CRC for
Water Sensitive Cities

Estimating the economic benefits of Urban Heat Island mitigation – Economic Analysis

Final Report (Work Package 6)
Kym Whiteoak and Jess Saigar

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1   Introduction

This report documents the application of a benefit estimation methodology for the estimation of economic values produced by urban heat island (UHI) mitigation in a new suburban development through urban greening and integrated water management (IWM). It presents the results of a case study application of the methodology in the west of Melbourne[1], Australia, building on biophysical and climate modelling undertaken for the assessment.   The biophysical modelling, upon which this economic valuation methodology is based, is documented in a CRCWSC companion report *Estimating the Economic Benefits of Urban Heat Island Mitigation – Biophysical Aspects.*

2   Assessment methodology

The assessment methodology used for this project is an economic framework for benefit estimation that draws from standard cost-benefit analysis (CBA).   CBA is used in public policy decision-making to explore the quantitative merits of an investment, policy or program, compared to the costs of its implementation.   In application, CBA considers benefits and costs of an intervention over an assessment period (typically 20-50 years for public policy investments).

This methodological approach is used in this study to explore the economic benefits of UHI mitigation.   There is a significant gap in evidence of the quantified benefits of UHI mitigation that can be produced from urban greening and IWM programmes.   This study seeks to add evidence to this gap by quantifying the economic benefits of UHI mitigation under different greening scenarios, applied to a specific case study area. Importantly, the purpose of the study is to demonstrate the application of a methodology for benefit estimation – it is not a cost-benefit analysis.   However, the results can be used in a CBA as one of multiple benefits produced from an urban greening or integrated water management (IWM) investment.

It is well recognised[2] that urban greening and IWM investments produce multiple benefits across the water cycle, often including savings to the potable and wastewater systems, improvements to waterway health, aesthetic and amenity benefits (often identified in property price increases), physical and mental health improvement to local residents from use of green space, and increased biodiversity.   These benefits can often be measured in economic terms, and can be compared to a project's costs to establish whether the greening investment can be justified in economic terms, as per Figure 1.

In Figure 1, the capital and operating costs (in red) add to total costs for an illustrative greening project (in this illustrative example, to a total of '$400,000' in present value[3] terms).   After this, a range of quantified benefits of the project are estimated (in blue), starting in the illustration at the total cost point, and adding upwards back toward the starting point (zero).   If these combined benefits exceed the total cost, the project is justified in economic terms and an economic case for implementation can be made.

In this illustration, the last benefit is UHI mitigation (represented in the illustration in green, to distinguish it from other benefits).   It is often asserted that urban greening and IWM projects will produce a cooling effect in urban and suburban areas, due to tree canopy shade and increased soil moisture reducing the UHI effect.   In turn, this cooling effect should produce benefits that are measurable in economic terms, such as reduced mortality and morbidity caused by extreme heat, reduced electricity use from residential and commercial cooling, and other benefits such as work productivity and community comfort.

However, to date there has been little detailed analysis that seeks to model and estimate the climatic changes that increased urban greening will produce in specific case study areas.   Equally, there is a dearth of analysis of the economic value of this cooling, across the different aspects of the cooling benefit (including health, electricity use, productivity etc).

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[1] The approximate coordinate of the location is -37.580060, 144.735870. Note that the development plan features and characteristics were solely hypothetical and developed for use in this academic simulation exercise only.

[2]   See, for example: Sharma, A., Gardner, T., & Begbie, D. (eds) (2018). *Approaches to Water Sensitive Urban Design, 1st Edition, Potential, Design, Ecological Health, Urban Greening, Economics, Policies, and Community Perceptions.* Elsevier.

[3]   That is, total project costs over the analysis period (say, 20 years), discounted to present day using a discount rate for future costs.
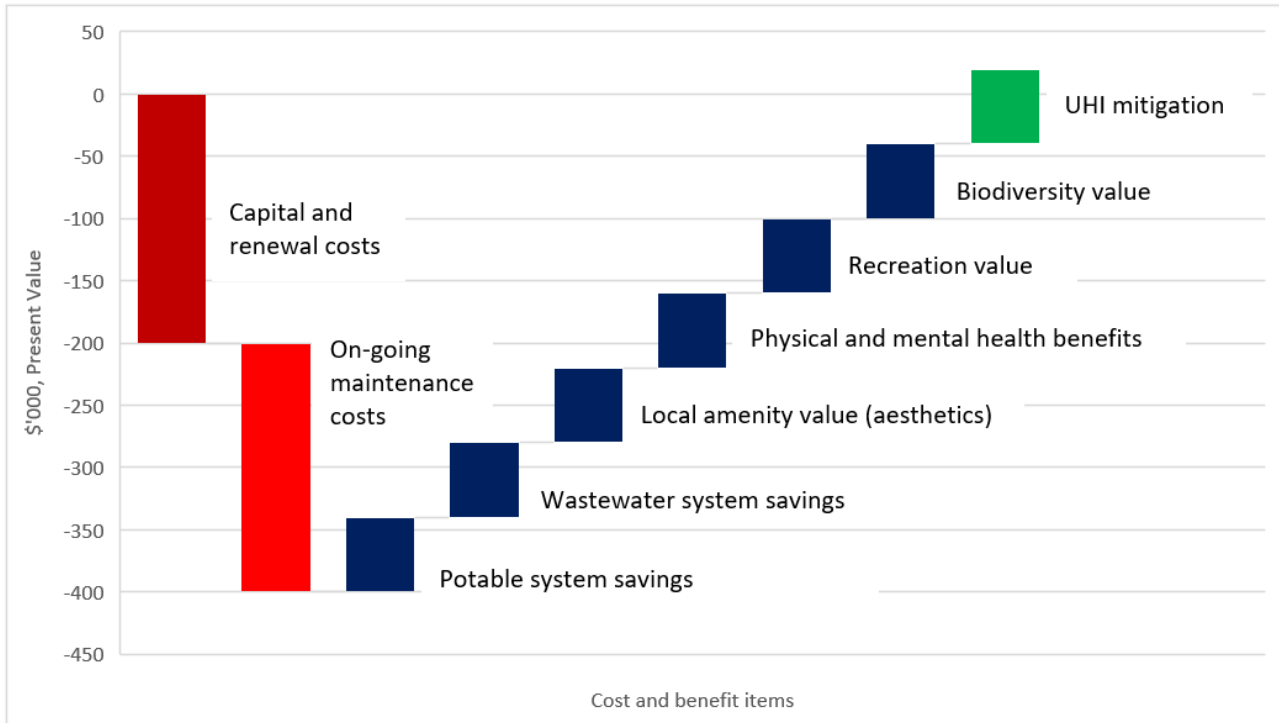
Figure 1: Illustrative example of costs (in red) and benefits (blue, and green for UHI mitigation) produced by a hypothetical urban greening or IWM investment[4]

This study was designed to add to the evidence base of UHI mitigation benefit estimation, by defining the economic framework for UHI mitigation benefits, and then estimating that benefit for a case study area in Melbourne with hypothetical development features. In so doing, it is an approach to defining a methodological approach to benefit estimation, and a quantitative estimate of the UHI mitigation benefit that might be produced by urban greening and IWM projects. These results could then be combined with many other benefits of urban greening and IWM illustrated in the figure above, when exploring the full costs and benefits of an intervention.

2.1 Scenarios

In the context of this assessment, the project team is focused on an estimation of the benefits of UHI mitigation under different broad scenarios that reflect public policy settings that would produce different scales of greening and IWM investment. As the case study area explored in this study is located in Victoria, we define four hypothetical scenarios that broadly align with IWM/greening policy settings in the Victorian context, ranging from no specific settings that would produce additional greening (Scenario 1) through to the highest plausible settings for IWM/greening (Scenario 4):

Scenario 1: No IWM regulation. This scenario considered a greenfield suburban development if no policy settings were imposed that relate to urban greening or integrated water management (IWM).

Scenario 2: Current IWM policy settings. This scenario reflects the current Victorian policy settings that influence green infrastructure and IWM in a new greenfields development. For example, in Victoria all new residential houses are required to include either a rainwater tank or solar hot water (with around 30 per cent selecting rainwater tanks). Also, current Best Practice Environmental Management (BPEM) standards for stormwater quality management are required, resulting in constructed wetlands or other measures to treat stormwater quality within the development.[5]

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4   Source: Adapted from Pickering, P. (2013). *Economic Viability of Recycled Water Schemes*. Australian Water Recycling Centre of Excellence
5   https://www.epa.vic.gov.au/business-and-industry/guidelines/water-guidance/urban-stormwater-bpemg (accessed 20/02/2019)

Scenario 3: Potential future IWM policy settings. This scenario reflects a potential higher set of requirements related to green infrastructure and IWM, namely rainwater tanks on all dwellings and higher BPEM standards (including a 60% flow volume reduction target) leading to larger green infrastructure investments to treat excess stormwater.[6]

Scenario 4: Targeted UHI mitigation scenario. This scenario reflects a greenfield development area if all that was practically feasible was being implemented in relation to green infrastructure. This means more and larger street trees with passive irrigation, full irrigation of public open space and residential gardens.

Please see the accompanying report "*Estimating the economic benefits of Urban Heat Island mitigation - Biophysical Aspects*" for details on the biophysical outputs of each setting.

