Steering Business Toward Sustainability: New Strategic Choices Through the Zero Emissions Approach to Biomass Production

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ABSTRACT
This paper argues that if the management of renewable resources, in particular plantations, were to opt for an innovative approach to the full use of all components of the biomass generated by crops and trees, it would convert the producers of biomass into an economic power house of the 21st century, comparable to the petroleum industry of the 20th century. It would become an engine for growth, a generator of jobs and an example of sustainability. It is an ideal model of how to steer companies toward sustainability.

Business and society must respond to the needs of the people for water, food, health care, shelter, energy and jobs. The population explosion is adding stress to a system which is not able to provide even the most basic services to some 800 million people in the world. And with an additional 90 million inhabitants per year, the challenge is tremendous. Asia alone is responsible for some 54 million extra consumers on the globe this year. In order to respond to this increasing number of citizens, the globe needs to produce an additional 28 million tons of grain annually, or 78,000 tons per day.

Scientists and agronomists succeeded in achieving the First Green Revolution. Thanks to irrigation, the application of fertilizers, pesticides and the selection of high performance seeds, productivity has gone up dramatically. The irrigated land increased 2.5 fold between 1950 and 1990, expanding from 94 to 248 million hectares, two thirds of which are found in Asia. The world fertilizer consumption increased from 14 million tons in 1950 to a staggering 146 million tons in 1990. World harvest of grain increased over 40 years from 631 million tons to 1,780 million tons. The world production of beef nearly tripled from 24 to 62 million tons and the world’s fish catch increased more than fourfold from 19 to 85 million tons. The yield per hectare demonstrates the results over the forty year period with yields going from 1.06 tons per hectare to 2.52 tons.

But scientists agree that we cannot expect another three-fold increase in the productivity of land; consumers are moving up the food chain, which has a major impact on food security in the world.
up the food chain, whereas Indians only consume one quarter of the amount of grain and wheat that Americans consume, and only consume 30 eggs per year and 3 kilos of meat, which is very low compared to the American average of 174 eggs per annum and 123 kilos of meat. Moving up the food chain has a major impact on the world’s food security. The consumption of eggs is increasing 15 percent per annum in India, reaching 300 million eggs in 1995, projected to double to 600 million in the year 2000, and then 1.2 billion in 2005.

Plantations could play a central role in this emerging economy. Plantations could evolve from cash crop producers to major generators of wealth, trade and jobs in the world economy. The importance of plantations is increasing since their impact on the global environment reaches far beyond the use of water, fertilizers and pesticides. Plantations have the opportunity not only to position themselves as key carbon sinks and centers for the absorption of carbon dioxide, but also to become engines of sustainable economic development.

The plantation represents one of the best potential platforms of sustainable growth and socially equitable economic expansion. Based on an innovative form of management, which we label “zero emissions,” it is feasible to merge several agendas and convert the plantation industries into the forefront of the global economy, rivaling the petrochemical industry in magnitude, technology, and political influence.

Table 1 Traditional plantation vs. 21st century management called Zero Emissions

<table>
<thead>
<tr>
<th>Traditional</th>
<th>Zero Emissions</th>
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<tr>
<td>Linear approach</td>
<td>Systems approach</td>
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<tr>
<td>Core business</td>
<td>Clusters of industries</td>
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<tr>
<td>Yield of one crop</td>
<td>Value added of the total biomass</td>
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<tr>
<td>Sideline of world economy</td>
<td>Forefront of the world economy</td>
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CORE BUSINESS STRATEGIES: PETROLEUM VERSUS NATURAL PRODUCTS

Plantations are still a prime example of “core businesses.” After all, when you plant pineapples, you are in the pineapple business. When you harvest sisal for its fibers, you are in the fiber business. When you extract oil from palm fruit bunches or from olives, you are in the vegetable oil business. But this approach does not permit the valuation of the total potential of the plantations.

We often wonder how products from a nonrenewable raw material like petroleum can so easily out-compete substitute natural competitors from a renewable source. The reason is simple: if we were to hydrolyze (break down) all the macromolecules of the plantation in the same way as petrochemistry breaks petroleum into hundreds, even thousands of products, then the renewable resources of the biomass offered by the plantations would be in a position to eliminate synthetic materials within a decade. Unfortunately, plantations remain very much as core business operations, and petrochemicals thrive as a result.

The new view of plantations requires a shift from a linear approach, searching for one product, to a systems approach of recovering all components as value added. Instead of focusing on the core business, plantations could cluster several industries together (see Table 1). The yield of one component of the crop would be subordinated to the total value added generated by the total biomass. If this strategy is pursued, then the plantations will move from the sideline of the world economy to the center stage.

