KINETIC CITIES: VIABILITY OF ADAPTABLE PNP CONTAINER MODULES FOR SMART LIVING

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ABSTRACT

The US is experiencing a housing crisis, especially for first time buyers, low income and baby boomers, as well as globally in areas hit by natural disasters due to changing weather systems. Contributing factors to this issue include the slow rebound of housing production from the last recession as well as the recent Covid pandemic market rush to the suburbs, which has resulted in climbing prices and low housing availability (Joint Center, 2019, Spencer, 2021). One possible solution for these consumers would be a container house, but until recently this tiny house option meant that the homeowner would most likely be skirting by-laws since it is often illegal to build small dwellings in many municipalities. Few states or cities have yet created the innovative zoning necessary to address this new phenomenon in their land planning and building codes. In addition, the younger generations want environmentally friendly products and energy efficient homes, something that traditional house developers adopt in limited ways, but small house builders consider integral to their products.

These younger consumers are also interested in either avoiding a mortgage or having lower interest payments, so smaller housing usually means it is less expensive, which opens disposable income. This motivation is one factor in the emergence of the Tiny House movement whose followers watch shows like Tiny House Nation, Tiny House Hunters, Tiny House Builders and Tiny House Big Living on HGTV. These shows follow people as they build houses between 150- 500sf in size using innovative design and materials with the hope of spending less and allowing more lifestyle options. The trend appearing is that there is an increasing number of potential small home buyers, as per recent surveys (Keyser, 2017 & IPX, 2021). This reflects the desire for a minimalist lifestyle, housing mobility to relocate easily and lower house costs to avoid a mortgage for more financial independence and freedom, which are benefits of a smaller home (White Paper, 2017).

Those who are inspired to join the tiny house movement are from a range of ages and incomes, though this housing type especially appeals to the Millennial generation who have spearhead the recent urban revival. It is anticipated that the urban population density will increase even more in decades to come so a tiny house product that can move from being a single-family unit to linking into a multi-family building for urban locations could be a good solution. This could be achieved by using containers to provide these flexible options for a new kind of housing concept. While there are container homes on the market currently, they do not meet these criteria, and it would require a new product to be developed. These new container modules could be designed to address improved affordability, health, reduced energy consumption and increased mobility to create an alternate, and potentially better lifestyle solution for many people.

KEYWORDS

PnP Container Smart House Development, Disaster Mitigation, Recycled & Energy Efficient Housing, Sustainable Development, Urban Planning

1. KINETIC CITY INTRODUCTION

The vision for this project, Kinetic Cities: Viability of Adaptable PnP Modules for Smart Living, is to provide flexible, transportable, small footprint, cost-effective housing solutions that promote healthier lifestyles and energy efficiency for future 100-year smart lives. As each generation lives an additional 10 years on average, the financial ability to support those extended years and anticipated migration for jobs will become a serious problem requiring economical and potentially mobile housing solutions (Gratton, 2016). In addition, boomers are retiring at a rate of 10,000/day over the next 10 years with 46% of those selling their homes downsizing and this will have a significant market impact on housing (Landau, 2017, National, 2020). The critical housing and labour shortage from the last recession and Covid panic to buy single family homes, has resulted in climbing housing prices and limited downsizing options for the elderly, first-time buyers and low-income families (Joint Center, 2019).

Scientists also predict that in the future over 90% of the globes largest cities will experience flooding and extreme weather that will further compromise housing availability (Fixsen, 2019). Presently there is no one solution for all of these housing needs, so Kinetic Cities proposes a transportable, sustainable, and adaptable PnP (Plug ‘n Play) housing product. It will not be for all housing buyers, but the PnP can help fulfil the need for low-income housing, downsizing seniors and first-time buyers who require less space and disaster relief so families in need don’t have to live under temporary plastic.

The hypothesis for Kinetic Cities project is to test if the new PnP container modules can be built more efficiently, and faster at lower costs. It will also test if they can help reduce long term energy consumption and carbon emissions, while also providing significant expandability and mobility, compared to traditional housing – a potential green kinetic solution.