2.2 Assessment steps

Following scenario definition, the study undertook the following steps, focused on the case study area in Melbourne:

1. Biophysical modelling of the case study area for each scenario, including soil moisture, tree canopy area and size of water bodies.
2. Climate modelling of the case study area for each scenario, using the biophysical modelling outputs, producing daily minimum and maximum temperatures across the four scenarios for three representative summers in the historical record:

    i.   1986-87 (cool summer)

    ii. 1971-72 (average summer)

    iii. 2008-09 (hot summer)

    Summers are defined as extending from December 1st to February 28th (or 29th in the case of 1971-72). The climate modelling considered each day of these representative summers, with the real temperature data as the baseline reflecting Scenario 2 (current settings). These daily minimum and maximum temperatures were then remodelled for scenarios 1, 3, and 4 to consider how much they would change under the different biophysical conditions of those scenarios. Results are reproduced in Appendix 1.
3. Economic modelling of the four scenarios (described herein).

The economic modelling drew from economic and scientific literature to identify a range of costs linking extreme heat and economic outcomes. Costs were attributed to different temperatures drawing from this literature, and the different daily temperatures between scenarios drove the calculation of marginal costs or benefits between scenarios. Where a scenario produced daily temperature reductions compared to Scenario 2 (which reflects current conditions), the reduction in heat-related cost reflects a benefit of that scenario.

As such, the 'avoided cost' method was largely used to estimate benefits.

2.3 Discounted cash flow model

These results were then used as inputs into a discounted cash flow (DCF) model reflecting the development of the case study area over a 50 year time period. A 50 year time period was chosen to reflect the long time period over which this type of benefit may occur.

Selection of an appropriate social discount rate for public projects is a controversial topic without consensus, with many alternative options (opportunity cost of capital, private and social time preference). A real discount rate of 5 per cent was selected for this analysis, broadly reflecting the opportunity cost of capital, with sensitivities tested at 3 and 8 per cent.

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[6] This scenario was developed in discussion with staff from the Victorian Department of Environment, Land, Water and Planning (DELWP). It is not a formal policy position, but reflects current thinking on where future policy may go.

Drawing from a real case study in the west of Melbourne, the analysis considered the benefits that would be produced in the case study as it develops over this time period under the hypothetical development scenarios.

The new urban development is expected to populate progressively over 32 years from 2019, with a total number of dwellings of 11,800 (population 33,000) within two Precinct Structure Plans. The suburb population stabilises thereafter.

2.4 Consideration of climate change

Considering a 50 year time period allows for the consideration of climate change, which is expected to produce notable impacts on minimum and maximum temperatures over the coming decades. Climate change was not actively considered in the climate modelling, but the impacts on temperature were considered within the economic analysis using the following steps:

1) Consider latest projections for temperature in the case study area over the assessment time period, for 'average' and 'high' emissions scenarios
2) Estimate the mix of cool, average and hot years per decade based on this data
3) Allocate this mix of cool, average and hot years across the 50 year time series.

Temperature projections for the region, including Melbourne, have been sourced from www.climatechangeinaustralia.gov.au and for the average emissions scenario are reproduced in Figure 2. The blue line represents actual data from the historical record, the red a simulation for one selected model, and the grey bars represent the 10th and 90th percentile range.

Figure 2: Forecast average change in daily summer temperatures (degrees Celsius), Southern Slopes region, average emissions scenario[7]

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[7] Source: https://www.climatechangeinaustralia.gov.au/en/climate-projections/explore-data/time-series-explorer/ Note: Grey band (or plume): the range of model results is summarised using the median (central grey line) and 10th to 90th percentile range of the projected change in all available CMIP5 simulations. Blue line: the historic simulation from the one selected model (note that it is possible to select the historic AWAP data to display). Red line: the future simulation from the one selected model.
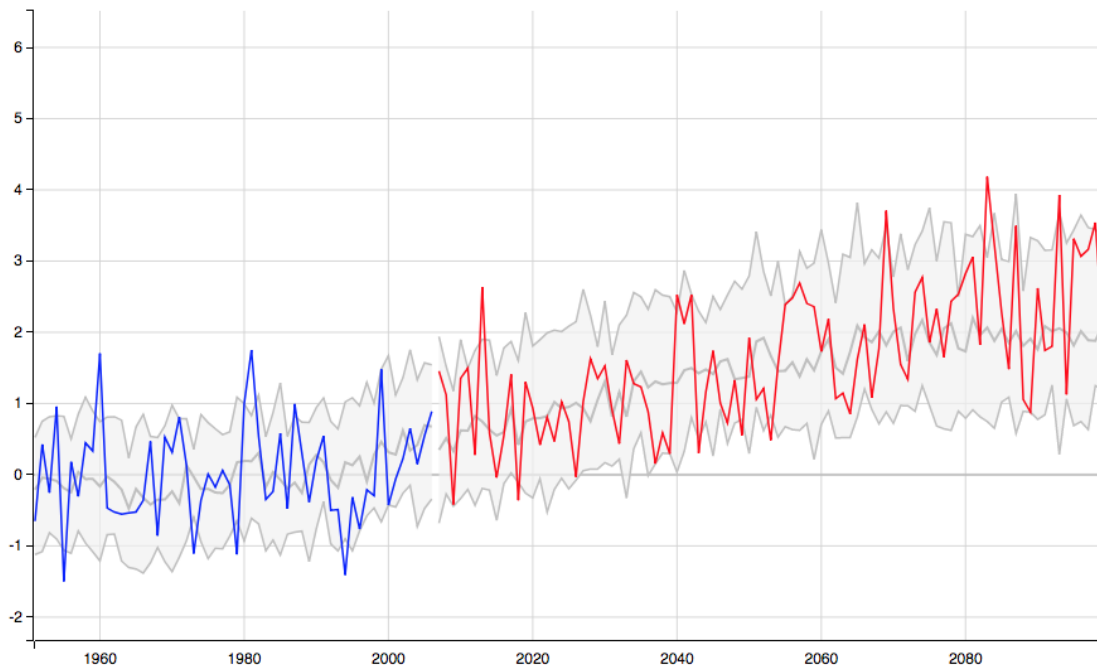
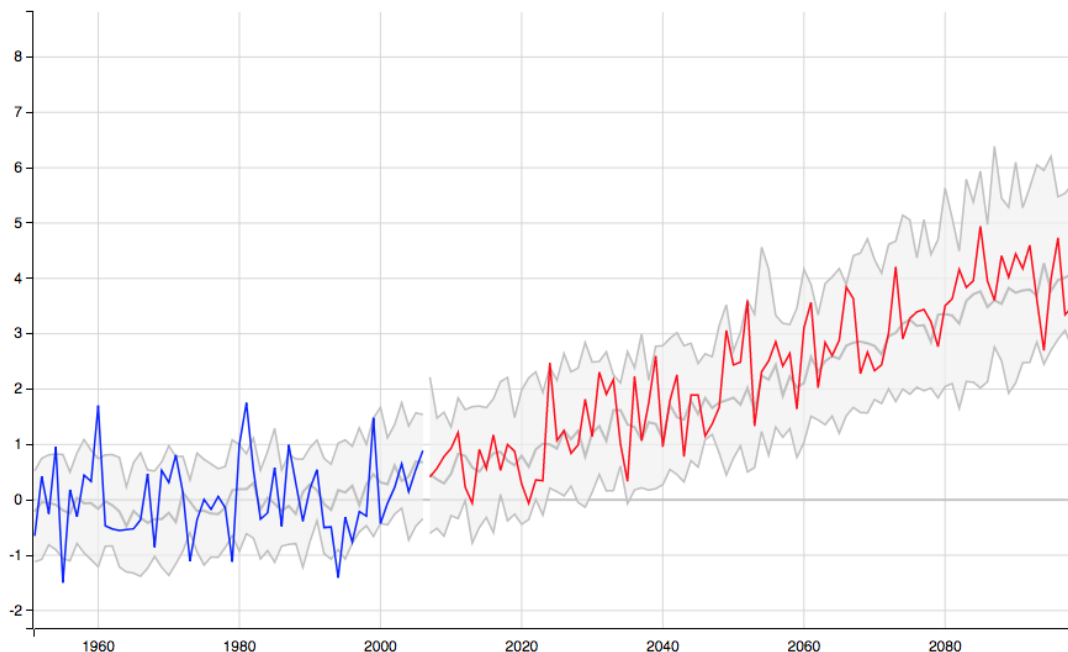The high emissions scenario outputs are reproduced in Figure 3.

Figure 3: Forecast average change in daily summer temperatures (degrees Celsius), Southern Slopes region, high emissions scenario[8]

As can be seen in both scenarios, the proportion of 'cool' years (extending down toward -1 on Figures 2 and 3) declines rapidly, and the proportion of 'hot' years similarly increases rapidly. Indeed, hot years quickly extend beyond those reported since 1950, under both average and high emissions scenarios.

From this data, the number of cool, average and hot summers by decade were estimated.

