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A study of Shipping Containers as a Living Space in Context of Sustainability

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Abstract
As is known, natural environment and ecological life are dramatically affected by building industry. Therefore 'Sustainable architecture approach' has become one of the most important cases as it proposes solutions to environmental problems and responds to needs of future generations. The main goal of sustainable architecture is to use renewable energy sources, to design environmentally friendly buildings that were built with recyclable building materials and to provide ecologically sensitive land use. In accordance with the objectives, although the initial investment cost for sustainable technologies is too much, they offer economic-ecological solutions for designers depending on energy saving overtime. It is also seen that containers, an innovative example of today and the future design, are intertwined with ecological and sustainable approach. In this regard, the purpose of the study is to draw attention to sustainable container architecture with low initial investment cost that has recently been in the agenda of architecture. In the study, container samples whose functions such as utilization of dwelling, office etc., are worldwide increasing are exampled and their design criteria is analyzed in terms of sustainability.

Key Words: Sustainable Design, Container Architecture, Shipping Containers.

1. INTRODUCTION

Global environmental problems facing us at the beginning of the twenty-first century are dominated by the potential and impending risk posed by the greenhouse effect and the resulting impact of climate change. There are also concerns about the damage being inflicted on fragile ecosystems by increasing development and resource extraction, and the depletion of the ozone layer, which allows harmful ultraviolet radiation to penetrate the lower atmosphere. In parallel with these often imperceptible effects there has been a general deterioration in air quality, most striking in urban areas (Wigginton and Harris, 2002).

A major driver of human impact on Earth systems is the destruction of biophysical resources, and especially, the Earth's ecosystems. The environmental impact of a community or of humankind as a whole depends both on population and impact per person, which in turn depends in complex ways on what resources are being used, whether or not those resources are renewable, and the scale of the human activity relative to the carrying capacity of the ecosystems involved. Careful resource management can be applied at many scales, from economic sectors like agriculture, manufacturing and industry, to work organizations, the consumption patterns of households and individuals and to the resource demands of individual goods and services (Clark, 2006).

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Architectural activities are directly responsible for 50% of energy consumption and indirectly responsible for approximately 60% (including activities directly associated with construction, such as construction tools and equipment, communication, publicity, marketing and property development), not to mention approximately 50% of the world's waste disposal and emissions. These statistics are proof enough; the basic fundamentals of architecture have got to be changed, without delay, there is clearly an urgent need to establish a new sustainable concept in architecture (Garrido, 2011a). In this regard, the purpose of the study is to evaluate - in terms of sustainable architecture - containers that have been recently in the agenda and utilization of which become more and more popular as an alternative to the present dwellings.

2. SUSTAINABILITY

By the 1990s, European and American architects interested in environmentally sensitive architecture supported a theoretical concept they called 'sustainable development' or, more commanly 'sustainability'. Sustainability was defined by the United Nations' World Commission on Environment and Development in the 1987 'Bruntland Report', as development that 'meets the needs of the present without compromising the ability of future generations to meet their own needs' (Gissen, 2003). The definition indicates a connection and a suitable equilibrium about sustainability. Because of provide necessaries, achievement of right composure between the needs of today and tomorrow lineage and community – environment connections are taken as a reference. Sustainability can be introduced in architectural terms as the long term philosophy of thought and action that starts with development of building program and includes future use of the building, life of the building, demolition/reuse process of the building (Özmehmet, 2007). According to Bourdeau (1999), the purpose of the sustainability approach is to introduce and achieve short/medium/long-term gains, and determine how to integrate technical data, methods, and experiences gained in the other stages with preliminary design process.

