Polar Sun-path Charts with shading masks to compare BIIPVs' overshadowing configurations (Urban Forestry- inclusive)

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Abstract. We consider over-heated and under-heated periods (when "thermal comfort" is lacking) and see how portions of overshadowing impact on them, in order to compare different overshadowing configurations.

In regard to Buildings and Infrastructures Integrated Photo Voltaic (BIIPV) the evaluation will be in terms of loss of efficiency of the BIIPV [PV] plant[s] given by shading, but if Urban Forestry is the overshadowing element then the trade-offs must be considered and the rating/ranking of the overshadowing objects must be changed accordingly.

How, and how much, the proximity of trees to BIIPVs affects overall BIIPV buildings/Infrastructures' energy-efficiency remains to be researched in further detail, as are the overall trade-offs of overshadowing Urban Forestry. An experimental simplified graphic method/methodology to compare overshadowing configurations - inclusive of Urban Forestry components - is proposed.

It is hoped that the above-mentioned proposed method/tool can aid decision makers and others make quantitative and qualitative evaluations and comparisons at an intermediate scale - that between single buildings and urban scale - with a level of precision that can grow as the number of related studies (for instance on native plants and trees' evapotranspiration levels) increases.

Introduction.

Cooling loads are one of the greatest reasons for peak energy demand in summer – especially in hot Countries (such as Australia). "In Sydney a recent experimental study showed Urban overheating can increase cooling demand by 16% per year"[9]. Various authors advocate that external shading is a most effective way of lowering cooling loads [6] [10], by up to 35% according to one 2015 source [6]. Therefore, trees surrounding buildings and/ or on them, are perfect passive design tools, that offer a mitigation strategy for the Urban Heat Island (UHI) so typical of climates such as the Australian one [9].

"Urban greenery can provide a mitigation potential in the range of 0.3-2.5 degrees Celsius, with an average value of 1.0 ◦ [degree Celsius]" [ib./9].

It is the aim of this brief work to go only into some detail about energy -efficient plant and tree selection and placement with respect to buildings – although it will inform the proposed evaluation/comparison Method – and focus more on mid-level scale of BIIPVs and Urban Forestry overshadowing configurations' evaluation[s].

Intuitively if buildings and Infrastructures impact on BIIPVs (building and/or Infrastructures) underheated period on the sun path with overshadowing masks, they will gain a "negative" ranking and, in general, buildings will rank higher (more "negatively") than Urban Forestry. Urban Forestry will therefore be ranked less negatively compared to buildings and Infrastructures, when impacting on underheated periods (unless the latter/Urban Forestry is detrimentally impacting/overshadowing underheated periods/areas and consequently rank somewhat more "negatively" [-] as well). The Overshadowing Configurations will rank "positively" [+] if they occupy/shade overheated periods on the sun chart [see figures 2 to 4]. Urban Forestry will rank higher (++) than buildings (+).

Crown opacity/transparency levels should also be a value used to rank Urban Forestry overshadowing configurations (for instance if a percent of radiation comes through foliage, then the Urban Forestry is ranked as: LOW, MEDIUM or HIGH in terms of density levels of the Urban Forestry obstacle [see table 1]).

Proposed Method/methodology.

"Precision" landscaping [2] (1981) and "Strategic" landscaping [11] (2021) methods equate to energy –efficient landscaping. What are the "ideal" distances and placements of trees from BIIPVs?

It will vary depending on individual cases and will be based on, at least, the following parameters: tree height; tree crown shape; tree crown density (per season/month/day and time of the day); the wall and window[s] azimuth and height from the ground (and surface area and material…); the solar sun altitude (based on day of the year and time of the day); the BIIPV [indoor] thermal comfort and the tree azimuth and distance from the BIIPV (Integrated building and/or infrastructure, or self-standing PV plant).

