PROJECT 1
"Grow Your Own House": Bamboo as a Construction Material

The United Nations estimates that at least one hundred million (100,000,000) people in the world have no home. If those with poor quality housing are included, the number is more than one billion (1,000,000,000). (Brown, 1999). And the news only gets worse, as the total number of homeless is growing (Worldwide housing needs are expected to double over the next 50 years. In Africa alone, they are expected to grow more than threefold.)

While awareness about the critical need for more affordable housing has grown, the solutions have not.

The five leading modern construction materials are cement, concrete, steel, bricks and wood. In the industrialized world, these have been used to build more comfortable housing than ever before. This has contributed to changing living patterns of the middle class, but not for the poor. Steel and cement are symbols of wealth and power - but many people cannot afford them.

Bamboo (Vegetable Steel)
We need radical new ideas for housing. For example, one of the best structural materials available in abundance is bamboo. It has a matrix of ligno-cellulose, which provides better tensile and compression strength than iron. There are many bamboo species, growing around the world. Bamboos, such as Guadua Angustifolia, have been used extensively as construction material in poverty-stricken regions.

There are many advantages to using bamboo in construction. It is a highly functional, beautiful, earthquake-indifferent material. Bamboo occurs in many sizes, many degrees of hardness, and many grades of color and occupies a wide range of habitats. It is possible to build multiple-storey buildings with bamboo. Whereas trees must be replanted when they are harvested, bamboo roots sprout up again quickly. The Guinness Book of Records (1999) reports that some of its species constitute the world's fastest growing plants. Some of its species grow at an incredible rate of 91 cm per day

Sadly, though, bamboo is not used in construction. Its potential is lost by the perception that it is for poor people. While the poor often have no choice *but* to build with these vegetable steels, the rich have only recently discovered the quality of bamboo as a construction material.

„Grow your own house"
Colombian architect Simon Velez has designed a two-story, 65 square-meter bamboo home. This beautiful home requires only 100 pieces of five-meter long bamboo, which can be harvested in four to five years on 500 square meters of land.

You can now „Grow your own house". The result could very well be a social housing program that offers beautiful, functional, cheap, earthquake-indifferent houses. It may seem like a dream, and many people still do not think it will work, but the concept initiated by the ZERI Foundation in Latin America has received support in Africa and is being displayed at the world EXPO in Hanover, Germany.

The ZERI Pavilion
To help promote bamboo as a building material ZERI decided to participate in the Expo 2000 in Hannover, Germany. The organizers of the EXPO had visited ZERI projects around the world and found that ZERI's projects and methodology epitomized the chosen theme of the EXPO 2000, "Humankind, Nature, and Technology." In 1997, the ZERI Foundation was invited to participate in EXPO 2000 with its own pavilion. The ZERI Foundation would be the only Non-Profit Organization with its own pavilion in the area reserved for nations.

It was decided that the ZERI pavilion should create astonishing beauty and push new building techniques to the limits, in order to establish bamboo as an accepted building material. ZERI decided to build the pavilion out of bamboo, alizo and arboloco, all trees that are indigenous to Colombia. It would be the only Expo pavilion that could be grown. Simon Velez was enlisted as the architect to design the pavilion.

Soon after the building was designed, it became clear that in order to meet the strict German building laws, a prototype of the ZERI Pavilion was needed. It was decided that the prototype should be constructed in Colombia, the heartland of the tropical construction materials to be used in the pavilion and the home of Simon Velez. The pavilion in Manizales took eight months to build in 1999.

Two core-building systems, invented by Simon Velez, were used in its construction. First, in order to maximize the traction strength of the material, fine cement is injected into the inside of the bamboo and tightened with copper bolts. This invention allows large bamboo structures such as the ZERI pavilion, with overhangs of up to 9 meters, to be constructed at a low price. In fact, the material has better characteristics than steel and cement, while offering a stunning visual effect both inside and outside of the structure. Second, filling two nodes with cement creates joints. Iron rods fix the two bamboo joints to create a strong union. On a weight/strength basis, it outperforms the tensile strength of steel.

Prof. Dr. Ing. Klaus Steffens, the director of The German Institute for Experimental Construction Engineering of the University of Bremen, did a series of tests to see if the pavilion would meet German law. The building carried up to 900 kg weight suspended from its 7-meter roof overhang. The second floor was subjected to 450 kg per square meter, and a series of 10 ton, long cable pulls. These tests simulated snow, weight, and wind. The building performed better than anyone would ever have expected. It is perhaps one of the first times in recent history that potential building materials from the tropics surprised the best European civil engineers.

Preservation: Smoking the Bamboo
The bamboo pavilion in Manizales led to an important rediscovery - preserving the bamboo.

While bamboo has been used extensively its use as a structural material has remained limited because once harvested it is quickly infested by insects and fungi. This weakens the inner part particularly affecting the joints.

However, bamboo can be preserved for at least 50 years using pyrolytic acid. Burning leftover pieces of harvested bamboo in a large oven smokes the bamboo poles. The smoking extracts the acid from inside the bamboo and evenly applies it to the surface.

This is an old technique from Japan. The architect of the Emperor of Japan, Mr. Kiyoshi Yasui, took a personal interest in the transfer of process know-how to Colombia. He also offered 400-year-old piece of treated bamboo to a ZERI delegation visiting Japan from Columbia.

With the agreement of the ZERI Foundation and the three developers of the preservation technique, Richard Perl and James Gollin registered the patent for smoked guadua in the USA.

Why bamboo is good for social housing

Land/Soil Use
The problem of 100 million people living without homes could be met by planting bamboo on only 500,000 HA of land. The State of Rio de Janeiro alone, plagued by its bad image of favelas (slums), has an area sufficient for this.

Bamboo, *Guadua angustifolia* and arboloco, *Montanoa quadrangularis* both grow rapidly in eroded soil, and even in contaminated brown fields, helping to recover the soil and improve its condition in a little over a decade.

This provides good news for Africa and other developing regions of the world, which are abundantly endowed with many species of bamboo and other flora

Costs
A two-story house constructed by carpenters in Calarca, Colombia, on a cement foundation, costs only 8 million pesos (approximately US$ 5,300 dollar). Doing it yourself drops the costs to an estimated US$ 1,700.

Local Industry
Bamboo has often been considered as a plant without value. Now, however, ZERI has helped show that it can help a local economy and development. This supports the argument that the solutions for the developing world are locally available and need do not be imported from elsewhere. The smoking preservation technique also cuts out imported chemicals.

Earthquakes & Storms
The bamboo houses designed by Simon Velez can withstand earthquakes. Also they can withstand wind gusts of 100 km/h, and three meters of snow on the roof.

Bamboo as a Carbon Sink
Too much carbon in the atmosphere causes global warming and the greenhouse effect. Although one cubic meter of mature bamboo sequesters less carbon dioxide than one meter of pinewood, it grows exceptionally quickly and requires a relatively small amount of land. One pine tree requires ten square meters of land to grow. One square meter of land can accommodate two bamboos. So, bamboo captures an estimated 40 times more carbon dioxide per hectare per year than a pine tree.

