



CRC for  
Water Sensitive Cities

# Trees for a Cool City: Guidelines for optimised tree placement

Andrew Coutts and Nigel Tapper



Australian Government  
Department of Industry,  
Innovation and Science

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## **Trees for a Cool City: Guidelines for optimised tree placement**

The design of the public realm to enhance urban microclimates (Project B3.2)  
B3.2.-1-2017

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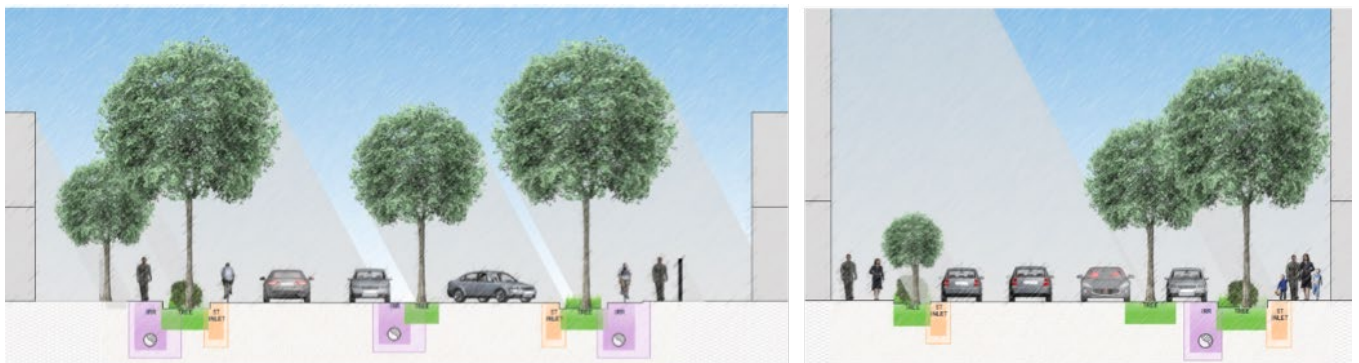
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# 1. Trees for a Cool City

The replacement of natural vegetated landscape with built-up, impervious urban materials through urban development often leads to higher urban air temperatures. High urban air temperatures, combined with heat waves, can increase the risk of heat related illness and mortality in cities (Nicholls et al., 2008). Recent research by the CRC for Water Sensitive Cities (CRCWSC) has also shown that, at least for Adelaide and Melbourne, the urban heat island (UHI) is enhanced during heat waves (Rogers, Gallant and Tapper, 2017). Increasing vegetation, especially trees, is an effective approach for reducing urban heat through transpiration and shading. Protecting, maintaining and growing street trees requires a long term investment. Considering street tree costs and the often-limited resources available for organisations responsible for street trees, it is critical that trees are planted and maintained in such a way that they deliver the largest benefits possible for the cost of their investment.



## About this document

This document provides guidelines for optimised tree placement to maximise the cooling effects of street trees and deliver the largest benefits for human thermal comfort. It provides guidance on where to place trees depending on the design and orientation of streets. This document also highlights the need to manage street trees in unison with urban water management to ensure trees are well watered. This will ensure that trees actively transpire and retain dense, healthy canopies so they can provide shade. Water should be provided through passive or active irrigation, via water sensitive urban design and/or alternative water sources. However it should be noted that trees that are not supported by irrigation will still provide some thermal benefit through shading and reducing heat storage.

## 2. Why trees

A range of urban greening options are available including trees, green open space, green roofs and green walls (e.g. vertical gardens). Trees are especially effective for urban cooling and improving human thermal comfort for several reasons. Trees provide cooling through both transpiration and shade. Shade in particular is critical for improved human thermal comfort during warm sunny conditions. Green open space and green roofs will not provide shade for pedestrians unless trees are included. Green walls and facades can provide shade if grown over artificial structures. Trees are an effective solution for several reasons. A vast range of tree species enables the selection of trees that best fit with the climate and environment of the location (e.g. soil type, water availability, light availability, etc.). Trees are also advantageous as their roots can access deep water sources, compared to shallow rooting grasses and shrubs. Trees provide multiple benefits in addition to urban cooling, including reduced stormwater runoff volumes, air quality benefits (depending on tree species selection), carbon uptake and storage, habitat and building and neighbourhood energy savings. Trees can also provide amenity benefits (McPherson et al., 2005). Finally, people have a greater understanding and connection with trees than with other types of urban vegetation such as green roofs.

## 3. Canopy cover targets

Many examples now exist in the research literature of the effect of increasing vegetation on reducing urban heat. This supports the setting of long term canopy cover targets across Australian cities. Research in the CRCWSC has confirmed relationships between vegetation cover and evapotranspiration, land surface temperature, and air temperature. This research complements that international research. Setting long term canopy cover targets is a good approach, but targets for reducing urban temperatures are difficult, as urban climate depends on so many different variables. For instance, while canopy cover may be increasing, so too could building heights, leading to no net reduction in air temperature. However, had vegetation not been present, urban temperatures would have been even higher. Setting targets to reduce the UHI is also problematic. This is because the intensity of the UHI (e.g. the difference between urban and rural air temperatures) depends as much on rural air temperatures as it does on urban temperatures. Air temperatures across cities are highly variable anyway, and not well characterised by a single value for the UHI.





The following provides four examples from CRCWSC research on how increasing tree canopy cover leads to an increase in evapotranspiration, a decrease in land surface temperatures and a decrease in air temperature.

### 3.1. Vegetation cover increases evapotranspiration

Demuzere et al. (2014) explored the impact of vegetated biofiltration systems (BFS) on evapotranspiration rates in the urban landscape. The *Community Land Model - Urban* was used to model a typical urban street in Melbourne, where increasing proportions of the ground were covered by BFS. The BFS were designed to take runoff from the road surface. In addition, the BFS could be irrigated using water harvested in rainwater tanks, as well as potable water.

The results showed (Figure 1) that as the fraction of vegetation BFS increased, the amount of evapotranspiration (ET) increased. ET increased rapidly up to around 35% before the benefits diminished. Adding rainwater tanks (22% of the rooftops) to harvest water and irrigate the BFS further increased ET while water was available (irrigation scenario I3). Irrigating using both harvested and potable water led to a linear increase in ET (irrigation scenario I6). More energy used in ET means less energy is available to heat the atmosphere.

