2011

Making Waste our Greatest Resource

The Small-Scale Production of Food, Fuel, Feed and Fertilizer

Vietnam faces waste management problems of almost unimaginable complexity, and consequently this dynamic country must go far beyond the usual practice of burning or burying waste. In this paper a waste management concept is proposed that involves the integration of several well proven technologies such as mesophilic and thermophilic composting, black soldier fly and red worm bioconversion, duckweed water filtration, gasification and lactic acid fermentation. These technologies will enable Vietnam not only to solve its waste management problems, but also to transform many different types of waste into resources of great value.

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INTRODUCTION

There are many options available to us in the disposal of solid waste. But one of the most problematic and dangerous ways of dealing with waste is to dig a hole and bury it. The soil which nourishes and sustains us should never become a depository for waste. Once the soil comes into contact with waste, it becomes just as toxic as the waste that it entombs. Rainfall floods this hole and washes deadly chemicals and microbes into aquifers, streams, rivers and even oceans. Anaerobic bacteria proliferate in this watery grave, emitting methane and other greenhouse gases. Instead of solving a problem, we create a problem so big that it becomes thoroughly impossible to fix. Instead of wisely managing money, we uselessly throw it away.

Often we look outside of Vietnam to find models that make sense in dealing with waste. But Europe and America have little to offer. For many decades they have dug holes and buried waste. Only recently have they begun to understand in depth the health and environmental consequences of burying waste. They are just beginning to admit that the concept of a "sanitary" landfill is anything but sanitary. For within a few decades after the plastic sheet lining this hole is laid down, it breaks, and there is no feasible way to repair leaks underneath such a mass of rotting garbage. Over time hundreds of hectares in the vicinity of this hole, as well as thousands of kilometers of streams, rivers and aquifers, are irreversibly polluted.

While Europe and America struggle to solve their waste problems, Vietnam and other developing countries in Asia have a completely different set of options available to them. To the extent that Vietnam views waste, not as waste, but as one of the most valuable resources it could ever possess, it puts itself in the enviable position of leaving Europe and America far behind.

But for waste to have value, it must be dealt with in a commercial manner. As in any commercial enterprise, we need technologies and strategies that will allow us to minimize cost and maximize profit. Obviously the first big cost that we can eliminate is the huge cost of collecting, transporting and burying waste. Estimates extended out to the year 2020 situate at about $30 US dollars (600,000 VND) per household per year. To the extent that waste management authorities do not collect, transport and bury waste, they obviously save huge sums of money.

If we seek to maximize profitability, we must understand that waste is highly variegated, and that there is no single technology, no magic bullet, that will do the job. Each type of waste quite often demands a specific technology or combination of technologies to deliver the highest profit. At times the products derived from waste might command a price as high as $500 US per ton. At other times they might have a value of no more than $25 US per ton. But one thing is certain: there is no type of waste that must be handled and processed at a loss.

Assembling the right technology for the right kind of waste, however, is not enough. There's a powerful socio-economic reasoning specific to a country like Vietnam that we cannot ignore. It involves tapping into the entrepreneurial spirit of the Vietnamese people who never walk away from the smallest opportunity to make money. It is this spirit that distinguishes the Vietnamese from the affluent people of the West who easily turn a blind eye to the value of waste. Let me give an example.

I know a middle-age lady who regularly walks the streets in Dalat in search of waste. She shoulders a flexible bamboo plank, and at each end is a large basket or sack filled with waste. She does not rely on garbage trucks to assist her in carrying out her task. She does not even use a push cart. She works for no one but herself, and makes on average about 60,000 VND or $3.00 US per day, a lot more than most laborers in a rice field.

This lady does not operate out of love for the environment. Yet very few people in Vietnam do more for the environment than she. She embodies the very essence of the small-scale entrepreneurial spirit that should pervade every aspect of waste management in Vietnam. This does not mean that all those involved in waste management should resemble her in every detail. But it does mean that the primary emphasis in waste management should be away from big companies with big capital and expensive equipment.

Many tend to view the 20,000 tons of waste generated each day in Vietnam as a large-scale problem demanding state-of-the-art garbage trucks, huge bulldozers, and massive craters that swallow endless quantities of waste. Nothing could be further from the truth. Vietnam has a large population (84 million inhabitants), but very little in Vietnam is large-scale.

Agriculture is still Vietnam's most important sector (almost 22% of its GDP), and more than two-thirds of the Vietnamese people work in this sector. There are over 11 million household farms in Vietnam, and about 90% of these farms cultivate less than one hectare of land.[1] Rice is grown on about 84% of agricultural land,[2] and it is cultivated in a highly labor-intensive manner. Almost all planting, fertilizing and harvesting operations are done by hand. Very seldom does one see on any of these 11 million household farms a tractor, a truck or some other large piece of equipment.

By contrast, rice farms in the USA can encompass hundreds, and at times, thousands of hectares. They employ large tractors and combines. Planting and fertilizing are not done by hand as in Vietnam, but by airplane.

If we attempted to employ this large-scale model in Vietnam, rice production would drop to nothing, and tens of millions of people would be unemployed. The large-scale model makes sense, perhaps, in Louisiana and Arkansas, but it makes absolutely no sense in Vietnam.

Likewise, the large-scale model of dealing with waste that we see in the United States and Europe, when applied in Vietnam, is equally problematic. The lady referred to in the above example operates on an extremely small-scale. Yet she and many others like her are among the few in Vietnam who approach waste at the proper level or scale, and actually know how to sort and collect waste profitably. It should surprise no one that this lady used to work as a laborer in a rice field. When she migrated to Dalat, she did not have to undergo extensive training in order to collect and sell recyclables. The transition was smooth and quick, and she now earns far more money than before.

If the technologies that we assemble to process specific types of waste are to be used effectively in Vietnam, they must align themselves with the socio-economic structure of Vietnam. They must be small-scale, low-tech and easily operated by someone like the lady in the above example. And most importantly, they must target all of the waste that she does not currently recycle.

Let us begin with biodegradable household waste.

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[1] See: http://www.aares.info/files/2004_marsh2.pdf

[2] See: http://www.cid.harvard.edu/neudc07/docs/neudc07_poster_vu.pdf

MESOPHILIC STORAGE AND REDUCTION

At the University of Dalat a study was conducted to determine the composition of residential waste. The study was conducted over a period of 50 days, and it focused on the waste of 101 inhabitants from 21 households. Not all residential waste in Vietnam has this composition, but biodegradable waste (henceforth called bio-waste) is always the largest component:

1.	food waste	54.02%
2.	garden and plant waste	27.76%
3.	non-recyclable waste paper	3.63%
	total bio-waste	85.41%

In view of such findings, one cannot help but conclude that what is needed is a mesophilic storage and reduction unit that would be installed at each household where space permits. Gone is the costly burden of collecting, transporting and burying bio-waste each day. Instead it would have to be collected but once every year or two, and the residue collected would represent but a small fraction of the original weight and volume of the waste. This storage unit, however, has to be designed with certain constraints in mind:

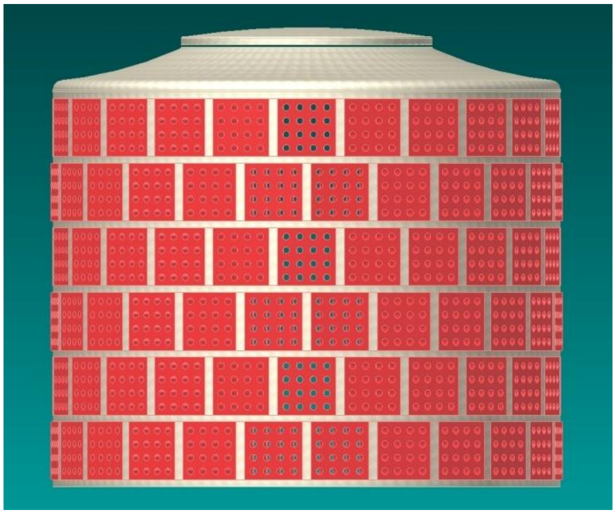
1. it must be fabricated out of durable materials that last indefinitely;
2. it must be relatively inexpensive,
3. it must be well aerated;
4. it must not smell or attract flies;
5. it must be heavy (hard to steal) and of little recycle value (not worth stealing);
6. it must be strong enough to keep out dogs, rats, mice and other creatures;
7. it must be easy to stir and clean out.

I suggest two ways of constructing such a bin. In the first approach, the body of the bin is molded in three sections, and the three sections are held in place by three wires. The lids of this bin are formed in concrete on inexpensive sand molds shaped by the spinning of a radial arm – a technology available everywhere in Vietnam.[3]

Some households have little or no ground space. Some have only a small concrete or tiled patio floor located in front or in back of the house. A bin without a bottom cannot be situated on such an impervious floor. Liquids must be able to drain. The drawing on the left depicts the same concrete storage bin situated on a base designed to allow liquids to drain into a jar.

[3] They can also be fabricated out of a special fabric reinforced with metal rods. The characteristics of this fleece material will be explained in much greater detail toward the end of this paper.

A second and far better way to construct a mesophilic bin is by means of bricks. The sixteen-hole quarter-brick featured here can be bought wholesale for about 250 VND or 1.25 cents US a piece.



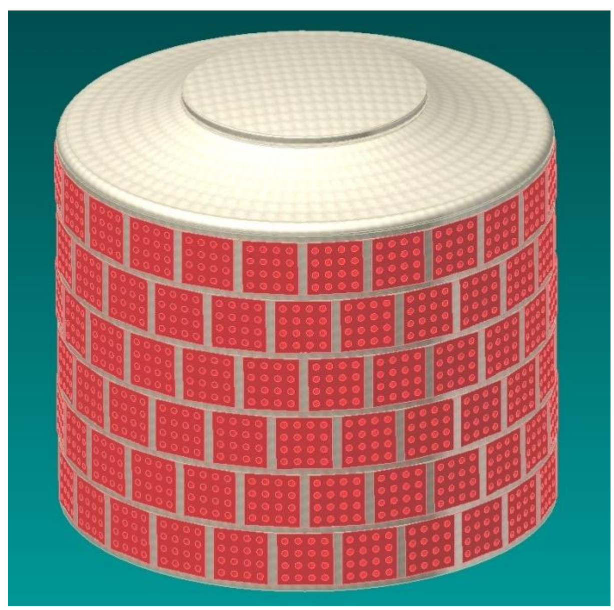
This brick bin is cheaper to build than the previous bin, it is stronger, and it has a lot more aeration holes.[4]

The total cost for the 84 bricks needed to construct a bin of a 60 cm diameter is about 21,000 VND or $1.05 US. The total cost of the 144 bricks needed for an 80 cm bin is 36,000 VND or $1.80. The labor needed to lay the bricks for either bin is more or less one man-hour. The 80 CM bin depicted here has 2,304 aeration holes.

If a particular household has no outdoor space where a bin could be installed, but if a neighbor does, then arrangements could be made for these two households to make use of the same bin. In Dalat over thirty households living in an apartment building shared a single bin of an 80 cm diameter. This bin was located in a small flower garden near the apartment building, and it received on average more than 30 kg's of bio-waste per day. It was able to handle such a large quantity of waste due to the fact that it was well populated by the larvae of the black soldier fly – a creature that will be explained in the following section.

If need be, households on an entire section of a street could all make use of the same bin or series of bins. In this case, each household would isolate its bio-waste in plastic sacks that a scavenger could collect and bring to the shared bin or bins.

Mesophilic creatures require oxygen. That is why the sides of the bin have aeration holes. But these holes are not enough to keep the contents of the bin fully aerated. A certain amount of stirring is required. A significant amount of stirring is done by black soldier fly larvae. But this natural stirring is still not enough. Humans must also help out from time to time, otherwise foul odors are created.



It is not necessary to remove the large lid each time the contents of the bin must be stirred. Stirring can be easily done by means of a large corkscrew device commonly used for aerating mesophilic bins.

In this concept, bio-waste goes directly from the house into the bin, and it never comes into contact with other types of waste. This is absolutely critical in any recycling effort. If

[4] See Appendix II for a complete set of drawings on how to make this bin.

source-separation does not take place, then it will be impossible to separate bio-waste from a long list of materials that might contaminate it. If compost, for example, is produced from previously commingled materials, this compost will be toxic and dangerous, and totally unfit for agriculture.

This storage unit is designed to receive waste that naturally breaks down within a period of about one year (bone and shell are the only exceptions). Materials that do not break down include glass, metal, plastic, rubber, foam rubber, wax-coated items, textile, stone, sand, rock, rock wool, sponge, brick, porcelain, ceramic and other such durable items. These items should never be put in this storage unit.

Of course we should not put into this storage bin bio-waste that is recyclable. But at times paper becomes wet or soiled and is not valued by scavengers. Such paper can be put into the storage bin, together with toilet paper and paper towels.

Food preparation waste and table scraps belong in this storage bin.[5] Food preparation waste includes nut, fruit and vegetable matter along with their seeds, peelings or shells. It also includes poultry, meat and fish cleaning residuals, including feathers, scales, shells, bone and hair. Table scraps include all food waste left over from a pot, dish or plate, along with any bones, scales, and shells. Soups and broths can be put into the unit, provided there is sufficient waste paper in the unit to absorb these liquids. If the unit does not contain enough absorbent materials, then the soups and broths should be sieved to extract fine solids, and only the solids should be put into the bin.

Spent bouquets of flowers can be put into the bin. Small amounts of garden waste are also acceptable. Large amounts of garden waste would quickly fill up the bin and should be kept out. If a household generates large amounts of garden waste, and if it has sufficient space, it might be provided with a swatch of compost fleece - a pile or windrow cover that will be explained further on. Once again several households might make use of the same compost fleece.

Large branches and pieces of wood should not be put into the storage unit or compost pile. They should be collected, perhaps, on a weekly basis and shredded at a decentralized site. Some of this material can be used as mulch, some as a bulking material for thermophilic composting, or some as a feedstock for gasification.

About a year and a half ago, 30 mesophilic storage units were set up on in the village of Xuan Tho in Vietnam. One bin in particular was closely studied after it had been in operation for eight months. During this time, this bin had received a total of about 720 kg's of biodegradable solids (960 liters). At the end of this period, there had been a 92% reduction in the weight of the waste and a 79% reduction in its volume.

There are no unpleasant odors coming from such bins. There are no flies. Even though a bin might receive 3 kg's of waste per day, it would only have to be cleaned once every year or two. After clean-out, the contents of the storage bins might be brought to a small site where they would be shredded and then routed to thermophilic composting operations using a compost fleece. This cured biomass serves as an effective aeration and starter material for thermophilic composting. A far more exciting way to add value to this shredded material will be explained shortly.

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[5] Food preparation waste and table scraps from households could, at times, be subjected to a special collection where they would be sterilized and fed to pigs, as will be explained later on.

As noted in the introduction, estimates of the average yearly cost per household of collecting, transporting and land-filling waste situate at about $30 USD or 600,000 VND per year. The cost of constructing a mesophilic storage unit of an 80 cm diameter is less than $12 USD or 240,000 VND. Therefore the cost of a bin can be recovered within a matter of months. Since these bins are designed to last indefinitely, the long-term savings are huge.

Furthermore, one mesophilic bin can offset about one ton of CO_2 per year, and certified emission reduction (CER) credits are projected to trade for about $20 USD or 400,000 VND per ton of CO2. If one mesophilic bin can eliminate a cost of $30 USD and if, at the same time, it can earn a profit of $20 USD, it represents an incredible economic opportunity for waste management authorities. Note that this $50 USD or 1,000,000 VND per household does not yet include revenue from the sale of the many products derived from waste.

THE ROLE OF SCAVENGERS

If bio-waste is stored and processed on site, and is not commingled with other types of residential waste, then it becomes a lot easier for scavengers to hand sort and recover recyclables. Both the quantity and quality of recyclables recovered by scavengers will greatly increase.

Since no large company, private or public, has ever been able to compete with scavengers in the recycling of residential waste in Vietnam, it would be unwise to exclude their involvement in any proposal to dispose and recycle residential waste.[6] The lady referred to in the introduction is, no doubt as you guessed, a scavenger (see here her picture). Scavengers are the only people in Vietnam who know how to make money in the initial collection of raw waste from households. Scavengers who work landfills do not have to buy waste, and therefore they can make as much as 100,000 VND or $5.00 USD per day.

Even though local government should pay nothing to scavengers for fulfilling their task, local government can empower scavengers in a variety of ways:

1. by protecting them from mafia middlemen who typically exploit their labor;
2. by encouraging them to form cooperatives free of middleman control;
3. by helping them to negotiate and obtain the highest prices for their recyclables;
4. by equipping them with gloves, face masks and other safety equipment;
5. by monitoring their health, especially their exposure to toxic substances;
6. by leveling fines on households co-mingling food waste with everything else;
7. by granting tax incentives to companies manufacturing goods from recyclables recovered by scavengers;
8. by restricting the import of recycled materials into Vietnam that undermine the scavenger economy;
9. by providing scavengers with carts that would allow them to transport waste with ease and efficiency;
10. by greatly expanding the scope of their activities;
11. and most importantly, by continually celebrating their status as the champions and heroes of the entire recycling effort in Vietnam.