RESEARCH AND DEVELOPMENT OF TODAY

Research and development for plantation industries has focused on how to increase yield: how more vegetable oil can be pressed from coconuts, olives and oil palm with a given acreage; how more coffee beans can be processed; or how more citrus fruit can be harvested using less water. This clear focus on yields and productivity of the core product stimulated the responsible use of water, fertilizers, pesticides and herbicides. Careful seed selection and cloning of pest resistant varieties, sometimes the product of genetic engineering, certainly pushed the results beyond imagination.

While the success of this scientific approach, spearheaded by prominent institutions like PORIM in Malaysia, certainly cannot be debated, the time may have come to introduce a new focus. Indeed, scientists agree that while yields can be expected to go up even further, no one is expecting a continuation of the same dramatic improvement as has been witnessed during the Green Revolution.

If we were to hydrolyze all the macromolecules of the plantations in the same way as petrochemistry cracks petroleum into thousands of products, the renewable resources of the biomass would be in a position to eliminate synthetic materials within a decade.
There has been a call for a second green revolution, but what type would that be?

It seems there are increasing problems with pests which have become resistant to some of the previously effective chemical controlling agents. La broca, the pest affecting coffee plantations in Latin America, is gaining ground. Even when new pesticides are introduced and stringent controls are implemented, more advances in protection of the existing plantation have to be achieved. Coffee is not the only crop affected. Banana plantations are infested and new varieties have been cloned rapidly to secure the survival of the industry; the palm and coconut tree, attacked by fungi from within, falls over when it is too late to do anything about it. There are few plantations indeed which are free of pests. Biologists will confirm that anytime a monoculture takes over a patch of land, pests will have a chance to invade and dominate.

As a result, the focus of research seems increasingly directed toward preserving what has been achieved. While the further increase of yields is not out of sight, there is another factor compounding the search for ever higher yields: price. Since many commodity prices have spiraled downward over the past decade, world prices have not motivated researchers to imagine a new tripling of output. On the contrary, conservation has often become the name of the game.

Table 2  Environmental Management of Plantations in 60s, 80s, and the 21st century

<table>
<thead>
<tr>
<th>1960s</th>
<th>1980</th>
<th>2000</th>
</tr>
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<tbody>
<tr>
<td>practice</td>
<td>substituted by</td>
<td>in addition to all previous</td>
</tr>
<tr>
<td>pesticides spraying undergrowth</td>
<td>biological pest control plant nitrogen fixing cover crops</td>
<td>reuse of all biomass in clusters strategic planning of carbon sink</td>
</tr>
<tr>
<td>fertilizers monocultures</td>
<td>waste as soil enrichment seed bank expansion</td>
<td>establish tradable carbon rights productivity thru biomass reuse in other industries</td>
</tr>
<tr>
<td>selection for high yield</td>
<td>selection for pest resistant</td>
<td>cloning of biochemically rich varieties</td>
</tr>
<tr>
<td>clean clearing and burn</td>
<td>zero burning</td>
<td>search for value added</td>
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Biodiversity, DDT, Slash and Burn

Plantations are certainly not known for their contribution to biodiversity; on the contrary, too many varieties have been lost in this drive toward higher yields. Only now are scientists sometimes desperately searching for alternate varieties which may offer the only security against infestations of mildew, fungi, and insects which have developed resistance or immunity against the harshest forms of chemical control. While monocultures are the norm, plantations around the globe are searching for new varieties, even studying the DNA of long lost plants and fruits in the tombs of ancient civilizations.

Plantations have evolved from centers of consumption of DDT, the widely banned chemical substance unmasked by Rachel Carson in the early 1960’s in her epoch-making book *The Silent Spring*, to test beds for biological control. While chemical spraying was the norm, now it has become increasingly the defense of last resort. While spraying noxious undergrowth used to be the tradition, now plantations conserve soil by planting species that will avoid the extraction of nutrients from the soil, while the growth cycle of these undergrowths will even plow nitrogen back into the fertile ground, enhancing the plantation and reducing the need for chemical fertilizers. Table 2 reviews the strategies of the past, the concepts which are gaining ground now and the progress that needs to be achieved in the future in order to achieve a truly competitive industry.

Plantations have been criticized for their clean clearing, involving burning in order to prepare the fields for planting or replanting. Now, most responsible plantation companies owning large acreage across the globe are self-imposing the “no-burn option,” meaning that none of the biomass waste will be incinerated. This no burn option is one among many relatively innovative approaches introduced by Malaysian palm oil plantations such as Golden Hope Plantations Berhad or the pineapple plantation Gunung Sewu (Great Giant Pineapple Plantation); it is not yet mainstream. It has been suspected that plantations are a major contributor to global warming due to the repeated release of carbon dioxide into the atmosphere through the practice of burning. The alternative reuse of this biomass as a fertilizer or a soil amendment is a first step, although it is not enough. If a process can be identified that permits the generation of value added, then it will be embraced by all plantations around the world in no time. This needs some solid argumentation and scientific proof and has been the main thrust of the Zero Emissions Research Initiative.
HOW TO STEER PLANTATIONS TOWARD SUSTAINABILITY?

