|  |
| --- |
|  |
| Modular Housing Efficiency |
| Kai Taylor |
|  |
|  |
|  |

|  |
| --- |
|  |

A glimpse into the mentality behind your home

**Abstract**

The field of modular housing involves the research and construction of dynamic or prefabricated houses. This style of housing is both spatially and energy efficient to its very nature. Due to Earth’s rapidly growing population special efficiency is key. Though many architects have designed such buildings there is still a lack of documentation regarding the efficiency of prefabricated homes. Instead the bulk of research consisted of calculated values for efficiency as well as energy savings when comparing modular homes with standard homes of a similar size. Modular housing has proven to be a highly efficient, durable, and cost effective solution for housing and energy needs. Research has proven that prefabricated homes are being adopted very rapidly in countries such as Germany, where population density is spiraling out of control. Prefabricated building styles however have not caught on as quickly in the United States where population density is not as prevalent an issue. The results of the \investigation have shown that while modular housing styles have caught on in other areas such as Europe, the United States is still reluctant to adopt the style on anything more than a private level. With more research, an argument can be formed to convince contractors to build this new style of housing. With current lack of documentation and research this still remains difficult. The study of modular housing falls within environmental fields due to the homes efficient nature. With further research these homes can solve environmental issues.

**Super Density and Modular Housing**

The Earth is scorched continuously every day. Wild fires run rampant in dry prairies where there is no water to keep the fields green. The Earth is dying while humans live in obnoxiously large housing and are packed elbow to elbow in over crowded cities as they scramble for resources. How can this be stopped?

 The only sensible way to live with Earth’s booming population and declining natural resources is to develop high density cities using pre fabricated housing, because this style of housing allows for homes to be built in a more energy efficient manner while being more economically sustainable as well.

Through this research paper the author intends to outline a few of the issues facing Earth as well as arguments to support prefabricated housing. Although economic factors also influence the decision to build prefabricated homes it is outside the scope of this paper and will not be discussed in detail. This paper will focus on current implementations of prefabricated housing and look into the specifics of super density. Finally, the author will also touch on the subject of interior design with a focus on lighting interior spaces.

When studying the effects of housing on a population it is important to look at many different factors. For example pre fabricated houses are not only rather simple, many of these homes have an elegant flair to them. While this may seem like an un related fact it brings about the interesting point of innovation. Most houses in American suburbia tend to be over built and lack space efficiency while having a large negative influence on the environment. With today’s technology there is no excuse for homes not to be highly efficient. (Living Super Efficient) Not only has technology for insulating homes improved, but the price has been lowered significantly. With the Earth’s growing population another factor is population density. Cities are sprawling faster and faster while little has actually been done to prevent this expansion. This phenomenon is most significant in the United States where the general housing style has changed very little from the original colonial house design. New construction in Europe, specifically Germany, reveals this innovation and displays very modern homes. Homes in Germany are built with new energy efficient materials and have definitely progressed from the metaphorical "colonial style" farm house.

The previously mention colonial style refers to the original American farm. This farm usually consisted of a farm house, a barn, and was then surrounded by farm land. As time progressed the farm land diminished but the same farm house was still built in the same style even for non farmers. A different effect was seen in Europe however which showed a noticeable shift away from all the farm aspects when most of the population moved into cities and apartment blocks. The original colonial style is still very prevalent and even brand new neighborhoods are built in this manner. Although there have been significant advances in technology that allows for much more intricate and resilient designs the general style of building houses with pine studs and dry wall coverings has remained. This design is not efficient and while other countries have moved on and embraced new building styles the overall design in the United States has remained unchanged. Countries in Europe such as Germany are beginning to become overcrowded and therefore have moved on to different forms of housing. While the original colonial house may have worked out in the prairie the style is not space efficient enough for living in the suburbs. European nations primarily live in cities and apartment blocks. This form of living takes advantage of the huge amounts of space above the Earth. By building skywards instead of outwards the dreaded urban sprawl. Living in high density pre fabricated homes is a solution to population density issues in the US. Pre fabricated homes are cost very cost efficient although they are still a relatively new concept. With future technology the cost can be driven down even further. Homes can easily be assembled on site and transported very cheaply. Assembly is also much simpler since most pre fabricated homes snap together like an IKEA cabinet. This will allow relief efforts for disaster areas or third world countries to require fewer volunteers while still providing large amounts of aid. The homes would only have to be shipped to a port or delivered on trucks. Local inhabitants can then take over the actual assembly process. Architects have also begun repurposing old shipping containers and converting them into modular housing. This allows hundreds of these homes to be shipped very easily and over great distances. By maintaining the standard sizes and attachment methods, they can easily be shipped like any other freight container. The great thing about these shipping containers is that they are widely used all over the world. Many countries have made accommodations to transport these containers via truck, train and even by ship.