Only by empowering scavengers, greatly expanding the scope of their activities and maximizing their profitability, will a sound micro-economic base be created that permits virtually all household waste to be recycled properly. The definition of the word "scavenger" has to be expanded to include many people who would not normally fall into this category.

[6] On the importance of scavengers throughout the world in the recycling of waste, please see: http://www.nytimes.com/2009/08/05/opinion/05chaturvedi.html?th&emc=th

If bio-waste is source-separated and processed in mesophilic bins, scavengers should be able to recover well over half of the remaining waste. Only a small percentage of the residential waste stream remains. Of this, the fraction > 20 mm could be separated manually by scavengers at decentralized material recovery facilities into two groups: organic and inorganic.

The organic fraction can be shredded and gasified, and the inorganic can be pulverized into a low-grade aggregate. The fraction < 20 mm can be separated by means of a small dense medium separator employing a sand medium (as shown below),[7] and once again, the same solution applied. In the responsible and sustainable management of waste, nothing, absolutely nothing, has to be buried.

[7] This dense medium process is fully described at: http://www.esrla.com/pdf/separation.pdf

Black soldier fly (BSF) adults are attracted to mesophilic storage units as an ideal site to lay eggs. Once BSF larvae reach maturity within the storage unit, they easily find a way out through the aeration holes. They then dig down into the soil where they pupate and later emerge as adults. The storage units therefore serve as ideal seeding units for the promotion of an abundant wild population of BSF. But why cultivate BSF larvae?

BSF larvae are some of the most voracious eaters within the natural world. They can effect as much as a 20-fold reduction in the weight and volume of food waste in a period of less than 24 hours. In an area of only one square meter, they can eat up to 40 kg of fresh food waste per day. And for each 100 kg of food waste, there are roughly 20 kg of nutrients of a high protein (42%) and fat (34%) content. BSF larvae can eat just about any type of fresh putrescent waste, even meat and dairy products.

The functioning of a mesophilic bin is in no way comprised if BSF larvae are not present. Mesophilic decomposition is driven mainly by bacteria, fungi, actinomycetes, protozoa and rotifers – all operating at mesophilic temperatures. But when BSF larvae are present, a bin that might ordinarily handle 3 kg's of food waste per day, becomes supercharged and can handle as much as 30 kg's per day. The size and capacity of a bin, however, must always be rated or configured based on its functioning without BSF larvae.

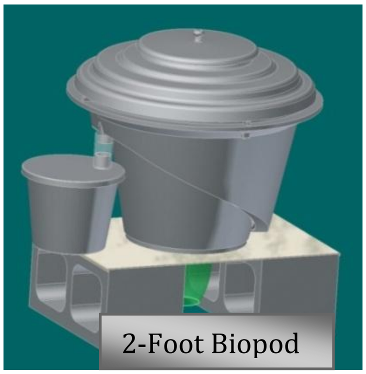
BSF larvae thrive in the presence of salt, ammonia and food toxins. *They can easily digest food waste that is far too toxic to feed to pigs or other animals.* It takes them roughly two hours to die when submerged in rubbing alcohol. They can be centrifuged at 2,000 g without harming them in any way. They are tough, robust and adaptable.

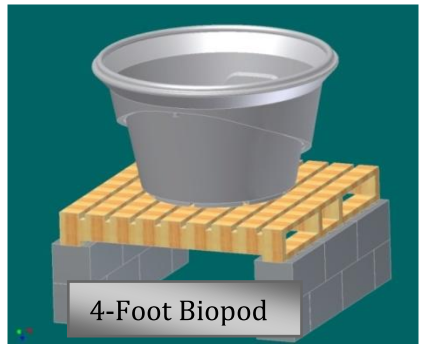
BSF larvae emit a distinctive odor that drives away all other species of flies. This is a mild odor that can be sensed by humans but in no way is it offensive. BSF adults do not bite or pester humans. They do not have functional mouth parts. They do not eat, or regurgitate on human food. They do not go into houses. They have never been associated in any way with the transmission of disease.

The picture below on the left shows BSF larvae right after eating a large pumpkin. The picture below on the right shows them eating watermelon. Both pumpkin and watermelon were eaten in less than 24 hours.

After about two weeks of incessant eating, the larvae mature. These prepupal larvae then set out in search of a dark, dry place where they can pupate. They search the periphery of the waste, and if, within a container, they are provided with two small ramps, they easily crawl up and out of the waste. The two ramps spiral up (left and right) to the top of the container where an exit hole is provided. The larvae then fall into a bucket. This special container, called a biopod, has no moving parts. It requires no energy, no electricity, no fuel, no chemicals - nothing, not even water.

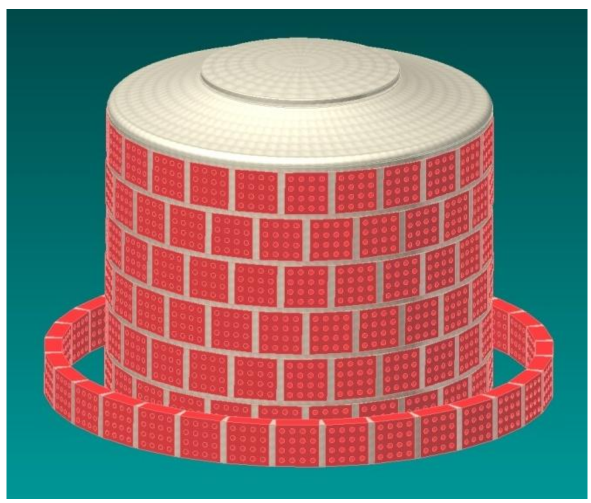
Two sizes of biopod are now being manufactured in Vietnam: 2-foot and 4-foot. The 2-foot is ideal for household use. A household wishing to enhance the capture of larvae can operate a 2-foot unit alongside a mesophilic bin. The 4-foot is designed for small-scale commercial use. This larger unit can handle up to 40 kg's of waste per day.





It is even possible to construct a mesophilic bin that allows for the capture of BSF larvae. When mature larvae migrate out of the bin through aeration holes, they fall into a small concrete trench at the base of the bin, as shown in the drawing below.

From a third to a half of larval fresh weight can be processed into a dry meal that has roughly the same value as Menhaden fish meal valued at about $1,200 US dollars per ton. Of course, not all fresh weight converts into dry meal due to the moisture content of fresh larvae. Also, about 3% to 5% of the harvested larvae should not be processed and sold, or otherwise consumed. They should be stored under protected conditions until they emerge as adults. These adults should then be released into the wild so as to maintain an abundant population of egg-laying females.



BSF technology is not in itself a total solution in the disposal of putrescent waste, due to the fact that larvae leave behind a small fraction of waste or residue. But BSF residue to the red worm is not a waste: it constitutes an ideal substrate. In fact red worms grow 2 to 3 times faster on BSF residue than on partially decomposed food waste.[8]

BSF larvae digest fresh putrescent waste, something that red worms cannot do, and red worms digest the more recalcitrant cellulosic materials, something that larvae cannot do.

[8] Professor Tran Tan Viet of the University of Forestry and Agriculture in HCMC has carefully studied the mutually beneficial relationship between BSF larvae and red worms in disposing of putrescent waste.

Together they form a perfect partnership, recovering all possible nutrients. Red worm residue (or castings) constitutes one of the best growing mediums for plants. It effects an enormous reduction in the amount of fertilizer required to grow plants:

A study in Connecticut (Lunt and Jacobson, 1944) reported worm castings increase the nutrient availability of the soil by 1.4 fold for calcium (Ca), 3.0 fold for magnesium (Mg), 11.2 fold for potassium (K), 7.4 fold for phosphorus, and 4.7 fold for nitrate-nitrogen (NO3--N).[9]

Red worms are commonly fed to shrimp in Vietnam to suppress disease. Chickens fed small quantities of red worms consume less feed and have a higher growth rate than chickens not receiving this supplement.[10] Pigs in the wild thrive on insects and worms, and worms in the diets of pigs reduce the incidence of disease.

Red worm castings sell in Vietnam for as much as $500 US dollars (10,000,000 VND) per ton. Therefore the contents of the mesophilic storage units acquire considerable value, if further processed by red worms. Mesophilic residue could be collected, shredded and processed by scavengers in small-scale vermi-composting facilities. Scavengers might even be forced to buy this residue from households, just as they now buy recyclables. Note that the city would not have to clean out mesophilic units or transport residue. Scavengers would do this based purely on the value of the mesophilic residue.

Before concluding this section on BSF/red worm bioconversion, we must address doubts that some have expressed about the existence of BSF in Vietnam.

As previously noted, BSF adults are far from being a pest, and because of their benign and unobtrusive behavior, they are not easily noticed. Most Vietnamese, when shown a picture of BSF adults or larvae, would say that they have never seen them before. Yet as any Vietnamese entomologist will readily confirm, they are present throughout Vietnam, from north to south, from hot tropical coastal areas to cool mountainous highlands.

I have seen them in waste dumps and manure piles throughout the Mekong. They are abundant in every district of Ho Chi Minh City. I have even observed BSF larvae in a biopod set up on a second-floor patio of an apartment house in District 5. They are even present in Dalat at 1,500 meters above sea level.

Right before Tet 2011, the Water Supply and Sanitation Project in Binh Dinh Province commissioned a study to verify the presence of BSF in Binh Dinh province. [11] Todd Hyman, who conducted the study, visited all of the dumpsites in four districts of the province. He had no problem finding and photographing BSF larvae and adults on all of these sites.

If putrescent waste is made available to them under the right conditions, BSF larvae appear naturally from wild populations. In tropical areas, BSF larvae usually appear within 7 to 10 days. The manual seeding of a bin or pod with young larvae is normally not necessary.

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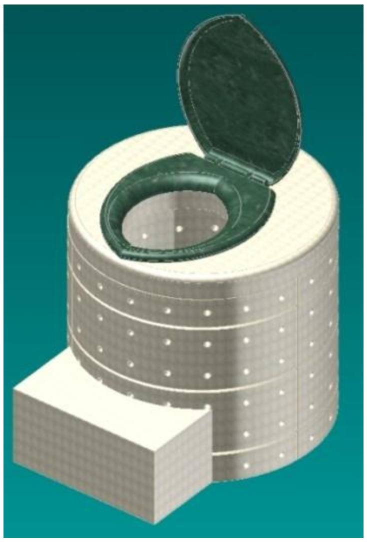
[9] *http://www.scribd.com/doc/30909297/Biochar-Article*

[10] http://www.lrrd.org/lrrd21/11/ton21192.htm

[11] Project VIE0703511

RECYCLING HUMAN WASTE

On a yearly basis a human produces roughly 500 liters of urine and 50 liters of feces. These two products contain enough nutrients to grow most of the plants that this person needs as food. But instead of utilizing these 550 liters as a resource, we mix it with roughly 15,000 liters of water, and all goes down the drain. Before it reaches the sewage plant, if there is one, this slurry gets mixed with hundreds of pollutants along the way.



The conventional sewage plant rarely retains or destroys all bacterial and viral contaminants, it produces a large amount of sludge generally unfit for agriculture, and it causes severe pollution in freshwater and seawater ecosystems. This end-of-pipe solution recycles nothing. It takes valuable resources and transforms them into pollutants. As fertilizer prices rise throughout the world, and as water becomes an increasingly scarce commodity, this approach is not sustainable and makes no sense.

Modern agriculture gets the nitrogen it needs from ammonia-producing plants that utilize fossil fuels such as natural gas, LPG or petroleum naphtha as a source of hydrogen. This energy-intensive process dumps carbon dioxide into the atmosphere, it consumes a finite hydrocarbon resource, and it is not sustainable.

Modern agriculture gets the phosphorous it needs from phosphorous-bearing rocks. But these reserves are rapidly dwindling and increasingly contaminated with pollutants such as cadmium. In as little as 25 years apatite reserves may no longer be economically exploitable and massive world-wide starvation is predicted to follow.[12]

If we are serious about achieving sustainability in this regard, our first, and perhaps most important duty, lies in not mixing urine with feces. Within the human body these two wastes are produced and stored separately, they are excreted separately, and afterwards they should be contained and processed separately. A double-outlet toilet, one for urine and the other for feces, is all that is needed.

The feces receptacle, except for the lid, is exactly the same device used for the mesophilic storage of household biowaste, and if carefully utilized and cleaned out, the one bin could receive all bio-waste from the household, including human feces. Such a toilet is ideal, especially in an rural setting where a toilet in many cases is nothing more a platform above a catfish pond or a hole in the ground. Quite often people in a rural setting do not even use a toilet of any kind. There are enormous environmental and health problems in Vietnam associated with outdoor urination and defecation.

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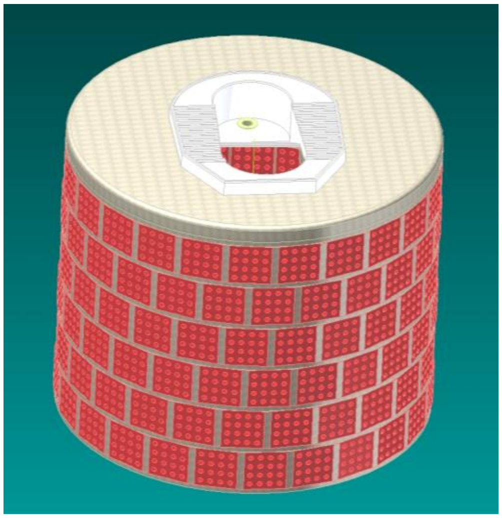
[12] See: http://www.theglobeandmail.com/news/national/article1140936.ece or http://vsrbc.web.officelive.com/PF.aspx



This toilet can be manufactured as a pedestal toilet or a squatting toilet. Since, in the case of a pedestal toilet, the feces receptacle has to bear the entire weight of a person, it is best constructed out of brick. The structure housing the toilet can be cheaply constructed out of bamboo and palm leaves, brick or ferrocement (as shown below).

The feces storage bin is inhabited by BSF larvae within about 20 days after its construction. BSF larvae eat human feces within an hour or two after it is introduced. This is a powerful factor in eliminating odor.

Biochar can also be added to the storage bin from time to time to further eliminate odor. Since biochar captures ammonia in gaseous form, biochar can also be added to the urine receptacle of this toilet. Then there is the concept of a biochar urinal, a concept that will be explained more fully in the conclusion.

Urine could be collected from urine-diverting toilets, diluted and directly applied to certain crops as a source of NPK. Simple soil insertion techniques prevent the volatilization of ammonia.

However, if the transport of urine is not feasible in some areas, there is another approach, and it allows for the complete processing of urine on site. This approach involves a tiny aquatic plant that is one of the fastest growing plants on earth. As it floats on the surface of the water, it extracts NPK and other nutrients from water through all surfaces of its leaf. Given sufficient sunlight, it can reduce quantities of NPK in water down to almost undetectable levels. This amazing plant, found throughout the world, is called duckweed.

Under optimal conditions, certain duckweed can double in mass within a period of only 16 hours. Its protein content is one of the highest in the plant kingdom (sometimes as high as 45%). It is also rich in beta carotene, xanthophylls, as well as vitamins A and B. It contains very little fiber and indigestible matter.

In this approach, urine would be flushed from the urine-diverting toilet into a small duckweed pond located near the toilet, as shown on the left. Since duckweed covers the entire surface of the pond, very little ammonia would volatilize and give rise to unpleasant smells. The duckweed harvested each day makes a wonderful feed for chickens, pigs, fish and, of course, ducks.

Duckweed can be dried, ensiled, blanched or fed fresh. The picture on the left is that of sun-dried duckweed. Note how well dried duckweed retains its beautiful green color.

The logic of the sustainable processing of human waste has certain parallels with the logic of the sustainable processing of residential bio-waste. Both demand separation at source. Both employ mesophilic bins, BSF and red worms. Both refuse to define themselves as independent large-scale waste disposal activities, and both are intimately connected to the sustainable production of food, feed and fertilizer. Human waste, like pig waste, is far too nutrient-rich for the production of fuel by means of methanogens.

We talk a lot about sustainability, but we will never achieve true sustainability until we learn to give back to nature in a closed loop everything that she needs to sustain us. Giving back to nature all of the nutrients within our own waste is perhaps our first and most important duty as citizens of planet Earth.

