Rammed Earth Stove

The family has been huddling around the "three-stone" fire for thousands of years. Their food sources have changed some, and so have the materials used for the room they live in, but the fire that warms them, and the smoke that shortens their lives by decades, has been with them for longer than memory. The simplest tools or household items are treasures of great importance.

This minimum standard of survival remains the same for millions in the world today. Most of the victims of this trap are neither lazy nor stupid, but what can you do with life if all you have are fire dirt, and barely enough food to survive?

This exercise begins with fire and dirt, and develops a technology path that leads towards modern levels of convenience and health. The tricky part of this is that the path must begin in a manner that is acceptable to such cultures and must be sustainable locally without a continual supply of outside help.

Over 40% of the energy available in wood is in the form of smoke. By burning this smoke we create healthier living conditions, and also increase the efficiency of the fire (reducing the amount of wood needed). These advantages could be invested in developing further advantages.

This project has been further developed to demonstrate minimal blacksmithing capabilities, and the addition of a small kiln for ceramics and other thermal processes. These in themselves are not impressive, but they do empower the poorest of households to repair and produce products that they would otherwise have to buy.

Fire and future

The ability to harness fire is one of the defining advantages that separate mankind from animals. The sophistication with which fire is controlled and applied continues to relate to the levels of comfort and empowerment among humankind into our present time.

Historically, when the use of fire was extended beyond comfort and food preparation, those able to form tools and weapons of bronze and iron were able to outlast and conquer those who could not. Controlling specialized fuels enabled the Chinese to produce explosives and rockets. By harnessing fire to propel cannon balls, Napoleon made city walls obsolete.

Building on cannon technology, cylinders were bored for the steam-driven pistons that powered the industrial revolution. Internal combustion engines and steam turbines now power our infrastructures.

Not all the world enjoys such benefits. Millions of impoverished people are barely able to warm themselves or cook their food. Many of them pay a heavy price health-wise -- losing decades of their life expectancies due to the continual inhalation of smoke within their dwellings. The inefficiencies of their "three-stone" fireplaces waste much of the precious fuel in the form of the smoke that fills their lungs and homes

The poverty and scarcity of fuel in many areas makes it difficult to purchase simple pottery, or to forge tools for agriculture and other applications.

There is also the case of areas that have been devastated by war or natural disasters. The once-comforting infrastructures have broken down and no one in town knows how to put them together again.

Unavoidably, the remaining primitive cultures are being devoured by the crowding, and mobility of our modern world. The preservation of the ancient crafts and cultural histories is an important concern, but such must be preserved through other means than that of denying that the world is shrinking.

A proactive approach of empowering primitive lifestyles with greater levels of health and comfort will do far more to preserve them than allowing them to dissipate into the slums of sprawling cities through the lure of temporary jobs.

Designing a solution

The most productive approach to design is to begin with the question "What do you want?" When you begin by worrying about whether each proposed detail is possible or economically feasible, etc., you never begin.

We need a fire-based technology that will

1. Be acceptable – indeed attractive – to those within the target lifestyle
2. Require a minimum of steel or manufactured components
3. Be capable of evolving to where it could provide a variety of cottage-industrial services such as:
   (a) The firing of clay for
   - Pottery
   - Roof tiles
   - Floor tiles
   - Bricks
   - Cylindrical tiles for vents, drains, and water-courses
   - Various tools and implements
   - Art

   (b) Blacksmithing
   (c) Preparation of cement and plaster bases from bones, limestone, or other minerals
   (d) Perhaps at some point, power simple engines for shop use, or the production of electricity
4. Utilize as much of the fuel's energy as possible
5. Consume and convert the smoke into energy
6. Minimize the release of fly-ash
7. Motivate the users to plant trees to insure a continuing supply of fuel.

Goal: Requires a minimum of manufactured materials:

In my personal experiments, the primary material used was earth dug up from a few feet away. It was mixed dry with about 5-10% cement, and moistened just enough so it could be packed together into firm clods. It was then packed firmly into oiled 2X4 frames by beating it first with a brick, and then a 3-lb hammer, and then it was allowed to dry. This is an unsophisticated form of "rammed earth". The cement could be eliminated in cases where the components would be fired or protected by a coating of plaster. Every soil is different of course, so experimentation would be required locally to assess proportions, drying times, strength, etc.

These frames were 14" square, and sometimes fitted with special plugs to create various features. The frames were held together with bolts, so they could be dismantled easily without disturbing the curing mud, and in some cases they were stacked two-deep to create more specialized forms.

The critical compromise in this material is the proportion of cement. Cement returns to its anhydrous state when subjected to high temperatures, and loses all strength – sometimes exploding in the process. When subjected to high (red hot and above) temperatures, the earth itself begins to fire into material that will not be dissolved by water.



