Hexayurt infrastructure

From Appropedia

Hexayurt.com (http://hexayurt.com/) - Project Home - Burning Man Construction - Assembly - Plans - Mass Evacuation - Rapid Deployment - Materials - **Infrastructure** - Informatics - Education Concept - Research Agenda - Press - Contact -

Newsflash: we now have fire test data on R-MAX / Tuff-R. . Please read the Hexayurt Safety Information before building your hexayurt

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Overview

Take your house. Cut off the water, the electrical power, the natural gas, and the sewage lines. That's what a hexayurt is like without the infrastructure systems which need to be shipped with it as an integral part of the housing system.

Contents

It helps to think of your own house as you go through this: replace each system in your mind with the one from the outline below. Remember that the systems are huge: the electrical system isn't the wires in your house, or strung along the poles outside. It's the power station, the huge transformers, the high voltage long distance lines, and the aspects of the government which regulate the grid, as well as the banking infrastructure to keep all that stuff paid for.

To provide services in the traditional way in the developing world is extremely difficult. Even though some of these line items look expensive, it's important to remember that they are very, very cheap compared to their first world equivalent service infrastructures!

Hexayurt solar

Substitute for national grid or heavyweight solar with:

- One 80 watt panel connected to a 15 minute AA battery charger (e.g. the new generation Rayovacs)

These items will be connected into a "power pillar" - a walk-up charging station where people come with their empty NIMH batteries, drop them into the charger, wait 15 minutes, then take them home. Assuming a 10 hour charging day, that services 40 sets of batteries.

Each AA NiMH battery has a capacity of approx 2000 mAh at 1.25V, equivalent to 2.5 VAh. If charger efficiencies are 25% (my guess) then we need about 10 Wh to charge each battery.

80 W for 10 hours is 800 Wh per day or enough to charge 80 batteries a day.

Applications for this system include:

- Lighting: cold cathode fluorescent lights (see: http://ledmuseum.candlepower.us/dbright.htm), LED headlamps, etc.
- Communication: cell phone chargers, FRS-type radios, other battery powered radios etc.
- Entertainment: pretty much any general purpose device can be found in a AA configuration, like televisions (http://www.amazon.com/Casio-TV-980-2-3-Portable-Color/dp/B0000CGCCM)
- Wood gasification stove (see below)

What won't work:

- Heavy-draw mains appliances (toasters, video projectors)

Financial model:

- $400 for the panel, $100 for the charger and pillar. ($12.50 per household)
- $200 for 80 fast charge AA batteries say 4 each for 20 households.
- $100 or 20 lighting units.
- $700 total or $35 each for 20 households.

$50 per household should comfortably buy everything required for basic electrical services. A bare bones system (lighting and stoves only) would be about $12.50 per household because the cost of the panel, charger and pillar could be split between 80 households.

Hexayurt cooling

(This is theoretical. Can someone with more practical experience of using the Hexayurt please review).

When the Hexayurt is used in a hot climate it will get hot inside. The heat comes from four sources:

- Solar gains due to sunlight warming the fabric
- Fabric heat gains due to outside air being hotter than inside air
- Ventilation heat gains due to incoming air being hotter than the inside air.
- Heat from people and equipment in the Hexayurt.

The Hexayurt has good insulation. It is highly reflective (when new and clean) so it reflects most of the solar energy. However it has very low thermal mass so that, with no air conditioning, it will heat up when the sun is out.

Increasing the Thermal mass

If there is a significant temperature difference between day time and night time temperatures (i.e. desert areas) then increasing the thermal mass of the Hexayurt will slow down the speed with which the Hexayurt heats up during the day, reducing the temperature inside the yurt during morning and early afternoon. The simplest way to increase the thermal mass of the Hexayurt is to use the thermal mass of the ground under it. During the night maximise the exposed area of ground. Roll up any floor coverings, open all the vents. Sleep on camp beds raised off the ground so the night time cold air can circulate below the beds (or sleep outside). Wrap the floor coverings round you so they keep you warm but not the floor. Get the ground as cold as you can. As soon as the outside air temperature rises above the ground temperature (probably soon after dawn) close the vents and put back the floor coverings. In some cases the simplest way of doing this may be to move the entire Hexayurt at dawn and put it down on a nice cold bit of ground.

