EXPLORING THE POTENTIAL FOR URBAN FOOD PRODUCTION ON SYDNEY'S ROOFTOPS.

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Abstract

There are environmental, economic and social benefits of retrofitting rooftops on city buildings for food production. Environmental benefits include lower carbon food miles, potential reductions in building related operational carbon emissions, reductions in the urban heat island, increases in bio-diversity and reductions in storm-water run-off. Economically, the benefits are reduced roof maintenance costs, lower running costs and direct access to fresh food. Thirdly the social or community gains are the creation of spaces where people can engage in growing food. Psychological and therapeutic gains accrue when people engage with natural environments. However there are barriers which include perceptions of greater risk of building leaks, high costs of installation and maintenance, and access and security issues.

Although the technology to design and install food production on rooftops exists, the uptake and the demand have not been high to date. Overall, the gains are not deemed sufficient and in Sydney Australia, the existing numbers of food producing rooftops are testimony to this observation. This research reports on three rooftops set up in 2013 in Sydney which are producing food. The social, economic and environmental aspects and physical aspects of the installation are described in this paper.

Keywords: Green roofs, Sydney, urban food production, case studies.

Introduction

As millions face starvation globally and the proliferation of food waste becomes endemic, a recent report released by the Institution of Mechanical Engineers estimated "that 30-50% (or 1.2-2 billion tonnes) of all food produced is lost before reaching a human stomach" (Fox, 2013). Some reasons for this amount of wastage are poor engineering and agricultural practices, inadequate transport and storage infrastructure. Urban rooftop farming has the potential to ameliorate some of these problems by shortening the food supply chain. One advantage of growing food close to consumers is reduced carbon miles. Currently, fresh food consumed in cities is transported great distances. It is estimated that the cost of transport of a $1 supermarket lettuce is around 40 cents (Midmore, 2011). Rooftop agriculture has the potential to create healthier communities in alimentary and psychological ways. Urban rooftop agriculture could provide access to fresh, healthy, nutritious produce due to reduced time spent in transit and storage.

In addition there is evidence that city dwellers and workers are increasingly detached from nature, and that this contributes to rising stress and dissatisfaction with contemporary society (Shepard, 1982). It is posited that "humans have a profound need for regular contact with the natural environment for continued well-being" (Kellert and Wilson 1993). In summary "Rooftop gardening means taking up an inspiring, ecological and productive activity, and developing new links with the food chain, the seasons, the environment and the community" (Germain, 2008).

A complementary social benefit of rooftop farming may be community volunteer programmes where citizens and workers engage in food production. An example is the Eagle Street Rooftop Farm in Brooklyn New York (Rooftop Farms, 2013) which runs a small community supported agriculture program and an onsite farm market which supplies local restaurants. Trained interns, urban farming apprentices and host volunteers provide the labour during growing seasons. In partnership with Growing Chefs the farm holds educational and volunteer programs to bring city-dwellers closer to their food source (Growing Chefs, 2013). Given that there are many successful examples of urban agriculture in North America, Cuba, Canada and Germany, it is surprising that Sydney has so few examples of rooftop urban food production and to date, no empirical studies as to its viability.

Some barriers to rooftop food production include perceptions of greater risks of building leaks, high costs of installation and maintenance, and access and security issues. Property practitioners and built environment professionals have little direct experience of urban agriculture and; as a result, are sceptical and risk averse. There are questions about financial viability of such enterprises in Australia, even though viable, successful rooftop farms exist in cities such as New York where climatic conditions preclude food production during winter months.

Sydney is located in a temperate climatic zone with rainfall spread throughout the year. Annual meteorological data for 2012, showed 1213.6mm of rainfall, a mean maximum temperature of 22.7°C and a mean minimum of 14.4°C (BoM, 2013). Sydney’s annual average of sunshine is almost seven hours a day (City of Sydney, 2013). Sydney’s rainfall averages 11 wet days per month, with over 40% falling between March and June. With a population of 4,391,674 for Greater Sydney in the 2011 census (ABS, 2014b), Sydney is growing at a rate of 1.7% per annum with two-thirds of New South Wales population living in the city. Furthermore Sydney has the highest density in Australia with 8800 people per square kilometre in Sydney's east and 7900 people per square kilometre in Sydney City's west. By comparison to other global cities Sydney’s density is high, Mexico City has 8400 people per square kilometre, London 5100 people per square kilometre, Paris is lower still at 3550 people per square kilometre and Los Angeles has a population density of 2750 people per square kilometre. With increasing urban density and a growing population the disconnection to the natural environment is set to increase. Furthermore the demand for food is also increasing. One part of the solution may be urban farming on rooftops.