The outer portions will never achieve such temperatures however, so they depend upon just enough cement to prevent the rain from eroding them. Bottom line: Use some cement, but as little as you can get away with.

In the photo illustrating the "barbecue" stage, commercial bricks were used because they could be conveniently reconfigured. In actual practice, hardened or fired mud bricks would serve every bit as well. As you see commercial bricks in some of the other photos to come, think "mud". In the case of any such components, always fill all the cracks between with mud so that the only drafts are the ones you've intended.

The stack is of course sheet metal, and it was made to taper from 6" at the base to 4" at the top. You could probably build one out of mud, but so far I haven't needed to.

Goal: Acceptability:

I know of a situation where volunteers actually built vented stoves in single-room dwellings to protect the occupants from smoke. There were clearly reservations among many of the recipients.

These people were accustomed to the instant radiated warmth of an open fire. I am sure that it was also obvious that all that nice warm smoke was being drawn up the chimney – indeed, even the best of high-tech woodstoves seldom leave more than about 60% of the wood's energy indoors, and traditional masonry fire places never leave no more than about 20% under the best of circumstances (only when the fire is large).

The "barbecue"

This system begins with no more than a smokestack with a simple barbecue attached. Admittedly this is not real exciting, but there are a few things to be said for it.

- Most importantly, it is the first step on a path to a real solution. It would be helpful from an acceptance standpoint if potential users had a chance to see a fully-developed system, along with samples of the products it could produce.
- The stack, though only three feet tall, draws the smoke out of the user's face and into their hair. The stack is tapered to increase the draw, as well as for stability.
- The draft caused by the stack seems to concentrate the fire enough to burn more of the smoke than is burned by the more random drifting of an open fire, although not always all of it.

More energy is derived, and less smoke is produced.

- The exhaust heat which at this point would normally rise directly towards the ceiling as it seeks its exit, now warms the stack, causing it to radiate heat into all visible parts of the room.
- On the first system I built, I provided pedestals for mounting a pot or plate on top of the stack to scavenge the flue heat. As it turned out, there really wasn't enough heat escaping up the stack to do much good.
- A certain amount of heat remains stored in the masonry long after the fire is out, and we all know that there is nothing more cuddly than a nice warm block of dried mud.
- The open radiant fire is still there – point one of the rejection goes away.
- At least the heat of what was the smoke stays in the room – scratch point two. Point two should be negotiated though, because there are still things that can kill you even in the invisible gasses – especially if you didn't have leaky walls and a tile or thatched roof.

Before leaving this "barbecue" phase, let's exploit the technology potential just a little further.

During each cooking session, it would be possible to fire the face of a well-dried brick or two by building the fire directly on them. This could also work for simple tiles, and perhaps a few other shapes. Some additional work might be performed by packing items along the sides of the fire. The objects could then be turned to expose another face for the next session.

Consider also the reduction of bones, limestone, and other minerals for the preparation of plasters and cements. We are obviously talking small quantities here, but with a few months of almost normal living, such resources would begin to add up. The energy required in this case, would cost almost nothing, since you are using portions of the heat otherwise wasted while your are cooking etc..

The forge

The next phase of fire-control begins when we cover the brick trench with something like a mud toilet seat – potty train the kids somewhere else, or they'll never get the hang of it.

You can still see the fire, but by controlling the air and fuel from both the top and the front, you can begin to develop some pretty fierce temperatures. It would also be good to increase the height of the stack to at least 8 or 10 feet. This will provide a more powerful draft to intensify the fire (further reducing the emissions), and safely vent any unburned exhaust to your neighbor's lungs.

  

Eliminating smoke

If you stand wood on end in a short tube inserted in the fire hole and covered by a lid, you can have a small fire that is very hot, smoke-free, and very efficient for fairly long periods. The actual burn rate will be controlled by the thickness of the wood, and the amount of air you allow. The burn will last

longer, because longer pieces of wood will gravity-feed into the small intense fire at the bottom.
The 5/8” drill rod you see protruding from the reduced opening in the front of the stove is the subject of a simple blacksmithing operation. The wad of moist mud resting on it is intended to keep the rest of the rod cool enough to handle.

The smoke you see flowing from under the lid in this case, can be controlled by reducing the size of the opening. You will want some means of easily controlling the amount of air entering the fire, because you will want to cut it off completely whenever you add fuel -- Otherwise, you will always have a mass of smoke flowing into the room every time you lift the lid to add fuel.

