

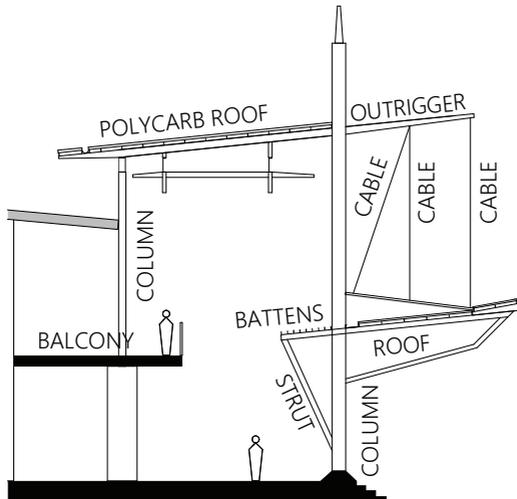


Paul Pholeros
FOUNDATION

SHADE STRUCTURES FOR NORTHERN AUSTRALIA

FRANK HOLLINGSWORTH

GUIDEBOOK



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⁵ Then Jonah left the city and sat down on the eastern side. There he made a shelter for himself and sat down under its shade to see what would happen to the city. ⁶ The Lord God prepared a vine plant, and it grew over Jonah to shade his head and provide relief from his misery. Jonah was happy—indeed, he was ecstatic—about the vine plant.

*Jonah 4:5-6 ISV
4th-5th cent. BCE*

INTRODUCTION

This Guidebook and Atlas is the result of an idea formed while working in Townsville as an architectural graduate. Traveling around northern Australia for work, particularly to Mount Isa and Cloncurry made me very aware of the issue of heat in Australian towns. Having grown up in Darwin this had been an interest of mine for much of my life that was further encouraged by my return to the tropical North.

CSIRO has predicted the ongoing effects of climate change in Australia will particularly affect the tropical north of the country in the form of extreme heat events. These are measured as the amount of days above 35 degrees Celsius per year. Heatwatch Australia has projected that there may be as many as 32 days over 35 degrees Celsius in Townsville by 2050 (Ogge, Browne and Hughes 2019).

With the generous help of the Paul Pholeros Foundation I was able to set some time aside to document and analyze the various shade structures I had seen in my trips. The Guidebook and the Atlas are the collation of this information.



ACKNOWLEDGMENTS

This self-guided research and analysis would not be possible without the generous support of the Paul Pholeros Foundation. Within the foundation I would like to give particular thanks to Sandra, Anne, Jake and Ross for their continuous support and guidance, as well as their patience. A general thanks to the Foundation and its myriad of architects, plumbers, dentists and other skilled people for their inspiring work.

Thanks to Lawrence Neild for his time and direction, and the enormous resource of his and the UNSW's analysis of the Darwin CBD without which there would be little basis for this project.

Thanks to Mark Kennedy of Counterpoint Architecture for his mentorship during this project and generally.

Many thanks to Kerri Stallard of the Townsville City Council for their time and direction, as well as the City Councils of Darwin and Cairns for their excellent resources on climactic design.

Nicholas Loder of City Space Architecture has my thanks and appreciation for his interest in the project from its presentation at the Paul Pholeros Foundation fundraiser. He went above and beyond in providing me with many research papers and ideas for the application of my research.

Finally, thank you to my wife Georgia for her support and her patience, one couldn't hope for a better partner in life.

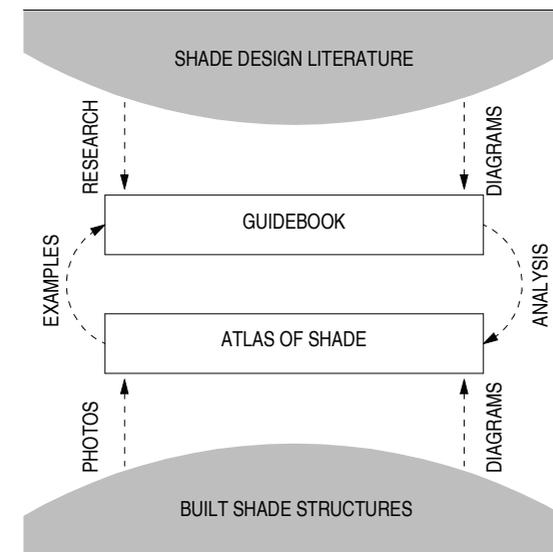
METHODOLOGY

The collection of information for this project was typically opportunistic in more than one sense. The project was initially conceived as simply a collation of all the ways I had seen shades structures built in northern Australia. The selection of structures to be included in what became the Atlas was sporadic – based on my travels for work and leisure and a few select trips to Darwin and other regional areas. From observing the variety of shade structures, a desire to understand the design decisions of each drove my interest in classifying based on type. From this came an investigation of available literature on general climactic design from sources known to me from my education as well as interviews with council members and architects that informed much of my research. This research then gave me a framework for the analysis of each shade structure I had documented.

The decision to divide the project into two reciprocal documents (the Guidebook and the Atlas) was based on the way the project was conceived – first as a mapping and documentation exercise and then as a collation of theory and existing knowledge. The Atlas draws from material examples and orders them with reference to their perceived form and function while the Guidebook draws from existing research and literature to inform the analysis of the Atlas and furnish itself with real, specific examples for its general concepts.

The Guidebook provides a structured theoretical understanding of the concepts that influence how shade is built, it attempts a top-down understanding as opposed to the Atlas's ground-up mapping. Reading through the Guidebook should give a general understanding of the things that should be considered when designing for shade. The Guidebook then has been collated to reference the Atlas projects wherever possible to illustrate the concepts and technologies it discusses.

The Atlas provides a series of specific examples of shade structures in northern Australia in counterpoint to the general concepts laid out by the Guidebook. The examples are divided into formal types, these types were identified by myself in the course of collecting examples and while arguably arbitrary provide a helpful structure for the document. This formal understanding I believe will be useful for the user in finding precedents for future shade projects design. For example, anyone looking to build an Awning on a shopfront could refer to the wide variety of Awnings collated in the Atlas for examples that might relate to their specific context. In this way I hoped to make accessible the more technical concepts at play by providing the user with a toolbox of ideas and forms that could be copied, stretched, merged and taken apart to inform future practice.



There are significant limitations to the project, namely the sporadic collection of both shade structure examples and literature. With more time and means, the Atlas could be added to and refined to an almost endless degree. The scope of examples taken was limited to northern Australia while many of the issues addressed by shade structures could have allowed for the collection of examples Australia-wide and indeed overseas. Collection of examples was by no means methodical, a more scientific method of collection for the towns I visited would have served the project well. The investigation of literature was based on the resources I knew about already and any introduced to me from my interviews and connections during the project (many thanks to Lawrence Neild and Nicholas Loder for their help in this instance). There are likely other books, research papers and interviews that could be added to the body of research undertaken already that would need to be read and incorporated into the Guidebook to make a document that was anywhere near becoming comprehensive, the book *Sunshine and Shade in Australasia* by RO Phillips being one example that has only come to my attention in the final stages of the project that doubtlessly needs full review.