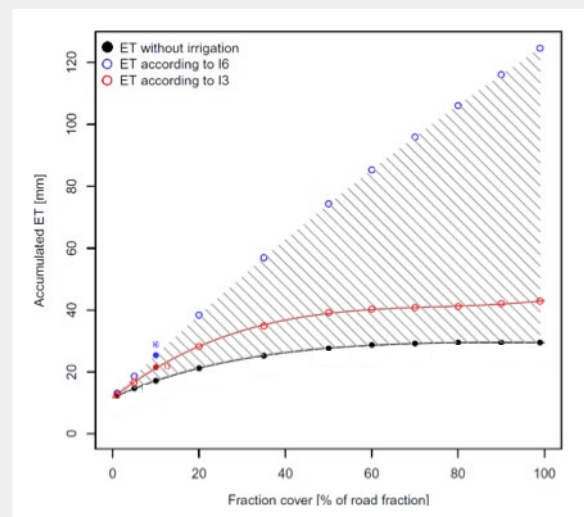


Figure 1. Accumulated ET over the period 9 Feb – 9 Apr 2012 for three difference water availability scenarios. As the fraction of biofiltration systems increased, the amount of evapotranspiration increased.

### 3.2. Vegetation cover reduces land surface temperature

Research by Coutts et al. (2016) explored the impact of increasing vegetation cover on *land surface temperature*. The study drew on data from high resolution, airborne thermal infrared remote sensing, conducted during a hot day (37.1°C) and night on 25 (26) Feb 2012 for the City of Port Phillip in Melbourne. The high resolution land surface temperatures data (0.5 m) were aggregated to 30 m and compared with vegetation cover derived from high resolution aerial photograph, hyperspectral data and LiDAR data.

As the fraction of vegetation cover increased (Figure 2), the land surface temperature decreased. Coutts et al., (2016) found that during the day, for a 10% increase in vegetation cover, there was a 1.2°C reduction in land surface temperature. Klok et al. (2012) found a similar relationship in Rottendam, Netherlands using Landsat data where a 1.3°C reduction in land surface temperature was observed for a 10% increase in vegetation cover.

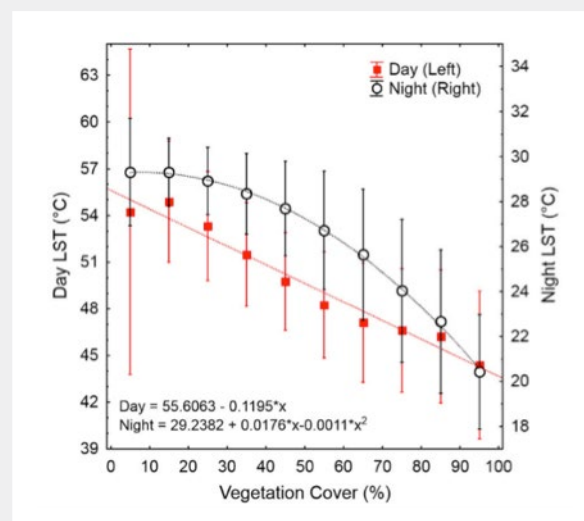


Figure 2. Relations between vegetation cover and land surface temperature during the day and night aggregated to 30 m. As vegetation increased, land surface temperatures decreased.

### 3.3 Vegetation cover reduces air temperature

Broadbent et al. (2016) investigated the impact of irrigation on urban cooling for the suburb of Mawson Lakes in Adelaide. This research was conducted using an urban climate model called SURFEX run at a 25 m resolution. The model was validated using a comprehensive dataset collected in Feb 2011 using 27 weather stations located across varying land uses and land covers in Mawson Lakes. The impact of irrigated was explored over a heat wave from 26 Jan – 8 Feb 2009.

Irrigation helped to cool the landscape, and was most effective in areas of greater pervious surface cover (i.e. vegetation + water). As the irrigated pervious cover increased (Figure 3), the greater the amount of daily cooling. Also, the amount of daily cooling increased as more irrigation was applied to the landscape. For an irrigation scenario of  $20 \text{ L m}^{-2} \text{ day}^{-1}$  during the heatwave, a 10% increase in irrigated pervious cover led to a  $0.25^\circ\text{C}$  reduction in daily average temperature. The amount of cooling tapers off at high irrigated pervious covers and/or high levels of irrigation as the maximum amount of cooling is reached.

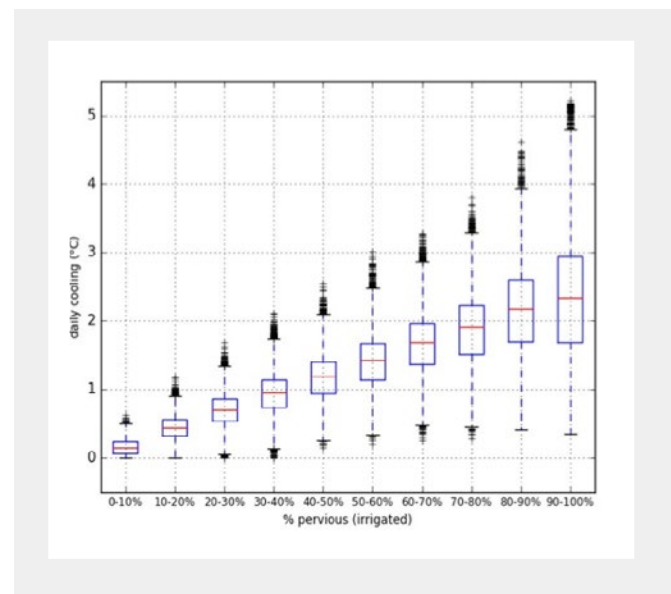


Figure 3. The daily cooling ( $20 \text{ L m}^{-2} \text{ day}^{-1}$ ) for each grid cell during the heatwave period grouped by pervious (irrigated) fraction. As the amount of irrigated vegetation cover increased, the air temperature decreased.

### 3.4. Unirrigated vegetation reduces night temperatures

Jacobs, Gallant and Tapper (2017) used the Weather Research Forecasting (WRF) meso-scale model with an urban canopy scheme to show the relative benefits of cool (high reflectivity) roofs and unirrigated vegetation for reducing temperatures in the Melbourne urban area during heat wave conditions. Various combinations of 30% and 60% cool roofs (0.7 reflectivity), and 5%, 10% and 40% vegetation cover were tested.

Even without irrigation, vegetation provided substantial cooling at night relative to a control. Averaged across Melbourne the cooling was  $0.2^\circ\text{C}$ ,  $0.3^\circ\text{C}$  and  $1.0^\circ\text{C}$  for 5%, 10% and 40% vegetation cover. Figure 4 shows the modelled pattern of cooling across Melbourne for the 40% scenario, where the largest cooling benefits of  $1.5^\circ\text{C}$  was seen across the northern and western suburbs. The reduction in modelled air temperature from increased vegetation is primarily related to the reduction in ground heat storage as a result of shading and insulation of the surface. By increasing the vegetation fraction, less heat is absorbed and stored in the ground and buildings during the day, and consequently less heat is re-emitted at night, thereby keeping the air temperatures cooler. Irrigating vegetation would dramatically increase the cooling benefit by day.

