MAKING WASTE OUR GREATEST RESOURCE

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

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Imparting Value to Waste

The idea here is quite simple: to impart value to waste.

If we give it enough value, there will be a lot of people lining up to recycle it.

The first step in doing this, is to realize 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.

Mesophilic Reduction and Storage

The first technology we will examine: the mesophilic reduction and storage of bio-degradable waste (bio-waste).

In Vietnam bio-waste is by far the largest component of the residential waste stream, sometimes as much as 85%.

We propose that the household isolate its bio-waste and keep it separate from all other types of waste.

We propose that it put this waste into a mesophilic bin.

This bin would be set up at each household where space permits.

Strategy

- Bio-waste remains separate and is deposited into the mesophilic bin.
- All other waste is set aside and collected but once each week or two.
- The daily collection of household waste is completely eliminated.
- Since, in most instances, there is but one bin per household, it is easy to monitor and enforce source-separation.
- Over time bio-waste in a mesophilic bin reduces by as much as 90% in volume and almost 80% in weight.

Strategy

- The bin that we propose can hold more than 330 liters of residue.
- This means that for the average family, the bin must be cleaned out once each year or two.
- Scavengers will buy this residue from households and shred it.
- They will either compost it as a filler material (along with other waste), or they will vermi-compost it.
- If composted, it is worth from $25 to $50/ton.
- If vermi-composted, it is worth up to $500/ton.

Strategy

- If a household produces 120 kg's of residue per year, this residue has a value of $60 as vermi-compost.
- Since bio-waste is not mixed with recyclables, scavengers will recover more recyclables of a much higher quality in far less time.
- The quantity of recyclables recovered will increase well beyond its current level of 15%.
- The yearly cost per household to collect, transport and landfill its waste situates at about 30 $ USD.
- Most of this cost will be eliminated.
- This strategy can deliver as much as $20 USD per household per year in carbon credits.

Mesophilic Bin

This concept is all about saving and making money:

1. $30/household/year (money saved)
2. $20/household/year (revenue in carbon credits)
3. $60/household/year (revenue in worm castings)

This adds up to $110/household/year.

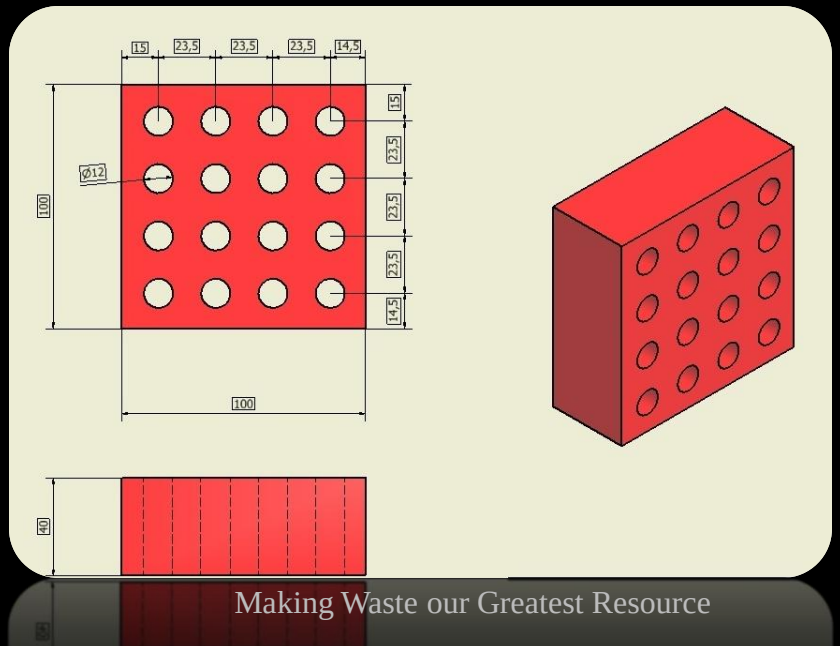
The following pictures show a mesophilic bin that was set up at my house in Dalat:

New Way to Make a Bin

The bin in these two pictures was constructed out of pre-molded concrete sections.

Since then we have discovered a much better and much cheaper way to make a bin.

Here we use a 16-hole brick designed specifically for this purpose:

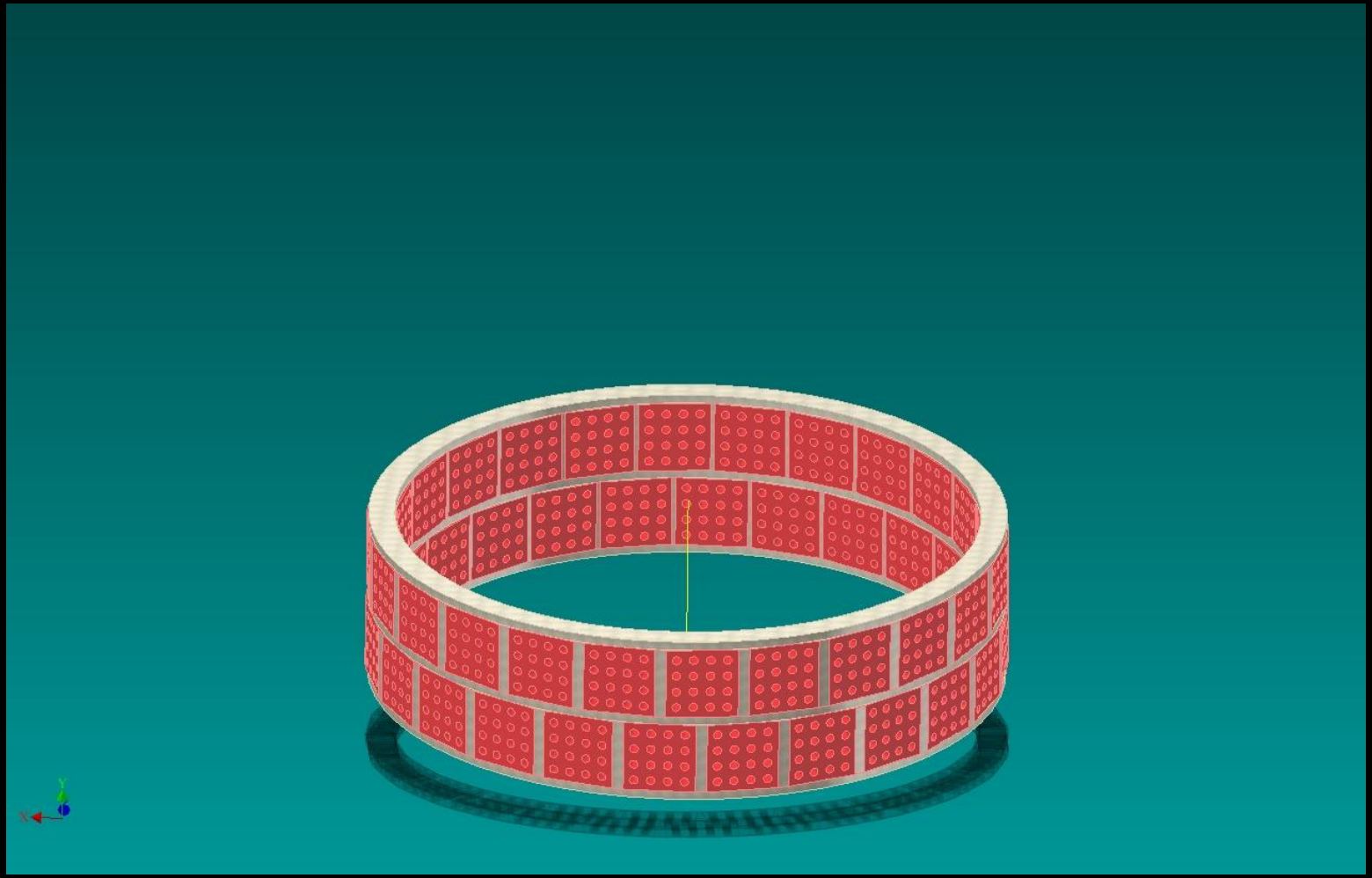


Cost = 200 VND or
$0.01 USD per brick

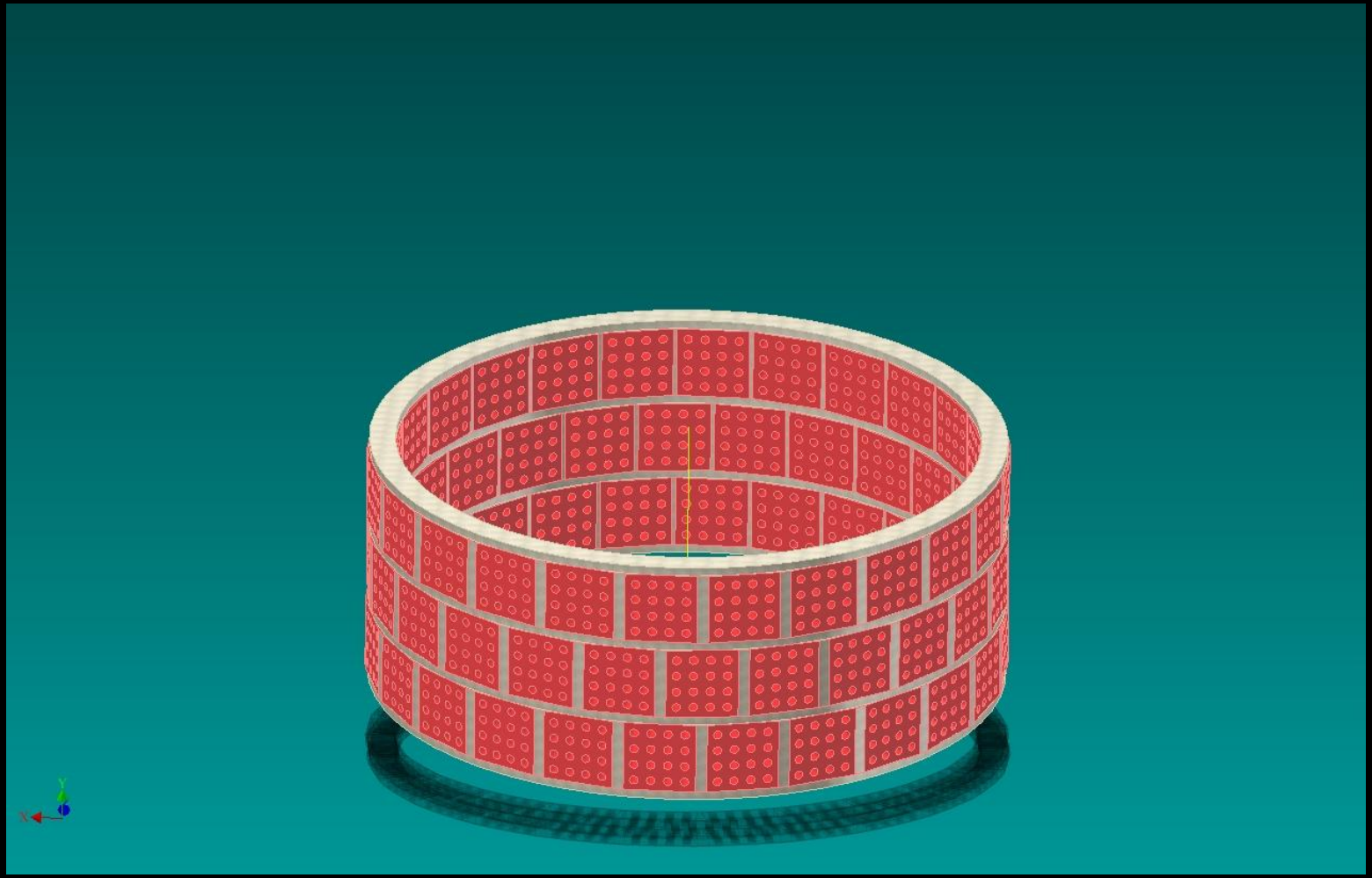
Brick for Meso Bin

First Layer of 24 Bricks

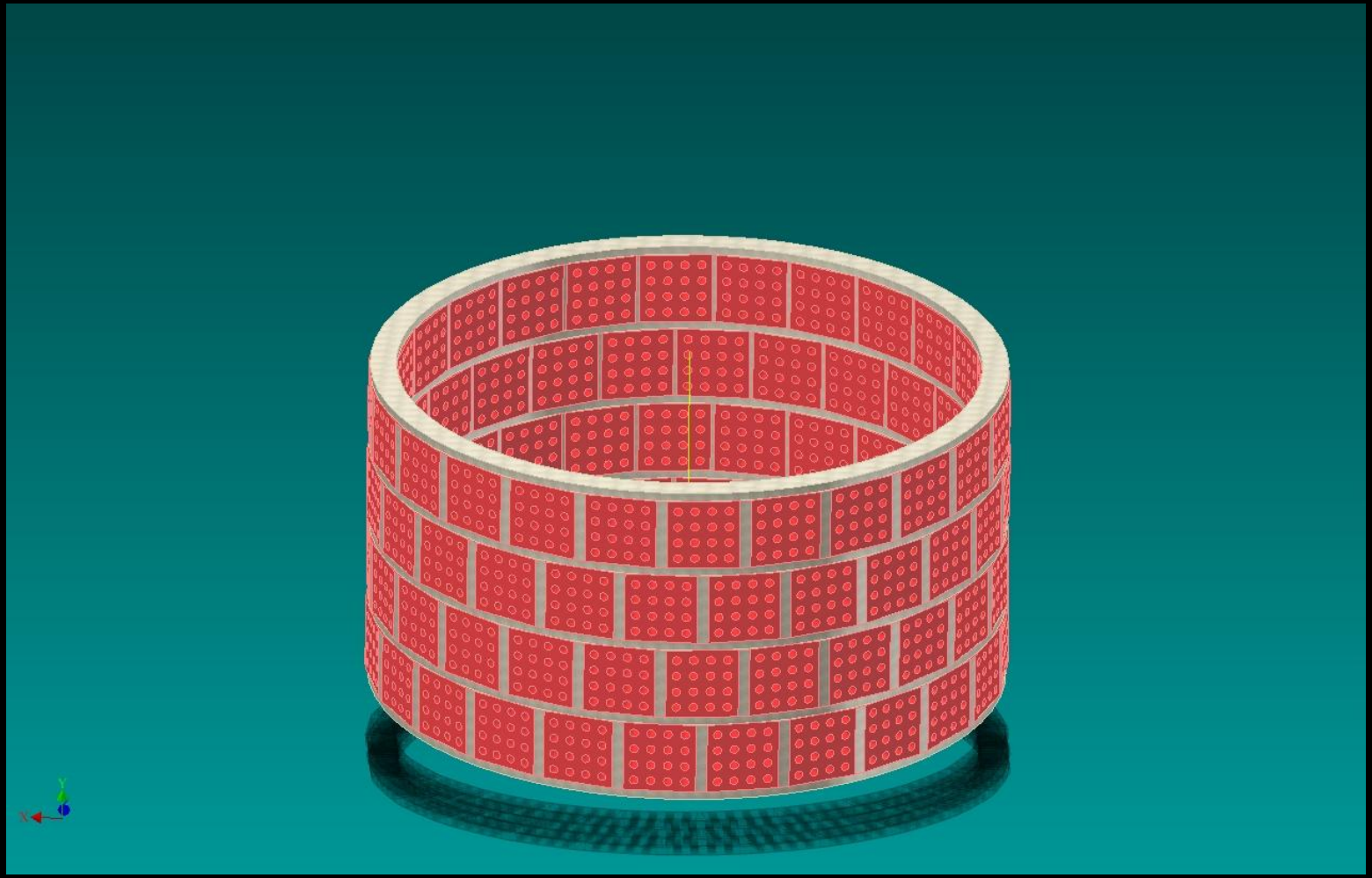
Second Layer



Third Layer



Fourth Layer



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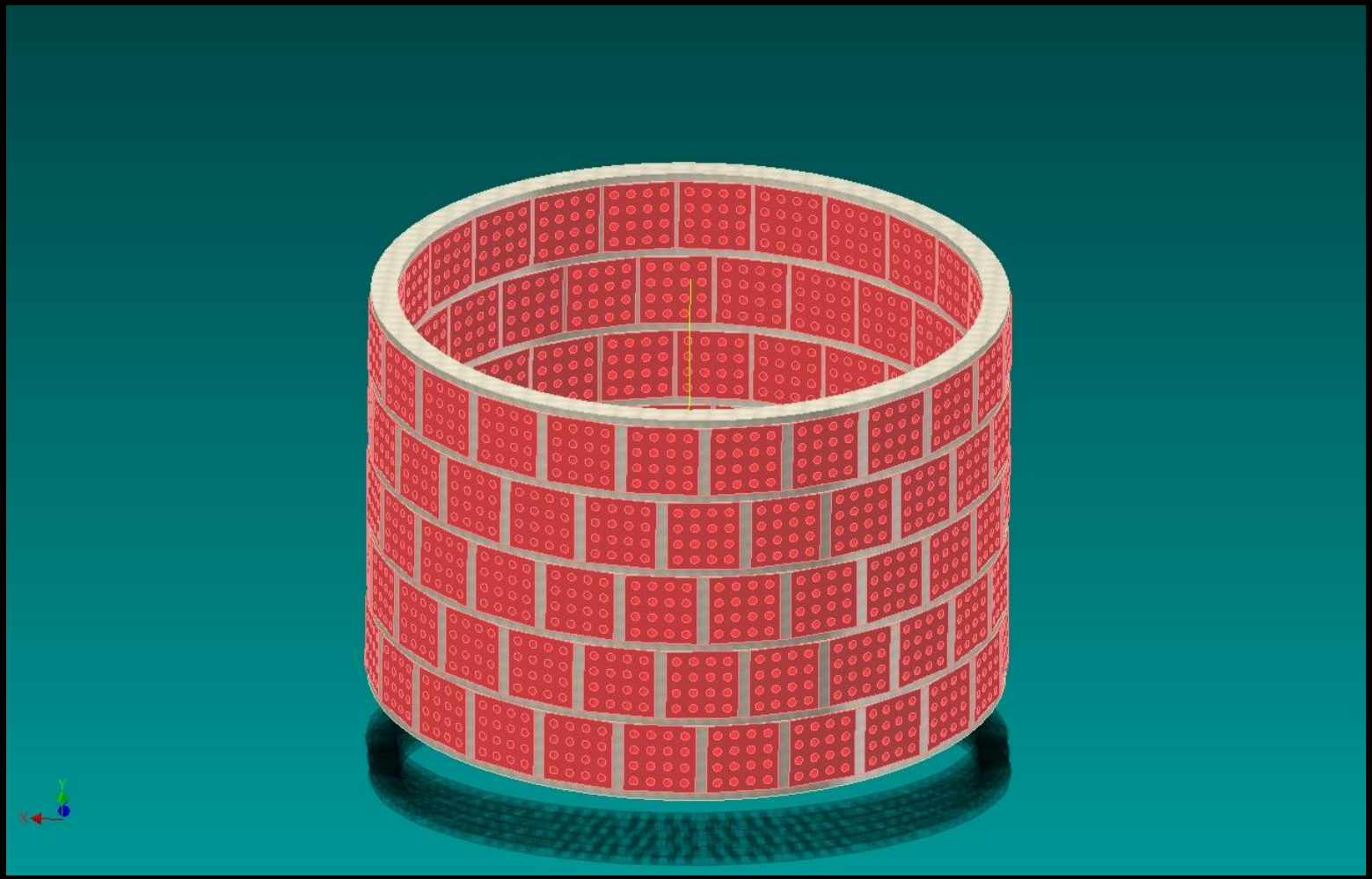
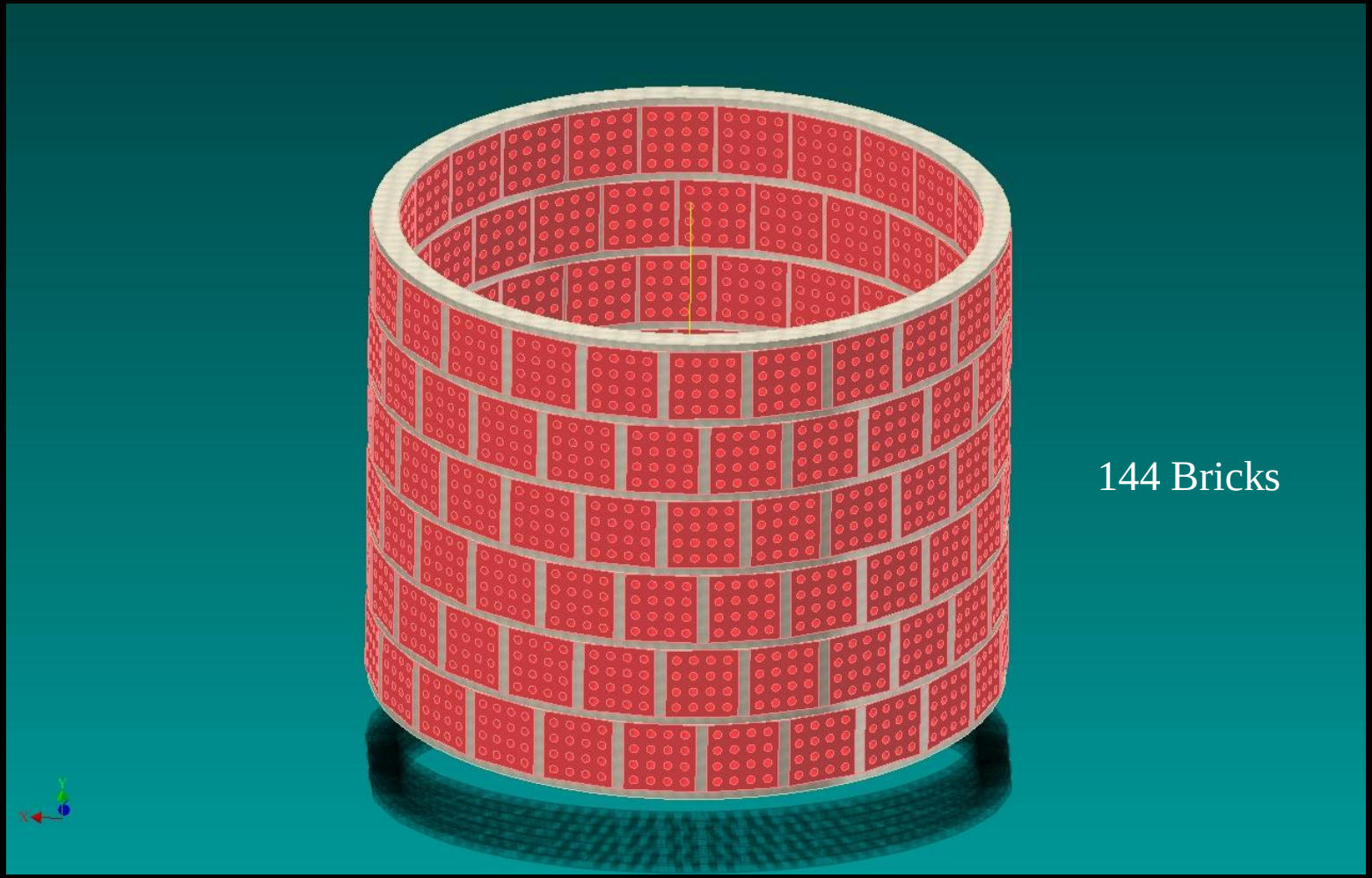
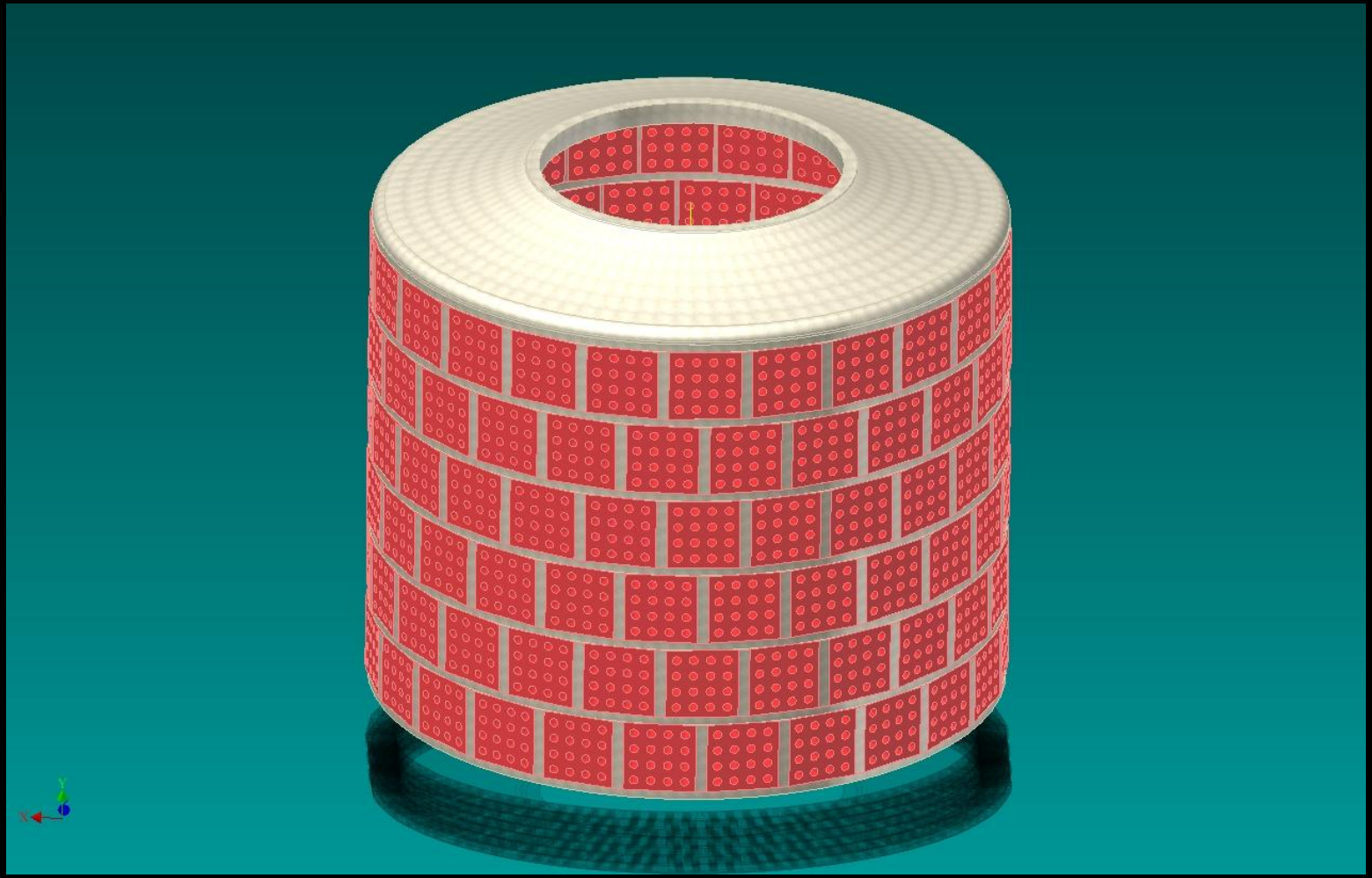