Research Aim

There is a growing body of research into the benefits or otherwise of specifying new or retrofitting green roofs to existing buildings for food production. However much of the empirical research has been undertaken in cities outside of Australia, in Europe and the northern hemisphere which has quite different climatic conditions. This research evaluates three different approaches to rooftop food production in Sydney. The objective is to use an empirical study to identify the gaps in knowledge for the city and to establish a research agenda to close the knowledge gaps. All research has limitations and in this case, given that the beds are raised and/or have limited direct contact with the roof structure and covering there are limited impacts on the thermal performance of the building. Where garden beds have direct contact the roof structure there will be an impact on thermal performance. There are social and economic impacts of urban food production which are part of this study but are excluded from the scope of this paper and are reported elsewhere.

Rooftop garden bed designs

Some of the options available for rooftop agriculture include portable containers, raised beds and vertical garden units. The issues to consider are access, portability, cost and the types of vegetables and plants to be grown. Containers come in various forms, are typically smaller than raised beds, and are easily portable. By using containers that would otherwise go to landfill, rooftop gardeners can recycle on garden plots of varying shapes and sizes. Milk crates with hessian sacks, recycled plastic wading pools, buckets, packing crates and recycled wooden pallets are examples. Container gardening allows growers to take their project with them should they be required to relocate and this can be useful when renting property. The factors to consider when creating a container bed are drainage and root depth. The most important aspect to consider when using recycled containers is toxicity and all treated and painted timbers should be avoided as well as plastics that contain solvents, PVC and high density polyethylene (HDPE).

The wicking bed derives its name from the cloth that is placed between the soil and a water reservoir inside the garden container that works much like a wick in an oil lamp. By giving the plants access to water at their root zone, when and where they need it, it reduces the potential for plants to become water stressed. Furthermore less water is wasted as evapotranspiration and the gardener does not need to water the plants as frequently. A simple way of building a self-watering garden bed or sub–irrigated garden is to use a plastic pond which is positioned directly onto the waterproof membrane of the roof. A hose is attached to an overflow outlet and the excess water is channelled to a drain. This type of garden bed has a very minimal impact on the surface of the rooftop. The weight is reduced by using agricultural pipe below the growing medium, separated by a layer of geo-textile fabric.

Another option is to elevate or raise the garden beds, and having a working height of 1100 mm from roof level is more comfortable than traditional gardening methods. This is a good solution for those who have mobility issues and furthermore, there is less direct contact with the roof membrane which is reassuring to some owners and property managers. The drainage can be channelled by hose from the garden bed outlet to stormwater pipe outlets which should ameliorate concerns about potential roof leaks or staining on tiles. Raised garden beds can be heavy and create point loads on the roof and therefore careful thought is required with regards to the design and construction of the trestle. There are proprietary garden beds such as those made from recycled UV stabilised plastic which are lightweight and easy to transport to the roof top, as well as kit form corrugated zincalume which are relatively lightweight and portable. Other options include timber framed beds manufactured in-situ.

There is a range of vertical garden beds produced and sold in hardware stores. Transportation to and accessibility of the roof top has to be taken into account with this option. Some systems may be good for growing herbs and flowers, but if gardeners are intending to use a spare north facing wall to grow food, which generally requires seasonal replanting, the ease of removal and planting out of new vegetables and the root zone depth required need to be considered when choosing a vertical system. The majority of vegetables grown by urban farmers are seasonal, and the plants will need replacing quite often as the seasons change and they either get picked or die off. A planting system that has inadequate sized apertures can be difficult to plant out. Some vertical planter systems accommodate small garden pots, and though convenient; it does limit planting to those with shallow root systems. There are vertical garden systems which have deep troughs that can be used to grow some very large vegetables and herbs. Due to the shallow depth of the growing mediums in most vertical gardens, they require more frequent watering and run the risk of water stress. The installation of a drip irrigation system on a 24 hour timer can provide reliable watering.