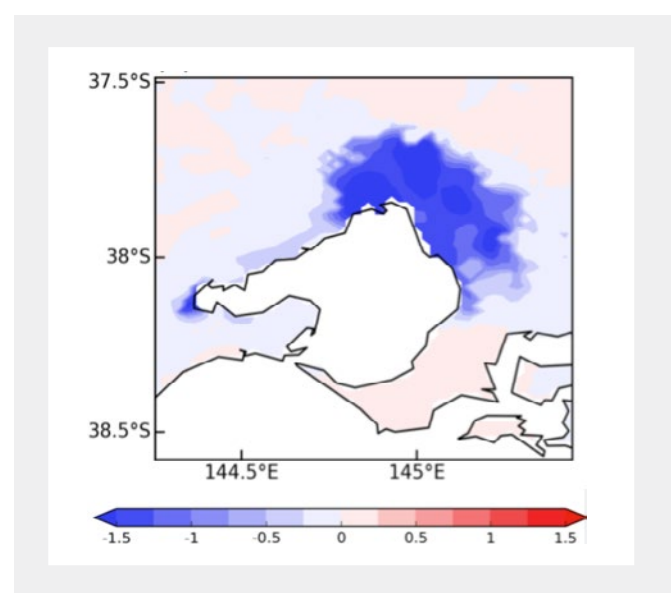


Figure 4. Relative cooling provided by 40% vegetation cover across Melbourne, averaged over 10pm-2am for 39 heatwave days. A relative cooling benefit was seen over the northern and western parts of the city.

## 4. Human thermal comfort

While air temperature is often quoted when discussing urban heat or the urban heat island, when it comes to the human thermal perception, air temperature is just one element affecting how people feel. Human Thermal Comfort (HTC) and whether a person experiences heat stress is influenced by air temperature ( $T_a$ ), humidity, wind speed and mean radiant temperature ( $T_{mrt}$ ) (Figure 5). As humidity increases, the ability for the body to cool through evaporation of sweat is limited. As wind speed reduces, the ability of the body to cool by transporting heat away from the body is limited. HTC also varies depending on physiological traits (age, gender, etc.), clothing, and activity (e.g. walking).

Mean radiant temperature is the heat the body feels from radiant heat sources, like solar radiation from the sun. Radiant bar heaters are a good example of heating the body through radiant energy.  $T_{mrt}$  considers radiant energy from all directions around the body. The higher the temperatures of objects around (such as the ground and walls) the greater the radiant heat received by the body. During the day under warm sunny conditions,  $T_{mrt}$  is the most important environmental variable influencing HTC. Therefore, providing shade to block solar radiation and to reduce the temperature of urban surfaces is critical.

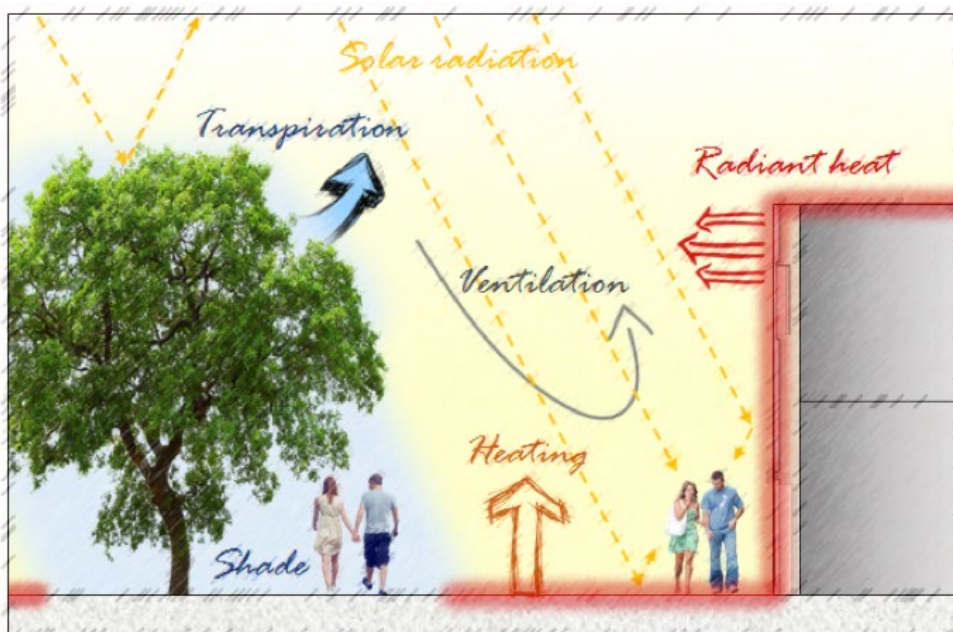


Figure 5: Key environmental components influencing human thermal comfort during the day. Trees block (e.g. absorb and reflect) solar radiation and shade urban surfaces. Cool surfaces, such as ground surfaces below trees, emit less radiant heat than hot surfaces. Roofs and walls heat up during the day and emit radiant heat. Trees also transpire meaning less energy is used in heating the air. Ventilation is also important for human thermal comfort, so tree placement needs to allow winds to flow and disperse heat.



## 5. On-ground implementation of tree cover

To help meet canopy cover targets, trees should be placed strategically throughout the landscape to ensure that they deliver the largest cooling and thermal comfort benefits possible (Figure 6). To achieve this, tree retention, maintenance and planting should occur in areas of:

- High urban temperatures or hotspots where there is a large amount of impervious surface;
- High population vulnerability (e.g. high proportion of older (>65 years) or very young (<4 years) persons); and
- High behavioural exposure, where people move and gather, such as public transport corridors, schools and public spaces.

This framework was developed by Norton et al. (2015) in collaboration with the CRCWSC and can be applied at the city, neighbourhood or street scale to guide where investment in urban greening should occur. It used earlier CRCWSC work by Loughnan et al. (2013) to identify vulnerability. Areas that intersect all three components of the framework (C) in Figure 6 should be prioritised and will deliver the greatest return on investment.

In addition to this framework, two sets of guiding principles are provided below to help guide the management and implementation of trees throughout the urban landscape. They provide a set of 'principles' and 'guidelines' based on published research, points on why they are recommended, and brief examples of their meaning. These tables were developed through research undertaken within the CRCWSC:

**5.1. Principles for landscape-scale tree management**  
based on Coutts et al., (2013b);

**5.2. Guidelines for targeted street scale tree arrangement**  
based on Thom et al., (2016).

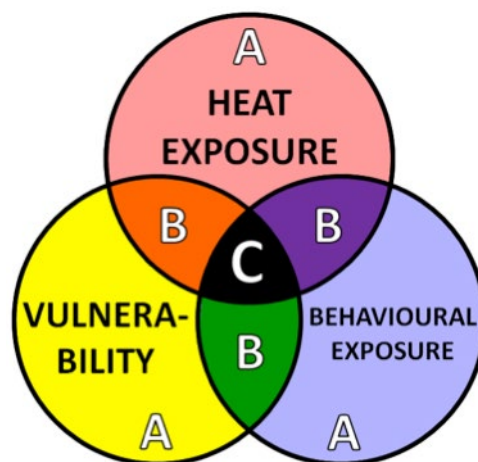







Figure 6: Factors required for identification of neighbourhoods of high (C), medium (B) and moderate (A) priority (Norton et al., 2015). Heat exposure is areas that are considered hot spots (e.g. identified by thermal remote sensing). Vulnerability is areas with high population vulnerability (e.g. elderly), and behavioural exposure is where people are outside and active (e.g. public transport corridors)

## 5.1. Principles for landscape-scale tree management

(Coutts et al., 2013b): This table provides broad principles for how to manage and increase tree cover across the urban landscape. These principles are provided with the specific objective of reducing urban air temperatures and improving human thermal comfort.