A bamboo-housing program launched in Brazil to "Grow your own house", captures more carbon dioxide than is needed to build the houses.

Bamboo - Housing - Where does it go from here?

The ZERI Pavilion has demonstrated that bamboo meets the most stringent construction codes (Germany). It has also shown that bamboo buildings radiate a beauty that is appreciated across cultures and classes. ZERI hopes to make bamboo a standard building material in the near future.

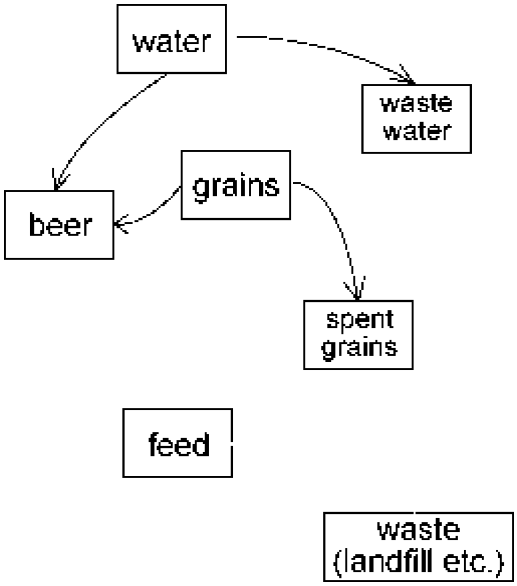
ZERI will embark on an aggressive campaign to inspire scientists to undertake extensive research on the biology and ecology of Africa's bamboo species, including the properties of the grass and the economic benefits of various natural products. Efforts will also be made to promote sustainable farming of promising bamboo species. Finally, training programs will be developed in the construction of low-cost, affordable, bamboo houses.

The Governments of Malawi and The Gambia are the first to confirm their desire to start building with bamboo. The United Nations Development Program (UNDP) has committed to provide the start-up funds.

Simon Velez has a portfolio of bamboo construction projects around the world, from Australia to the Caribbean. In addition, the Vitra Design Museum in Germany has decided to build ZERI-style homes at its training center in the South of France.

Project 2
Beer Makes Bread – The ZERI System

A traditional brewery (see model below), produces beer, but also produces organic waste and lost energy. As most waste is organic it means that its polluting effect could minimal. However, given the quantities of beer produced today this organic waste is a problem. Also a small percentage of the nutrients, and all the protein in the spent grains are wasted.



In the traditional process the following material is wasted:

Spent grains - Only 8% used for beer, 92% wasted
Water - 20 and 40 liters per 1 litter of beer depending on the brewery being

Sometimes the spent grains are used for animal feed. This is not the best use, however, since the spent grains are 70% lignin cellulose fiber. This is tough for the animals to digest because they do not have the enzymes to do so. The poor digestion process of cattle results in the generation of gases (methane). This is the second largest source of methane gas in the world, and one of the biggest contributors to global warming

The process under Zero Emissions

Spent grains, such as barely, are rich in fibers and protein and are an excellent substitute for flour in bread. It is important to note that not all the breweries use the same spent grains. Based on the tests, ZERI has concluded that the spent grain „Bielstein," which uses pure malted barley, is very good for making bread. Other kinds of spent grains cannot be used for making bread but do have other uses.

When mixed with other fibers such as rice straw, the grains can also be used for growing mushrooms, such as Shii-take. Shii-take is a high-growth business - today's world market for Shii-take is $2.4 billion and growing at 16 percent a year for the past 15 years.

Mushrooms eat the fibers and lignin cellulose in the spent grain and break these down into carbohydrates. Carbohydrates are much better food for cattle and easier for them to digest. This has already been tested with success in Kyoto, South Africa, Fiji, Hong Kong, Sweden, and Colombia.

The spent grain from barley is also rich in protein and is very good for growing earthworms. On 1,000 pounds of spent grain, it is possible to extract 130 pounds of earthworms, which convert

the vegetable protein into animal protein. Earthworms are 60% protein and make a very healthy feed for chickens, as they are very easy to digest and eliminate all pathogens (diseases).

Wastewater from the brewery, the waste of the livestock and spent grains used for mushroom farming can be flushed into a digester. A digester is a container where no air can get in, and creates anaerobic (without oxygen) digestion conditions. Anaerobic bacteria are more active than aerobic (with oxygen) bacteria that are present in usual septic tanks. It converts 60% of the organic matter into nutrients in 5 to 6 day thus producing a biogas ($CO_2 + CH_4$) or methane gas. The gas can then be used as a source of energy for the brewery. When the water leaves the digester it is rich in nutrients, which can be digested by algae that then will work as fish food as the water flows into a fish basin.

As modern breweries use huge amounts of water not all of it may go into the digester. But this wastewater cannot just go down the drain because it has been combined with caustic soda and is alkaline. Local authorities normally require the water be treated chemically with acid so it becomes pH neutral.

An alternative to the chemical treatment of wastewater is algae. There are specific types of algae that grow in alkaline waters. These types of algae are protein-rich, for example Spirulina, which is a mixture of beta-carotene, antioxidants, vitamins and protein. The spirulina algae together with the water and nutrients from the digester, goes to a large fish basin. This fish farm needs to have a variety of 8 different fish in order to mimic a natural environment, keeping disease to a minimum and maintaining the health of the basin. One of these fish swims from bottom to top all the time in a way that it aerates the water, constantly maintaining a flow of oxygen in the fish basin. In this way, each fish has an important role to play in the ecosystem that is being simulated.

It has been tested and proven that in a one-hectare pond twelve feet deep it is possible to grow fifteen tons of fish per year. In this process, food is provided for free, by using the waste from another processes.

Social and Economic implications

The cash flow from a ZERI brewery is better because it is not only beer they are selling. They are also selling Shii-take mushrooms, organically fed chickens and fish, and free biogas. The brewery will also save money in areas such as wastewater treatment.

By using all of the by-products of the brewing process, a brewery under the zero-emissions concept can generate three times more revenue than if it was only producing beer. At the same time, it generates two times more jobs. It also eliminates waste generated by the process and strengthens its competitive position against the other breweries in the market.

Where does it go from here?

Currently the following people are working with ZERI to establish breweries under the zero emissions concept:

The Chairman of Namibia Breweries, Werner List together with George Chan developed the project to start the first brewery under the zero emissions concept with funds from the United Nations University. There are several different by-products generated by the brewery: mushrooms, cattle feed, chicken feed, earthworms, biogas, spirulina, and fish.

Michael McBride was the first entrepreneur to visit the Namibia Brewery in Tsumeb in 1998 and concluded that if this can be done in the desert, it can be done in Newfoundland, Canada. He launched his ZERI Brewery with mushroom farming in the summer of 1999.

Dr. Haas of Erzquell Brauerei, based close to Cologne, supported by the company's master brewer Jens Hoffman took up the concept in Germany for making bread with the waste from the brewery. The bread baking started in February 2000, and growing mushrooms in the old malting rooms was launched a few months later with the support of Ivanka Milenkovic. She has been instrumental in the introduction of mushroom farming on beer wastes in this brewery.

