Abstract
This paper reports on the URBox concept encompassing the high tech end of solar energy and informal low cost and affordable housing. It aims to contribute to solving the global energy crisis by building solar energy settlements in deserts where land is affordable and sunshine in abundance.

First the award winning Solar City 2050 is described and already existing technology is mentioned. In addition to the energy crisis there are the potential food, water, health, housing and immigration crises that need to be faced and dealt with. Although it is understandable and tempting to copy the affluent world technology to developing countries: value is created at the price of more energy, natural resources and pollution, rather than less. Therefore new ways need to be explored. To that purpose, new solutions in the field of housing have been developed with the URBox formula.

URBox advocates a different approach of the complete building manufacturing, marketing, using and re-using process. Using local construction materials and local labour resulting in a built environment that can be managed and controlled on a local scale should challenge the housing crisis. Its formula is based on construction rules applied to an urban pixel of housing, the smallest identifiable practical dwelling unit, less than four by four meters, with a column and beam based load bearing structure, separate inner and outer skins and walls and guide lines for running ducts and services in and between the units. The URBox units can then be combined as multifunctional houses, and settlements. The same idea can be applied on the industrialized world with its own housing crises, presenting themselves in niche markets of housing for starters and low-income housing.

URBox will be available in two different variants: Its very low cost housing variant challenges the housing crisis by using local construction materials and local labor resulting in a built environment that can be managed and controlled on a local scale. Its affordable housing variant is meant for the industrialized world with its own housing crises, presenting itself in niche markets for starters and low-income population groups.

At this moment URBox can be illustrated by sketching scenarios, in order to demonstrate its universality.

Like solar power knowledge is indestructible and infinite. This is a call for academic support to make the knowledge and design power available in order to tackle the crises we face.

Keywords: Open Building, Lean Construction, Affordable Housing, URBox

INTRODUCTION

In 1961 John Habraken wrote ‘We should not try to forecast what will happen, but try to make provision for what cannot be foreseen’ (Habraken, 1990). Although the future is hard to predict we do not completely stare in the blind. Some developments indicate what is to happen. Today’s demographic data give indications about the world’s population in the near future. Maslow (1943) gave us psychological insights in the hierarchy of needs. Alvin Toffler (1980) identified the sociological context of the agricultural, the industrial and the information wave societies go through. The Club of Rome warned us for the depletion of natural resources (Meadows, 1972). Looking back many of these visions proved to be true
and their inertia generate a momentum that make the observed forces hard to stop or bend. At the same time it is dangerous to extrapolate these forces towards tomorrow. Technological developments have made communication available to the masses at a higher speed than anticipated, and the 2011 earthquake in Japan and its nuclear crisis sows that the unforeseen can throw a spanner in the works. This is the context of certain certainties and certain uncertainties ideas were developed to use solar energy as an endless source of energy to replace the consumption of carbon energy and to use locally available building materials and human resources of owner dwellers to create a built environment that works.

**SOLAR CITY 2050**

First the award winning Solar City 2050 is described and already existing technology is mentioned. In addition to the energy crisis there are the potential food, water, health, housing and immigration crises that need to be faced and dealt with. Although it is understandable and tempting to copy the affluent world technology to developing countries: value is created at the price of more energy, natural resources and pollution, rather than less. Therefore new ways need to be explored.

**The proposal**

In 2008 Frans Cuppen and Dirk Smets proposed a framework for a Solar City to be operational in 2050. It aims to be a large infrastructural scheme to accommodate the social-economic development of North Africa. In addition it could complete a fully sustainable energy supply for European countries. North Africa faces the task to build millions of dwellings in a short period of time. Consequently complete new towns need to be developed that offer jobs for millions and that need to be supplied with food, water and sustainable energy.

North Africa lies at the brink of Europe, in search for solutions for climate related problems. Therefore it needs serious consideration to connect the development of North Africa and the repair of Europe. The Solar City 2050 project is based on the hypothesis that the new settlements in North Africa will be equipped with large solar energy plants, not only for the local energy demand but for export to energy hungry Europe as well. Large-scale desalination plants can win fresh water from the sea in order to irrigate the dry land and transform it into fertile ground for growing crops. This will boost the already existing biological way of farming, in turn feeding the cities in the region, newly developed tourist resorts as well as exporting their products abroad (Cuppen et. al., 2008).