Principle	Why?	Example of each principle
<b>EXISTING TREES</b> <i>Aim to maximise the cooling potential of existing trees and vegetation cover first. Trees that are healthy, with a full canopy and actively transpiring will provide the greatest benefit. Existing vegetation must be supported with sufficient water (preferably from water sensitive urban design or alternative water sources)</i>	<ul style="list-style-type: none"> <li>Water stressed trees limit their water loss during hot dry conditions and can lose their canopy. This can compromise both evaporative cooling and shading.</li> <li>Existing trees already provide a substantial cooling benefit. Lead times for tree replacement limits cooling.</li> </ul>	 <p>Example of an unhealthy tree versus a healthy tree. Greater shading and transpiration from the healthy tree canopy.</p> <p>Cooling from a single tree can reach over 1.0°C during the day beneath the tree canopy with a much greater reduction in 'felt' temperature</p> <p>Large trees with unrestricted water supplies can transpire hundreds of litres of water per day</p>
<b>LACK OF VEGETATION</b> <i>Focus on dense urban environments with little or no vegetation. Well-watered vegetation is most effective at cooling under warm/hot and dry conditions and this coincides with areas of highest heat exposure that can place vulnerable populations at risk.</i>	<ul style="list-style-type: none"> <li>The warmer and drier atmosphere means trees will transpire more (if well-watered).</li> <li>Greater opportunity for trees to shade urban surfaces (roads, pavements, walls) in denser urban environments, reducing surface heating.</li> <li>Focusing on dense urban environments will deliver a greater cooling benefit per tree.</li> </ul>	 <p>Example of very high amounts of impervious surfaces where trees are drastically needed.</p> <p>Wide streets are exposed to large amounts of solar radiation and require shade.</p> <p>This example is likely to be a hotspot with high heat stress in an area with parking, restaurants, public transport and health services.</p>
<b>USE TREES</b> <i>Harness the cooling and HTC benefits of trees that achieve cooling via both evapo-transpiration and shading. Trees also deliver more cooling and improvement in HTC for the amount of water applied, compared to other urban green approaches.</i>	<ul style="list-style-type: none"> <li>Trees prevent solar radiation reaching pedestrians, reducing <math>T_{mrt}</math>. Green roofs and walls do not shade pedestrians.</li> <li>Trees provide more °C of cooling per litre of water than grass and other green infrastructure, such as green roofs.</li> <li>Shading from the tree canopy makes trees the most effective and efficient vegetation approach for cooling.</li> </ul>	 <p>Example of trees providing shade for roads, buildings, sidewalks and pedestrians, especially in wide-open streets. Trees can drastically reduce heat stress.</p> <p>Further greening could occur via wall and rooftop greening to improve building energy efficiency, to reduce heat storage in the ground and urban materials, and to reduce air (and in the case of walls) <math>T_{mrt}</math> temperature.</p>



Principle	Why?	Example of each principle	
<b>DISTRIBUTE TREES</b> <i>Trees and vegetation need to be distributed at regular intervals throughout the urban environment. Distributing trees throughout the landscape should provide a larger areal extent of cooling than large, but isolated green areas</i>	<ul style="list-style-type: none"> <li>The cooling effects of trees are highly localised (especially from shade). Cooling effects extend downwind to a distance equivalent to tree/park width.</li> <li>People are distributed throughout the landscape, so trees (and their cooling effects) should be too.</li> </ul>		<p>An example showing green areas that are well vegetated and irrigated, providing downwind cooling effects extending to around one park width.</p> <p>This example also shows only few trees in surrounding streets and hence limited sidewalk shading for pedestrians beyond the park boundary. Green corridors should connect separated urban parks wherever possible.</p>
<b>SMART PLANNING</b> <i>Work with the built environment to accentuate cooling influences through strategic design. Urban spaces should be sensitive to local and regional climatic influences (such as sea breezes and prevailing winds) and maintain natural cooling mechanisms such as ventilation and trees.</i>	<ul style="list-style-type: none"> <li>Tree cooling effects can be enhanced or negated by the built environment (e.g. buildings shading trees, or large buildings blocking downwind cooling effects).</li> <li>Strategic design can deliver larger cooling benefits for \$\$\$ invested.</li> </ul>		<p>An example of how buildings already provide some shade. Carefully consider the placement of trees to maximise their cooling benefit and achieve the largest benefit for their cost (i.e. don't replicate shade).</p> <p>Follow the '<i>Guidelines for targeted street-scale tree arrangements</i>' that consider street orientation, street widths and building heights that all impact shade.</p>

## 5.2. Guidelines for targeted street-scale tree arrangement

(Thom et al., 2016) This table provides more specific guidance on where to target tree planting to achieve the largest air temperature reductions and improvements in outdoor human thermal comfort.

Guideline	Why?	Example of where to target
<b>STREET WIDTH</b> <i>Target wide, open streets with a low "Building Height to Street Width ratio" (H:W) to provide shade</i>	<ul style="list-style-type: none"> <li>Wide open streets are exposed to greater amounts of solar radiation leading to higher daytime heat stress.</li> <li>Tree canopies absorb and reflect solar radiation, reducing the amount of radiation that reaches pedestrians and urban surfaces below.</li> </ul>	
<b>STREET ORIENTATION</b> <i>Target east-west oriented streets</i>	<ul style="list-style-type: none"> <li>East-west oriented streets are exposed to more solar radiation during the day compared to north-south oriented streets where some building shading occurs in the morning and afternoon.</li> </ul>	
<b>STREET SIDES</b> <i>Target the southern side of east-west streets (in the Southern Hemisphere)</i> <i>Target the eastern side of north-south oriented streets</i>	<ul style="list-style-type: none"> <li>The north facing walls are exposed to greater solar radiation throughout the day, leading to heat stress.</li> <li>The west facing walls are exposed to greater solar radiation at the peak daytime heating period (maximum air temperature).</li> </ul>	
<b>TREE GROUPING</b> <i>Trees should be clustered together in groups where possible, with overlapping canopies to maximise shading.</i>	<ul style="list-style-type: none"> <li>Isolated trees can be exposed to high heat and radiation loads in urban areas, increasing tree water stress.</li> <li>Clustering trees delivers greater reductions in air temperature and <math>T_{mrt}</math> below the canopy than isolated trees.</li> </ul>	
<b>TREE SPACING</b> <i>Groups of clustered trees should be interspersed with open spaces</i>	<ul style="list-style-type: none"> <li>Groups of trees provide shading during the day, while the open spaces between allows for surface cooling and ventilation (wind) at night.</li> </ul>	



## 6. Specific visual examples of idealised streetscapes

In addition to the prioritisation framework developed by Norton et al. (2015), their research on Planning for Cooler Cities also classified streets into varying levels of priority for street tree implementation (Table 1). This table was developed with the aim of reducing street surface temperatures during the summer solstice in Melbourne. Table 1 identifies which streets should be prioritised for street trees based on the street orientation (e.g. east-west or north-south), the width of the street and the height of the buildings abutting the street. The ratio of building heights to street width is known as the height to width ratio (H:W) and is represented by the numbers in Table 1. Table 1 can be modified as required for the latitudes of other Australian cities. The prioritisation reflects the Guidelines for targeted street-scale tree arrangement above.