The key question we have to ask ourselves is: How can we stimulate plantations to embark on a real sustainable strategy that goes beyond biological pest control, safeguarding of biodiversity, and non-incineration of biomass waste? These are solutions and practices already generated in the seventies and eighties. The United Nations Conference on Environment and Development took place in Rio de Janeiro five years ago and the results will be subject to a review during a special session of the UN General Assembly from June 23-26, 1997. The time has come for plantations to go beyond the ideas of the past. We must ensure that plantations evolve into examples of environmentally sustainable development. We must envision a strategy that enables them to become examples of resource productivity. How can we ensure that this approach is embraced and remains successful? The main objective of this paper is to formulate responses to these two fundamental questions: (1) Can all biomass be reused? (2) If so, will the plantations move to the center stage of the economy and offer a prime example of how to achieve an increase in resource productivity?

If we can demonstrate that innovations in plantation management will not only lead to a sustainable exploitation of renewable resources, but also yield multiple revenue streams, then no investor or owner would object. When it is a matter of competitiveness, a question of value added, and a cash flow with good returns on investment, then all plantations will be prepared to join. This requires innovation in management and technology; consequently, a new management concept is needed. Governments can regulate, NGOs can agitate, but only business can innovate. And in order to move plantations toward sustainability, numerous innovations are needed.

THE ROLE OF GOVERNMENT

Many would stress the role of government in steering business toward sustainability. This is an important issue. Excesses need to be restrained. Basic needs for food, water, health care, and shelter must be met. But government should refrain from going beyond these main tasks. This is not a plea for laissez-faire policies, with a blind belief in the invisible hand of Adam Smith. However, it is appropriate to point out that the introduction of quality management, for example, and the application of the ISO 9000 standard was never imposed by law nor demanded by NGOs. Businesses, including plantations, know all too well that if they do not embark on a quality
program, they will lose their competitive position on the market. It was competition that drove industries towards new management practices where quality stands central (Table 3). It is competition that will drive plantations to the Zero Emissions management concept.

AN EMERGING MANAGEMENT STYLE: ZERO EMISSIONS

The concept of “zero emissions” is a new management instrument which emerged only a few years ago in the field of industrial ecology (Table 3). It is comparable to the total quality management (TQM) concept without which no business can prevail today. Total quality is equated with zero defects. Zero emissions can be compared with the just-in-time, or no inventory, concept which clusters suppliers around major assemblers like the car industry. The concept of zero emissions is the continuation of the concept of total customer satisfaction, where no executive will rest until all customers call for repeat business. It is a “zero defection” target. Just as no manager can tolerate one fatal accident (zero accident or total safety) in his company, the objective of business must be zero emissions, or nothing wasted. It is only when all materials are fully used that processing industries reach their highest potential.

Zero emissions basically means that “nothing will be lost, all waste will be used as value added.” Residues can either be reused within activities of the industry itself, or as a value added input for other industries. It is a systems approach, and differs as such from the linear approach where only one product is targeted based on the core business strategy.

This new management concept of Zero Emissions has the potential to reposition plantation industries in the world economy. The application of the ZERI methodology, which is described in the appendix, could very well catapult the plantations to the forefront of the economy and global environmental politics. This methodology searches for cleaner production methodologies first, then it identifies the value addition that can be generated on the basis of the waste. It will describe the clusters of industries that could emerge, or nothing wasted.

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<table>
<thead>
<tr>
<th>Management Concept</th>
<th>Target</th>
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<tbody>
<tr>
<td>Total Quality Management</td>
<td>Zero Defects</td>
</tr>
<tr>
<td>Just in Time</td>
<td>Zero Inventory</td>
</tr>
<tr>
<td>Total Customer Satisfaction</td>
<td>Zero Defections</td>
</tr>
<tr>
<td>Health and Safety in the Company</td>
<td>Zero Accidents</td>
</tr>
<tr>
<td>Total Productivity of Materials</td>
<td>Zero Emissions</td>
</tr>
</tbody>
</table>
single out the technologies needed, and conclude which government policies are necessary to support this approach. Table 4 highlights the results of such a methodological approach to palm oil plantations.

While single crops and numerous by-products of limited value are standard in business, the time has come to imagine plantations at the core of a cluster of industries which generate an economic value previously unimaginable. This really is a continuation of striving for higher levels of productivity.

**PRODUCTIVITY OF THE PLANTATION**

As discussed above, plantations like any other business need to focus on increased productivity. One never reaches the limit; there is always the chance to go beyond the current level. As mentioned above yields have improved tremendously and scientists agree that further dramatic increases are not expected. The first green revolution succeeded and reached its limits. While incremental improvements are certainly around the corner, the plantation industry can envision a doubling or tripling of revenues only when it targets the full use of the biomass it is producing.