**The proposal illustrated**

The artist’s impression (illustration 1) gives an indication of one of a 100,000 inhabitant solar city in North Africa. The settlement includes a harbour, industry zones, desalination plants, bio nurseries, forests and areas for leisure and tourism. The solar energy parks with plants and turbines cover an area of 330 km². Crops are grown partly shaded by thermo-solar and photo-solar panels that deeply penetrate the hot desert. At both sides of this solar power ribbon 220 km² of algae fields extend surrounded by untouched nature. Every aspect of this settlement is sustainable and climate neutral;

- The conversion of solar heat and light into electricity;
- Desalination of seawater;
- Production of bio-fuels and bio-chemicals;
- Farming crops, life stock and fish;
- Mining and processing of resources and regaining waste;
- Traffic and transportation on electrical power and bio-fuels;
- Living, communication, services and trade;
- Leisure and tourism

**Illustration: 1 Solar City 2050**

1. sun tower
2. trough mirrors
3. fresnel mirrors
4. desert road with water supply piping
5. power stations
6. water basins
7. transformer station
8. ultra high voltage direct current cable to Europe
9. water desalination and pumping station
10. pisci-culture in salt and brackish water
11. agriculture and horticulture
12. sylvi-culture with dates, figs and almonds
13. chemical industry: salt, chlorine, cement, glass, technical gases
14. aluminum production (factory walls are rigid giant trough mirrors)
15. blotter fields with effluent recovery
16. new founded band shaped city; on central axis runs electric shuttle
17. recreation and tourist resorts
18. primordial natural areas
19. tanker for bio synthesis gas from organic waste
20. zeppelin for solar mirror transport and trips poor in CO2
21. yacht-basin
22. intercity station on the Trans Maghreb line
23. electro-genic blimps
24. mobile solar power units with dish mirrors
25. experimental solar chimney
26. solar furnace for heat technology
27. drip irrigation with desalinated marine water
28. market in the city with locally extracted products
29. methane production from hydrogen and CO2
30. horticulture and pisci-culture below the fresnel mirror fields
31. upper town for pedestrians with traditional shady lanes
32. downtown with electrical traffic
33. technical installations in the downtown
34. logistic centre
35. warm marine water spa
36. giant construction robots laying new mirror fields
37. building blocks and panel bakery with solar heat technology
38. embarking and disembarking of goods
39. low accumulation lake for nocturnal current generation
40. water turbines in the low lake dam
41. wind turbines assisting the drain of the low lake for nocturnal current generation
42. CO2-free cruises to solar city-resorts
43. xerofites on aride soils for vegetable oil: yatrofa, ricinus etc.
44. factory pressing feed cakes, oils, greases and biodiesel xerofites
45. conversion and recycling of solid waste
46. algae basins and bio-fuel refineries
47. maglev line, cargo tube, aqueduct, high tension line and service lane
48. solar energy plasma reactor
49. Fischer-Tropsch gasification for bio-fuels and bio-char
50. sustainable air traffic with bio-fuels

**Table I: Legend for Solar City 2050, illustration 1**

The 10,000 megawatts power plants generate enough energy to compensate the future electricity shortage of a country like the Netherlands, including its electrical cars. Its algae plants can contribute to fuel for cargo and passenger transport by air. To this aim the countries involved are connected to a smart intercontinental High Voltage Direct Current grid with low transmission loss and equipped with the latest in energy recovery and storage. Approximately forty large settlements of this kind in North Africa and the Middle East as
well as many smaller settlements in Southern Europe do not only cover the local need for energy, water and food, they also quench the energy thirst of Europe. They aim to contribute to a climate of political and economical stability, reduction of the green house effect and to prosperity and well being of millions. The ambitions and feasibility of this concept can be seen as an international Apollo project. In the final analysis globally less than one percent of all deserts are sufficient to supply ninety percent of the world population with sustainable energy, water and food. Frans Cuppen and Dirk Smets as members of the Dutch Society for Concentrated Solar Power (VZKC) developed this concept with support of the Foundation for Large-scale Utilization of Solar Energy, GEZEN. It complies with the European ‘Plan Solaire pour la Méditerranée’ and the Desertec Industrial Initiative, launched in 2009. (See website references). This scenario can be made with technologies that exist today or are within reach. It could take the pressure off the looming energy, air, water, food and migration crises for the millions. But how would a matching technology be to house the millions? That is the subject of the next paragraph.