Each garden has different advantages and disadvantages. With each; accessibility, transportation and the load bearing capacity of the roof structure has to be considered. Orientation and access to sunlight, the availability of water and a power supply should also be scrutinised. Finally, cost and any issues regarding the comfort for the gardeners are decision factors as the working height of the bed affects gardeners comfort.

Research methodology

This research uses empirical evidence derived from growing plants and vegetables on three different rooftops at the University of Technology, Sydney (UTS), in New South Wales Australia in 2013 and 2014. Three different types of rooftop garden beds are described in three illustrative case studies below.

The research is qualitative, sharing the three basic assumptions identified by Patton (1980) of being naturalistic, holistic and inductive. Naturalism involves seeing the phenomenon in its natural occurring state, in this case by visiting the three sites to observe what has taken place. The holistic aspect involves looking at the whole problem to develop a more complete understanding of the influencing factors and variables with regards to three different approaches to rooftop food production in Sydney. The inductive approach is derived from the literature review whereby a picture of the problems and issues emerge as the researcher becomes more familiar with the topic area. The literature review identified which areas needed to be addressed.

An advantage of case study research is that it is a flexible and adaptable method which can be adapted during the research (Robson, 2011). With this research three different types of beds are evaluated on three different roofs and so it is not possible to make exact comparison on outputs. However that is not to say that the conclusions which may be drawn from the study are not valid.

A limitation of the case study technique is that the researcher does not sample widely enough and that studies may represent the peripheries and not the average (Robson, 2011). However Yin (1989) observes that case study is concerned with analytical and not statistical generalisation. Care was taken to ensure conclusions drawn are noted as being analytically general rather than statistically representative in any way. The criticism of case study as a 'soft option' was rejected as the method requires preparation, knowledge of procedures (in this case food production on Sydney rooftops) and analytical skills (Robson 2011). It is soft in the sense that no hard and fast rules exist for the researcher to follow.

The means of data collection was through observation and direct experience which was deemed most suitable because it allowed the researcher to collect identical data from each site (Moser and Kalton, 1979). Records were kept on bio-diversity, watering, weather, bed costs, planting, dates, fertilisers used and crop yields.

Case studies

The first task was to find suitable roofs on the University campus. After a number of visits to rooftops it was found that there were issues such as accessibility, where one had a series of narrow steps out onto the rooftop. Another had a telecommunications mast which precluded any other activity on the roof. A third roof was discounted as it was heavily overshadowed and poorly orientated to the suns path. The property managers were also a significant factor and finally the team met one who was also a gardener. This staff member was helpful and knowledgeable and took the team to several potential roofs before a joint decision was arrived at with the Gumal roof described below. The Science Faculty are involved in this research and had test beds on their roof and permission was given to position another bed on their roof. Finally the researchers' home faculty have a roof space directly outside the staff kitchen and the DAB Faculty Manager gave permission to site the V garden beds here.

Science Roof

This roof is located at 7^{th} floor level on the corner of Harris Street and Thomas Street in Sydney. The roof faces north-west. The roof construction comprises reinforced concrete with an impervious covering. The roof is protected with walled structures approximately three metres high to three sides and a glazed screen to the Thomas Street elevation. The garden bed chosen for this site was a plastic wicking bed.

The bed was a pond purchased at a cost of $280. It has a 320 litre capacity and the dimensions are 1500 mm x 750 mm x 300 mm high. The reservoir in the bed is created by laying 100 mm agricultural drainage pipe across the bottom of the pond. A short section of tube is positioned vertically from the bottom of the pond up to the top (in a place where the overflow is visible). This is the filler tube and a section of agricultural pipe is used. A hole, to accommodate a 30 mm threaded tank outlet, is drilled into the pond shell at the height presented by the top of the agricultural pipe, here 100 mm from the base. The outlet has a washer to eliminate leaks. The overflow outlet was located as close as possible to the rooftop drain to minimise the trip hazard created by a hose. A layer of geotextile fabric was placed on top of the agricultural pipe and poked down slightly between random sections of the agricultural pipe to prevent the soil and roots from entering the reservoir and to allow the capillary or wicking action to irrigate the garden bed. Plate 1 shows the bed immediately following planting in December 2013.

