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THE GREEN CITY

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Article at a glance

This paper discusses the feasibility and effects of the widespread use of biotic or living environments on the roof-tops of large Australian cities. Before water conservation became the most crucial sustainability issue for the Australian city, air quality and microclimatic environments of dense urban areas was the area of major concern. These remain chronic, rather than acute problems experienced by cities that require real, long-term solutions. The implementation of city-wide roof top gardens poses a real solution; however one that requires a significant cultural shift in the way that Australians understand their cities.

Roof gardens provide a real and effective way of cooling a city by reducing the amount of solar energy absorbed by the buildings. The albedo or rate at which the heat is reflected from the city is one of the contributing factors to the city ability to cool itself at night and therefore reduce reliance on air conditioning and refrigeration. The albedo also affects precipitation rates, air quality and reduction of summer time heat peaks.

The roof top garden on a single building has little effect on these issues, however if implemented at a wider city scale it has the potential to affect real change. On a single building scale the evaporative cooling, circulation of air collected form the rooftop, and thermal resistance by adding (bio)mass, all contribute to the innovation sought after in six star rating by the Green Building Council of Australia.

Breaking away from the normative response to greening or dressing up commercial property in the central business district, this study looks far beyond the use of indoor plants and the numerous European green roof technologies. It asks the question of feasibility of specific species in the high wind velocity, weight restricted and access intensive environments of roof-tops and building facades. The Bass Coast and Great Ocean Road landscapes of southern Victoria begin to give a clue to the types of vegetation and landscape character that could be easily achieved.

The broader scale benefits to such a proposition are not merely poetic. The proposition essentially calls for the instatement of high altitude tracts of native flora and avifauna habitat. The biodiversity achievable is not yet known however the superimposition of a viable green corridor over the top of some of the densest urban environments in Australia is a goal worth achieving.

Cover image courtesy of Mauro Resnitzky

Anthropological climate change caused by humans, is unfortunately still disputed in some isolated pockets of the scientific world. So too was the deterioration of the air and water quality in London in the early nineteenth century until the air became almost unbreathable. The poor were dying in their thousands and the stench of the Thames drove the politicians from Westminster. The reaction to this was numerous Clean Air acts passed by parliament and the development of public parks throughout London. These green lungs were to provide healthy green spaces for the people. It was essentially a regional scale, infrastructure response to the increasing density of the city and a shift in the way of living. Since then, such parks have been established in many other urban centres. To tackle the current environmental problem without delay we need to identify how cities can take charge and develop a response to densification and climate change simultaneously, using green open spaces as a vehicle for change. One answer is green roofs.

Green or living roofs have existed long before the term 'climate change' came in to popular use. For several decades in Europe green roofs have been used successfully on large, low-rise buildings, typically in industrial parks and on the edges of cities. These are usually isolated examples and in the context of climate change are just scribbling in the margins. As our global society becomes more aware and conversant with the dynamics of climate change we need to stop ignoring the 'elephant in the room' and deal directly with the regional infrastructure of our cities. A building-by-building approach is simply too slow.

This article intends to look at the simple realities of living roof technology and some of the successes around the world as a way of establishing the feasibility of a city scale response to both climate and cultural change in an increasingly dense urban centre.

Artist's impression of a green city. Reproduced with permission from the City of Sydney

Extensive and intensive living roofs

Up front it must be said, that the living roof includes far more possibilities than the exclusive penthouse patio garden complete with topiary hedges in terracotta pots. Borrowing from Sidonie Carpenter, a prominent Australian green roof researcher, there are broadly two categories of living roof: extensive and intensive. The former requires very little maintenance and the physical loading on the building structure is minimal. The intensive type involves a heavier and far more diverse use of vegetation and materials.