Sixth Layer

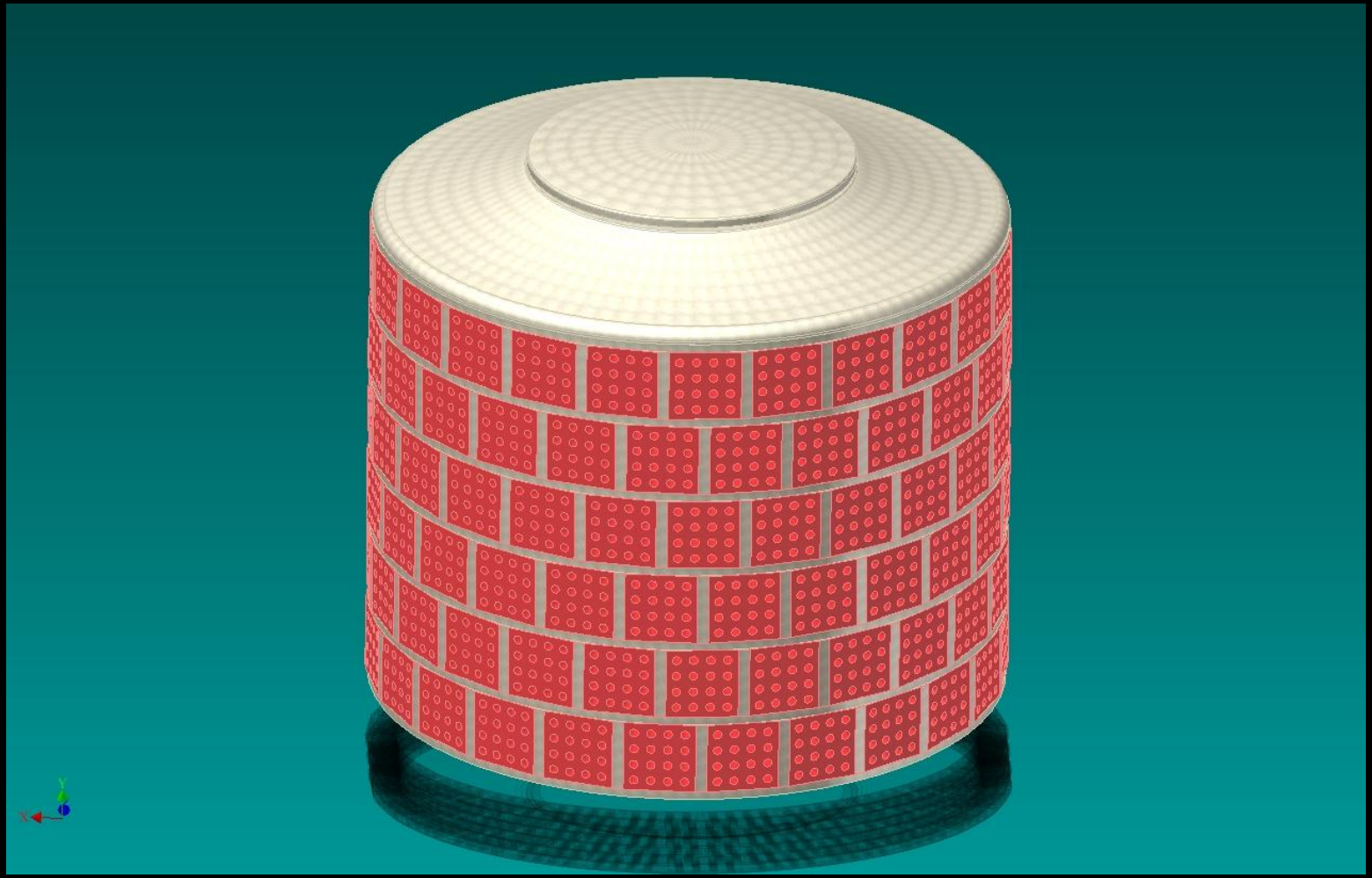


144 Bricks

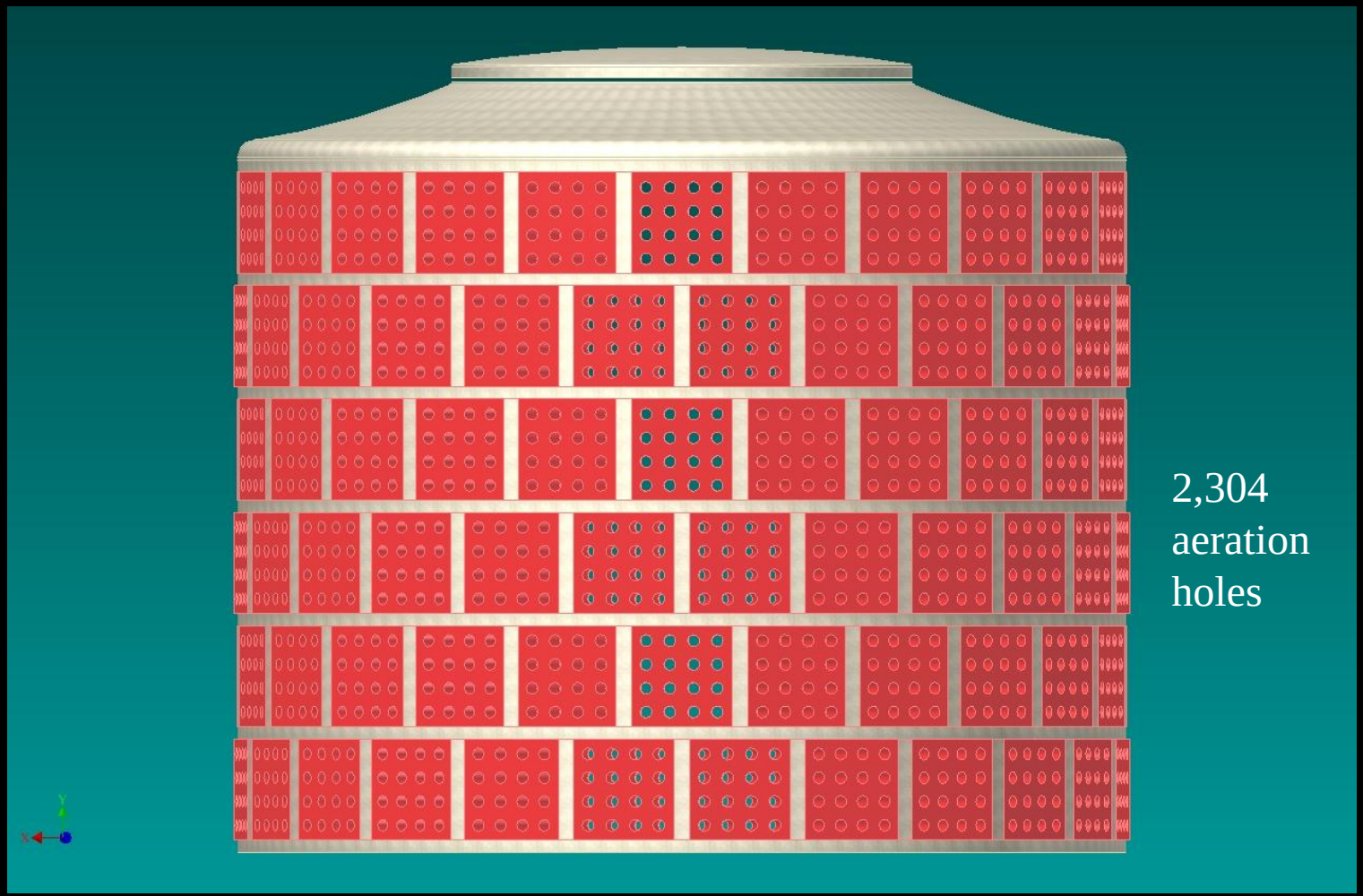
Big Lid



Small Lid



80 CM Bin



2,304 aeration holes

Fabrication cost: $12 USD or 250,000 VND

Lids

The small and large lids are fashioned by local craftsmen.

This technology is available everywhere in Vietnam.

Large Lid

Large Lid

Small and Large Lid

Mesophilic Bin

Shared Bins

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.

If need be, households on an entire section of a street could all make use of the same bin or series of bins.

Tenants in an entire apartment building could share bins.

It is easy to imagine many other ways in which bins could be shared.

A Dalat Scavenger

Scavengers are the only people in Vietnam who, up ‘til now, know how to make money recycling residential waste.

Micro-Economics

We want to expand what scavengers are doing far beyond recyclables into the realm of the whole of bio-waste.

The primary emphasis here is away from big companies with big capital, and to make it possible for a large number of Vietnam's poor to benefit directly from the recycling of waste.

With a lot of people making money recycling waste, more waste gets recycled at higher levels of efficiency and sustainability.

The Final Fraction

Only a small percentage of the residential waste stream cannot be given value by scavengers.

We propose that the fraction > 20 mm be separated manually at decentralized material recovery facilities into two groups: organic and inorganic.

The organic fraction should be shredded and gasified, and the inorganic should be pulverized into a low-grade aggregate.

The Final Solution

The fraction < 20 mm can be separated by means of a small dense medium separator, and once again, the same solution applied.

In the responsible and sustainable management of waste, nothing, absolutely nothing, has to be landfill.

Large Dense Medium Facility

I spent more than 20 years designing such recycling systems.

Large Dense Medium Facility

Large Dense Medium Facility

Large Dense Medium Facility

Small Separator for Vietnam

Black Soldier Fly Technology

Mesophilic bins will eventually be inhabited by the larvae of the black soldier fly (BSF) - some of the most voracious eaters within the natural world.

These larvae 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.

The Adult Black Soldier Fly

BSF Larvae

Larvae Eating Pumpkin

Eating Watermelon

Eating Fish, Fruit and Vegetable Waste

Eating Horse Manure

Same Horse Manure 40 Minutes Later

Same Horse Manure 24 Hours Later

Eating Road-kill and Shrimp Waste

Time Lapse

Input of 6 Kg's Food Waste

1.5 Hours Later

3 Hours Later

4 Hours Later

7 Hours Later

9 Hours Later

22 Hours Later

24 Hours Later

Tough and Robust

BSF larvae can eat just about any type of putrescent waste.

They thrive in the presence of salt, ammonia and food toxins.

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.

Highly Beneficial Insects

- These larvae emit a distinctive odor that drives away all other species of flies.
- 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 with the transmission of disease.

Black Soldier Fly Technology

When the larvae mature, they set out in search of a dark, dry place where they can pupate.

If they are in a mesophilic bin when they mature, they will crawl out through the aeration holes.

