simultaneously unlocking the value of this biomass and improving waste management issues. Pure Power, as the technology provider, enables the construction of the commercial bio-refinery which uses its proprietary technology to produce xylose, lignin and ethanol. These lignochemicals are then sold in global markets for use as feedstocks for downstream applications.

ASSESSING THE OPPORTUNITY

In a recent independent assessment of the opportunity for developing a lignochemical industry, Randall W Powell, Dean T Didato, Peter Nelson and Jan Bouten of an industrial biotechnology analyst, BioDimensions, Inc., noted that the shift from fossil-based resources to renewable, biomass feedstocks, although in its infancy, is rapidly accelerating, and new bio-chemical and thermochemical processing technologies are constantly emerging. Although there has been much support for advanced biofuels, driven by US national security concerns, there is a shifting emphasis toward higher value bio-based chemical products (Anon., 2009).

They noted that a major characteristic of the emerging bio-economy is the formation of new supply chains and new partnerships, allowing innovative companies to participate in new ways in this industry.

Further they recognized that some bio-based products are not readily accessible through traditional fossil fuel-based processing, and these therefore represent an opportunity for novel and enhanced product features and performance.

Their conclusion was that, while new technologies carry inherent risk, they also present significant opportunity, given the fossil feedstock supply and price uncertainty, expanding carbon policy initiatives, environmental benefits and potential superior product performance.

CONCLUSION

Palm oil waste, around 92 t of which are produced per hectare each year, currently has a number of low value uses including compost, pulping, charcoal, mulching animal feed, insulation and pet foods.

Pure Power's proprietary lignochemical process technology represents an opportunity to unlock the value of those waste streams – empty fruit bunches, mesocarp fibre and fronds, with their relatively high proportions of lignin and hemicellulose, in particular. Targeting these waste streams also results in improved waste management.

Converting oil palm waste streams into high value lignochemical products allows plantation owners to diversify plantation revenue by addressing the continuing global demand for specialty chemicals and utilizing existing infrastructure and environmentally sound processes.

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