Extensive living roofs are often used on large, low-rise roofs, typically industrial sheds, and use local grasses, wild flowers and sedum plant species. Often dubbed ‘meadow roofs’ in Europe and North America, they are large enough to create significant regional habitats for insects and birds as well as local flora species. This roof type can become so simple that it requires only crushed rock or rubble on a waterproofed concrete base. The rock, possibly reclaimed from the site, provides a simple habitat for insects, spiders and birds. Small amounts of soil mixed with the seeds of local grasses may also be added. Overall the depth required is often around 300 millimetres, with a loading of between fifty to 150 kilograms per square metre. Generally these roofs are not designed to be viewed or visited by humans, much in the same way a simple concrete slab or metal sheet roof remains hidden. They are intended to establish a micro ecosystem of self seeding plants that attract insects and birds; they are in effect self-sustaining systems. The largest example of this type is the Ford truck assembly plant at Dearborn, Michigan. This structure is basically a giant shed with a living roof measuring 42 000 m^2 and uses a thin mat system that retains soil from which the vegetation grows. This type, although visually similar to a public park, would not suffice as a place for people.

The intensive roof types offer a far greater range of possibilities for the designer; however they are heavier and more expensive. They offer the environmental and economic benefits of the extensive roof type with the ability to blur the distinction between the internal and external spaces of a building. This roof type is as much a design proposition as a scientific or engineering one. Such a roof would require approximately 2000 kilograms per square metre of structural loading, with a maximum depth of 1.8 metres, depending on the design. The challenge for the

roofs of this type is the creation of an environment that is both comfortable for people, relevant to the use of the building and the vegetation species that will survive the exposure of a roof top. This balance of function and feasibility requires a high level of collaboration between designer and engineer.

Temperature

The primary benefits to the building do not just come from the vegetation visible above the soil; it is the soil itself that provides the most immediate effect, that of thermal insulation. The best example of this is perhaps the oldest, pre-Roman earth dwellings across northern Europe. The benefit of such structures is primarily the same as that offered by contemporary living roofs; regulation of the internal temperature. When applied over a much larger scale, a large industrial shed for example, the living matter acts as a thermal regulator resisting the daily thermal changes. In addition to this the green surfaces of a living roof can actively cool the air around them, thereby reducing the ambient air temperature adjacent to the building.

Green surfaces cool local temperatures in two ways. Firstly, the green surfaces absorb less heat from the sun. Hot surfaces warm the air around them, so by cooling the surface, the vegetation also affects air temperatures. Secondly, the plants also cool the air by evaporating water in a process known as evapotranspiration.

Eleftheria Alexandri and Phil Jones at the University of Cardiff published a study (2004) that found living roofs could reduce the temperature of their local areas by up to 11.3 degrees Celsius. They used a computer modelling technique to recreate the microclimate surrounding single buildings in six major cities around the world. The biggest temperature changes were in the hottest cities with Riyadh in Saudi Arabia registering a theoretical 11.3 degree Celsius drop in temperature in the microclimate adjacent to a building with a living roof and wall system. An Australian city was not tested, however given that our cities are dryer and hotter than most, these findings are important to consider. While the research is limited as a computer model it is highly significant to cities in North America and Europe who have recently experienced some of their most extreme heat waves in recorded history. The reduction of the ambient temperature of a major urban centre can in some cases literally save thousands of lives.

Photo courtesy of Scott Henderson

Additional sources such as Environment Canada estimate that “converting just six per cent of roof space in Toronto to green could reduce summer temperatures by one to two degrees and save up to five per cent in energy costs” (Martineau, 2004). Canadian Stephen Peck, who is founder and President of Green Roofs for Healthy Cities North America, has described living roofs as “air conditioners for the outside”.

The effect of cooling the inside of a building has been remarkably well demonstrated also in the largest living roof installation at Ford’s Michigan plant. The studies of this building have demonstrated that during the summer months the interior of the assembly plant remained eleven degrees cooler than the outside ambient temperature. Ford was able to save up to fifty per cent on air conditioning. Similar proof has been collected from low-rise large footprint buildings in Europe. These figures provide a compelling financial case for living roofs regardless of wider social and environmental benefit, a crucial factor in the persuasion of many developers and facility managers when considering the design of new buildings.

It is curious whether this will apply for tall buildings with far smaller roof:floor-space ratios and whether similar economic motivators could be used in denser urban centres. Available studies have not focused on this relationship however if the majority of the total surface area of any building was covered in a living roof or wall then the principle should still apply. In addition to this, dense cities suffer from a climatic phenomenon known as ‘heat island effect’. The intensity of this effect varies from city to city however it is the larger more dense cities that suffer the most. There are many contributing factors and ways to measure this effect however its basis is in the reflection of solar energy from the surface of the city up toward the atmosphere.