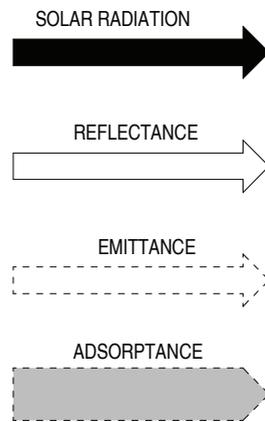
The decision to present each shade structure as a photo and a diagrammatic section was made for the sake of brevity - a more complete analysis of each would include a diagrammatic plan showing orientation and environmental factors such as nearby water sources, prevalent breezes and vegetation. The section and photograph were chosen to efficiently present the construction and spatial characteristics of each example while the Guidebook sections on Orientation and airflow might generally address some of the desirable design features that could be investigated in plan.

The following is a general explanation of the concepts to be considered for the design of shade. These concepts should be referred to in conjunction with the examples noted from the Atlas. With an understanding of the concepts that drive shade design the examples should become more accessible as precedents for future projects.

SOLAR RADIATION

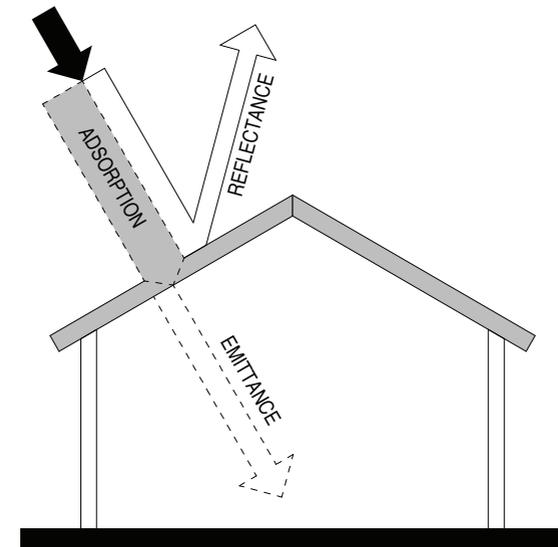
Solar radiation is the energy emitted by the sun.

Naturally solar radiation is relevant to shade design, and its interactions with the material fabric of the urban environment can be understood in the three concepts of reflectance, absorptance and emittance (Szokolay 2014)



Reflectance (or albedo as it relates to the average reflectance over all angles of a material) in the context of this guidebook relates to the built environment's ability to reflect heat away from the urban area – usually back toward the sky. . As illustrated below, a roof will reflect or adsorb the sun's radiation – any heat adsorbed will eventually be emitted.

The environment on a hot day will ideally reflect or radiate heat out to the open sky to disperse it rather than adsorb it. This can be achieved by increasing the reflectance of surfaces facing the open sky such as roads and roofs.



It should be noted that increasing reflectance of walls in an urban setting may also reduce heat however it will increase reflectance and glare which may affect the comfort of pedestrians and inhabitants (Khan, et al. 2025). Consider the context – if pedestrian comfort is of consideration other means of reducing heat adsorption (ie. shade structures) may be more suitable.

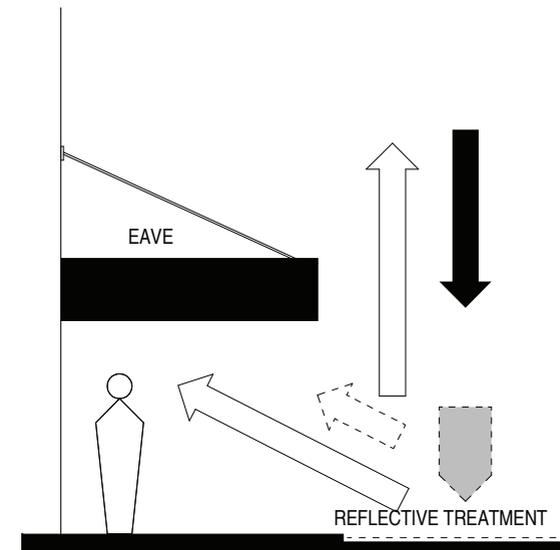
Neild and Santamouris' study in Darwin identifies the increase of reflectance (or albedo) in the urban environment with decreasing heat gain (Santamouris, et al. 2017). This is particularly relevant for roads. Roads typically make on average 30% of the urban fabric (Rodrigue 2024) - often more in regional areas due to the increased width of roads used historically for stock mustering (see Rockhampton) and the lower premiums on space.

The dark colour of the road and its high thermal mass (see Thermal Mass below) create a massive store of heat in the most towns which will radiate throughout the day and night. If the area does not fully cool down over night it will become cumulatively hotter the next day due to the stored heat (see Urban Heat Island Effect) (Meyers, et al. 2020).

Studies finds high cost-to-benefit ratio in the coating of roads and rooftops with high-albedo paints and surface treatments (Santamouris, et al. 2017). Shade structures with reflective roofs (high albedo) can be used to prevent sunlight from reaching surfaces with high thermal mass in lieu of coating roads (see Cavenaugh St Shade Structure Atlas pg. 72-73) .

See:

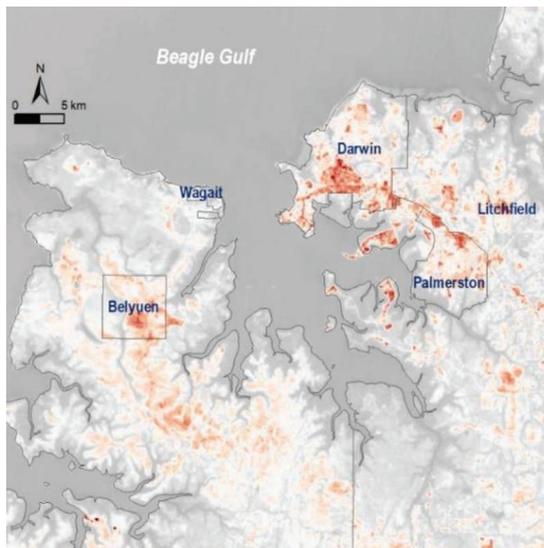
- Cavenaugh St Shade Structure Atlas pg. 72-73
- Darwin Mall Shade Atlas pg. 74-75



URBAN HEAT ISLAND EFFECT

Urban heat islands are urban areas that become significantly hotter than surrounding areas due to human development affecting various factors such as thermal mass, reflectance, airflow, artificial heat output from cars and airconditioned buildings and evapotranspiration due to lack of planting. It is important to understand the artificial nature of this increase in heat, which indicates some level of similarly artificial design may mitigate its effects.