The proposed method explained: The traditional tools used are the solar polar sun charts, as shown in Johnson (1981)[1][5], with shading masks, [3][5], shading mask protractor [1] [as opposed to using 'eaves'/overhangs and fins to shade the building/BIIPV, this method puts forward the idea of using Urban Forestry and the shading mask protractor to calculate/evaluate the most effective ways possible to shade the areas most in need], the site survey method as explained by Szokolay (2014)[5] in method sheet 2.2; Marsh's (2016) "Dynamic Overshadowing" [7] and the "timetable" plot (a graphic plot of average monthly temperatures) method as explained in a you tube video [8].

- Step1: transpose (indoor when applicable) thermal comfort data on polar sun chart (as per Szokolay [5] Johnson [1], and timetable plot method [8])
- Step 2: get 2 different Overshadowing Configurations (A&B) drawn on polar sun chart [3][5]
- Step 3: check areas where overshadowing masks impact on overheated (Overshadowing Configurations ranked: +) and/or on underheated periods/areas (OCs ranked as: -)
- Step4: make qualitative and quantitative computations, evaluations and comparisons with respect to areas as described in step 3 (based on "proximity matrix" [to critical areas] get results)
- Step5: repeat steps 1 to 4 with other Overshadowing Configurations (eg: C,D,E,F,G, etc.)

Validation of method and limitations: A few case studies (in GIS) should be undertaken to verify the actual (statistically significant) results of the proposed method; grasshopper scripts ('not an "easy" task' [14]) – and they'd need to change for each point location[ib./14]/BIIPV]) run; comparisons with Autodesk Revit, Ecotect, simulated "scenarios" made. Wind channelling considerations are lacking.

Conclusions.

Urban Forestry (UF) is a UHI mitigation strategy and, therefore, a priority. The author advocates the need (in order to aid decision makers, designers, planners and technologists alike) to bridge the gap between the building and the urban scale. This is done by providing a needed [12][13], user-friendly, technical tool (automated to the extent possible) that can help evaluate different BIIPV overshadowing configurations (inclusive of Urban Forestry), compare them – even though extremely roughly at first – and rank them as more or less suitable/"sustainable".

In case of new BIIPVs one of the assumptions will be that the thermal comfort of the BIIPV building being impacted by different Overshadowing Configurations will vary (with daily/seasonal climatic changes and other factors – such as tree characteristics, etc.) and can be aided by energy-efficient Urban Forestry strategic placement.

In terms of BIIPV "retrofit" integration in the built environment, it's not so much the same old "best practice" for BIIPVs of tactical avoidance of Urban Forestry [4], as an overshadowing element, altogether, but more so an energy-efficient and Urban Forestry management approach, for better PV integration efforts and results.

From the "OUT!" (of the way - of BIIPVs) UF/Overshadowing old motto [4]/[12], a paradigm shift should take place, towards more of an "AUT – AUT…" (either, or) policy, by making it possible to somehow compare overshadowing configurations, be they "de facto" or designed/planned ones.

Table 1 Urban Forestry estimated "green" shading factor (*crown density*- based)

Frangipani	***Medium***	***Low***	Shading factor1
Hoop Pine	***Medium***	***Medium***	Shading factor2
Tuckeroo	***HIGH***	***HIGH***	Shading factor3

Fig.1 Shading Masks laid over sun paths (ex Szokolay, 2014, but with North up top)

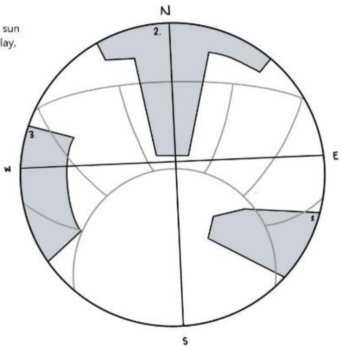


Fig.2 Thermal overheated period (in red) laid over sunpaths (one for each semester)

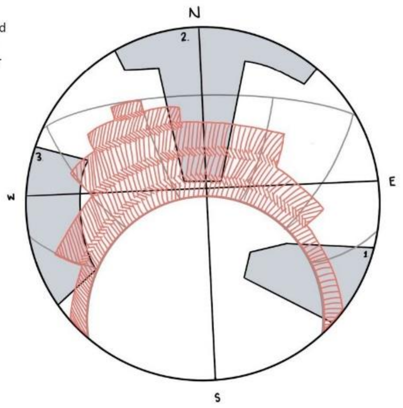


Fig.3 Overshadowing Configuration A.