*Table 1: Table of Height to Width ratio (H:W) for streets in Melbourne and their priority rating for protection and implementation of trees to improve daytime human thermal comfort (Norton et al., (2015)). Those zones marked as red are of a high priority for street tree planting as they are exposed to high amounts of solar radiation and so tree shading is most needed. Those zones marked green and blue are less of a priority as buildings along the street provide shade.*

Canyon width	Street tree prioritisation									Orientation
<b>Very wide</b> 40m	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	E-W
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	N-S
<b>Wide</b> 30 m	0.13	0.27	0.40	0.53	0.67	0.80	0.93	1.07	1.20	E-W
	0.13	0.27	0.40	0.53	0.67	0.80	0.93	1.07	1.20	N-S
<b>Medium</b> 20 m	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	E-W
	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	N-S
<b>Narrow</b> 10 m	0.40	0.80	1.20	1.60	2.00	2.40	2.80	3.20	3.60	E-W
	0.40	0.80	1.20	1.60	2.00	2.40	2.80	3.20	3.60	N-S
<b>Canyon height</b>	4 m	8 m	12 m	16 m	20 m	24 m	28 m	32 m	36 m	
	Low			Medium			High			

To aid in the interpretation of Table 1, a set of specific visual examples of idealised streetscape is presented below\*. The examples are for east-west oriented canyons covering the range of H:W ratios in Table 1. Table 1 suggests the streets where street tree planting should focus, while the examples illustrate how the implementation should be done. Some key points to note in the examples are:

- Each street is just one of many design forms of a particular H:W. Attention should focus on the placement of tree and the total density of canopy cover, rather than the overall street design (e.g. parking, cycle lanes, property boundaries).
- Street tree placement is considered only for public land. Private land is not considered in the examples (e.g. in the wide open street with low buildings typical of low density residential areas). Private landholders should also be encouraged to support trees, especially in wide, open streets.
- Water should be provided to street trees wherever possible through passive and/or active irrigation as suggested in Figure 7. Trees exposed to sunlight for a longer duration of the day should be identified for irrigation as the demand for water is higher. Further trees exposed to sunlight during the peak heating period of the day (e.g. in the afternoon when maximum temperatures are reached and when humidity is low) should be identified for irrigation as evaporative demand is high at this time. These trees are identified in the examples and it is suggested that they be irrigated (see Figure 7 for more detail).
- For simplicity, the street tree arrangements are only provided for east-west oriented streets. However, the same arrangement can be effectively applied for north-south streets and all orientations in between (Figure 8). An east-west street of a particular H:W (and its tree arrangement) can be rotated clockwise or anticlockwise until it reaches an orientation of 315°, at which point the tree arrangements 'flip' to the opposite side of the street.
- In streets where there are constraints on trees (e.g. above or underground services) or specific land uses that limit the planting of trees, then greening on the ground and walls should be encouraged. Climbing plants grown over artificial structures should be encouraged as a good alternative in space limited areas where tree canopies are constrained by space.
- In streets where the need for trees is not as critical and where buildings are tall, then green walls should be encouraged. This can help improve the energy efficiency of buildings.
- Green roofs may also be implemented to improve the energy efficiency of buildings, however, their benefits for street level human thermal comfort are limited. The cooling benefits of green roofs can be enhanced through irrigation, allowing a more diverse range of plant species that transpire at a higher rate than conventionally used succulents (see Coutts et al., 2013a).
- While not discussed here, tree species may also be important for maximising cooling benefits. While no recommendations are made, what is important is that a diversity of tree species is encouraged. A diverse mix of tree species helps to build resilience against changes in climate and water availability.

\* The streetscape designs were created using the Abu Dhabi urban street and utility design tool <https://usdm.upc.gov.ae/USDM/>



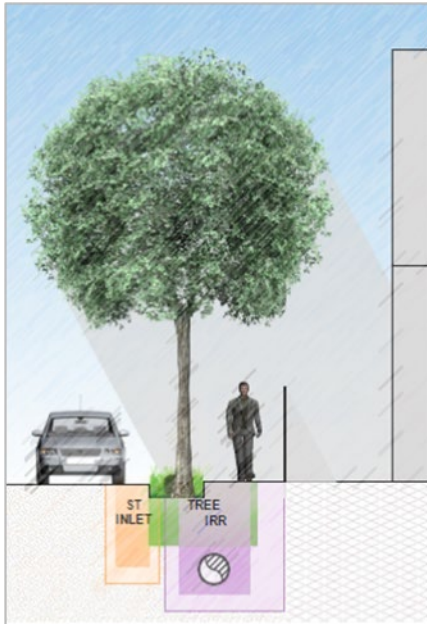


Figure 7. An example of street tree arrangements. Trees are used as part of Water Sensitive Urban Design (WSUD) and runoff from stormwater inlets (ST INLET) infiltrates soils surrounding trees. Growing conditions are improved when adequate root space is provided (TREE). Also indicated is where street tree irrigation (IRR) should be considered. Trees on the south side of the street (in the Southern Hemisphere) use more water as they are exposed to more sunlight. Trees on the east side of the street are in sunlight when the temperature is highest (e.g. afternoon) and the air is often the driest. High temperature and dry air increase the evaporative demand on trees, and if water is not available, can lead to water stress.