Albedo

The generic measurement of reflectivity of the earth’s surface is known as ‘albedo’. California has long had albedo legislation requiring developers, architects and landscape architects to reduce the overall solar and heat reflection from their sites. Solutions involve reducing dark coloured metal, concrete and bitumen surfaces and introducing vegetation. The overall solar heat gain and retention of a building, and the surrounding urban landscape, radiate heat into the atmosphere. This increases the local ambient air temperature creating an urban environment far hotter than nearby rural areas.

Ford Michigan green roof. Photo courtesy of Karen Chung

For several years, the city of Chicago and the states of California and Georgia have had ‘cool roof’ rebates and grants for developments that conform to low reflectivity and emissivity levels and higher vegetation cover. Such legislation has dramatically increased the number of living roofs installed in new and existing buildings in those areas. Similar ordinances have been introduced in Japan for the installation of ‘brown roofs’ on existing buildings. Brown roofs are the simplest of roof treatments and comprise a thin layer, 50–150 millimetres of crushed rubble and rock, often reclaimed from the building project. These form a habitat for insects, hardy self sown grasses and some bird species.

In a report authored by Shepherd and Jin in 2005 as part of NASA’s Global Precipitation Measurement Mission, the importance of urban development and its reduction of albedo was cited as a major issue in the adverse changes in local climates and the ways in which they are modelled.

… the construction of buildings, parking lots, houses, urban areas dramatically change the smoothness of a surface, thermal conductivity (the ability of a material to transmit heat), hydraulic conductivity (measure of the ability of soil to transmit water), albedo (reflectivity off of Earth’s surfaces), emissivity (the ratio of radiation emitted by a body or surface) and vegetation cover. As such, urban landscapes change the typical physical processes of land surfaces, and importantly, also add new and unique characteristics to land surfaces and atmosphere (cited in Cook-Anderson, 2005).

Water absorption

This statement introduces another benefit of the living roof, the absorption of rain water within the urban environment. When rain falls in urban areas, including roofs, it is not absorbed by the ground it falls on. It is redirected to storm water systems and is completely lost to the parts of the city that should have received it. It also brings in trace amounts of nitrates and sulphates absorbed from the atmosphere that are then carried into the waterways. This scenario becomes a real problem when rain water is collected from a building that is located on contaminated soil. The storm water leaches the soil contaminates into waterways often causing serious environmental problems of regional significance.

Photo courtesy of Sandy Edge

The living roof is able to absorb and directly use the water that falls on it. It requires no ‘water harvesting’, storage and irrigation infrastructure. During heavy rainfalls the living roof can, depending on its design, retain approximately half of the water that would normally be lost in the storm water system. If used throughout a dense urban centre, the effect on the peak storm water drainage system of a city could be dramatic. For this reason the effect of the water absorbing qualities of the living roof have a great impact in dense urban environments and again help to reduce the operational costs of city buildings.

Clean air

Not as relevant to the operation of a single building but far more significant to the wider urban environment is the ability of the living roof to clean the air. Plants are most effective at trapping the larger particles in the air. Such particles contribute to the urban haze effect, the brown smog that floats above a city. Plants are able to trap larger particles made up of organic carbon compounds: elemental carbon or soot, salt, sulphates, nitrates and dust. Other benefits such as carbon sinking and conversion of carbon dioxide into oxygen via the process of photosynthesis also have impacts on the wider environmental quality of the city. The reinstatement of lost habitat for local species is an aspect best suited to the low-rise mega sheds on the city fringes.

These are the benefits, the reasons why living roofs should be more prevalent in our cities. But what are the obstacles faced in adopting these systems and how does the introduction of this technology affect the construction industry and economy in general?

Obstacles

Cities in Europe, North America and Japan have legislated the use of green roofs and many have started to insist that the most basic type of roof treatment, the brown roof, be added to all projects with existing roof structures. So why has Australia sat on the fence during this extraordinary shift in development? Is it cost, climate or consciousness of what is possible?