2. RESEARCH OBJECTIVES

The intent of this research is to develop a better housing product which may be more cost effective than what is currently available. There are container houses on the market for sale now from $42,000 to $174,00 for 320sf one-bedroom units but they are not expandable, or movable once assembled and tend to be lower quality or over-priced (Simpleterrra, Homobo 2020). Other modular home concepts will not withstand high winds and they have limited life spans of just 15-20 years (Laizhou, Boxal, 2020). Conventionally built houses can contribute to poor health and chronic diseases due to the chemicals and plastics used, while new construction and renovation work saturates landfills with approximately 135 tons of wastage annually and adds to deforestation.

Smaller affordable PnP container houses could plug into an urban high-rise grid, drop into a suburban pocket community or be sited on sections of the decommissioned Hood Canal bridge so they can be floated to hurricane hit islands or even San Francisco Bay. PnP container homes, like tiny houses can potentially reduce carbon emissions by up to 90% (Matthews, 2014), limit landfill waste, remove the equivalent of 230,000 ICE cars off the road by recycling the Hood Canal pontoons, and offer a healthier, more self-sufficient housing model that could benefit individual homeowners, developers and communities (Figure 1).

Figure 1 – Kinetic Cities Multi-Story, Floating Disaster Mitigation, Single Family PnP Communities (C. Spencer 2021)

3. RESEARCH

As determined, there is a target market of approximately 10.8 million potential customers for the PnP modules, including approximately 2.2 million retirees downsizing, 5.6 million lowincome purchasers and approximately 3 million first-time buyers who are interested in smaller energy efficient homes (National, 2020). This number is growing exponentially since a 2020 survey by Fidelity National Finance Company found that 56% of the respondents would consider a tiny house (IPX, 2021) while in 2017 it was only 15% (Keyser, 2017). But of those recently surveyed, a majority, 54%, also wanted their house to be mobile and preferred it to be under 400sf (IPX, 2021). That mobility has been offered by RV's (recreational vehicles) and THOWS (Tiny Houses on Wheels) in the past, but those products are not allowed as permanent housing in many municipalities.

The fact is that single family house types have increased 60% in size over the last 40 years and the zoning rules grew with them. So, it will take policy changes to these government regulations and bylaws to allow smaller residential footprints and other sustainable designs for both urban and rural settings (Keyser 2017). In cities like Seattle and Portland that are critically short on available housing, single-family house costs can average $500,000 to $1 million, well beyond what most young professional can afford. In San Francisco, Toronto and New York many residents just assume that they will not be able to afford to buy a home since the lowest priced houses there can start at $800,000 (Spencer, 2021).

Tiny houses have provided opportunities for first time buyers and lower income families to buy, which gives comfort and owner pride to those who wouldn't normally be able afford a house. Living simply and embracing nature also can have a calming effect and lower stress. The reduced expenditure for housing and utilities gives the tiny house owners the opportunity for a richer lifestyle. They have more choices in where and how they want to live. A single smaller living space is easier to condition, clean and control for security. Less time and money are spent maintaining and repairing the house leaving more time for relaxing and spending time with family. As a result, tiny living can actually be a healthier way to live both physically and mentally.

Large residential developers, like David Weekly and Camden Properties, are now recognizing this new market for small houses and they are starting to build single-family rentals (SFR) that start at 600sf (1bedroom, 1 bath) and move up to 1250sf (3-bedroom, 2.5 bath) which are still ½ the size of a traditional house (Spencer, 2021). Other developers are building small houses to sell in Portland, Asheville, Austin, Oakland and Denver where Planning Commissions have allowed special pocket communities. The non-profit, Cas Community Social Services, developed a new concept for a pocket community in Detroit of tiny houses on a two block section of the city that needed more density, and affordable housing for low income families. Each home was from 250-

400sf, eco friendly, and located on a small lot of 30'x100' (Meyers, 2015). These pocket communities often enhance the neighborhoods where they are created since they add common amenities, bring in younger owners and increase the need for walkable services and stores nearby.

Another critical housing issue is that natural disasters leave damaged homes littered with tarps on their roofs for years, as in the Florida panhandle, or destroy them completely as the back-toback hurricanes did in St. John USVI in 2017. Those lost houses had not been replaced as of 2019, resulting in 25% of the islands population being unable to return (Spencer, 2019). This left the island short on teachers and skilled labor to rebuild their services and education system.