Palm oil plantations in Indonesia, Malaysia, and Brazil generate an estimated 200 million tons of biomass per annum. Sisal plantations in Tanzania alone generate over 10 million tons of biomass. These amounts are comparable to the volumes processed by the petrochemical industries. The core question that needs to be posed is: How much ends up in the commercial trade? A minor fraction, indeed. There are few plantations which are capable of putting a commercial value on more than 10 percent of the biomass that they generate each year. Most of the plantations commercialize less than 10 percent of the green mass, trunks and fruits generated. The palm oil represents approximately 8 percent of the biomass of the plantation over its life time, the sisal fiber is just about 2 percent per harvest, sugar is some 15 percent of the cane. By all standards, this is not a very productive operation; there is much room for improvement.

The efficiency of the tropics in generating biomass is unique and well documented. Photosynthesis in the equatorial climate is more effective than under the Arctic circle. But when the biomass is so massive on the one hand, and so under valued on the other, then we have to question what can be done. It is immediately obvious that where the main crop is concerned, little can be done. Coffee farmers in Colombia cannot double their yields with new varieties. The sugar plantations in el Valle del Cauca cannot harvest more than their current international record.

The ZERI methodology could very well catapult plantations to the forefront of the global political economy. This methodology searches for cleaner production methods first, then identifies the value added that can be generated from the waste. It will describe clusters of industries that could emerge, single out the technologies needed, and conclude which government policies are necessary to support this approach.
After decades of requesting the earth to produce more of the same, the time has come to do more with what the earth currently produces. This is probably the most important step that plantations can take towards sustainability and environmental stewardship. It is a creative process that must go beyond the current "best practice" (Table 4).

Table 4: Existing best practice for waste and potential new use

<table>
<thead>
<tr>
<th>Output Type</th>
<th>Existing Best Practice</th>
<th>New usages under research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Palm Oil</td>
<td>raw material for palm oil refining</td>
<td>palm diesel production</td>
</tr>
<tr>
<td>Trunk</td>
<td>Soil conditioner (zero burning technique)</td>
<td>wood products (fiberboard, particleboard, furniture), pulp/paper, animal feed, glucose, cellulose, fuel, palm heart, activated carbon, polypropylene filler</td>
</tr>
<tr>
<td>Fronds</td>
<td>Soil Conditioner</td>
<td>Vitamin E extraction, fiberboard, particleboard, pulp/paper/paperboard</td>
</tr>
<tr>
<td>Pericarp Fiber</td>
<td>Fuel for mill</td>
<td>fiberboard, mushroom growing substrate, pulp/paper, roofing tiles/cement aggregate, sorption for heavy metal cations</td>
</tr>
<tr>
<td>EFB</td>
<td>Mulch for soil application</td>
<td>fiberboard, substrate for growing mushrooms, beta carotene production, solid fuel</td>
</tr>
<tr>
<td>Shells</td>
<td>Fuel for mill</td>
<td>Activated charcoal, cement aggregate, potting medium</td>
</tr>
<tr>
<td>sterilizer condensate</td>
<td>(see Total POME)</td>
<td>cellulose, single cell protein substrate</td>
</tr>
<tr>
<td>sludge</td>
<td>(see Total POME)</td>
<td>feed supplement</td>
</tr>
<tr>
<td>hydrocyclone water</td>
<td>(see Total POME)</td>
<td>(see Total POME)</td>
</tr>
<tr>
<td>Total POME</td>
<td>Closed tank or lagoon digestion to produce anaerobic slurry for fertilizer use, and biogas for heat/power generation</td>
<td>ethanol/amino acid production</td>
</tr>
<tr>
<td>Washings</td>
<td>(see POME)</td>
<td>(see Total POME)</td>
</tr>
<tr>
<td>Boiler Ash</td>
<td>Fertilizer, detergent, land fill</td>
<td>-</td>
</tr>
<tr>
<td>Kernel</td>
<td>kernel meal, animal feed</td>
<td>-</td>
</tr>
<tr>
<td>crude palm kernel oil</td>
<td>raw material for palm kernel oil refining</td>
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FROM DOWNCYCLING OVER RECYCLING TO GENERATING VALUE ADDED

Plantations are not discarding all waste materials from fields or processing units. Many use the waste from fruits as a soil amendment or fertilizer. But how many by-products generate additional value that in general outstrips the cost of production and disposal? Very few indeed. How much do coconut plantations in Sri Lanka or Cote d’Ivoire receive for the fiber of the fruit which is used to wrap drainage pipes in Europe? How much do sugar plantations in South Africa derive from the sales of bagasse to cattle farmers? What is the caloric value of the bamboo plantation waste in Indonesia? How much do citrus farmers get for the pits?

While we all underwrite initiatives and support the desire to reuse wastes as by-products, the question is how much value added is and can be generated? All too often, the value is minimal and resembles more a downcycling, getting rid of waste at a price cheaper than the straightforward disposal, or a cheap recycling under the form of a fertilizer, euphemistically called a soil amendment. Only if the plantations will generate considerably more money from the additional harvesting and processing will these materials be used.