Building 3 is more in need of urban greenery (and with higher crown density); Building 2: intermediate need of green roof (with medium level of crown density); Building1: low need of Urban Forestry (with low level of crown density recommended)

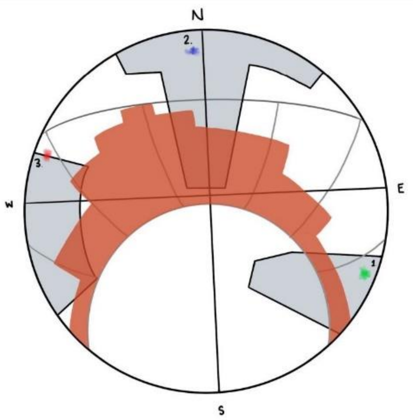
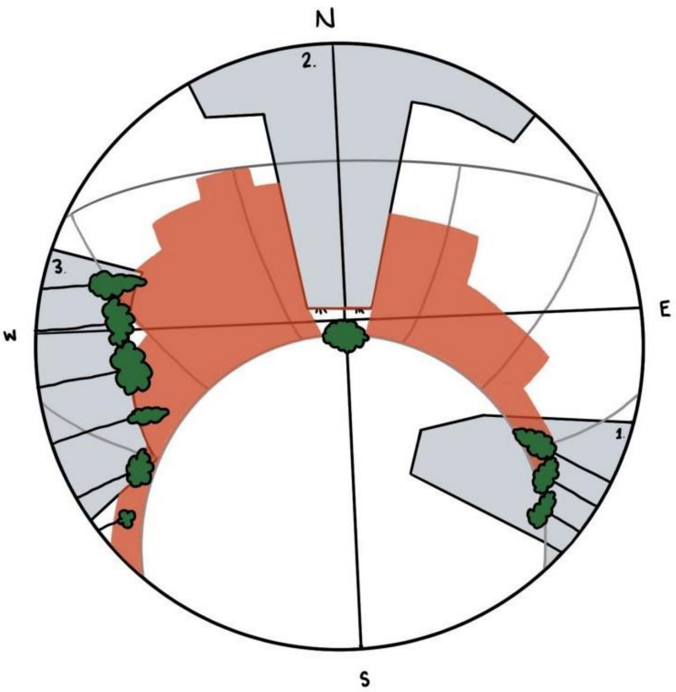


Fig.4 Overshadowing Configuration B.

Configuration B ranks better than configuration A.

Buildings and Urban Forestry ranked according to percentage of overheated (or underheated) periods/areas they shade (and based on "proximity" to BIIPV and overall proximity to "ideal" angles of shading based on shading mask protractor method), also based on the azimuth [wall] angles of the overshadowing configurations



Figures 1-4. Urban Forestry 'green' shading factor vs buildings grey shading percentage. Plant, ex –novo, trees with high density crown to shade critical areas of [indoor] thermal comfort (plotted on polar sun-charts with overshadowing configurations). If reading an actual Overshadowing Configuration we can compare it with other Overshadowing Configurations by accounting for percentages of areas that are "adequately" shaded and areas that are not.

Additional note. For the purposes of developing the method locally, the Building Code of Australia (BCA) climatic zones should be used as a starting point – as they are: eight, or, at least initially, four [compacting/joining them two by two], and the book "Bee-friendly: a planting guide" (2012), by Dr Mark Leech,[available online] used as a guide for selection of plants and trees based on exact BIIPVs location and relative climate. (BIIPVs to leave East. aspect on hills free for bees to rank +).

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