Table 1: Number of cool, average and hot years by decade, average and high emissions scenarios

REPRESENTATIVE YEAR	COOL		AVERAGE		HOT	
Emissions scenario	Avg	High	Avg	High	Avg	High
2019-2028	2	0	3	3	5	7
2029-2038	1	0	3	2	6	8
2039-2048	0	0	3	2	7	8
2049-2058	0	0	2	1	8	9
2059-2068	0	0	0	0	10	10

As can be seen in Table 1, both average and high emissions climate scenarios quickly gravitate to a majority of hot years per decade. This is due to the temperature projections rapidly exceeding any recent historical

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8 Source: https://www.climatechangeinaustralia.gov.au/en/climate-projections/explore-data/time-series-explorer/ Note: Grey band (or plume): the range of model results is summarised using the median (central grey line) and 10th to 90th percentile range of the projected change in all available CMIP5 simulations. Blue line: the historic simulation from the one selected model (note that it is possible to select the historic AWAP data to display). Red line: the future simulation from the one selected model.

precedent. This suggests that the analysis is conservative and that additional work might be considered to develop data for 'very hot' and 'extremely hot' years, which this analysis cannot consider.

These years are then spread across the 50 year time series for use in the discounted cash flow analysis.

3 Benefit identification and valuation estimates

A broad range of literature that explores the costs and benefits of extreme heat in urban and residential settings was reviewed for potential use in this analysis. Literature was filtered for contextual relevance, transferability to the Melbourne context, timing, and risk of double-counting with other potential values. Studies were selected for benefit transfer that were undertaken in the Australian and preferably Melbourne context within the past decade, and that were considered relevant to the potential changes that urban greening would produce, including impact on:

- Mortality
- Morbidity
- Work productivity, and
- Residential electricity use.

We discuss these in turn.

3.1 Mortality

There are several papers in the international literature exploring the relationship between extreme heat and avoidable loss of life, and it appears to be generally accepted in this literature that beyond certain temperature thresholds there is an increase in avoidable deaths within an urban population.

It is logical that both the threshold temperatures as well as the subsequent relationship between temperature and mortality will differ by location, for a number of reasons. People living in Darwin may respond physiologically in a different way to a 31°C day than might a resident of Melbourne or Hobart. Additionally, residential building styles will differ by location, partly in response to climate, producing different effects on human health.

As such, the project team sought evidence on the relationship between heat and human health in the Melbourne context.

Nicholls *et al* (2008)[9] explored the relationship in Melbourne between overnight minimum temperatures, daily maximum temperatures, daily mean temperatures (average of today's maximum and tonight's overnight minimum) and mortality data for those aged 65 and over, using data from 1979 to 2001.

The strongest relationship was found linking mean temperatures and mortality, and minimum temperatures and mortality. Daily maximums had a weaker relationship, which the authors hypothesised may be due to

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[9]   Nicholls, N., Loughnan, M., Tapper, N. 2008. A simple heat alert system for Melbourne, Australia. Int J Biometeorol (2008) 52:375–384

sudden cool changes which dramatically reduce maximum temperatures in Melbourne, perhaps reducing mortality effects.

Mean temperatures were used, with estimates of mortality for daily mean temperatures drawing on the source data from Nicholls *et al* (2008) which shows that mortality increases beyond a mean daily temperature of 21.7°C.

The cost of avoidable mortality used in the analysis is based upon:

- the value of a statistical life, drawn from the Commonwealth Office of Best Practice Regulation and indexed to 2018 using CPI ($4.532m)[10];
- average life expectancy of those aged 64 is 79.1, a difference of 15.1 years[11];
- the value of a statistical life year is estimated at $191k (based on the above two data points), indexed to 2018 using CPI;
- therefore, using a 5 per cent discount rate, the present value cost of an avoidable death for someone aged over 64 is $1.984m

There is a broad range of values in the literature for the value of a statistical life (VSL), reflecting country and methodological differences.[12] The United States Department of Transportation recommended the use of US$9.6m in 2016[13], compared to the Commonwealth Office of Best Practice Regulation estimate of $4.5m (indexed to 2018). We double the value estimated above to test it for sensitivity.

3.1.1 Avoided mortality cost by scenario

The value of an avoidable death as estimated above is modelled across the four scenarios for the daily mean temperatures for each representative year, with differences compared to Scenario 2 (the status quo under current regulatory settings) to identify the cost savings that additional greening produces due to lower temperatures and therefore lower mortality costs. Results are presented in Table 2, which shows annual[14] mortality reduction benefits for each scenario, for a cool, average and hot summer period.

Interestingly, Scenario 1 (no IWM Regulation) has a small cost saving compared to Scenario 2 – this is due to the margin of error in the climate modelling. There is essentially no temperature difference between Scenario 1 and Scenario 2. This essentially demonstrates that the current regulation associated with IWM in Victoria does not produce a meaningful UHI mitigation effect. This is expected – current IWM regulation is designed to encourage alternative water supplies (e.g. rainwater tanks) or strip stormwater of key pollutants before entering waterways (e.g. constructed wetlands) – it is not designed to produce a UHI mitigation effect.

This logic holds for Scenario 3 (the 'next stage' of IWM regulation), which essentially entails rainwater tanks on more dwellings (100% compared to the 30% estimated in Scenario 2) and larger constructed wetlands to treat stormwater pollution. As can be seen in Table 2, the mortality effect of introducing these higher standards are best described as small but significant: around $500k mortality savings per year per 100,000 population.

Table 2: Mortality cost differences compared to Scenario 2, per representative summer, per 100,000 population

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10 Department of Prime Minister and Cabinet (2015). Value of Statistical Life, Office of Best Practice Regulation
11 https://www.aihw.gov.au/reports/life-expectancy-death/deaths-in-australia/contents/life-expectancy
12 https://www.oecd.org/env/tools-evaluation/env-value-statistical-life.htm
13 https://www.transportation.gov/sites/dot.gov/files/docs/2016%20Revised%20Value%20of%20a%20Statistical%20Life%20Guidance.pdf
14 Technically, per summer rather than per year.

	NO IWM REGULATION (S1-S2)	CURRENT IWM REGULATION (S2)	FUTURE IWM REGULATION (S3-S2)	MAXIMUM UHI MITIGATION (S4-S2)
Average	-$109,876	$0	-$421,565	-$1,254,768
Cool	-$117,264	$0	-$272,571	-$729,957
Hot	-$151,264	$0	-$514,795	-$1,552,779

As can be seen in Table 2, Scenario 4 produces the largest marginal reduction in mortality costs compared to Scenario 2. This is to be expected, as it is the only scenario in which the settings have been designed specifically to produce a UHI mitigation effect. The mortality reduction benefit is higher in a hot year than in a cool or average year, again an expected result as mortality increases with heat.

3.2 Morbidity

Morbidity refers to ill health, not resulting in death. Extreme heat can cause ill health, especially in the most vulnerable members of the community, who may then require the use of ambulance and hospital services. Morbidity costs of extreme heat are measured by the costs of ambulance and hospital services that receive higher demand during periods of extreme heat.

An ideal data set to measure morbidity effects of extreme heat would be similar to that used for the mortality estimate described above: time series information with ambulance and hospitalisation data that can be matched with daily temperature data to estimate a statistical relationship. Unfortunately, such a dataset could not be identified for Melbourne. However, a study by AECOM (2011) reported an increase in morbidity estimates for Melbourne associated with daily maximum temperature above 30 degrees Celsius, as per Table 3. This source data is used to estimate changed morbidity cost for the different scenarios.

Table 3: Morbidity effects and costs of extreme heat, Melbourne[15]

MORBIDITY EFFECTS	INCIDENCE	UNIT	COST PER USE[16]
Ambulance attendance - heat related	0.09	Per 100,000 persons per 1°C above 30	$1,204
Transported to hospital	80%	Assumed treated in Emergency Department	
ED Presentations, aged 64-74 years	0.52	Per 100,000 persons per 1°C above 30	
ED Presentations, aged 74+ years	3.82	Per 100,000 persons per 1°C above 30	$4,876

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15 Source: AECOM, 2011. Economic Assessment of the Urban Heat Island Effect. Note: ED = Emergency Department
16 Source: Department of Health (2017), Ambulance Fee Schedule 2017-18, http://www.health.vic.gov.au/ambulance/fees.htm, retrieved 13 Dec 2017

3.2.1 Avoided morbidity cost by scenario

The cost per morbidity effects (ambulance attendance and visit to emergency department) are provided in Table 34, drawn from the Victorian Department of Health and updated for CPI. These inputs are modelled with daily summer temperature data to produce total costs per 100,000 population for each representative summer over the four scenarios.

Table 4: Total morbidity costs per scenario and representative summer, per 100,000 population, Melbourne

	NO IWM REGULATION (S1-S2)	CURRENT IWM REGULATION (S2)	FUTURE IWM REGULATION (S3-S2)	MAXIMUM UHI MITIGATION (S4-S2)
Average	$0.80m	$0.84m	$0.72m	$0.51m
Cool	$1.25m	$1.26m	$1.19m	$1.04m
Hot	$2.53m	$2.56m	$2.45m	$2.23m

Marginal cost differences between each scenario and Scenario 2 were then created, as summarised in Table 5. These were then used in the discounted cash flow analysis, the results of which are presented in the next section.