Controlling Ventilation heat gains

During the day limit the amount of hot outside air which comes into the Hexayurt. This will reduce the heat gains due to incoming air.

Bring the air in at low level so the cold ground can cool this incoming air so it doesn't heat the Hexayurt. This doesn't reduce the ventilation heat gains but it does improve conditions in the Hexayurt because the heat goes into the ground rather than warming the inside air and then using the ground coolth to cool the air.

The hottest air will accumulate at the highest point in the yurt so your exhaust vent should be higher up, on the downwind side of the yurt. As we have limited the ventilation to a minimum therefore we want to make sure the exhaust air takes away as much heat as possible. A Solar chimney can be used to help move the exhaust air and this will also help draw in supply air where there is no wind. (*See also Cheap solar chimney)*

Alternatively you can cover the ground with an insulating layer (sleeping bags, carpet etc.) to keep the ground cold during the day. You now have some nice cold ground to sit on when the Hexayurt seems hot; just pull back the floor covering and sit down. Sitting on the floor also means you are out of the bubble of hot air at the highest point in the Hexayurt. In this way the coolth stored in the ground is controlled and used for personal cooling rather than cooling the entire yurt.

Reduce the solar heat gains

Any shading which reduces the amount of sunlight hitting the Hexayurt will reduce the solar heat gains. Shading in the morning will keep out heat which would otherwise be in the Hexayurt all day. Putting the Hexayurt under trees or next to a hill can give this effect. A large banner if properly sited can cast a shadow which reduces the solar gains.

Keeping the Hexayurt shiny will mean more sunlight is reflected away and less is absorbed by the roof.

Reduce Fabric gains

Even if sunlight impinging on the Hexayurt is reduced the Hexayurt will still heat up till the outside surface is close to the temperature of the outside air and if this is hotter than the inside air then heat will leak through into the Hexayurt and heat the inside air adjacent to the walls and roof. Lining the walls and roof with drapes will keep this hot air from getting into the rest of the Hexayurt. These need to be light due to the limited load bearing capacity of the Hexayurt

Reduce equipment heat gains

As the Hexayurt is so well insulated any heat in the yurt will stay inside so be wary of operating any machinery in the Hexayurt during the day. Any heat given off will serve to heat the Hexayurt. Any computers should be laptops, not towers. Limit the amount of sunlight you let into the yurt - a lumen of light from an LED or a fluorescent lamp gives off fewer watts of heat than a lumen of sunlight. Any fridge or cooling unit should be set up so it's heat rejection (the pipe coil on the back) is to outside the yurt. If you do not do this then a fridge or cooling unit will just heat up the yurt.

SleepBreeze personal cooler

The SleepBreeze personal cooler is an intersesting device. Basically it is a small fan and which blows air into a long sock. The air leaks out of the sock creating a gentle breeze. If you put one on the bed beside you then it can create a current of air over you which may help you sleep.

Humidity

The paragraphs above consider the temperature. When considering the conditions inside the Hexayurt we also need to consider the humidity. If the Hexayurt is naturally ventilated then the moisture content of the air inside the tent (in grams of H2O per kG of air) will be pretty much the same inside and outside. If there are a lot of people or kettles boiling in the Hexayurt then moisture content will be higher inside. Moisture content is however not the same as relative humidity. When we talk of humidity we are usually talking about the relative humidity which is the moisture content as a percentage of the maximum moisture content at that temperature.

When we cool air then eventually the air gets so cold that water starts to condense out of the air as condensate or dew. That temperature is the **Dew point** and it is a measure of the moisture content of the air; the point at which the relative humidity is 100%. If we have air with a dew point of 10C then it's relative humidity will be 100% at 10C, 80% at 14C, 60% at 18C, 40% at 25C. The dew point of this air will still be 10C because the moisture content has not changed. The Psychrometric chart shows rH relative to temperature and dew point.

Cooling air will not affect the moisture content but it will increase the relative humidity. The only way to reduce the moisture content is to cool the air to below the dew point and make the moisture condense out. Then keep this drier air from mixing with the more humid outside air.