 During the development of the US including the Industrial Boom the government used the West as its “relief valve” stating that if the East became over populated then expansion could easily spread to the West. This feeling of security has left the US building inefficient houses and not really researching new styles of building. It is a sort of procrastination. Other countries such as Japan have looked into more efficient housing due to the extreme pressure of a small land mass. The US has simply been sprawling and has never been forced to research more efficient housing. This will eventually be the downfall because by the time the US actually needs to develop more efficient housing it will be too late. One of the largest factors inhibiting this development is mostly the mentality of the people.

 Citizens in the US feel they are entitled to their own little house with a white picket fence and a garden. It is this sort of mentality that prevents the development efficient housing. The problem with these private yards, fences, and gardens is that people do not always care for their gardens and often leave them messy looking. A more efficient manner would be to have large community gardens that are well kept and maintained by the city or county. This will allow houses to be placed closer together while still having large green spaces for community use. One of the largest problems in neighbor hoods is that some people care for their yards and maintain their flower beds while other neighbors let their yards go to waste. This creates an eyesore for the rest of the neighborhood while also lowering property values. Having a large community area that is well kept will boost property values as well as curing many of the “apartment block syndromes”. These include acoustic insulation and lack of privacy. Most apartment residents complain about having a lack of a peaceful area to relax and enjoy the outdoors and therefore having large green spaces will allow residents to divide the area into quiet areas and more lively areas.

 A large concern amongst apartment residents is social interaction. Many apartments either have the issue of way too much social interaction or nearly none at all. Imagine an apartment building in which every resident had his own private entrance and never saw another resident while within the building. Eventually the apartment complex would feel more like solitary confinement. On the other hand there are also apartments that have too much interaction, such as the entrance to someone else’s apartment is in a living room. This is just an example however the issue of too much interaction is there. (Details of High Density Housing) Japanese architect, Yamamoto, has addressed this issue in his Zurich “Circle” apartment block. In this building there were many exterior gardens as well as interior roads. This fine balance between private green space and public hallways allows residents to choose whether they would like to interact with other residents or they would prefer to enjoy their private green space. Another architect to embrace this concept has experimented with modular apartments. Kazuyo Sejima, also a Japanese, architect has addressed the issue of growing families. As families grow, so must their living space. Sejima allows families to expand their living space with “add-on” blocks for their apartment. Both of these architects have shown that living at or near super density is not only possible, but it is also possible to live with the comforts of suburban living.