The early concepts for Birrung Mar in Melbourne called for a mega structure, a large mixed use, low-rise building sitting under the green open space of the park. Similarly when the NWHB joint venture teamed up with convention centre guru Larry Oltmanns, the design team originally conceived the Melbourne Exhibition and Convention Centre as the sixth park of Melbourne, with the plenary and exhibition spaces sitting under the elevated park surface. This approach was not new as the initial ideas for the Crown Casino development also included significant elevated parkland over the built form. Why then did these and other proposals never make it to the next stage of design consideration? Not surprisingly the answer lies in cost, engineering expertise and the operational feasibility of such schemes.

The reality is that the technology cannot be easily imported and research into biotic species appropriate to our climate still needs to be progressed. Local builders need to learn the skills and often the whole of life operational benefits are not taken into account. Above all, both the major national developers and governments of all tiers need to minimise the risks involved in the construction of a large living roof in the city. It is certainly not through lack of motivation from many designers, economists, engineers and others.

The irony is that the Australian Federal Government sits under one of the largest living roofs in the world, Parliament House, built and designed by Italian born international architect, Romaldo Giurgola. The design intent of this roof is a strong response to the bold geometry and 'Garden City' aesthetic of Burley Griffin's National Capital Plan. Essential to Giurgola's design is the smooth clean materiality of the well-maintained lawn that forms the buildings roof. Green Roofs Australia president, Geoff Wilson, called for the roof of Parliament House to be replanted with native grass species that would not require watering or mowing. Such a gesture would decisively signal a shift in thinking to the rest of the country. Giurgola responded to Wilson's comments with horror—how could the nation's capital building be desecrated with native, rougher looking species? This exchange of views demonstrates one of the key issues surrounding living roofs; differing cultural values. The term green roof seems to conjure up the aesthetic of a neat little roof garden in many people's minds. The reality of the scrubbier native grass lands and 'bushscapes' that are far more feasible is a significant cultural shift in the way we view our national urban landscapes. This is more a challenge to designers than to the engineers or legislators who also play a vital part in embedding the living roof as part of the Australian city.

Cost

Simply put the cost of a green roof in Australia will be approximately four times that of a simple lightweight roof structure. Even the simplest extensive type living roof will cost around A$50 per square metre, not including the supporting concrete slab. The lessons and techniques from Europe, North America and Japan are a fantastic starting point, however their application in Australia has only been demonstrated through a number of demonstration projects with many poor examples of badly constructed patio type roof gardens leaking into the building.

Photo courtesy of Pascalle Male

Now that the Green Building Council of Australia's Green Star rating has been generally accepted by the industry, the savings that heating, sinking or thermal massing brings can be systematically and transparently translated into benefits other than the whole of life economic implications. Innovation points within this star rating system are also available depending on the complexity of the roof. The GBCA states that it is aiming at the top ten per cent of the building industry, the innovators and leaders of our cities. However, we will need to do better than ten per cent if we are to develop a serious construction industry that operates in both an economically and environmentally sustainable manner.

The obvious wider implications on the environment cannot be easily argued with the single building developer. These wider benefits have been understood long before the term 'climate change' replaced the Cold War as the next great challenge to western civilisation. Benefits such as reduced water run-off, air quality improvements, reduction of reflected solar radiation and increased habitats for indigenous species are all essentially urban issues and incur costs to the operation of urban infrastructure. They directly affect the immediate region in which the disturbances occur. This means that each city directly benefits from the changes it makes within its own environs. This perhaps explains why some of the more determined and decisive legislative moves have often come not from national governments but from local mayors and their councils. With the aid of universities, professional institutes and local business people a series of living roof demonstration projects has sprung up around the world.

Photo courtesy of Sussanah Xu

Benchmark examples

American Society of Landscape Architects Green Roof Project embarked on a green roof project above its own national headquarters in Washington DC. Designed by Michael Van Valkenburgh Associates the green roof was developed and built from donations and has been operating for almost one year (Werthiem, 2007). The roof is used as a kind of living roof laboratory that observes how different species perform around the roof. The roof has been designed to provide a variety of different aspects and conditions and its form is dominated by two great 'wave' forms whose curved surface provides steeply graded planting areas of two different aspects. The roof has its own web page, complete with webcam, and features current information on the performance of species around the roof.

