

Assessing heat health vulnerability

A comparison of methods





Mosaic Insights recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia.

We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Melissa Barton. This piece was commissioned by the Alluvium Group, and tells our story of caring for Country, through different forms of waterbodies, from creeklines to coastlines. The artwork depicts people linked by journey lines, sharing stories, understanding and learning to care for country and the waterways within.

This report has been prepared by Mosaic Insights Pty Ltd for **Merri-bek City Council** under the contract entitled '**Heat methods comparison**'.

Authors: Amala Mathew, Dom Blackham, Jan Orton, Jake Allen
Review: Dom Blackham
Approved: Jan Orton

Version: R01V03
Date issued: 10 February 2025
Issued to: Mara Baviera, Merri-bek City Council
Citation: Mosaic Insights (2020). Assessing heat health vulnerability: a comparison of methods. Report to Merri-bek City Council.

Cover image: Breese Street in Brunswick (photograph Dom Blackham)

Contents

1	Introduction	1
1.1	<i>Council's response to urban heat risks</i>	<i>2</i>
1.2	<i>Project objective</i>	<i>3</i>
1.3	<i>Assessment criteria</i>	<i>4</i>
	Data currency.....	4
	Data accuracy.....	5
	Feasibility and ease of use	5
2	Overview of the approaches	6
2.1	<i>Integrated Heat Vulnerability Index (iHVI)</i>	<i>6</i>
	Description of the approach	6
	Outputs from the approach.....	7
2.2	<i>Heat-Health Risk Index (HHRI).....</i>	<i>8</i>
	Description of the approach	8
	Outputs from the approach.....	9
2.3	<i>Cooling and Greening Melbourne.....</i>	<i>11</i>
	Description of the approach	11
	Outputs from the approach.....	11
3	Results of assessment.....	13
4	Discussion	17
4.1	<i>Summary of assessment</i>	<i>19</i>
	iHVI.....	19
	HHRI	19
	Cooling and Greening Melbourne	20
4.2	<i>Conclusions.....</i>	<i>20</i>
4.3	<i>Considerations for nominated Council service areas.....</i>	<i>22</i>
	Appendix A: Data inputs and sources	25
	Data inputs and sources used in the iHVI tool.....	25
	Data inputs and sources used in the HHRI	27
	Data inputs and sources used in the Greening and Cooling Melbourne.....	28

Tables

Table 1. Data currency sub-criteria	4
Table 2. Data accuracy sub-criteria	5
Table 3. Feasibility and ease of use sub-criteria	5
Table 4. Results of the assessment of each approach	15
Table 5. Summary of assessment	18
Table 6. Considerations for application of heat vulnerability assessment approaches to specific service areas	23
Table 7. iHVI tool data inputs	25
Table 8. HHRI approach data inputs	27
Table 9. Cooling and Greening Melbourne data inputs	28

Figures

Figure 1. Climate Risk as a product of Hazard, Vulnerability, and Exposure. Reproduced from the Merri-bek City Council Climate risk strategy (2022)	2
Figure 2. <i>Conceptual framework for heat vulnerability index assessment</i>	7
Figure 3. HVI by SA1 for 2021 for the Merri-bek LGA	8
Figure 4. HHRI at SA1 scale mapped for the Merri-bek LGA	10
Figure 5. Sample output of a HVI map at SA1 scale and change in vegetation cover map produced using the Greening and Cooling Melbourne map at Mesh Block scale.	12
Figure 6. Overview of data inputs and methods for each approach	14
Figure 7. Heat vulnerability index map from iHVI (2021), HHRI (2021) and Greening and cooling Melbourne (2018) approaches	21

Glossary

ABS Australian Bureau of Statistics

ACS Australian Climate Service

Australian population grid 2022 The Australian population grid 2022 is a modelled 1 km x 1 km grid representation of the estimated resident population (ERP) of Australia from 30 June 2022. The population grid is created by reaggregating estimated resident population data from Statistical Areas Level 1 (SA1) to a 1 km x 1 km grid across Australia based on point data representing residential address points.

ASGS Australian Statistical Geography Standard

BoM Bureau of Meteorology

CSIRO Commonwealth Scientific and Industrial Research Organisation

GIS Geographic Information System

iHVI Integrated Heat Vulnerability Index

HVI Heat Vulnerability Index

The heat vulnerability index (HVI) is a rating system that shows how vulnerable a population is to extreme heat. It is calculated using three components: exposure, sensitivity, and adaptive capacity.

HHRI Heat-Health Risk Index

IEO Index of Education and Occupation

IEO is one of the four indexes that form part of the ABS Socio-Economic Indexes for Areas (see below for more information). It measures the educational and occupational characteristics of people and households within a geographic area.

LGA Local Government Area

LST Land Surface Temperature

LST refers to the temperature of the Earth's surface as measured from satellite or ground-based sensors. It indicates how hot the surface of the land would feel to the touch, factoring in all natural and man-made surfaces, including soil, vegetation, water bodies, roads, and buildings.

Mesh blocks Mesh Blocks are the smallest geographic units for which statistical data is collected and processed by the ABS. Mesh Blocks vary in

size from part of a city block to large areas of rural land. Each of these borders another to form a network covering the whole country including inlets and coasts

NDBI Mean Normalised Difference Built-up Index

The Mean Normalised Difference Built-up Index (NDBI) is a metric used to identify and quantify built-up or urbanised areas. It is derived from satellite imagery using reflectance values from shortwave infrared (SWIR) and near-infrared (NIR) bands.

NDVI Mean Normalised difference Vegetation Index

The Mean Normalised difference Vegetation Index (NDVI) is used to quantify vegetation greenness and is useful in understanding vegetation density and assessing changes in plant health using sensor data.

SA1 Statistical Areas Level 1

SA1s are larger geographical units that have a population of between 200 to 800 persons with an average population of approximately 400 persons. SA1s aim to separate out areas with different geographic characteristics within suburb and locality boundaries.

SA2 Statistical Areas Level 2

SA2s are medium-sized general purpose areas built up from whole SA1. SA2s generally have a population between 3,000 and 25,000 with an average of about 10,000 people.

SEIFA Socio-Economic Indexes for Areas

The Socio-Economic Indexes for Areas is a suite of indexes developed by the ABS to measure the relative socio-economic conditions of different areas across Australia. SEIFA is based on data collected in the Census of Population and Housing and is widely used to analyse and compare the socio-economic conditions of communities.

UHIE Urban Heat Island Effect

The Urban Heat Island Effect (or UHIE) is the result of the surrounding environment absorbing or reflecting heat during the day. Studies have found that urban (built-up) areas are hotter than natural areas, as the hard surfaces of roads, roofs, gravel and concrete absorb heat from the sun.



1 Introduction

Merri-bek City Council (Council) understands the ongoing impacts of climate change, and the need to consider these impacts for reliable service delivery into the future. Council recognises the critical need to respond to urban heat particularly for its most vulnerable populations, and commissioned Mosaic Insights to deliver a comparison of available approaches for assessing the vulnerability of the Merri-bek community to extreme heat. The work will allow Council to better understand heat vulnerability data to inform effective service planning and programming.

Extreme heat causes significant social, mental health, and economic impacts in Australia. Research by Natural Capital Economics for the Victorian Government estimated that heatwaves cost Victoria \$87 million annually (in 2018 terms). It is estimated that in labour productivity alone Australia loses \$8.7 billion per year from heatwaves. It is estimated that, in labour productivity alone, Australia loses \$8.7 billion per year from heatwaves.¹ The social and mental health impacts are also profound, with heatwaves contributing to increased hospital admissions, exacerbation of pre-existing mental health conditions, and heightened stress levels, particularly among vulnerable populations.²

The impact of extreme heat in urban areas is a significant, complex and multifaceted issue, intersecting with and impacting on human health and wellbeing, infrastructure resilience, environmental sustainability and economic activity.

Urban heat has a range of deleterious impacts on human health and wellbeing, including heat stroke, cardiovascular stress, mental, respiratory and diabetes related conditions.³ Extreme heat kills more Australians every year than all other natural hazards combined⁴. Extreme heat can affect everyone, but some people are at higher risk, especially vulnerable sectors of the community including older and very young people, people with existing health conditions and more disadvantaged members of the community.⁵

Urban areas are particularly exposed to extreme heat because of the UHIE, which leads to higher temperatures in urban areas compared to their rural surroundings. In some cases, urban surfaces and buildings can be up to 10–20°C warmer than surrounding areas.⁶

¹ Natural Capital Economics. (2018). Economic impact of heatwaves in Victoria: Report for the Victorian Government. Victorian Government.