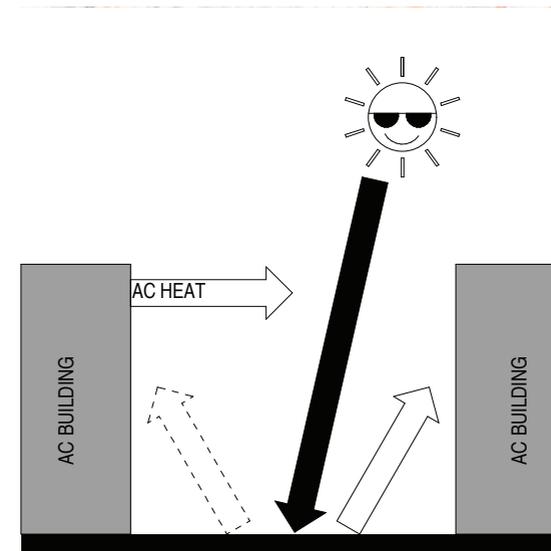
UHI effect gets its name from the 'island' of heat that is identifiable around urban spaces at night with thermal imaging (Meyers, et al. 2020, p3), which is indicative of its cause – the urban environment does not cool down enough overnight and so heat is gradually accumulated over days and months to unbearable levels rather than dissipating overnight.



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UHI effect is linked to a variety of health effects, reduced air and water quality, and increased energy use for air conditioning (Meyers, et al. 2020, p11). It is also, from the perspective of design and planning, part of the cause of abandonment of public space which has knock-on effects for social order and economic growth (Northern Territory Government, City of Darwin 2021, p 12) Marginalized communities and vulnerable members of society such as the elderly, disabled and homeless suffer disproportionately from the effects of UHI effect (Meyers, et al. 2020, p11).

The United Nations has noted concern for UHI effect and the requirement for passive cooling measures to be designed into the urban fabric of cities (UN EP Beat the Heat).

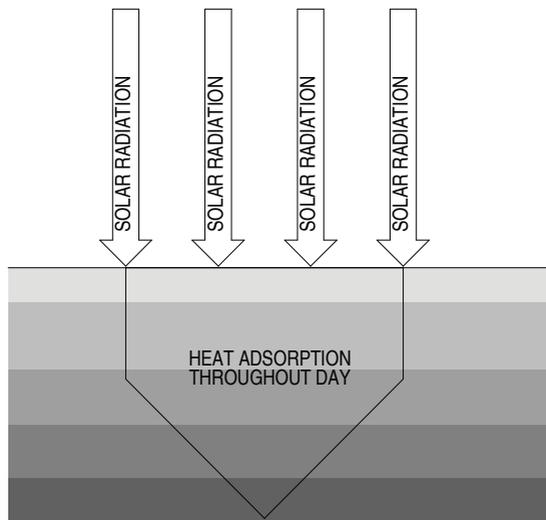


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THERMAL MASS

Thermal mass (or thermal capacity) is the capacity of a material to absorb, store and release heat. For example, a bitumen road (low albedo) exposed to the sun for the entire day will absorb heat and radiate that heat throughout the night - if it can not sufficiently cool overnight it will continue to radiate heat throughout the day as well (see Urban Heat Island) (Koenigsberger, et al. 1973) (Meyers, et al. 2020).

The time it takes for a material to emit heat on the opposite side of its exposure is known as its lag. Knowing the time-lag of a material can allow design of structures that absorb heat during the day to cool a space down and radiate it when the space is uninhabited or warmth is desired (such as in a desert climate). A rule of thumb is that massive masonry, earth or concrete walls have a time-lag of roughly 10 hours per 300mm (Koenigsberger, et al. 1973). This is useful in desert and similar climates where the night temperature may drop below comfort levels however it causes issues in hotter climates and seasons where radiant heat at night is not welcome or not fully dispersed overnight (see urban Heat Island Effect)

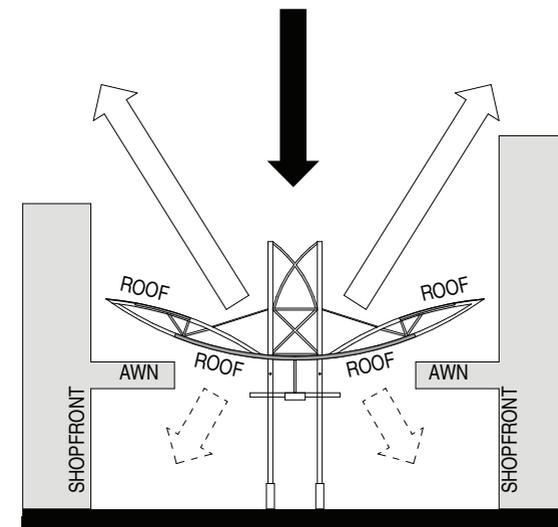


If thermally massive materials are kept cool or actively cooled they will absorb heat from the space and cool it down. For example an underground car park that is always cooler than the street outside, or the ground under a large tree.

The Mall below (Darwin Mall structure Atlas pg. 74-75) prevents direct solar radiation on its ground slab, allowing it to absorb emitted heat from the roof and keep the space cool.

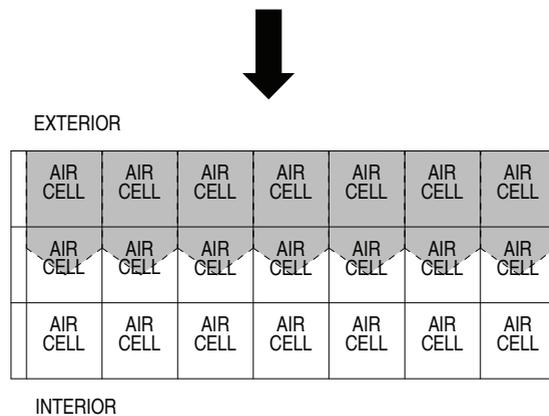
See:

- Proserpine Entertainment Center Atlas pg. 22
- The Oasis Central Shade Atlas pg. 46
- Comfort Stop Atlas pg. 47
- JCU Peer-to Peer Shelter Atlas pg. 53
- Shaded Court Atlas pg. 61
- Stock Exchange Building Atlas pg. 70-71



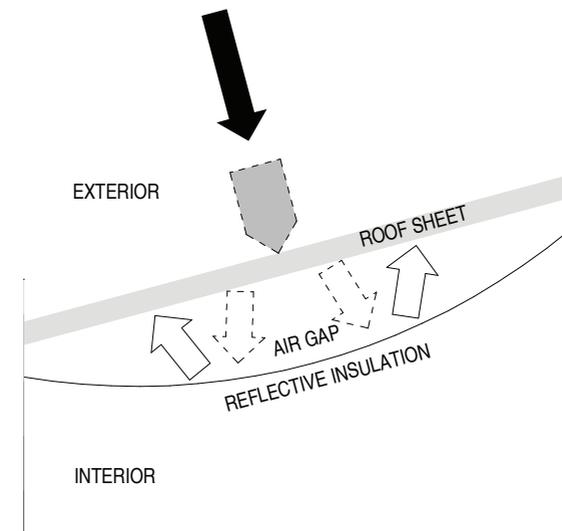
INSULATION

Insulation relates to the control of heat flow in and out of a space. It has three types, reflective, resistive and capacitive. Air is a most thermally resistive substance and so resistive insulation is achieved with materials that hold air in pockets. Resistive insulation is typically associated with fiberglass bats and various foam products that resist the transfer of heat through their thickness (Szokolay 2014).