 As was mentioned in the previous paragraph super density is defined as any city having over 150 residents per hectare. (Living at Super Density) While this may seem like a whopping amount Tokyo has over 500 residents per hectare. Foreign countries have much more efficient housing due to this very fact. America is the second largest country in the world second only to Russia. While Russia may have much more land space, nearly 66% is frozen solid. This makes building houses or even roads a monumental task. For arguments sake we can consider that America has the largest inhabitable land mass. Smaller countries such as Japan and Germany already feel the pressure of high population densities. These countries have been proactive in designing highly efficient apartments and cities. One of the largest arguments against living at super density is that there is still space to expand so that there is no need to live at such high density. However, just because there is space does not mean it must be used up. This is clearly evident in new neighborhoods where entire forests are cleared and a nearby neighborhood seems to have been copied and pasted over. The irony in all this is that America already has an over inflated housing market and that a by building more houses simply drives the cost of housing way out of control. The houses already on the market already need to be sold first before new houses are built. Living in high density apartments often comes with visions of loud neighbors and cramped hallways. However, many apartments are very acoustically private and new building materials can dampen sound very well. New housing designs implement unique designs that minimize cross talk between rooms. Addressing these issues is one of the main concerns when designing high density cities. Complexes such as these must be designed with this sort of efficiency in mind from the very start.

In the year 2011 the world population broke the coveted 7 billion mark. Growing population is one of the greatest concerns for many governments all over the world. In the 1800s less than 3 percent of a countries population lived in cities. By the end of 2008 however this percentage had climbed to a sky high 50%. (Mega cities) Governments are becoming concerned with over population and many governments in Europe have begun sponsoring programs to develop more efficient forms of housing. Cities such as London and Berlin have definitely caught on and have begun building up and not out. American cities on the other hand still continue to spread out. Mega cities have condensed large populations into relatively small areas. This has definitely proven efficient for countries with small landmass and high population. With growing population however these cities must be designed with super efficiency in mind. Just the density alone of these cities produces intense amounts of heat.

Green roofs, help to mitigate this heat however many builders neglect to add in these features due to a slightly higher cost. Although the cost of installing a green roof is slightly higher than installing a regular roof, it increases thermal efficiency of a building by 280%. When looking at a thermal scan of an average city large amounts of heat can be seen clinging to the buildings. This is what drives the temperature inside the buildings up and makes cooling the buildings very energy costly. Designing every building in a city from the start will prevent the need for later retro fitting when problems actually arise. One of the best ways to design a city is to start from scratch and have every building designed in the same style. Starting from scratch will allow all the buildings can fit together to provide maximum airflow through the city. Just like airflow through a living space is important, cities also need ventilation. In large cities such as London or New York that has many tall buildings, warm air can become trapped and cause large clouds of grime and dust to move through the city. With proper ventilation this warm air could move through the city without becoming trapped in tight alleys or between tall buildings. These small spaces occur because of disregard by one architect for another. Often time’s buildings are simply built around other buildings and this leads to small spaces that trap air and dirt. Old style brick houses also trap incredible amounts of dirt while being thermally inefficient and rather weak. With new technology buildings can be built out of smooth plastics that do not break down nearly as quickly and also traps very little dirt. Since the smooth surface buildings would have few pockets to trap air there would be very little turbulence throughout cities. While this turbulence is not directly noticed by cities inhabitants, turbulence does decrease air flow greatly. When air is blown across a rough surface it does not flow as quickly and creates excessive friction. The same concept is seen in airplane wings that are covered in ice. The air does not flow enough and will not create lift. The only difference is that instead of creating lift it creates turbulence and dust builds up around buildings.