The bed was filled with a mixture of soil and compost to a depth of approximately 200 mm. It was top dressed with a compressed pelletised organic seaweed fertiliser (Seamungus). The bed was filled with water through the vertical filler tube until it overflowed from the outlet. It was topped up over the two days while the soil conditioned and after this initial phase it was topped up with 30 - 40 litres of water every five to six days. The bed was planted with a mix of eggplant, zucchini, basil, carrots, beetroot, lettuce, chilli, capsicum, silverbeet, celery, rocket, mizuna and marigolds. After planting, the bed was mulched with lucerne hay and fertilised topically fortnightly with an organic fish emulsion and Seasol (a seaweed tonic) was applied typically once a month. The bed was planted out in December 2013 which is summer in Sydney Australia. The total cost of the bed was $412 plus labour.

Plates 1 Wicking Bed on Science Roof.

Gumal Student Housing

This roof is located at 9th floor level on Broadway in Sydney. The roof faces south east. The roof construction is reinforced concrete with an impervious tiled covering. The roof is designed for access and has a concrete perimeter wall approximately 1200 mm high 600mm wide and 800 mm deep which is planted out. There is lift access to level 9. It is exposed and open to the wind and sun. The garden bed chosen for this site was a recycled plastic raised bed supported on a timber frame trestle. The UV resistant recycled plastic was extremely light, easily assembled and its dimensions were 3300 mm long x 1200 mm wide x 300 mm deep. See plates 2 and 3.

A 3600 x 1200 mm trestle was constructed from 90 x 45 mm treated pine frames, braced with galvanised strapping tied together using a 90 x 45 mm treated pine rail top and bottom. The frames were prefabricated off site to minimise the noise impact during construction, and for easier transportation. Two sheets of ply 1800 x 1200 mm formed the top of the trestle and supported the plastic framework for the bed.

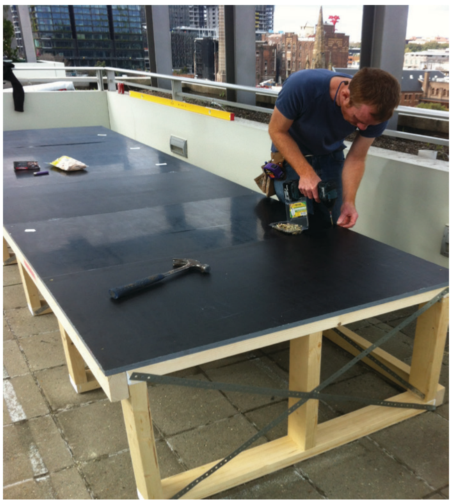

Plate 2 Gumal under construction.

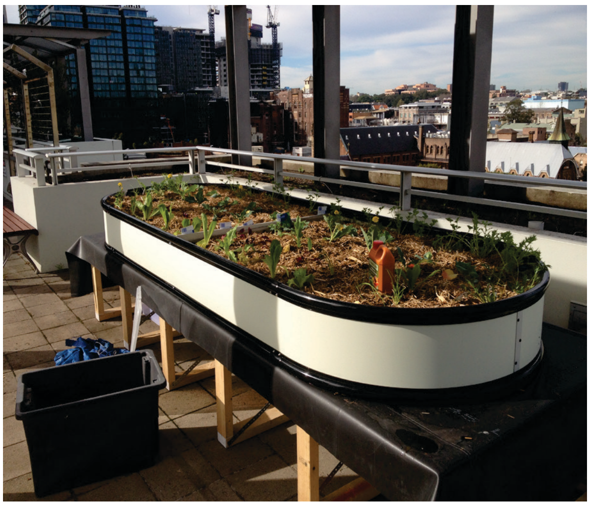

Plate 3 Gumal bed planted out.

A layer of food grade rubber waterproofing membrane, ethylene propylene diene monomer (M-class) rubber (or EPDM) was placed over the timber trestle as weather protection. The plastic pod was positioned on the membrane and a bead of food grade silicone sealed the base of the garden bed and held it in place. At one end a floor drain was installed and sealed with silicone, and using a spirit level and some small plastic wedges, the end of the trestle furthest from the floor drain was raised slightly to facilitate drainage. A layer of 20 mm drainage cell sheeting was placed across the floor of the bed with a layer of geo-textile fabric laid over the drainage cells to keep the soil and plant roots from blocking the drain. A layer of fine gravel 20 mm deep was laid onto the geo-textile fabric, followed by another layer of geo-textile fabric. The bed was divided into two sections for different growing media; one was filled with an organic composted cow poo and garden soil mixture and the other a lightweight engineered substrate with a mixture of coir bark, perlite P400, Canadian peat, 0-8mm composted pine bark, all trace elements, Calcium Nitrate, coarse granular Dolomite, Gypsum, Superphosphate, Zeolite 1-3mm and Magrilime. Both beds were top dressed with a compressed pelletised organic seaweed fertiliser (Seamungus), and mulched with lucerne hay. Both were fertilised topically fortnightly with an organic fish emulsion and Seasol (a seaweed tonic) was applied topically once a month.