2.1. Sustainable Architecture Design

Sustainable buildings that are both environmentally and resource-friendly enjoy an increasingly higher standing when compared to primarily economically oriented solutions. Aside from social and economic factors, steadily rising energy costs over recent years facilitate the trend towards sustainability. Taking into account both contemporary energy prices and price increases, energy saving measures have become essential in this day and age. Since energy is essential, many investors and operators place their trust in new technologies and resources in order to become independent of global development. Users look for sustainable building concepts, with low energy and operating costs, which offer open, socially acceptable and communication-friendly structures made from building materials that are acceptable from a building ecology point of view and have been left in as natural a state as possible. They analyze expected operating costs, down to building renaturation, and they run things in a sustainable manner (Bauer et al. 2009). Sustainable architecture is the design of sustainable buildings. Sustainable architecture attempts to reduce the collective environmental impacts during the production of building components, during the construction process, as well as during the lifecycle of the building (heating, electricity use, carpet cleaning etc.) This design practice emphasizes efficiency of heating and cooling systems; alternative energy sources such as solar hot water, appropriate building siting, reused or recycled building materials; on-site power generation - solar technology, ground source heat pumps, wind power; rainwater harvesting for gardening, washing and aquifer recharge; and on-site waste management such as green roofs that filter and control storm water runoff (Yan and Stellios 2006). Sustainable building is the practice of creating structures using resources that are environmentally responsible and energy-efficient. It encompasses factors such as internal and external design, construction, operation, maintenance, renovation, and deconstruction. The aim of sustainable building design is to reduce the overall impact of the built environment on human health and the natural environment (Anonymous, 2014a).

Figure 1. *Main goals for sustainable building design (Anonymous, 2014a)*

3. METHODOLOGY

The main purpose of the study is to examine application methods of conceptually-suggested sustainable architecture criteria on containers that are adapted to daily living, and embody solution proposals. The study consists of 2 sections. The first one introduces the container architecture and analyses significant criteria (sizes, settings, thermal properties, insulations etc.) related to the design of the containers which are used for functions such as dwelling, etc. The second section evaluates the impact which the integration of sustainability with architecture has on built environment by considering the container samples chosen globally. Environmental approaches and natural and technological analysis for containers examined in the context of sustainability are evaluated under the following titles.

- Optimization of resources (natural and artificial)
- Reduction of energy consumption
- Utilization of alternative energy sources
- Reduction of waste and emissions
- Improving people's health and wellbeing
- Reduction of building costs and maintenance.

Brief descriptions related with this title that used in the analysis of sustainability are given in **Table 1**.

Table 1. *Design Principles of Sustainability*

Optimization of resources (natural and artificial): Buildings that use natural durable, reclaimed and re-usable materials and resources can be designed.
Reduction of energy consumption: Designing bioclimatic buildings, having energy efficient construction solutions that use natural energy sources and local materials. Reducing transportation of materials.
Utilization of alternative energy sources: Buildings using wind, solar and geothermal energy as passive-active integrated systems can be designed.
Reduction of waste and emissions: To reduce and manage the pollution and waste, it can be used waste products, putrescible and non-polluting materials.
Improving people's health and wellbeing: Fulfilling people's social life and relations and enhancing their life quality, using of healthy materials, providing natural ventilation.
Reduction of building costs and maintenance: To reduce price and maintenance buildings having extended life cycles and technological solutions can be designed, by using reclaimed and re-used materials.

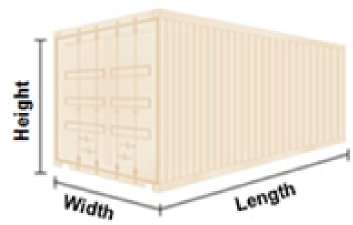
4. CONTAINER ARCHITECTURE

The container is at the core of a highly automated system for moving goods from anywhere to anywhere, with a minimum of cost and complication. The container made shipping cheap and changed the shape of the world economy. The widespread use of the modern metal shipping container can be traced back to the mid-1950's. According to Levinson, in April 1956 an oil tanker traveled between Newark and Houston with 58 rudimentary "shipping containers," (actually refitted aluminum truck bodies) sparking a modern revolution in moving goods around the world. However, an unexpected result also eventually transpired: shipping containers became recognized as an attractive building material by many architects (Levinson, 2006). Container architecture is a form of architecture using steel intermodal containers (shipping containers) as structural element, because of their inherent strength, wide availability, and relatively low expense.

Containers are in many ways an ideal building material. They are designed to carry heavy loads and to be stacked in high columns. All shipping containers are the same width and most have two standard height and length measurements and as such they provide modular elements that can be combined into larger structures. This simplifies design, planning and transport. As they are already designed to interlock for ease of mobility during transportation, structural construction is completed by simply emplacing them. Due to the containers' modular design additional construction is as easy as stacking more containers. They can be stacked up to 12 high when empty (Wikipedia, 2014). The following figure shows the weights and dimensions of the most common types of containers. The weights and dimensions quoted below are averages. Containers of the same type of produced by different manufacturers may vary slightly in actual size and weight. Containers, also known as an ISO shipping container or Intermodal Steel Building Unit (ISBU) come in several standard sizes, but residences typically use 20 ft, 40 ft or 40 ft High Cube sizes **(Table 2)** (Anonymous, 2014b).