² Berry, H. L., Bowen, K., & Kjellstrom, T. (2010). Climate change and mental health: A causal pathways framework. *International Journal of Public Health*, 55(2), 123–132.

³ World Health Organization. (2021, August 18). *Climate change, heat and health*. World Health Organization. <https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health>

⁴ Department of Health, Victoria. (2018). *Heat health*. Your health: Report of the Chief Health Officer, Victoria 2018. <https://www.health.vic.gov.au/your-health-report-of-the-chief-health-officer-victoria-2018/environmental-health/heat-health>

⁵ Basu, R., & Samet, J. M. (2002). Relation between elevated ambient temperature and mortality: a review of the epidemiologic evidence. *Epidemiologic reviews*, 24(2), 190–202.

⁶ New South Wales Government. (n.d.). *Urban heat*. Climate Change in NSW. <https://www.climatechange.environment.nsw.gov.au/impacts-climate-change/built-environment/urban-heat#:~:text=In%20some%20cases%2C%20urban%20surfaces,vegetation%20compared%20to%20rural%20areas.>

Extreme heat can be measured and described in numerous ways. The BoM defines a heatwave as three or more days in a row when both daytime and night-time maximum temperatures are unusually high in relation to the local long-term climate and the recent past.⁷ Merri-bek, like other Victorian Councils, follows the BoM classification of heatwaves and adheres to official advice on heatwave forecasts and warnings.

Extreme urban heat events are expected to be more frequent, longer and more intense as the climate continues to warm. Understanding the risk to communities from urban heat is becoming increasingly important and is critical to creating effective policy, planning, and interventions to minimise risk.

1.1 Council's response to urban heat risks

Merri-bek City Council (Council) recognises the need for taking urgent action on climate change, accelerated by declaring a Climate Emergency in 2018 and the inaugural Climate Risk Strategy released in 2022.

Council considers the risks associated with a changing climate as part of its Risk Management Framework to inform its service planning and investments. Council defines these climate risks as the potential for climate change to harm people and the environment. Risks from climate change arise through a combination of weather events (hazard), the characteristics of impacted people (vulnerability), and how exposed people or things are to that weather event, based on their location or physical condition (exposure).



Figure 1. Climate Risk as a product of Hazard, Vulnerability, and Exposure. Reproduced from the Merri-bek City Council Climate risk strategy (2022)

⁷ Bureau of Meteorology. (2023). National heatwave warning framework.

In the urban heat context, climate hazards include acute impacts (very high heat days and multiple-day heatwaves) and chronic stresses (higher day- and night-time temperatures year-round, lower average rainfall which may decrease the availability of water for cooling purposes). The Victorian Government's Climate Science Report 2024⁸ anticipates an average annual temperature increase in Victoria of 1.5 degrees C by 2050 under a global high-emissions scenario. The average number of annual 'heatwave days' is also expected to increase from 20 to 30 or greater per year under the same scenario.

While hazards are determined by large-scale, global climate trends, risks to the Merri-bek community and to Council can be minimised by addressing vulnerability and exposure at the local level. Ensuring vulnerable community members can access support systems, minimising the physical exposure of spaces and events to high temperatures, and providing resources which help people better adapt to their environment are all viable ways to reduce the risks associated with urban and extreme heat.

Climate related action has been elevated to a whole of organisation responsibility, cross-cutting different business units and levels of Council to support proactively planning for and responding to the impacts of climate change. Council is also discharging its duty of care to exercise functions and powers in a way that manages foreseeable risks.

1.2 Project objective

The objective of this project is to critically review three heat vulnerability assessment approaches (referred to as 'approaches' in this report) and provide technically sound advice on the suitability of each approach in supporting decision-making in Council.

The approaches share a common high level purpose and method. At a high level, they aggregate data relevant to urban heat, ascribe weightings to different data sets, and use the weighted data to determine an overall 'vulnerability' index/rating, that allows place-based assessment of community vulnerability to the health impacts of heat.

An overview of the three approaches, which were nominated by Council, is provided below. More details the approaches are provided in Section 2.

Integrated Heat Vulnerability Index

The integrated Heat Vulnerability Index (iHVI) tool was developed by RMIT University as the first nationwide dynamic and interactive heat vulnerability assessment toolkit. The tool integrates multiple data sources and uses cloud computing and Web GIS technologies and draws on multiple spatial data sets that describe temperature, urban development and greening, and socio-demographic and economic conditions.⁹

Heat-Health Risk Index

The Heat-Health Risk Index (HHRI) was developed by the Australian Climate Service (ACS), a partnership between the BoM, CSIRO, ABS and Geoscience Australia. It is a national initiative developed as part of the National Climate Risk Assessment to support decision making on mitigation, preparedness and response options to extreme heat.

⁸ Victorian Government. (2024). Victoria's climate science report 2024. Department of Energy, Environment and Climate Action.

⁹ Sun, Q., Das, S., Wang, K., Tao, Y., Amati, M., Hurley, J., ... & Duckham, M. (2022). iHVI: AN Open-Source Toolkit for Constructing Integrated Heat Vulnerability Index in Australia. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 48, 175-182.

Cooling and Greening Melbourne

Cooling and Greening Melbourne is a Victorian Government initiative that provides mapping of metropolitan Melbourne and brings together research and spatial data on vegetation, urban heat and social vulnerability to heat. The Cooling and Greening Melbourne interactive map was developed under the auspices of Action 91 in the Plan Melbourne Implementation Plan 2017-2050, which commits to developing a whole-of-government approach to cooling and greening metropolitan Melbourne. The initiative aims to enhance urban resilience by integrating green spaces and cooling solutions to mitigate heat-related risks and improve the liveability of the city.

1.3 Assessment criteria

A set of assessment criteria were established to allow a consistent assessment of the heat vulnerability approaches. The criteria reflect the characteristics of data analysis techniques that are most relevant to Councils and other agencies and are:

- Data currency
- Data accuracy
- Feasibility and ease of use

The criteria (and the more detailed sub-criteria that sit within them) are described in this section. The heat vulnerability approaches were assessed against the criteria to provide an assessment of their benefits and limitations to allow direct comparison between them. Thresholds used to rank each approach were developed to provide a consistent framework.

Data currency

Data currency is a measure of how current and relevant the data are (Table 1).

Table 1. Data currency sub-criteria

	Ranking		
	High	Medium	Low
How recent is the data	Most data inputs are from 2023 or later.	A significant portion of data inputs ranges from 2020 to 2023.	Most data inputs are from before 2020.
How frequently will the data be updated	Every 1-2 years	2-8 years	Every eight years or more, or no known commitment to update

Data accuracy

Data accuracy refers to the spatial resolution, reliability and quality of data (Table 2).

Table 2. Data accuracy sub-criteria

	Ranking		
	High	Medium	Low
Level of detail What is the level of detail / spatial resolution of the data:	Very granular data with fine spatial resolution e.g. Mesh Block scale or finer	Moderately detailed with acceptable resolution e.g. SA1 scale	Coarse data with limited spatial resolution e.g. SA2 scale or larger
Reliability /quality	Well-validated, and trusted data sources, e.g. State Government sourced or peer-reviewed data	Validated data from a variety of sources that may contain minor inconsistencies	Low-quality data with limited validation

Feasibility and ease of use

Feasibility and ease of use refers to the degree an approach can be used without significant additional resourcing or external assistance (Table 3).

Table 3. Feasibility and ease of use sub-criteria

	Ranking		
	High	Medium	Low
Cost Cost involved in the purchase of data	Low cost / open-source data	Moderate cost, partially open source	Expensive to purchase data
Skills required Skills required to apply the approach (e.g. advanced GIS processing capabilities)	Highly user-friendly, no GIS skills needed	Basic GIS skills required	Advanced technical expertise (data analyst) needed
Integration Can the outputs be downloaded by Council and integrated into other tools.	Outputs are fully downloadable in compatible formats	Outputs are partially downloadable or require additional processing	Outputs are not downloadable
Availability of raw data Availability of raw data to further integrate the analysis with other tools	Raw data is fully available to download	Partially available raw data	Raw data is not available to download
Repeatability Comparison over time	Allows for consistent comparison	Some inconsistencies in repeatability	Not comparable over time

2 Overview of the approaches

This section evaluates the three heat vulnerability approaches. A description is provided for each approach including the methods and outputs.