St. John along with many other islands and remote communities often have limited access to skilled construction labor and materials, so everything would have to be shipped in, and the cost to build a traditional house in St. John is currently at about $700/sf (Spencer 2019). Alternatively, a completed container house could be shipped in by boat then trucked to a site where it could be set on either the existing foundation of a former house or on new poured piers. The cost to ship a container house to St. John is approximately $7000/container so it is a much more cost-effective method to replace the destroyed housing relatively quickly.

Containers are already built to resist the high winds of typhoons, so they are inherently more structurally sound and water resistant than traditional houses. The PnP can be built in two sizes, recycled custom 10'x40' containers for the modules or 8'x20' reused containers for disaster relief (Figure 2). Both would be high cube, meaning that they would be 12" taller than the standard container, allowing for ceilings of 8'-5" inside once 6" steel ceiling channels are installed to carry the insulation and reinforced roof support. They can also be designed with pull up decks or close-down canopies, unique to containers, to shield glass walls from hurricane winds and fitted with water catchment systems, solar panels, radiant water heating and hydroponic greenhouses for self-sufficiency and reduced utility costs.

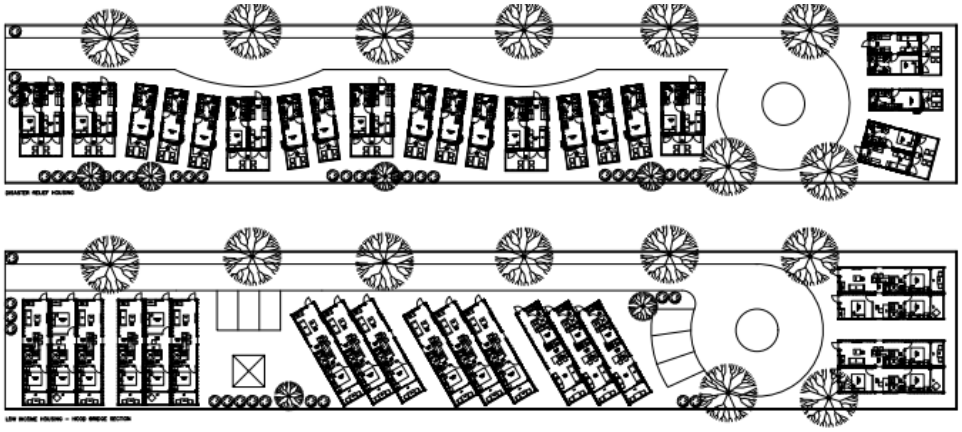

Figure 2 - Hood Pontoon Designs for Disaster Relief & Low-Income Housing by C. Spencer

4. RENEWABLE ENERGY STUDY

A study using wind and solar photovoltaic power for 20 proposed container homes for Gifft Hill School in St. John to house teachers, calculated a potential annual income of $15,510 due to selling the excess power back to the local utility. This process of collecting power from renewable systems and selling the excess power generated is known as Net Metering. Currently the power for St. John is sourced from turbines located on St. Thomas, driven by fossil fuels of oil or propane, and the power produced from them is then fed through underwater lines to the

island, which is very expensive and increases emissions to the atmosphere exasperating climate change with its extreme weather. Renewable energy would provide great cost benefits and the PnP containers could be self-powered.

These PnP renewable energy cost benefits could be applied to other locations in the US with similar energy outputs, though not necessarily the same return on investment depending on local electricity charges and utility policies. The smaller volume, simple form and limited fenestration of the PnP allows for easier self-reliance by renewable energy powering.

Regarding traditional houses, Net Metering along with government tax credits have become one of the lures to get current homeowners to install solar panels since the claim is that your monthly power bill will be reduced. The electrical bill may be reduced but that extra money is usually then absorbed as a loan payment for the purchase and installation of the solar panels. Also, using solar power in with larger houses, is unlikely to be able to supply all the power needed and the cost, even with tax incentives, can come in at approximately $20,000 for an average house requiring a 20 year+- return on investment.