Table 2. *The containers dimensions for 20', 40' and 40' High Cube*

	External *(20 ft)*	External *(40 ft)*	External *(40 ft HC)*
Length	6.06 m	12.19 m	12.19 m
Width	2.44 m	2.44 m	2.44 m
Height	2.59 m	2.59 m	2.89 m
	Internal	Internal	Internal
Length	5.87 m	12 m	12 m
Width	2.33 m	2.33 m	2.33 m
Height	2.35 m	2.35	2.65 m
Weight	2.230 kg	3.660	3.840 kg



The containers have been designed to store and transport goods over long distances, and in a tight, economical and safe way. However, it also happens, the curious coincidence that the spaces that have been designed for storing and transporting goods, have a proper human scale. That is, they are also valid for designing living spaces. However, one must never forget that the containers have not been designed to be lived in. Therefore, the first thing to be done when using containers in architecture is to ensure the minimum conditions of habitability inside (Al, 2011).

Construction companies and retail stores use shipping containers to keep goods, equipment, and store safe from nature events and robbery. However, building designers utilize containers in order to show up attractive places for people to live in.

4.1. Design Principles of Containers

In following, a list of considerations that should be taken into account when executing truly sustainable architecture using containers has been provided (Garrido, 2011b).

Thermal Properties: Containers are built of steel plating and sections. Only the interior floorboards are built of wood planks or plywood sheets. It is for this reason containers heat up quickly through solar radiation, and cool down immediately after this solar radiation disappears. Furthermore, container weigh quite a lot, which means their thermal inertia is also elevated. Containers must be outfitted with thermal insulation in order to ensure their inhabitability.

Exterior insulation – Interior thermal inertia: If thermal insulation is installed inside the container, the only result is that of diminishing one of the most important qualities of containers: their high thermal inertia. In winter, the exterior sheet metal heats up through solar radiation, but the unit rapidly cools when night falls, which means heating systems must be used, With their ensuing energy consumption, in the same way, in summer the sheet metal cools down at night, but quickly heats up as soon as the sun comes up. It is clear that insulation must always be installed on the exterior, no matter what type of building it is or what materials re being used **(Figure 2, 3).**

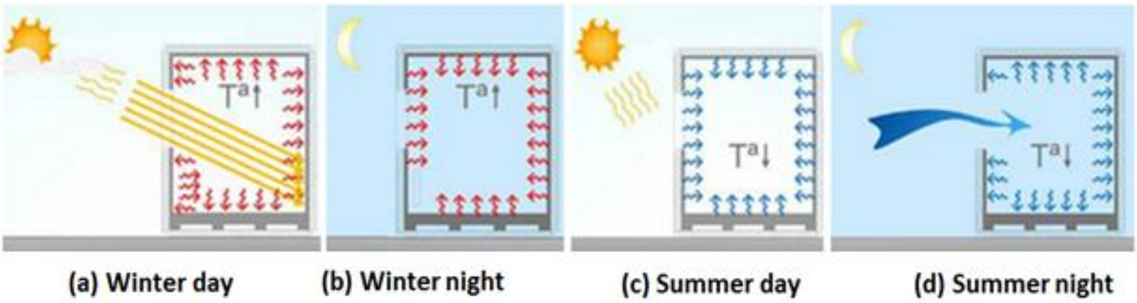


Figure 2. *The containers thermal performance with exterior insulation (Garrido, 2011b).*

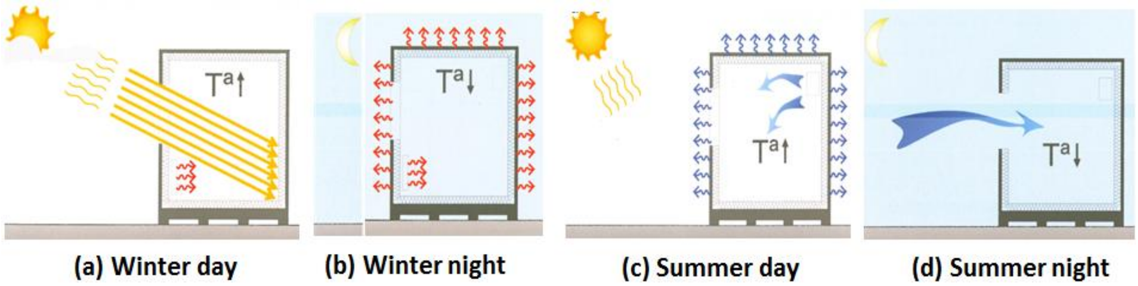


Figure 3. *The containers thermal performance with interior insulation (Garrido, 2011b).*