2.1 Integrated Heat Vulnerability Index (iHVI)

Description of the approach

The integrated Heat Vulnerability Index (iHVI) tool was funded by the Australian Urban Research Infrastructure Network (AURIN) and developed by researchers from RMIT University. The index was developed to meet the increasing demand in heat vulnerability assessment for identifying areas that are vulnerable to heat waves, and takes into account the location of vulnerable members of the community, such as the elderly, very young and factors such as population density, the percentage of elderly (65+), the percentage of young children (aged 4-), the percentage of the population needing care, education level, and low income level.

The tool was developed to establish a first nationwide dynamic and interactive heat vulnerability assessment tool, which integrates multiple data sources and uses cloud computing and Web GIS technologies. It integrates multiple spatial data sets that describe temperature, urban development and greening, and socio-demographic and economic conditions. The outputs from the tool are heat sensitivity, heat adaptive capability indicators, and a composite integrated heat vulnerability index (iHVI).

The iHVI is expressed as a score from one to five, with five being the most vulnerable and one being the least vulnerable.

Nine indicators relating to a range of factors are processed in the tool to calculate three indices:

1. Heat exposure index
2. Heat sensitivity index
3. Adaptive capability index

The workflows in the tool are illustrated conceptually below in Figure 2.

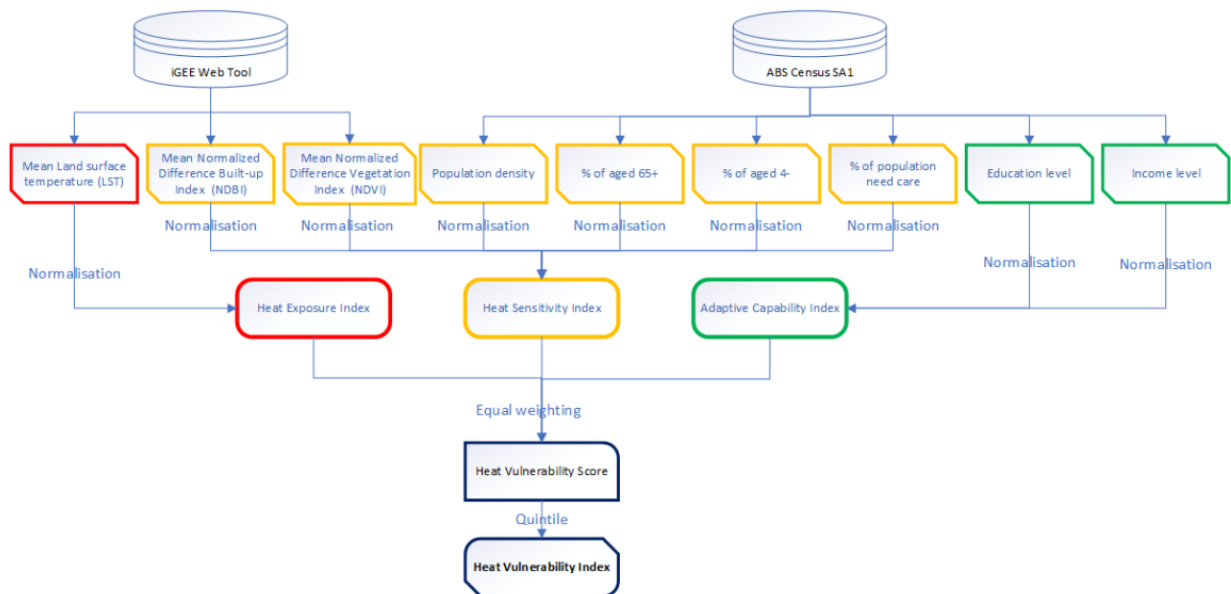


Figure 2. Conceptual framework for heat vulnerability index assessment

Outputs from the approach

The core output from the iHVI tool is a map that displays HVI across a study area. HVI for SA1 is based on the quintile of the composite heat vulnerability score computed from the three indicators: heat exposure index, heat sensitivity index and adaptive capability index. The quintile method takes the observed indicators and provides three cut points as to divide the SA1s into 1-5 quintiles. Areas are ordered from lowest to highest values and divided into 5 equal sized groups that are easy to interpret. A lower value indicates that an area is relatively at less risk compared to an area with a higher value.

- Lowest 20% of areas are given a quintile number of 1 ('Low')
- The next lowest 20% of areas are given a quintile number 2 ('Low-Medium')
- The next lowest 20% of areas are given a quintile number 3 ('Medium')
- The next lowest 20% of areas are given a quintile number 4 ('Medium-High')
- The highest 20% of areas are given a quintile number 5 ('High')

iHVI tool enables to perform LGA specific quintile classification. The visual differentiation facilitates quick identification of regions that may require targeted interventions to reduce the impact of heat.

An example of HVI mapping outputs for the Merri-bek LGA is shown below (Figure 3).

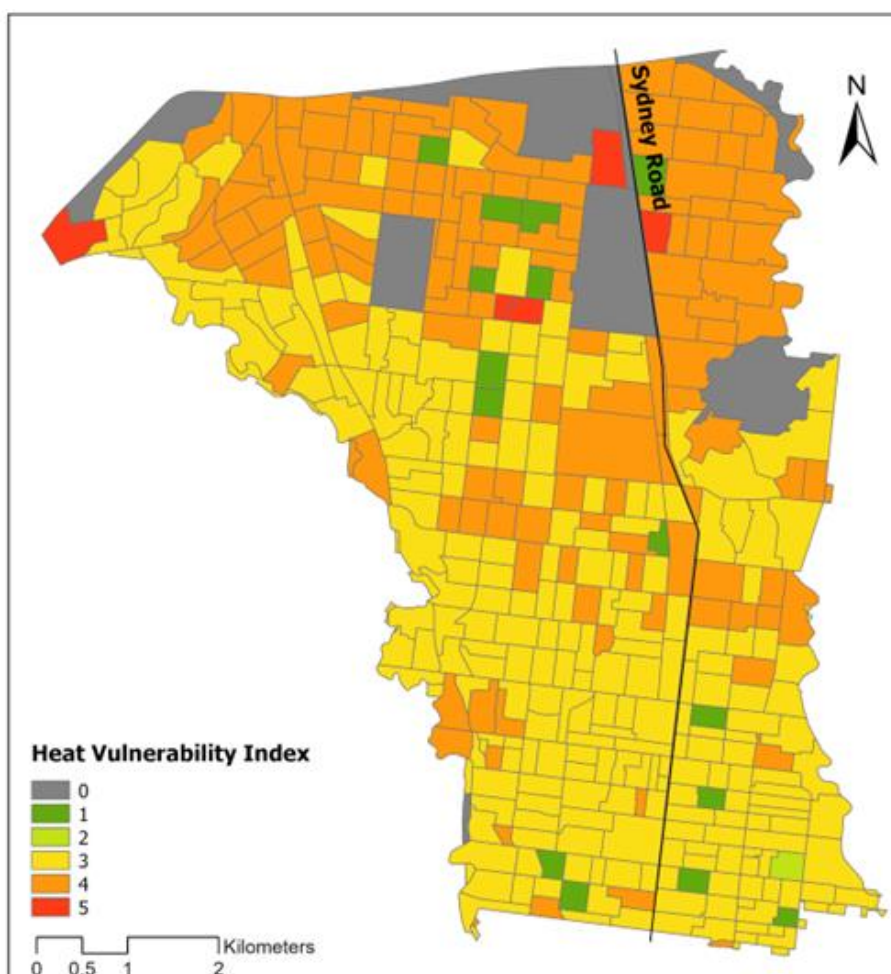


Figure 3. HVI by SA1 for 2021 for the Merri-bek LGA

2.2 Heat-Health Risk Index (HHRI)

Description of the approach

The Heat-Health Risk Index (HHRI) project was developed by the ACS, a partnership between the BoM, CSIRO, the ABS and Geoscience Australia. The approach provides a detailed spatial view of the people and places most at risk. The methodology behind the HHRI has been adapted from risk frameworks developed by the Intergovernmental Panel on Climate Change¹⁰, particularly from the Sixth Assessment report (AR6) and several international best practice frameworks and updated to take into consideration the latest thinking on climate risk.