BIOMASS GASIFICATION AND THE BENEFITS OF BIOCHAR

When we think of air pollution, we normally think of outdoor air pollution in heavily populated urban areas. However some of the worst air pollution occurs indoors in rural areas. The burning of biomass such as wood, coconut coir and other crop residues as a source of fuel generates smoke, particulates, carbon monoxide, methane and hundreds of organic compounds including many carcinogens. As a result, thousands of people in Vietnam die each year.

According to World Health Organization estimates, more people in the developing world die each year from conditions related to indoor air pollution—mostly from inefficient, solid-wood-burning stoves—than tuberculosis or malaria.[13]

But the use of cookstoves is not limited to rural areas. Throughout Vietnam, streets are often filled with smoke coming from small outdoor kitchens and restaurants. Low-grade biomass is often burned in the preparation of fresh noodles and in other applications where a lot of boiling water is required. Households, even in an urban setting, burn yard waste and other trash as a means of getting rid of it. This horrible practice continually fills the air with pollutants.

One might argue that many people cannot afford kerosene, LPG or propane, and that little can be done to stop the burning of low-grade biomass fuels. Ultimately the answer does not lie in abandoning low-cost biomass fuels, but in extracting from them a gas that burns as cleanly as propane or any other fossil fuel. With the help of Alexis Belonio the fabrication in Vietnam of top-lit, updraft (TLUD), forced-air gasifiers has begun. These gasifiers operate quite well on many types of fine and undensified biomass wastes such as rice hulls, coffee bean husks, coconut coir, bagasse, wood chips, sawdust, the shells of nuts and so forth.

Some types of biomass, such as straw and pine needles, must be slightly compacted or shredded to increase their bulk density. Forestry waste should be chipped. But the costly step of pellitization (as much as $125 US/ton) is generally not required. Ideally the moisture content of the biomass should not exceed 12%. Biomass can be sundried, it can be dried thermophilically using a compost fleece, and it can be dried using residual gasifier heat.

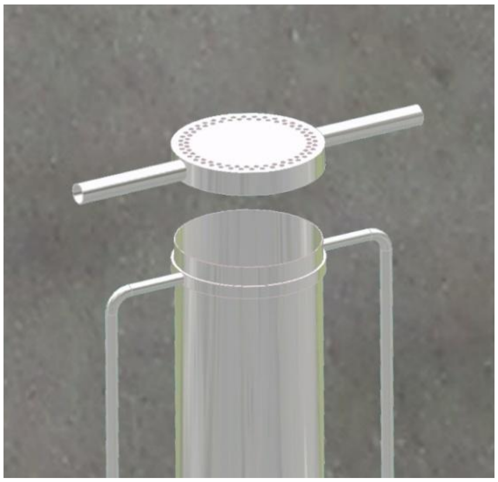
This gasifier is nothing more than a vertical cylinder with a removable burner on the top and a grate at the bottom. A small fan supplies air underneath the grate, and the speed of the fan is controlled by means of a speed regulator. The diameter of the reactor determines the amount of gas produced, and the height of the reactor determines the length of time that this gas is produced.

Many types of undensified biomass, such as rice hulls and bagasse, have a negative angle of repose and have a tendency to resist movement or flow through a gasifier or any other device. In this gasifier, biomass is never in movement

[13] See: http://www.newsweek.com/id/226941/page/1

within the reactor during the gasification process. Other than the small fan that supplies air underneath the grate, there are no moving parts. Very little can break down. There is virtually no maintenance. The process is easy to monitor and control, and the turnaround time between batches is measured in seconds, not minutes.

In starting the process, the burner is removed and the reactor is filled with biomass.[14]



The fan is turned on, and paper is placed on the top of the biomass and lit by means of a match or cigarette lighter. Once the paper burns over the entire surface of the biomass, it only takes seconds for the biomass to ignite. A flame then rises up from the top of the reactor. The burner is placed on the reactor, and the flame comes through the holes of the burner. The fan speed is lowered according to the amount of heat required. Note that there is no lighting of gas.

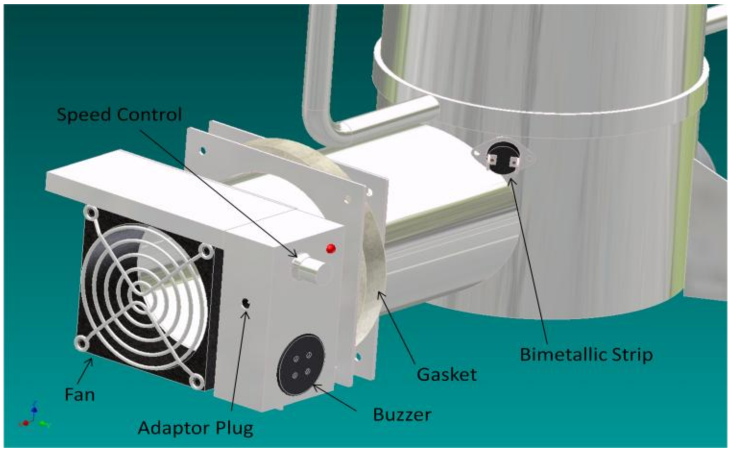
This is quite important from the point of view of safety, since at no time is carbon monoxide being discharged. Once the burner is placed on top of the reactor, the open flame within the reactor goes out, and true gasification begins. Soon the temperature within the reactor reaches as high as 1000C, provided of course that the biomass is sufficiently dry.

As the burn proceeds from top to bottom, a thick layer of hot fine char is formed above the point where the gases are released. As the gas is forced through this bed of fine char, most complex hydrocarbons are broken down into hydrogen and carbon monoxide. It is this intimate and prolonged contact of gas with hot char that results in the beautiful blue flame so characteristic of this type of gasifier. This does not happen in a bottom-lit updraft gasifer or in a side-draft gasifier. Also, there is a distinct advantage in burning the gas at the top of the reactor.

The gas does not cool down or have to be cooled down prior to combustion. There is none of the inefficiency or loss of heat associated with remote burners. This is why, in many cases, the bottom-lit downdraft design is not ideal. In the case of this TLUD design, if more burners are required, more gasifier are put in operation. They might be of different diameters, and their fans might all be operating at different speeds. This gives a high degree of flexibility and control.

When the gasification process is finished, the operator might become distracted and not empty the gasifier of char in a timely manner. If the fan continues to run, the char would burn up, and this

[14] The start-up procedure is clearly shown in a video clip at: http://www.esrla.com/pdf/gasifier.mpg



would severely overheat the gasifier. Therefore a large heat-resistant gasket has been inserted into the air delivery pipe, and when the temperature near the grate rises, a heat sensor activates an alarm.

In more recent models, a smaller fan is used, and with a smaller fan, it is possible to employ a smaller air pipe. This smaller air pipe can be extended upward quite a distance, and this eliminates the need for the gasket. The air pipe itself then serves as a bottom handle.

Someone might argue that a natural draft gasifier is simpler and therefore better than a gasifier that requires a fan. But in order to draft naturally, a TLUD gasifier must be filled with fairly large pieces of biomass that allow for the easy passage of air and gas. But if the gas can freely flow around the large pieces of char that lie above the gasification zone, there is no close contact between char and gas. Therefore very little filtration of the gas takes place, and this results in a dirty flame.

Also a natural draft stove, filled with large chunks of biomass, takes relatively long to light, and during this lengthy start-up procedure, a lot of smoke is released that poses health risks to the operator. Perhaps a better way to proceed would be to grind or chip large chunks of woody biomass, and present this fine material to a TLUD gasifier equipped with a fan.

Note that the electrical consumtion of the fan is negligible. No more than about 1.5 watts is needed to power the smallest gasifier featured in this paper, and about 7.50 watts is needed to power the largest.

The speed regulator moves in very small increments and gives the operator a high level of control throughout the gasification process, especially in start-up when a lot of air is required. A powerful fan and good speed regulator, therefore, are two of the most important features of this type of gasifier. Three models of stoves are now being fabricated. The model number and the diameter of the gasifier in mm are the same:

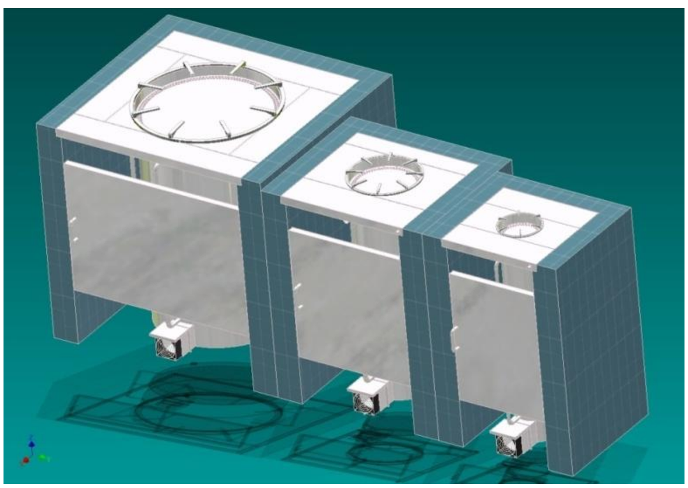
1. model 150 = 2 kg to 4 kg of biomass per hour selling for $52 USD
2. model 250 = 5 to 10 kg of biomass per hour selling for $90 USD
3. model 500 = 20 to 40 kg of biomass per hour selling for $232

The gasification of roughly 90 kg's of rice hulls can deliver a gas of the same calorific value as 12 kg's of propane. A 12 kg tank of propane costs 350,000 VND ($16.66 USD). If so, then one kg of rice hulls will produce about 3,889 VND ($0.18 USD) in gas. Also one kg of rice hulls will produce about a half kg of biochar. When mixed with compost, this biochar has a value of about 1,050 VND ($0.05) per kg. Therefore one kg of rice hulls has a combined value in gas and biochar of 4,400 VND ($0.21

USD). In other words, one ton of rice hulls has a combined value in gas and biochar of 4,400,000 VND or $210 USD. Vietnam produces each year about 7,200,000 tons of rice hulls, which, if gasified, would have a value of $1.512 billion USD.

All components in these gasifiers are fabricated out of high-quality stainless steel. These prices will drop considerably when these gasifiers are produced in large numbers. These prices include the fan, the adapter, the speed control unit, the buzzer, the bi-metallic strip and a set of motorbike cables. If there is no electricity from the mains, the speed regulator can be connected to any 12-volt battery, even the battery within a motorbike.

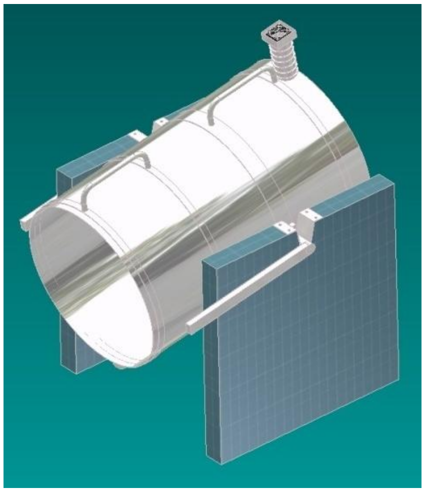
Many attempts have been made to surround the reactor with a metal housing and to blow air between the two so as to prevent the housing from getting hot. But the transfer of heat to air in this case is inefficient, and the housing nonetheless becomes very hot. Very little is gained in terms of safety, and a housing in stainless steel is relatively expensive. Also if ever the reactor should corrode and develop a leak, such a dangerous situation would not be easily detected.



It is advisable, therefore, that the reactor not be housed but that the gasifier be enclosed. An enclosure not only limits access in touching the hot reactor, but it also makes it quite difficult for someone to accidently knock over the gasifier. With an enclosure, pots and pans are not supported by the gasifier, but by the burner grate on the top of the enclosure. An enclosure can be inexpensively constructed out of brick or stone as shown in the two drawings above.

In a large commercial kitchen, emptying gasifiers of char within the same area where food is being prepared is not ideal. Therefore it is recommended in this case that enclosures be mounted against a wall, and that enclosure doors open up, not into the kitchen, but into the space on the other side of the wall.

When the reactor gets so big that it is too heavy to lift, it can be pivoted. The drawing below depicts a reactor of an 800 mm diameter. This unit can gasify from 50 to 100 kg's of rice hulls per hour.



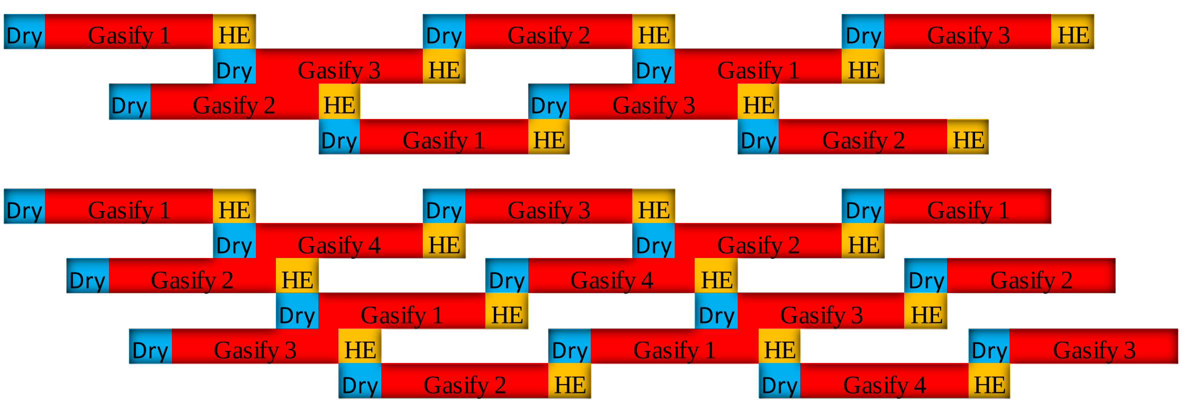
A reactor can also be equipped with a removable or collapsible grate. This means that this gasifier has few constraints with respect to size. Depending on the amount of gas required, diameters might range from 10 cm to 1.2 meters or more. Depending on how long this flow of gas is required, heights might range from 40 cm all the way up to 4 meters or more. With several reactors in active gasification mode at any one time, a continuous flow of gas can be assured.

The fact that this gasifier operates in batch mode allows it to fulfill other important functions. At the end of a batch cycle, the biochar within one reactor generally contains enough heat to dry the biomass (loaded but not lit) within a second reactor. Therefore the one reactor can be designed to serve as a multi-purpose vessel: a dryer, a gasifier and a heat exchanger.

Air devoid of oxygen is blown in at the bottom of a first reactor filled hot char. This hot air slowly rises through the char and is then routed to the bottom of a second reactor filled with moist biomass. The moist air from this drying process is routed to coils within a tank filled with water. The moisture within the air condenses out, and this dry air is routed back to the first reactor filled with hot char. This cycle repeats until the biomass in the second reactor is fully dried. In this way, warm water is also produced.

Therefore biomass does not have to be transferred from dryer to gasifier, and char does not have to be transferred from gasifier to heat exchanger. When biomass is finally lit in a reactor that served as a dryer, it is fully dry and gasifies at maximum temperatures. When biochar is finally evacuated from a reactor that served as a heat exchanger, it is relatively cool and does not have to be sprayed with water.

The following diagram shows two time sequences with respect to a dryer/gasifier/heat exchanger: one with 2 reactors and the other with 3 reactors. There is always a continuous flow of gas.



Wood, branches and other waste of a high cellulosic content can be shredded by means of low-cost shredders, as designed, for example, by the SPIN organization in Hanoi. One model of shredder costs about $100 US or 2,000,000 VND, and can process up to 600 kg's of chips per hour. These chips can be dried thermophilically down to about 23% moisture under a compost fleece located outdoors.[15] The final drying down to 12% moisture can be accomplished using residual gasifier heat, as explained above.

Municipal waste of a high cellulosic content can be shredded by means of low-cost shredders in a small-scale, decentralized manner. The shredded material can be used as mulch, or it can be composted or gasified. There are significant advantages, as we shall soon see, of mixing compost and biochar.

Thousands of years ago Amazon Indians incorporated charcoal into the soil to enhance its fertility, and surprisingly a lot of this charcoal still remains fixed in the soil to this day. If we want to combat global warming and remove carbon dioxide from the atmosphere, we can also incorporate biochar into the soil:

- AL GORE - *"One of the most exciting new strategies for restoring carbon to depleted soils, and sequestering significant amounts of CO_2 for 1,000 years and more, is the use of biochar."*
- BILL MCKIBBEN - *"If you could continually turn a lot of organic material into biochar, you could, over time, reverse the history of the last two hundred years…"*
- DR. TIM FLANNERY - *"Biochar may represent the single most important initiative for humanity's environmental future...."*
- DR. JAMES LOVELOCK - *"There is one way we could save ourselves and that is through the massive burial of charcoal."*

Adding biochar to the soil also increases the water and air holding capacity of the soil, and it promotes the proliferation of mycorrhizal fungi and other beneficial soil microbes. Biochar improves the cation exchange capacity of the soil and prevents nutrients from being washed away. When biochar is incorporated into the soil, we see a 50% to 80% reduction in nitrous oxide emissions, as well as a reduced runoff of phosphorus into surface waters and leaching of nitrogen into groundwater.