All four major Japanese beer brewers (Kirin, Asahi, Suntory and Sapporo) commit to reach the target of zero emissions by 2010.

Finally, the ZERI Pavilion at the World Expo launches the 'Beer Bakes Bread" concept, selling with each half liter of beer a half a kilo of bread made from spent grains.

PROJECT 3
Coffee and Mushrooms

The coffee farm is a symbol of Colombia. Coffee was introduced to Colombia over one hundred years ago from Sahara Africa, and the plant has adapted remarkably well to the tropical Andean Mountain climate. Coffee, and the Coffee Farmers' Cooperative, emerged as early leaders of rural development, with success in creating wealth. But after bonanza came crisis. When the first dramatic drop in coffee prices struck the region in the eighties, coffee farmers searched for diversification into new crops in order to regain their level of income. The diversification strategy proposed to drop coffee all together and introduce new fruits, nuts and vegetables. This attempt had limited results. When coffee prices per kilo dropped once more below the one-dollar mark, crisis became pressing.

Then the ZERI concept was applied to coffee farming. The idea emerged that the coffee farm could introduce a diversification strategy without eliminating coffee. The ZERI Foundation launched several initiatives in cooperation with the National Coffee Federation and the Manizales Chamber of Commerce to demonstrate that the tropical Andean ecosystem is not only an outstanding for coffee, but also numerous other untapped opportunities.

Coffee Production

Coffee farms harvest green beans, which represent just 3.7 percent of the total biomass of the bush. After roasting and brewing coffee, the solid matter, which finally ends up in your cup of

coffee are, a mere 0.2 percent of the biomass generated in the tropical highlands. 99.8% is considered waste.

The process under Zero Emissions
A farmer has the option of harvesting coffee under the Zero Emissions concept. Thanks to research undertaken at CENICAFE directed by Carmenza Jaramillo and guided by Prof. Dr. S. T. Chang from the Chinese University of Hong Kong, it has been demonstrated that with 100 kg of sawdust, shells, coffee leaves and pulp, 75 kg of tropical mushrooms can be cultivated. This diversification can be implemented without dropping the long standing culture of coffee farming, on the contrary, if there is no coffee farm, then there is no substrate to farm tropical mushrooms.

The world market for mushrooms is already larger than the world market of coffee (US$ 14 billion vs. 12.5 billion in 1998). Tropical mushrooms are in growing demand for both nutritional and medicinal use. The popularity of mushrooms is easy to understand. They contain no cholesterol, no saturated fatty acids, are rich in vitamin, proteins and some trace minerals, some including medicinal properties.

Feed for cattle and pigs
The organic wastes from a coffee farm contain biochemicals, which do not permit their reuse as cattle feed. Therefore, they could at best be used for earthworm farming. However, we now know that enzymes of the tropical mushrooms are capable of neutralizing these biochemicals. Even better, the mushroom mycelium (roots) are rich in protein (up to 38 percent). This means that the waste from the coffee farm - after mushroom farming - becomes an excellent additive to cattle and pig feed.

Currently coffee farms do not generate enough income, and are a risky undertaking at a time when the world market prices are at a record low. Coffee farmers are therefore tempted to simply cut all coffee bushes, converting their land into grazing range, sustaining a maximum of two cattle per hectare. This has less risk, offering a predictable, but lower income. However, if the farmers grew mushrooms on coffee waste, they could feed up to 8 cattle per hectare of coffee farming.

The clustering of these productive systems is no more than a simulation of nature. There is no need for the Colombian farmer to use synthetic fertilizer, no need for genetic manipulation, no high investments, and most important no need at all to drop coffee which is recognized as being the best in the world.

Waste from pigs, biogas to pasteurize substrates
Four kilos of vegetable or fungal protein produces one kilo of pig meat. In the case of cattle farming, the ratio is 7:1. Many consider this to be a very inefficient way for us to get protein.

However, we usually do not consider the volume of energy pig or cow manure can produce in a digester (see Project 2). 100 pigs produce enough manure each day to generate a calorific energy value equivalent to 10 liters of petroleum. The farm Las Gavilanes in Risaralda has 1,000 pigs, producing sufficient waste to generate an energy flow of 150 kW. If the waste from the one

million pigs in that region was used, there would be enough biogas to run all buses in the State on pig manure.
Manure energy (biogas), should be used first and foremost by the coffee farmer for the preparation of the substrate for mushroom farming. The coffee bush waste needs to be pasteurized, and for specific types of mushrooms sterilized, before being used as a mushroom growing substrate. And since this requires a continuous flow of energy, it is best to use a locally available renewable energy source - and pigs always produce waste.

The generative capacity of the farm can go even further. As with the ZERI brewery case, the waste water can grow algae that can be used as additives to cattle and pig feed. The residual water, now nearly fully mineralized, is perfect for phytoplankton, zooplankton, benthos, crustacean, macrophytes and halophytes, all natural feed for fish. In this way, 1,000 pigs provide sufficient food for 15 tons of fish per year. Fish can be sold on the market, or used as pig feed, complementing the nutrients already obtained from the mushroom farming and the algae.

Social and Economic Implications
Colombian coffee farmers focusing solely on the coffee bean are not capable of generating sufficient income to ensure a good quality of life, let alone food security. The quality of Colombia coffee already gets a premium price but this still is insufficient to reach self-sufficiency. This adversely affects the quality of life of 400,000 farmers. If Colombia is looking to increase labor productivity as a competitive edge against competitors such as Vietnam and Indonesia, it is likely to loose if only 3.7 percent of the total coffee biomass is being harvested.

If on the other hand Colombian farmers were to generate extra revenues from the coffee bush waste they could stop the further elimination of coffee in favor of cattle farming, rediscover biodiversity through mushrooms and fishes, introduce renewable energy at the farm level, and add new export products. This will lead to an outstanding management of the Andean ecosystem, which today is at risk.

PROJECT 4
FIJI - Integrated Bio System

In 1996, Prof. George Chan, a leading advocate of integrated farming, met S. T. Chang from Chinese University of Hong Kong, Gunter Pauli, and two teachers from the Montfort Boy's Town school in Fiji. They chose Fiji as a site for an integrated biosystem project for reasons such as an established fish farming industry, and its main economic resource, sugar, was predicted to decline in the near.

Integrated biosystem farming offers an efficient method for sustainable agriculture without introducing problems such as pollution, vulnerability to pests, loss of jobs, and heavy export dependence. While the Montfort Boys' Town school was already using traditional fish farming methods, George Chan, using the Zero Emissions concept, designed a new sustainable farming system.