5. FINANCIAL EVALUATION

To determine viability early in the research process, a preliminary CBA was developed comparing the construction cost of a PnP container house against an average traditional house. The research found that the container house with the same number of bedrooms and baths, can be built for about 1/3 the cost of conventional construction, but it is also 1/3 the size. Some studies have found up to a 10% savings for the container house (Forrest, 2015) but the CBA showed a higher square footage cost to build as often happens in construction when the same elements are built into a smaller space in comparison to a larger space. Inevitably the savings are in the reduction of habitable space, efficient design and simplicity of the materials with the PnP concept. However, in future there may be additional price reductions if the modules could be factory built on an assembly line in higher volume.

Factory manufacturing uses approximately 25% less material with more accuracy, has fewer worker accidents and production hold-ups due to weather. They can also have parts robotically fabricated, offsetting the labor shortage as the unskilled labor pool shrinks (Joint Center, 2019). In addition, recycling the steel containers creates a circular economy since after being utilized in shipping for 20 years, used containers are available for purchase for only $1800-$4500 to become buildings or melted down for scrap (Metal Building Homes, 2020). Reusing the 7,700lb steel container, along with utilizing renewable energy, could contribute to a zero-carbon footprint for the PnP, since the only modifications to the shell are to add doors, windows, insultation and some structural work in the custom sized ones. The initial emissions in the production of the container, including the mining, shipping of the raw materials and the forging the steel, which is estimated at 2 tons of CO2 emissions per ton of steel, are offsets of the shipping business not the building process.

The PnP houses could also be built almost entirely of sustainable and recycled materials since the interiors can utilize re-engineered wood flooring and baseboards as well as recycled glass countertops by ICE or a similar manufacturer. The kitchen cabinets can be a product certified by the Kitchen Cabinet Manufacturer's Association Environmental Stewardship Program (ESP) and bamboo used for décor items and paper goods. The framing would be proposed as FSCCertified wood and the deck an eco-friendly composite made of 95% reclaimed wood by Trex or equal. These are sustainable opportunities that are easier to achieve for the PnP rather than traditional housing due to adapting the following ECD - environmentally conscious design (Huang, 2009).
The ECD guidelines and objectives are the following:

- Minimized material types
- Reduce product weight, waste and consumption of energy
- Minimize product volume and size
- Selected recyclable, non-toxic and reusable materials
- Compliance with the law by not using restricted or hazardous materials
- Specified recycled materials to reduce raw material use
- Selected materials with little pollution during their formation
- Selected materials with lower energy content

These guidelines are a method of streamlining the design by looking at the efficiencies of each product and determining that the benefits to the environment match the benefits to the project. The PnPs being a completely new product makes it simpler to adapt interior décor products in a thoughtful and sustainable way, while traditional houses built by any number of sources, often have budget, customer appeal and profit as their primary considerations.

6. TECHNOLOGY INTEGRATION

Le Corbu envisioned that "A house is a machine for living in" (Kohlsedt, 2018) and by integrating smart living devices, for energy consumption and health monitoring within the modules, this vision could be a reality. Americans spend more than $400 billion annually for home improvement and repairs with the types of projects trending toward energy-efficiency, healthy and "smart home" technologies (Joint Center, 2021). Products such as Nest thermostats and security, Flow water monitoring, Hue LED lighting, Sonos audio, Tesla solar panels and Powerwall along with software, predictive flows, and environment controls by apps on a smart phone, can be integrated into the PnP for improved lifestyle. Many of these technologies are offered by developers for new traditional housing but most, beyond solar, are not offered in tiny houses or container houses yet.

Multi-family PnP projects could utilize digital FM (facilities management) data collection, automated monitoring and predictive modelling to determine local market needs. This FM programming could be developed like the WeWorks optimization for offices but altered for residential (Chaillow, 2018). In that model it concludes that the computer predicting can surpass designer prediction in the determination of the market demand for buildings. The PnP modules could then be adaptable to programmatic changes by utilitizing sliding walls, concealed quick connect utility fittings and modular cabinets to change a 3 or 4-bedroom unit into several 1-bedroom units, or the reverse, if that is what the current market requires. By combining advanced technology, along with creative design solutions, this could be a new green sustainable machine for living that offers flexibility and healthy options while reducing the carbon footprint for future generations.