Over the national border in Alberta, Canada, twenty-two businesses came together to fund and develop the Alberta Eco-Roof Initiative. Larger than the ASLA Green Roof Project it focuses more on grass land and agricultural species testing. This project has a greater relevance to Australia, according to the building manager Dave McKillop, as the Alberta local climate is "semi-arid, almost desert-like, with lots of chinooks and a significant amount of precipitation from thunderstorms" (2007).

In Australia, Melbourne City Council's Council House 2 project has a roof garden that also provides a comfortable environment for people to spend time in. This building incorporates a green veil of climbing plant species growing across the north-western facade. The vegetation has been installed on a series of small narrow balconies and has been trained along steel guide wires up the ten level face of the building. The veil acts as a heat and glare screen allowing internal temperatures to be better controlled. More profoundly, however, is the impact it has on the indoor environmental quality. The daylight filtering through this network of vertical vegetation and the views from inside the work area gives a strong perception of a forest canopy.

Most demonstration projects such as these have used very simple growing and cultivation systems. This seems to be as much a reaction to the costs as to the risks involved. The basic components of these living roofs are: the structural concrete slab, the water proofing, the drainage, the growing media, and of course the vegetation. In 2001 Takaharu Yoshioka and Minoru Yoshida of Greenwich Garden in Tokyo, developed a 'plant cultivation mat' that combined the means of drainage, growing media and vegetation in a single unit (Brooke, 2002). The mat can be laid over a concrete roof slab as tiles and virtually forgotten. The depth required on the roof is approximately 100 millimetres with a loading of fifty kilograms per square metre. The crucial part of this is the selection of the right type of grass and wild flower species.

While far more sophisticated and less labour intensive, this idea is not new. These systems are as old as the grass sod dwellings of ancient Europe. The relative ease and low cost, however, is difficult to translate in the Australian climate. San Francisco's Academy of Sciences' project is at the other end of the scale for complexity and innovation. This living roof has been designed not as a simple 'green lid' to the building but as an integral part of its experience and operation. The roof intends to be visited much in the same way protected grassland is experienced from a boardwalk. The roof form allows steeper vegetated areas to collect water, directing it to lower points much like natural topography provides a variety of micro climates suitable for different flora and fauna species. This is an excellent example of the observation and translation of something that works in 'nature' applied to a human problem. If the living roof concept is to be accepted in mainstream Australian cities, the solution must sit somewhere between the simple big shed meadow roof and the Academy of Sciences' demonstration project.

Issues for high rise application

Almost all of these demonstration projects have been constructed on 3–10 level buildings or lower rise sheds on greenfield sites. The climatic and wind conditions are not much harsher than a garden or park located at ground level. If green roofs are to become relevant to the dense contemporary city how can they be adapted for life 300 metres above the ground?

At sixty-five metres above the ground, the average yearly wind speed in Melbourne CBD is thirty kilometres per second. At such an altitude the winds often gust at velocities well over 100 kilometres per hour. This constant movement of air also decreases the ability of plants to absorb moisture from the atmosphere. As the wind velocity increases, plants literally are sucked dry of all moisture regardless of how well watered their roots may be. Structural damage and constant wind burn are the main challenges to designers when selecting plant species.

Little research has been conducted into planting for high wind velocities however an excellent place to start would be species that have naturally developed a resistance to similar conditions. Melbourne for example could use local coastal species that thrive along the rugged cliff tops of the south-facing coast. ‘Wind hardening’ should also be a consideration. This is a developmental cultivation technique that exposes young plants to high wind conditions creating eventual structural resistance. In addition to these measures, the overall wind resistance of the roof top plantation needs to be considered. Again the observation of how high wind tolerant habitats exist in nature can guide the designer. By using plants of various sizes the plantation is able to operate more effectively as a self-sustaining habitat. The larger tree and shrub species can provide shelter for the small and more vigorous grass and ground cover species. Co-dependent planting with the design of fixed screens and baffles provides a strong basis for high altitude living roofs.

Given the high wind velocities, it is unlikely that the roofs of tall buildings will ever be desirable places for people to spend time. The greening of these roofs then becomes a question of wind resistance rather than aesthetics. Therefore, a green city is likely to be made up of a tiered system: high altitude habitat reserves at upper levels; smaller more private garden roofs at the mid levels; and finally larger roofs with supporting public parklands at lower levels.