Table 5: Morbidity cost differences compared to Scenario 2, per representative summer, per 100,000 population, Melbourne

	NO IWM REGULATION (S1-S2)	CURRENT IWM REGULATION (S2)	FUTURE IWM REGULATION (S3-S2)	MAXIMUM UHI MITIGATION (S4-S2)
Average	-$40,447	$0	-$126,675	-$335,923
Cool	-$14,052	$0	-$72,836	-$225,518
Hot	-$21,512	$0	-$110,767	-$323,971

3.3 Work productivity benefits

Extreme heat can have a variety of impacts on population productivity. For example, Park[17] explored the impact of daytime temperatures on educational performance over the short and long term in the USA, finding significant negative impacts of extreme heat. Comparable studies on this topic were not identified in Australia.

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[17] Park, Jisung. *Hot Temperature and High Stakes Exams: Evidence from New York City Public Schools (Job Market Paper).* Unpublished Manuscript, Harvard University Economics Department, Submitted. https://pdfs.semanticscholar.org/0a27/102e886ddeb88d08c5fc2662ba9a0f6703fc.pdf

Assessment of the impact of extreme heat on work productivity has been explored, however usually in specific contexts (such as mining, manufacturing[18] and construction sectors[19] of different countries), or cross-country comparison using average temperatures and national production[20].

Despite growing evidence of the link between overnight temperatures, sleep and work productivity[21], very few studies in the international literature appear to have been undertaken which quantitatively assess this relationship and its associated economic costs.

Regardless, international studies can be considered poor opportunities for benefit transfer in this context because too many local contextual factors would limit the accuracy of any benefit-transfer estimate. For example, differences in residential building materials and local climatic conditions would limit the relevance of a study from, say, Hamburg, on the impact of heat in Brisbane.

One study[22] undertaken in the Australian context surveyed respondents in all capital cities, asking them whether they had experienced hot days in the previous two months, and whether it had affected their work productivity, and by how much. The study was undertaken in May and October of 2014, and repeated in the same months in 2017. Along with a range of other questions (heat-related questions were added to a broader survey), respondents were asked:

- How many days in the preceding two months had they lost productivity due to heat?
- What was the percentage reduction in productivity that this caused?

The project team for this project was provided with the original data set for the above study, for further analysis. The subset of respondents from Victoria was extracted from the data set, producing 673 responses of which 265 reported productivity loss in the previous two months. The following analysis and manipulation was undertaken:

- Each respondent's self-identified postcode was matched to the nearest Melbourne weather station[23]
- Respondents in post codes that were more than 15km from the nearest Melbourne weather station were discarded
- Maximum temperature data for the relevant weather station was matched to each respondent
- Self-reported number of days affected by heat were matched to the days with the highest maximum temperatures of the previous two months
- Average productivity loss across the full sample was calculated for each daily temperature, starting from 25°C
- A trend line was estimated across the data to give average productivity losses per worker for each temperature registered, from 25°C to 36°C

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18 For example, see: Cai, Xiqian *et al*. 2018. *The Impact of Temperature on Manufacturing Worker Productivity: Evidence from Personnel Data*, in the Journal of Comparative Economics, vol 46, issue 4, December 2018 pp889-905
19 Al-Bourathan et al. 2019. *Assessment of Heat Stress Exposure among Construction Workers in the Hot Desert Climate of Saudi Arabia*, in Annals of Work Exposures and Health, Volume 63, Issue 5, June 2019, pp505–520
20 Such as: Heal, G *et al*. Labor Productivity and Temperature. https://geoffreyheal.files.wordpress.com/2017/09/yale_paper_draft_august_25.pdf (accessed 10 August 2018)
21 For example, see: Zheng, G. et al. 2019. *The Effects of High-Temperature Weather on Human Sleep Quality and Appetite*, in Int J Environ Res Public Health. 2019 Jan; 16(2): 270. Also, see: Hillman, D. *et al*. 2018. The economic cost of inadequate sleep. In Sleep. 2018 Aug 1;41(8)
22 Zander, K., Botzen, W, Oppermann, E., Kjellstrom, T., Garnett, S., 2015. Heat stress causes substantial labour productivity loss in Australia.
23 Melbourne (Olympic Park), Melbourne Airport, Avalon Airport, Latrobe University, Cerberus, Coldstream, Cranbourne, Botanic Gardens, Essendon Airport, Fawkner Beacon, Ferny Creek, Frankston AWS, Geelong Racecourse, Laverton RAAF, Moorabbin Airport, Phillip Island Penguin Reserve, Rhyll, Scoresby Research Institute, Sheoaks, Viewbank

- While the trend line could be extrapolated out to 42°C, no primary data was gathered beyond 36°C and the maximum benefit is capped at 25°C from this temperature (given that the survey was undertaken in May and October, no data was gathered for days hotter than 36°C).

The impact on worker productivity of daily maximum temperatures is provided in Figure 4, starting on 0.6 per cent per worker at 25°C, and extending to 25 per cent per worker for a 36°C day.
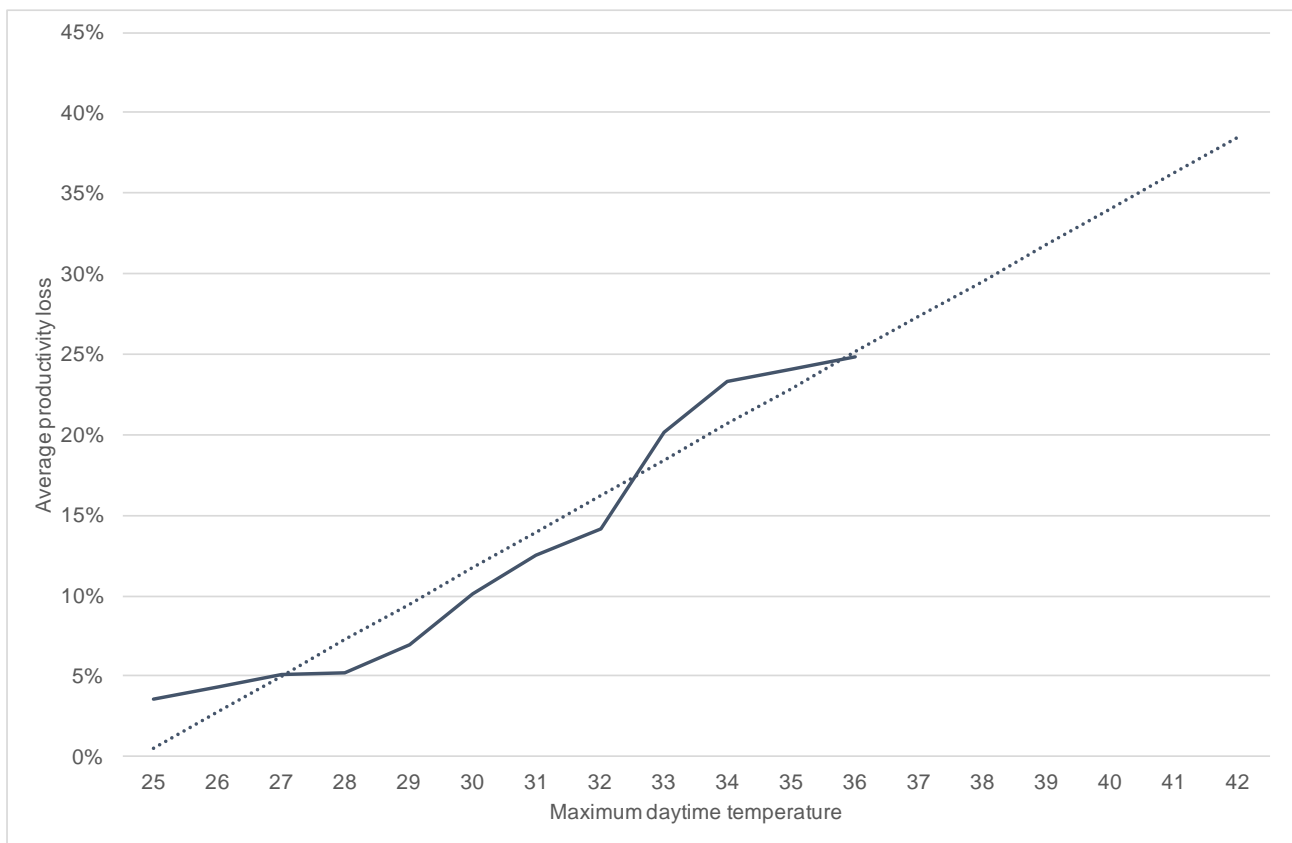

Figure 4: Estimated relationship between maximum daily temperature and average productivity loss

3.3.1 Avoided productivity cost by scenario

This percentage loss of productivity per worker was then applied to the jobs within the new development. Importantly, the survey data does not reveal whether respondents were affected by overnight temperatures which impacted sleep and next day productivity (regardless of where they worked), or by daytime maximum temperature which would affect those who work in unairconditioned environments. As such, we target only those jobs that would be located within the development itself, considering only impacts caused by daytime maximum temperatures.

This is undertaken in the following way:

- Council estimates that there will be 4,484 jobs located within the development, spread across retail, commercial, industry, commerce and home-based business

- We assume these jobs will develop broadly in line with the overall population development (over 32 years)
- We further assume that only a proportion of jobs will be affected by daytime maximums, either because some will be in air-conditioning or are otherwise unaffected by daytime temperatures (such as evening jobs). In the absence of guidance on this matter, we conservatively assume 20 per cent of jobs are affected by daytime heat.