Poorly lit rooms often have a negative effect on the health and minds of people that inhabit them. Studies have shown that lighting has a profound effect on people. Whether a space is meant for socializing, mourning, or shopping the lighting is all different and affects how people think and act in that space. Using natural lighting, or day lighting, has shown higher morale and enhanced mood. On the other hand spaces that are lit by unnatural light or have a lack of windows have a negative psychological effect. This is the same reason torture rooms are located underground and lack windows. The body uses sunlight to stimulate essential bodily functions such as regulating metabolism and creating nutrients. Light level not only affects mood but also energy level. On cloudy, rainy days, the body is often exhausted due to lack of sunlight thus the proverbial “rainy day”. If natural lighting cannot be implemented a good alternative is full spectrum lighting. Full spectrum lighting emits all the colors of sunlight and thus gives the body all the nutrients it needs. Fluorescent lighting emits light in a very narrow spectrum. Many common bulbs are labeled as “cool white” or “warm orange” however these bulbs emit very few colors depriving the body of important nutrients. A full spectrum bulb emits light across the entire spectrum while still providing a pleasant light that is bright enough to work in. Colors also tend to be skewed by fluorescent lighting. The color of an object is affected by the spectrum of light that hits its surface and therefore a person may look healthy under a full spectrum lamp but have an unhealthy skin tone under a fluorescent lamp. Textiles can also be faded under fluorescent lighting. While this effect is not noticeable after only short exposures, longer exposures have a more harmful effect. A long exposure can include going to work every day or studying at school. The amount of time spent in such places also affects skin health. Just as fluorescent lighting fades textiles due to the high UV content, it also deprives the body of vital nutrients and causes cells to break down and die faster than normal. Bet you did not think you had to wear sun tan lotion to work did you?

 Living underground allows for protection from the elements while also lowering energy costs. Having dirt insulation on three or four sides of a building keeps the temperature pretty constant. A home exposed to the elements and covered only by vinyl siding will fluctuate temperatures much more frequently. The earthen insulation however, buffers the temperature change and therefore lowers heating and cooling costs. A home with only one exposed side can withstand very cold winters with nothing more than a wood burning stove. This concept can then be implemented further with technologies such as active and passive solar heating. Having large floor to ceiling windows will allow sunlight to enter throughout the day and the heat will be retained over night by the earthen walls. The same holds true in summer where the constant earth temperature will keep the interior of the living space approximately 68 degrees Fahrenheit. Having a building that remains at a somewhat constant temperature reduces strain on heating and cooling systems allowing for more efficient use of energy. Using solar water heaters located above ground or geothermal water heaters located far below ground buildings can be heated and cooled while hardly impacting the environment at all by using 100 percent natural sources of energy. Even a dwelling only covered by a few feet of earth or having one side exposed will allow for far more efficient use of energy. One of the advantages of staying near the surface is that it allows the use of skylights. This can help alleviate some of the negative effects previously mentioned due to lack of natural light in living and working spaces.(Hussein) Having a large wall of windows combined with natural skylights can let in more than enough light even to a home that is primarily subterranean. Using thermally efficient windows will also prevent heat from escaping or cold air from entering. Another naturally occurring effect that can be exploited to more efficiently heat and cool a space is the suns “angle of attack”.

 The sun sits higher in the sky in summer and lower in winter. This effect can be used to place windows in such a way that they allow maximum sunlight to enter in winter but are shaded in summer. This overhang would be just long enough to shade the windows in summer and as the sun becomes lower in the sky, thus meaning the temperature is also dropping, more and more of the window becomes exposed. More direct sunlight could then enter the living space and heat the interior areas of the building.

 Combining the concept of pre fabricated housing and underground dwelling will allow all previous concepts to be bound into one subject, underground high density prefabricated cities. By burying prefabricated homes in craters with excess inert fill from construction sites or mining operations, the benefits of both styles of building can be enjoyed. Shipping containers have been shown to be able to withstand the force of the earth. Shipping containers would first be assembled in the proper layout. Then they would be buried under a mound of dirt leaving key areas exposed for skylights or windows.
 An emerging building style in all areas of the world is the straw house. This is a step up from the houses of the Native Americans in that bales of hay are used to create the rough shape of the building. The hay bales are then covered in plaster and painted. This creates extremely thick and insulating walls. The large amount of air pockets in the hay trap heat extremely well and the plaster covering makes the design suitable for both the wettest and driest climates. While a standard adobe house might only be suitable for an extremely dry climate the hay bale building style can with stand all sorts of weather. Building materials for this construction technique are also very common. Instead of cutting down large forests for the creation of neighbor hoods, hay can be used instead which is very abundant. Many farmers even have problems disposing of excess hay. Some fields can produce 2-3 harvests in a single season. (Bale Watch) This would be enough for quite a few homes per year. Buildings of this type can also be erected with very little skilled labor. This makes it ideal for countries that lack construction skills. The only task necessary is the rough work of laying out the hay bales and then covering them with plaster. This is easily accomplished even by uneducated populations and can easily be taught at workshops or conventions.