How effective materials are at resisting heat transfer positively correlates to their R-value. Just as resistive insulation slows heat flow into a space it can also slow its release - if it is necessary to cool a space overnight (tropical climate zones 1 and 2) resistive insulation may hinder this (Szokolay 2014).

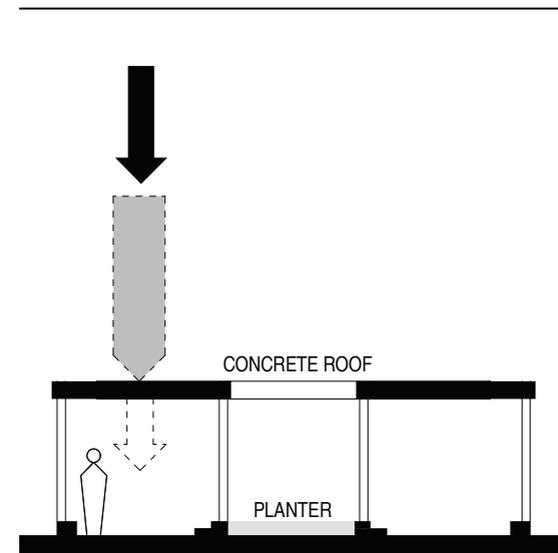
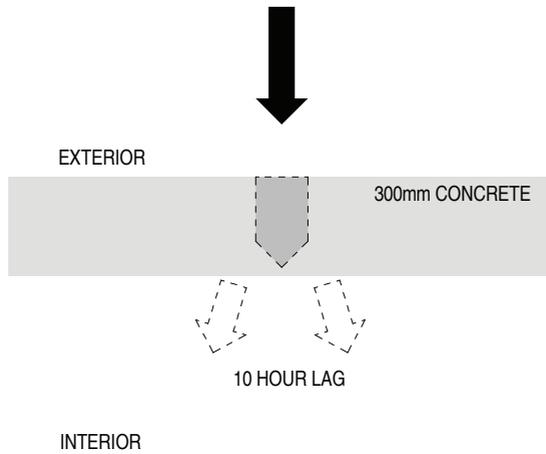
Reflective insulation reflects the radiant heat from the roof above - it has negligible R Value. When installed in ceilings facing up it can be prone to collecting dust, thus reducing its reflectivity which is why it is typically installed as a sarking under roof sheeting with the reflective side facing down. It must have an air gap (minimum 25mm) between it and the adjacent hot surface (the roof sheet) in order to be effective. If it is in contact it will conduct heat. (Szokolay 2014)



Because of its reliance on air gaps and its lack of R-Value, reflective insulation can be effectively used in hot humid climate zones (tropical zones 1 and 2) where ventilation and low thermal mass are prioritized.

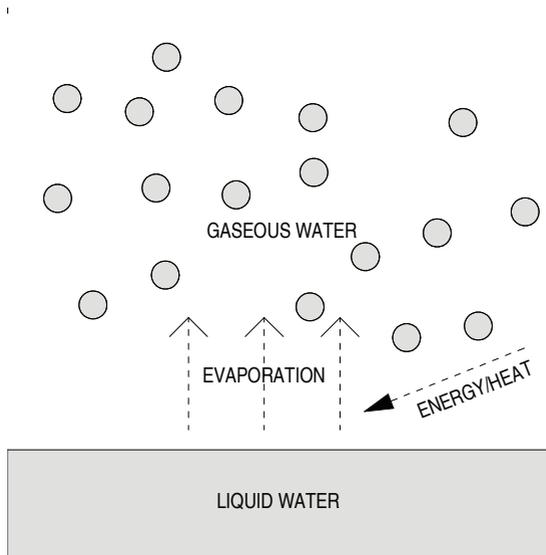
Capacitive insulation is a similar concept to thermal mass however it relates to a material's ability to resist heat transfer through its capacity to absorb it while thermal mass relates more broadly to a materials capacity to absorb, store and emit heat (see Thermal Mass). Due to the thermal lag it creates it can be used effectively in zones with high variance between day and night temperatures (ie. desert climate zones 3 & 4).

The Townsville Oasis (see Pavilion Atlas pg. 46) has a Pavilion with a concrete roof approximately 200mm thick - allowing for some thermal lag to occur and heat to emit from the structure in unoccupied hours.



EVAPORATION

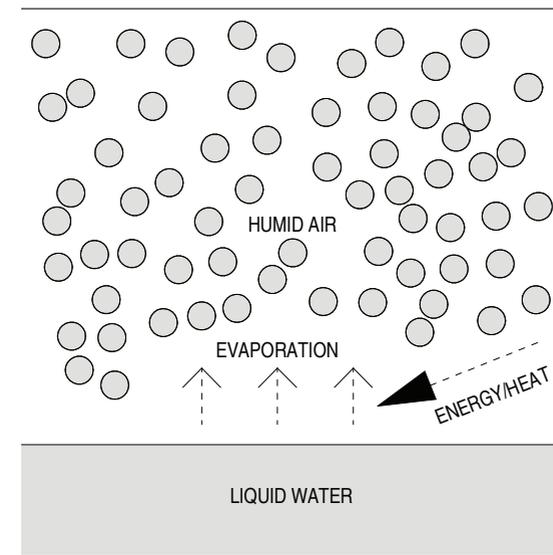
Evaporation is the process that water undergoes when it is heated into a gaseous form. Water in the air after it has evaporated is measured as humidity. Evaporation slows down when the air is already saturated with water. The process of evaporation absorbs heat. Due to this endothermic process we can reduce the temperature in a space by evaporating water in it. However, when a space is humid (ie. the air is saturated with water) water will not evaporate as much and evaporative cooling will not be as effective (see Humidity) (Szokolay 2014) (Koenigsberger, et al. 1973).