URBox

URBox advocates a different approach. Using local construction materials and local labour resulting in a built environment that can be managed and controlled on a local scale should challenge the housing crisis. URBox is based on basic construction rules applied on the pixel of housing, the smallest identifiable unit, less than three by four meters, with a column and beam based load bearing structure, separate inner and outer skins and guide lines for running ducts and services in the unit. The URBox units can then be combined as houses, housing structures and settlements. The same idea can be applied on the industrialized world with its own housing crises, presenting themselves in niche markets of housing for starters and low-income housing.

At this moment URBox can be illustrated by sketching scenarios, in order to demonstrate its universality.

The design, construction and maintenance are only a small part of the housing crisis. It has to comply with the constraints dictated on higher levels of decision-making. These decisions can be of (inter-) national political and economical order, hard to influence, but still negotiationable or from a more phenomenological order, such as an earthquake: it happens and cannot be negotiated. In acting to shape day-to-day life we cannot wait for all the constraints to be clear. We have to act now and prepare ourselves for the unknown. This paragraph describes the URBox (Urban-Rural-Box) concept, guidelines to design, build and operate low cost and affordable housing. U and R indicate that the concept is applicable in different environments, Box refers to the smallest pixel of the urban fabric. The concept is explained with examples that make the concept suitable for emerging economies; it can also be applied in the industrialized world for upmarket niches.

The formula

URBox is an assembly system of connectable spatial units for living, small workshops, leisure and internal traffic, for urban and rural environments. It can be finished according to the vernacular. The units can be connected horizontally and are stackable. Its normal size, the pixel, 3.6 x 3.6m allows every free standing and attached configuration as well as placing on slanting and sloping lots. Both the Very Low Cost URBox variant and the Affordable URBOX variant are a dedicated mix of existing well-proven technologies and innovations, based on the strategies of Open Building and Lean Construction (Cuperus, 2001). In both systems parts and tools are manufactured project independent off-site: Parts for Very Low
Cost URBox are made locally from nearby produced materials with lend-lease tools by an all-out effort of local cooperatives, minimizing physical and project waste of adapting and transportation. Affordable URBOX, meant for people that have to buy or rent, is realised by a specific interpretation of mass customization: parts are fabricated fully-automated off-site and completely project independent, thereby exploiting at maximum the economics of numbers, elements are assembled from parts off-site but nearby and project dependent, complete elements are then assembled on the site without intermediate storage. Finally cladding and finishing are added. These can be traditional building materials, elements chosen from trade catalogues to be fixed with hand tools or can be custom made by third parties. The standard URBox core unit enables variable additions to respond to geographical conditions, as well as local and individual cultures and styles. Call it Vernacular Staged Mass Customization.

The key to combining on-site and off-site production lies in an Open Building coordinated dimension system and rules for positioning and interfacing the parts. Then the unit is ready for finishings, such as decoration and appliances. Off site production and on site assembly results in a very short building time, thus eliminating the interest cost of financing time, on site security, material and process waste. As URBox is an incremental system with cavities to accommodate ducts and services, its units can be re-subdivided and grow with additions to follow the user’s needs and budget. URBox real estate does not depreciate; it accumulates capital and thus becomes a pension for the future: its adaptability and sustainability is meant to counter the uncertainties of the fourth dimension.

In addition to the physical system, URBox can also be extended as a service provider. Imagine a web based network of sellers and buyers to exchange ideas, a market place for sites, parts new and used, financial and legal services, guarantees and insurances, contracts for connection to and delivering from water and energy, before, during and termination of use. In the final analysis, URBox is sustainable. It is lightweight, the on site construction is low on water consumption, can be demounted, repaired and re-used.

URBox applies a blend of Lean Construction and Open Building principles: It creates value and to banishes product as well as process waste.

From settlement to building parts, decision-making and control are decoupled on the private, communal and governmental levels in a such a way that in each level specific persons can make specific choices, decisions and provisions about specific aspects and parts of the built environment and know by which specific experts they can be assisted, advised and supported. In the practice of very low cost housing and informal settlements for instance, it means that urban dwellers become builders who not only create value but can assist country dwellers building their farms who in their turn yield value as farmers by providing bio building materials to the urban dwellers; thus on the micro levels a micro economy can emerge, assisted by micro credits and infrastructure management from the meso level.