S. T. Chang assessed that the conditions and wet climate were suitable for three kinds of mushrooms: shiitake mushroom (lentinus)/ oyster mushroom (Pleuotus)/ straw mushroom (Volvariella). Unfortunately, no native mushroom species was available. George Chan designed a mushroom farm using traditional reed-thatched huts, and was built by students of the Montfort Boy's Town. The mushrooms were grown on spent grains from a local brewery

The brewer's spent grain is free. It used to be provided to the cattle farmer for only the transportation cost. Yet, according to both Chan and Chang, there are only two practical ways of breaking down the grain and making use of its protein. The first is feeding it to earthworms, and the second is growing mushrooms. Both ways were tried, however, mushrooms were the priority because of their higher market value.

Each day or two, animal waste from the schools farm is flushed with water into a digester. The methane produced is captured in bottles and either taken to a gas generator to power the school's lights, or used for the steaming the mushroom substrate. The digester produces the equivalent of three gallons of petrol a day.

Using gravity, the solid matter left after the gas is bled off moves in a solution of water through several compartments of the digester. At each stage losing some of its bacteria and some of its potential for spreading illness. When it emerges from the last compartment, this decontaminated manure has been converted into nearly the same nutrients as nitrogen, phosphorous, and potash used as farm fertilizers.

The nutrient enriched water then flows through three algae ponds, in which bacteria, plankton and other micro-scavengers consume any residual unwanted parts of the original animal wastes and secure mineralisation. The algae is harvested regularly and used as high-grade fertilizers for the vegetables and fruit grown on the dykes around the ponds or as a feed for livestock. The nutrient that emerges from the last pond then drops into a large fishpond, and is a perfect fish food. The large fishpond has an ecology of its own, with seven kinds of fish, from top-feeders and grass carp that eat napier and elephant grass from the embankments, down to scum-suckers or mud carp, small crabs, prawns and various types of plankton.

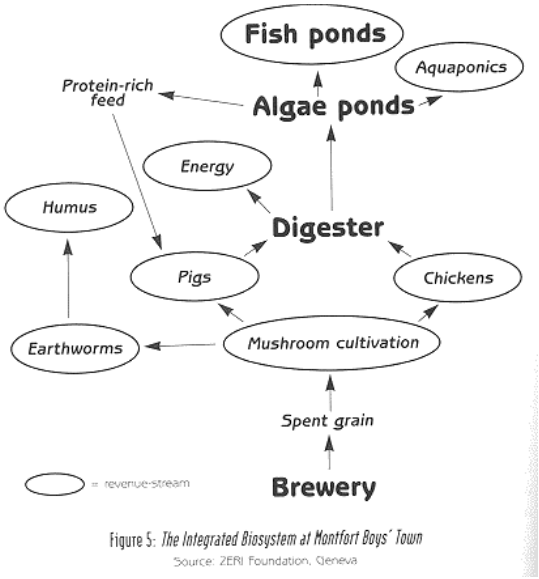


Figure 5: *The Integrated Biosystem at Montfort Boys' Town*
Source: ZERI Foundation, Geneva

While it is an artificial ecology, the ecosystem emulates nature and is designed to require no major interventions such as the use of antibiotics to fight disease required in conventional fish farming. Unlike conventional fish farming, Montfort does not have to purchase feed for fish, nor pumps or electricity for the ponds, since it uses a gravity system. Because the pond is not stocked by a single, monoculture species, it will not be vulnerable to having its harvest wiped out by a simple outbreak of disease.

Social and Economic Implications

Japanese industrial benefactors provided an initial capital investment of US$ 7,000. The structure planned for Montfort will hold 4,000 animals, generating about US$ 20,000 a year for the school. The two fishponds will add about US$ 10,000 a year to income. The methane will sell for about US$ 5,400 and the pigs will sell for about US$ 15,000, depending on market prices and production costs. With US$ 10,000 generated from mushroom cultivation and another US$ 15,000 or so from the floating aquaponics gardens and fruit and vegetables, the boys and their teachers could gross over US$ 60,000 a year. From this perhaps US$ 15,000 would go back into the costs of transport, chicks, containers for the methane, food supplements for chickens or fish and the amortization of the investment, leaving a net income of US$ 45,000. To put this in perspective, the Bank of Hawaii puts Fiji's per capita income at US$ 2,250 a year.

Where does it go from here?

After the test unit in Fiji, Namibian breweries adopted the Zero Emissions approach, repositioning the brewery from the Tsumeb industrial park onto a production farm in order to accommodate ZERI related activities, mainly focusing on the use of spent grains and spent water from the brewery. The construction of the brewery was completed at the end of March 1996 and production started in May of that year.

The Tsumeb brewery is the first in the world to seize the environmental and economic benefits offered by the integration of beer brewing and fish farming.

The application of the ZERI methodology to brewing is emerging in North America, Japan, Germany, Brazil, Colombia and the Seychelles.

Guinness has invited ZERI to apply its principles and concepts to its breweries starting with one situated in Africa.

In Bogota, Colombia, El Portico made an agreement to construct and operate a ZERI Brewery. El Portico is a major tourist attraction with restaurants, a farm complex and an amusement park attracting around 5,000 visitors each weekend.

PROJECT 5
Las Gaviotas

Since its establishment in 1966, Paolo Lugari has directed the Environmental Research Center „Las Gaviotas", in Vichada, Eastern Colombia. Here he has provided one of the most advanced applications of Zero Emissions. Whereas Colombia is facing one of the most dramatic social crises in its history, Las Gaviotas has created a socio-political environment displaying initiative and innovation from which the world can learn.

Paolo Lugari and Gunter Pauli, the Founder of ZERI, first met in 1984 at the Club of Rome Conference in Bogota, Colombia. ZERI thinking ever since has been inspired by the creative approach of Paolo Lugari's team. In fact, Las Gaviotas was the first real example of the Zero Emissions concept in the developing world and is exclusively the result of a Colombian's search for efficiency.

Las Gaviotas - The site

Reforestation

The fact that Colombia primary forests are a large supplier of oxygen to the world is the starting point for this project. Logging at the rate of 650,000 hectares a year is fast destroying the forests regenerative capacity. Las Gaviotas is committed to the most important reforestation program ever initiated in Colombia. Reforestation not only fixes CO2: it also responds to the need to recover the lost biodiversity. Las Gaviotas is thus part of the global challenge to secure that the earth's cap is covered with sufficient forests to reverse global warming.

It is a massive challenge to plant trees in Vichada. The soil is acidic, with a pH of 4. The extreme summer conditions - with temperatures in excess of 40 degrees and nearly no rainfall - limits the chances for young trees to survive. There is not a wide choice of suitable trees for planting. After careful analysis, it was concluded that the native Caribbean Pine (*Pino de Caribe*) would be an excellent tree to plant and grow in the savanna of Eastern Colombia. Las Gaviotas started cultivating these trees, and after the first two years of planting, it proved that this pine species, aided by mushroom-based compost soil conditioner, had the right resistance to the tough climate.

The planting of 7,500 hectares has lead to some surprising results and unplanned successes. The pine trees protect the soil from the harsh sun, and the continuous dropping of needles results in the recreation of a rich humus cap. This has improved the pH level of the soil from 4 to 5. The improved pH level of the soil has, in turn, facilitated the arrival of many new plants, trees and forest undergrowth.