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HUMIDITY

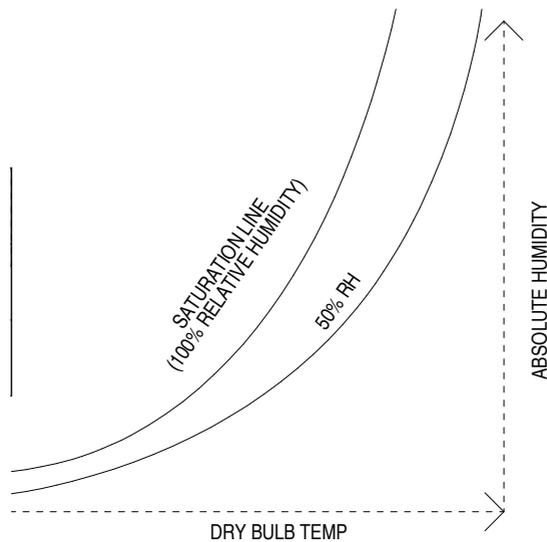
Humidity relates to the amount of evaporated water in the air. It can be expressed as Absolute Humidity or Relative Humidity. These different terms relate to the more general measurement of water to air ratio (Absolute Humidity) and the evaporation potential of the air (Relative Humidity). This is useful because the saturation point of air increases as its temperature does and therefore increases its capacity to aid evaporative cooling. Relative humidity is usually included in the details of a weather forecast.



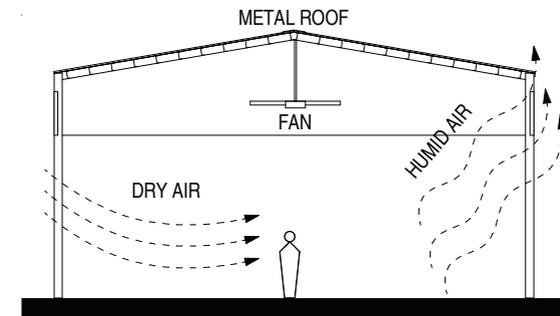
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This means that cool air will hold less humidity and therefore presents less potential for evaporation and therefore cooling of a space. Hotter air, if it is not already saturated will evaporated more water and therefore produce a greater cooling effect in a space. Hot humid air, such as is present in the tropics, has little capacity for evaporative cooling (Koenigsberger, et al. 1973) (Szokolay 2014). For example, the one finds themselves soaked in sweat in humid environments because the sweat produced by the body's cooling mechanism cannot evaporate into the already humid air. Only increasing airflow over the skin can aid in sweat evaporation and therefore cooling, hence this is one of the only non-mechanical methods for cooling spaces in hot-humid climates.

The diagrammatic psychrometric chart below indicates that as temperature increases, so too does the capacity for humidity.



The Pavilion covering a basketball court below (see Cloncurry Basketball Shelter pg. 43) allows for the replacement of air made humid and hot by human occupation.

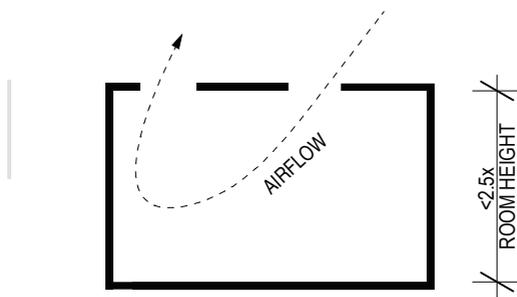


AIRFLOW

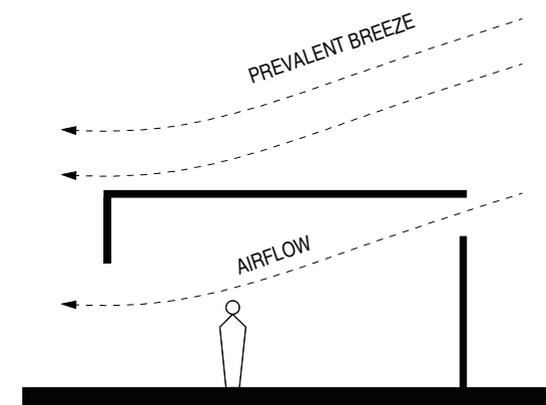
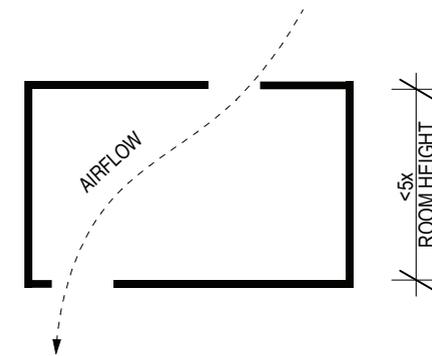
Airflow in a space relates to the rate at which the air moves through it and is replaced. It can be achieved with fans, ducts, wind-catchers and convection. As human habitation will increase the heat of a space, high airflow usually desirable in tropical climates. Shade structures in desert climates however may seek to prevent cool air from being replaced by hotter outside air during the day.

Fans are used to great effect in Darwin and Townsville (see Youth Foyer Atlas pg. 63) to recirculate or encourage ventilation of hot air, while correctly orienting a shade structure to capture a prevalent breeze is a good way to achieve airflow without mechanical aid.

As a rule-of-thumb, a space can be ventilated naturally with opening only on one side if its depth is two-and-a-half times its height. Cross ventilation can be achieved with a space depth as much as five times its height. This effective depth can be increased by the use of fans.



The positioning of openings in plan and section can be used to control how air moves through a space – consider where people will be occupying a space and design openings either side.

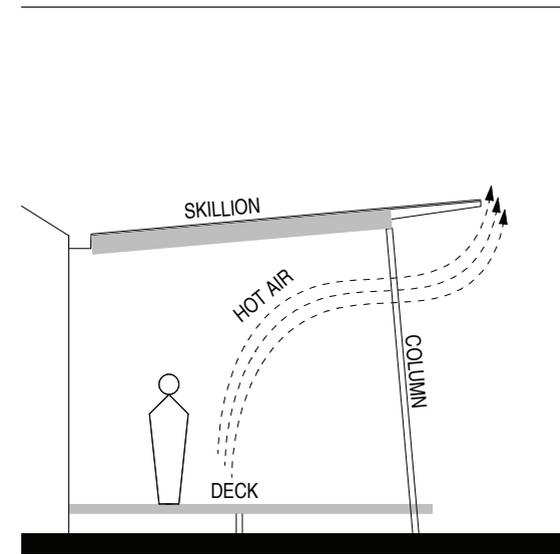
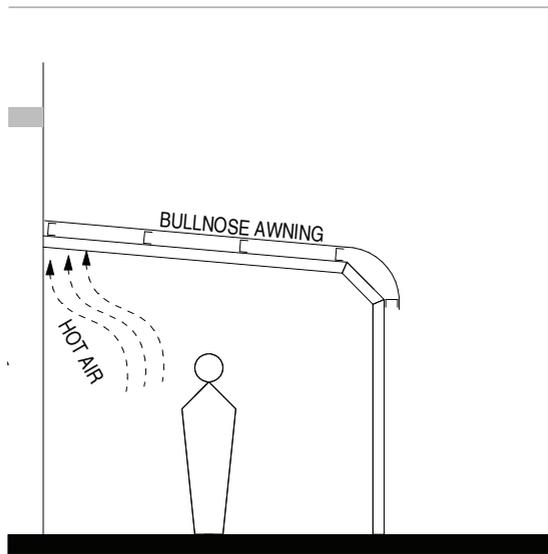


Convection is the process brought about by hot air rising in a space. If hot air is allowed to escape the pressure difference this causes draws more air in from the outside. Convection is desirable when the outside air is a comfortable temperature as it allows the air heated within a space by roof radiation or human habitation to escape. Convection does not cause sensible air flow and therefore will not actively cool a space unless other techniques are employed to aid it.