7. METHODS

7.1. Interviews – Tested by Personal Research & Survey

To test the PnP hypothesis, a feasibility study was initiated with interviews to assess whether a container design would appeal to the buying public as well as those who would be financing and building them. The interviews were conducted with several developers, contractors and potential single-family buyers who had already expressed interest in containers or tiny homes. Each party had different housing needs, including single-family, multi-family and developing low-income communities, but several common requirements surfaced from each interviewee – speed of build, lower cost and sustainability or minimum environmental impact.

In a survey by Fidelity National Finance Company, over 56% of potential buyers said they would live in a tiny house and respondents cited affordability, efficiency and eco-friendliness as the top appealing factors to tiny living. In addition, 54% of those who would live small also wanted mobility. These potential customer requests became the critical elements of the PnP hypothesis to test for viability

7.2. Speed to Deliver Analysis – Tested by Data and Research

A PnP module has not yet been assembled to verify the time it would take to construct but a comparable product for the commercial market has been built by Boxman Studios, who specialize in container repurposing. The Sparkman Wharf project used 20 individual containers that were custom outfitted with kitchens and lounges then set on waterfront property in Tampa to revitalize the downtown (Spencer/Boxman, 2020). Personal experience designing those units and coordinating with Boxman, determined that a 40' residential unit container could be factory built in 8-10 weeks. In addition, Simpleterra who build made-to-order container homes, have a 40' two-bedroom unit that they claim can be ready for delivery in 10 weeks or less (Simpleterrra, 2021). Compared to the approx.12 months that it takes to construct a traditional stick-built house, the container PnP house would be significantly faster.

7.3. Cost Comparison – Tested by a Cost Benefit Analysis (CBA)

A Cost Benefit Analysis was done to compare the construction costs of a traditional house verses a PnP container house, with both having 3 bedrooms and 2 baths. The results showed that a container house of 800sf (2 containers) is approximately $131,775 to build at $165/sf, verses a 2500sf traditional house costing $296,651 at $119/sf to build. These prices include estimates for grading, foundation, driveways, decks, landscaping, permits and fees but not including land, marketing expenses, profit or sales commissions. Compared on a square footage cost, the container house is approximately 39% more costly to build, since only the exterior skin and structure are a savings, while the interior is stick-built the same as a traditional house, until factory production is available.

Nevertheless, the ownership rate of tiny houses is 78% of the available market and just 65% for traditional houses. In addition, 68% of tiny house owners have no mortgage as opposed to 30% for other US homeowners (Gaille, 2018). Also, the average traditional homeowner will pay over $1 million in maintenance, taxes, insurance and interest on their home over a lifetime while the tiny house owner will only have a fraction of those expenses (Gaille, 2018).

So, it is the compact simplified design that is the reason for the substantial savings and long term reduced maintenance. The cost then to buy a single container, one bedroom and one bath at 400sf, the most affordable PnP unit, is estimated to be $65,000, which is still affordable for tiny home buyers as per the survey by Fidelity (IXP, 2021). At this price point, many buyers could purchase a PnP house without a mortgage and achieve an improved financial situation with disposable income to do other things.

7.4. Sustainability Evaluation – Tested by Statistics, Data and Comparative Charts

The real estate market figures from the National Association of Realtors, are shown in a chart of the Environmentally Friendly Features considered important to buyers. The graph is divided into age brackets since each group polled had different sustainability concerns. Younger generations considered the commute costs most important while age 63 and up considered items such as energy efficient windows, lighting and HVAC systems to be more important. It also shows how environmentally friendly community features and landscaping are slightly more important to

older buyers than younger.

One item that is considered important to buyers in all age groups, at levels between 3-6%, is solar panels. This item might not have even been on the chart a decade ago, but the recent California state law requirement to have solar panels on all new houses, easier access to solar products at building supply stores like Lowes and acceptance of panels commercially for renewable energy, has changed the public perception of this technology.