Converting containers into housing can be ideal when using those which are pre-insulated. The insulated containers have been designed for transporting perishable goods and foods. The insulation is a compact mineral wool; and without metal or wood studs, there are no cold bridges **(Figure 4)** (Michel, 2010).

Bioclimatic design: The use of containers by no means restricts the decisions required to carry out a proper bioclimatic design of the resulting building. The roof is always the bottleneck in container constructions, as in one way or another, both its insulation and thermal inertia must be increased the best way of doing so is to have a roof garden. Although this increase can also be attained by using elements (sun panels etc.) providing shade that have a high degree of thermal inertia themselves.

Transpirability and ventilation: Metal elements don't breathe, which means that we can only attain sufficient energy efficient ventilation by stimulating transpirability from the ground, or removing part of the sheet metal of the containers and replacing it with other construction materials that are both ecologic and transpirable. It is important the point out that containers have a hollow base that can be closed off and used for natural ventilation of the interior rooms.

Impermeability: The sheet metal and the other steel parts of containers may start to rust, which is why it is fundamental to protect them against water. In this sense, having the right decision is much more important than what impermeability materials are being used.
Systems used to fasten the containers: Bolts must be exclusively used in order to fulfill the purpose of being able to assemble and disassemble the containers as many times as necessary.
Interior finishes: All interiors finishes must be installed using pressure, gravity or nails and bolts so they can be assembled and disassembled as often as required (Garrido, 2011b).