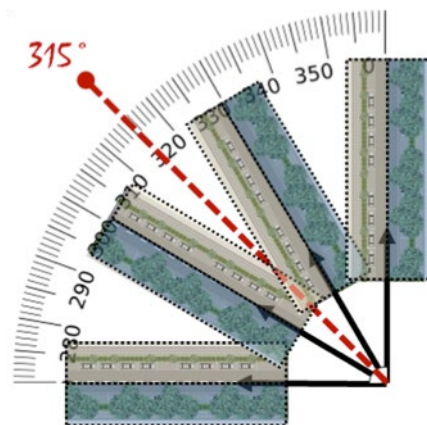
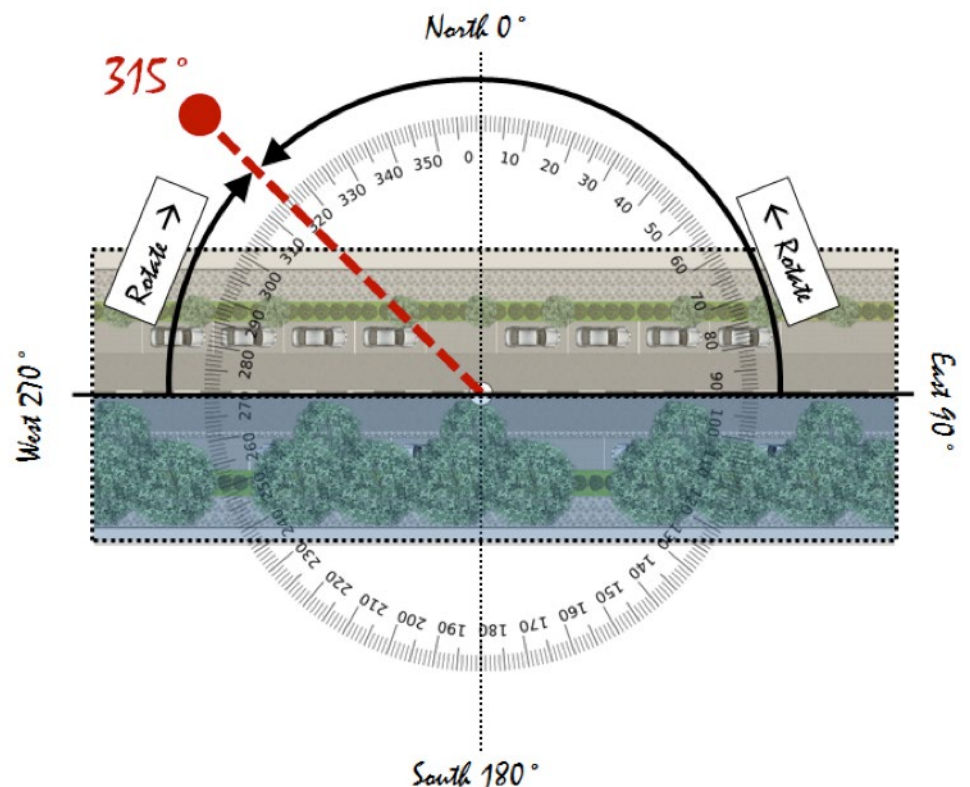


Figure 8: The examples for street tree placement in this document are for East-West oriented streets. Essentially, the same type of tree arrangement can be applied to a street of any orientation. Given the south (in the Southern Hemisphere) and west sides of the street should be targeted, the East-West oriented street can simply be rotated to determine which sides of the street to target with tree planting. The side of the street dominated by tree shade flips at 315°.



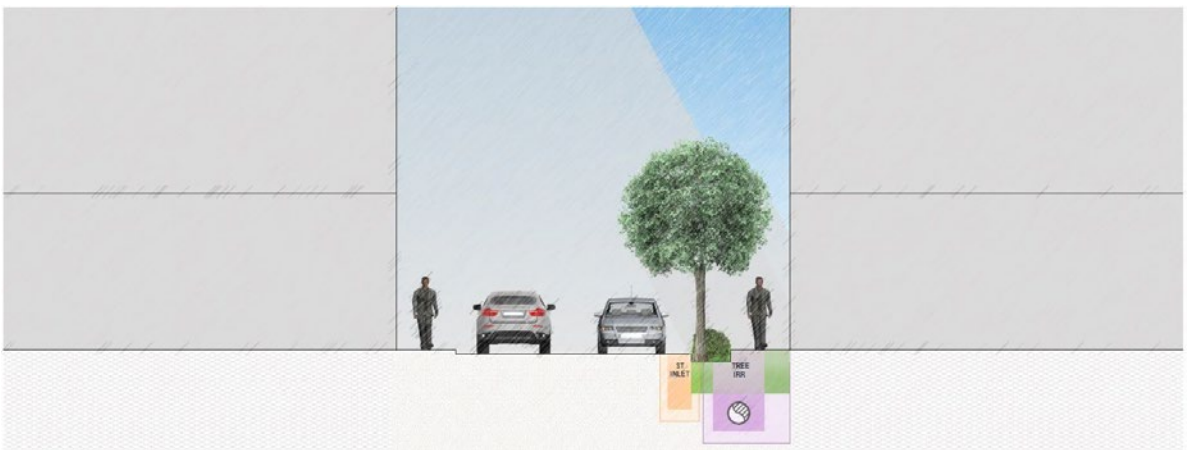
Cross section: *Narrow Street, 10 metres*

