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. Coffee farmers either ferment wet coffee pulp (feed) or gasify dry coffee husks (fuel and biochar).
12. Fishery waste and slaughterhouse waste are also fermented and sold either as a protein supplement for pigs and other animals, or as a fertilizer. Shrimp and crab waste are also fermented to separate chitin from protein. Chitin is transformed into chitosan and sold at an incredibly high price. Protein is processed into a high-quality fish feed.
13. 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.
14. Local government allocates small portions of land within the city for the processing of bio-waste.
15. 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.
16. 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.

17. 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 an agriculture that is thoroughly sustainable. 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. Waste management authorities should be obliged from time to time to attend seminars highlighting some of the latest advances in sustainable agriculture.

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).[1] 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

[1] "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

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.

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 pasteurized with gasifier heat and then fed to pigs. Pasteurized 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 rid food waste of pathogens; 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 pasteurization 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 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).[2] Methanol can be dehydrated into dimethyl ether (a high quality fuel in diesel engines),[3] 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. In Ho Chi Minh city biochar sells for $150 US per ton (3 M VND). If blended with vermi-compost, biochar 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.[4] 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

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

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 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.[5]

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.[6] 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 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 biochar from forestry waste can be returned to the forest to replenish and sustain its soils.[7]

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

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

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

[7] See: http://www.biochar-us.org/forests.html

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 produces no smoke. This stands in sharp contrast to what we see, for example, in Binh Dinh province where entire valleys are so polluted by smoke coming from brick kilns burning sawdust and other low-grade biomass, that even on sunny days, it is impossible to see the sun. Biochar can even be incorporated in the clay prior to the extrusion of the brick. Except in the beginning to initiate the baking process, no external heat is required. As the biochar heats up within the brick, the brick bakes itself. Tiny air pockets within the brick are formed, and this produces a lighter brick.

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.[8] 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.[9] 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.

The pig-on-bedding technology offers another exciting way to transform urine into a usable and stable product. This is a simple mesophilic process in which the decomposition of a urine-soaked

[8] See: http://en.wikipedia.org/wiki/Compost
[9] Biochar urinals are gaining in popularity, especially in India. See: http://e-biocharurinals.blogspot.com/

biomass is greatly aided by the addition of biochar and effective microorganisms (EM). Dr. Preston has done interesting research on how EM enhances the effectiveness of biochar and how biochar enhances the effectiveness of EM.

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 hexahydrate ($NH_4MgPO_4 \cdot 6H_2O$). 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 evaporated from the urine in a packed tower using a small 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 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 - $150/ton
- Rice hulls (gas + biochar) - $283/ton
- Activated carbon from rice hulls - $750/ton
- Activated carbon from coconut shells - $1,900
- Chitosan from shrimp and crab shells - $16,000 plus/ton
- Food waste (heat-pasteurized) - $100/ton
- Fermented fruit and vegetable waste - $100/ton
- Fermented coffee pulp - $50/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.