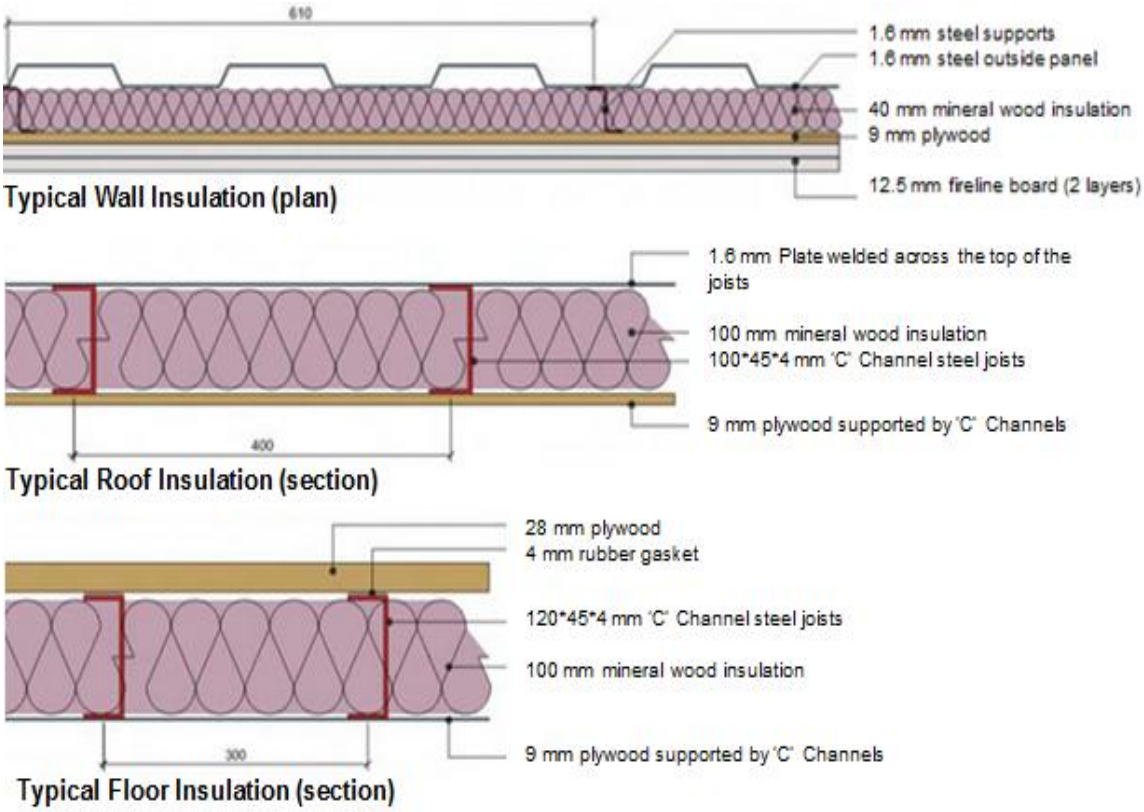


Figure 4. *Typical wall, roof and floor insulation of containers (Michel, 2010)*

5. ANALYSIS OF SUSTAINABLE CONTAINERS SAMPLES

Within the scope of the study, several container projects are examined and 5 of these projects that shine out in terms of sustainability are sampled. 3 of the samples are a dwelling-function building, an accommodation-function hotel, and an accommodation-function dormitory. In the study, analysis tables in which sustainability criteria mentioned in the methodology section are evaluated are provided for the container projects. The container projects are named as Sample1, Sample2, Sample3, Sample4, and Sample5 respectively.

Table 1. *Analysis of Y Container House (Zimmer, 2011; Guodong, 2012; Pierce, 2011; Defendorf, 2011; Lea, 2011)*

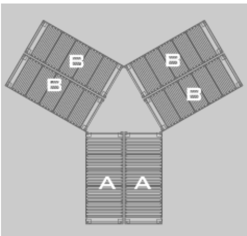
PICTURES	**Sample 1:** Y Container House, 2011, USA, designed by Team China for Solar Decathlon 2011
	Cons. Detail: Y Container, combines six recycled prefabricated containers, 2 types A+B
	  
PRINCIPLES OF SUSTAINABLE DESIGN	**Optimization of resources:** The Y Container allows residents to live just about anywhere freely, with self-sufficient off-grid energy sources and a lightweight mobile design. The home has three verandas that face the surrounding landscape, each capped with an open porch for enjoying the fresh air of the outdoors. Wooden screens line the perimeter of the façade, and can be rolled back to reveal the open interior. Energy-efficient features such as super-insulating materials and a natural ventilation tunnel contribute to the sustainable design. Lining the outside of the home is a series of plants which provide oxygen, cool breezes and fresh vegetables.
	Reduction of energy consumption: Y Container combines six recycled shipping containers into a succinct, Y-shaped solar house. At the center of the Y, three solar light tubes accentuated the amount of natural light in the space situated furthest from the windows. Each wing of the home acts like a natural ventilation tunnel, creating a continuous flow of air. The exterior sides of the structure are layered with rigid insulation under bolt-on zinc-plated steel sheets, creating a waterproof, reflective shell that enhances the performance of the bifacial photovoltaic panels mounted on the rooftops of the spurs.
	Utilization of alternative energy sources: The flat roof is lined with photovoltaic panels. It transfers the heat collected from the sun to heat the Y Container's floor, as well as the hot water used within. The temperature of the interior is also passively controlled with vacuum insulation, blocking heat loss and gain.
	Reduction of waste and emissions: Rainwater is harvested, purified and stored on site. The corners of the triangle are equipped with downspouts for water collected on the rooftops of the spurs and on the central-area canopy. The water flows from the downspout to collection pools that are integrated into the exterior decking.
	Improving people's health and wellbeing: Y Container is easy to transport, assemble, and expand—providing the freedom to live anywhere with low costs and clean energy. It is a living house that can contain the energy, water, and plants required for an individual to enjoy an independent and natural lifestyle. Two large glass doors faced the south and allowed sunlight to enter and naturally light the space. The white modular furniture reflected the light and gave the impression of a much larger space. The house was less than 1000 sq. feet, yet even while filled with people, there seemed to be ample space. Y Container uses these standard modules and special conjunction components to help people expand their living space according to their wishes.
	Reduction of building costs and maintenance: The shape of a Y is the junction where the 6 shipping containers meet. Each prong was comprised of two containers joined together to make up different modules of the home. The designer team of Y container from China explained that by using recycled shipping containers that are structurally strong yet inexpensive, it allowed the cost of the home to be affordable, thus a larger solar array could be utilized.