The beds were planted out with eggplant, zucchini, basil, carrots, beetroot, lettuce, chilli, capsicum, silverbeet, celery, rocket, mizuna and marigolds. These beds were planted out in November 2013 and the costs for the beds was $1350.62 plus labour.

Vertical Gardens.

This roof is located at 5th floor level on Harris Street in Sydney. The roof faces North West. The roof construction comprises reinforced concrete with an impervious tiled covering. The roof is designed for access and has a concrete parapet wall approximately 1200 mm high and 200 mm deep to one side. Two sides are flanked by buildings which rise to a height of 7 floors and 20 floors. The remaining edge has a metal framed glazed fence and over looks an internal courtyard at fourth floor level. The roof is enclosed on all sides by tall buildings. In summer months, when the sun is high there are around six hours of direct sunlight on the roof, however in winter months there is minimal direct sun. Furthermore the buildings do encourage very high wind levels at times. There is lift access to level 5 however there are steps out onto the roof terrace area which made transportation less easy. The garden beds used on this site were supplied by V Gardens in Sydney. The beds have a timber frame and a large base bed with a series of metal framed horizontal trays to a height of 1600 mm. The horizontal trays are approximately 150 mm deep. One bed has a self-watering system on a 12 volt timer which utilises a submersible 12 volt pump and drippers. It is powered by a battery which is recharged by photovoltaic cells and the sun. The reservoir at the base of the garden houses the submersible pump and acts as a wicking bed for the lowest garden. The second bed is identical in design apart from the irrigation system and wicking bed. See plate 4.

These beds were planted with a variety of herbs including basil, mint and oregano and vegetables such as lettuce, eggplants, silverbeet, and capsicums. Larger root vegetables such as carrots and beetroots were grown in the base bed. The beds were planted out in November 2013.

Plate 4 V Gardens on DAB Level 5 roof

Results and interpretation

Social

There has been considerable interaction and interest from staff within the faculties where the beds are sited around the university. This interest is focussed on what has been planted, and whether anyone can join in to water the plants and harvest the food. Without prompting, staff in the DAB put up a wall calendar with a pen in the staff kitchen to record whether the plants had been watered. When watered, the staff member or person simply ticks the date and others know when the plants have been watered. It is a simple system and few plants died despite a record breaking hot, dry Sydney summer. People ask and talk about the plants regularly and will often describe the meals they have cooked with the plants and the flavour of the herbs and vegetables they have used. Other staff such as security guards also expressed interest in the rooftop gardens, imparting tips and guidance where they think it needed. One staff member, upon learning that the beds were an experiment to see what could be grown on Sydney rooftops, noted that 'this is why the Cubans survived and the North Koreans starved to death'. They have given advice also about the timing of the watering and care of the plants. Students approach the researchers when attending the gardens at Gumal and chat freely about the plants. One student this semester, a journalism student from Germany decided to write about the gardens for her assignment. Industrial design students have used the gardens and rooftop agriculture in their major design projects. Overall the social interactions are high and positive.

Economic

The costs of the beds varied as described above. Furthermore the amount of growing space also differed between the three roofs. The costs are reasonably affordable, although it would take many years to grow sufficient food to pay back the initial costs.

Environmental considerations

The three locations experience different weather conditions to some extent. For example the Gumal rooftop is exposed to sun and high winds, which scorched the plants on a number of hot summer days. The beds needed more watering due to accelerated evapotranspiration. The Science roof however was sheltered from wind on three sides as described, and the plants received more shade during the hottest months resulting in less leaf burn and water stress. High winds were experienced in the DAB roof area and although the V Garden's construction, with the weight centred at the base meant that neither structure was affected by the winds, some of the larger vegetables were badly battered on these occasions. The DAB roof is surrounded by high buildings on all four sides and consequently during autumn and winter periods less direct sun is experienced on the roof and this will effect production rate. However in the summer the plants here have more respite from the effects of intense heat and direct sunlight.