The system
The technical system is based on a 1.2 m module and its halves dimension system (Ill. 2), the smallest possible inhabitable unit measures 2.4 x 2.4 m. The structural integrity of the Very Low Cost/low tech variant is based on four in situ poured concrete columns rigidly connected to four beams (ill. 3). The industrialized version is made with a steel structure, the lightest possible option with cold rolled steel profiles (ill. 4). To the four sides of the floor plate walls or facades can be added at choice (ill. 5).
Mechanical, Electrical and Plumbing

Positioning building parts such as skeleton, partitions, the mechanical and electrical engineering as well as the plumbing makes usable space (ill. 6). By their different nature MEP conflict with columns and walls. They do not mix well and they compete for the same space. In the industrial version, all units have their own load bearing structure and they are always separated by a cavity that fulfils a dozen functions, the most important being to run ducts and services (ill. 7).
Illustration 6: traditional duct shaft in stacked configurations

Illustration 7: MEP in cavities between units and inner-partitions

Especially in URBox applications like multifunctional buildings or hospitals this MEP-cavity will allow for extensive installations without disturbing the other building subsystems, which again is a typical Open Building feature.

Illustration 8: URBox hospital structure

Illustration 9: URBox hospital

URBox includes a set of rules for zoning space and material and for interfaces of building parts. The rules not affect the choice of materials and the level of their sophistication. As such URBox can be used as a blueprint for low cost housing as well as niche markets in the industrialized world, such as affordable housing or roof additions to existing buildings.
A scenario
The minimum URbox to live in measures 3.6 x 3.6 m. In order to determine the lowest possible cost the cheapest available building materials need to be identified. In very low cost housing communities labour is by definition not on the critical path of the construction process, it needs to be taken into account. The costs of construction materials even if they are local, are related to the world market of natural resources. There are minimum costs to cement, steel, copper and plastics. Nevertheless, apart from the cost of the site and its infrastructure and under strict conditions like lend-lease of tool containers and the installation of cooperatives, it will be possible to realise a four-box or 50 m² very low cost house for about US$ 5000 (ill. 10). It is also realistic to determine the lowest level of feasibility for affordable housing. Here we leave the world of construction and enter the realm of politics and economics which exceed and not the subject of this paper.

Illustration 10: very low cost 4 pixel urban dwelling

Illustration 11 URBox neighbourhood in Solar City

CONCLUSIONS
Construction in the industrialised world is a source of mistakes and waste we can learn from. Rather than learning from our mistakes it is more efficient to learn from successes. The concepts of Open Building (how to build for a changing demand in an uncertain future), Lean Construction (create value and banish waste, by doing things right the first time), modern energy concepts and material science are some of the fields we can adapt. In this paper some of these concepts were explored and combined in a scenario for low cost and affordable housing. The pixel as the smallest building bloc has been described as a contribution to a vision on tapping solar energy as an infinite carbon free resource. The field of town planning falls out of the scope of this paper and is left to the higher Open Building decision making and control levels that provide the border conditions in which the urban pixels can thrive freely (ill. 11). For the urban fabric creates capacity for placing the smallest pixels to configure streets and urban spaces that make society work. Transformations on the urban
scale touch the powerful interests of landlords, economics and politics. They also create conditions for and constraints to low cost and affordable housing. This paper has been limited to constructing the pixel.

Like solar power knowledge is indestructible and infinite. This is a call for academic support to make the knowledge and design power available in order to confront the crises we face. It could take the pressure off the looming energy, air, water, food and migration crises for the millions. The real obstacles may have a political and power nature. Energy is a hot commodity with well-divided interests. In Toffler’s terms: Introducing third wave technologies that can tap infinite resources such as seawater, sand and solar energy may result in a dangerous power-shift, not appreciated by second wave parties who now control the energy supply. There is an underlying economic rationale that the very poor live in least fertile places such as deserts. Developing areas occupied by the very poor potentially creates enormous cultural conflicts; first wave societies are propelled into a third wave world, without being asked. The best third wave inspired intentions should not be experienced as neo-neo colonialism, but as a genuine common effort to make provisions that are fit for the foreseeable and adaptable to what cannot be foreseen.

LITERATURE
Cuperus, Y. (2001). An Introduction to Open Building. IGLC9, the Ninth Conference of the International Group for Lean Construction, Singapore, National University of Singapore.

WEBSITES