It is important in shade structures (particularly Awnings) that hot air is allowed to escape. If hot air remains trapped against the ceiling of a structure, it greatly contributes to heat retention due to its insulative capacity.

See:

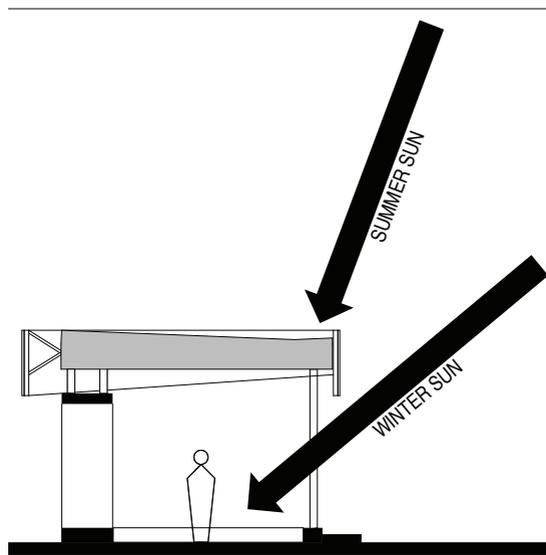
- Cavanaugh St Awning Atlas pg. 6
- Eva's Cafe Extension pg.13



ORIENTATION

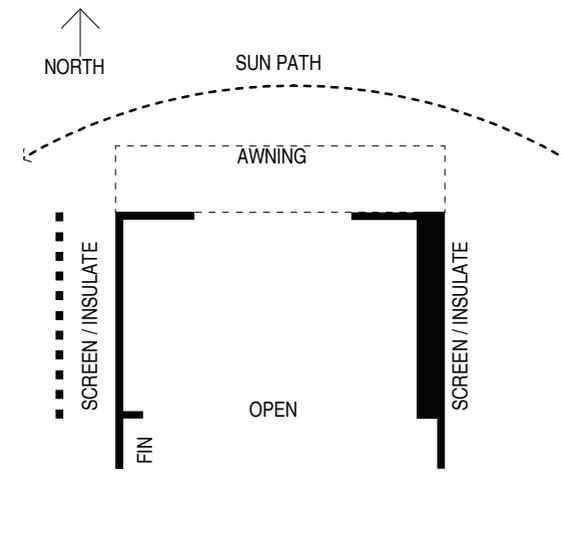
A shade structure's success in keeping a space cool relies in part on its orientation in relation to the microclimate it inhabits. Major factors to consider when choosing the orientation of a structure are the seasonal variation of sun path and prevalent wind directions. The sun is higher in the summer than it is in the winter – this allows for shade structures to be calibrated to allow the sun's rays in during the winter and exclude them in the summer.

See:
- JCU Peer-to Peer Shelter Atlas pg. 53



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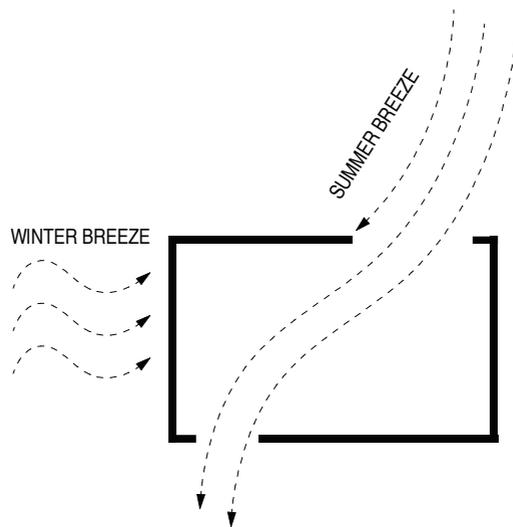
The sun's position throughout the day should be considered. Typically morning and afternoon sun is low and will enter a space if not prevented by a screen or insulated wall. In latitudes close to the equator the sun in summer can even enter from the south at the beginning and end of the day - consider fins to prevent ingress at these times. Northern sun is typically excluded by increasing the depth of shade in that direction.



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Considering wind direction can also be advantageous to passively cool a space via the replacement of air by opening the structure to breezes. A southerly breeze may be welcome in the summer however an easterly in winter may be undesirable. Control of breeze ingress can be achieved with walls and screens.

Urban space is mostly often the result of town planning provisions that aren't concerned with thermal comfort such as the city grid, car parking, adequate roads, and so conditions and context are rarely optimal for its realisation. The below 'technologies' are mostly simple functions or devices that can be utilised in the construction of a urban space to mitigate negative factors such as adjacent cars, bad orientation relative to the sun, humid conditions, hot winds etc.



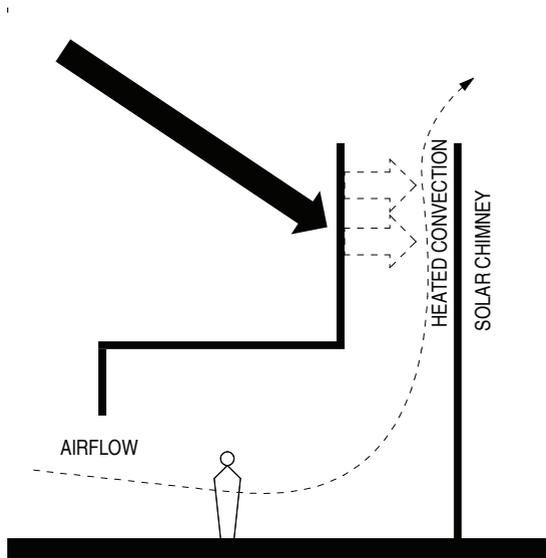
VENTILATION

Ventilation relates to the increase or control of airflow in a space by passive or mechanical means. Passive measures can simply be the orientation of the structure to capture prevalent breezes, and adequate openings to allow convection to allow hot air to escape the structure. More complex structures such as solar chimneys can be used.