Table 2. *Analysis of R4 House (Garrido, 2011 and Anonymous, 2011)*

	Sample 2: R4 House, 2007, Spain, designed by Luis De Garrido
	Cons. Detail: R4 House combines six units 40 ft containers, (173 m^2)
PICTURES	  
PRINCIPLES OF SUSTAINABLE DESIGN	**Optimization of resources:** The house makes the most of resources like the sun (to heat the home), the breeze and the earth (to cool the home and to cover the top of the container), rain water (to water the garden and fill the toilet cisterns), sheep and hemp wool (for the insulation). The most is made of the materials, and no waste is produced. The small amounts of waste produced have been utilized within the same construction.
	Reduction of energy consumption: In context of construction, R4 house has been built with a minimal energy consumption, in an interval of seven weeks. Thanks to its outstanding bioclimatic characteristics, R4 house has a zero consumption of conventional, non-renewable energy. The house is heated by the greenhouse effects and by the underfloor heating system fed by 7 thermal solar panel (supply hot water). No support boiler is needed, thanks to the building's enormous thermal inertia. The house is capable of cooling itself down by means of an architectural cooling system composed of a system of underground galleries. In winter, the air duct on the solar chimney is closed so it does not cause warm air to flow out of the dwelling. All the materials used in the house can be recovered easily and can be used again in the construction of another building. Locating the insulation on the outside of each container – component of house bring the energy consumption of a building down to the minimum.
	Utilization of alternative energy sources: Three types of energy are used in the house: thermal solar (solar panels underfloor heating, and evaporation of water to cool the air), photovoltaic solar (to generate the electricity the home needs), and geothermal (air cooling system which takes advantage of the low temperatures underground in the subterranean galleries.
	Reduction of waste and emissions: The dwelling does not generate emissions of any kind, and only organic waste. Part of this domestic waste is reused conveniently (grey water for the garden). Meanwhile no waste has been produced in the construction (everything has been used).
	Improving people's health and wellbeing: All the materials used are healthy and organic, and don't let off any emissions which could be harmful to human health. The home has natural ventilation and makes the best use of natural light; this creates a healthy atmosphere and makes for the best possible quality of life for the inhabitants. It should be pointed out, that thanks to the perforations in the side of the containers; the dwelling maintains the natural electromagnetic equilibrium of its surroundings.
	Reduction of building costs and maintenance: The dwelling has been planned in a rational manner, optimizing the resources used, and using reclaimed and re-used materials. All this allows it to be built at a very low price, even with the environmental equipment incorporated. Also, the home demands very low maintenance, ordinary cleaning, and twice-yearly treatment of the wood with vegetable oils.

***Table 3**. Analysis of Ecopod Container Home (Walsh, 2013 and Alter, 2008)*

PICTURES	**Sample 3:** Ecopod, Canada, designed by Dwight Doerkson
	Cons. Detail: Ecopod combines 20 ft steel storage container
	
PRINCIPLES OF SUSTAINABLE DESIGN	**Optimization of resources:** The Ecopod was designed to be a self-contained off-grid unit. The house makes the most of resources like the sun (for electric energy), rain water (to fill the toilet cisterns). Ecopod is equipped with Sun-Mar composting toilets, which evaporate the water from the toilet waste and carry it back to the atmosphere via a specially designed vent system. The household water needs are taken care of by a Water Mill, which is an atmospheric water collection device that works to condense water vapor, while also purifying it.
	Reduction of energy consumption: The wall insulation of ecopod is soy-based and water-blown into walls and ceiling cavities to provide the needed thermal protection to the home. This type of insulation contains no formaldehyde or other harmful and irritating matter. It is also mold resistant and is not a food source for rodents or insects. This type of insulation is also Class 1 fire rated, meaning it will char but won't sustain a flame.
	Utilization of alternative energy sources: Power to the ecopod is supplied via an 80 watt solar panel and 12 volt battery, which eliminates any need to run power lines or trench power cables to the unit, meaning that it is ready to live in right after set up. One of the 20-foot side walls of the ecopod can be lowered by 2 hydraulic cylinders to form a sturdy deck. This wall is lowered with the use of a solar-powered electric winch. The deck can be raised to secure the ecopod when leaving the dwelling for a longer period of time.
	Reduction of waste and emissions: The floors of ecopod are covered by ECOsurfaces flooring which is made of recycled tire rubber and Color Mill EPDM, which is comprised of pre-consumer waste and organic fillers. Together these two materials form a water based polyurethane polymer. The resulting flooring has low-Voc emissions and is recyclable and can contribute toward earning 9 Leed points.
	Improving people's health and wellbeing: The outer shell and structure of an ecopod is made from a standard 8'x20' steel shipping container. For the interior walls the Magnesiacore Technology is used. This technology uses proprietary processes with magnesium oxide compounds to deliver a multi-purpose, non-combustible, and versatile board material, which provides full Leed credit for all uses. Magnesiacore boards are made primarily from Magnesium Oxide (MgO), which is a naturally occurring compound. So all the materials used are healthy and organic, and don't let off any emissions which could be harmful to human health.
	Reduction of building costs and maintenance: Ecopod's designer has developed "an affordable eco-friendly building that's transportable and doesn't need to be hooked up to the grid"- out of shipping containers. He cuts out an entire wall and hinges it, so when you want to leave your ecopod you simply flip a switch and a solar powered winch pulls up the deck and closes up the box. The floors are recycled rubber, the walls are FSC birch ply over bio-based green foam insulation, the optional toilet is composting and fridge is solar powered. All this allows it to be built at a very low price, even with the environmental equipment incorporated.