Protecting and Recovering Biodiversity
With a survival rate of 92 percent, Las Gaviotas has demonstrated that reforestation is feasible in the harsh conditions - even when first considered impossible. When it became known that the *pino de caribe* was selected for the plantation, it did not take long for the first voices of criticism to argue that the region would be covered with only one species and that Las Gaviotas had introduced monocultures as a standard. It was considered by many to be an un-ecological decision. However, nature responded differently than many expected. According to the last botanical count, some 260 new species are found in the microclimate of the Las Gaviotas forests. Many of these species cannot be found anywhere else in the savanna. The birds, the bees and the wind carry spores and seeds with them from the tropical forests located some 300 miles to the East, where the Orinoco River marks the beginning of the Amazonian jungle. With all of these new plant species come new bacteria, insects, birds and even mammals. The indigenous people of the Llanos are excited. They have rediscovered many medicinal plants that had been considered lost. Paradise is being recovered.

Development of Appropriate Technologies
Since the planting season of the pine tree in Vichada is limited to three months a year, Las Gaviotas had to design appropriate planting technology. The imported planting equipment with tractors had to be adapted to the terrain, the soil and the speed with which the planters can operate. Today, the team succeeds in planting nearly one tree per second, 24 hours per day, three months per year, recovering some 1,000 hectares of lost land. It is probably one of the fastest planting machines in the world.

Generate Value Added - Colofon
The pine tree is resistant to the acidity in the soil, and even better it is productive. The tree grows to maturity in eight to ten years, and quickly produces seven grams of colofonia per day. This can be processed into a gum resin which when refined is a prime input for natural paints and glossy quality paper - products in growing demand. Today, Colombia imports 4,000 tons of colofonia per year, mainly from Honduras, Venezuela, Mexico and China. Las Gaviotas could supply the local market with a local product refined on site in El Vichada. The market price varies between 1,000 and 1,300 dollars per ton. With a target production of 50 tons per month, Las Gaviotas will generated a good, sustainable value added product from the pine tree. This revenue will finance the activities of reforestation, creating biodiversity and technology development through the open market. By the year 2001, Las Gaviotas will process 20 tons of gum resin per day.

Packaging
The search for value added products led to more innovation. The packaging of colofonia used to be complex and heavy work. However, the workers of Las Gaviotas being a collectively intelligent team, even with limited formal education, developed an easier way. They took a close look at packaging alternatives and designed a cardboard box with triple layers and a hole in the

middle. This allows easy filling of the folded box with the hot colofonia, fresh from the distillation. The innovative package weighs only 25 kilos, which can easily be carried by one person saving on handling, and eliminates the need for a separate cooling step. The cardboard is made from recycled material. This packaging design turned out to be a major innovation which the producer Papel de Colombia (not Las Gaviotas!) received a national prize for innovation in industrial packaging material. The Las Gaviotas team is delighted that someone, somewhere was recognized for their breakthrough.

Compete With Quality

The reforestation and the production of colofonia would not have been possible without a donation of US$ 2 million from the Japanese Extension Fund for International Cooperation, managed through the InterAmerican Development Bank. This has meant that the Colombian team of engineers could carefully study existing facilities around the world before designing and installing an improved production process in perhaps the cleanest natural resins factory ever operated. The factory is not only clean: it also produces the best colofonia on the market. Quality is the result of the careful design in every step in the process, and the dedication of all the employees such as Hernan, Head of Production, who only has a fourth grade education. The motivated work force creates quality employees.

Las Gaviotas is not only capable of manufacturing - it produces with quality, and competes on quality.

From Cleaner Production to Zero Emissions

The production process has zero emissions as a target. All the polyethylene (PE) bags used to tap the colofonia are recovered and reconditioned as pipes. Once a month, all waste is collected and shipped to Bogota for processing. The plastic bags are collected and dried on the premises so that all waste colofonia - a mere 0.2% of the harvest - can be recovered. This recovered colofonia would otherwise have been toxic waste in soil, and the recovery of this minor amount actually represents one free production run per year. Waste colofonia that ends up on the bottom of a water pond is also recovered and used to produce water-resistant bricks, the main building material of the local houses. Las Gaviotas is meeting the Zero Emissions challenge to use all resources, emulating nature, where nothing gets wasted, thus supplying more with the same amount of renewable resources.

The hospital

The design and construction in Vichada of a self-sufficient hospital capable of producing energy, distilling water, cooking locally grown food, reducing humidity in the surgeon's room, and providing natural air-conditioning in the other rooms shows an innovative, sustainable solution for the developing world’s need for quality health care. The hospital also features a special recovery area with hammocks for indigenous patients, who are uncomfortable convalescing in a modern bed with white sheets.

Solar panels on top of the hospital distil, purify and demineralize water without any need for non-renewable energy sources. The solar energy also heats coconut oil in a vacuum tube to a temperature of 180 degrees for cooking meals twice a day.

Food is mainly provided by a local vegetable garden. Since the indigenous families generally accompany the patient to the hospital to assist and comfort his or her recovery, the family brings local medicinal herbs and preferred food. After a few years, Las Gaviotas has accumulated a unique herbal garden with a wealth of knowledge from the indigenous tribes.

Recently, the government in Bogota passed legislation insensitive to the rural needs, which unfortunately forced the closure of this cutting-edge hospital. The law states that hospitals must have a minimum level of equipment, and variety of specialized medical doctors. Further, the law prescribes that a hospital must be affiliated with an insurance system with minimum 10,000 members. This makes sense in a city, but in the field it is very difficult to motivate a specialized medical doctor to pursue her or his career in the middle of nowhere in the service of the indigenous people. Also the lawmakers neglected the fact that Vichada, the size of Denmark, Belgium and Luxembourg, has a population of only 26,000. It could never have a hospital based on the public insurance system.

It is hoped that policy makers will come to their senses and take the reality of the rural regions into account. In regions like Vichada, where poverty is rampant and health care scarce, uniform standards appropriate to a booming urban center make little sense

Water and Health
Paolo Lugari and his team however were not discouraged. As creativity is the name of the game at Las Gaviotas the forced closure of the hospital left the extraordinary building without a use for only a few months.

70 percent of the health problems in the Vichada region are directly related to water so most of the hospital treatments had been for gastrointestinal illnesses (diarrhea, cholera, typhoid, hepatitis, dysentery, salmonella and E colli). The leading cause of infant death is poor water quality.

Today, the hospital provides one of the best contributions to the health care system of Vichada: the local production of quality water at a low cost. It collects, distils and packages water from the newly planted forest which functions as an excellent filtering unit, creating outstanding topsoil water, rich in minerals and purified by soil bacteria. The hospital distils and packages the water in the best of sanitary conditions and at a very low cost. 250 ml of water from Las Gaviotas only costs 62 pesos. This is one fifth of the cost of mineral water shipped from Bogota.

It is hoped that this preventive Medicare will contribute to the original objectives of the field hospital - which hopefully can soon be reopened,

Social and Economic Implications

Generate Jobs
The reforestation and production of colofonia have led to a full time staff of 160 sustaining over 1,000 families. The revenues are sufficient to maintain the payroll and housing and dining facilities. This region has never seen any initiative that created any employment.