In consideration of this assessment, the estimated energy consumption between a container house verses as traditional house was developed into a comparison chart which shows the substantial savings in electrical use and C02 emissions for the smaller PnP house. Fully powering a traditional house with renewable energy is harder to achieve due to the larger volumes, additional windows, doors and lights. Overall, a container house may produce only 4000lb of carbon emissions per container unit annually, compared to 28,000lb for a standard house, making it significantly more sustainable (Matthews, 2014).

7.5. Energy Efficiency Calculations

The more compact a building, the more energy efficient it is as well. So, using the Surface to Volume Ratio (SVR) and COMcheck it has been proven by calculation that PnP containers comply with Passive House Standards and are extremely energy efficient. Since the PnP has a compact rectangular design without high volumes or unusual shapes it is ideal for the SVR efficiency (Vidmar, 2019). Traditional houses often have 9’ ceilings or higher, two-story volumes – either at stairs or cathedral ceilings - and often excessively spacious rooms which are less energy efficient. Both traditional houses and PnP’s would have to comply with the International Energy Code so both would have the same insulation R-values required for the walls and ceilings, depending on the location and climate Zone. However, the amount of glass, the number of doors and windows also contribute to the efficiency of a house and that is measured by inserting that data in the COMcheck analytic software. When the PnP information is entered into the COMcheck system, using Fort Lauderdale, Florida as the location and climate Zone 1a, it demonstrates that the container exceeds the energy requirements by 51% as per Appendix 4.

- Surface to Volume Ratio: (SVR) = Envelope Area (EA)/Volume (V) 1555/3325 = .46
- Passive House Surface to Volume ratio is 0.8 or less so the PnP complies to Passive House Standards and would be considered highly energy efficient.
- COMcheck verified that the Envelope passed Design 51% better than the Energy Code

7.6. Material Aging & Toxicity – Tested by Statistics, Data and Comparative Charts

The life span of materials and their potential toxicity was reviewed by a comparison of both traditional and container house construction products. The data collected shows little difference for aging except for the exterior materials which demonstrated that the steel skin of the container has a 100+ year life while various exteriors for the traditional house went from 50+ years for EIFS, 60 years for vinyl siding, which contains toxic components, and up to 100+ for brick (InterNACHI, 2020). While the interior materials were similar in aging, various components of a new traditional house were highly toxic - such as gas HVAC systems and cook stoves, shower curtains, wall coverings, vinyl flooring and carpet. These materials can contain Di phthalates, VOC’s and per fluorinated chemicals (PFCs), which can cause cancer, respiratory, reproductive and neurological problems (Yale, 2013).

Older traditional homes can also have led-based paint or pipes installed, common in many houses

before the Safe Drinking Water Act of 1974 (EPA, 2021). Asbestos can also be found in vinyl tiles, glue used for the tile or HVAC pipe wraps, which can also cause cancer, hormonal imbalances and developmental problems (Yale, 2013). These materials and products would not be used in the PnP modules, but they are in the marketplace when homeowners are looking to purchase traditional homes. An environmentally conscious design (ECD) approach for the PnP's would aim to produce as little environmental impact and health concerns as possible while not compromising quality, cost or performance.

7.7. Flexibility and Mobility Review – Tested by Design Development

The PnP concept has been designed with two levels of flexibility, one being the physical aspect of the design and the other is a computer modelling opportunity which is not possible with conventional condominiums or apartments. As demographics shift the PnP needs to be able to physically adapt to the market as well as allow smart phone app controls and e-commerce purchasing, which is growing by 18% each year (Chaillou, 2018). The public is increasingly interested in buying direct from the manufacturer, and they expect quick delivery.

As a result, the PnP modules have been designed identically, with interchangeable kitchens, walls and doors. A one-bedroom unit can connect to additional containers adding any number of bedrooms or it can be divided back to one-bedroom units. They all have recessed patios, window box gardens, canopy shading and connectors for solar or wind. The multi-story frame design will allow the modules to be delivered by crane and tracked into their slots using a new guide system of channels and rollers. The guide system will require further structural design development since this concept has not been done before.