*East-West orientation*

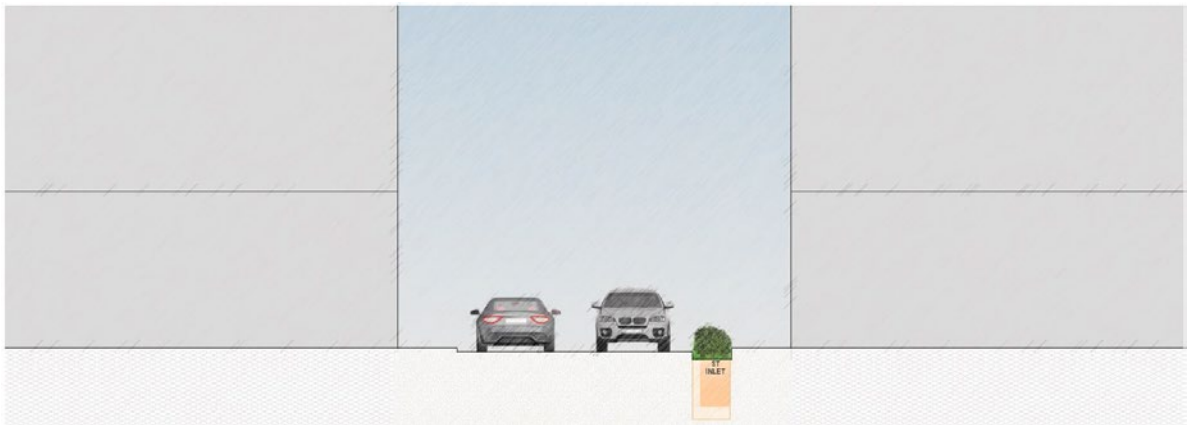
*Low Buildings, 8 metres  
H:W = 0.8*



*Medium Buildings, 20 metres  
H:W = 2.0*



*Tall Buildings, 32 metres  
H:W = 3.2*

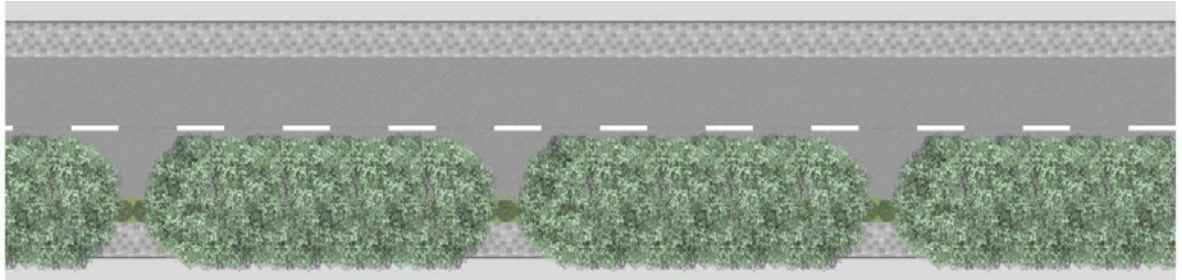


Plan view: Narrow Street, 10 metres

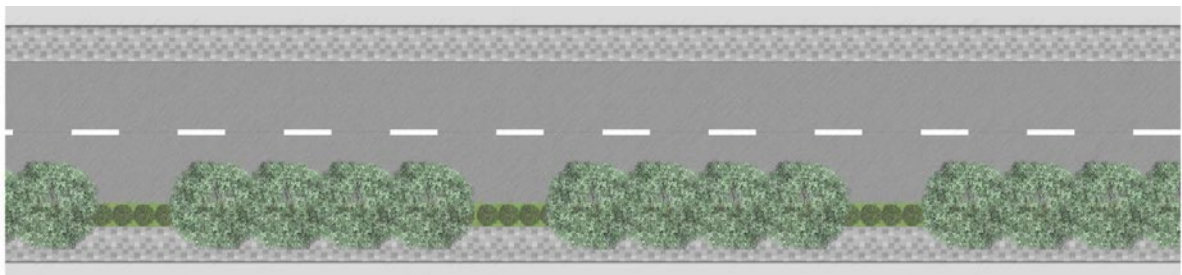
East-West orientation



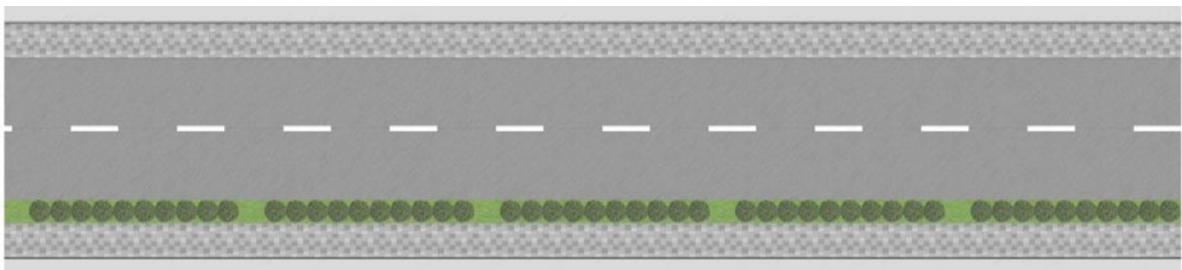
Low Buildings, 8 Metres  
 $H:W = 0.8$



Medium Buildings, 20 metres  
 $H:W = 2.0$



Tall Buildings, 32 metres  
 $H:W = 3.2$

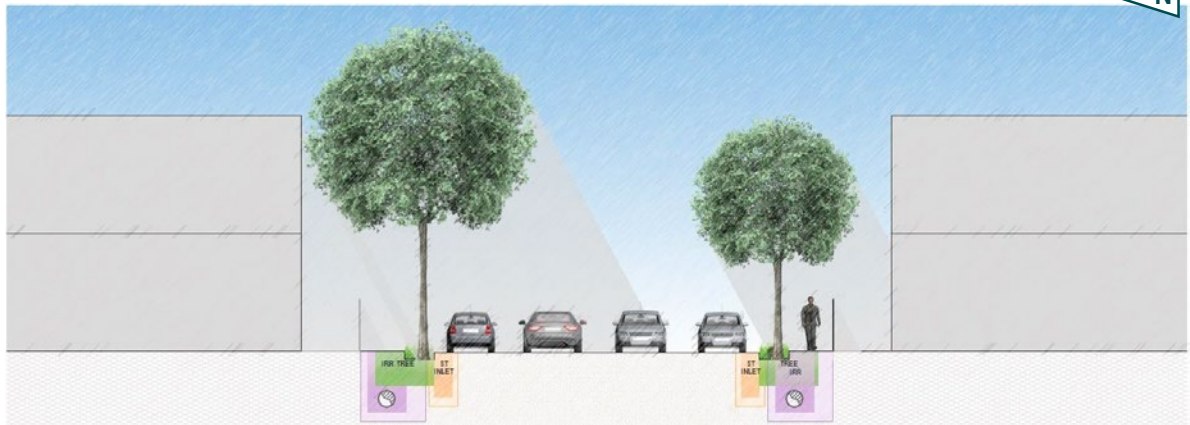




Cross section: Medium Street, 20 metres

East-West orientation

Low Buildings, 8 metres  
 $H:W = 0.4$



Medium Buildings, 20 metres  
 $H:W = 1.0$

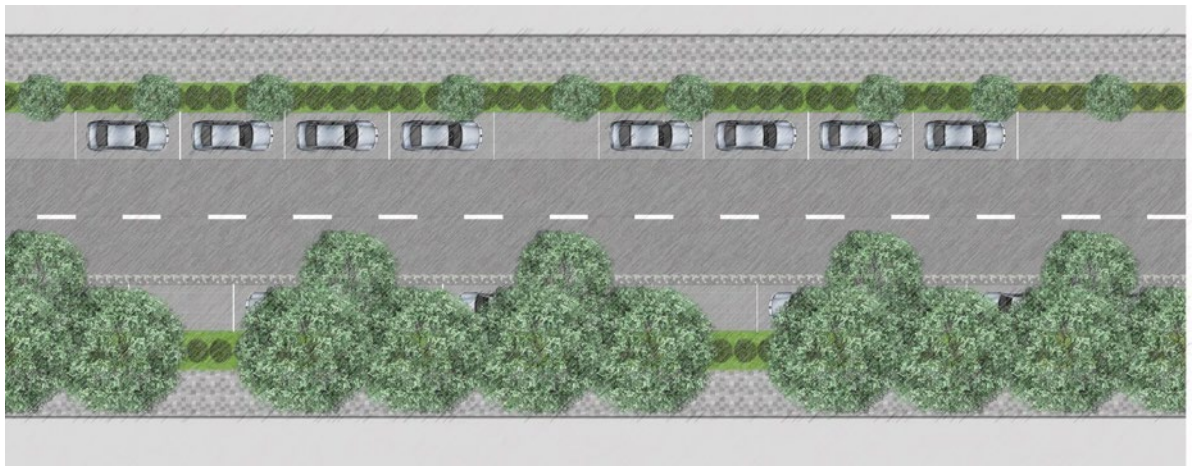


Tall Buildings, 32 metres  
 $H:W = 1.6$



Plan view: Medium Street, 20 metres

East-West orientation

Low Buildings, 8 metres  
 $H:W = 0.4$ Medium Building, 20 metres  
 $H:W = 1.0$ Tall Buildings, 32 metres  
 $H:W = 1.6$ 