Biochar reduces the amount of methane released from the soil. It adsorbs dissolved organic matter and prevents their rapid consumption by soil microbes. This adds even more carbon to the soil. This eventually becomes stable humic matter, the most beneficial form of carbon needed for plant growth. *As a soil amendment, biochar significantly increases the efficiency of, and reduces the need for, traditional chemical fertilizers, while greatly enhancing crop yields.*[16]

Dr. Boun Suy Tan of Cambodia recently did a study on the benefits of rice hull biochar and compost added to the soil in growing rice. He set up four plots:

- plot 1 = no biochar and no compost
- plot 2 = 5 tons compost/ha
- plot 3 = 5 tons compost/ha + 20 tons biochar/ha
- plot 4 = 5 tons compost/ha + 40 tons biochar/ha

[15] See: http://www.tencate.com/smartsite.dws?ch=&id=1185 as well as http://www.angliawoodfuels.co.uk/_Attachments/Resources/12_S4.pdf

[16] See: International Biochar Initiative (IBI)

The yield in kg's per hectare:

- plot 1 = 1,252
- plot 2 = 1,504 (a 20% increase in yield)
- plot 3 = 1,817 (a 45% increase in yield)
- plot 4 = 3,756 (a 300% increase in yield)

As we compare plot 1 with plot 4, we should keep in mind that adding rice hull biochar not only yielded 3 times the rice, but also 3 times the rice hulls, hulls that can produce 3 times the biochar. Here we see a very positive amplification of effects.

Water spinach grown in soil amended with rice hull biochar does exceedingly well, as indicated in a recent study in Laos (April, 2011). In the first treatment on the left (see picture below), a nutrient-rich bio-digester effluent was added to the soil (Soil). This first treatment represents what most farmers consider to be good growing conditions. In the second treatment in the middle, there was the same bio-digester effluent added, plus rice hull biochar from a 250 gasifier (Biochar). In the third treatment on the right, there was the same bio-digester effluent added, plus wood charcoal (Charcoal).

It is easy to spot the winner in this experiment.

Biochar, and especially rice hull biochar, is easily activated or functionalized. Activated carbon currently sells from $500 to $ 2,000 per ton. But it is not always necessary to activate it.

Biochar derived from cow manure, for example, can be used to sorb from wastewater both metals and organics. It can sorb awful pollutants such as lead and atrazine (an herbicide). This cow manure biochar is six times more effective in sorbing lead from wastewater than activated carbon.[17] It eliminates 99.5% of lead in wastewater.

Biochar produced from pine needles is quite effective in removing naphthalene, nitrobenzene and *m*-dinitrobenzine from water. Another study indicates that pine needle biochar is quite effective in removing some of the same polycyclic aromatic hydrocarbons from the soil. PAHs are ubiquitous pollutants in agricultural soils in China and Vietnam.[18] Soil amended with biochar derived from rice or wheat straw neutralizes herbicides such as duiron and atrazine.

The biochar produced in the gasification of biomass has a much greater value in general than the biomass utilized to produce it (including its delivery to the site). In other words, a high-quality gas

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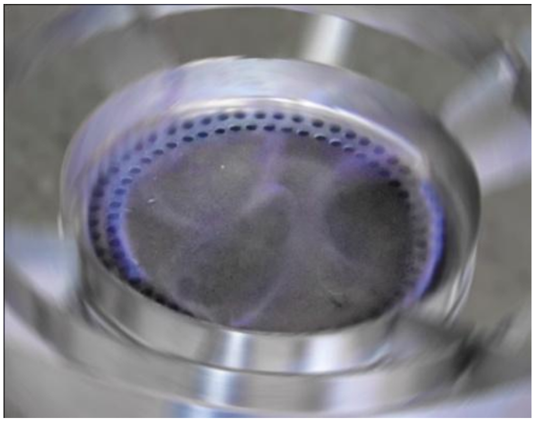
[17] See: *lqma.ifas.ufl.edu/Publication/Cao-09a.pdf*
[18] See also http://www.springerlink.com/content/8p413624j3n0440x/ as well as http://pubs.rsc.org/en/Content/ArticleLanding/2008/EM/b712809f



can be produced at a negative cost or profit. Each household or small business operating a gasifier can sell bio-char and, in so doing, completely offset the cost of gathering or purchasing the biomass it needs.

Scavengers could buy biochar from households and businesses. They might sell it to companies who would activate or functionalize it, or they might sell it to companies who would utilize it for soil remediation, or for water and gas filtration. An entire industry centered in the buying and selling of biochar could be created. If revenue from carbon credits is added to this strategy, then it is hard to imagine a cheaper form of energy that could be made available to the people of Vietnam.

The gasification of roughly 90 kg's of rice hulls can deliver a gas of the same calorific value as 12 kg's of propane. 12 kg's of propane cost 350,000 VND ($16.66 USD). If so, then one kg of rice hulls will produce about 3,889 VND ($0.18 USD) in gas. One kg of rice hulls will also produce about a half kg of biochar. At a value of 1,050 VND ($0.05 USD)/kg, this half kg of biochar has a value of 525 VND or ($0.025 USD). Therefore one kg of rice hulls has a combined value in gas and biochar of 4,400 VND ($0.21 USD). Likewise one ton of rice hulls has a combined value of 4.4 M VND or $210 USD. Vietnam produces yearly about 7,900,000 tons of rice hulls, which, if gasified, would have a value of $1.659 billion USD.

If we apply this same logic to rice straw, the numbers are even more impressive. Vietnam produces more than 75 million tons of rice straw each year, which, if gasified, would have a value in gas and biochar of over $15.5 billion USD.

A gasifier cook stove, manufactured in stainless steel, can be situated on the market for less money than a propane/butane stove top which also includes a deposit for gas tank. Many industries that could never exist due to the high cost of energy could arise.

Food waste can be cook and sterilized with gasifier heat and fed to pigs. The feces of the pig is then fed to BSF larvae, and the residue of the larvae is fed to red worms. Some report that biochar added to the substrate fed to red worms results in acceleration of the vermi-composting process and a higher yield of worms. Gasifier heat initiates the process, and gasifier char comes in at the end.

Many soil scientists believe that the agricultural benefits of biochar can be enhanced even more by combining biochar with vermiculture.[19] Both BSF residue and biochar enhance red worm growth, and when both are mixed together and fed to worms, the end result is a worm casting of superior qualities. Here we see several technologies coming together and mutually supporting one another.

This same gasification technology can be used to generate electricity. Normally the gas from a gasifier has to be cooled and filtered before it can be fed to an internal combustion engine within a gen-set. Perhaps a better option is to route gasifier heat to an organic Rankine cycle. In this case, the gas does have to be cooled and filtered. Steps are being taken to manufacture ORC units in Vietnam. Imagine making electricity from branches and other garden waste!

[19] See: http://www.scribd.com/doc/30909297/Biochar-Article

David Trahan of Louisiana, together with his team at 3R Sciences, has developed a small methanol synthesis plant capable of producing from symthesis gas about 100 liters of methanol per day.

The R3 GTL Methanol process converts the biomass-generated synthesis gas into methanol. The modular system is designed to allow placement at remote locations to meet supply availability of biomass feedstock.[20]

Methanol can be utilized directly in motorbikes and automobiles,[21] and it can be dehydrated into a type of diesel fuel called dimethyl ether or DME (CH_3OCH_3).[22] The small-scale production of bio-methanol for local transportation needs is truly an exciting possibility.

Prof. Dr. Le Chi Hiep,chairman of the Energy Council and head of the Dept. of Heat & Refrigeration at University of Technology in Ho Chi Minh City, is now designing small adsorption refrigeration units to make ice from gasifier heat. Such units are easily manufactured in Vietnam. This is one of the most efficient ways of making ice. Here electricity is not needed – only heat.

The cost of propane and butane will continue to rise. So will the cost of electricity, petrol, diesel and ice. At the same time Vietnam has hundreds of millions of tons each year of residential bio-waste, of agricultural and forestry bio-waste that for the most part are being dumped or uselessly burned. This simple gasification technology allows someone to utilize bio-waste in the place of fossil fuels and to actually earn money in doing so. We have definitively entered a new era in fuel production and consumption.

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[20] See: http://www.r3sciences.com/biomass.html

[21] "The methanol gasoline can reduce emissions of carbon monoxide, hydrocarbon and nitrogen oxides, with comparable or better performance, especially at high loads." See page 14 of http://www.afdc.energy.gov/afdc/progs/view_citation.php?10828/METH/print

[22] "Only moderate modification are needed to convert a diesel engine to burn DME." http://en.wikipedia.org/wiki/Dimethyl_ether

LACTIC ACID FERMENTATION

There is a lot of fruit and vegetable waste coming from markets and packing houses that is far too moist to gasify and far too nutritious to compost. It can be fed directly to pigs, goats, sheep, cows, rabbits, chickens and even certain fish. But the direct feeding of such waste is somewhat limited, since it is quickly degraded by bacteria, molds, yeasts, insects and rodents. This leads us to look for a simple and inexpensive way to preserve this material over an extended period of time.

Of course a lot of this waste could be sterilized and cooked using gasifier heat, but cooking demands time and space, and also, why use heat, if heat is not required? A lot of this waste could be fed to BSF larvae and red worms, but in this case we would be integrating this waste back into the food chain at a low trophic level.

The best solution for certain types of fruit and vegetable waste is lactic acid fermentation. Lactic acid fermentation is one of the simplest technologies available to us, and it has been employed in Vietnam and the rest of Asia for thousands of years.

Here lactic acid bacteria (LAB) consume water soluble carbohydrates (WSC) and produce lactic acid. As the pH drops below 4.2, (sometimes as low as 3.2) the waste is thoroughly sterilized, and nutrients can be preserved for an indefinite period of time. To get LAB to effect such a drop in pH, certain conditions are required:

1) There must be more than 150 g/kg in dry matter available WSC in the waste. Many types of waste contain far more than this. If they do not, it is easy to add a bit of molasses.
2) The fermentation vessel should be devoid of air. The vegetable matter should be tightly and firmly packed so as to exclude air. Plastic bags therefore are ideal fermentation vessels. A flexible but cheap inner bag can be housed and protected within a more rigid and more permanent outer bag. The inner bags are cheap and easily recycled.
3) LAB do not thrive well in the presence of liquids, and therefore a dry feed material such as cassava root or rice bran can be added to absorb the liquids released during fermentation. Instead of feeding cassava root or rice bran to pigs as part of a conventional pig feed, we can feed it as part of a fermentation mix.

The market or packing house would have two products to sell: fruit and vegetables for humans and silage for pigs. The silage mix, sealed in plastic bags or drums, could be sold and shipped out as quickly as the fruit and vegetables. Fermenting actually increases the macro- and micro-nutrient content of the fruit and vegetable matter and enhances its digestibility. It is well known that lactic acid bacteria have a beneficial health effect on the intestinal flora of humans and pigs. Pigs fed on this silage would have less gastro-intestinal problems than pigs fed solely on conventional diets.

Some lactic acid bacteria can actually feed upon and render harmless certain insecticides as a source of carbon and phosphorus – pesticides such as chlorpyrifos (CP),[23] coumaphos (CM), diazinon (DZ), parathion[24] (PT) and extremely toxic methyl parathion (MPT).[25] Within the first nine days of fermentation, CP is completely degraded and rendered non-toxic.

Second-hand plastic drums also make ideal fermentation vessels. The 55-gallon drums shown here are available second-hand in Vietnam for roughly 50,000 VND or about $2.75 USD. The drum serves as both a processing and storage vessel. It can be used over and over again.

Each and every day of the year, Dalat produces over 50 tons of cabbage waste. This represents but one type of vegetable waste among many that could be fermented in the region of Dalat. If fermented, these 50 tons of cabbage waste could provide nourishment to over 16,000 pigs. If fermented, it acquires a value of $100 USD or 2 million VND per ton, or a total value each day of about $5,000 USD or 100 million VND.

This valuable resource is currently being dumped into valleys and ravines. Levels of leachate and methane produced are horrific. It is hard to imagine a more senseless waste of nutrients, as we see in this picture taken at a packing house in Trai Mat, near Dalat. Each day this one packing house produces about 20 tons of vegetable waste.

All it takes is a bit of molasses (5% of total mix) and rice bran (10% of total mix) of a combined value of about 820 VND ($0.04 USD) to transform one kg of cabbage waste into a nutritious pig feed. But keep in mind that this 820 VND represents nutrients that for the most part are typically fed to pigs in any event, and these nutrients are not lost in the fermentation process.

Lactic acid bacteria appear naturally in cabbage waste. A starter culture is not required. It takes very little expertise to chop cabbage and blend in molasses and rice bran. The fermentation process is completed in about two weeks.

Also, fishery waste can be fermented into a highly nutritious protein supplement for pigs, fish and poultry. Here it acquires a value well over $500 USD (10 million VND). The molasses needed for this process is abundant and cheap, and since nothing in this fermentation process has to be heated, proteins are not denatured.[26] Also fish and shrimp waste, as well as slaughterhouse waste, can be fermented into liquid fertilizers that command a high price. There are some who suggest the

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[23] See http://en.wikipedia.org/wiki/Chlorpyrifos for the terrible health effects of chlorpyrifos.

[24] "Parathion is highly toxic to non-target organisms, including humans. Its use is banned or restricted in many countries, and there are proposals to ban it from all use." See http://en.wikipedia.org/wiki/Parathion

[25] See: http://pubs.acs.org/doi/abs/10.1021/jf803649z

[26] See: http://www.fao.org/docrep/003/x9199e/X9199E04.htm

fermentation of food waste on the household level in order to make compost,[27] but this gets somewhat complicated for a Vietnamese household to manage on a daily basis.

Through fermentation we transform the waste on the left into the highly valuable product on the right:

[27] See for example: http://www.bokashi.com.au/

THERMOPHILIC COMPOSTING USING A COMPOST FLEECE

Farmers produce a lot of biodegradable waste, and this waste is often dumped anywhere they find a convenient place. This practice of dumping waste not only pollutes the environment through the generation of methane and leachate, but it also facilitates the transmission of many soil-born pathogens. The diseases on one farm, instead of being contained on that farm, are transmitted everywhere.

Also, it makes no sense to collect farm waste, bring it to a centralized composting facility and later transport compost back to farmers. Thermophilic composting temperatures are not high enough to kill all pathogens, and a centralized composting facility, receiving waste from many farmers, creates a high degree of cross-contamination. *Each farm, therefore, should be obliged to compost its own waste.* Raw farm waste should never be allowed to exit a farm.

In dumping waste, the farmer is not only throwing away the means of making a valuable soil amendment, but he is often throwing away one of the most effective means he could possibly have of combating soil pathogens. The idea here is quite simple. Compost allows for the proliferation of beneficial soil microbes, and when present in sufficient numbers, these microbes combat a broad range of soil pathogens.

Clubroot is a serious disease that is quite common in Vietnam, and there is no approved effective chemical control available for this disease. EU composting studies show that when green waste compost is added to the soil at a rate of 30%, this disease is completely suppressed. When onion waste is composted and incorporated into the soil at a rate of 25%, the incidence of *Allium* white rot disease on onions is significantly reduced.

When onion compost is incorporated into the top 15 cm of the soil, this is just as effective in controlling onion white rot as fungicide (Folicur) treatment. Good results were also obtained in the suppression of certain root rots when the right compost at the right amount was incorporated into the soil. These are just a few examples of how compost combats disease.

A sort of "tea" can be made from compost when it is steeped in water. *This liquid is applied as a spray to non-edible plant parts, or as a soil-drench (root dip) for seedlings, or as a surface spray to reduce incidence of harmful phytopathogenic fungi in the phyllosphere. Compost tea has been shown to cause a 173.5% increase in plant growth by mass over plants grown without castings. These results were seen with only 10% addition of castings to produce these results*.[28] All of the beneficial effects of adding compost tea to soil or leaf surfaces are greatly amplified when vermi-compost tea is utilized.

Now that we have some insight into the importance of not dumping waste, of making and using compost and compost tea, we must ask: How do we design inexpensive thermophilic composting units for farmers in Vietnam?

The best and cheapest way lies in laying out farm waste in windrows and covering these windrows with a compost fleece. Making long, sheltered compost bins in cement or brick is far too costly. A compost fleece is a spun-bonded nonwoven fabric that:

[28] http://en.wikipedia.org/wiki/Compost

- prevents rainfall from entering the compost (a roof is not needed),
- protects the compost from drying out from sunlight and wind,
- allows for the exchange of gases (the compost breathes),
- retains heat, and
- assures uniform temperatures within the windrow for optimal thermophilic composting.