Evaporative cooling

See the article on Evaporative Cooling

If the humidity of the air is less than 100% then water will evaporate. It takes heat to turn liquid water into vapour so the remaining water will cool as it gives up heat to the vapour. In principal this will continue until the water temperature has dropped to the dew point of the air. This is how our bodies regulate their heat - by sweating and then, as the sweat evaporates, it takes this heat away, helping the body stay cool. This is why standing in a breeze feels so cooling - evaporation works much better if there is a constant stream of dry air on our skin. If the air is still we get a thin boundary layer of air which as been saturated in our evaporated sweat and this layer can't absorb any more moisture.

If, instead of a bucket of water we were to spray the water into the air then the water will evaporate in the air. As the water evaporates it cools until all of the spray droplets have evaporated and the air has cooled and the moisture content of the air has increased. This is known as Adiabatic cooling. Energy in the form of heat in the air is converted into energy in the form of water vapour in the air but the total enthalpy of the air doesn't change. The drier the air is the more effective evaporative cooling will be. From the psychrometric chart we can see that air with a dew point of 15C and a temperature of 30C (i.e. rH = 40%) can theoretically be cooled to 20C if we increase the rH to 100%. If we increase the rH to 70% then this will can cool the air to 24C.

In a Hexayurt possibilities include:

- Spraying the water into the air
- Spraying the water onto peoples skin or clothes so the cooling effect is directly applied to the body
- Put a net curtain in front of the incoming air stream with the bottom of the curtain in a trough of water so the water wicks up into the curtain as it evaporates off.

Note that the effect of any of these options will be to increase the relative humidity and the moisture content of the air.

See also Burning Man Evaporative Cooler

Hexayurt gas

Gas will be used for cooking and heating applications.

Substitute for natural gas infrastructure (pipes and plants, trucked in propane) with:

- A wood gasification stove. http://files.howtolivewiki.com/wood_gasification_stove_clip.mov has a (2M) video of the wood gasification stove from http://Spenton.net in operation.

Wood gasification stoves use sophisticated combustion engineering realized in the form of cheap sheet metal forced air stoves. Two AA cells power ten hours of cooking, with a peak heat output of 3KW from finger-sized twigs. Wood gasification stoves are low emissions because the fuel is burned either as gas (volatiles boiled out of the fuel) in super-abundant oxygen blown in by the fan, or as charcoal similarly burned in abundant oxygen.

Wood gasification stoves are rated as ten times more efficient than open fires, and three times more efficient than high-efficiency clay stoves.

Financial model:

- $20 or less per stove, one per household

Fuel costs are low, perhaps $1 per household per week or less. In a small and well insulated shelter or home, even this relatively modest heating device should provide most or all of the heat required -- even through the winter -- in most climates.

Hexayurt water

Introduction

A substitute for Water purification plants and pipelines, or trucked-in water, achieved with: Solar water pasteurization.

Purpose

Primary use of the cooker is to heat water to 160+F for the full day as a means of sterilizing both it and the container.

Designs

Build a simple solar cooker into the side of each hut using the same building materials as the rest of the unit (i.e., reflective insulation boards).

Issues

- Sterilisation is effective against biological contamination however it will not remove heavy meatal contamination.
- If the water temperature is less than 160F then bacterial growth will increase rather than killing bacteria off. Reliable indicators that the water has been fully treated, are being worked on by a variety of groups.
- Also, I do not suggest cooking on the Solar cooker as a core technology. General field reports seem to indicate solar cooking

doesn't go over terribly well in many areas.
- The aim of this is to capture solar heat and concentrate it in the water. This conflicts with the general cooling strategy for the Hexayurt, which is to reflect as much solar heat as possible and prevent it from being captured. Better would be to place the solar cooker facing away from the Hexayurt, towards the sun. Then it will intercept solar energy that would have hit the Hexayurt and direct it towards the water.

Cost & Materials

The financial model is based on $10 or less per household for one solar cooker.