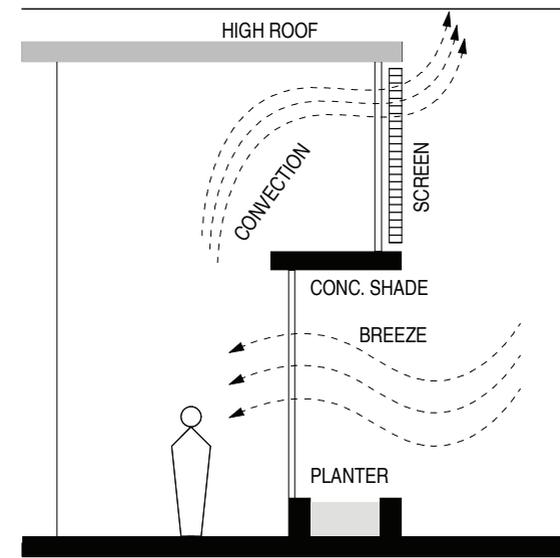
Passive measures replace the air in a space with outside air, aiding in keeping a space cool if the outside air is cooler than the inside air as is often the case due to human inhabitation producing heat. This may not be the case in desert environments and it may be better for thermal comfort to slow down air replacement.

See:

- Proserpine Entertainment Center Atlas pg. 22



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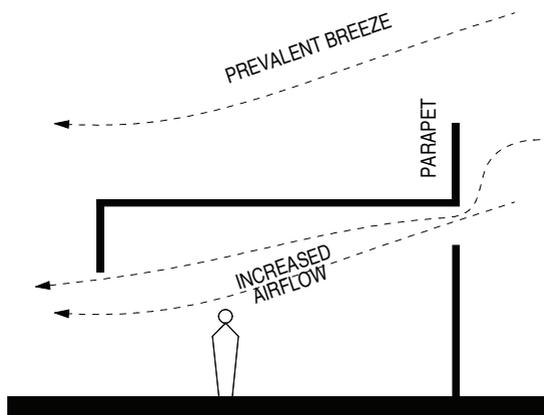


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In humid climates, the replacement of air near the body allows for evaporation of sweat. Without airflow saturated (100% relative humidity) air would sit against the skin, whereas sensible airflow over the skin allows for air with some capacity for moisture (eg. 90% relative humidity) to aid in cooling inhabitants. For this reason mechanical fans or wind towers or scoops might be deployed to cool a space as well as baseline air replacement brought about by convection. Even a simple parapet facing the direction of a prevalent breeze can increase the wind pressure against the building and therefore the speed of the air replacement in the space.

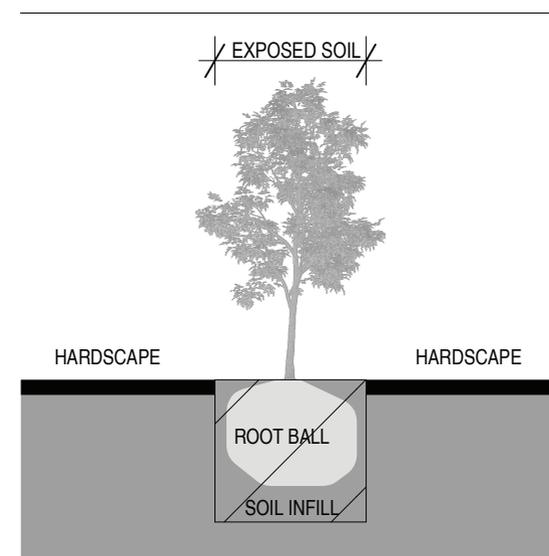
See:

- Mornington Island Airstrip Entry Atlas pg.12
- Kuranda Line Train Station Atlas pg.38
- Darwin Entertainment Center Entry Pavilion Atlas pg. 55
- Mitchell St Beer Garden Atlas pg.62



Trees are typically the most desirable form of public space shade due to their dappled shade, aesthetic appeal, evapotranspirative cooling and their elevated canopies allowing for free airflow across the ground plane.

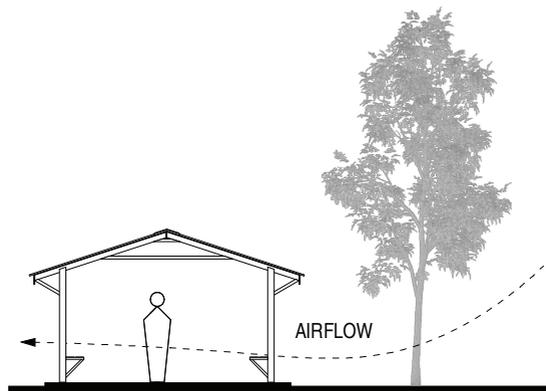
Trees are a great solution to public shade, however certain limitations make them at times undesirable, for example their upkeep – arborists and other professionals need to be consulted and their services retained for the life of the tree to avoid their death or dropping branches damaging people and property. Correct planting of street trees needs to be implemented. A tree will not grow to adequate size if its root ball is distressed or damaged due to it being overheated by adjacent tarmac or restricted by hard soil. Trees need to be adequately watered and adjacent soil needs to hold enough water to avoid stunting the tree. In cyclonic regions, trees can become projectiles during storms and in desert regions trees can require excessive irrigation to keep them alive where water is a premium.



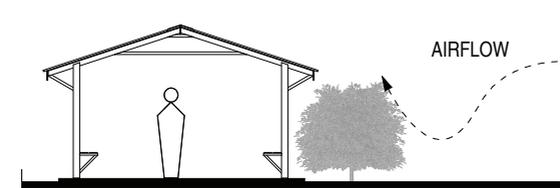
Trees can also drop fruit, leaves or flowers seasonally that cause slipping hazards, clog stormwater drains and attract vermin.

For all these reasons trees represent a considerable ongoing investment for a city and need to be properly installed and cared for to ensure their amenity. While they represent for many the ideal solution to public shade, their applicability to all environments and microclimates should be assessed on a case-by-case basis.

Low planting such as shrubs and grasses provide the evapotranspirative benefit of trees and while they do not provide much shade for habitation they cover the ground to prevent it absorbing the heat of the day. Low planting however can slow down or block breezes and thought should be put into their placement relative to prevalent wind directions.



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Trellis structures with climbing plants growing over them provide the benefits of trees without some of their difficulties. Trellis planting is unlikely to become a dangerous projectile in storms and vines are less expensive to replace after high winds than trees. Vines on trellis require less soil and space for root balls and depending on the trellis system can spread to shade areas much quicker and more efficiently than trees. The trellis structure itself can be designed to structurally withstand cyclones, so while it may represent more up front cost it can be more resilient and cost effective than trees in the long term.