Over 40 variables (Refer Appendix A for detailed list of data inputs) are used in HHRI tool to estimate the heat-health risk for local areas across Australia, using the ASGS, ABS 2021 data at SA1 and SA2. The overall risk index can be disaggregated into risk components i.e. exposure, vulnerability and response/adaptive capacity indices.

The HHRI integrates multiple data sets to create maps showing risk components across spatial resolutions SA1, SA2, and the Australian Population Grid. Key indicators include:

¹⁰ Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Impacts, adaptation and vulnerability*. (H.-O. Pörtner, D. C. Roberts, M. Tignor, et al., Eds.). Cambridge University

- Exposure: Average summer temperature, bare ground, dwelling types.
- Vulnerability: Socioeconomic status, household composition, language, culture, housing conditions, and health status.
- Adaptive Capacity: Accessibility to healthcare, cool places, and social connectedness.

Outputs from the approach

The outputs are provided as a set of maps showing the degree of heat-health risk in local communities and the different components that contribute to the overall risk and is based on the distribution of population.

The heat-health risk indicators and indices are developed into a series of maps to help assess how risk varies socially and spatially across Australia. Three versions of the maps were created with different spatial resolutions in SA1, SA2 and on the Australian Population Grid 2022.

The overall HHRI value provides the ranking of places from low to high risk. The composite heat health index is based on exposure index, social vulnerability index, and adaptive capacity index. Areas are ordered from lowest to highest values within Australia, and divided into 5 equal sized groups that are easy to interpret. A lower value indicates that an area is relatively at less risk compared to an area with a higher value.

The output of the HHRI analysis for Merri-bek is provided below (Figure 4). It should be noted that the HHRI map is produced using the HHRI ArcGIS Map Viewer so the classification of areas into quintiles is based on the national data set, rather than being specific to individual the Merri-bek LGA. This is illustrated in Figure 4, where areas outside the Merri-bek LGA boundary are masked to emphasise the data within the LGA.

The implication is that there may not be an even distribution of spatial units into quintiles within the Merri-bek LGA, which reduces the spatial variability and potentially obscures differences in vulnerability to some extent. However, the raw HHRI data set is available as an ArcGIS Feature Service, which can be downloaded and used to further analyse the outputs in a GIS to create quintile maps for specific areas (such as the Merri-bek LGA).

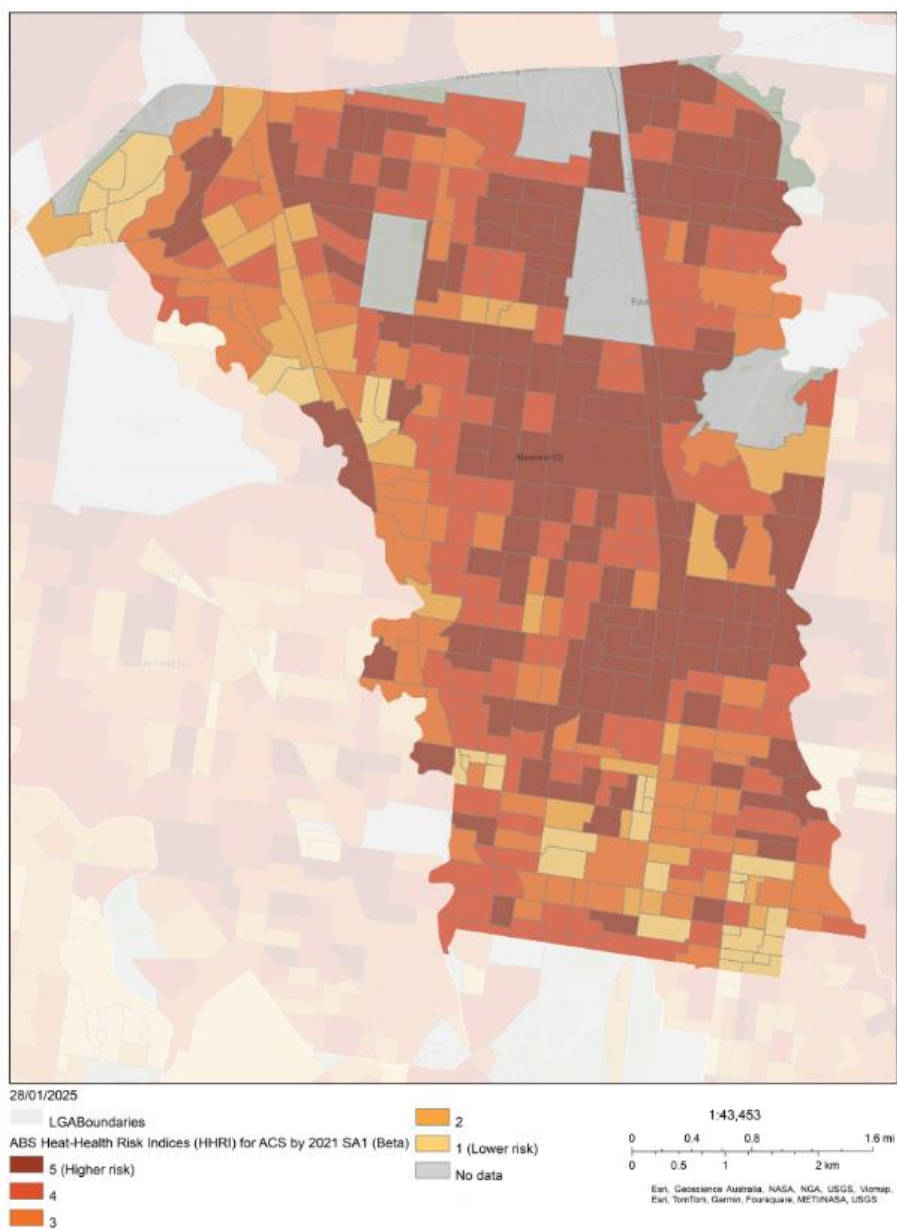


Figure 4. HHRI at SA1 scale mapped for the Merri-bek LGA

2.3 Cooling and Greening Melbourne

Description of the approach

The Cooling and Greening Melbourne Interactive Map was developed by the Victorian Government's Department of Transport and Planning as part of the Plan Melbourne 2017-2050 Implementation Plan. Specifically, it supports Action 91, which commits to a whole-of-government approach to cooling and greening Melbourne. The data for the tool was prepared collaboratively by RMIT University, CSIRO, and the Clean Air and Urban Landscapes (CAUL) Hub as part of the National Environmental Science Program.

The tool brings together 2014 and 2018 vegetation, urban heat, and heat vulnerability data covering Melbourne's urban areas. The vegetation cover data set also includes a layer comparing the change in vegetation between 2014 and 2018.

Outputs from the approach

The tool allows users to download and print maps with selected data layers and export data in formats like CSV, XLSX, or Shapefiles for further analysis. HVI data is processed at SA1 due to the integration of demographic and socio-economic data processed by the ABS at this level. Although, the change in vegetation cover and heat exposure data is available in mesh block scale. The HVI rating is determined by three components:

- Heat exposure
- Sensitivity to heat due to land cover, population density and age
- Adaptive capacity, for example, socioeconomic advantage or disadvantage.

This data is then integrated by summing the scores of the three vulnerability components and dividing the statistical areas into quintiles with a ranking of 1 – 5 (low to high vulnerability).

An example output of heat vulnerability index and change in vegetation cover from 2014 to 2018. Is shown below (Figure 5).