Sustain the Culture of Indigenous People
Las Gaviotas is responding to a special challenge: generate jobs for the local people. Las Gaviotas mainly employs indigenous people who speak several languages, and proudly pays them more than others. These workers join the pine plantation from Monday morning through Friday afternoon, after which they return to their settlements located within a three hour radius.

By providing meaningful work Las Gaviotas is contributing to the alleviation of poverty and sustaining the culture of the indigenous people.

Where does it go from here?
Colombia is a country in search of harmony. Violence and corruption are rampant. But when one listens to the dynamic local music and sees the sheer charm of the local dances, it is clear that deep in their hearts, Colombians share a sense of harmony. Through their culture, music, dance and songs, the workers in Vichada demonstrate their fondness for community. It is here that one learns that changing the country for the better in a time of crisis can only be realized by breakthrough initiatives at the periphery. It is here where one learns that the survival of the fittest is not the answer, but that cooperation and teamwork, offer the only way out of the present vicious circle of poverty.

There are 6 million hectares of land in Colombia that could be forested and developed as Las Gaviotas did with 11,000 hectares.

US$ 100 secures the redevelopment of 1,000 square meters (10,000 square feet) of land and provides jobs and drinking water!

Now we can imagine how to recover biodiversity, and how to reverse an the exodus to the overcrowded cities, back to the countryside.

Paolo Lugari had the largest mural painting in the region made. It depicts the history of Las Gaviotas and the dreams that are yet to be realized. Much still remains to be done, but one thing is certain: there is no place on earth that has succeeded in implementing the zero emissions concept like Las Gaviotas - responding to the need for employment, health care, social development, economic activity, technological breakthroughs, and water supply. As the mural states:

'The maturity of the human being is to know how to realize its dreams'.

PROJECT 6
CEMENT FACTORY GOES ORGANIC

The challenge of waste disposal
Today, waste disposal is a major, global problem. The escalating population and the growing demand for consumption creates a huge transfer of organic material from the countryside to the cities, where the problems of waste disposal have increased dramatically. Large landfills have been created around the centers of population. These landfills have their own associated environmental problems of leachate, methane, and vermin. In a bid to reduce the impact of

landfills, the European Union Landfill Directive now requires that Member States reduce the landfilling of biodegradable to 50% of 1995 levels within eight years.

Soil Depletion

The overuse of chemical fertilizers in farming has caused a number of problems in many countries. A large quantity of the easily soluble commercial fertilizers leaks out to groundwater, lakes, and the sea with devastating effects.

Over the years, the use of chemical fertilizers, as a substitute for natural organic fertilizers, has depleted the humus in our soils and upset the delicate balance of elements that create healthy soils. According to the UN, about 25 percent of all arable land shows reduced production in spite of increasing doses of chemical fertilizers. Due to erosion, urbanization, and industrial farming methods, infertile desert-like areas are created, and about 11 million hectares per year of arable land are depleted. During the last 25 years the world has lost about one quarter of all arable land.

Restructuring an Inefficient and Polluting Industry

The cement industry is in crisis. Demand has dropped and existing plants across Europe and Asia are operating at low capacity, often just hovering around 50%. Either, kilns are closed and the company incurs an unwelcome extraordinary loss due to the write-off, or the company is forced to undertake large investments in order to neutralize the adverse environmental impact. A third option is to dramatically increase production capacity so that the average cost per ton will decrease and cement will be more competitive. The dilemma of what to do with the cement plant is further complicated by the fact that the closure of cement kilns is accompanied by a high decommissioning cost. Cement plants are often embedded in an asbestos-frame building. The conversion of a brown field into a useful facility clean enough for redevelopment is expensive. This means that the closure will not only force the immediate amortization of assets, it will also generate additional losses, over and above the social expenditures that are to be borne.

When Swedish construction engineers Sture Baeckmann and Anders Byström designed a process to convert old cement kilns into large composting units, it became clear that their proposal was more than a simple conversion of a polluting unit. It was an idea that offered simultaneous solutions to many pressing challenges. In 1995, they established the company Rondeco. The initial idea for Rondeco was to apply the process they had developed to an old cement plant in Stora Vika, south of Stockholm, to reuse it as a composting unit.

In 1996, Anders Wijkman, a member of the board of Rondeco and deputy administrator of the United Nations Development Program (UNDP), introduced the ZERI concept to the management of this start-up company. Later that year, the ZERI Foundation wrote a concept paper about how the old cement plant can be converted into an engine for social, sustainable and economic development. Applying the ZERI concept, the contaminated and defunct cement plant, formerly a vivid symbol of pollution and economic stagnation, could become a prime case for the competitiveness of the 21st century by converting a depressed region into an environmental wonder and an engine for economic development.

From municipal solid waste to organic fertilizers

The City of Stockholm ships its solid municipal waste by boat to this "new" composting center. Building such a center from scratch would simply be too expensive to be feasible. Instead, the project uses an existing infrastructure and kiln, which have been rendered useless for cement making, but are ideal for composting. Hence, compost can be produced at low cost, competing with synthetic fertilizer on both price and quality. Everyone gains: the cement company reduces decommissioning costs, the city lengthens the life of its landfill, local industry benefits from reduced waste charges, farmers buy competitive compost. This open system creates new industries. Waste, including wasted plants and equipment, puts everyone to work efficiently.

The core of the operation is the cement kiln. This 145-meter gigantic tunnel of 5-centimeter thick steel, rotating and well contained, is the centerpiece of the composting process. While composting has been around for centuries, the use of the cement kiln for composting allows a composting rate of 300 or even 1,000 Tons per day. A new composting unit of that size built from scratch would cost millions and could never count on the quality, the scope and the infrastructure offered by a defunct cement plant.

The cement kiln is not a stand-alone unit. It comes with a large and well-developed infrastructure, including a dock for barges, silos for raw materials and finished product, weighing stations and conveyer belts. Regular composting units could hardly afford this infrastructure. Solid municipal waste, fast food or airline waste can arrive here by boat and can be introduced into the kiln from the docks using conveyer belts. This dramatically reduces the air pollution generated by trucks.

In addition to the municipal waste, the kiln can also receive sludge from wastewater treatment units. This can be retained in the huge lime-mixing unit that is standing idle in the cement plant. Normally, this slurry is a major residual problem since its quality cannot be guaranteed and it is therefore increasingly sent to landfills. The integration of sludge into the cement kiln actually helps composting by adding water and the valuable nutrients to the household waste.

All of the waste is loaded, untreated and unseparated, into the cement kiln composter. The composter consists of three compartments and the mixture spends one day in each compartment.