Note well that rainwater cannot penetrate the fleece, even when all is laid out outdoors. If the waste is properly bulked using rice hulls or some other filler material, the windrow *will not produce leachate*. Therefore a concrete slab for leachate management is not required.

A compost fleece weighs as little as 150-200 g/m2. Once or twice a week, the farmer removes this lightweight fabric to turn and aerate the waste. Compost fleece is inexpensive, and it lasts up to 10 years when manipulated without machines and when not subjected to snowfall. A compost fleece also enables farmers to store manure or even finished compost outdoors without fear of degradation and loss of plant nutrients. It is also commonly used for the thermophilic drying of biomass, as explained previously.

Farmers and scavengers can be easily taught how to create optimal conditions for thermophilic composting. The requirements are quite simple:

- temperature at 65 C for 3 days,
- moisture levels from 55 to 60%,
- CO_2 content not to exceed 20%,
- oxygen level > 5%,
- 30% free air space,
- pH < 8,
- carbon to nitrogen ratio at about 30 to 1,
- undetectable nitrite levels, and so forth.

One 40-foot container will hold about 30,000 m2 of compost fleece at a delivered cost of about $1.00 (20,000 VND) per m2 or $30,000 US (600 million VND) per container. This amount of fleece can cover almost 22,000 m3's of waste materials at any one time. If the composting process is completed within 40 days, then this amount of fleece can handle over 200,000 m3's of waste per year.

In the first year, the cost of a compost fleece per m3 of waste composted is roughly $0.15 US or 3,000 VND. Since a compost fleece can last up to 10 years, the cost of compost fleece per m3 of waste composted is virtually nothing! Keep in mind that brick bins, aeration tubes, concrete slabs and buildings are not needed in composting with a compost fleece. With an investment of less than $30,000 USD (600 million VND), about two million tons of waste can be composted over the 10-year lifetime of this fleece.

In an urban setting, it is not necessary to transport waste materials over long distances in order to compost them. As we have noted previously, households or even entire streets can be supplied with swatches of compost fleece. Scavengers could collect and transport waste down a street where a small composting site could be made available to them by the city. Scavengers could also scour markets in search of compostable materials, and they could also be provided with nearby sites where they could compost these materials. Composting sites could be set up throughout the city wherever waste transfer stations are currently located, or they could even be set up on empty city lots. The possibilities here are endless.

A good compost sells in Vietnam from 500,000 to 1,000,000 VND per ton or $25 to $50 US per ton. If a scavenger sells five tons of compost per month, she would make more money than she is currently making dealing in recyclables. If she collects cured residue from mesophilic bins and vermi-composts this material, she could have a product worth up to $500 US dollars per ton. She might buy biochar from households and businesses, and blend it with either compost or vermi-compost to create additional high-value products. In all of these scenarios, she makes a lot of money.

Roughly three tons of waste will produce one ton of finished compost.[29] Therefore two million tons of waste represents about 666,000 tons of finished compost. At a sales price of $25 USD per ton, this represents gross revenue to scavengers of $16,600,000 USD or 333 billion VND. This is not bad for an initial investment of $30,000 USD of compost fleece.

A final note of caution here is in order. When we see the value of compost and how easy it is to produce with a compost fleece, we might be tempted to turn this into a "big business." Then comes the idea of a centralized composting facility supplied by a large fleet of trucks. On this site there might even be fancy compost turning equipment as well as equipment to manipulate mechanically the compost fleece. All of this looks so modern and so good, but in most instances, it is the wrong economic model for Vietnam and will fail. If somehow this model is successful, it will leave behind a large carbon footprint, the cost of making compost will be high, and many poor people will be deprived of a marvelous means of income.

[29] In most cases it takes two tons of waste to produce one ton of finished compost. But if the raw waste has a moisture content of over 90%, and if no dry filler material is added (as when perforated pipes are used), it might take as much as five tons of waste to produce one ton of compost. In the composting of cabbage waste in Dalat, it takes three tons of cabbage waste plus dry filler to produce one ton of finished compost.

INTEGRATED PIG FARMING

Before concluding this paper, let us turn to an example of how many of the technologies featured in this paper can be integrated. Here we emphasize the pig as an important recycler of waste. If waste management authorities do not have a good understanding of what a pig can do, they will not have all options before them.

Sadly most pig farms in Vietnam are far from being integrated. Feces and urine are allowed to flow together, and this slurry is discharged into nearby black-water lagoons where at times nothing grows but a slimy scum, not even duckweed. Water from these lagoons is often used to wash and cool down pigs. Disease is rampant. Antibiotics proliferate. The stench is unbearable.

In spite of the enormous pollution that the pig farmer generates, he makes little money. The price of soy bean meal, fish meal, and rice bran (main ingredients in pig feed) has risen dramatically in recent times, while the price of pork has declined. The main cost in raising pigs is the cost of feed (up to 70%). The pig farmer in Vietnam has simply become the means by which large feed companies make money.

Pigs, like humans, have inefficient digestive systems compared to many simpler organisms. A fair percentage of the nutrients eaten by the pig remain in its feces. Of course methanogens can convert fecal nutrients into methane, but in this case, a lot of nutrients are not returned to the food chain.

What we propose here is that pig waste be processed in the same manner as human waste: that the feces of the pig be collected and processed by the combined action of BSF larvae and red worms, and that the urine of the pig be flushed to a duckweed pond. The larvae, red worms and duckweed can be processed and fed back to the pig. In the picture above, we see BSF larvae grown in the Mekong on nothing other than pig feces. Below we see the biopods in which they were cultivated.

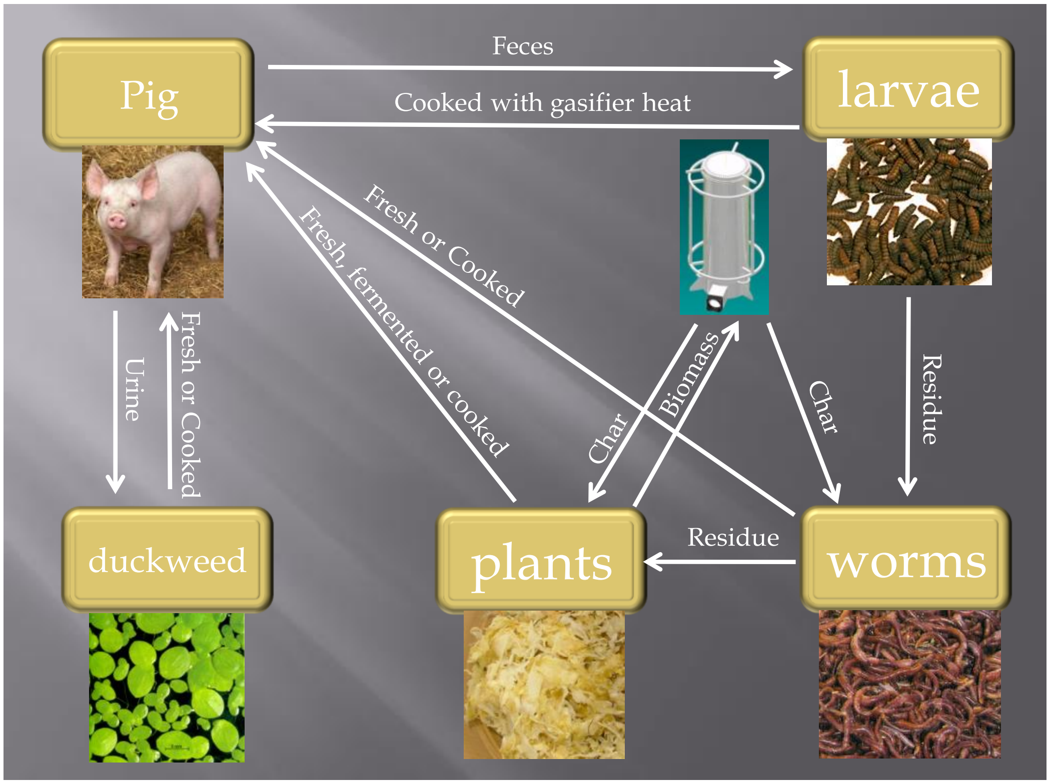
Many pig farmers in Vietnam make rice wine, and the mash from this process is fed to pigs to offset the cost of feed. Gasifier heat can now be used in the distillation of rice wine. This eliminates the environmental and health problems associated with the burning of low-grade biomass. Gasifier heat can also be used to blanch or cook unprocessed vegetable matter such as fresh taro leaves, sweet potato vines and banana stems.

Also many pig farmers search for different types of waste to feed to their pigs. However they are reluctant to feed these wastes directly to their pigs for fear of the transmission of disease. But with gasification and fermentation technologies, the pig farmer is free to cook or ferment many types of waste. Large quantities of restaurant and institutional food waste are available, as well many types of market waste such as vegetable waste, fish and chicken offal, and so forth. Those pig farmers who operate just outside the city in proximity to large sources of waste enjoy a distinct advantage over those who do not.

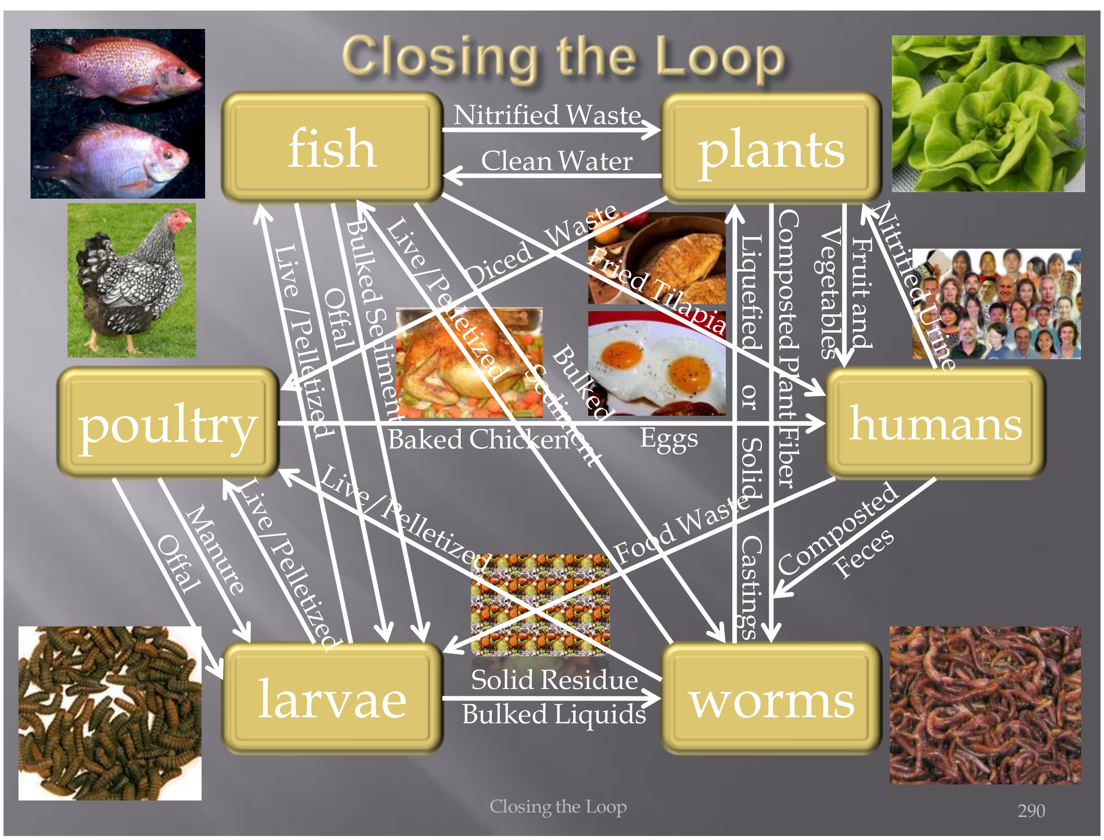
After the pig farmer prepares and cooks his own feed, he does not have to dry and store it, as in the case of a feed company. He can feed the freshly cooked or fermented material immediately to his pigs. This eliminates a costly drying step and results in a substantial savings in the cost of feed.

So we see that the pig farmer in Vietnam is in an entirely different position than before:

1. By making use of BSF larvae, red worms and duckweed, the pig farmer eliminates the odor and pollution associated with pig waste.
2. In so doing he recycles a substantial portion of the nutrients in pig waste, and he feeds these nutrients back to the pig.
3. He locates his farm as closely as possible to urban areas to take advantage of the large amounts of waste generated there.
4. He employs the pig as a scavenger to dispose of many different types of waste nutrients.
5. He cooks wastes with gasifier heat, or he ferments it with lactic acid bacteria.
6. With gasifier heat he also distills rice wine in a smokeless and pollution-free manner.
7. He grows taro and other fast-growing plants to feed to his pigs, and at times he blanchs, cooks or ferments these plants prior to feeding.
8. He composts with a fleece most of the non-putrescent biomass that he generates.
9. He blends biochar, worm castings and compost, and he forms a co-op with other pig farmers to export high-value soil amendments.
10. Only with the sale of soil amendment products, he covers a large portion of his costs.
11. He buys virtually nothing from feed companies, and for the first time in his life, he is in a position to make money.
12. On the one site, he produces food, fuel, feed and fertilizer, as we see in the diagram below:



It is easy to make similar diagrams involving chickens, rabbits, goats, cows, fish and so forth. The following features fish and chickens:



All too often in waste management we forget the importance of the pig, who prior to its domestication, was a forager and scavenger. The pig's ability to consume and digest many different types of waste, prepared in many different ways, makes him a key player in sustainable waste management.

CONCLUSION

Returning to the broader waste management concept, we see that everyone has a role to play in managing waste:

1. Households source-separate their waste. They store on site source-separated bio-waste by means of mesophilic bins.
2. Because source-separation takes place, scavengers are able collect and sell far more recyclables than before. The quality of their recyclables improves considerably, and they sell at higher prices. The scavenger recovers recyclables under far more hygienic conditions.
3. Scavengers clean out mesophilic storage bins, and at times they are obliged to pay households to acquire this residue.
4. Scavengers shred and sell mesophilic residue to farmers as an aeration and starter material for thermophilic composting. Some choose the more lucrative option of vermi-composting mesophilic residue.
5. Scavengers collect and shred branches and other woody biomass which they sell to composting and gasifier operations. Some choose to compost this biomass themselves.
6. With respect to residential waste, waste management authorities collect, transport and bury virtually nothing.
7. Households manage human waste with mesophilic bins, BSF larvae, worms and duckweed. Expensive sewage lines and sewage treatment plants are not needed. The incidence of disease related to open defecation, conventional outdoor latrines and the discharge of raw sewage or poorly treated sewage effluent drops dramatically.
8. Farmers compost their bio-waste by means of a compost fleece.
9. Restaurants and institutions sell far more food waste to pig farmers than previously. They add value to it by grinding and sterilizing it, or they let pig farmers do this.
10. Packing houses and markets source-separate their waste, and they pack into fermentation vessels a portion of the fruit and vegetable waste they separate. They then sell these fermented nutrients to pig farmers.
11. Fishery waste and slaughterhouse waste are also fermented and sold either as a high quality protein supplement for pigs and other animals, or as a fertilizer.
12. Market and packing house bio-waste that is not fermented, cooked or gasified, is collected, shredded, blended and composted by scavengers. Or it is sold by scavengers to farmers as a feedstock for their composting operations.
13. Local government allocates small portions of land within the city for the processing of bio-waste.
14. Local government also apportions land outside the city to enable pig farmers to locate near large sources of food waste. These small pig parks are fully integrated and create no smell and no pollution.
15. Local government sets up a comprehensive carbon credit program that enables it to be handsomely remunerated for each type of waste that it no longer collects and buries.
16. Local government uses some of this money to begin the daunting task of closing down and cleaning up landfill sites.

The job of managing waste is not a burden that government alone must bear. Rather it falls squarely on the shoulders of each person, household, company, restaurant, institution, farmer, market, slaughterhouse, fishery and packing house that generates waste. Here everyone has a role to play. Everyone is responsible.

It is relatively easy to encourage responsible behavior, for throughout this multi-faceted strategy, there is money to be made. With the full implementation of this waste management strategy throughout Vietnam, several million jobs will be created. These green jobs are precisely the kind of jobs that Vietnam's huge agrarian labor force can so easily handle and is so eager to take on.

But the large majority of these new jobs do not involve a shift away from agriculture. They are simply a new category of jobs within agriculture. A manager of bio-waste looks more and more like a farmer or someone providing a product or service to a farmer, and a farmer looks more and more like an expert in the management of bio-waste. With eleven million household farms in Vietnam, we have in theory eleven million centers where bio-waste can be processed and its many products utilized or sold.