The mere volumes of biomass with which plantations have to deal are staggering. A palm oil plantation generates on average 25 tons of biomass waste per year, so that a 40,000 ha plantation, which is nothing unusual in Kalimantan, Indonesia, already has to handle 1 million tons on its own. This means that any valuable component that can be identified represents a major additional industry.

The first requirement is to think beyond the core business. The second requirement is to identify the biochemical components which are outside the mainstream of the plantation business, but which could be inputs into a clear stand-alone industry, with a unique competitive position, if and when extracted efficiently. A concrete case is the isolation of furfural from the African oil palm. The Latvian State Institute of Wood Chemistry demonstrated furfural processing from biomass of the oil palm with its pilot unit in Riga. The Institute has designed a test unit for immediate installation.

Not many oil palm planters have even heard of furfural, so no one can blame them for their lack of strategy. Furfural is a natural anti-enzymatic and efficient bactericide used, for example, in the paint industry as a solvent. It commands a higher price on the market than palm oil (US$1,350 per ton). When biochemists found that the conversion of hemicellulose from the trunk of the tree into furfural reached 17% at laboratory scale, it is no surprise that this

Zero emissions is the continuation of the concept of total customer satisfaction. It is only when all materials are fully used that processing industries reach their highest potential.
high concentration calls for an investment strategy. Then a palm oil plantation is not only in the palm oil business, it is also in the fur-fural business. Of course, if all plantations were to engage in this extraction, prices would drop, perhaps to half or even one-third of the present world market price. Today, furfural is available in both its synthetic and its renewable form. As the natural variety becomes cheaper than the petrochemical one, it would take over the market and plantations’ revenues would increase.

The palm oil plantation could be on the verge of converting itself into an industry with many by-products like the petroleum industry. The petrochemical industry does not lose one molecule. The value of this non-renewable resource is considered so high at $23 per barrel that everything is broken down into useful chains of products. Why do plantations not engage in a similar approach? After all, the variety of components of a plantation can always be reduced to a few core products, namely cellulose, hemicellulose and lignin and a wide variety of specialty chemicals such as proteins, lipids, waxes, etc.

The biochemical study of the sisal plant, a crop that is rapidly losing popularity due to the advent of synthetic ropes at a cheaper price, confirmed that the bowel of the sisal plant can serve as an excellent basis for the fermentation of citric and lactic acid. The price of citric acid is 10 times higher than the price obtained for sisal fibers. The citric acid production process is a fermentation system. The tropical climate in Africa permits a solid state fermentation, eliminating the need for expensive steam which is widely used in Europe and America. Just imagine that the sisal fiber represents 2% of the biomass and that 10% of the bowel can be converted into citric acid at ten times the value. It will be possible to regain the competitive position for sisal fibers when additional revenue is generated from the production of the food additives.

These are just two concrete examples of the value that can be extracted if one is willing to do the homework. Consider the iodine from seaweed plantations, the beta carotene from the avocado, the vitamin E and anti-oxidants from coconuts, palm oil, and the pits of citrus fruits. There is so much that can be extracted and we have only seen the beginning. Multidisciplinary research that goes beyond the boundaries of one sector will undoubtedly find numerous additional products for extraction and commercialization. The comparison will, for example, indicate that coconuts are much richer in Vitamin E than palm oil, while palm oil is richer in betacarotene. The potential is vast.
FIBERS

One component of plantations deserves special attention: the fibers or lignocellulose. The massive capacity of plantations to generate cellulose deserves special attention. Let us take a global perspective. Not one environmental program in the world has been as successful as the recycling of paper. All countries around the world are dedicated to the recovery of used paper. The reason is simple. People are aware that trees are logged in order to supply cellulose from which pulp and then paper is made. The Japanese recover over 50% of all paper, while American states even legislate the minimum content of recycled fibers in newsprint. Demand for cellulose for the production of paper and packaging materials is increasing. It is no secret that the increase in literacy and the improvement in living standards stimulates the demand for paper. The arrival of 400 million middle class consumers in Asia is a major challenge for the world. These middle class consumers have one dollar a day available to buy a newspaper.

The need for fibers goes beyond pulp, paper, and packaging. Cellulose is used in construction materials, such as cement additive, rendering the cement board more resistant in tropical climates. One cement board factory will need a 2,000 ha bamboo plantation in order to have access to the right blend of green mass to strengthen its cement.

Somehow, the plantations around the world seem to neglect, or we neglect, that they represent the largest source of cellulose in the world. Any plantation, of whatever type, could be considered a cellulose factory. Most of them are located in the most productive areas, offering a quality that competes perfectly with the cellulose varieties found in Scandinavia or North America.

PLANTATIONS AS CARBON SINKS

As major cellulose producers, plantations can also be classified as one of the most efficient carbon sinks, capturing carbon from the air through photosynthesis and returning oxygen to the atmosphere. This basic function of the forests is indeed also assumed by plantations, and the job is performed in a very controllable fashion. The disposal of cellulose from plantations has been a major problem in the past. Indeed, most of it was either plowed back into the soil or even incinerated, contributing to carbon emissions.