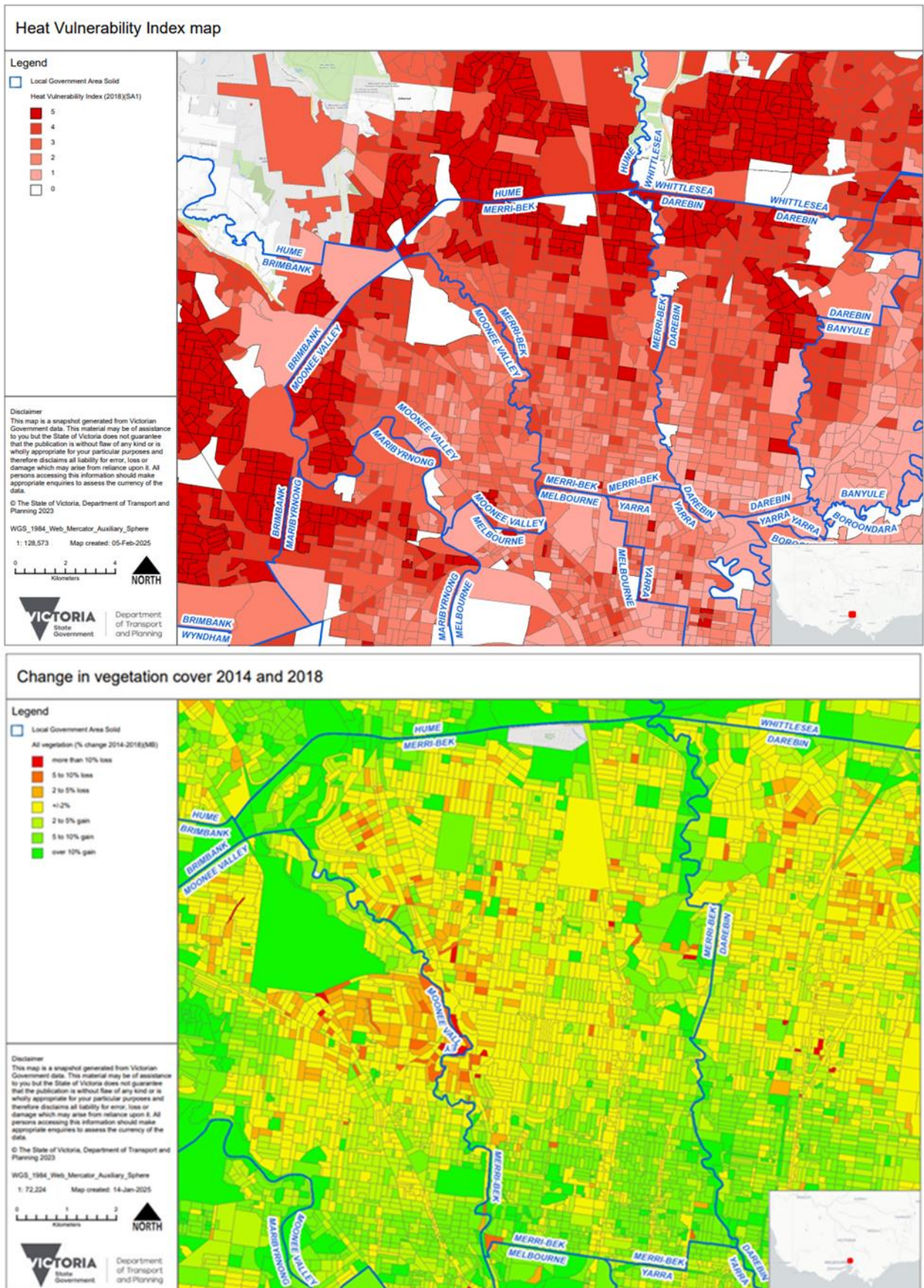


Figure 5. Sample output of a HVI map at SA1 scale and change in vegetation cover map produced using the Greening and Cooling Melbourne map at Mesh Block scale.

3 Results of assessment

The three approaches assessed in this study all provide spatially explicit estimates of the heat-health vulnerability of communities for the Merri-bek LGA. In this section the benefits and limitations of each approach are explored, building on the detailed descriptions of the approaches elsewhere in this report.

The data inputs used in calculating heat health vulnerability by each approach are summarised on the following page (Figure 6). A detailed assessment of each approach against the criteria is then presented (Table 4). The implications of the varying approaches for Council are discussed further in Section 4.

iHVI		HHRI		Cooling and Greening Melbourne	
Data inputs	Heat exposure	Mean Land Surface Temperature (LST)	Heat exposure	Heat exposure index - Average summer temperature - Bare ground - Dwelling type - Pre-1980 construction (%) - Outdoor workers (%)	
	Heat sensitivity	Mean NDBI (normalised difference built-up index)	Heat vulnerability	Housing condition - Social housing (%) - Renters (%) - Crowding(%) - Private renters (%)	Language and culture - First Nations (%) - New arrivals (%) - Low English language proficiency
		Mean NDVI (normalised difference vegetation index)		Health status Health status index based on the prevalence of chronic disease by type. (Asthma, Diabetes, Kidney disease, Mental health, Arthritis, Cancer, Dementia, Vascular and Heart disease)	
		Population density		Household composition - Age 4 years or less (%) - Living with a disability (%) - Singleparent households(%) - Livingalone (%) - Aged 65 years or more (%)	Socioeconomic status - Unemployed(%) - Low-income households (%) - Education year 10 or less (%)
		Percentage of aged 65+			
		Percentage of aged 4			
	Percentage of population need care				
Adaptive capacity	Education level	Adaptive capacity / Response diversity	Access to health services - Emergency department walk and drive times - Hospital walk and drive times - GP walk and drive times - Mental health walk and drive times - FirstNationals health centre walk and drive times - Pharmacy walk and drive times - Aged care walk and drive times		
	Income level		Access to cool places Composite cool place accessibility index based on access to parks, vegetation, water bodies, and air conditioned spaces.	Social connectedness Based on access to transportation, volunteerism, and movement into and out of are over last 1 and 5 years.	
				Heat exposure	Land Surface Temperature (LST)
				Heat vulnerability	Land cover- specifically, the presence of vegetation and roads
					Demographic data, including: - Population density - Age - people younger than 4 and older than 65 are more sensitive to heat related health complications - Persons in need of care
				Adaptive capacity / Response diversity	- Index of Relative Socio-Economic Disadvantage (IRSD) - Index of Education and Occupation (IEO)

Figure 6. Overview of data inputs and methods for each approach

Table 4. Results of the assessment of each approach

		iHVI		HHRI		Cooling and Greening Melbourne	
Criteria	Sub-criteria	Ranking	Description/details	Ranking	Description/details	Ranking	Description/details
Data currency	Recency	Medium	The iHVI tool uses Landsat 8, Sentinel-2, and MODIS satellite data to derive the LST to calculate the heat exposure index. Landsat 8 provides satellite image from 2013 to present, and MODIS satellite data provides LST from 2002 to present. The heat sensitivity index and the adaptive capacity Index which are two of the three components used for calculating the Heat Vulnerability Score is based on the ABS data source depending on the Census data from 2021.	Medium	Data is sourced from a wide variety of collections, both ABS and National Health Services Directory. The indices are constrained by the information available in the source data 2021 Census.	Low	The data used for vegetation layers and urban heat layers is from 2014 and 2018, which limits the tool's ability to reflect current conditions.
	How frequently will the data be updated	Medium	Satellite data is updated based on data acquisition cycles (Landsat 8 updates every 16 days). ABS Census data is updated every five years, which limits the update frequency for the socio-economic factors used in the tool.	Low	Data updates occur every five years, synchronised with ABS Census updates and other national data sets. There is no information publicly available on the policy for updates to the data sets.	Low	Updates are reliant on funding from the Victorian Government, with the date of any updates unknown at this stage.
Data accuracy	Level of detail	Medium	LST data through Landsat 8 is provided at 30 m spatial resolution and MODIS at 1000 m spatial resolution. NDBI and NDVI is also acquired at a finer 10 m spatial resolution. The heat vulnerability index outputs from the tool are provided at SA1 spatial scale.	Medium	The heat-health risk indicators and indices are available in a series of maps to help assess how risk varies socially and spatially across Australia. Three versions of the maps were created with different spatial resolutions in SA1, SA2 and on the Australian Population Grid 2022. The heat vulnerability index outputs from the tool are provided at SA1 spatial scale.	Medium	Vegetation data is derived from CSIRO's Urban Monitor with a 20 cm resolution, and urban heat data uses Landsat 8 thermal imagery with a 30 m resolution. The heat vulnerability index outputs from the tool are provided at SA1 spatial scale.
	Reliability / quality	High	Satellite derived and ABS data sources are reliable national (or international) programs.	High	The tool uses reliable national data sets from the ABS and other authoritative sources, ensuring a robust framework for assessing heat-health risks. Data values have been randomly adjusted or suppressed to avoid the release of confidential data. In some cases, small cells have been randomly altered to zero. Some data values have been converted from one geographical boundary to another in order align to SA1 boundaries.	Medium	While the tool uses trusted data sources and methodologies, the results are outdated and there is no stated update procedure/program. Unlike the HHRI and iHVI tools, it is not possible to disaggregate the components of sensitivity and adaptive capacity for more detailed analyses.
Feasibility and ease of use	Cost	High	The iHVI tool is hosted on GitHub, making it an open-source and freely accessible tool.	High	The HHRI tool is freely accessible through the ArcGIS Online Map Viewer.	High	The tool is freely accessible.
	Skills required	Medium	Successful implementation of the iHVI tool requires users to have a basic understanding of GIS software (e.g., QGIS, ArcGIS), raster and vector spatial data sets and Microsoft Excel to process and analyse outputs. Although the tool requires GIS knowledge, step-by-step documentation and examples on GitHub help	High	Basic to medium level familiarity with ArcGIS is recommended. Users with minimal GIS experience can navigate the tool's simpler features, while more advanced users can perform detailed analyses (LGA specific quintile classification).	High	Basic GIS skills and familiarity with spatial data interpretation are useful, but the Plan Melbourne web maps that use the data sets are user-friendly enough for minimal technical expertise.