The term "scavenger" at times has a negative connotation, conjuring up images of waste pickers who are mostly thieves. Waste pickers and pick-pockets are often lumped together in the mind of the general public. Yet Vietnamese scavengers in general are not thieves, and it would be totally wrong to characterize them as such. They unfortunately operate along the fringes of society, and they (mostly women) are easily preyed upon and exploited. There is an urgent need to organize them into cooperatives where they would be granted formal recognition and status, and where they would be protected in the exercise of their trade (see Appendix I).[30] It is of paramount importance that they receive a fair price for the goods that they collect. Some of the wealthiest people in Vietnam are wholesalers who buy and resell recyclables from scavengers. When we see this kind of wealth derived from the labor of such marginal people, we cannot help but wonder if scavengers are getting a fair market price for their goods.

Since waste would be source-separated, scavengers would no longer scavenge amidst the filth and stench of commingled waste. Waste would be made available to them under far more hygienic conditions. If scavengers should no longer scavenge in the same filthy manner as before, the word "scavenger" should come to signify something quite different. In any case let us redefine and greatly expand its meaning to include people who not only collect but also process waste. It should also include people who would ordinarily be described as farmers. Since both scavengers and farmers work side by side in collecting and processing many of the same types of waste, we should elevate both to the status of manager of waste.

With respect to bio-waste, we must no longer think in terms of an independent waste management industry or an independent sewage treatment facility. In the case of both of these conventional industries, nothing is recycled, and every resource taken in is systematically transformed into a pollutant. Instead we must think in terms of sustainable agriculture where all is recycled in a closed loop, and every resource is fully utilized. These two conventional industries cease to be independent to the degree that they become sustainable.

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[30] "Within a number of large cities, such as São Paulo and Buenos Aires, recyclers have opted to come together, pool capital, and create cooperatives. Some of these are done with the help of micro-financing. These cooperatives empower the recyclers, increasing their selling power. Some cooperatives are able to purchase such capital as warehouses, transportation, and compactors."
http://en.wikipedia.org/wiki/Waste_picker

In this waste management concept, there is always more than one approach to the recycling of a particular type of waste. For example, food waste at times can be fed directly to pigs, or if there is a chance that it might be a vector for disease, it can be sterilized with gasifier heat and then fed to pigs. Sterilized food waste has a value of about $100 USD per ton. Some food waste can be fermented and fed to pigs and would have roughly the same value. If it is not fresh enough to cook or ferment and feed to pigs, it can be fed to BSF larvae. If it is many weeks old and is no longer a suitable substrate for larvae, it can be fed to red worms. Finally, if all of the above technologies cannot be applied for some reason, food waste can be composted either mesophilically or thermophilically.

Furthermore, these technologies, as we have seen, can be combined in multiple ways. Gasifier heat or lactic acid is used to sterilize food waste, this waste is fed to the pig, the feces of the pig is fed to BSF larvae, and the residue of the larvae is mixed with biochar and fed to red worms. Both larval residue and worm castings can be added to a thermophilic composting mix to enhance the value of the final product. Worm castings can be added to the soil, they can be added to a container mix, and they can even be mineralized for use in an aquaponic or hydroponic setting (as shown in the diagram above). Market forces and the logistics of waste handling will determine which options in a particular area are most feasible.

Branches and other woody biomass can be shredded and applied directly as mulch, they can be shredded and gasified, or they can be shredded and composted. Some of the fruit and vegetable waste from markets and packing houses can be fed directly to animals, some can be fermented or cooked and then fed to animals, some can be fed directly to BSF larvae, some can be cured and fed directly to red worms, and some can be composted thermophilically. Fish waste can be fermented into a high protein supplement for pigs, it can be fermented into a liquid fertilizer surprisingly free of odor, or it can be cooked and fed to pigs. Since it is high in nitrogen, fermented fish waste can also be blended into a thermophilic composting mix as a source of nitrogen to achieve a suitable C:N ratio. Similarly slaughterhouse waste can be fermented into a fertilizer, some of it can be cooked and fed to pigs, and all of it can be blended and composted. Human feces, pig feces and many other types of manure can be processed by either BSF larvae or red worms, through the combined action of BSF larvae and red worms, or via mesophilic or thermophilic composting methods.

Perhaps the simplest of all the technologies outlined in this paper is lactic acid fermentation. A plastic sack or drum is all that is needed for both processing and storage. Both sack and drum cost very little, and they can be used over and over again. Lactic acid fermentation works on a variety of waste materials. No starter culture is required. Complete sterilization takes place. Proteins are not denatured, as when heat is applied. Fermentation might require a bit of chopping, mixing and blending, but it is no more complicated in principle than the fermentation of vegetables for human consumption. Once a recipe is known for a particular type of waste, almost anyone could become an expert in its fermentation.

Fermented products have a value about 2 to 4 times greater than that of compost. Fermentation is considerably faster than composting, it involves less labor, and as a feed, it comes in at a higher level in the food chain. If products, either fermented or heat-treated, go through the chain of pig, larva and red worm, not only do we end up with additional products, but we also have roughly the same amount of soil amendment as in the case of having directly composted the original waste. But the soil amendment in this case is vermi-compost, not compost, and vermi-compost has a value up to 20 times greater than that of ordinary compost.

The compost fleece featured in this paper has multiple uses. It can be used as a cover in both mesophilic and thermophilic composting operations. It can be used in the thermophilic drying of biomass. It can be used for the outdoor storage of compost or of pre-compost ingredients such as manure and straw. This inexpensive fabric, so light-weight and easy to handle, requires little start-up capital and provides abundant economic opportunity for many poor people, especially women. Compost fleece, a spun-bonded fabric, can even be fabricated out of the plastics collected by scavengers.

A composting facility should be small. For example, it could be operated by a single scavenger, and it might produce no more than 5 or 10 tons of compost per month. All that this scavenger would need is a piece of ground not subject to flooding, a small amount of compost fleece, and access to a small shredder from time to time. In the beginning the scavenger might pay a fee per kg for the use of a shredder. The small shredder could be operated by a motorbike driver who would transport it from time to time to many small composting sites. Eventually the scavenger might accumulate enough capital to buy her own shredder.

Many types of undensified biomass can be dried and gasified in a top-lit, updraft, forced-air gasifier. The gas produced in this process can be combusted for a variety of purposes: cooking, boiling, steaming, heating, drying, distilling, ice-making, air conditioning and power generation. Instead of combusting this gas, we can filter and synthesize it into an excellent fuel for automobiles and motorbikes (methanol), or into a fertilizer (ammonia).[31] Methanol can be dehydrated into dimethyl ether (a high quality fuel in diesel engines),[32] or it can be processed into plastics and many other useful products. In time methanol, no doubt, will be used to power methanol fuel cells.

Biochar from gasification can be used directly as a soil amendment. It can be blended with compost, vermi-compost or bio-digester solids. If blended with compost, it acquires a value of about $50 USD per ton. It blended with vermi-compost, it acquires a value of about $500 USD per ton. Biochar can be incorporated into a container mix, as is commonly done in Dalat. It can be activated or functionalized for use in water and gas filtration. Activated carbon from rice hulls has a value of about $750 USD per ton. Activated carbon from coconut shells has a value of about $1,900 USD per ton. Activated carbon, functionalized carbon, and duckweed are powerful tools in water filtration. As we have noted, some biochars sorb pollutants from soil and water even without activation.

Dr. Thomas Reginald Preston has done invaluable research in demonstrating that biochar could play an important role in the reclamation of about two million hectares of acid sulphate soils found in the Red River Delta in the north and the Mekong Delta in the south.[33] These soils are extremely acidic, and consequently the growth and yield of many crops grown in these soils are limited. But when biochar is added to these soils, normal plant growth and yield are obtained. Because Vietnam's security in food production comes into play, Dr. Preston states that the reclamation of these two million hectares is not a luxury, but a necessity. Vietnam has enough waste biomass to carry out this reclamation in a relatively short period of time.

But using biochar in combination with compost and bio-digester solids to reclaim deficient soils should not be limited to these two million hectares. Agricultural experts predict that within 20

[31] Small-scale methanol synthesis plants can also produce ammonia as a by-product.
[32] See: http://en.wikipedia.org/wiki/Dimethyl_ether
[33] See: http://www.lrrd.org/lrrd23/2/siso23032.htm and http://www.mekarn.org/workshops/pakse/abstracts/khang.htm

years from now, the soils of Dalat will be depleted and no longer fertile. What happens then to Ho Chi Minh City that depends so heavily on fruit and vegetables from Dalat? Already more than 25% of the agriculture lands in China are barren primarily as a result of a long history of unsustainable agriculture. To avoid a similar fate, Vietnam must quickly put an end to unsustainable agricultural practices that employ the heavy use of chemical fertilizers, pesticides and herbicides. There is no greater champion of sustainable agriculture in Vietnam than Dr. Preston, and the thousands of articles that he has authored and co-authored in his lifetime in this regard are an inspiration to us all.[34]

In the introduction we stated that rice is grown on about 84% of agricultural lands in Vietnam. But sadly, wherever rice is grown, we witness the burning of both rice hulls and rice straw as a means of disposal. This creates air pollution on a colossal scale. At the same time, hundreds of thousands of hectares of forest are set on fire each year in Vietnam in controlled burns to prevent catastrophic forest fires.[35] Households in urban areas routinely burn yard waste and other debris rather than bring it to the street for collection. Since waste collection services do not exist in most rural areas, many households burn waste rather than bury or dump it. Landfills in Vietnam are often set on fire as a means of increasing landfill capacity. When municipal workers rake leaf litter and gather branches along streets and boulevards, they often set fire to this biomass right within the city limits. They do this, no doubt, to avoid having to transport it to a landfill and perhaps burn it there.

The burning of biomass and other waste materials takes place throughout all of rural and urban Vietnam. When the pollution from all of this burning is combined with the pollution from conventional cook stoves fueled by low-grade biomass, the damage to human health and to the environment is immeasurable. Since most of the biomass now being wastefully burned can serve as a valuable feedstock for composting or gasification, *burning waste as a means of management, control or fuel must come to an end*.

If minority peoples living in mountainous areas were to gasify forestry waste, then the burning of forestry waste as a fire control method would not be necessary. Tens of thousands of small gasifiers could be set up throughout mountainous areas, and the gas produced could be burned for home or farm cooking needs, or it could be routed to small-scale methanol synthesis plants producing less than 500 liters of methanol per day. The biochar produced from pine needles can be used for many purposes, including water filtration and the sorption of pollutants from soils, as we have seen.

The one mesophilic bin can receive residential bio-waste, human feces or both. This bin can be powered, as its name implies, only by microscopic mesophilic creatures. If seeded and managed properly, it can also function seamlessly as a small vermi-composting unit. If inhabited by BSF larvae, it can handle a lot more waste than foreseen in its original design. With a slight modification involving a small gutter at its base, it can also be used for the capture of BSF larvae. Of course those wishing to facilitate the capture of BSF larvae can use a biopod. The biopod can be manufactured from roto-molded plastic or from brick.

The bricks used to make a mesophilic bin can be fired in a kiln that utilizes gasifier heat. Such a kiln would produce no smoke or particulates. This stands in sharp contrast to what we see, for example,

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[34] See: http://www.mekarn.org/publ.htm as well as http://www.lrrd.org/ and http://www.mekarn.org/workshops.htm

[35] At times during dry season, the city of Dalat is completely filled with smoke from the burning of forestry waste.

in Binh Dinh province where entire valleys are so polluted by smoke and particulates coming from brick kilns burning low-grade biomass, that even on sunny days, it is impossible to see the sun.

Whether a mesophilic unit is cleaned out once every two years, one a year, or twice a year makes little difference to waste management authorities, since clean-out and collection will be carried out by scavengers, who no doubt, will be forced one day to buy mesophilic residue from households just as they buy newspapers. Scavengers will be eager to shred and grind this residue as a feedstock for red worms. This will enable them to engage in the lucrative business of selling worm castings worth about $500 USD per ton. Once vermi-compost is incorporated into the soil, the demand for fertilizers, as you might recall, drops dramatically.

The urine from urine-diverting toilets is typically sterile and can be collected by scavengers and sold to farmers as a wonderful and bountiful source of NPK. After being diluted at least 8 to 1 with water, this resource can be inserted by farmers into the soil with very little loss of ammonia. When this practice becomes widespread in Vietnam, the demand for chemical fertilizers will drop significantly. But instead of selling urine to farmers, scavengers could utilize the urine they collect in their own composting operations as an important source of nitrogen. [36] Urine-collection and thermophilic composting work hand in hand.

Another option is a biochar urinal, an incredibly simple device that consists of a PVC pipe, a clay pot or some other vessel filled completely with biochar.[37] Biochar urinals could be set up at households, restaurants and other public places. They can be adapted to serve both men and women. Since biochar captures gaseous ammonia, the urinal is very much odor-free. When the urinal fills up with urine, the vessel is emptied of both urine and biochar. It is then reloaded with fresh biochar.

Scavengers could service biochar urinals, and sell this mix of urine and biochar to farmers. Or they she could utilize this urine-impregnated biochar in their own composting operations in order to produce a top-quality compost. Now we see that urine-diversion, composting and gasification work hand in hand. Of course, if the transport of urine, or the transport of biochar and urine, is too burdensome, urine can be processed on site by means of fast-growing duckweed. Duckweed can be fed fresh or blanched, or it can be stored indefinitely either dried or fermented. Fermented duckweed has a value of about $100 USD per ton. Dried duckweed has a value of about $500 USD per ton.

Another possibility of treating urine on site would be to add to it inexpensive magnesium compounds to precipitate out all of the phosphorous and some of the ammonium in the form of magnesium ammonium phosphate (struvite). As a slow-release fertilizer, struvite crystals sell at over $1,000 USD per ton. The remaining liquid would still contain nitrogen, and this nitrogen could be distilled from the urine using a modest amount of gasifier heat. The gaseous ammonia released in this distillation process could be captured using biochar. The struvite and nitrogen-rich biochar could be blended and sold as a dual purpose fertilizer and soil amendment. The advantage of this approach is that any pharmaceuticals or hormones in urine are excluded from the final product.

We could go on and on explaining the enormous flexibility in processing waste that these technologies provide. With so many waste processing pathways available to so many people

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[36] "Adding a healthy person's urine to compost usually will increase temperatures and therefore increase its ability to destroy pathogens and unwanted seeds." http://en.wikipedia.org/wiki/Compost

[37] Biochar urinals are gaining in popularity, especially in India. See: http://e-biocharurinals.blogspot.com/

seeking economic opportunity, Vietnam will eventually find itself in the peculiar position of not being able to find enough waste to meet the enormous demand for it.

Let us look once again at the money that can be made from waste:

- Red worms - $500/ton
- Red worm castings – $500/ton
- Fermented duckweed - $100/ton
- Dried duckweed - $500/ton
- Fresh BSF larvae - $500/ton
- Dried BSF larvae - $1,000/ton
- Biochar - $50/ton
- Rice hulls (gas + biochar) - $210/ton
- Activated carbon from rice hulls - $750/ton
- Activated carbon from coconut shells - $1,900
- Food waste (heat-sterilized) - $100/ton
- Fermented fruit and vegetable waste - $100/ton
- Thermophilic compost –$25 to $50/ton

This waste management concept does not ask for a high level of environmental awareness. It is primarily about making money. It opens up employment possibilities for millions of people in Vietnam. It lifts many people out of poverty. It reduces the need within Vietnam to import food, fuel, feed and fertilizer, and this in turn has a positive impact on Vietnam's balance of trade. It makes Vietnam no longer dependent upon foreign assistance in managing its waste, and it has the potential to make Vietnam a world leader in waste management, far surpassing Europe and the United States.

Many people involved in waste management have been using an economic argument over many years to justify the current state of the affairs, saying that since Vietnam is so poor and the cost of managing waste properly is so high, Vietnam must resign itself to living in a polluted world. Hopefully we have demonstrated that we can reach precisely the opposite conclusion based on Vietnam's supposed poverty.

Vietnam is too "poor" to waste large sums of money on burying waste. Vietnam is too "poor" not to take advantage of carbon credit revenue that could be obtained from each type of waste not buried. Vietnam is too "poor" not to profit handsomely from the many high-value products derived from waste. In the end, Vietnam is too "poor" not to make of waste its greatest resource.

With this small-scale, decentralized, integrated and highly profitable waste management concept, we are no longer forced to consign waste to a watery grave. Instead we can recycle it all and become active participants in that wondrous cycle of rebirth and renewal.

APPENDIX 1 –WASTE RESOURCE CENTERS, EXTENSION SERVICES, CO-OPS, AND REGULATORY AGENCIES

If the implementation of the technologies outlined in this paper is to take place in an effective manner, several types of support institutions will be required. Let us begin with the concept of a waste resource center.