Therefore, it does not make much sense to engage in the planting and harvesting of trees like spruce and Douglas fir which need at least 20 years to be harvested and are shipped to the centers of new
cellulose consumption, which are rapidly shifting to South East Asia and Latin America, when the plantations there could easily respond to the demand. The richest concentrations in cellulose are found in bamboo, sugar cane, rattan, palm oil, banana, and coconut trees, the quality of which could match the traditional sources of fiber extracted from hard or softwoods.

Why is the extraction of cellulose from the plantation neglected? When Indonesia declared that it plans the construction of 30 new pulp mills by the year 2010 with a capacity of 11.1 million tons, it unfortunately did not indicate its sources of cellulose. At a time when the harvesting of primary forests is prohibited and the replanting of the cleared land will take years, the plantations offer the logical answer. If Indonesia were to engage in special forestry projects, then we are missing a unique opportunity to valorize the plantations’ biomass. Indeed, the booming plantations on some of the 13,000 islands of Indonesia could become the key supplier of cellulose in a variety of strengths and lengths that meet even the most demanding pulp buyers in the world. The full 11 million tons could be supplied by the 2.2 million ha of palm oil plantations.

The implementation of this strategy requires multidisciplinary research in which forestry experts cannot expect to take a lead. They have an existing business to defend. It is up to the plantation industry to take the lead and demonstrate its feasibility, both technically and economically, in order to move forward. And it is also up to the plantation industry to identify the new technologies that are needed to facilitate their task and their challenge.

This is an environmental and economic opportunity of great significance. Moreover, it is the birth of a new industry, complementary to the plantations’ original business, oil from the palm or the coconut, or sugar from the cane. This use of cellulose represents a major additional demand for biomass which is not exploited today. And the value generated is much higher than the economic importance of the soil enricher which is hard to find in the bottom line of the plantation. Even at the rock bottom price of US$ 400/ton, it is good for an extra annual revenue between US$1,100 and 1,700 per ha.

THE NEED TO FIX CARBON

This is quite a breakthrough, since such a reuse of the fibers not only generates additional business, it also represents the creation of a massive carbon sink. The world is in urgent need of carbon sinks. We are creating an excess of CO₂ around the globe and as a result, scientists fear that global warming is imminent. The world is not
sitting still. Massive research efforts are being undertaken not the least by the Japanese who wish to find the best technologies to quickly reverse the danger of global warming due to the excessive exhaust of carbon dioxide. The Research Institute for Innovative Technologies for the Earth (RITE), located in Japan, has some US$80 million in research funds per year.

If just a fraction of that budget could be reserved for studying the carbon sink capacity of plantations through the commercial reuse of cellulose, it would not only capture the carbon in endurable products, it would also offer the opportunity to create new jobs, expand trade, and enhance investments. What more can you wish for than the merging of all these agendas? The reuse of most of the plantations’ biomass will result in the long term capture of carbon dioxide, and that is a priority for humanity. There is probably no sector in the world economy capable of contributing to this like the plantations around the globe.

CERTIFICATION OF CARBON SINKS

Plantations could consider quantifying through certified organizations how much carbon dioxide they are effectively fixing, and how to increase it. Why? In the first place, this background data could spur international interest in the role of plantations and secure funding for research. Longer term it could even represent a key source of revenues. Over time, there is likely to be established a system of tradable rights for carbon dioxide emissions. That means that each company will have a specific limited number of emission rights and when they exceed these rights, they must either reduce them, which may technically not be feasible, or they must buy the rights from those who either did not use them, or who are massively capturing carbon dioxide from the air.

The question, “In which business are you?” has been posed a few times in this article. And while plantations may be willing to consider entry into new biochemical components which were not valorized before, the entry into tradable carbon dioxide rights may seem very farfetched today, but certainly it is not theory anymore. The Dutch government already requires industries to compensate for their carbon dioxide emissions by initiatives outside the country. It is only a matter of time before this becomes a global practice. Again, Japan confirms that this is on the priority list for moving toward global environmental stewardship. When the Japanese Energy Institute studied in detail the possibilities for establishing such a system, the core element that was missing was the producers of the sinks.

Plantations: In which business are you?
Specialized corporations like SGS, based in Switzerland, have established a world business in certification of products for export and the certification of quality. Now, the next new line of products they are likely to certify is tradable carbon dioxide rights. After all, who has the independence and the authority to establish how much an industry has wasted in terms of CO₂ and how much it should purchase additionally from elsewhere?

EXTENDED LIFE CYCLE ANALYSIS

The third challenge of the plantation industries is to introduce to its clients a full life cycle analysis (LCA). At present LCA is gaining ground in industrialized countries, permitting better insights into the impact of products on the environment. A thorough LCA takes years to establish and often the data to permit a full view are missing. While every effort has to be made to determine the life cycle of a product from cradle to grave, here we arguing for a new extended form that can be introduced in the next few years. No one else is better placed than plantations to take the lead.