The natural microbial activity within the three compartments of the aerobic composter breaks the organic matter down into raw compost in three days. Neither heat nor chemicals are added to the aerobic composter. The heat of the process is obtained and maintained by microorganisms digesting and breaking down the bonds in the mixture. During the second day, the process temperature reaches 70 degrees Celcius. Controlled temperature and time guarantee that all material is sanitized, resulting in the elimination of all bacteria harmful to humans. Each batch of compost is analyzed and controlled for quality. Oxygen is an essential part of the process. The carbon-nitrogen ratio and the water content are other parameters that are monitored.

Since no grinding or shredding is used in the process, non-biodegradable materials come through the composter intact. This allows them to be separated for further recycling and reuse. After three days in the composter, the material is unloaded onto a conveyor and run through a primary trommel screen with holes of about 25 mm. Metals and plastics are then available for recycling. Using a de-stoner, small parts of glass and metals are separated from the raw compost. Only a small part is sent to landfill.

The remaining six-week post-composting phase is computer monitored to ensure maturation of the product. The finished compost is controlled, analyzed and dried before being pelletised and packaged ready for sale.

The set-up designed by RONDECO for the conversion of the cement plant goes beyond composting kilns and humus. A large greenhouse was also constructed in the old installations in Stora Vika in the Stockholm archipelago. Composting generates heat and carbon dioxide. This combination offers a welcome option for temperate and cold climates such as the one in Sweden: farming tomatoes and other vegetables, commercial plants, and flowers all year around. Tomato farming requires carbon dioxide, which is in abundance in this facility. Because of this and since heat is generated at no cost, there is an opportunity to make the greenhouse farming competitive.

Compostable Plastics

The Rondeco process allows entrepreneurs to imagine new products that are rich in organic material and that can now be converted into completely compostable materials.

The Italian company Novamont is a pioneer in compostable plastics made from starches, an abundant renewable resource. It licenses its know-how to companies that are ready to move away from the use of non-renewable plastics. Non-renewable plastics are often labeled as 'compostable', but are seldom composted or recycled. If they are recycled at all, these plastics are actually downcycled since their characteristics do not match the specifications requested by the user from the first application.

Starch-based plastics are generally thought to be more expensive than regular plastics. While the direct purchasing cost of biodegradable plastics is considerably higher, if all of the costs of clustered activities within the Rondeco system are considered, their cost is actually lower than that of regular plastics. This encouraging conclusion is based on a detailed integrated cash flow analysis, comparing investment, transportation, composting, cost and revenues generated in a disposal system based on landfill versus a solid waste management system based on cement-converted-compost approach. The use of compostable plastics becomes affordable when one considers the landfill fees and carbon taxes that can be avoided and the access to cheap biological compost that becomes available. In fact, if all waste were compostable, then the compost fee would be reduced even more. Thus, the Rondeco process supports and self-finances the conversion from a non-renewable system to a renewable one.

Thanks to Novamont, companies such as airlines or supermarket chains, which generate massive amounts of plastic waste, can replace the non-compostable products with a material that can be returned to the Earth without adverse impact. Airlines, which have previously been choosing between plastics and stainless steel, have a better ecological option: use compostable plastics only. The plastic bags from airlines and the waste baskets of fast food chains can all go straight into the Rondeco process and be returned back to the soil as a nutrient, eventually sold as compost to farmers or forestry companies.

Based on the same logic, McDonalds in Austria and Sweden have initiated a long-term program to replace all its non-compostable material into compostable ones. The program is strengthened

by the fact that McDonalds will even suggest that its suppliers of tomatoes, potatoes and salads begin converting to compost as fertilizer instead of the synthetic alternative. Imagine McDonalds, long a symbol for waste, promoting organically grown food, fertilized with its waste, based on an integrated system, which secures that nothing, is wasted. Even the trucks could be powered by methane gas generated in the process.

Another example of the opportunities presented by compostable plastics brought about by the Rondeco process is in the disposal of human organic waste in diapers. It does not make sense that human organic matter is „wasted" in a combination of several non-compostable plastics (PE, PVC, PP) with a half-life of several years. If the use of the diaper is limited to a few hours, why do the plastics need to stand the test of time over years? Why do the coloring agents have to maintain a stable color for years as well when it will get stained in just a matter of hours?

Just a few months after the composting program of Rondeco was formally initiated in Stockholm, a group of entrepreneurs launched a compostable diaper, which passes the tests of time and comfort. It is no surprise that this diaper immediately received an enthusiastic response from consumers. This is the shift in production and consumption pattern that is needed to move our societies towards sustainable livelihoods.

Packaging

The separation of all layers of aseptic packaging, especially the aluminum and the low-density polyethylene is a second new business unit in development. This would ensure that the material from one of the largest components of municipal waste – packaging – is re-used rather than sent to landfill.

Social and Economic Implications

Over 80 percent of the factory equipment and infrastructure can be used in the conversion into a composting unit. With this process, cities have a way to return to agriculture and forestry that which was taken off fertile and productive land. The cement-turned-compost factory ensures that there is no leaching, that the excess carbon dioxide is fully recovered, and that carbon dioxide and heat can be put to use for year round farming of salads and tomatoes at competitive prices.

All stakeholders contribute to the operation so that the cost of compost leaving the plant is targeted to be ZERO. The compensation for taking care of the waste covers all the capital and operating costs.

The City of Stockholm and all other partners recognize the advantage of this systems approach. If all the compostable material can be converted through the kiln into a commercially viable material, produced in large volumes, then the life of the existing landfill will be extended for an additional 5 to 6 years. As previously mentioned, if the waste can be transported by boat, then it also reduces carbon emissions.

The cement factory owners have an interest in transferring their plant into this new entity. They provide the facility for no charge, and may even be willing to pay for it, if they can transfer the liabilities for the brown field. Instead of having to deal with an increasing landfill fee, companies that generate waste now see their waste go through a productive conversion process. This not only makes biological sense, but also offers some unique marketing arguments for companies.

Farmers can buy compost at a competitive price, shifting from synthetic to organic produce at no incremental cost. The sale of large volumes of compost pellets to forestry companies opens a second avenue for large-scale consumption. Forestry companies, which were previously tempted to plant genetically manipulated trees in order to increase yield, can now secure access to pelleted compost at a competitive cost. Boatloads of pellets can be shipped to the North of Sweden (Norrland) where it can be applied to forests. The forests grow faster and healthier thanks to this rich compost input. In fact, forestry companies in Norrland concluded that the impact of the application of pelleted compost on tree growth justified a compost price of SEK 1,000 per ton. The products are safe; performance is good; and the price is right.

Where does it go from here?
The relevance of and opportunities from the Rondeco example are obvious for the cement industry worldwide.

Until October 1999, RONDECO operated on a pilot scale of 7 to 8 tons of compost generated from select sources each day. The conversion of the first cement kiln will result in an increase in production to 70 to 80 tons of compost per day. By spring 2001, the total production capacity will have increased to 300 tons per day. Within a few years, this old cement plant will convert 1,000 Tons of waste into compost each day. That means that an estimated 10% of all of the household waste generated in Sweden will be dealt with at Stora Vika. If ten additional plants were made available around the Baltic, all of the organic waste from Sweden could be converted into food for the Earth. Preliminary research indicates that there are half a dozen cement plants polluting the shores of the Baltic.