A waste resource center, as its name suggests, is a center that helps manage resources derived from waste. Such centers could be set up in each province in Vietnam, along with branches or outreach stations within each district. The waste resource center would be staffed by experts highly skilled in mesophilic and thermophilic composting, BSF and red worm bioconversion, duckweed cultivation, gasification and lactic acid fermentation. Additionally, the agricultural departments of all of the major universities in Vietnam would be called upon from time to time to provide graduate or post-graduate students to serve as temporary teachers and trainers in the waste resource center.

After several days or even weeks of training, those graduating a waste resource center would be recognized as certified waste managers. Scavengers would be invited to participate in all of the activities of the center, and they too would be granted formal recognition, certification and status. Various apprenticeship programs might also be set up. From time to time the center would invite experts to hold workshops explaining the latest advances and improvements in sustainable waste management.

In addition to training and certification, the waste resource center would offer counseling and advice. It might attempt to match the skills of a trainee to the type of work involved in processing a particular type of waste. It might assist in identifying waste processing opportunities in a particular area within a city, district or province. It might explain the economics and logistics of processing waste in a particular area. It might identify existing markets and help create new markets for the products derived from waste. It might assist in apportioning small tracts of land set aside by local authorities for the decentralized processing of waste. It might offer health and safety counseling to all those exposed to toxic substances or disease-related materials in the handling and processing of waste. It might offer micro-credit for the purchase of waste processing equipment: equipment such as biopods, gasifiers, shredders, compost fleece, fermentation vessels, push-carts or small motorized carts. It might offer micro-credit for the purchase of safety equipment, such as gloves and masks. It might identify the best suppliers of process and safety equipment, and allow them to display, demonstrate and sell their equipment at or in proximity to the center. It might keep records of types and tonnages of waste not buried, burned or dumped, so as to meet the requirements of carbon credit certification.

But perhaps the most important function of waste resource center would be to organize and manage cooperatives on behalf of scavengers. Note that the center is not itself of a co-operative, but it would play a vital role in organizing scavengers into cooperatives. It might actually staff and run cooperatives, enabling scavengers to focus fully on collecting and processing waste.

The one waste resource center might manage many different cooperatives. There might be, for example, a co-op for those involved in composting, another for those involved in vermi-composting, another for those collecting food waste for pig farmers, another for those cultivating and trading in BSF larvae, another for those collecting and trading in recyclables, and so forth. Each cooperative would need collection and processing equipment specific to that co-operative. Some equipment would be jointly owned by the co-op. Some would be owned by individual members of the co-op.

A cooperative would exercise formidable power in helping scavengers to obtain the highest prices for their recyclables and waste-derived products. A cooperative would seek out companies manufacturing goods from its products and invite them to set up shop in the area. It would set standards for the quality of its products, and it would certify that all of its members adhere to those standards. A cooperative would make sure that all of its members undergo regular medical checkups and would have adequate and affordable health insurance. A cooperative might assure that the children of its members attend school and are not exploited for their labor. Cooperatives would put an end to the exploitation of scavengers currently exercised by mafia middlemen in Vietnam. Cooperatives would attract a lot more people to the profession of waste management, and they would elevate their members to a high level of social acceptability. The stigma often associated with the word “scavenger” would eventually disappear.

The waste resource center would serve primarily women. Women are readily disposed to dealing with waste on the level that this concept so often demands. For example, women are not afraid to clean out mesophilic bins; to grow red worms and sort them from their castings; to put food waste into biopods and harvest larvae; to chop and blend vegetable waste for input into fermentation vessels; or to collect recyclables, biochar and urine from households. These are all jobs that women are socially inclined to do. The co-op relieves her of having to spend a lot of time on the managerial aspects of running a business, and it allows her to focus all of her attention on the task at hand.

So co-ops would be comprised mostly of women. Instead of working under a boss, a member of a co-op would remain at all times her own boss. Instead of selling at low prices to a middleman, she would receive for her goods approximately the same prices that the middleman currently receives. As a member of a co-op, waste becomes in her hands a resource as never before. This will attract more people to the waste management profession, and with more people, comes more competition and more waste recycled at higher levels of efficiency and sustainability. Every type of waste will be exploited for all it’s worth.

This preference or bias in favor of women operating at the level where scavengers currently operate defines generally what “small-scale” should mean in the context of waste management in Vietnam. *It says that the poor people who go in and do all the dirty work should be the primary recipients of the income associated with such labor.* The co-operative provides the necessary condition for this small-scale waste management effort to thrive.

Households, businesses, markets, schools and other institutions must learn the basics of source-separation, and the waste resource center would provide formal instruction as well as on-site training in this regard. The center would hold seminars and workshops in both rural and urban settings to explain all aspects of source-separation. It would publish and distribute pamphlets and brochures. It would write articles in newspapers. It would produce television programs and short films. It would target in particular primary and secondary schools, and it would provide teachers there with the resources they need to teach their students the importance of source separation.

But the waste resource center might go further and instruct those who generate waste on how to process some of the waste they generate. For households the primary waste processing unit, of course, is the mesophilic bin, and the center could organize neighborhood training sessions on how to manage a mesophilic bin. If a household should have a problem with a mesophilic bin, the waste resource center would send out an expert to resolve this problem. The most common problem encountered with a mesophilic bin: it begins to stink due to the fact that it is not properly aerated.

This trouble-shooting role of the center must also go beyond technical issues into the social domain. Imagine two households that have a long history of not getting along with one another, and they are called upon to share a mesophilic bin. Imagine two scavengers in competition for the same type of waste. Imagine a household and a scavenger in dispute over the clean-out of a mesophilic bin. The center will inevitably be called upon to address social problems such as these.

Some households might want to learn how to capture and sell BSF larvae cultivated within mesophilic bins, and the waste resource center would provide the necessary technical and commercial support. Some households might want to learn how to operate a small vermi-composting facility composed of one or more mesophilic bins stocked with red worms. Packing houses and markets could be taught how to ferment and sell their fruit and vegetable waste. They could be taught how to shred on site certain types of waste so as to immediately reduce its volume. They could be taught how to shred, blend and prepare certain types of waste for thermophilic composting operations. Restaurants and institutions could be instructed on how to prepare (grinding and possibly sterilizing) food waste for consumption at pig farms. Many more examples could be given. To the extent that the center succeeds in getting people involved in preparing and processing waste, more waste will get recycled at higher levels of sustainability and profitability.

The waste resource center would handle all aspects of waste collection, preparation, processing and recycling (with the exception of anything relating to landfills). It would function under contract to government as a business organization that is both private and non-profit. It would be funded from two sources. 1) The center would sell all goods collected and processed by the cooperatives, and for this service, it would collect a small fee. 2) The center would handle the administration of carbon credit certification, and for this, it would also collect a small fee. With the exception of these two fees, all revenue from the sale of goods and from carbon credits should go entirely to the cooperatives.

As a non-profit organization, the waste resource center would pay no taxes. Cooperatives would also be exempt from any form of taxation. In exchange for this tax exempt status, neither the waste resource center nor the cooperatives would charge local government anything for the collection and processing of bio-waste.

The waste resource center would be staffed by social and environmental entrepreneurs totally focused on providing jobs for the poor and cleaning up the environment. Managing a waste resource center that works with scavengers means recruiting people who truly care about the poor and are willing to work with them in creative ways. Gaining the total trust of the scavenger community is of paramount importance. Those hired by the center should spend at least a year demonstrating their interest in serving the poor.[38] They should be equally passionate about sustainability in all aspects of how humans relate to the natural world.

On April 9, 2007, the Vietnamese government issued a decree (No. 59/2007/ND-CP) that stipulates unequivocally that solid waste must be *segregated at source*, and that source-separated materials have to be reused and recycled. No type of domestic solid waste is exempted or excluded from this

[38] This is the recruitment policy practiced by the Grameen Bank. See: http://opinionator.blogs.nytimes.com/2011/03/21/microfinance-under-fire/?nl=opinion&emc=tya1

requirement. Note that this decree is not simply the expression of wishful thinking on the part of government. This decree actually calls for monitoring and implementation.

If the only option available to waste management authorities at provincial and district levels would be to bury waste at an enormous loss, perhaps they would be justified in ignoring this decree. But in light of the substantial economic opportunity that the technologies outlined in this paper represent, every directive spelled out in Decree 59 should be seriously considered and fully implemented. In fact, with these technologies, all of the waste management goals and timelines set out in this decree can be easily met and surpassed.

While waste resource centers and cooperatives might train, enable and facilitate, they would not have the power to monitor and enforce. This is where local government can intervene in a powerful and positive way by setting up a waste management regulatory agency.

As one of his most important tasks, an officer in this agency would be called upon to monitor and enforce the source-separation of waste. The use of a mesophilic bin makes it quite easy for him to do his job at the household level, since he knows well who deposits waste into each bin under his jurisdiction. Most often there is but one bin per household, and he would examine each bin on a regular basis in search of misplaced material. He would fine any household depositing, for example, glass, metals, textiles or plastics into a mesophilic bin. Exceedingly high fines would be levied if toxic waste such as batteries or light bulbs is mindlessly thrown in. He would be assisted by certified waste managers who would report to him the presence of any bio-waste in the non-bio-waste fraction put out on the street, and the waste management officer could take appropriate action. The waste management officer would also patrol markets, canteens, restaurants and other businesses to monitor and enforce strict adherence to Government Decree 59 in its call for source-separation, reuse and recycling. Households and other waste generators that do things properly would receive each year substantial rewards.

So we see that waste resource centers, cooperatives and regulatory agencies all have an important role to play in the implementation of this waste management concept. The first teaches and advises, the second implements, and the third makes sure that all regulations and directives regarding waste are strictly followed.

Since the management of bio-waste is so intimately connected to agriculture, there must be close interaction and communication between waste resource centers and agricultural extension agencies. Since farm waste can be processed by many of the same technologies used for domestic bio-waste, many of the experts at a waste resource center could advise farmers on waste processing issues, and many extension agents could inform waste management trainees about many aspects of how waste-derived products are used on farms. Nonetheless, the waste resource center and the extension service are not the same and should remain distinct.

An enormous amount of agricultural waste in Vietnam is created by farmers who are not properly advised on what to plant at a particular time. If, for example, too many farmers plant onions, a lot of onions remain unsold and get discarded as waste. This waste ends up on farms, at packing houses and markets. Normally it is the job of extension agencies to advise farmers on what and when to plant. Vietnam, no doubt, should invest a lot more in agricultural extension services so that farmers would grow crops that are in demand and do not unnecessarily create waste.

Another possibility might be to promote the formation of agricultural cooperatives that oversee many critical farming issues on behalf of its members. A farmers' co-op could also advise farmers on what and when to plant. It would assist the farmer in the marketing of his products at fair market prices. It would also advise its members to avoid the use chemical pesticides and herbicides, and to adopt instead the use of bio-pesticides and bio-herbicides. Many bio-pesticides, such as compost and vermi-compost teas, are fabricated out of products derived from waste.

Just as there might be a close connection and interaction between waste resource centers and agricultural extension agencies, there might also be a close connection and interaction between waste co-ops and farmers' co-ops. For example, when a waste co-op sells its products to farmers, it does so in large quantities preferably through a farmers' co-op. The farmers' co-op in turn prefers to deal with the waste co-op because it knows that the latter goes to great lengths to assure the quality of its products.

Waste co-ops might exert pressure on farmers' co-ops to limit the use of chemical pesticides and herbicides, since the presence of these chemicals negatively affects the quality and marketability of many of the products derived from bio-waste. At the same time the use of products derived from bio-waste greatly reduces the need for chemical fertilizers, pesticides and herbicides. Just as good communication between waste resource centers and agricultural extension agencies is important, so is good communication between waste co-ops and farmers' co-ops.

Finally, just as there should be an agency regulating the source-separation, recycling and reuse of domestic solid waste, there should also be an agency regulating what happens on farms. This agency would strictly enforce sustainable manure management practices. It would fine any farmer involved in dumping, burning or discharging solid or liquid waste. It would do everything within its power to prevent the overuse of chemical pesticides and herbicides. It would totally ban the use of antibiotics on pig farms.[39] It would apprehend anyone engaged in the sale of agricultural chemicals banned internationally. It might even conduct soil testing at each farm in order to determine levels of soil depletion and chemical contamination. In conclusion, this agency would play an absolutely vital role in maintaining the safety and security of Vietnam's food supply.

So we see in conclusion that waste management in partnership with sustainable agriculture is not an activity that spontaneously self-organizes as if by magic. It requires waste resource centers, extension services, co-ops, and regulatory agencies – all operating in close collaboration with one another.