Let us take the case of coconut from plantations in the Philippines. As Japanese consumers become increasingly aware that detergents are a major uncontrollable cause of water pollution, they may wish to substitute the very slowly degradable chemical tensides with fast degrading vegetable-based water surface tension reducers. This is certainly to be applauded. The most popular vegetable surfactants are fatty acids derived from coconut oil, palm kernel oil and especially the lauric ether sulfate. An extended LCA of a coconut based detergent looks straightforward, but here we propose a different assessment.

While the rivers in Japan or Europe may be cleaner thanks to the use of these environmentally less detrimental raw materials of vegetable origin, we have to admit that there is a major flaw in the logic. Indeed, the fatty acids from the coconut oil represent only 4% of the biomass generated annually from the plantation. Nearly all the rest is being discarded. How responsible is this? Considering that the petroleum-based molecules were part of a long chain, where nothing got lost in the process, which is environmentally more responsible: using nearly 100% of a non-renewable source, or using only 4% of a renewable source?

It would be in the interest of the Philippine coconut plantation industry to remind the Japanese that if they wish to have cleaner rivers, they might consider an extended life cycle analysis revealing the impacts this environmentally sound product development could have in their industrialized society. This line of product development could benefit the planters more than just the sale of a com-
modity like fatty acids. The coconut tree is not just the provider of oils and acids, it is also the supplier of cellulose, which represents one third of its biomass, more than anything else. It is a source of biochemcials and clean fuels (like lignin) which can be used in an efficient manner. The small fibers can be recovered in the form of particle board. The coconut is rich in Vitamin E. So, instead of having just one business, we see the emergence of five industries, all clustered around the coconut tree and the desire of the Japanese and Europeans to clean up their rivers.

This extended life cycle analysis potentially offers answers to many challenges. It is more than an environmental strategy: it is an investment platform, a trade generator, a job machine. Then the LCA becomes a most attractive tool for sustainable development, instead of being today a mere tool for environmental performance. If years of research are needed, it had better be useful for more than just compiling statistics on the production and disposal of products.

The Zero Emissions Research Initiative has already undertaken biochemical assessments of the biomass from palm oil in Malaysia and Indonesia, sisal in Tanzania, sugar cane plantation industries in Brazil, and pineapple plantations in Indonesia—all with success. Other plantations are preparing for the application of this analysis, like the olive oil plantations in Italy. While these are the first steps indeed, the methodology is expanding rapidly, since all partners in the exercise realize that this offers a unique chance to merge agendas: preservation of the environment, increased productivity of the biomass, creation of jobs, attraction of additional investments, expansion of trade and the pursuance of innovative research and development programs. Not the least, it decreases the risk run by any single-product business.

PORTFOLIO APPROACH

This clustering of industries around the biomass factory, i.e. the plantation, moves this business from a single-product enterprise, which is subject to volatile changes in the world commodity prices, to a portfolio of businesses and derivatives which are part of different business cycles, and therefore guarantee better stability in revenues. Throughout history we have too often seen that the overproduction of one crop risks wiping out nearly all plantations, or that a synthetic substitute, like synthetic rubber, eliminates fortunes in a few years’ time, as the city of Manaos in Brazil stands to witness for generations to come.

A portfolio approach, based on biomass generated in the commercial exploitation of one species, will offer in addition to the
core crop a set of other products which could challenge the petro-
leum derivatives in price and volume.

CONCLUSIONS

The design of the environmentally sustainable plantation of the 21st century is more than a strategy to preserve the environment. It is a challenge to make plantations more competitive among each other and against substitute materials of synthetic origin. Increased competitiveness can be achieved by continuing to focus on higher levels of productivity. Now that yields of crops have reached their limit, plantations will undertake analyses to unveil the opportunities in derivatives which can be extracted from the massive amounts of biomass which remain without value added. This is a fertile basis for new investments, for job creation, for trade and for technological cooperation.

It requires a multidisciplinary approach. It can only succeed with cooperation across business sectors. Fibers from the plantation are reused in the pulp industry, lignin as a binding agent, hemicellulose in the food industry, just to name the most important ones. We know that the Japanese government is prepared to cooperate in such an analysis, and industry will be prepared to convert the findings into new industrial development schemes. The Zero Emissions concept has found fertile ground, and if demand were presented by the major planters around the world, backed by their governments, then several initiatives could be started in the short term.

After a decade of downsizing, agro-industries can imagine a strategy for upsizing. Whereas downsizing targets producing more with fewer people, upsizing demonstrates that one can produce more with more people.