Photo courtesy of Pascalle Male

Conclusion

Western city developments are composed of a vast multitude of private property holdings. The coordination of vast tracts of publicly accessible space may one day be feasible in an engineering sense however we need to accept that a green city will be one of various unconnected and privately owned patches of living roof. If a significant number of these private holdings develop their roof top area to a living roof the environmental benefits for single buildings and entire regions will still be realised. However, the ideal of urban dwellers communing on green roof tops is far less feasible.

Many of the projects discussed in this paper are low-rise developments; buildings that have a large footprint with a low altitude roof-top. Some are privately operated public buildings. Provided security and all-hours access issues can be overcome, such projects offer a considerable opportunity for genuinely public evaluated parkland. Driven by the global concern for climate change the technology and political will to realise such schemes is becoming prevalent. Perhaps the most significant hurdle is the cultural shift required.

Consider the debate over Australia's Parliament House roof. Green Roofs Australia called for it to be replanted, knowing full well that this would in fact make the building blend into the surrounding landscape rather than stand proudly distinct from it. Perhaps this is the crux of the matter. If a significant part of a city's public realm became an indistinguishable piece of bushland in the city, would our current culture be left wanting more?

In Australia the effects of drought and fire dangers are easily understood. The challenge is to create a low altitude roof top environment that comprises more than a simple, flat, grassland system susceptible to drought and bushfire. The introduction of larger and thicker species that are able to mitigate the drying effects of cross winds and direct sunlight will provide a more robust and drought tolerant living roof. The integration of significant topography in the environment would lessen the exposure of the roof and would begin to aid water retention. These are lessons learnt from observation of native habitats and landforms in Australian grassland regions.

As urban parks and street trees have become accepted as a significant part of a mature and sophisticated city, perhaps one day so too will the greening of the higher levels of large buildings. To achieve this, living roofs need to be regarded more seriously than simply making use of the left-over space on the tops of buildings. To be truly part of the city they must contribute to the environment of the city as well as its economic and social fabric; they must be embedded into the infrastructure of the city. We currently have tax deductions for hybrid cars. It won't be long until we see the same for living roofs on new buildings and old.

References

Alexandri, E. & Jones, P. (2004). The thermal effects of green roofs and green façades on an urban canyon. Retrieved December 1, 2007, from http://alexandria.tue.nl/openaccess/635611/p0846final.pdf

Brooke, J. (2002, August 13). 'Heat Island' Tokyo is in global warming's vanguard. Retrieved February 17, 2007 from http://query.nytimes.com/gst/fullpage.html?res=9E0DEED8103AF930A2575BC0A9649C8B63&scp=1&sq='Heat%20Island'%20Tokyo%20Is%20in%20Global%20Warming's%20Vanguard&st=cse

Martineau, C. (2004). Fresh veg city. Retrieved December 2, 2007, from http://209.85.141.104/search?q=cache:CBwvPdswabUJ:www.montrealmirror.com/ARCHIVES/2004/070804/news2.html+Environment+Canada+estimate+that+converting+just+eight+per+cent+of+roof+space+in+Toronto+to+green&hl=en&ct=clnk&cd=1&gl=au

McKillop, D. (2007). Businesses team up for model green roof template. Retrieved February 10, 2008, from http://greenroofs.wordpress.com/

Shepherd, J. and Jin, M. In Cook-Anderson (2005). Satellites and the city: NASA scientists encourage satellite observations to improve our understanding of urban effects on climate and weather. Retrieved December 5, 2007, from http://209.85.141.104/search?q=cache:iTb9ZwRMUKkJ:www.nasa.gov/vision/earth/environment/urban_effects.html

Werthiem, C. (2007) Green Roof: A case study: Michael Van Valkenburgh Associates' design for the headquarters of the American Society of Landscape Architects. Princeton Architectural Press.

About the author

Tim O'Loan is a registered landscape architect and has a broad experience in all scales of design and development within the urban environment, in both Australia and the UK. This has enabled Tim to develop a sophisticated, rigorous, and mature approach to the critical design processes of public realm development, urban design and masterplanning. Through practical application of these processes he has honed and developed the skills of: visual communication, project management, and design advocacy. He has a multi-disciplinary background, and, enjoys bringing new knowledge to the design process.

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Master of Architecture RMIT
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