Currently, container projects are upfitted in a factory or on site, then set, stacked and welded together permanently. They are not considered movable except those commercial concepts designed to be temporary structures such as kiosks, band shells for music concerts or exhibit showrooms (Boxman, 2020)

The multi-story PnP building has the potential to collaborate with Farm Pod to mount their containers on the roof for vertical aquaponic farming. The roof can also hold solar panels, a common garden space or a green roof option to reduce heat loss. Rainwater can be collected for a grey water system to irrigate the roof garden or use for toilets and showers. There can also be recreation items on the roof including a pickle ball court, a hot tub or pool and lounge seating areas. These common amenities may not be possible for some traditionally constructed multistory building when they must use large sections of the roof for chillers and compressors. The PnP's can function more like hotels with self-contained HVAC systems in each unit rather than bulky and expensive roof top units with rated shafts to condition the entire building. Only the lobby, stair wells and elevators would be common areas in the PnP building and those could have separate HVAC systems in each to avoid the large chillers.

On the decommissioned Hood Canal pontoons, the units could be stacked as two-story housing for low income or tightly sited as a village of smaller 20' containers for disaster relief, that could be transported on semi-submersible ships for delivery anywhere in the world. These can be temporary PnP villages for assistance to communities in need after a natural disaster or permanent low-income housing.

The remaining thirty-one Hood Canal pontoons, which were bought by True North Services, represent a unique opportunity to create a floating infrastructure that adjusts to rising water levels and has minimum impact on its surroundings. Repurposing them also qualifies for carbon credit offsets, special financing and grants since they are considered green development. The pontoons

that have been repurposed already have become floating event centres, car park buildings, stationary docks and ferry terminals in Australia, Canada and Alaska. Pontoons were also used to develop floating multi-family housing in the Netherlands and various countries are considering the development of floating cities due to concerns about rising sea levels, but none have a comprehensive solution yet.

7.8. Code Adaptions – Technical Research

The IRC (International Residential Code) has recently come out with an amendment for the 2018 building code called Appendix Q which has relaxed some regulations for tiny house compliance, allowing houses under 400sf to fall into this category. Appendix Q reduces loft floor areas to 35sf, width of rooms down to 5', reduces stair widths from 36" to 17", and tread heights increased from 7" up to 12", but these altered regulations don't necessarily benefit the PnPs (Spencer, 2021).

The building code adaptation also does not help with zoning by-laws which are unique to every municipality and set the minimum size of lots and houses. Pocket communities, allowing smaller houses need to become part of standard land planning. In many cities such as Detroit, MI, Rockledge, Florida and Ashville, NC pocket communities in Planned Unit Developments (PUD) have enriched the cityscape and in California small Accessory Dwelling Units (ADU's) are being promoted for infill to solve their housing shortage.

Another new concept called co-housing has been developed as a community of small housing for seniors who want to downsize and live in a supportive environment where they can share meals, companionship and rides to doctors as an alternate to assisted living (White Paper, 2017). Developers seeing the advantages of these small co-housing and single-family house communities may begin applying pressure on Planning Departments to become more inclusive to alternate housing types including PnP container homes.

8. HYPOTHESIS DETERMINATION

The research methods completed verified that the PnP module proposal satisfies the hypothesis test for reduced cost, speed, lower emissions and higher mobility for a container house verses a traditional house. The summary of the tests is listed below:

Speed to Build:	Traditional house=12+-months
	Container house=10+-weeks
Cost Comparison:	Traditional house=$296,651 for Construction
	Container house=$131,775 for Construction($65,000+-/unit) Energy
Consumption:	Traditional house = 12,773 kwh/yr
	Container house=3656kwh/yr*
Carbon Emissions:	Traditional house C02 Emissions:28,000lbs/yr
	Container house C02 Emissions:8000lbs/yr*(less toxins in material)
Adaptivity/Mobility:	Traditional house = limited
	Container house=easy to add bed room units or move the house

* Figures are for a 3-bedroom, 2 bath, two-container unit house, 2021 pricing

9. RECOMMENDATIONS

The Future Improvements for the PnP could include:

- More efficient and cost-effective production by using robotic manufacturing
- Computer printed modules of organic materials • Improved food self-reliance incorporated into all modules
- Additional built-in self-sufficient energy production
- Aesthetic improvements such as add-on paint colours, wood screen walls & trellises

10. DISCUSSION

One important feature of the proposed PnP is that it can be ordered on-line along with additional bedroom units, kitchen units and other add-on elements including solar panels, decks, canopies, rainwater capture and vertical hydroponic gardening (Figure 3). This list of menu items could be increased if the PnP's are each designed to allow the extras to be easily plugged into the modules as initial installations or after-market DYI. Alternate energy options like wind and biogas can be considered as options as well.