This can greatly help relief efforts where relief workers are often plagued with having to do manual labor as well as guide relief work. By spending time teaching the native population how to construct such buildings, their time may be spent with administrative tasks such as food and water distribution. This will greatly speed up relief efforts and quickly build new houses in disaster areas. Hay bale homes can be erected in a matter of days and can provide immediate shelter and relief.

One of the greatest aspects of the hay bale building is its organic design. The building can easily be built into a hill or partially buried. The hay can support large amounts of weight and can easily be buried to provide additional insulation or architectural flair. Living or working in a visually appealing space has been shown to boost productivity as well as reduce stress. A partially buried work place or living space will reveal plenty of green area and calm the mind. This relates back into the idea of apartment complexes needing natural green areas. Natural green spaces will help to negate the stress of living in very dense living conditions. As long as there is green space that the mind can escape to the body has no problem with living in a high density apartment complex. (Bale Watch)

Using shipping containers as a construction material opens a whole range of possibilities concerning creativity as well as cost. Squatters have used the containers as makeshift shelters while world renowned architects have used them to design luxury condos as well as sky scrapers. This shows just what kinds of possibilities are available with these containers. Not only is there incredible versatility but they are also extremely cost efficient. A typical home in the United States costs approximately 80 – 300 dollars. (Trulia) This does not even include the cost of the land which can vary greatly depending on location. A shipping container costs ludicrously less, a mere 15 dollars per square foot. (Ocean Container Dimensions) Once shipping containers pass a certain age they are no longer deemed “seaworthy” however containers are often just melted down or sold as scrap. Many of these containers are still very suitable as a construction material.

Some shipping companies sell their overdue shipping containers as “scrap metal” to recycling companies for as low as one thousand dollars per container. The all steel construction of these containers is extremely durable and can easily weather a great many storms. Even after the containers have out lived their useful life as freight transporters, they can be repurposed to build creative offices or used in the construction of think tanks where the world’s great minds will think of the world’s greatest idea.

Shipping containers are built from a special non corrosive Corten steel that stands up to one the most demanding environments on Earth, the deck of a freight ship.(Ronin)

The combination of salt water and wind on the deck of these freight ships will easily strip the paint off of normal steel and then proceed to eat the metal more quickly than a hot knife through butter. The Corten steel however resists the properties of the salt water and holds on to the paint very well. This defeats common household issues such as mold and mildew. Mold and mildew are often linked to allergies and sicknesses in homes where water may enter through a leaky roof and accumulate. This then breeds mold which releases its spores into the ventilation system of a building. Finding the cause of mildew outbreaks can be difficult since spores can travel a large distance before being inhaled and causing a reaction. By using sealed shipping containers such pathogens can be avoided. “Using shipping containers is a great way to reduce the cost of homes and can allow for more intricate designs than previously possible.” (Falls)

Modern containers also have seals that can be applied to the doors to create a near airtight seal that helps keep even more airborne pathogens out. This property can be applied to war zones, where contamination is prevalent in the air. Such containers can also be used to house military servers and computers which are very susceptible to dust and airborne pollutants. Housing them in containers would keep the servers clean and well protected from damage as well as being easily transportable. These containers can be designed with interlocking connectors that allows multiple containers to be linked together increasing processing power when necessary. In the modern battlefield computers are used for everything from firing artillery to making sure soldiers get fed. The military has already been mounting drone control stations inside containers for the control of unmanned aerial vehicles or UAVs. These containers are then built into miniature apartment blocks where the pilots can then take control of their machines. The use of the shipping container allows for the easy stacking and transport of hundreds of containers for a very low cost.