Other countries are interested in the Rondeco technology as well. Rondeco is studying the possibility of converting cement plants in Neira, Colombia and in Edmonton, Canada. Also, Taiheyo Cement, a Japanese cement giant and a key partner of ZERI since our establishment in 1994, has acquired the Rondeco technology for its own use in Japan and Asia.

PROJECT 7
The water Hyacinth Weed in Africa: an opportunity in Disguise
by Dr. Keto Mshigeni,
(Proceedings of the Third Annual UNU World Congress on Zero Emissions)

The Southern African region has an abundance of the waterweed commonly known as water hyacinth (*Eichhornia crassipes)*. This aquatic weed has become a serious problem because it grows very fast and in the process chokes up waterways, blocks navigable waterways, reduces

fishing points, and in some cases blocks water pumps. In Zimbabwe, lake Chivero became choked to the extent that the water hyacinth mat could support human weight (Machena, 1997). The adverse impact of the excessive growth of the water Hyacinth is being felt in the economies of all lake districts of Africa: Zimbabwe, Malawi, Zambia, Tanzania, Kenya, and Uganda.

However, water hyacinth has a unique capacity to absorb and concentrate massive amounts of inorganic minerals dissolved in the water mass. With its special character, undesirable weed could be converted into an important resource, which can be utilized for the good of mankind if it can be utilized for mushroom production.

Prof. Keto Mshigeni visited Zimbabwe during the first half of 1995 and invited Gunter Pauli, Founder and Director of ZERI to Zambia to see the population of water hyacinth at the Fakue dam, near Lusaka.

A year later Prof. George Chan and Prof. Mshigeni visited Malawi to discuss with scientists from Bunda College of Agriculture of the University of Malawi. Mr. Pauli and Prof. Chan later visited Tanzania for the same purpose. Under the ZERI vision, the great water hyacinth problem came to be seen as a great opportunity.

Commission for Science and Technology and colleagues at the University of Dar es Salaam, all support the vision of promoting the harvesting and using of water hyacinth as an agro-fertilizer, as a livestock feed supplement, as a substrate for raising mushrooms and earthworms, and as a source of biogas energy. These uses provide both an immediate and a long term solution to the problem.

Scientific research initiated by the ZERI Foundation demonstrated that dried water hyacinth is the best substrate for farming mushrooms. This program directed by Prof. S. T. Chang, an authority on the matter, confirmed that the water hyacinth is a blessing in disguise. Sociological studies confirmed that nearly all African cultures had mushrooms as a part of their diet. The spent substrate after fungi harvesting is rich in protein from the mycelia of the mushrooms and are excellent feed for earthworms, which convert it all into humus and can be fed to chickens, ducks and pigs.

Under the guidance of Prof. S. T. Chang, a viability study would be undertaken in the Southern Africa Development Community (SADC) region: Malawi, Namibia, Tanzania, Zambia, and Zimbabwe. A group of scientists quickly reconvened after the first meeting at the African University in Mutare, Zimbabwe, and under the co-ordination of Mrs Margaret Tagwira, the initiative unfolded.

The system

After only 30 days, the dried substrate from water hyacinth produced a variety of mushrooms. Once harvested, it did not take more than ten days to harvest a second and even a third flush. One ton of dried water hyacinth substrates generated 1.1 tons of mushrooms, thus generating more mushrooms than base material and out-performing traditional substrates such as sawdust. In addition, since the substrate of water hyacinth is rich in minerals and nutrients, the oyster and straw mushrooms cultivated ended up enriched with potassium, magnesium, iodine and calcium,

along with numerous other components that are critical to a healthy food diet. Much of what was lost in the form of washed-away topsoil can be recovered in the mushroom. The water hyacinth can also recover harmful metals such as cadmium and lead if they are found in rivers or lakes.

The residual substrate of water hyacinth after mushroom farming, is a rich food-base for cattle. Since nearly all the ligno-cellulose has been broken down by the enzymes of the mushroom, the rest of the material can also be used to farm earthworms, which will convert the material into a humus. The humus that is produced in the process would then be reapplied to the soils, recovering and replenishing some of the lost topsoil. Earthworms are also an excellent chicken feed.

The cycle of biomass around the water hyacinth also allows for the production of biogas generated from the waste-streams, which are needed to sterilize the substrate for the mushrooms.

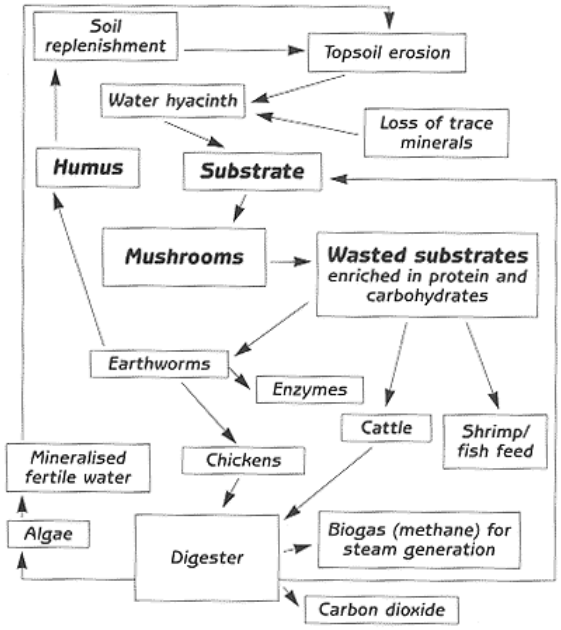


Table 16: *The Integrated Biosystem for the Water Hyacinth*

Cattle and chickens produce a lot of manure, which can be channeled into a digester. This avoids the need to cut firewood. The upshot is a system that generates both revenues and jobs and converts a problem into an opportunity.

The pilot project at the African University in Zimbabwe has demonstrated effectiveness. Instead of depending on imported mushrooms from South Africa, Zimbabwe can generate income and jobs from a renewable resource currently considered a threat.

Social and Economic Implications

In general, 60 - 80% of the cost of mushroom farming relates to the preparation of the substrate and the energy needed to treat it. In the case of water hyacinth, the raw material - water hyacinth - is free for the mushroom cultivation, and the energy cost can be limited to the purchase of a digester and the use of free raw materials. This means that the process will require limited amounts of capital. An individual farmer would have to invest no more than USD 500 to start up

an operation and the first mushroom harvest can be sold as early as one month after the harvesting of water hyacinth. Digesters for individual unit, designed by George Chan cost no more than USD 20. A more professional and industrial unit would require USD 5,000 to start up with a 10-20 m3 digester, but it could achieve payback within a year. Therefore, the program is suitable for a complementary micro-financing scheme or small-scale investments.

Uses for water hyacinth include:

-feed supplement of livestock
-a substrate for cultivating edible mushrooms
-for raising earthworms that constitute an excellent chicken feed
-for paper production
-for biogas and electricity generation, creating less dependence on wood fuel and arresting desertification
-after drying, for value-added products such as baskets, domestic furniture