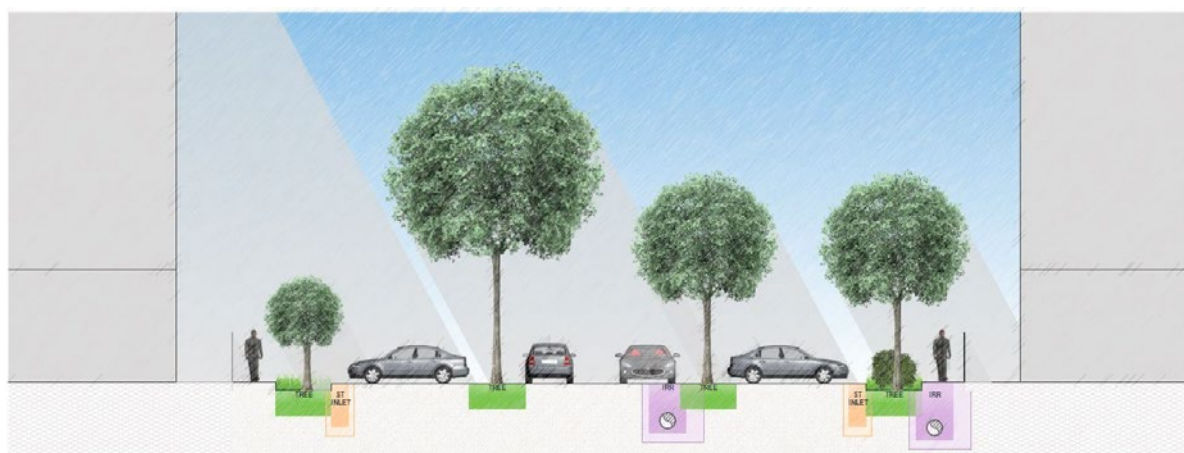
Cross section: Wide Street, 30 metres

East-West orientation

Low Buildings, 8 metres  
 $H:W = 0.27$



Medium Buildings, 20 metres  
 $H:W = 0.67$



Tall Buildings, 32 metres  
 $H:W = 1.07$





Plan view: Wide street, 30 metres

East-West orientation

Low Buildings, 8 metres  
H:W = 0.27



Medium Buildings, 20 metres  
H:W = 0.67



Tall Buildings, 32 metres  
H:W = 1.07





Cross section: Very Wide Street, 40 metres

East-West orientation

Low Buildings, 8 metres  
H:W = 0.2



Medium Buildings, 20 metres  
H:W = 0.5



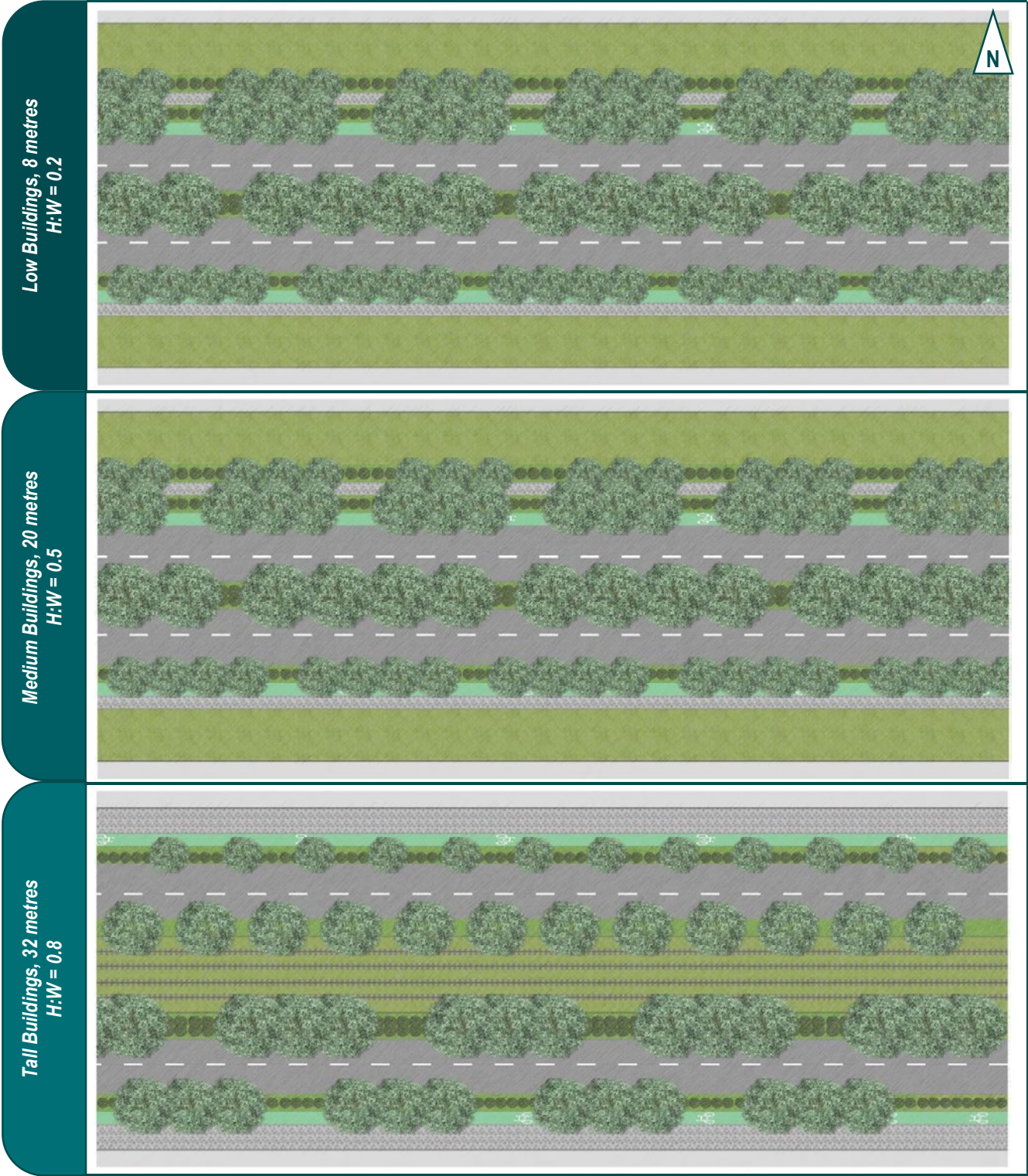
Tall Buildings, 32 metres  
H:W = 0.8





Plan view: Very Wide Street, 40 metres

East-West orientation





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