Table 4. *Analysis of I-Sleep Hotel (Garrido, 2011; Al, 2011; Anonymous, 2008)*

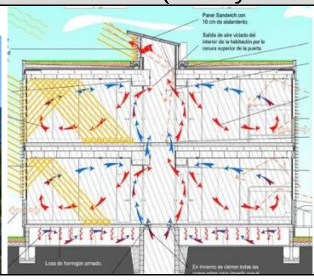
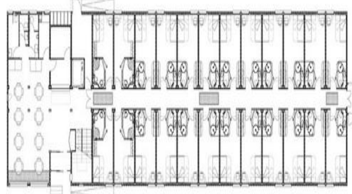
PICTURES	**Sample 4:** I-Sleep Hotel, 2008, Spain, designed by Luis De Garrido
	Cons. Detail: Containers size; 12m*2m*3m (Totally 1300 m^2), room's size; 18 m^2
	  
PRINCIPLES OF SUSTAINABLE DESIGN	**Optimization of resources:** The I-Sleep Hotel conceptual model provides a construction alternative that has no environmental impact and no energy consumption yet is entirely relocatable, movable, reconfigurable and expandable. And the best thing is that it can be considered as a fixed or movable asset, with all the advantages that brings to rural environments.
	Reduction of energy consumption: I-Sleep Hotel consumes 40% less energy than a conventional hotel with the same surface area and similar characteristics. Thanks to material chosen, the walls transpire naturally and continuously, allowing for natural ventilation to take place without any energy loss. Exterior air enters the set of underground chambers and cools down. The cool air from the underground chambers penetrates the building through a set of grates located in the floor and the corridors. Cool air flows through all the bedrooms and cools them down. So it is not necessary to connect or utilize mechanical climate control system.
	Utilization of alternative energy sources: Solar energy panels are used in the hotel. I-Sleep is heated in winter by a combination of 3 different systems: the right bioclimatic design and a high level of insulation, the incorporation of a system of solar energy panels and the incorporation of an highly energy-efficient inverted heat pump. The hotel keeps cool in summer using a combination of 2 different system: the right bioclimatic design and the incorporation of an economic and ingenious system of underground galleries to cool the air down. The mechanical cooling system is only activated on days when it is needed. The system uses very little energy.
	Reduction of waste and emissions: Due to the building system that is employed, practically no waste is generated in the construction of the I-Sleep Hotel. The little waste that is created (shaving, small fragments) is practically negligible.
	Improving people's health and wellbeing: Direct sunlight shines on the slats, lighting up the white ceiling of the bedrooms. In this way natural light is spread evenly to the farthest corners of the rooms. The slots in the corridor let natural light enter from overhead. When the air inside the skylights heats up, the warm air rises quickly by natural convection and drawing out the air inside the hotel. In this regards, I-Sleep hotel has natural ventilation and makes the best use of natural light; this creates a healthy atmosphere.
	Reduction of building costs and maintenance: I-Sleep Hotel has been planned in a rational manner, optimizing the resources used, and using reclaimed and re-used materials. Due to the rapid assembly and disassembly, the hotel can be moved easily, meaning the entire hotel can be placed in the most profitable location at the time. Each module-container that the hotel is built of can be moved without having to use special transport systems.