The combination of unit configurations includes stand-alone units, combined units for extra bedrooms, In-law suite setup, units around a courtyard, double story stacked units with a spiral staircase cut in, and multi-story stacked units for condo complexes. They are like Lego block housing with many options depending on the owner's program and needs. They also provide the ability to change the configuration, increase or decrease the size of the home or move it, allowing the flexibility and mobility that society is trending towards.

Figure 3 – Kinetic Cities On-line Ordering by C. Spencer

11. CORE QUALITY OF LIFE

The PnP modules do represent a change in habitation related to size and relationships to other people in the living space. Some people may not be able to adapt to tiny living and discarding accumulated goods of a lifetime, while other find it liberating. When refugee families are offered two apartments upon coming to the US, as per regulations based on their numbers, they often prefer just taking one apartment since they are used to living in close quarters together and Kinetic Cities: on-line ordering PnP Element Main Container Extra Bedrooms Deck Shade Canopy Solar Panels Power Wall Green Roof Rain Water Capture Biogas & Burner Vertical

Garden Visual Image Estimated Cost $65,000 $55,000 $6,000 $2,000 $8,000 $5,000 $5,000 $1,500 $2,000 $1,000 Configuration Options prefer it, in addition to saving money. The issue of space can be a cultural consideration as well as a psychological or physical one.

The advantages and disadvantages to the PnP quality of life include the following:

- Healthy environment - Reduced indoor toxins, better air quality & organic products benefit well-being
- Welfare - Less stress, maintenance and monetary concerns, as well as increased mobility options contribute to better mental and physical comfort
- Safety - Limited access and comprehensive security systems make a safer home
- Affordability – Lower cost of purchase and potential of no mortgage gives more freedom
- Recycling – Reuse of materials and reduction of waste helps communities • Low energy consumption – Reduced CO2 emissions can help the planet
- Patio living – Being outside releases body toxins, reduces anger and rejuvenates
- Gardens (indoor & outdoor) – Healthy foods, oxygenated environment & less respiratory diseases

Disadvantages include the following:

- Loss of Privacy - Close quarters may cause tension between inhabitants
- Less Accessibility – Tight areas to work and smaller appliances can be frustrating
- Limited Storage – Less space for storage which may require an off-site rental
- Entertaining challenges – Limited number of guests in the winter especially

Overall, many owners of tiny homes claim they feel better without all the baggage and clutter; they have more free time, less worries, more money and they tend to get closer to their spouse, which creates a higher quality of life. But they must be creative about maximizing space, expand living to the outdoors and becoming better organized to be comfortable with the reduced living area.

12. CONCLUSION

In conclusion, these new PnP container modules can be designed to address improved affordability, health, reduced energy consumption and increased mobility in housing. They also offer a rare opportunity for flexible living in both offering alternate expanding or contracting floor plans and changes in location without selling the home. These options are paired with the expectations of upcoming homeowners as well as addressing the future of climate change and disaster relief.

These PnP modules may start as containers, but eventually more advanced versions might include computer printed modules using biological materials with robotic manufacturing technology. Individual modules could also have more advanced integrated smart living devices in the future, that might include push button movable walls or furniture. Solar glazing may eventually become a form of powering buildings or utilities may utilize all renewable energy sources, so panels aren’t necessary.

In conclusion, by taking advantage of developing advanced technology, along with creative solutions, we can advocate for a new green sustainable machine for living that offers flexibility and healthy options while reducing our carbon footprint for future generations.

Figure 4 – Kinetic Cities PnP Container Modules by C. Spencer

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