APPENDIX: ZERI METHODOLOGY

The introduction of a new concept of productivity, focusing on the complete reuse of the biomass and the advent of the use of biomass as a tool for trade and development, is a complex issue. Addressing complex issues is not easy. Available analytical methods are not well equipped to take numerous different components into account. Worse, business executives rarely have all the expertise under one roof, which would permit immediate access to the in-house process engineering knowledge that is needed to demonstrate the viability of reusing other compounds commercially. As mentioned, business
has been pressured to focus on its core business strategy, reducing its scope to those activities at which it is best. These elements have led to the study of the problems of the industry within the industry. A survey of the opportunities outside the industry has not been easily initiated. Just as waste exchanges are emerging in different parts of the world, the clustering of industries based on waste material cycles is emerging as a strategy for economic development and enhanced competitiveness of industries.

The ZERI (Zero Emissions Research Initiative) of the United Nations University has worked out a methodology which facilitates the envisioning of solutions to these complex issues. This methodology is based on two assessments: an input-output table, and an output-input table. The first part is based on the ISO 14000, or just good housekeeping procedures, that could lead to the certification that the company has the best possible standards and processes within the industry. The input-output table puts on the vertical axis all the inputs that are needed in the process. On the horizontal axis, all outputs are enumerated which are left over in the process. Table A shows the case of beer.

This simplified version for the case of beer indicates the process of inputs being converted into outputs and the other waste streams that are generated in the process. Cleaner production will aim at improving the process, for example, by reducing the consumption of water. A more efficient use will halve the amount of water needed in order to produce the same amount of beer. The malt, on the other hand, cannot be changed. After all, the taste of beer is the result of a fermentation process which cannot be altered if the end result is to be that recognizable drink with foam called beer.

<table>
<thead>
<tr>
<th>Table A: Basic Input-Output table</th>
<th>Cleaner Production i/o table</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>o</td>
</tr>
<tr>
<td>Beer</td>
<td>H2O</td>
</tr>
<tr>
<td>H2O</td>
<td>10</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Malt</td>
<td>8</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>......</td>
<td></td>
</tr>
<tr>
<td>H2O</td>
<td>50</td>
</tr>
<tr>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>Malt</td>
<td>8</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>......</td>
<td></td>
</tr>
</tbody>
</table>

YALE F&ES BULLETIN
The second part of the methodology is unique to Zero Emis-
sions: the output-input table. Zero emissions stands for “noth-
ing gets lost--everything is reused” and as a result there is no
waste and no pollution. After all, that is the way nature works.
Everyone produces waste, but it is always food for someone else.
This requires a creative approach and is the basis of the search
for value added components. The vertical axis enumerates all
the outputs which are not part of the final product; on the hori-
zontal axis a creative inventory is made of all possible users.
Obviously, this process is only valuable when the input-output
table has been established and documented and when the com-
pany has made all possible efforts to reduce cost and improve
the throughput, i.e. do more with less.

When all outputs have found a way to be used as inputs for
other industries, then the industry under examination has at-
tained the target of zero emissions. Each of the new uses should
then undergo the same process. Zero emissions are not achieve-
able within each business alone, but only by considering clusters
of industries which all share responsibility. Just as the ecosystem
around the tree deals with waste leaves as food, it is possible to
imagine that all waste be reused to achieve the zero emissions
target in a output-input process. This process requires a
multi-disciplinary approach, searching for options not previ-
ously considered within the business. A simplified version of the
output-input table might look like the following:

<table>
<thead>
<tr>
<th>i</th>
<th>cleaning</th>
<th>fish farm</th>
<th>algae</th>
<th>irrigation</th>
<th>mushroom</th>
<th>earthworm</th>
<th>...</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2O</td>
<td>2</td>
<td>80</td>
<td>10</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>...</td>
<td>100</td>
</tr>
<tr>
<td>Spent Grain</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>60</td>
<td>40</td>
<td>...</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>...</td>
<td>100</td>
</tr>
</tbody>
</table>

The Zero Emissions Research Initiative thus offers a tool for
analysis. The output-input tables offer an instrument for chan-
neling in a most creative manner the products and components
which today find no value in the plantation processing or pro-
duction process. It leads to the identification of potential value-
added uses of elements that have no market value today. Such
an exercise requires homework indeed. A detailed biochemical
dissection of the residues involved is a prerequisite to being able
to start the work.
GUNTER PAULI
Gunter Pauli obtained his Master’s in Business Administration from INSEAD, Fontainbleau, France. His entrepreneurial activities span business, culture, science, politics, and the environment. Under his leadership, a small European company pioneered the first ecological factory in Europe. He founded and directs the “Zero Emissions Research Initiative” of the United Nations University in Tokyo where his focus is redesigning manufacturing processes into non-polluting clusters of industries. He is co-founder of the ZERI Foundation which aims to implement the research findings. Fluent in six languages and having lived on all continents, he is a world citizen. He has written eight books which have been published in 15 languages. His next book Upsizing, will be published in the Fall of 1997. Since 1994 he has lived with his wife and two children in Kamakura, Japan.

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