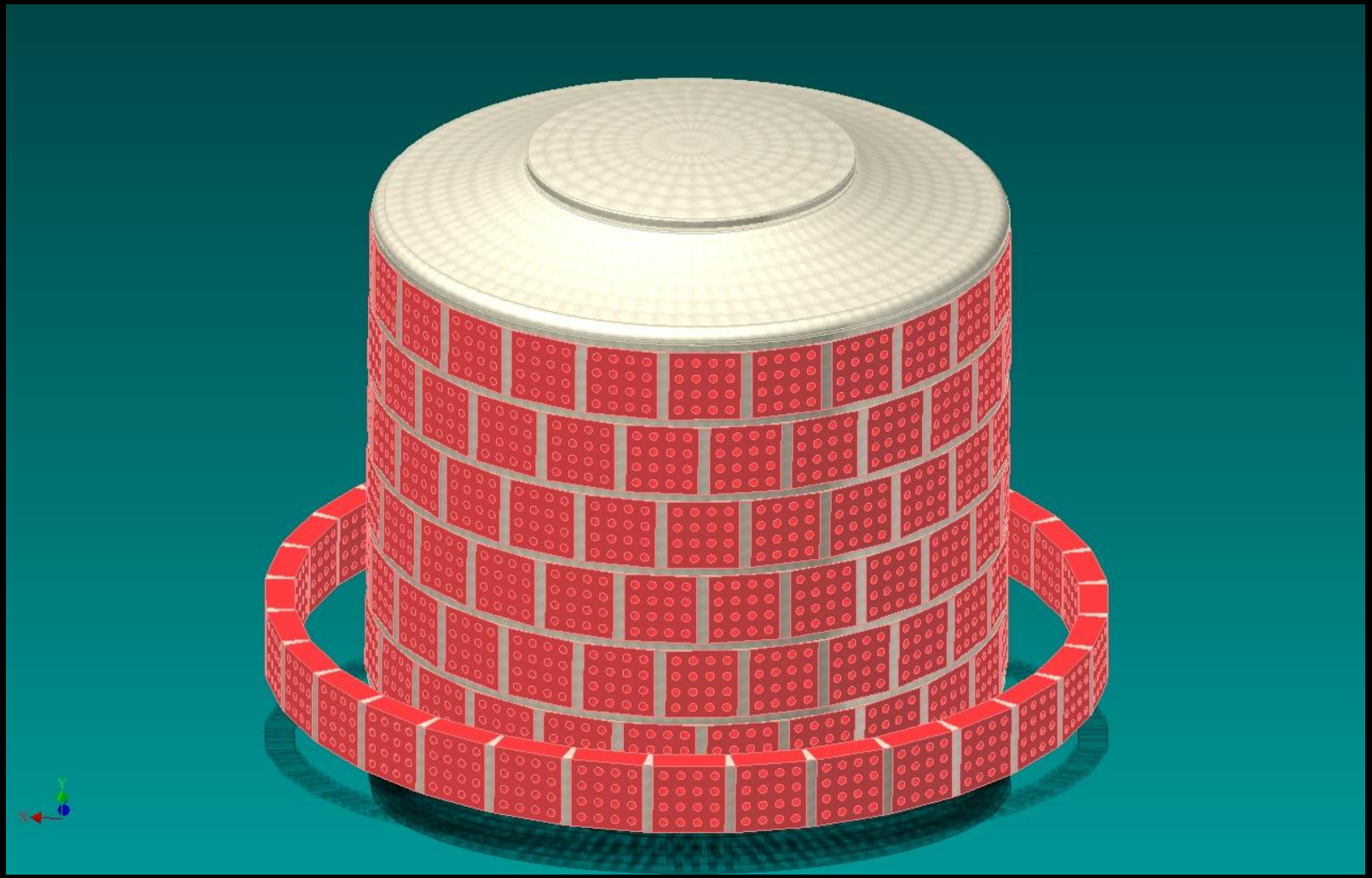
If we construct a gutter at the base of the bin, they will fall into this gutter.

If we put a small amount of dry rice hulls within the gutter, they will feel safe and stop their migration.

They can then be collected from the gutter and sold.

Or chickens can be given access to the gutter where they will collect and eat the larvae.

Meso Bin with Gutter

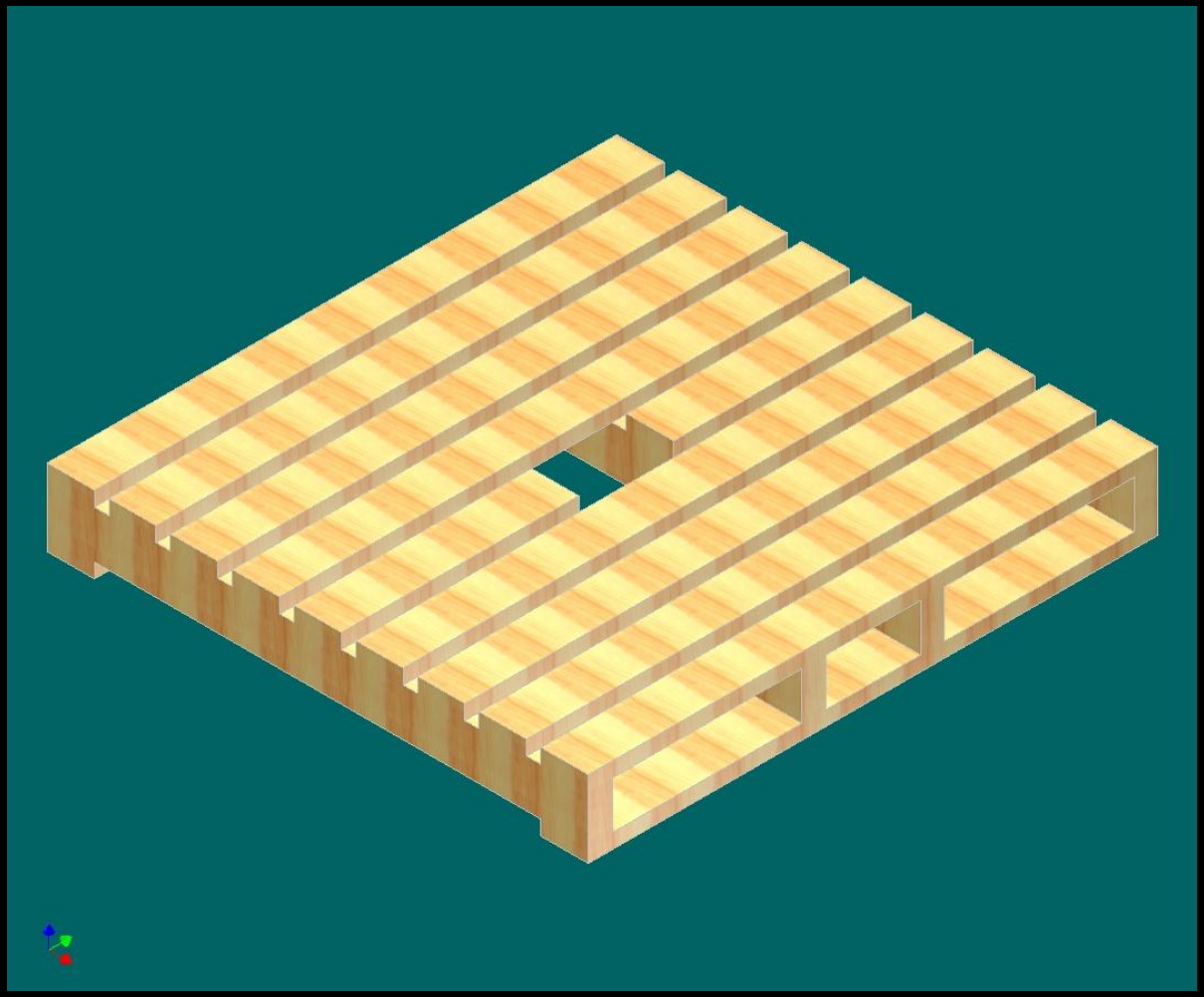


Biopod

We also make a plastic bin, called a biopod, that has two small ramps that allows larvae to crawl out of the waste and fall into a bucket.

We make a large biopod (4-foot) and a small one (2-foot).

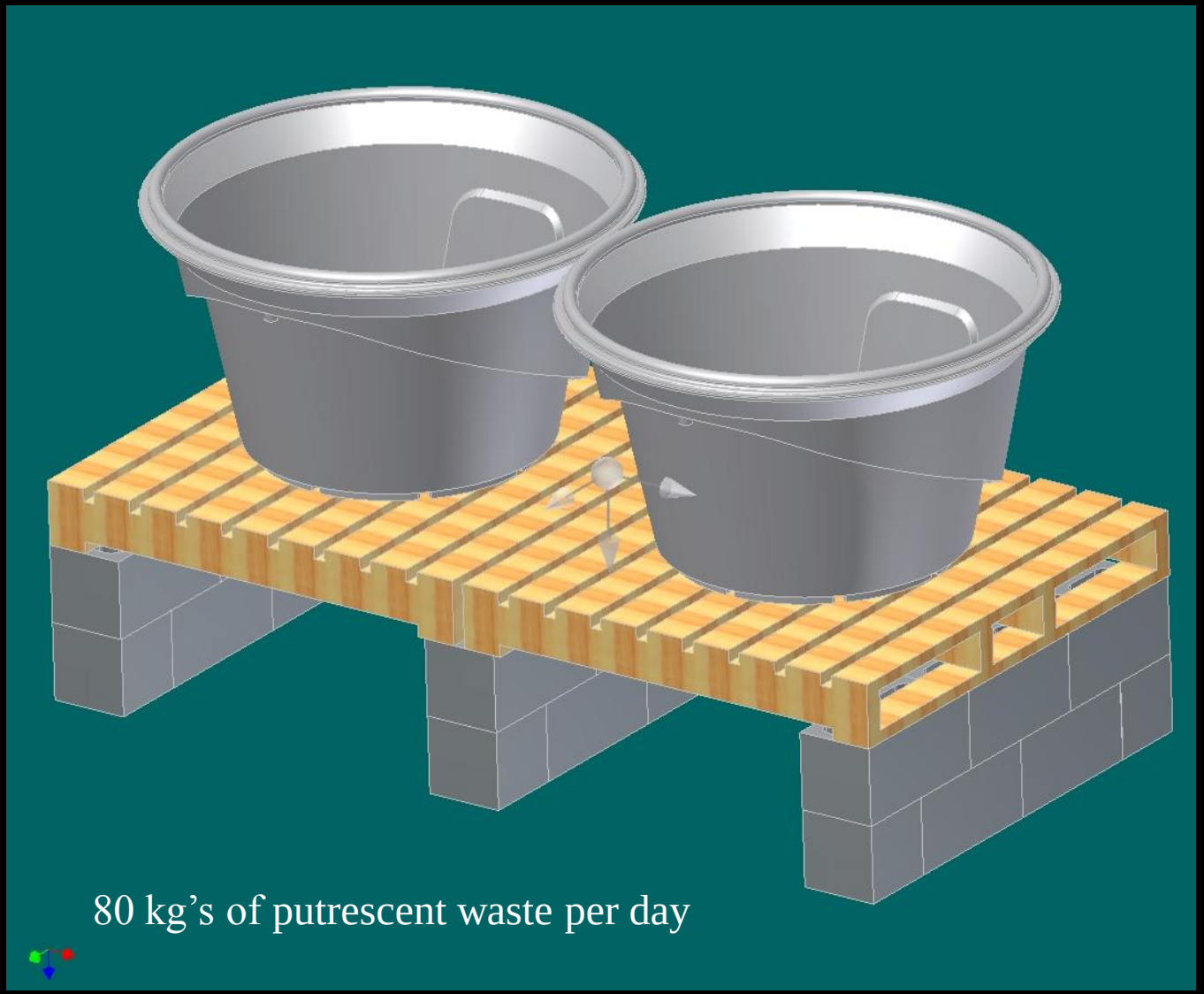
Pallet



Pallet on Blocks

This unit can handle 40 kg's of putrescent waste per day.

Pallets on Blocks



Menhaden Fish Meal

From a third to a half of BSF 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.

First Biopod in Binh Dinh

Here we see the first biopod set up in Binh Dinh province as well as the first larvae harvested from it:

Red Worms

BSF residue constitutes an ideal substrate for red worms.

In fact red worms grow 2 to 3 times faster on BSF residue than on partially decomposed food waste.

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.

Red Worms

Together they form a perfect partnership, recovering all possible nutrients.

Red worm castings constitute one of the best growing mediums for plants.

They greatly reduce the need for fertilizers.