We apply productivity impacts to the median wage of the case study area ($707.7 per week, or $141.55 per day[24]) and apply real wage growth of 1 per cent per year in the discounted cash flow model[25].

We also apply a number of general assumptions to the analysis:

- The days reported by the respondents as affecting their productivity were the hottest days in the preceding two months[26]
- If a respondent reported productivity loss of a given day, they would experience the same productivity loss for a hotter day. For example, if a respondent reported a productivity loss of five per cent for one day in the previous two months, and we find that the hottest day in the preceding two months was 32°C, we assume they would experience a five per cent loss for every day that exceed 32°C.

There are several shortcomings and limitations to this analytical approach:

- The study was not undertaken in the peak of summer, so data on extreme heatwaves is lacking from the analysis
- The highest temperature day in the dataset is 36°C. It could be possible to extrapolate a straight line trend across the data set to 42°C, however it is possible that the response to higher temperatures is non-linear
- It is possible that people will gradually adjust and adapt their behaviour (working pattern) which has not been captured. The benefits are under the assumption of current working pattern
- We cannot distinguish between those affected by overnight heat on sleep (high overnight minimums), and those affected by heat during the day (daytime maximum).

Results of the analysis are provided in the below tables. Table 6 reports the total productivity costs per average worker by scenario for each representative year.

Table 6: Total productivity costs per representative summer period, per worker, Melbourne

	NO IWM REGULATION (S1)	CURRENT IWM REGULATION (S2)	FUTURE IWM REGULATION (S3)	MAXIMUM UHI MITIGATION (S4)
Average	$724	$724	$682	$600
Cool	$580	$580	$554	$498
Hot	$868	$868	$832	$764

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[24] Source: ABS (accessed 14 August 2018), and adjusted for inflation
[25] Source: https://static.treasury.gov.au/uploads/sites/1/2017/11/p2017-t237966.pdf (accessed 14 August 2018) wage growth averaged 1% per year in the previous decade.
[26] It is possible that they were not working on the hottest days, and thus were referring to other, less hot days. Assuming the hottest days is therefore a conservative assumption.

Table 7 shows the marginal productivity costs per average worker per representative summer, compared to Scenario 2 (the status quo).

Table 7: Marginal productivity cost differences compared to Scenario 2, per representative summer, per worker, Melbourne

	NO IWM REGULATION (S1-S2)	CURRENT IWM REGULATION (S2)	FUTURE IWM REGULATION (S3-S2)	MAXIMUM UHI MITIGATION (S4-S2)
Average	$0	$0	-$42	-$124
Cool	$0	$0	-$26	-$82
Hot	$0	$0	-$36	-$104

Interestingly, despite higher total costs during hot years, average years produce greater cooling between Scenario 2 and Scenario 4. This is because the cooling effect of green infrastructure is less pronounced at higher temperatures than it is milder temperatures, combined with the 'cap' of production losses at 36°C.

3.4 Electricity use

One of the often-cited benefits of UHI-mitigation is the potential savings to electricity use associated with cooling a community's living and working spaces during hot periods. As greening reduces maximum temperatures, it is logical to expect that cooling costs will decline.

Electricity savings can occur in two main ways:

- Reductions in volumetric use of electricity associated with cooling that produce direct savings to users in their bills
- Reductions in electricity use across a large geographic area that lead to reductions in the scale of distribution infrastructure needed to service an area or region.

It is also possible that temperature reductions across a region might reduce the number of faults that might occur along that distribution infrastructure. In the context of this analysis, it is unlikely that the scale of electricity use reductions over around 12,000 properties will produce significant savings to distribution infrastructure, nor to faults along that distribution network. As such, we focus on the volumetric savings to residents.

For this, it is useful to consider a few contextual matters:

- As the case study area is a greenfields site, it can be expected that the homes are built to current standards of insulation and energy efficiency
- We expect that, while green infrastructure is likely to reduce summer maximum temperatures, winter temperatures will remain largely unaffected
- We consider the standard home being built in the case study area, namely a three-bedroom, two-bathroom brick home with air conditioning and roof insulation
- We consider savings via a flat tariff of $0.28/kWh.

3.4.1   Avoided electricity cost by scenario

It was beyond the project scope to model the daily electricity use of each scenario across the three representative years. However, an order-of-magnitude scale of the electricity savings value produced from summer temperature declines was estimated through modelling, which showed the effects on household electricity use of an average two-degree reduction in summer temperatures.[27]

The modelling analysed electricity use of the properties with the same characteristics in two climate zones, with differences in summer temperatures of around 2°C. For this, Melbourne Tullamarine and Ballarat were selected, with Ballarat's average daily maximum summer temperatures roughly 2°C lower than Tullamarine's (see Figure 5 and Figure 6).

Modelling was undertaken with two options: living-room only air conditioning, and the larger central ducted air conditioning for the entire house. This analysis produced the following differences across the three summer months:

- Living-room only air conditioning savings: $43/house/summer
- Central ducted air conditioning savings: $65/house/summer.

We assume the higher energy central ducted air conditioning option for subsequent analysis, as this is judged to be more likely for new dwellings.
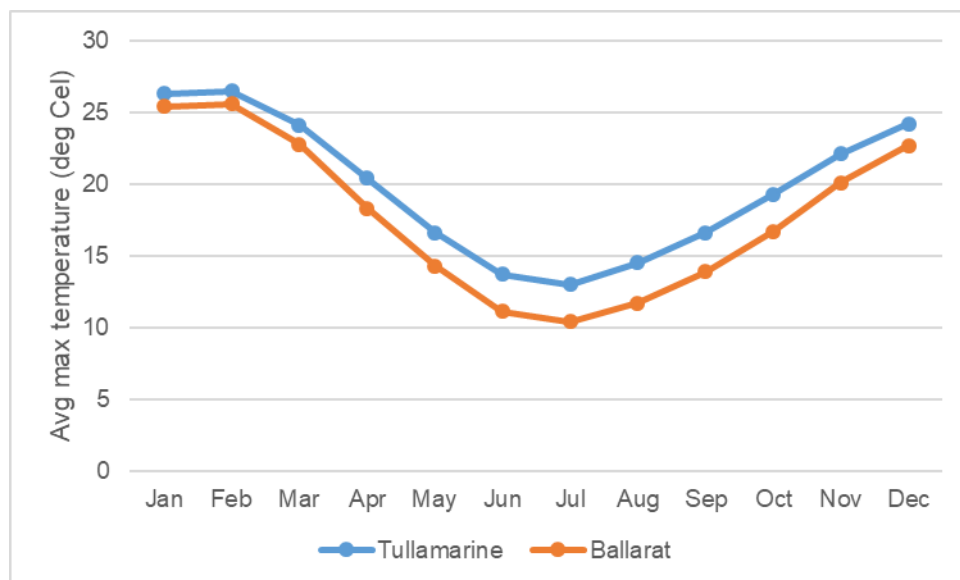

Figure 5: Average maximum daily temperature, Tullamarine and Ballarat Victoria[28]

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[27]   This modelling was undertaken for the project team by subcontractor Ecologic.
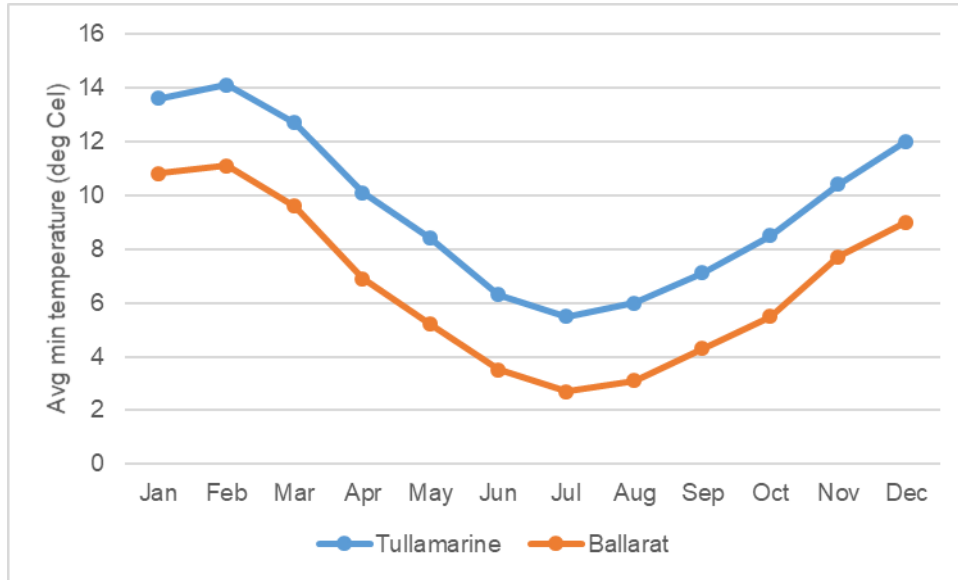[28]   Source: Bureau of Meteorology

Figure 6: Average minimum daily temperature, Tullamarine and Ballarat Victoria[29]

We scale the above electricity saving proportionately to the extent of temperature reduction produced in the average year for each scenario[30]. As can be seen in Table 8, Scenario 1 has a negligible difference compared with Scenario 2, however Scenario 3 produces an average daily maximum temperature reduction of 0.34°C, and Scenario 4 produces an average daily maximum temperature reduction of 1.15°C, compared to Scenario 2. Scaling these to the electricity savings value of a 2°C cooling produces annual cost savings per household per year as presented in the table. Scenario 4 produces a household saving for a centrally ducted air conditioned house of just over $37 per year, or almost $25 per year for a household with living-room air conditioning only.