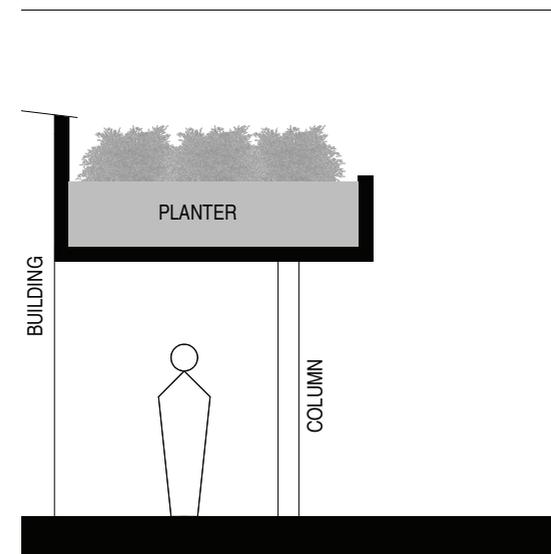
See:

- Cavanaugh St Shade Structure Atlas pg. 72-73
- Florence Clark Memorial Park Atlas pg. 31
- Darwin Botanic Gardens Visitors Center Atlas pg.65



Green roofs provide much of the benefits of street planting evapotranspiration. Soil depth and water capacity are required for growing trees for shade on roofs, however trellis structures adjacent can be used to allow vines. Green roofs are not apparent in the Atlas, their perceived slow uptake may be due to the expense they and complexity they can add to a building due to their waterproofing requirements.

The JCU central Pavilion by Cox contains several raised concrete planters as adjacent structures to the main pavilion. Green awnings (see Awnings below) could be utilised with less risk of water damage to a building if their waterproofing fails. Though green roofs by their nature typically require elevated access that may complicate their upkeep.



EVAPORATIVE COOLING

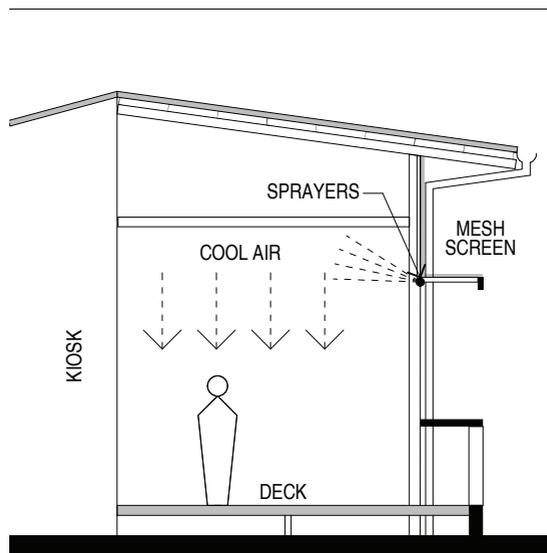
Utilising the cooling effect of evaporation, outdoor spaces can be cooled. Evaporative cooling is typically effective only in dry-hot climates, however it has been utilised to some positive effect in the tropics during the dry season. Studies have found that the cooling effect of evaporative cooling measures is typically localised and can be dispersed by excessive wind. Reducing airflow with screens, walls or planting should be considered when installing evaporative cooling.

Fountains are a popular form of evaporative cooling in public spaces, while sprayers are a more versatile and efficient technology that can be incorporated into most structures. Keeping in mind that cold air sinks, sprayers should be installed above head height for greater effect.

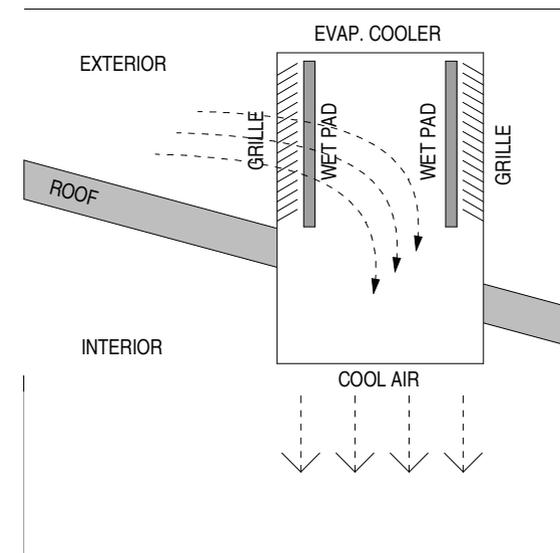
Evaporative coolers are a roof mounted product that evaporates water to cool down a space typically a domestic home, though it could be used for public spaces. They lose effectiveness in humidities above 65% however they are very cost effective to run.

See:

- Mt Isa Hotel Deck Atlas pg. 20
- Cavenaugh St Shade Structure Atlas pg. 72-73



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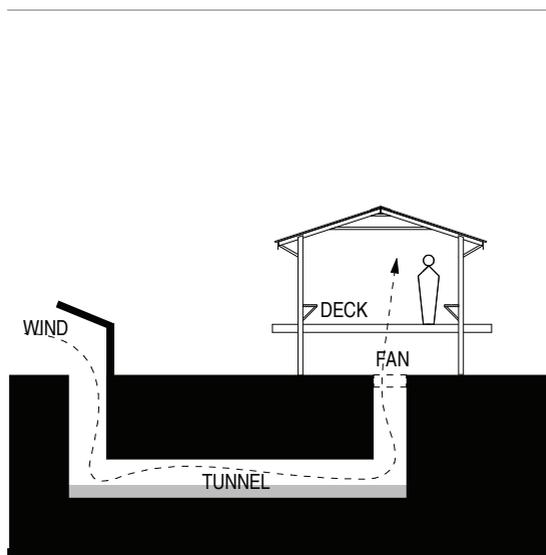


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HEAT EXCHANGERS

Heat dissipation techniques relate to the removal of heat via various methods of geothermal exchange, ventilation and evaporative cooling in built form. These techniques can be complex and are typically deployed on a case-by-case basis. Underground heat exchange via reticulating air through buried pipes is a well know example used in middle eastern architecture and possible in several buildings in Alice Springs. This is because the temperature of the earth below a certain point is stable and can be used to absorb heat from outside air. Measures must be made to avoid ingress of water and mould into pipes, and in humid environments condensation in the pipes can cause mould issues if drainage and cleaning are not considered. These systems need to be designed to avoid possible health issues and the risk of this may be the reason they are seldom seen in the public realm.

I also heard a story of a farmer who had submerged a pipe beneath his dam from which he pumped air into his house in summer. While I heard of a few examples, I did not come across any in the timeframe of this research.



Shade structures offer many possibilities for the mitigation of heat and can form the structure to which other technologies can be attached. Generally they increase the reflectance of an urban environment and prevent the sun's rays from reaching thermally massive elements such as roads and footpaths. Specifically they can utilise the technologies and concepts listed above to form micro-climates and pockets of thermal comfort in hot climates, essential to public space in Northern Australia. The Atlas outlines examples found throughout the region of travel.

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