In terms of thermal performance, the installation of rooftop gardens should inevitably result in some reductions in cooling loads. Due to the inherent thermal properties of shading, the temperature under the raised bed was significantly cooler and this provided a reduction in the temperature of the roof covering. With the wicking bed and its direct surface contact, higher levels of thermal performance would be expected. No data was recorded on temperatures in the rooms directly below the beds though this might be worth exploring in the future. Given the absorptive properties of the growing mediums, there was as was to be expected, a noticeable diminution in the amount of water entering the rainwater drainage systems of each of the roofs as a result of the installation of the garden beds. The Gumal beds had plastic tanks sited below the drainage outlet and this allowed the researchers to ascertain the approximate amounts of pluvial runoff from the beds compared to rainfall recorded in a rain gauge. The science roof beds drained onto the roof and into an open drainage channel. No silting of the drains occurred on any of the roofs as the geotextile fabric ensured only water passed through the textile.

With regards to attracting bio-diversity, as soon as all three roofs were planted insects appeared. Native and European bees were spotted on all sites. On the Gumal roof a group of cockatoos visited the site on the first day and uprooted the majority of the plants. Protective screens of wire mesh were fixed temporarily to deter the birds. Both yellow and orange lady beetles encamped within just a few weeks and within all the beds worms are seen on a regular basis. No actual tests have been conducted on air quality around the beds but it should be the case that the air should have higher levels of oxygen and lower carbon dioxide as the plants photosynthesise.

Physical and location

Access to all three roofs varied. Gumal, because it was always intended for public access had amenable conditions from the basement car park through to the rooftop. There are convenient water and power sources on this roof too. The recycled plastic garden beds were delivered in a long tube which was lightweight and could fit in the passenger lift. The prefabricated trestle frames and the pine sheet were heavy and cumbersome but these also could fit in the lift, as did the substrates and membranes. The 3600 mm rails had to be carried up the fire stairs. Once assembled these beds were very heavy and not easily relocated.

With the science roof access was via a goods lift from the car park to level 7. However due to the sensitivity and security concerns of the science labs, special access had to be negotiated for the researchers and no public access was possible. With the DAB roof top there is lift access to the floor but the space planning and configuration of offices meant there was a circuitous route to get the V Garden to the roof top. Fortunately the units are not too heavy for two people to carry. The DAB roof does not have a water or power supply and therefore water has to be transported from the adjoining staff kitchen to the gardens. Although a solar powered pump on the larger bed with the wicking bed provides irrigation to that bed, it does require topping up with water on a regular basis.

Table 1 summarises the three bed types and their performance in respect of the categories described above.

	Bed 1 – Science roof wicking bed	**Bed 2 – Gumal raised bed**	**Bed 3 – V Garden**
Transportability and assembly.	Very easy.	Difficult. Some carpentry skills required.	Units easily transported with 2 people and a trolley but location presented a challenge.
Ease of working.	Low to ground.	Easy.	Very easy.
Costs / metre square of growing area.	Medium.	Very High.	High.
Ease of watering	Easy.	Manual, every other day in summer.	Easy.
Plant growth	Very good.	Varied.	Good.
Water usage	Low.	Medium to high.	Medium.
Exposure to wind	Low.	High.	high
Exposure to excessive summer sun/heat	Medium.	High.	Medium.
Bio-diversity attracted to bed	Very Good.	Very good.	Good.

Conclusions and further study

This research reports on three rooftops set up in 2013 in Sydney which are producing food. The social, economic and environmental aspects and physical aspects of the installation are described in this paper.

Despite varying conditions on all three rooftops, production over the summer period in 2014 was good. There were different challenges with all three roofs with the physical environment and environmental conditions. The social impacts were overwhelmingly positive in all respects. Economically there is variation in the costs of the beds and amount of skill and labour required for installation and set-up, however there are options to suit most budgets.

This project did not test any of the plants grown for the presence of heavy metals and this work is currently underway and will be reportedly in a following paper. Further funding is being sought to measure and ascertain the impact on thermal performance on buildings of the rooftop beds.

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