Table 8: Average temperature reduction per scenario, by type of year

	COOL	AVERAGE	HOT	AVERAGE SUMMER	SAVING/HH/ YEAR (DUCTED AC)	SAVING/HH/ YEAR (LIVING ROOM AC)
No IWM Regulation (S1-S2)	-0.01	-0.01	-0.01	-0.01	-$0.47	-$0.31
Future IWM Regulation (S3-S2)	-0.35	-0.34	-0.34	-0.34	-$11.06	-$7.32
Maximum UHI mitigation (S4-S2)	-1.19	-1.14	-1.11	-1.15	-$37.27	-$24.65

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29 Source: Bureau of Meteorology
30 For example, if a 2°C reduction in temperatures is valued at $65, then a 1°C reduction is valued at half this amount ($32.50)

4 Analysis results

The outputs provided in the previous section were used in a discounted cash flow (DCF) analysis over a 50 year time period, using a real discount rate of 5 per cent. We present the results per household and for the case study area.

4.1 Results per household

A discounted cash flow analysis was undertaken over 50 years using a 5 per cent discount rate to estimate the economic value of UHI mitigation of the different scenarios on a per household basis. Results using an average emissions scenario, are summarised in Table 9 and show negligible economic value produced from Scenario 1 (no IWM Regulation), the results of which are essentially driven by the margin of error in the climate modelling.

Table 9: Household marginal economic benefit (present value) per scenario compared to Scenario 2 (status quo), 5% real discount rate (average emissions scenario)

	NO IWM REGULATION (S1-S2)	FUTURE IWM REGULATION (S3-S2)	MAXIMUM UHI MITIGATION (S4-S2)
Mortality	$67	$228	$681
Morbidity	$0	$0	$0
Productivity	$0	$61	$179
Electricity	$9	$202	$680
Total	**$76**	**$492**	**$1,541**

Moving from current regulatory settings to a higher standard of current regulations (from S2 to S4) produces an economic value of around $492 per household in present value terms. Moving from current regulatory settings to the maximum UHI mitigation settings (from S2 to S4) produces a present value benefit of $1,541 per household.

Considering the composition of these values, they are comprised largely of mortality benefits and electricity, at around 44 per cent of total benefit each for the maximum UHI mitigation settings. Productivity benefits are around 12 per cent of total benefits, and morbidity benefits are too small to register.

Table 10: Household marginal economic benefit per scenario compared to Scenario 2 (status quo), 5% real discount rate (high emissions scenario)

	NO IWM REGULATION (S1-S2)	FUTURE IWM REGULATION (S3-S2)	MAXIMUM UHI MITIGATION (S4-S2)
Mortality	$71	$245	$737
Morbidity	$0	$0	$0
Productivity	$0	$62	$181
Electricity	$9	$202	$680
Total	**$79**	**$509**	**$1,597**

As expected, considering a high emissions scenario increases the benefits compared to the status quo (Scenario 2), particularly for the maximum UHI mitigation scenario (S4). However, the increase in benefits under a high emissions scenario are not as high as might be expected, for a number of reasons:

- The mitigation effect of greening appears to reduce under higher temperatures, and the representative 'hot' year used in the analysis is characterised by several days of extremely hot weather.
- As discussed in Section 2, the modelling used representative summers from the historical record for cool, average and hot years. Climate forecasting over the next 50 years suggests future years will be significantly hotter than anything on the historical record, rendering this methodology conservative.
- The methodology used to estimate productivity benefits is 'capped' at 36 Celsius, for reasons of data integrity. As such, days with higher maximum temperatures than this do not register a change in benefit due to greening[31].
- The climate modelling used for the study was not able to consider different emissions scenarios.

As such, we expect that this methodology underestimates the impact of climate change on temperature mitigation from green infrastructure, and future research in this may improve on this work.

Again, the benefits are driven by mortality and electricity savings, comprising 90 per cent of benefit. Productivity benefits are essentially unchanged in a high emissions scenario compared to an average emissions scenario, for reasons described above[32]. See Table 10 for details.

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[31] This is an unavoidable shortcoming of the methodology, and something that could be improved upon in future work.
[32] Mortality benefits increase at higher temperatures, despite the decreasing cooling effectiveness of green infrastructure at higher temperatures, due to the non-linear effects of heat on mortality (that is, mortality effects grow disproportionately as temperature increases).
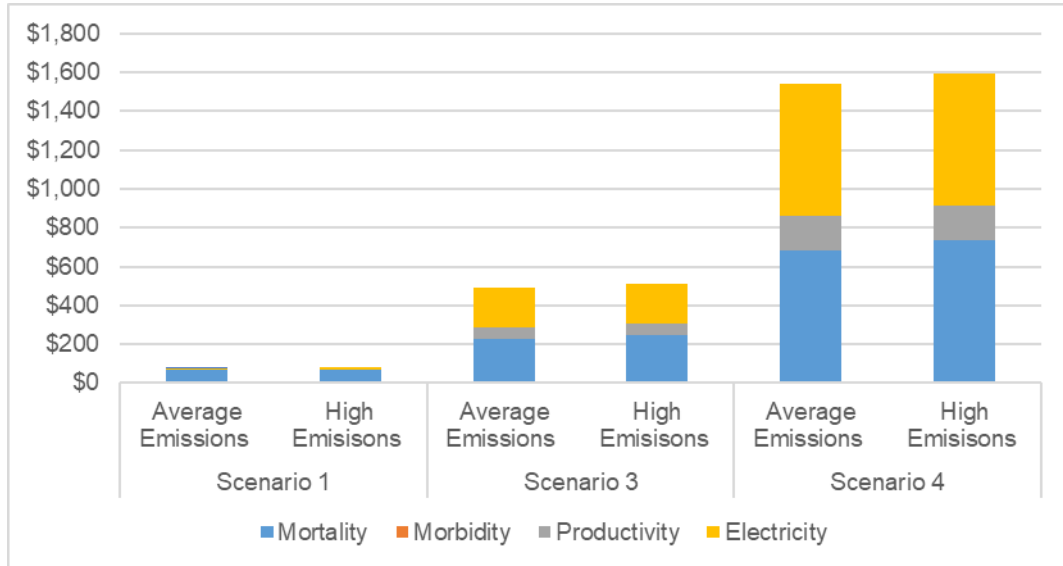
Figure 7: Results by benefit type, average and high emissions scenarios, $NPV/household

Figure 7 shows the present value results for households, illustrating the difference between average and high emissions for each scenario. The chart demonstrates the dominance of electricity and mortality on results[33].

4.2   Results for the case study area

The outputs provided in the previous section were used in a discounted cash flow (DCF) analysis over a 50 year time period in a greenfields case study area in the West of Melbourne under hypothetical scenarios. This is a real area that will develop progressively over a 32-year time period, starting in 2019 (as per Figure 8), with total households expected to number 11,800 and a population of 32,000.

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[33]   Productivity benefits are estimated to be higher in average years than hot years in the model. This is because the benefits underpinning productivity benefits is capped at 36 degrees Celsius due to data availability. In reality, this may understate the productivity benefits of hot years – we discuss the potential to improve on this data in Section 5.
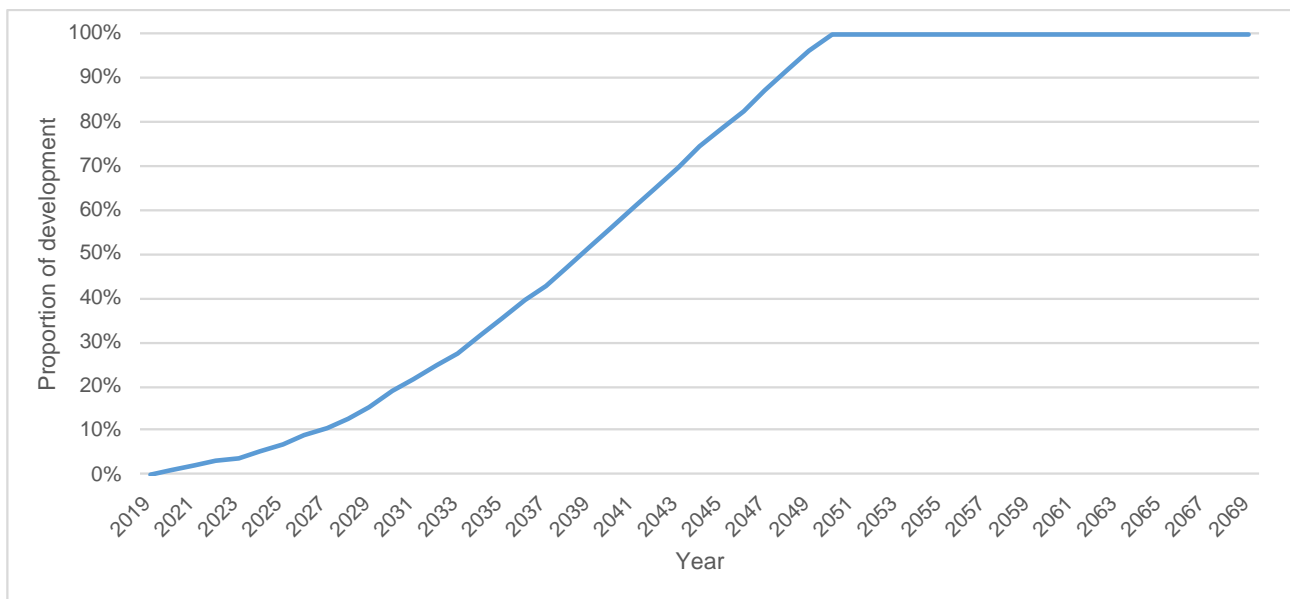
Figure 8: Case study area development schedule[34]

The key results for the case study area are provided in Table 11. All results are marginal to current settings (S2), which represents development of the case study area under status quo conditions.