			lower the learning curve for users with moderate technical expertise.				
	Integration	High	Outputs can be exported in various formats (e.g., CSV, XLSX, Shapefile) and saved locally for further analysis or integration with other data sets	High	The tool integrates with other ABS data sets available on the ArcGIS platform, offering scalability and adaptability for broader analyses.	High	Outputs can be exported in various formats (e.g., CSV, XLSX, Shapefile) and saved locally for further analysis or integration with other data sets.
	Availability of raw data	High	The tool supports exporting data in various formats such as CSV or shapefiles facilitating compatibility with other analytical platforms.	Medium	Very few of the data layers used in the HHRI tool are directly available for download. The raw data set is available as an ArcGIS Feature Service. This data set can be downloaded for offline use or exported into software like QGIS, which does not require a license. Additionally, GIS platforms such as QGIS, Python, or R can be used to generate LGA-specific quintile results.	High	Most of the data layers are available for direct download access.
	Repeatability	High	iHVI tool can access long-term satellite data, enabling historical analysis. It executes a well-defined, step-by-step process that can be replicated and repeated to produce readily comparable results by different analysts.	Medium	Though ABS data is updated every five years, it is contingent on the ACS to recalculate and upload the results of the analysis.	Low	The tool provides a consistent framework for monitoring greening and cooling over time, but updates depend on the availability of new data sets (there is no stated ongoing update program) and so, at this stage, does not support ongoing monitoring and change analysis.

4 Discussion

In this section a summary of the assessment for each approach (Table 5) and key considerations for Council are provided in Section 4.3.

Table 5. Summary of assessment

Criteria	iHVI		HHRI		Cooling and Greening Melbourne	
	Ranking	Rationale	Ranking	Rationale	Ranking	Rationale
Data currency	Medium	The tool relies on the latest ABS data for population and age data and SEIFA for socio-economic factors which is updated every five years. The most recent SEIFA data was released in April 2023, based on the 2021 Census.	Medium	The data is reasonably current, sourced from a wide variety of ABS and non-ABS collections. The most recent SEIFA data was released in April 2023, based on the 2021 Census.	Low	Data relies on older sources (2014 and 2018 for vegetation and urban heat layers), limiting the tool's ability to reflect current conditions. Updates are infrequent and depend on outdated data sets.
Data accuracy	Medium	The iHVI tool uses reliable data sources, including LST data from Landsat 8 (30 m resolution), MODIS (1000 m resolution), and finer-resolution NDBI and NDVI data (10 m resolution). Both satellite-derived data and ABS data ensure high accuracy, supporting robust analysis. A number of the data inputs are only available at SA1 scale, limiting the spatial resolution of the HVI mapping output to that scale.	Medium	Very high quality and detailed data on social aspects of vulnerability, but more limited in consideration of urban greening. Data values are adjusted or suppressed to maintain confidentiality and converted for geographical alignment. Reliable data sets from ABS and authoritative sources are used.	Medium	High-resolution data (20 cm for vegetation and 30 m for urban heat) derived from trusted sources like CSIRO and Landsat 8. However, some limitations exist in methodology robustness for assessing adaptive capacity and heat sensitivity. A number of the data inputs are only available at SA1 scale, limiting the spatial resolution of the HVI mapping output to that scale.
Feasibility and ease of use	High	The tool is freely available and can easily be run by GIS analysts or other staff in Council with moderate technical knowledge. Outputs can be easily combined with other data sets	Medium	The HHRI tool is freely accessible, requires basic to moderate GIS skills, integrates well with ABS data sets, and supports repeatable assessments every five years. However, not all raw data is available to download.	Medium	Open-source and freely accessible, with basic GIS skills required. Outputs can be exported for integration, but repeatability is limited by the reliance on infrequently updated data sets.

4.1 Summary of assessment

Key aspects of the assessment are provided below for each approach.

iHVI

- The tool is based on research by Melbourne-based academics, but not widely published or used by other Councils (at least in the public domain)
- Uses the highest available resolution data for LST (Landsat 8)
- Uses authoritative ABS data for socio-economic inputs (which are subject to the five year timing of the Census)
- Approaches uses less (and less detailed socio-economic) data inputs than the HHRI tool, which means the HVI relies on the smaller number of social inputs to be a surrogate for the level and spatial distribution of other social factors that influence vulnerability to heat. Conversely, it means that social factors are not over-represented in the approach potentially leading towards a skew in the results.
- Relatively low resolution representation of urban greening (NDVI) compared to Cooling and Greening Melbourne, which makes it less useful for urban forest and urban greening applications (but it is clear where the data come from and that they are regularly updated)
- Provides a mechanism for users to download input data sets for use in other applications
- Open source and freely available and can be updated when new socio-economic data are released over time
- Requires some level of technical expertise to apply the tool, extract outputs and create engaging maps of HVI
- Outputs can be combined with other data sets (e.g. Victorian Government or Council data) as required to create richer more relevant data sets

HHRI

- The tool has been developed by a partnership of leading national agencies, so is considered highly authoritative
- Allows comparison and benchmarking with LGAs or other areas across Melbourne and Australia.
- Uses authoritative ABS data for socio-economic inputs
- More (and more detailed) data sets relating to social factors contributing to heat vulnerability (e.g. considers single parent households, people living with a disability, and new arrivals). As described above, the additional inputs on social factors allows the HHRI approach to be more tailored to Council's programs around aged care and social disadvantage.
- Considers some factors around dwelling type and age that are not considered in the other approaches
- Lack of clarity about the data and methods used to represent urban greening, so less informative for urban forest and urban greening applications
- Open source, freely available and easy to use tool
- Require GIS skills to download and combine outputs from the tool with other data sets

- HHRI is described as a pilot program and there is no clarity if and when it will be updated. Not feasible for Council to undertake its own updates due to the somewhat black box nature of the tool and difficulty in accessing some of the input data sets.

Cooling and Greening Melbourne

- The tool developed by (some of) the RMIT University researchers responsible for the iHVI, so it shares some common elements in terms of data inputs and methods
- Uses the highest available resolution data for LST (Landsat 8)
- Uses very high resolution vegetation cover data from the CSIRO Urban Monitor program, but the data were collected nearly ten years ago and will accurately reflect the current state of urban vegetation
- Uses authoritative ABS data for socio-economic inputs, but the data are drawn from the 2016 Census so are not the latest.
- Open source, freely available and easy to use tool
- Requires some level of technical expertise to apply the tool, extract outputs and create engaging maps of HVI
- Outputs can be combined with other data sets (e.g. Victorian Government or Council data) as required to create richer more relevant data set

4.2 Conclusions

The iHVI approach provides the best combination of recent data inputs and user flexibility, but has fewer social inputs than the HHRI approach and lower resolution greening inputs than the Cooling and Greening Melbourne approach. Council can re-run the analysis at any point in time as new data sets become available. It can be used to inform urban greening and other physical cooling interventions, although the measure of greening used in the approach (NDVI) is not as high resolution as other urban greening data sets available in the market, and it is measure of greenness, rather than tree canopy. The iHVI tool provides a method for ingesting and viewing up-to-date LST and remotely sensed data. As a bespoke method, results from the iHVI tool cannot easily be used to compare Merri-bek to other Councils who have not applied the tool and made the results available.