Rather than worry about the status of the air flow, I fitted the opening with a rectangular tube 5” wide by 1-1/2” high, by 4” long. I then screwed a weighted bolt through a 6”-long steel strap, and attached a metal flap as shown below.
When the balancing bolt is properly adjusted, this device will keep a constant vacuum in the system regardless of the burning conditions. To a degree, the exhaust temperature will also be regulated, and here’s why: The amount of draw increases with the heat of the gasses in the flue. When the gasses start to get hotter, the additional vacuum draws more fresh air under the flap, diluting the heat of the fire’s exhaust. Another benefit is that this gate will automatically shut down the instant the lid is lifted, redirecting the vacuum to draw the smoke *down* the tube. Necessity may be the mother of invention, but

the daddy of invention was a lazy man.
This gadget may be especially helpful for regulating the temperature of an oven to be described shortly.


Care and feeding

With this level of control over your fire, your fuel options greatly expand. Pallet boards and orchard prunings burn as well as quality firewood. I was able to get some fairly intense fire from handfuls of chips and twigs raked together from an area in which I had prepared the season's firewood.

This arrangement of course also affects your access to the fire. It's still great for space heating, and the mud enclosure will remain warm long after the fire is gone, but you don't get to see much of the fire.

At this point you must definitely attach a vent through the roof. Now that you can limit the oxygen supply to the fire, it is possible to produce considerable quantities of carbon monoxide. Another good reason for a thru-ceiling vent is that more intense fires and some types of fuel will require you to pull a greater draft of air through the fire. This will require a greater stack height.

This arrangement also makes it more difficult to start the fire. It is sometimes helpful to blow on a beginning fire to drive enough of the heat towards the stack to get the draft going; otherwise, the smoke will tend to flow right up the pipe containing the wood.

Although the efficiency of this stove leaves a minimum of ashes, there will of course be some. These fine powders are a health hazard when air-born, so take care as you remove them. They are also a resource as nutrients for some plants, and as a component of cements and plasters.

The kiln

We advance to the next stage by placing an insulated chamber between the fire supply and the stack. The walls need to be thick to contain the heat, and the sides must be sealed with mud (inside and out) to eliminate all the stray drafts.

Getting the fire started under these conditions becomes even trickier. Unless the system is still warm enough to have a draft flowing through it, burn something small right in the stack chamber to get the draft started, then proceed as before.

You can cover this with a block of mud (cast as shown earlier), or a sheet of steel or ceramic for a cooking surface.


If you are installing a cooking surface, add some bricks or other obstacle for the flue gasses to jump over, so they will be forced to travel against the bottom of the plate.


If you are going to use this space for an oven or a kiln, place a lower obstruction just in from the firebox to keep the flames from directly striking the object/s in the chamber. You would also need to use the thick mud lid, and seal the edges with mud. The high temperatures required take a little work to achieve, so all extraneous drafts must be blocked. It is also helpful to drill a couple holes in the lid (to be covered with lumps of clay or brick most of the time), so you can spy on the conditions of the fire and the work.

For the intense temperatures needed for firing clay, prepare a supply of finely split hard dry wood. Use larger pieces for long slow burns at lower temperatures for your oven experiments, and for normal space heating.

By using small amounts of used crankcase oil, I was able to get temperatures hot enough to melt copper. This represents cone 04 in kiln parlance, and is above that needed for bisque ware and raku glazes.

Be Sustainable

For those who would apply these technologies, I would encourage you to consider the big picture: Plant trees.

My dad planted a 150’ row of eucalyptus trees to use for fuel to warm his cottage. The fall before the summer he died, he felled the last one he would ever need; it was a full 24” across at the base. The world continues to be blessed by the many tons of carbon dioxide that have been extracted from the atmosphere and stored in this graceful row of trees.

You can’t control others, but by actions and example, you can help lead the way towards a sustainable future for small-scale industries.

What we have

- A fire-based technology that can literally be created from the earth
- Ways of reducing or eliminating smoke – reducing a health hazard
- Ways of making such innovations more acceptable to existing cultures
- Fuel savings by virtue of higher burn efficiencies (and temperatures)
- Multiple options for cooking (barbecue, oven, grill, pot)
- Blacksmithing capabilities
- Ceramic capabilities
- Automated temperature control
- Compact size – only 14” wide by 40” long (including the kiln chamber)

Now what?

For my part, I don’t plan to develop and write any more about this stove. I have provided a group of basic technologies and features in a very compact package. Open this package and expand it to suit your own needs.

If you are planning to use it as a kiln, there are a couple of things you should consider: (a) Insulation is critical to efficiency; increase the thickness of the walls as you increase the size.
(b) I have used a small fraction of the firebox size recommended for wood-fired kiln projects, in proportion to the volume of the kiln. It takes fine tuning to achieve the required temperatures under these conditions, so you might want to figure out how to expand the size of the fire relative to the chamber size.

There is no end to the potential applications. I would encourage people to explore such things as hot-water heaters, and tying into various forms of central heating systems – maybe as just a backup for people who worry about such things (I do).

For my part, I plan to apply this heat source to such things as power-generation, and the production of petrochemical replacements from biomass – it would be nice to not need petroleum from nations that hate us.