Worm Castings

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).

http://www.scribd.com/doc/30909297/Biochar-Article

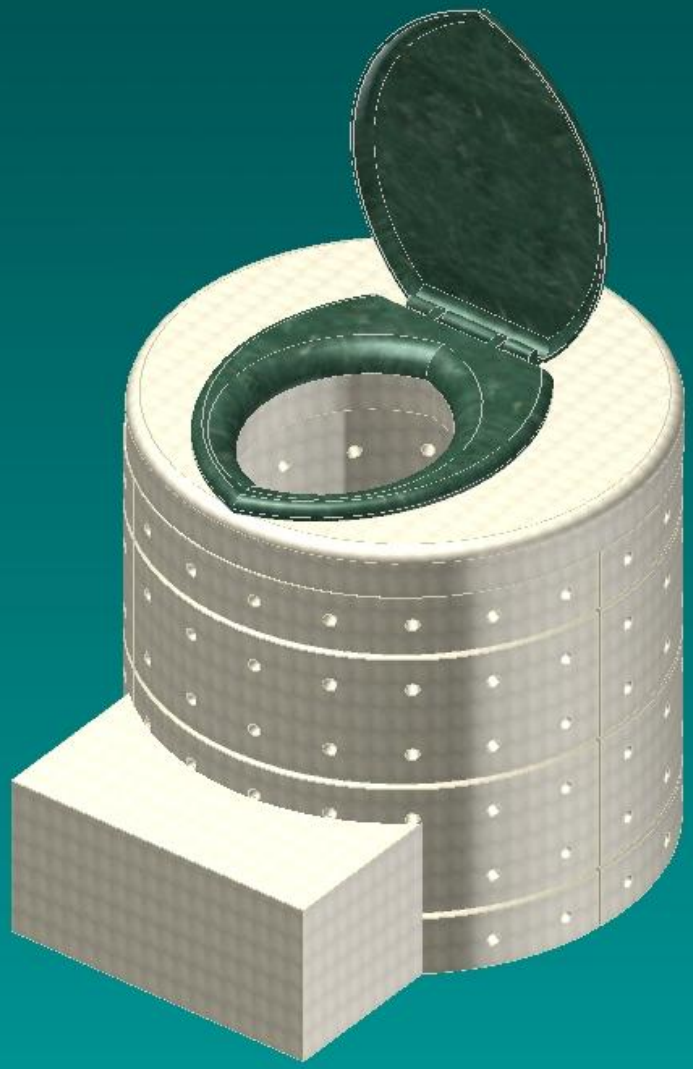
Human Waste

We can also use the mesophilic bin for the processing of human feces.

But in this case, urine is kept separate at source and routed into a plastic container.

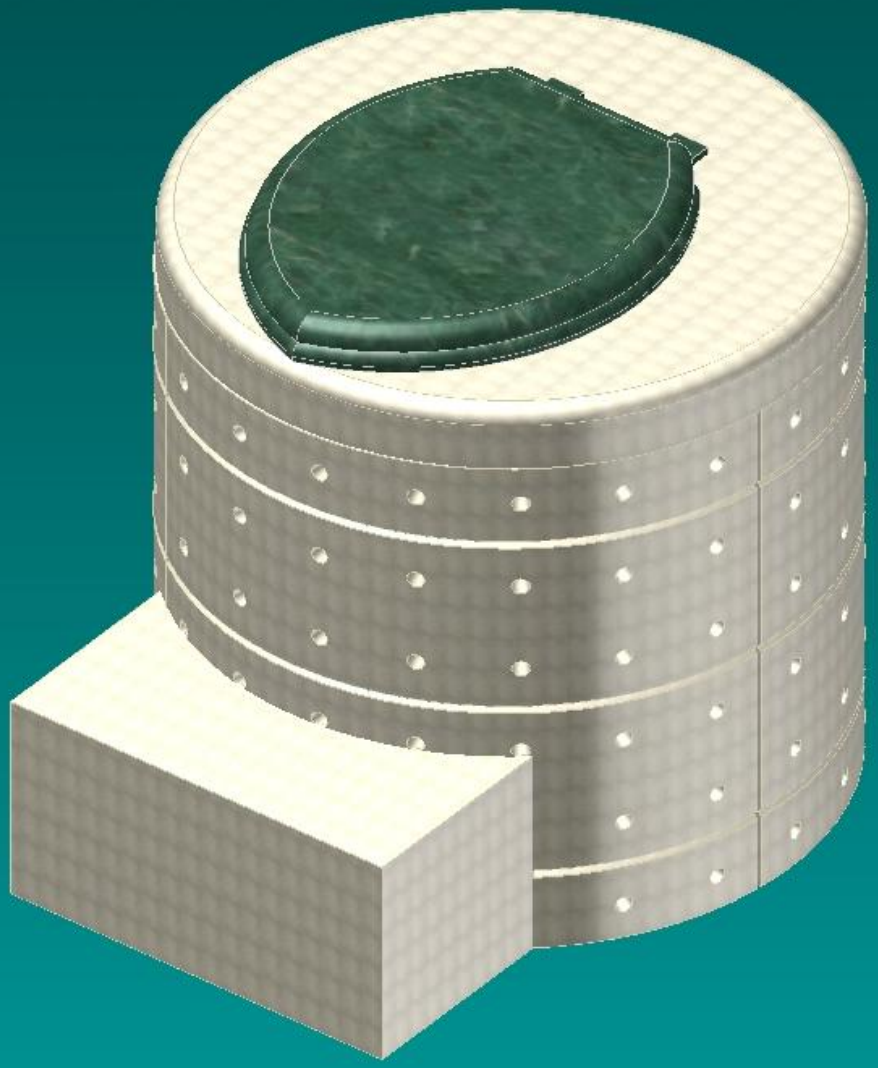
Toilet Seat & Step

The plastic toilet seat shown here costs about $2.11 USD.



Top View

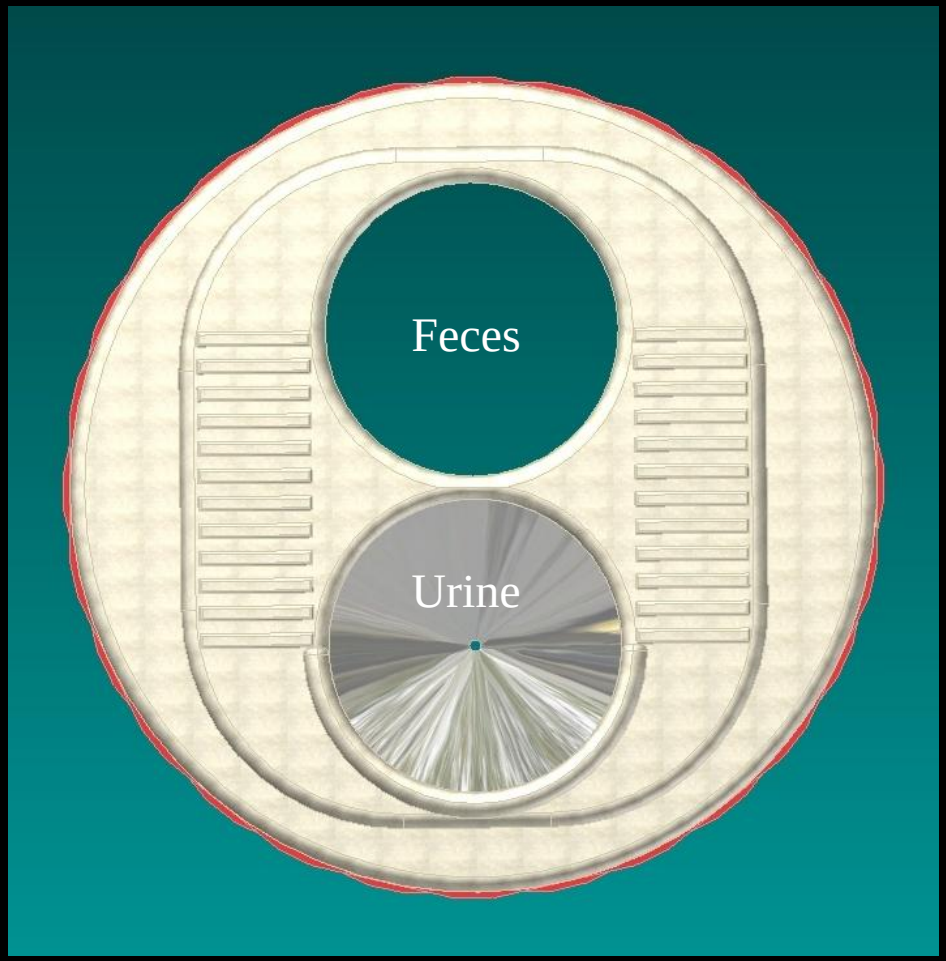
Complete Pedestal Toilet



Squatting Toilet

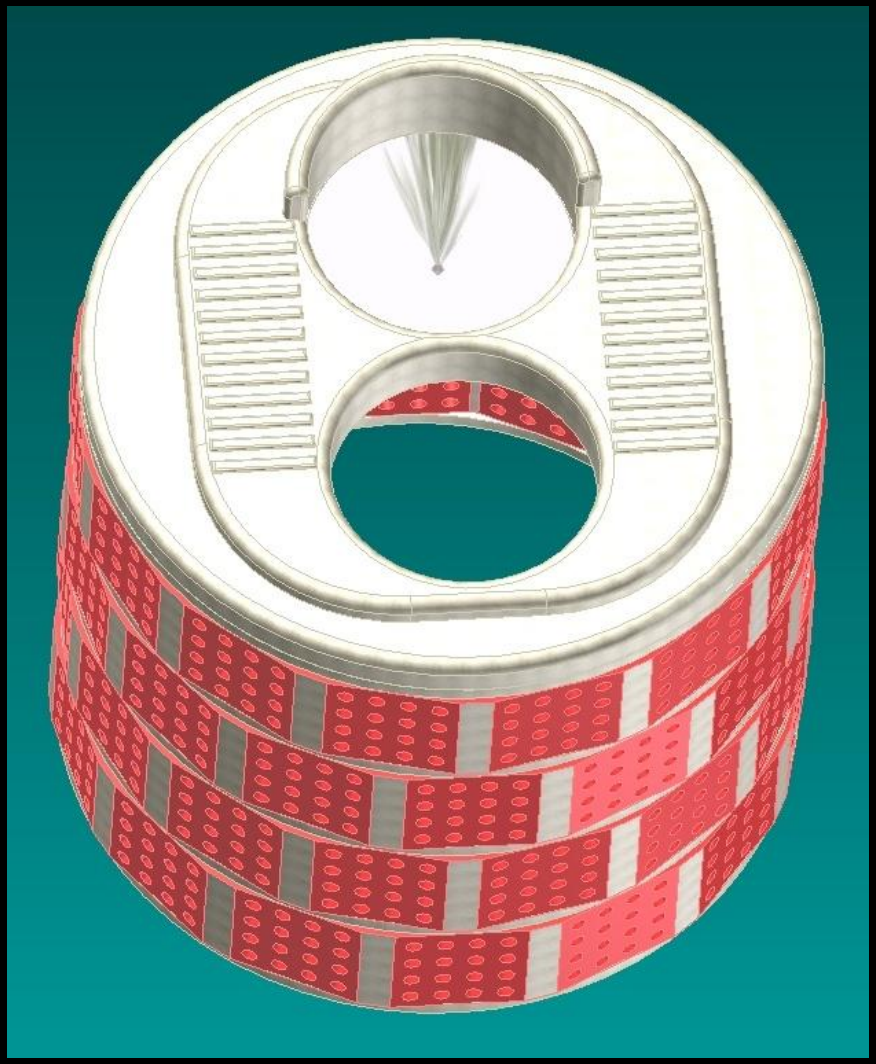
Another option is a squatting toilet.