The 'no IWM regulation' scenario (S1) produces benefits of around $350k compared to the status quo (S2), reflecting slightly lower temperature data for S1 than for S2 that was produced by the climate modelling. In reality, this result reflects the margin of error within the climate modelling and can be ignored. The key message from this part of the analysis is that the current settings influencing greening and IWM do not produce any meaningful temperature mitigation.

The 'future IWM scenario' (S3) produces present value benefits of $2.26m. This means that moving from the current regulatory settings for IWM to the higher standard in S3 would produce cooling benefits of $2.26m over 50 years. This is a significant benefit, however, given the likely scale of investment required to produce this outcome, it is likely to represent a relatively minor benefit compared to the additional cost of the Scenario 3 investment. As discussed in Section 2, it should be remembered that UHI mitigation is one of many different benefits that is produced by Integrated Water Management (IWM) investments related to urban greening. The same project could produce a range of other benefits such as savings to the potable and wastewater networks, waterway health improvement, and aesthetic benefits.

The Maximum UHI Mitigation scenario (S4) produces the largest benefits compared to the status quo: $7.06m PV. These are significant benefits, however as with S3 this scale of benefit is unlikely to justify the costs of investment alone in implementing a 'full greening' scenario such as S4.

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[34]   Source: RMCG data from previous work

Table 11: Case study PV economic benefit per scenario compared to Scenario 2 (status quo), 5% real discount rate (average emissions scenario)

	NO IWM REGULATION (S1-S2)	FUTURE IWM REGULATION (S3-S2)	MAXIMUM UHI MITIGATION (S4-S2)
Mortality	$0.30m	$1.03m	$3.10m
Morbidity	$0.01m	$0.06m	$0.16m
Productivity	-	$0.30m	$0.88m
Electricity	$0.04m	$0.87m	$2.93m
Total	**$0.35m**	**$2.26m**	**$7.06m**

When considering the higher emissions climate scenario (Table 12), the Future IWM Regulation scenario (S3) produces present value benefits of almost $2.3m over 50 years. As with the average emissions scenario, it would appear unlikely, given the likely scale of investment required to produce this outcome, that this benefit would justify that scale of investment alone.

Table 12: Case study PV economic benefit per scenario compared to Scenario 2 (status quo), 5% real discount rate (high emissions scenario)

	NO IWM REGULATION (S1-S2)	FUTURE IWM REGULATION (S3-S2)	MAXIMUM UHI MITIGATION (S4-S2)
Mortality	$0.31m	$1.08m	$3.24m
Morbidity	$0.01m	$0.05m	$0.16m
Productivity	-	$0.30m	$0.86m
Electricity	$0.04m	$0.87m	$2.93m
Total	**$0.36m**	**$2.30m**	**$7.19m**

Under high emissions, the 'Maximum UHI Mitigation' scenario (S4) produces $7.2m PV. These are significant benefits, however as with the Future IWM Regulation scenario (S3) it would seem unlikely to justify the costs of investment alone.

Figure 9 shows the results of the entire case study area, by average and high emissions for each scenario. As discussed, the high emissions scenario does not show significantly different results compared to the average emissions scenario. In reality, we expect that this underestimates the benefits of the high emissions scenario.
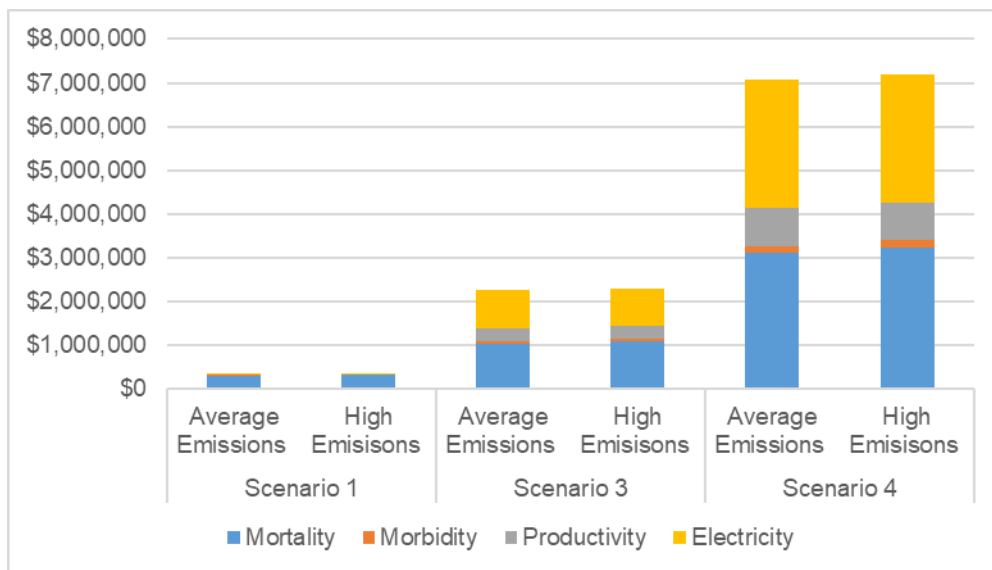
Figure 9: Results by benefit type, average and high emissions scenarios, $PV for case study area

It may also be interesting to consider the results per hectare of development. The study team undertook the analysis on a total area of development of 2,303ha. This included all land in the development, including riparian public open space. Table 13 provides an average annual benefit per hectare for the development at full development, for both average emissions and high emissions scenarios. While this provides a useful estimate, those seeking to use data from this analysis in benefit transfer within Melbourne might prefer to use the PV household estimate, which can be more flexibly adjusted for the number of properties in a new development (provided its landscape configuration is not too dissimilar to the case study area, which is fairly standard for new residential development areas in Melbourne).

Table 13: Annual PV benefit per hectare of development (excluding WTP), 50 years, 5% discount rate

	NO IWM REGULATION (S1-S2)	FUTURE IWM REGULATION (S3-S2)	MAXIMUM UHI MITIGATION (S4-S2)
Total value/ha, average emissions (total area)	$24	$154	$482
Total value/ha, high emissions (total area)	$24	$155	$484

4.3   Sensitivity test

In this section, we test some of the key inputs and assumptions, particularly discount rate and mortality value.

As can be seen in Table 14, the results are sensitive to these key assumptions, with results varying by assumption chosen, but not dramatically so. It is worth remembering that the scale of impact that this might have in a cost-benefit analysis will be less than is presented in the table, as in a CBA both costs and benefits will adjust with selection of discount rate, reducing the impact on the overall results.

Table 14: Sensitivity test, average emissions scenario, household ($PV)

	NO IWM REGULATION (S1-S2)	FUTURE IWM REGULATION (S3-S2)	MAXIMUM UHI MITIGATION (S4-S2)
Central assumptions	$76	$492	$1,541
3% Discount rate	$108	$700	$2,195
8% Discount rate	$50	$326	$1,020
$4m Value of a Statistical Life (double)	$143	$720	$2,222

Doubling the value of a statistical life (to $4m from $2m) has the largest impact on results, understandably given the relative contribution of mortality reduction to total benefits.

5 Discussion and suggestions for further work

KEY MESSAGES

- Heat mitigation in new greenfield suburbs can be achieved from urban greening and IWM policies

- The heat mitigation achievable from greening is modest but significant, as are the economic benefits that can be quantified from this mitigation

- The largest benefits from heat mitigation are estimated from reduced avoidable mortality, and energy savings

- UHI mitigation benefits alone appear unlikely to justify policies for greater urban greening

- However, UHI mitigation is one of many benefits from greening that can and should be quantified and used in cost-benefit analysis to justify policy changes.

- Replication of this study in other geographical contexts would be useful to build on this analysis

The project team understands that this is the first attempt to undertake an analysis of this kind: biophysical and economic modelling of the local climatic changes produced by urban greening in a greenfield residential setting.

The results produced in this work make best use of available tools for climate modelling and economic data. The results suggest that significant greening associated with plausible policy settings will produce meaningful if modest economic benefits for local residents in greenfields settings:

- around $500 per household for modest additional greening produced by higher stormwater management standards, or

- over $1,500 per household for a maximum conceivable standard for urban greening in a new suburb.

At a case study level, a new suburb of around 33,000 dwellings might derive a UHI mitigation value of around $2.3m in present value terms for modest additional greening investments, or up to almost $7.1m PV for a maximum urban greening scenario, based on this analysis.