Modular housing alleviates many of the issues with traditional building styles commonly found in the United States. The traditional stick frame building style has long since been out dated and many countries, especially in Europe, have moved onto more innovative styles of building. Not only do these countries reuse waste by repurposing shipping containers, but they are also innovators of more efficient and green technologies. The technology for highly efficient homes is definitely out there and often times even cheaper than traditional methods. It seems now only the mentality must change. Everyone feels entitled to their green space and white picket fence. This mentality is still from the Colonial time and still prevails in today’s building style. The “American colonial house” is still a very sought after building style even today with the discovery of modern insulation and more energy efficient building styles. The greatest obstacle in the design of newer more innovative homes and buildings is the mentality of Americans. Other countries such as Germany, Japan, and London have already embraced such new building styles and are already developing even newer buildings. Americans however are skeptical to embrace these building styles and still hold back. They are afraid.

Works Cited

Bale Watch, Robert Andrews, “Bale Watch” December 13, 2011.

Falls, Gregory. Personal Interview. December 23, 2011.

Ginthner, Delores A. "Lighting: Its effects on People and Spaces."
 *Implications*: 1-5. PDF file.

Hamilton, James. "Modular Data Centers." Cornell University Library, 06 Dec 2006.

Web. 18 Oct 2011. <http://arxiv.org/ftp/cs/papers/0612/0612110.pdf>.

Hussein, A. "High Density Housing." *THE DESIGN OF HOMES*. Word Press, 09 Sep 2007.

Web. 28 Oct 2011. <http://homesdesign.wordpress.com/2007/09/09/high-density-housing/>.

Li, Yuguo, and Julian Hunt. "Megacities at risk with growing population." *Jerusalem Post*. 26

Oct 2011: n. page. Web. 30 Oct. 2011. <http://www.jpost.com/Opinion/Op-edContributors/Article.aspx?ID=243299&R=R1>.

"Living at Super Density." *Design for Homes*. Design for Homes, n.d. Web. 26 Oct 2011.

<http://www.designforhomes.org/pdfs/Superdensity.pdf>.

McKnight, Karen, “Construction cost per square foot.” Trulia Real Estate April 16, 2008.

December 15, 2011. <http://www.trulia.com/voices/Market\_Conditions/What\_is\_the\_construction\_cost\_per\_square\_foot\_for\_-31246>

Ng, Edward. *Designing High-density Cities For Social And Environmental Sustainability*.

Earthscan / James & James, 2010.

"Ocean Container Dimensions." *Import & Export Resources: Foreign Trade Online*.

Foreign Trade. Web. 13 Dec. 2011. <http://www.foreign-trade.com/reference/ocean.cfm>.

"Population Density per Square Mile of Countries." *Info Please*. Info Please, 2007. Web.

28 Oct 2011. <http://www.infoplease.com/ipa/A0934666.html>.

Ronin, Renaissance, “Everything you never wanted to know about shipping containers.”

Renaissance Ronin, Renaissance Ronin. August 6, 2001. December 15, 2011. <http://renaissanceronin.wordpress.com/2008/08/06/everything-you-never-wanted-to-know-about-shipping-containers/>

Rybczynski, Witold. "Suburban Despair." *Slate*. (2005): n. page. Web. 30 Oct. 2011. <http://www.slate.com/articles/arts/architecture/2005/11/suburban\_despair.html>.

Schittich, Christian. *High-density Housing, Concepts, Planning, Construction*. Birkhauser, 2004.

"Successful European Eco-town research." *PRP Architects*. PRP Architects, 2008. Web.

26 Oct 2011. <http://www.prparchitects.co.uk/news/news-releases/2008/eco-town-research.html>.

Wulfinghoff, Donald. "Efficient Housing." Energy Books, n.d. Web. 22 Oct 2011. <http://www.energybooks.com/resources/tips\_super\_efficient\_house\_v040118.pdf>.