Squatting Toilet (top view)

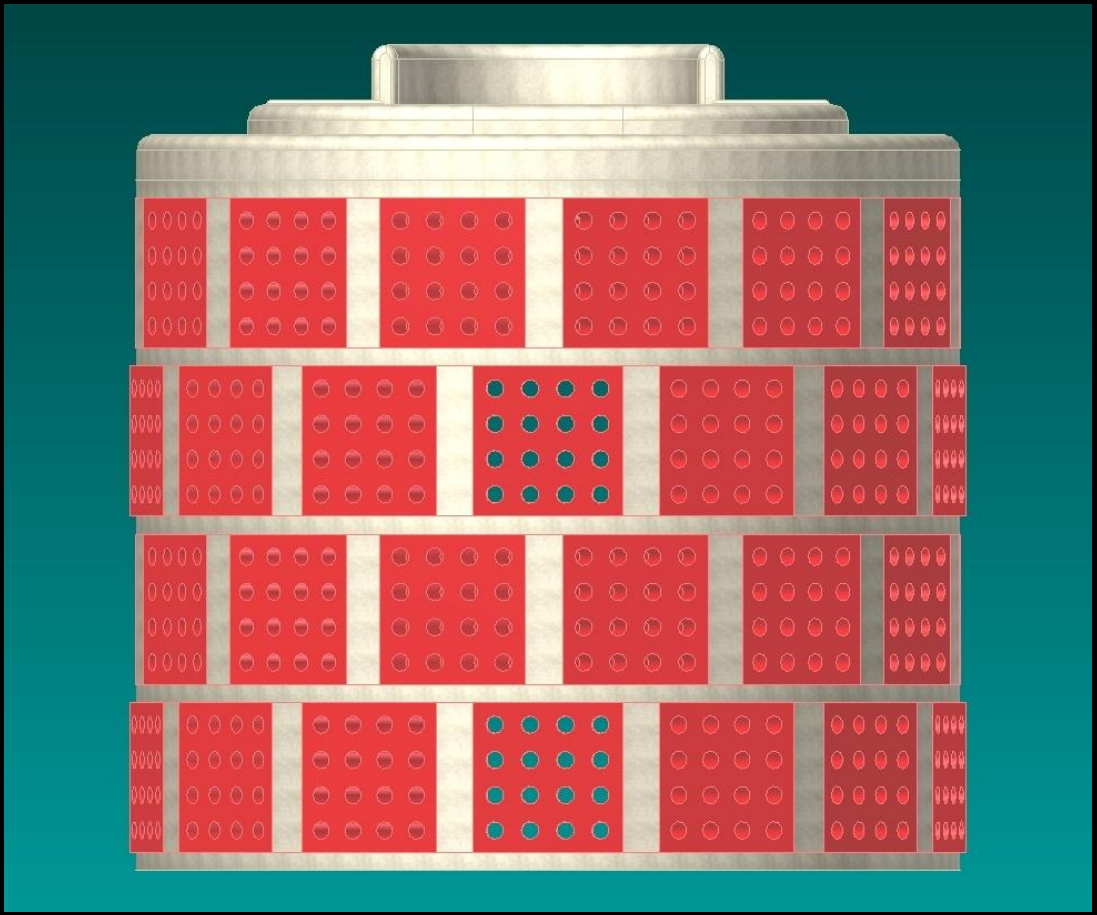


Urine Diversion

Squatting Toilet



Squatting Toilet (side view)



Feces Recycling

The feces storage bin is inhabited by BSF larvae within about 15 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.

But what happens to the urine?

Three Solutions

1. Urine could be collected from urine-diverting toilets, diluted and directly applied to certain crops as a source of NPK.
2. Urine can be collected by scavengers and farmers, and used as a source of NPK in their thermophilic composting operations.
3. Urine can also be processed on site by means of duckweed.

The Duckweed Solution

Duckweed is a tiny aquatic plant that is perhaps one of the fastest growing plants on earth.

It can double its mass in less than 24 hours.

As it floats on the surface of the water, it can reduce quantities of NPK in water down to almost undetectable levels.

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.

Duckweed

A Duckweed Pond

Urine would be flushed from the urine-diverting toilet into a small duckweed pond located near the toilet.

Since duckweed covers the entire surface of the pond, very little ammonia would volatilize and give rise to unpleasant smells.

The following picture depicts a 2 x 6-meter pond used to process the urine of a small restaurant in the Mekong.

A Urine-Processing Pond in the Mekong

Sun-dried Duckweed

The duckweed harvested each day makes a wonderful food for chickens, ducks and pigs.

Air Pollution

Tens of thousands of people in Vietnam die each year from the pollution associated with the burning of biomass either as a fuel or as a means of disposal.

To solve this problem we designed top-lit, updraft, forced-air gasifiers of several sizes.

These gasifiers produce a beautiful blue flame that in turn produces no smoke.

These gasifiers operate quite well on many types of fine and undensified biomass wastes such as rice hulls and coffee bean husks.

Undensified Biomass

Rice Hulls

Coffee Bean Husks

This TLUD Gasifier

This gasifier is a vertical cylinder or pipe with a removable burner on the top and a fixed 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.

All is fabricated in a heat-resistant stainless steel to last indefinitely.

Start-up

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

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.

The burner is then placed on the reactor, and the gasifier is in full gasification mode.

The lid of the gasifier and the burner are the same.

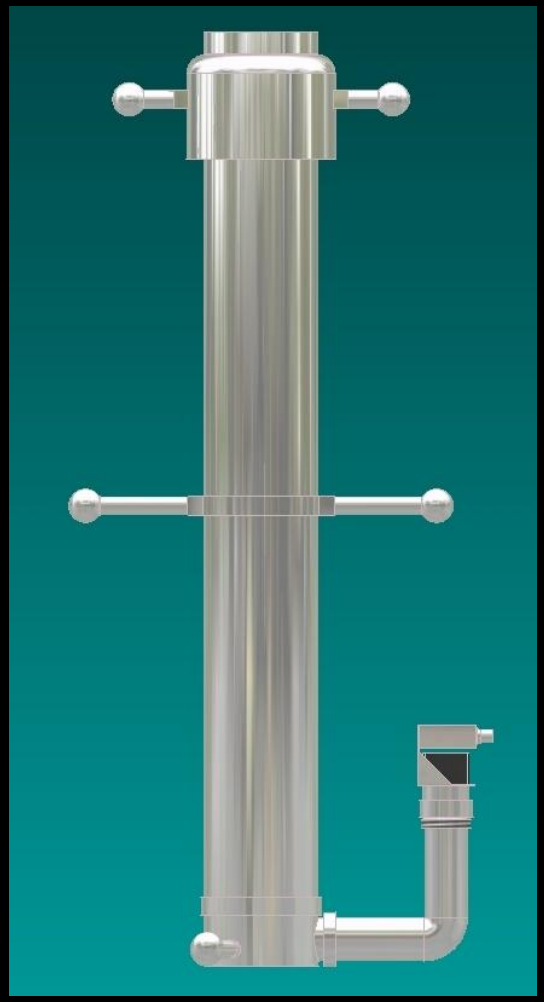
Here there is none of the inefficiency or loss of heat associated with remote burners.

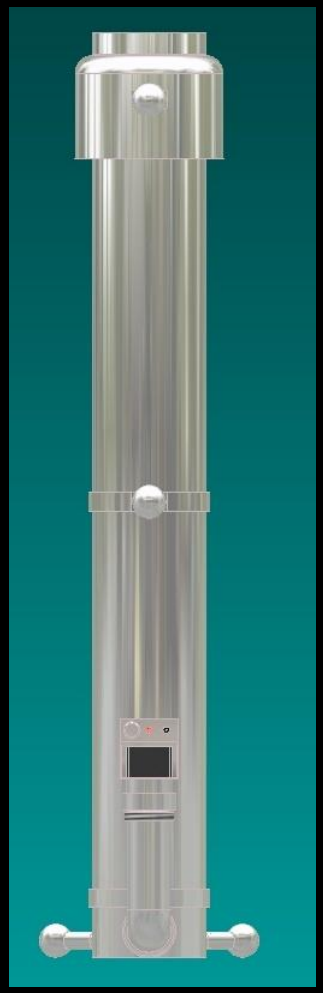
Four Models

Four models of gasifiers are now being fabricated:

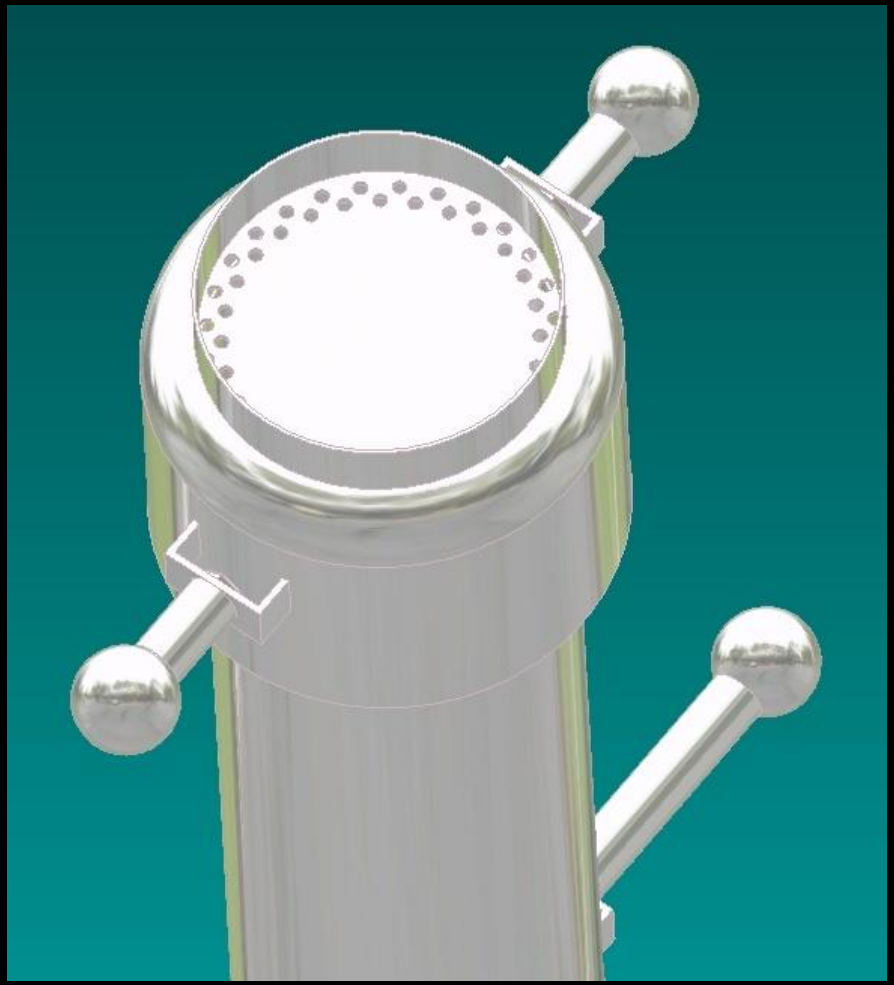
1. model 100 = 1 kg to 2 kg of biomass per hour
2. model 150 = 2 kg to 4 kg of biomass per hour
3. model 250 = 5 to 10 kg of biomass per hour
4. model 500 = 20 to 40 kg of biomass per hour