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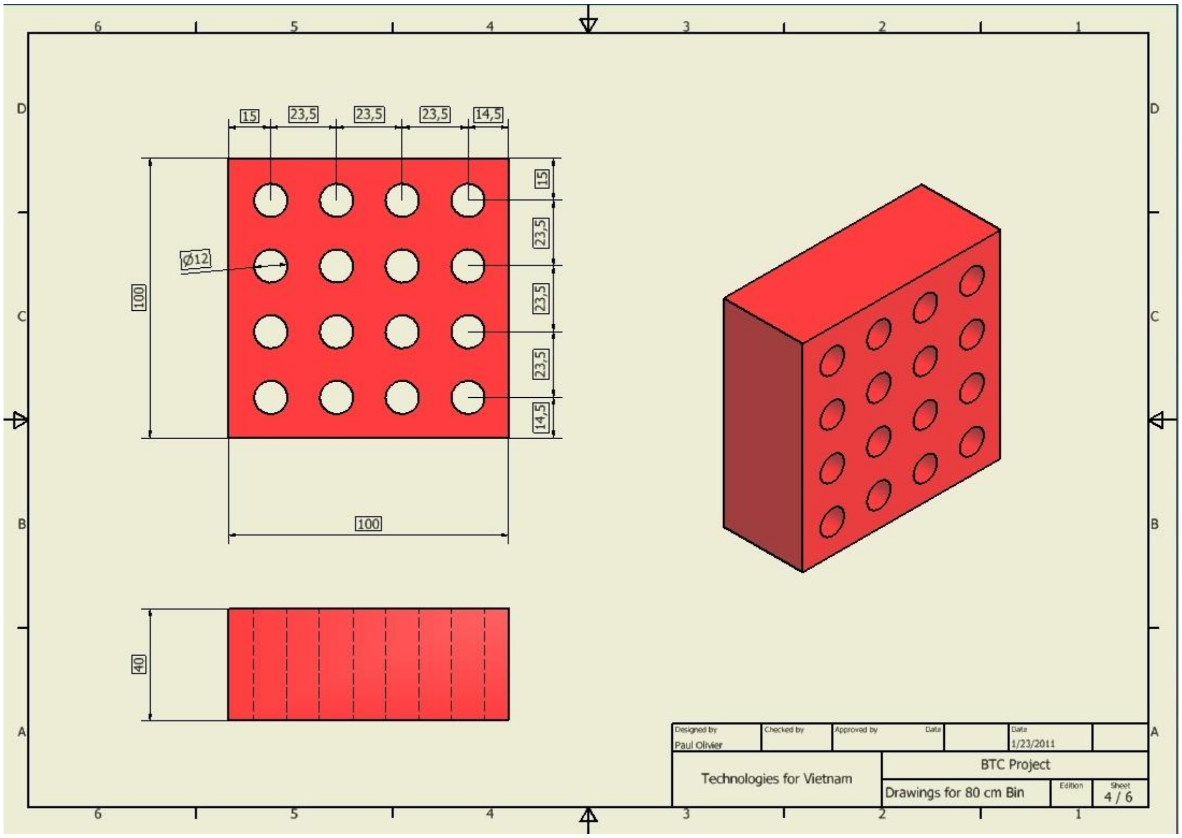
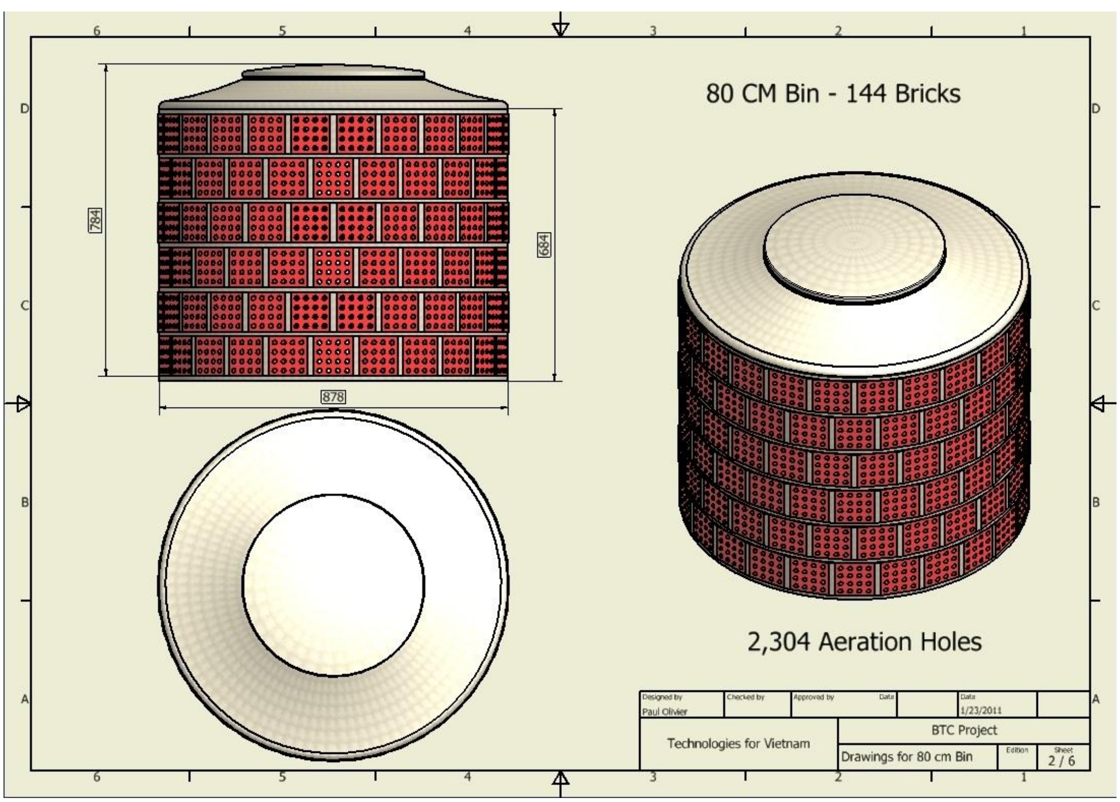
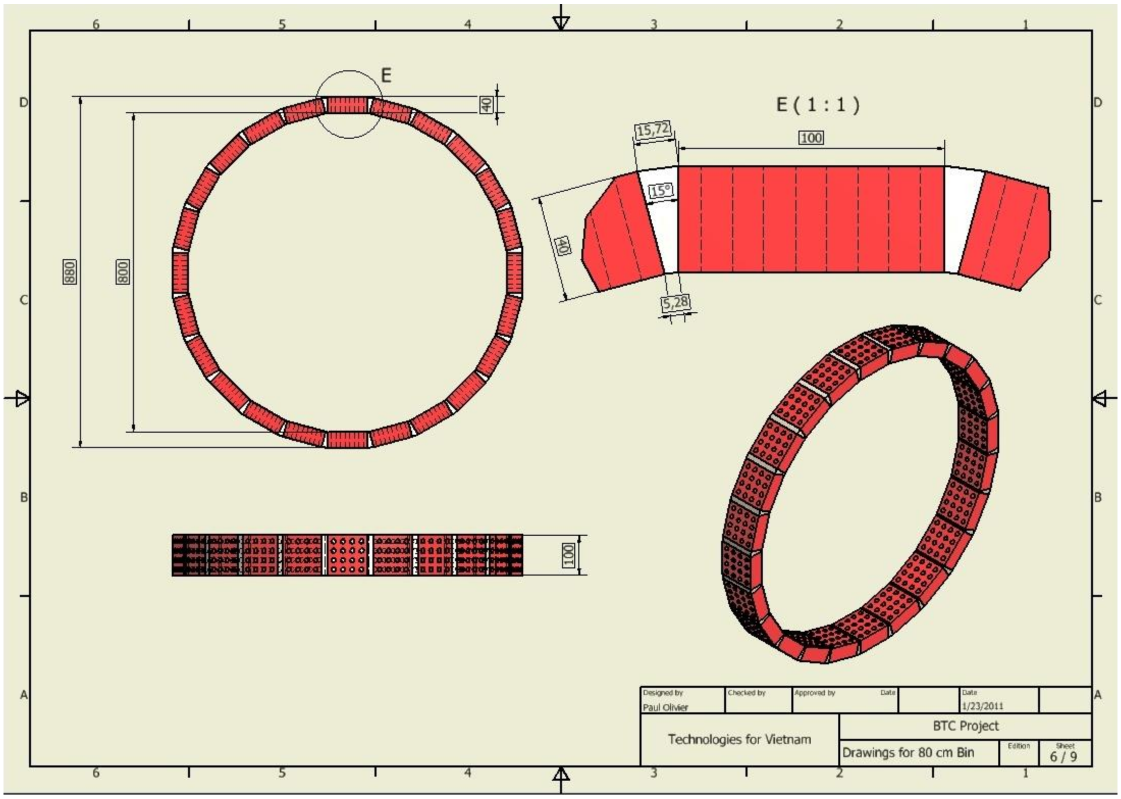
[39] The use of antibiotics on pig farms is a major contributor to the evolution of a staph bacteria called MRSA. These bacteria have become resistant to almost all of the antibiotics used each day in medicine. "MRSA (Methicillin Resistant Staphyoloccus Aureus) kills more people every year than AIDS. In the US alone 19,000 die from it each year, and another 369,000 are hospitalized because of it. The World Health Organization calls MRSA the most important health issue of the 21st century."
http://www.boingboing.net/2011/03/14/interview-with-autho-5.html

APPENDIX II - MESOPHILIC BIN DRAWINGS



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Technologies for Vietnam
BTC Project
Drawings for 80 cm Bin
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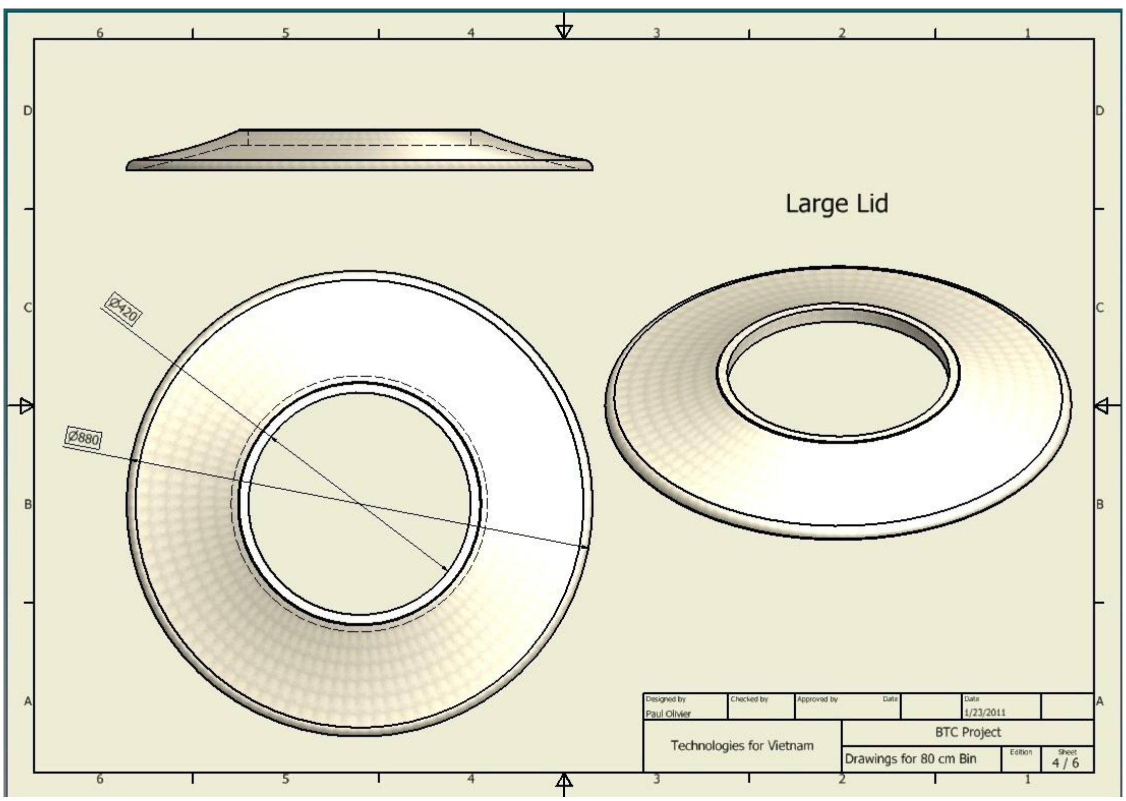
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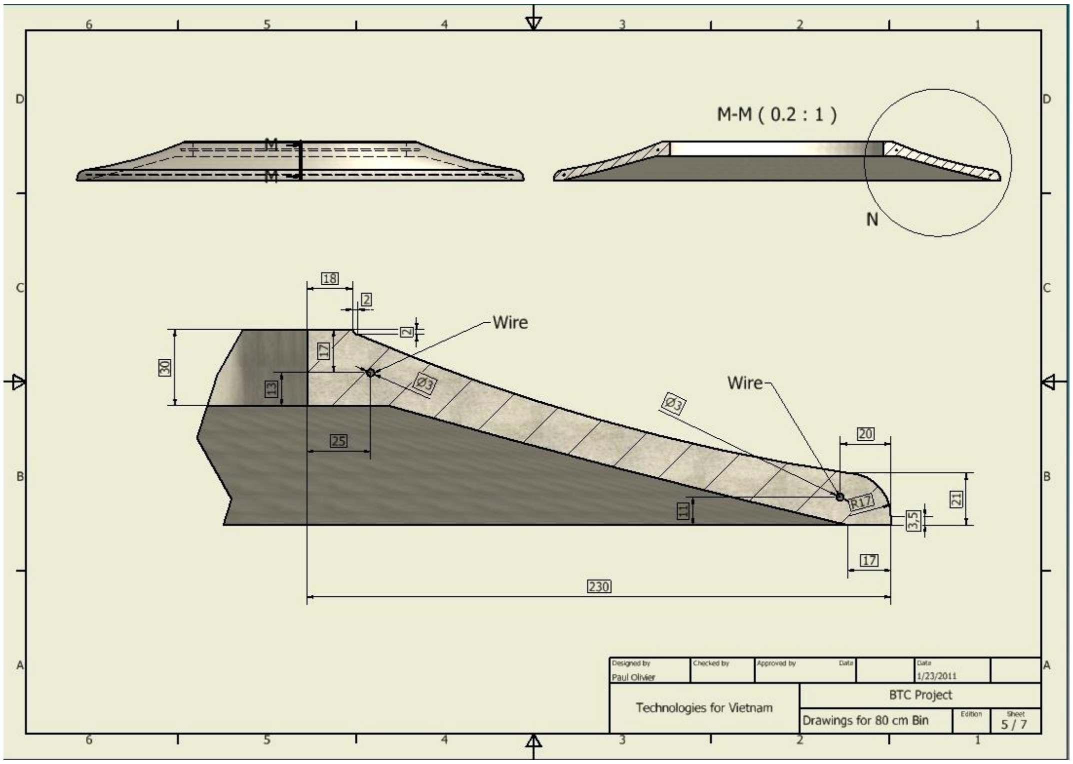
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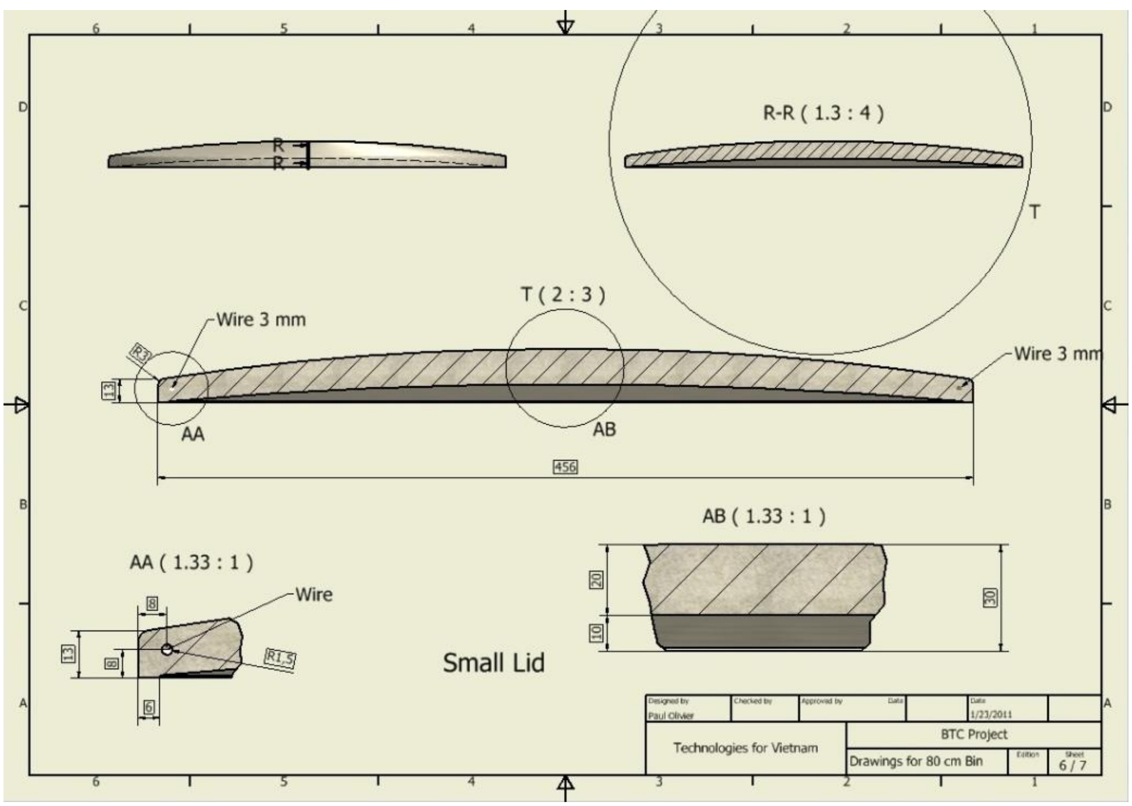
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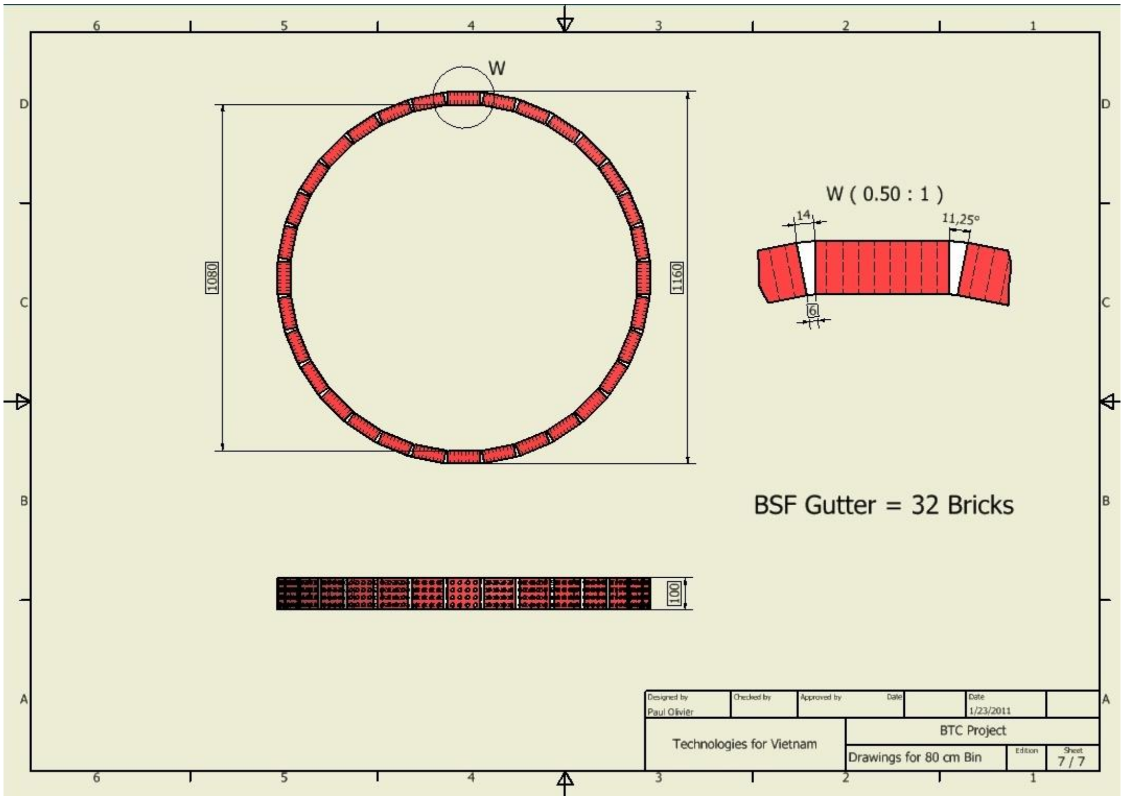
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