The HHRI provides the most detailed and nuanced representation of the social factors influencing heat vulnerability, and is well suited to understanding where heat vulnerability relating to a wider range of social factors is located in Merri-bek. The outputs cannot be updated by the user, so there is a risk that the data will not be updated, preventing Council from understanding longitudinal changes (in demographics or greening). The input data sets used to characterise greening are also not easily available or assessed, so the HHRI is not as directly applicable to urban forest and urban greening prioritisation in its own right.

The Cooling and Greening Melbourne platform is based around the same broach approach as the iHVI tool, but uses higher resolution greening data, and is available for the entire metropolitan Melbourne area, which allows comparison and benchmarking across metropolitan regions and LGAs. The core disadvantage is that the data are outdated and there is no public commitment from the Victorian Government to refresh or update the analysis and mapping.

HVI maps are provided below (Figure 7) derived from three different approaches: iHVI, HHRI and Greening and Cooling Melbourne. The most recent data available for iHVI and HHRI maps corresponds to 2021, whereas the data for Greening and Cooling Melbourne is from 2018.

All three approaches use quintiles to categorise HVI scores, ranging from the highest to the lowest in five levels. The comparable spatial data from iHVI and HHRI both based on 2021 data are evidently different in their categorisation. These variations are due to the differences in the approach and sub-indices used to assess the adaptive capacity and heat exposure. For instance, in the northeast area to the right of the Sydney Road. iHVI map classifies the location as having a medium to high HVI, while the HHRI map identifies the same location as having a high HVI level of 5. This discrepancy is spatially noticeable when comparing the two maps side by side. It is important to consider the differences in the input data and sub-indices when selecting a tool for a particular purpose.

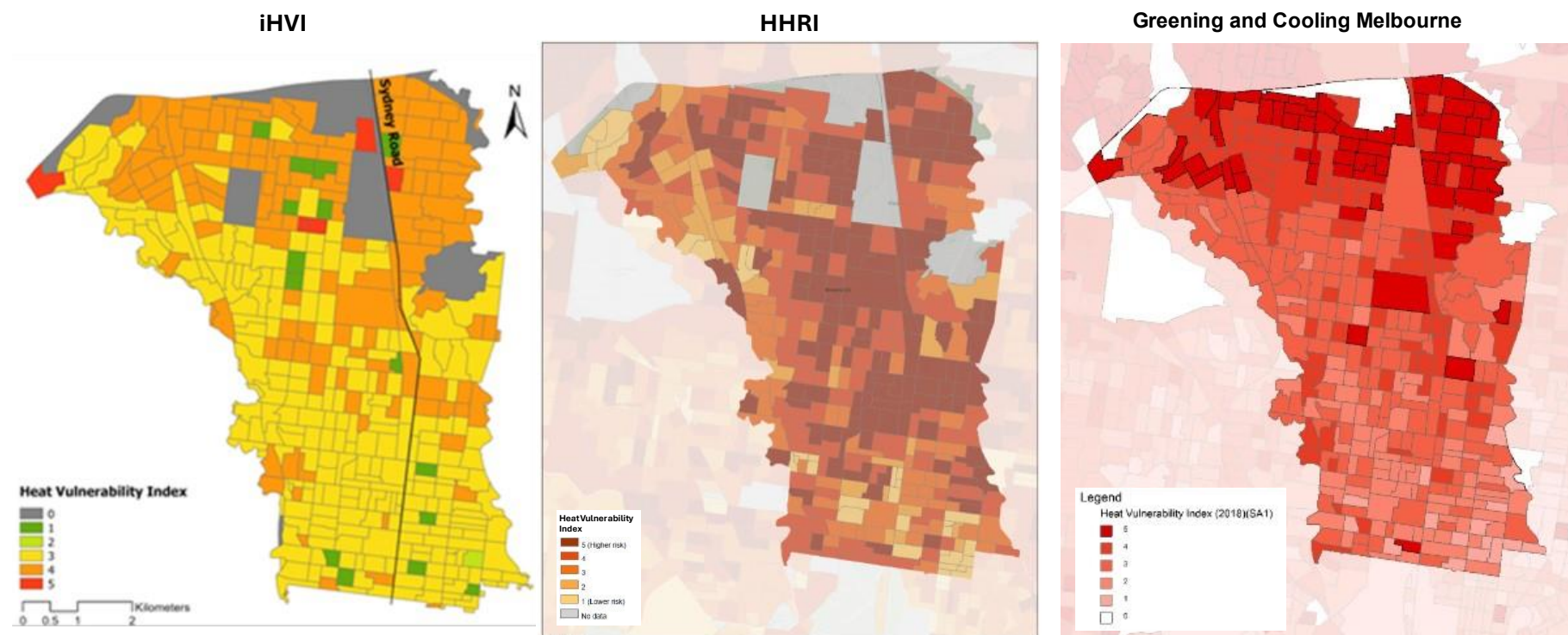


Figure 7. Heat vulnerability index map from iHVI (2021), HHRI (2021) and Greening and cooling Melbourne (2018) approaches

4.3 Considerations for nominated Council service areas

Council's Climate Risk Strategy¹¹ and Extreme Heat Sub-Plan of the Municipal Emergency Management Plan commit to significant action to address heat related risks, including through adaptation of community services. As part of this study, Council nominated three service areas to consider the application of the different approaches assessed in this study:

- **Early Years Services**
Promote awareness of the vulnerability of babies and children to extreme heat and the importance of helping children and young people to regulate their behaviour in extreme heat and develop appropriate responses during an extreme heat event.
- **Aged and community services**
Importance of preparing staff and clients for extreme heat events through updated guidelines, education, and communication. Staff are trained on the effects of heat, management strategies, and how to advise clients on keeping themselves and their homes cool.
- **Transport**
Recognising the critical role of transport systems in mitigating and adapting to heat-related risks. By integrating greening strategies, shade provision, and connections to activity centres enhances not only transport infrastructure but also the resilience of communities to extreme heat. Identifying and addressing gaps in transport infrastructure and vegetation cover is essential to create equitable and comfortable environments for all, particularly for vulnerable populations.

Table 6 outlines key priority areas of Council for urban heat mitigation efforts, highlighting the relevant data sets and corresponding considerations for each service area.

¹¹ Merri-bek City Council. (2022). Climate Risk Strategy.

Table 6. Considerations for application of heat vulnerability assessment approaches to specific service areas

Service area	Issues	Considerations
Early Years Services	• Heat exposure for people travelling to/from activities • Young people who are socially and economically disadvantaged • Potential for overcrowding in large households and negative impacts on children's health • Increase household stress, risk of family conflict and violence • Single parent families • Children with disabilities or health conditions • Temperature in babies' room • Families with language barriers • Families with transport barriers • Families with limited access to technology	All three approaches provide information on the young populations and socio-economic disadvantage. Although, HHRI provides more human-centric data sets to analyse adaptive capacity and heat sensitivity. HHRI uses data sets such as language barriers and housing conditions which is not used in iHVI and Greening and cooling Melbourne map
Aged and Community Services	• Public housing residents (hot housing) and homes that are not sufficiently cooled • Those without access to private transport. • Those lacking mobility to get out and about. • Those who are very isolated. • People with cognitive or psychosocial issues.	HHRI tool is more useful in assessing vulnerability of aged and community services with data sets on housing condition, health status, language and culture, socio-economic status, access to cool places, social connectedness and access to health services. The iHVI and Cooling and Greening Melbourne map only provides data on age, socio-economic status and health status. The iHVI may be useful for planning for older people in residential aged care or retirement communities as the areas in the highest risk quintiles correlate to locations of those facilities. However, it can be argued that older people living in their own homes in the community are potentially more isolated and vulnerable. Hence, the HHRI may be useful for planning for older people outside aged care and retirement living.