The 100 Gasifier





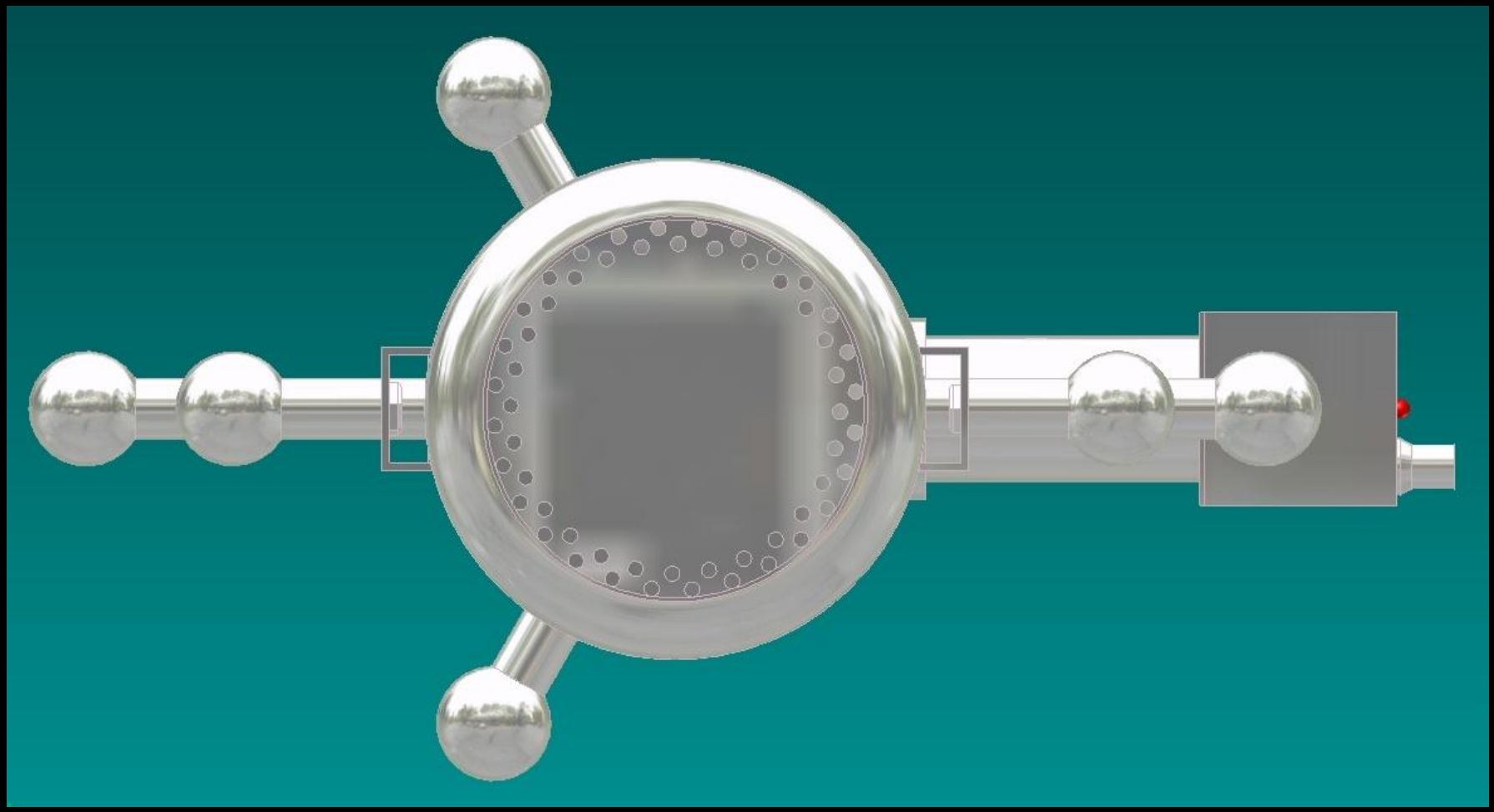
The 100 Gasifier Burner



Removable Fan Assembly

The power consumption here is less than 1 watt

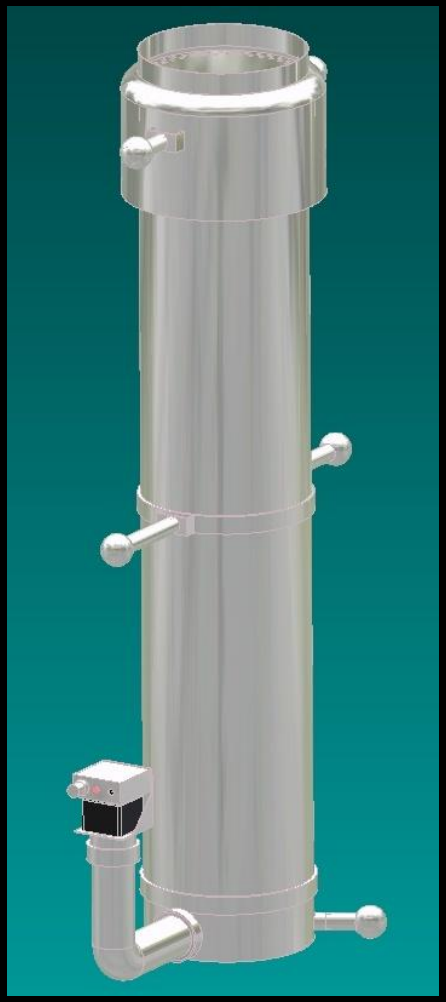
The 100 Gasifier (top view)

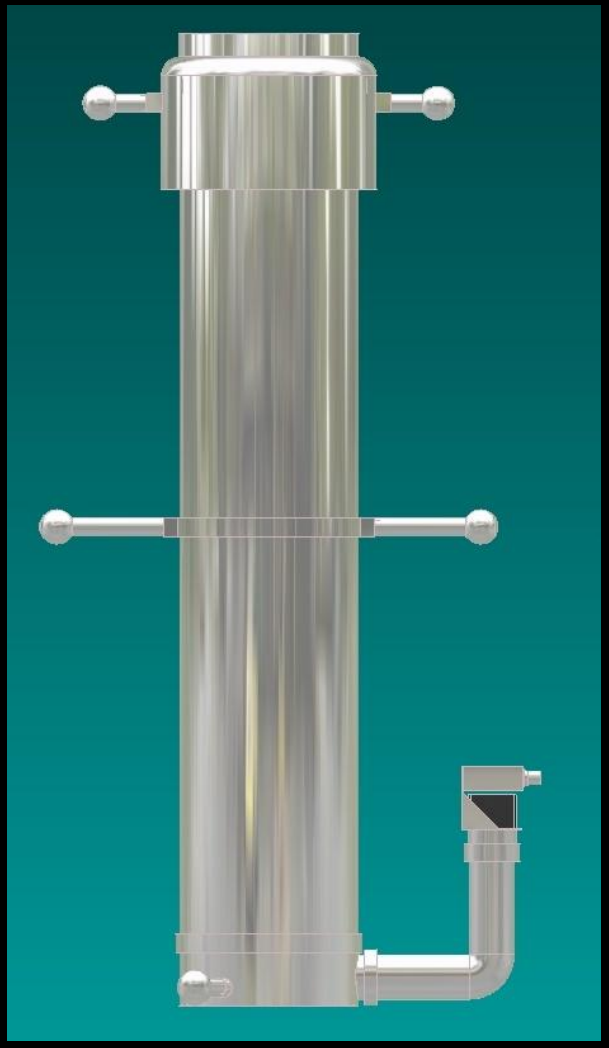


The 100 Gasifier in Operation

The 100 Gasifier

150 Gasifier

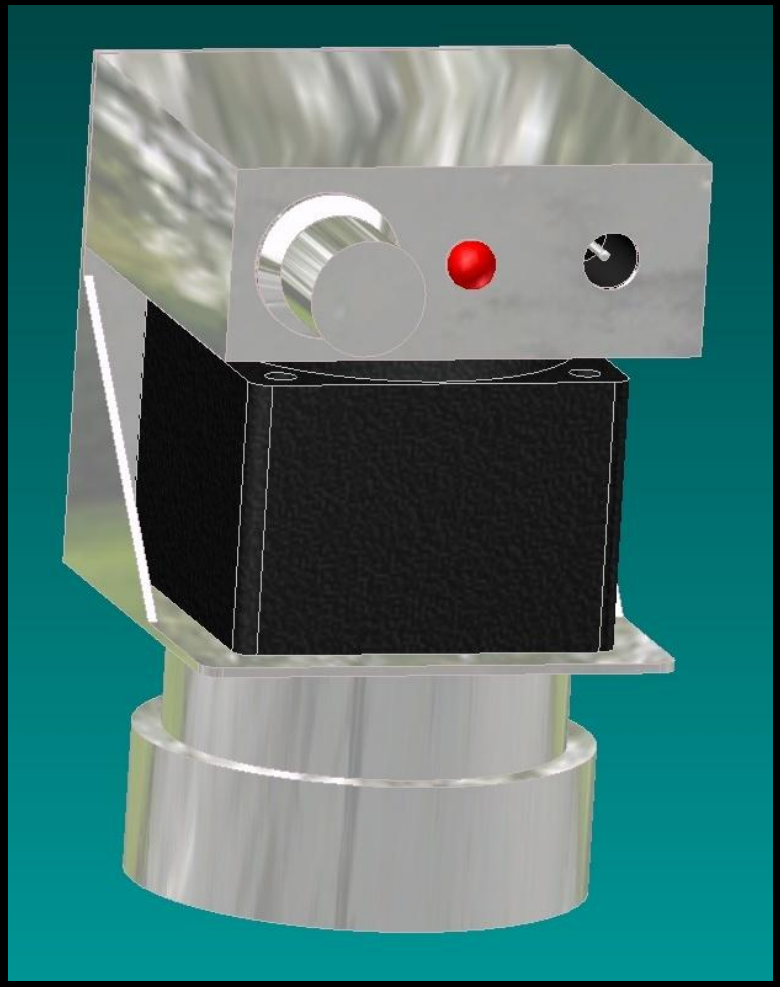




Fan & Speed Regulator

Fan speed =
16,000 RPM

Life expectancy =
65,000 hours at 40 C
or 7.5 years of
non-stop operation.



Air Delivery Pipe

This pipe screws on to the reactor.

Screw-On Handle

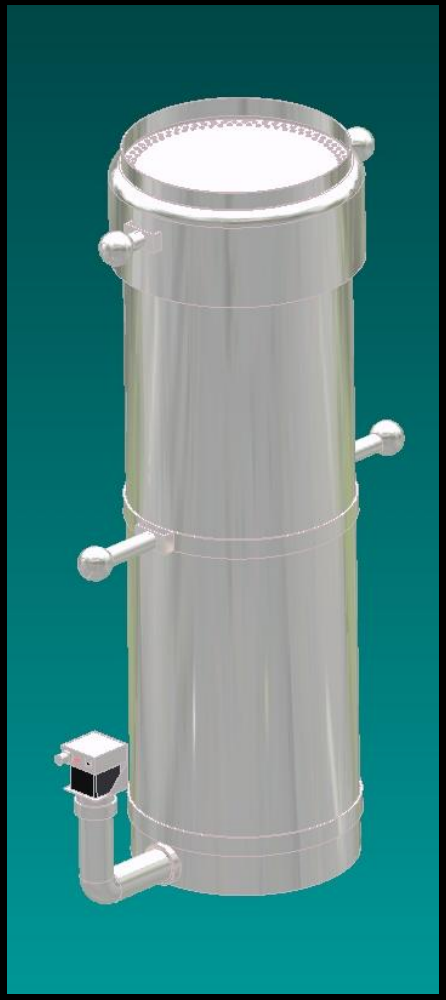
100 and 150 Gasifiers

The 100, 150 and 250 gasifiers make use of the same air delivery pipe, the same fan and speed regulator and the same handles.

All appendages screw on to the reactor and are removable.

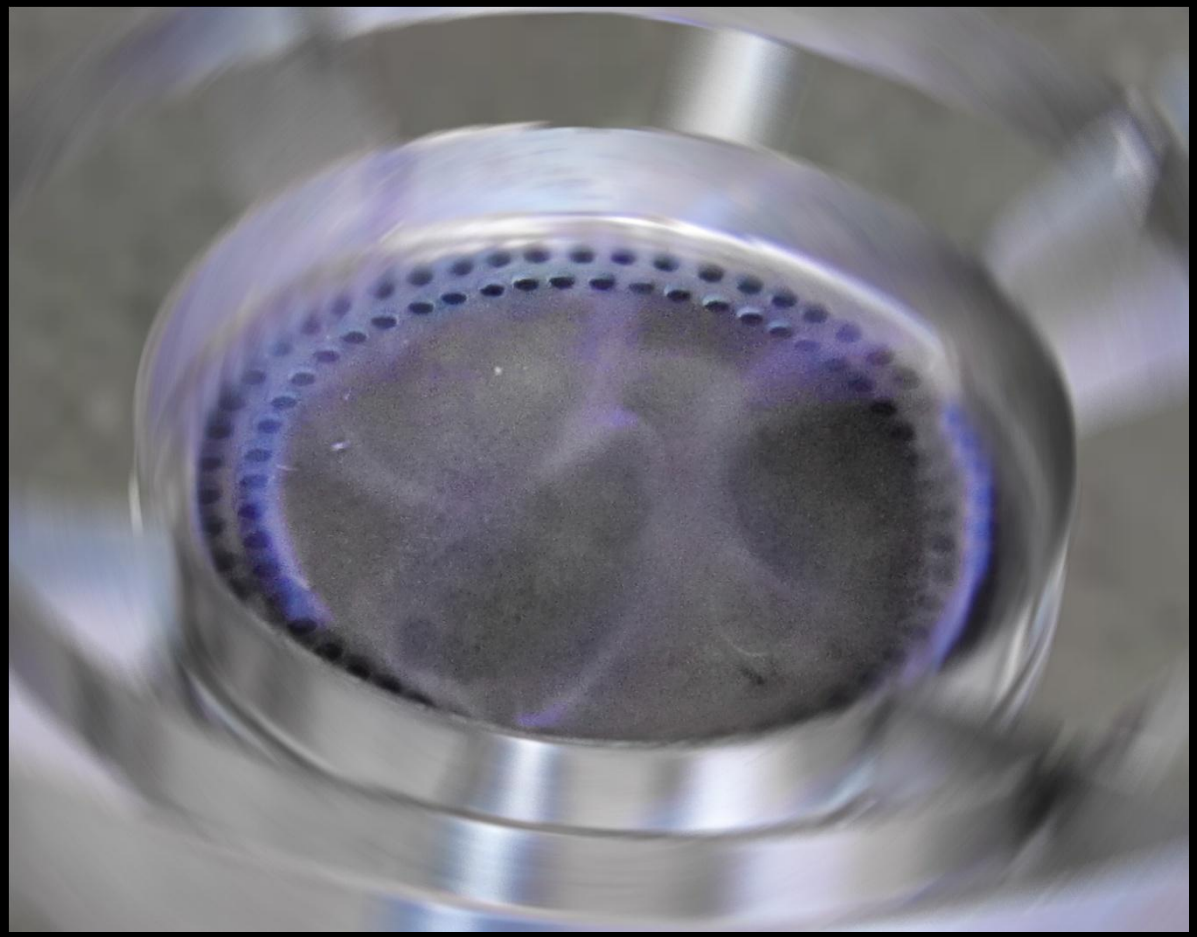
This greatly reduces the shipping volume of gasifiers.