Interwiki Links

- Wikipedia: Solar cooking (http://en.wikipedia.org/wiki/Solar_cooking)

- Wikipedia: Solar water disinfection (http://en.wikipedia.org/wiki/Solar_water_pasteurisation)

Hexayurt sewage

Substitute for pit latrines, septic systems or conventional sewage handling with:

- area-appropriate composting toilet design

Financial model:

Possibly as cheap as $20 per household in warm areas, assuming shared toilet banks. Practical, realistic designs have not undergone the "value engineering" necessary for this application yet, so are still too costly, although clearly a cheap, basic, functional unit for any given climate could be created.

Water System

Priorities

- public health is the overwhelming priority.
- low cost is essential - if it's not cheap, it won't be used as much and won't achieve as much.
- low ecological impact is very desirable if it doesn't compromise public health.
- suitable for various cultural practices. Target users may be accustomed to using water to cleanse (but can most often cope with small amounts of water), or other anal cleansing[W] methods, so the device should ideally tolerate sticks, rocks, paper, or whatever else is likely to be thrown in.

Options

- Ventilated Improved Pit Latrine (Practical Action Technical Brief) A simple design for a toilet that can be dug anywhere. Fill the pit with refuse and plant a tree when you are finished!
- Composting toilet
- Biogas toilet, too large scale for the specs; for longer term settlement (due to capital cost, time for construction); relatively unproven. (E.g. Bio Latrines in Kenyan Slums (http://www.afrigadget.com/2007/03/01/bio-latrines-in-kenyan-slums/) .)
- Non-composting, non-biogas toilets
  - Emphasis on public health (rather than sustainability or treating the waste as a resource).
  - e.g. the BiPu[W]
    - Cost? Chriswaterguy to find out.
    - What's the status of the solid material afterwards? Can be composted?
    - Proven in the field, including Aceh.
- Ultra-cheap systems, based on the Kamal Kar's work. Any

applicable to this situation? Chriswaterguy to find out.
- What about small community based Constructed wetlands?
- Sawdust bucket toilet, after Joseph Jenkins' "Humanure Handbook" (http://www.jenkinspublishing.com/humanure.html) (fundamental reference on this topic, free to download (http://humanurehandbook.com/contents.html)) -- hygienic, private, cheap, hard to screw up, makes great compost... why aren't you using one?

Development Status

Together these systems appear to combine to provide the majority of the services provided by the pipe-and-wire infrastructure harness of a first world household for a cost in the neighbourhood of $200 per household for a relatively plush system, and a minimalist installation could be under $100 per household or less with more resource sharing.

The vast majority of the products required to put together this package are common, off-the-shelf items. However, very few if any of them have gone through the rigours of deployment in the field conditions we are talking about. The CCFL flashlights are an excellent example: available in stores for around $10, with an excellent battery life and 10,000 hour or better tubes, they appear perfect. But the are not waterproof, only water resistant.

What would the failure rate be if we deployed them in a refugee camp? Would the manufacturer - either Eveready, or the plant which makes them in China, be willing to make small design changes or product a special edition, or would we hit dead ends unless we were willing to have a custom model produced from scratch (a whole different line of business.)

My hope is that we can rely on the open source approach to solve many of these problems - that as long as all of our intellectual property is open, then domain experts can help us find answers to all the questions that come up, without feeling like they are helping a for-profit or partisan group. Free IP means freedom to participate for many people. We can give the companies who produce the products we want tweaked or improved the ideas on how to do it, and they can use them or not as they please.

My estimate is that it will take 10 to 15 years for this approach to be fully vested - tried in the field, failures identified and rectified, and technologies matured to the point where it becomes obvious to all parties that we have a scalable solution. Whole systems design is hard, and takes time, and a lot of lives are at stake.

But if we don't start now, we aren't going to have that fully finished solution 10 or 15 years down the line.

This is not to say that we could not push much harder and much faster - deploy units in the field and just see what happens, and learn by doing.

PS: the $200 number is padded for a more expensive toilet, and for a share of village-scale utilities like the one-per-village 2 kilowatt central power utility.

PPS: http://www.rmi.org/sitepages/pid560.php (the Sustainable Settlements Charette, where a lot of the definition of scope happened)

http://worldchanging.com/archives/002202.html (some older writing I did on infrastructure which might help fill in some details in my unusual perspective on this stuff.)

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