Table 5. *Analysis of Keetwonen Student Housing (Pilloton, 2007; Uittenbroek and Macht 2009; Anonymous, 2014c)*

PICTURES	**Sample 5:** Keetwonen Container Student Housing, 2006, Amsterdam, designed by TempoHousing
	Cons. Detail: Keetwonen Student Housing combines 1000 units (40 ft) steel container
	  
PRINCIPLES OF SUSTAINABLE DESIGN	**Optimization of resources:** The project use re-used materials and resources. Shipping container construction that used in project is inherently mobile and after five years the units could be moved and reused on another site. And also Keetwonen has integrated a rooftop to accommodate efficient rainwater drainage while providing heat dispersal and insulation for the containers beneath.
	Reduction of energy consumption: The ventilation of the units is controlled by a combination of natural cross ventilation and a manual switch system that regulates mechanical ventilation. For insulation the designer company uses a box within box system. The walls and roof are insulated within each unit using rigid XPS extruded polystyrene insulation material covered with drywall. Between the walls, gaps are closed with a sealing band, but only at the facades. The units are designed to maintain average temperatures of 21 º, are soundproofed and fire resistant with one-hour construction.
	Utilization of alternative energy sources: One natural gas-fired central boiler per building provides heating. The hot water for the shower and the kitchen is fed by the each unit's own hot water heater. Recognizing the penchant for long student showers, designer company intentionally chose to reduce operating expenses by providing a 50-liter boiler per unit that gives the student the option to shower for up to15 to 20 minutes before the water turns cold. After this period the boiler needs time to reheat. The shower is also supplied with a water saving showerhead.
	Reduction of waste and emissions: At over 1,000 units, the Amsterdam student housing container project is far larger and demonstrates both its utility and economy. So, designer company reduce pollution by planning student housing containers that use non-polluting, biodegradable materials and also no waste has been produced in the construction.
	Improving people's health and wellbeing: The whole project was designed with an eye on how students like to live: a place for yourself, not having to share the shower and the toilet with strangers, but at the same time lots of possibilities to participate in the social life of the dormitory. Containers are home to not only the 1000 units that each has a private balcony, but a cafe, supermarket, and even a sports area. The whole project increases the quality of life and level of satisfaction for students in the buildings.
	Reduction of building costs and maintenance: The designer company chose to use an existing container factory in China to construct and convert the containers in a continuous sequence, which lowered the costs significantly. The containers were all adapted to make the infill construction fit better and make it easier to build the containers. A project of 1,000 units gave the advantage of economy of scale, which lowered the building costs of the project.

6. CONCLUSIONS

The ecological and sustainable goal in building design should be to strive for a reduction in the total primary energy needs to a minimum, and ideally down to zero, by using only renewable resources and incidental heat gains to drive a building's comfort system, and with the minimal use of continual importing of energy to maintain comfort. By utilizing the building fabric itself (the skin), artificial heating, cooling, lighting, and the other energy importing systems can be minimized, or avoided altogether (Wigginton and Harris, 2002). Depending on rising public interest in sustainability, designers from all over the world are getting wiser and wiser to use energy-saving technologies and sustainable design techniques. In this regard, today, shipping containers are being repurposed and turned into modern dwellings, workspaces, schools, cafes, hotels, and etc. as a sustainable buildings. Such containers are designed as eco-friendly and low-priced buildings. It is easy to move modular container units from place to place. Some benefits of recycled shipping containers are accessibility, flexibility, reliability, shorter and cost-effective construction period.

In the study evaluating the container projects it was defined that sustainable design approaches were applied in different scales. Innovative and sustainably friendly shipping containers that examined in study, active and passive design systems like location of the building, green roof design, usage of purified green water and rain water, choice of natural and durable materials, wind turbine, solar collectors and photovoltaic cells were used. Provided by shipping containers, advantages including availability, weather-resistant character, subsistent strength, and etc. make them a desirable and eco-friendly modular unit. They have low-cost construction techniques when compared to conventional buildings. Reutilize of a container as a prefab structural element decreases energy of buildings and allows for a second use. By this way shipping containers can be considered as a sustainable component in architectural design.

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