Transport	• Tree canopy coverage along major transport corridors and pedestrian routes. • Locations of existing green infrastructure, such as parks and vegetated buffers. • Opportunities for increasing urban greening in transport corridors. • Proximity and accessibility of transport routes to key activity centres (e.g., schools, healthcare facilities, shopping precincts). • Areas lacking shade along pedestrian and bike routes. • Data on pedestrian and cycling activities. • Heat maps identifying urban heat islands in transport zones. • Spatial analysis of vegetation cover versus impervious surface areas. • Areas with limited transport options or connectivity.	iHVI tool provides high resolution spatial data for assessing heat exposure and vegetation cover along transport corridors, helping identify areas that lacks shade or greening. Cooling and Greening Melbourne Map is also helpful to analyse change in vegetation cover from 2014 to 2018 at mesh block scale. Although it lacks to provide more recent data on the vegetation cover and urban heat data.
------------------	--	---



Appendix A: Data inputs and sources

Data inputs and sources used in the iHVI tool

An overview of the data inputs used in the iHVI tool is provided below (Table 7). For each index the indicators, and the rationale for their inclusions in the iHVI analysis, and detail on the indicators and the data sets used to calculate them is provided.

Table 7. iHVI tool data inputs

Index	Indicators	Availability of data	Description	Data source
Heat exposure	Mean Land Surface Temperature (LST)	Yes	Provides an exposure indicator of urban heat island effect and heat vulnerability	Satellite remote sensing platforms with thermal band (e.g. MODIS, Landsat 8, Sentinel 3)
Heat sensitivity	Mean normalised difference built-up index (NDBI)	Yes	NDBI is an index that highlights urban areas where there is typically a higher reflectance in the shortwave-infrared (SWIR) region compared to the near infrared (NIR) region. NDBI value lies between -1 to +1, where negative values of NDBI typically represent water bodies and areas of vegetation, whereas higher values represent built up areas	iGEE web tool www.gisonmeta.com
	Mean normalised difference vegetation index (NDVI)	Yes	NDVI is an effective index for quantifying green vegetation, where it normalises green leaf scattering in near Infra-red wavelengths with chlorophyll absorption in red wavelengths. The value range of the NDVI is -1 to 1, where negative values of NDVI (values approaching -1) correspond to water and values close to zero (-0.1 to 0.1) generally correspond to barren areas of rock,	iGEE web tool www.gisonmeta.com

			sand, or snow; low, positive values represent shrub and grassland (approximately 0.2 to 0.4), while high values indicate temperate and tropical rainforests (values approaching 1)	
	Population density	Yes	Prevents the generation of spatial biases induced by very large/small Census tracts. High number corresponding with a high sensitivity score, as denser of population are more sensitive to health complications.	ABS Census 2021
	Percentage of aged 65+	Yes	with high number corresponding with a high sensitivity score, as elderly people are more sensitive to heat related health complications.	
	Percentage of aged 4-	Yes	with high number corresponding with a high sensitivity score, as school kids are more sensitive to heat related health complications.	
	Percentage of population need care	Yes	with high number corresponding with a high sensitivity score, as more persons needing care indicating more sensitive to heat related health complications.	
Adaptive capability	Education level	Yes	as populations with higher education are more accessible for resources to respond to heat.	Socio-Economic Index for Areas (SEIFA), Index of Education and Occupation (IEO)
	Income level	Yes	as populations with higher income are more accessible for resources to respond to heat.	SEIFA: Index of Relative Socio-Economic Disadvantage (IRSD)

Data inputs and sources used in the HHRI

The data inputs for the HHRI approach are described in the table below (Table 8).

Table 8. HHRI approach data inputs

Risk components	Themes	Availability of data	Local area indicators	Data source
Exposure	Heat exposure index	The data set is accessible as an ArcGIS Feature Service, which allows it to be copied and saved in an offline format for further use.	• Average summer temperature • Bare ground • Dwelling type • Pre-1980 construction (%) • Outdoor workers (%)	National Climate Risk Assessment Stage 0 Pilot Project: Heatwaves and Human Health - 2023
Vulnerability	Socioeconomic status		• Unemployed (%) • Low-income households (%) • Education year 10 or less (%)	ABS data, 2021
	Household composition		• Age 4 years or less (%) • Living with a disability (%) • Single parent households (%) • Living alone (%) • Aged 65 years or more (%)	
	Language and culture		• First Nations (%) • New arrivals (%) • Low English language	
	Housing condition		• Social housing (%) • Renters (%) • Crowding (%) • Private renters (%)	
	Health status		Health status index based on the prevalence of chronic disease by type. (Asthma, Diabetes, Kidney disease, Mental health, Arthritis, Cancer, Dementia, Vascular and Heart disease)	
Adaptive capacity / Response diversity	Access to health services		• Emergency department walk and drive times • Hospital walks and drive times • GP walk and drive times • Mental health walk and drive times • First Nationals health centre walk and drive times • Pharmacy walk and drive times • Aged care walk and drive times	National Health Services Directory
	Access to cool places		Composite cool place accessibility index based on access to parks, vegetation, water bodies, and air-conditioned spaces.	National Climate Risk Assessment Stage 0 Pilot Project: Heatwaves and Human Health - 2023
	Social connectedness		Based on access to transportation, volunteerism, and movement into and out of area over last 1 and five years.	

Data inputs and sources used in the Greening and Cooling Melbourne

An overview of the data inputs used in the Greening and Cooling Melbourne map is provided below (Table 9)

Table 9. Cooling and Greening Melbourne data inputs

Risk components	Indicators	Availability of data	Description	Data source
Vegetation layers	Change in vegetation cover between 2014 and 2018	Yes	Vegetation cover data layers show the percentage of each boundary area (local government area, suburb and Mesh Block) that is covered by vegetation – limited to urban areas only. Vegetation cover is grouped into five height classes: • grass (0-0.5m) • shrub (0.5-3m) • small tree (3-10m) • medium tree (10-15m) • large tree (15m+)	CSIRO's Urban Monitor provides a three-dimensional spatial representation of vegetation at 20 cm resolution. It uses stereo photogrammetry to compare the height of identified vegetation through a digital surface model, relative to a ground elevation model, and estimates vegetation height. Images were captured in summer 2014 and summer 2018.
Urban heat layers	Heat data in 2014 and 2018	Yes	The 2014 and 2018 urban heat data layers show how many degrees Celsius the average temperature within urban parts of each boundary area is above or below the non-urban baseline. Boundary areas for the urban heat data layers are local government area, suburb, and Mesh Block. The urban heat island (UHI) is a measure of the deviation of urban temperatures relative to a non-urban baseline. Native vegetated sites were used to establish the baseline. The data provides a two-dimensional representation of UHI across Melbourne at 30-meter resolution landscape.	LST data is based on Landsat 8 thermal infrared data collected by the United States Geological Survey (USGS). The data provides a two-dimensional representation of UHI across Melbourne at 30-meter resolution landscape.
Heat vulnerability index		Yes	The 2014 and 2018 HVI data layers show the HVI rating at local government area, suburb and SA1 scales. This data was integrated by: • summing the scores from the 3 vulnerability components below • dividing the statistical areas into quintiles	

			attributing the statistical areas with a heat vulnerability rating: 1 = low vulnerability, 5 = high vulnerability.	
	Heat exposure	No	In the absence of a dense network of meteorological stations to measure air temperature, satellite thermal infrared imagery has been used to estimate LST. This is the indicator used to measure heat exposure within the HVI.	LST data based on Landsat 8
	Sensitivity to heat	No	Heat sensitivity is calculated using both demographic data and indicators that determine the extent to which heat is retained in urban environments: - land cover – specifically, the presence of vegetation and roads - demographic data, including: - population density - age – people younger than 4 and older than 65 are more sensitive to heat related health complications - persons in need of care	ABS data, 2016
	Adaptive capacity	No	2 types of socio-economic indexes for areas (SEIFA) were used as the adaptive capacity indicators: - Index of Relative Socio-Economic Disadvantage (IRSD) - Index of Education and Occupation (IEO) Less advantaged populations have fewer resources to respond and adapt to heat.	SEIFA