The 250 Gasifier



100, 150, 250 and 500 Gasifiers

Beautiful Blue Flame



Gasifier below Stove Top

Selling Prices

1. the 100 gasifier = $30 USD (1.5 kW)
2. the 150 gasifier = $50 USD (3.5 kW)
3. the 250 gasifier = $100 USD (10 kW)
4. the 500 gasifier = $250 USD (40 kW)

These prices will drop considerably when these gasifiers are produced in large numbers.

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.

Stove Tops

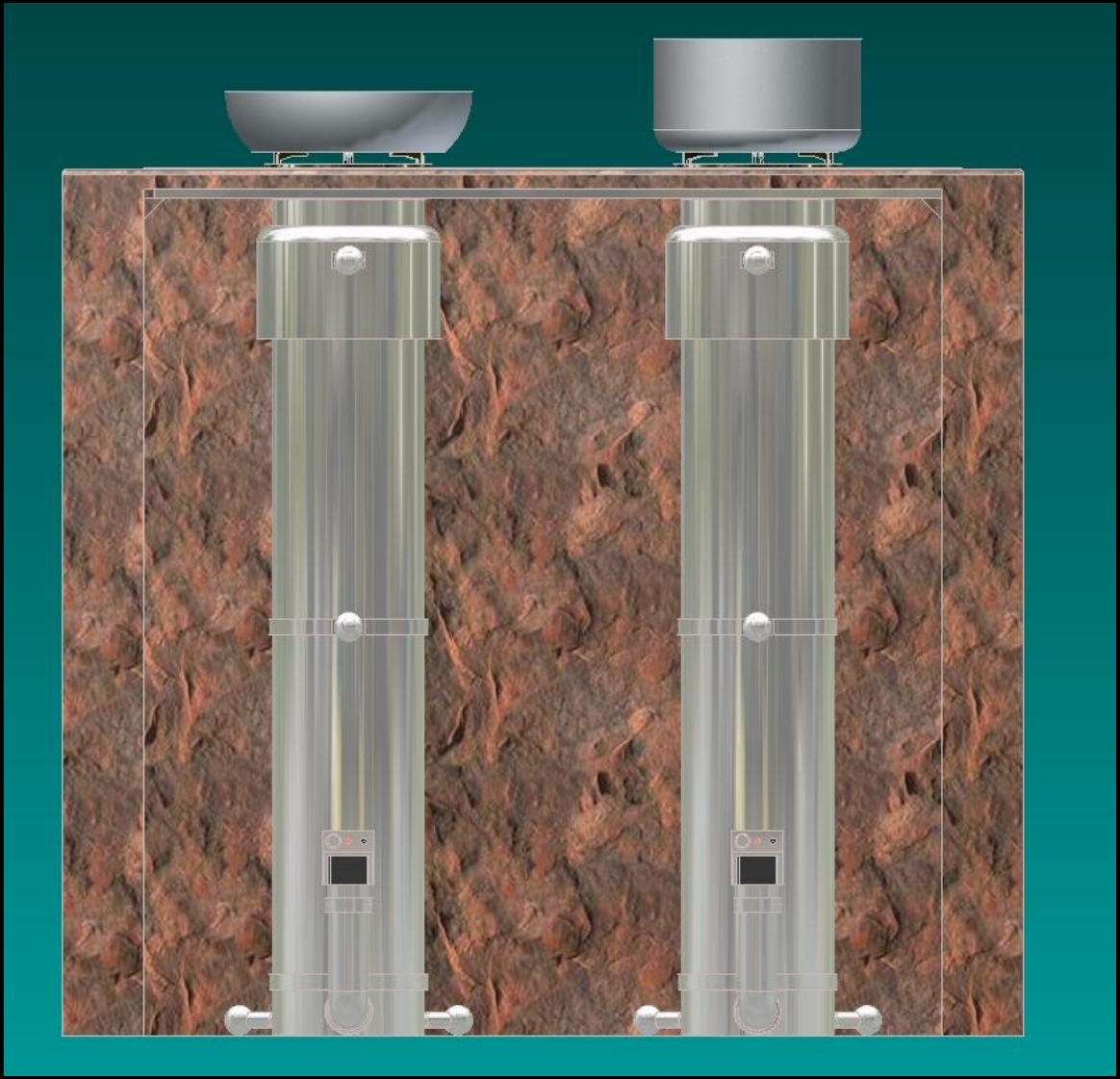
For safety reasons, gasifiers should be situated within enclosures.

An enclosure can be cheaply fabricated out of brick or more expensively out of stone or granite.

A top stove is situated above the enclosure to support cooking utensils.

Enclosures

Enclosures



The Shredding of Cellulosic Waste

Wood, branches and other waste of a high cellulosic content can be shredded by means of low-cost shredders, as designed by the SPIN organization in Hanoi.

One model of shredder costs about $35 US or 735,000 VND, and can process up to 600 kg's of waste per hour.

The shredded material can be composted or gasified.

Benefits of Biochar

Biochar locks carbon in the soil for over a 1,000 years.

Like worm castings, it promotes the growth of beneficial soil microbes and greatly reduces the need for chemical fertilizers.

It often increases plant yields in a dramatic way.

Dr. Boun Suy Tan of Cambodia recently did a study where he mixed into the soil 5 tons of compost and 40 tons of biochar per hectare.

He obtained a 3-fold increase in the yield of rice.

Benefits of Biochar

Next we see the results of an experiment carried out in Laos in April, 2011, on water spinach.

All three treatments received the same amount of fertilizer.

The biochar used in this experiment was rice hull biochar from our TLUD gasifier.

Benefits of Biochar

The Value of Biochar

In Vietnam many forms of biomass such as rice straw and rice hulls are simply dumped or uselessly burned.

In most cases they are available free-of-charge.

About half of the weight of this biomass can be converted through gasification into a biochar worth at least $50 USD/ton when incorporated into compost,

or about $500 USD/ton when incorporated into vermi-compost.

Rice hull biochar is easily activated, and activated carbon currently sells from $500 to $ 2,000 per ton.

The Value of Rice Hull Gas

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.

As we have seen, 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).

The Value of Rice Hulls and Straw

Therefore one kg of rice hulls has a combined value in gas and biochar of 4,400 VND ($0.21 USD).

One ton of rice hulls has a combined value of $210 or 4.4 M VND (roughly the same value of a ton of paddy rice).

Vietnam produces yearly about 7,900,000 tons of rice hulls, which, if gasified, would have a value of $1.659 billion USD.

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.

Energy Abundant and Free

There are thousands of small-scale commercial activities with a high demand for heat.

For example, brick kilns can use gasifier heat and would produce no smoke or other pollutants in making bricks.

The brick kiln can sell both bricks and biochar.

Noodle shops and pho shops, for example, can sell food and biochar.

The list goes on and on.

An Integrated Process

Food waste can be sterilized with gasifier heat and fed to pigs.

Rice wine can be distilled with gasifier heat, and the mash can be 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.

Biochar can be added to the BSF residue fed to red worms, and this accelerates their growth and produces more worms.

Biochar, compost and vermi-compost all work together in reducing the need for fertilizers.

Larvae Grown on Pig Feces

Larvae Grown on Pig Feces

All of the pollution and odor associated with pig farms is completely eliminated.

On a pig farm in the Mekong

Pig

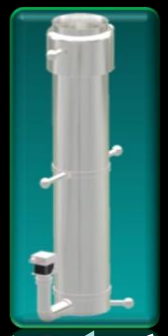
larvae

Feces

Cooked with gasifier heat

Fresh or Cooked

Fresh, fermented or cooked



Urine

Fresh or Cooked

Char

Biomass

Char

Residue

duckweed

plants

Residue

worms

Power Generation and Methanol Synthesis

This same gasification technology can be used to generate electricity via a gen-set or an ORC unit.

Gasifier gas can also be converted into methanol to power automobiles and motorbikes.

Gasifier heat can be directed to an adsorption refrigeration unit to make ice.

This is the cheapest way to make ice, and it requires no electricity.

Thermophilic Composting

To make a good thermophilic compost, we need carbon, nitrogen, water and oxygen in the right proportions, and soon temperatures reach as high as 65 C.

But if it rains on the compost pile, if the material dries out, or if there is no exchange of gases, then the composting process stops.

We might try to house this process in a building, or put a roof over it, but this generally is too expensive.

Thermophilic Composting

The best and cheapest way to do true thermophilic composting lies in laying the waste outdoors in windrows and covering it with special fabric called a compost fleece.

This is a spun-bonded nonwoven fabric that prevents rainwater from entering the pile, and yet it still allows for the exchange of gases.

A compost fleece weighs as little as 150-200 grams per m2, it costs about $1.00 USD (21,000 VND) per m2, and it lasts as long as 10 years.

TopTex Fleece

Thermophilic Composting

For less than $50 USD (1 M VND), a scavenger could be equipped with all of the fleece needed to earn a good living.

She could collect and transport waste down a street where a small composting site could be made available to her by the city.

She could collect compostable materials from markets, and could be provided with a site nearby where she could compost these materials.

Thermophilic Composting

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.

If a scavenger could sell 5 or 6 tons of compost per month at a value between $25 and $50/ton, she could make far more money than she makes collecting and selling recyclables.

Fruit and Vegetable Waste

There is a lot of fruit and vegetable waste coming from markets and packing houses that is highly nutritious and is far too valuable to compost.

It can be fed directly to poultry, animals and even certain fish.

But the direct feeding of such waste is limited, since it quickly degrades.

Culling and Packing

Choosing the Best Solution

Of course a lot of this waste could be sterilized and cooked using gasifier heat, but it often turns bad before it can be cooked and sterilized.

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.

Lactic Acid Fermentation

The best solution for certain types of fruit and vegetable waste is lactic acid fermentation.

Here lactic acid bacteria consume water-soluble carbohydrates 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.

Nothing Could be Simpler

All it takes, for example, is a bit of molasses (5% of total mix) and rice bran (10% of total mix) to transform one kg of cabbage waste into a nutritious pig feed.

The nutrients in the molasses and rice bran are not lost, and often they would have been fed in any case to the pig.

The chopped cabbage, molasses and rice bran are simply put into a sealed plastic bag or drum.

A starter culture is not required.

Fermented Cabbage

Increased Profitability

The market or packing house would have two products to sell: fruit and vegetables for humans and silage for pigs.

Fermented cabbage, for example, can be sold to pig farmers for as much as $100 USD (2 M VND) per ton.

Fermenting Shrimp & Crab Shells

An exciting new study conducted in Brazil indicates that shrimp heads and tails can be fermented by means of Lactobacillus plantarum 541 in a simple drum reactor to extract of chitin.*

This fermentation method is surprisingly just as efficient in the extraction of chitin as the chemical method.

Chitin can be refined and deacetylated into a multi-purpose biopolymer called chitosan.

http://ecosyseng.wetpaint.com/page/Clean+Green+Technology+for+Shrim+Biowaste

Fermenting Shrimp & Crab Shells

Some grades of chitosan sell from $10,000 to $100,000 US per ton.

The liquor by-product from this fermentation process is high in essential amino acids and could be processed into a protein powder fit for human consumption.

The same fermentation technology can be applied to the shells of crab and other crustaceans.

It can even be applied to the exoskeleton of BSF larvae.

Products Derived 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 - from $50 to $150/ton
- Rice hull (gas + biochar) - $210/ton
- Activated carbon from rice hulls - $750/ton
- Activated carbon from coconut shells - $1,900
- Chitosan - $10,000 to $100,000 /ton
- Food waste (heat-sterilized) - $100/ton
- Fermented fruit and vegetable waste - $100/ton
- Thermophilic compost –$25 to $50/ton

Waste Resource Center

A waste resource center, as its name suggests, is a center that helps manage resources derived from waste.

It would be staffed by experts highly skilled in the above technologies.

These experts would train, certify and advise scavengers.

Also the center would organize and manage cooperatives on behalf of scavengers so that they would obtain the highest prices for their

Waste Resource Center

recyclables and waste-derived products.

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 social enterprise that is both private and non-profit.

It would be funded from two sources:

Funding

1. The center would sell all that is 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.

Exempt from Taxation

The waste resource center and the cooperatives would be exempt from any form of taxation.

In exchange for this tax exempt status, neither the waste resource center nor its cooperatives would charge local government anything for the collection and processing of waste.

Staffing

The waste resource center would be staffed by social and environmental entrepreneurs.

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.

These recruits should be equally passionate about sustainability in all aspects of how humans relate to the natural world.

Waste Resource Centers

- Waste resource centers could be set up throughout Vietnam.
- They would handle the sale of hundreds of millions of dollars in recyclables and waste-derived products per year.
- The cooperatives that they manage would provide jobs to several million people.
- Virtually nothing would end up in landfill.
- No country in Asia, Europe or the Americas would be able to rival Vietnam in the sustainable management of waste.