5.1 Interpreting these results

The UHI mitigation value produced by these changes could most accurately be described as modest but significant contributions to the total value produced by IWM and urban greening. It would seem unlikely that the heat mitigation benefits alone would exceed the total cost of moving to higher IWM/greening settings, particularly when delivering those settings might require significant treatment of wastewater and/or stormwater, as well as a distribution network across the suburb. On this basis, the implication for policy makers is that heat mitigation benefits alone are unlikely to justify policy decisions for greater urban greening.

However, it is important to put this study into an appropriate context. Heat mitigation is one of several quantifiable benefits of urban greening and IWM. Hitherto, analyses of the costs and benefits of IWM and greening investment propositions have been able to use quantified estimates of most project costs, and only a number of key benefits – typically avoided costs of water infrastructure and other readily measurable benefits, and sometimes environmental values associated with waterway health or pollution abatement. In such analysis, the nature and scale of the UHI mitigation benefit that might be produced by such IWM/greening investments has been a quantitative gap of unknown size. This study provides estimates that can be used to fill this data gap, for new suburban developments in Melbourne.

Importantly, the IWM / greening investments that produce the UHI mitigation value estimated in this study, are likely to also produce multiple other benefits across the water cycle, such as savings to the potable and wastewater networks, waterway health improvement, and aesthetic benefits. The UHI mitigation benefits are but one of many quantifiable benefits of urban greening, all of which should be quantified to provide an accurate picture of benefits and costs of policies that produce these changes.

5.2 Using these results

The results produced in this study were developed using a methodology produced for a specific case study of a greenfield residential development in the west of Melbourne. The methodology was developed by reviewing the literature linking extreme heat and biophysical impacts, and the economic dimension of changes to those biophysical indicators. Previous stages of the study involved modelling the physical changes to the suburb that would be produced by the different scenarios, and then climate modelling at that location in the west of Melbourne. The results reflect this context and are not a general estimate of the economic value of reducing extreme heat in all contexts.

As such, the results can most accurately be used for greenfields developments in the west of Melbourne. Practitioners might prefer the use of the 'per household' benefit for UHI mitigation, to be added as one benefit in their cost-benefit analysis, where proposed investments best reflect the scenarios described in this paper.

The results are likely to hold relatively well for broader Melbourne, but might be adjusted downward slightly for areas of lower maximum daily temperature, with the west of Melbourne being generally hotter and dryer than the east.

Applying these results for studies outside of Melbourne or Victoria more broadly is faced with the challenge that context may differ significantly from those in which the study was undertaken: climate, housing type, suburb design, demographic profile. As such, use of conservative assumptions is advised when transferring these results outside of their original context. It is further recommended that the study be reproduced in other Australian contexts to broaden the data set of results, as discussed further below.

5.3   Further work

It should be acknowledged that the economic data used in this analysis was largely drawn from other studies or existing work that was not designed specifically for use in this context. To improve on this analysis, a number of options exist for additional work:

- **Productivity**: Data used in this analysis was drawn from the only attempt at measuring productivity impacts of heat available in Australia. However, as discussed before, there are a number of shortcomings associated with the use of this data for this project. To improve on this, a specific survey could be undertaken using modern technology timed to specifically target days or periods of extreme heat. This could use online tools that can survey respondents before, during and after periods of extreme heat to elicit accurate data on productivity impacts, as well as distinguish between the impact of overnight minimums (impacting sleep) and daytime maximums (directly affecting productivity of a range of different workers).

- **Mortality and morbidity**: Mortality benefits form a large proportion of the economic benefits of UHI mitigation. However, the data used in this analysis is almost a decade old, and could be revisited for more current information.

- **Climate change**: As shown in the analysis, the impact of climate change on expected maximum and minimum temperatures in Australia over the next 50 years will be significant. The analysis attempted to consider these changes through the economic analysis, however this could be more effectively handled through climate modelling. Additional work to consider climate change in the climate modelling would be highly valuable.

- **Other UHI mitigation options**: The focus of this analysis was appropriately on the UHI mitigation potential of green infrastructure and associated policy settings. However, it may be worth considering the UHI mitigation potential of green infrastructure combined with other relevant initiatives, such as white roofs, permeable paving and white roads.[35]

- **Other geographic settings**: this analysis focused on a geographic setting in the west of Melbourne, using a real case study location as the basis for biophysical modelling assuming hypothetical development features, climate modelling and economic analysis. The results are quite specific to this location and can be expected to differ in other locations around Australia. It may be useful to repeat this analysis in other Australian locations.

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[35] Some similar work on this topic has been undertaken in Sydney:
http://www.lowcarbonlivingcrc.com.au/sites/all/files/publications_file_attachments/20170705_crclcl_factsheet_cooling_western_sydney_final.pdf

Appendix 1: Minimum, maximum and mean temperature data

Table 15: Maximum daily summer temperature by scenario and year

DATE	S1 1971-72	S1 1986-87	S1 2008-09	S2 1971-72	S1 1986-87	S2 2008-09	S3 1971-72	S3 1986-87	S3 2008-09	S4 1971-72	S4 1986-87	S4 2008-09
1-Dec	20.58	27.39	21.08	20.6	27.4	21.1	20.20	27.11	20.71	19.21	26.43	19.74
2-Dec	20.28	27.09	22.18	20.3	27.1	22.2	19.90	26.81	21.83	18.89	26.12	20.91
3-Dec	30.49	29.39	21.28	30.5	29.4	21.3	30.22	29.12	20.91	29.62	28.49	19.95
4-Dec	20.08	21.28	25.59	20.1	21.3	25.6	19.70	20.91	25.28	18.68	19.95	24.52
5-Dec	23.99	26.79	31.69	24	26.8	31.7	23.66	26.50	31.43	22.82	25.80	30.85
6-Dec	18.88	30.89	27.19	18.9	30.9	27.2	18.48	30.62	26.91	17.40	30.03	26.22
7-Dec	23.28	23.79	18.98	23.3	23.8	19	22.95	23.45	18.58	22.08	22.61	17.51
8-Dec	30.09	16.38	22.68	30.1	16.4	22.7	29.82	15.94	22.34	29.21	14.74	21.44
9-Dec	30.59	19.78	19.18	30.6	19.8	19.2	30.32	19.39	18.78	29.72	18.36	17.72
10-Dec	21.08	26.99	17.98	21.1	27	18	20.71	26.71	17.56	19.74	26.01	16.44
11-Dec	21.18	17.68	22.68	21.2	17.7	22.7	20.81	17.26	22.34	19.85	16.13	21.44
12-Dec	26.19	17.98	22.38	26.2	18	22.4	25.89	17.56	22.03	25.16	16.44	21.12
13-Dec	29.29	19.48	16.58	29.3	19.5	16.6	29.02	19.09	16.14	28.39	18.04	14.96
14-Dec	17.68	15.88	18.18	17.7	15.9	18.2	17.26	15.43	17.76	16.13	14.21	16.66
15-Dec	18.68	24.79	20.38	18.7	24.8	20.4	18.27	24.47	20.00	17.19	23.67	19.00
16-Dec	20.48	21.28	19.28	20.5	21.3	19.3	20.10	20.91	18.88	19.10	19.95	17.83
17-Dec	19.18	19.68	19.18	19.2	19.7	19.2	18.78	19.29	18.78	17.72	18.25	17.72
18-Dec	17.58	19.98	20.38	17.6	20	20.4	17.16	19.59	20.00	16.02	18.57	19.00

DATE	S1 1971-72	S1 1986-87	S1 2008-09	S2 1971-72	S1 1986-87	S2 2008-09	S3 1971-72	S3 1986-87	S3 2008-09	S4 1971-72	S4 1986-87	S4 2008-09
19-Dec	19.58	24.99	17.68	19.6	25	17.7	19.19	24.67	17.26	18.15	23.88	16.13
20-Dec	27.59	19.08	21.38	27.6	19.1	21.4	27.31	18.68	21.02	26.64	17.61	20.06
21-Dec	30.79	19.68	29.09	30.8	19.7	29.1	30.52	19.29	28.82	29.93	18.25	28.18
22-Dec	34.19	18.18	34.49	34.2	18.2	34.5	33.93	17.76	34.24	33.42	16.66	33.73
23-Dec	31.59	20.18	19.68	31.6	20.2	19.7	31.33	19.80	19.29	30.75	18.78	18.25
24-Dec	30.99	19.18	23.18	31	19.2	23.2	30.72	18.78	22.84	30.13	17.72	21.97
25-Dec	29.29	26.69	23.79	29.3	26.7	23.8	29.02	26.40	23.45	28.39	25.69	22.61
26-Dec	30.79	21.98	29.69	30.8	22	29.7	30.52	21.63	29.42	29.93	20.70	28.80
27-Dec	22.68	19.68	29.19	22.7	19.7	29.2	22.34	19.29	28.92	21.44	18.25	28.28
28-Dec	22.18	23.99	28.49	22.2	24	28.5	21.83	23.66	28.21	20.91	22.82	27.56
29-Dec	28.09	21.68	22.28	28.1	21.7	22.3	27.81	21.32	21.93	27.15	20.38	21.01
30-Dec	21.58	34.39	23.48	21.6	34.4	23.5	21.22	34.13	23.15	20.27	33.63	22.29
31-Dec	18.38	26.39	23.28	18.4	26.4	23.3	17.97	26.10	22.95	16.87	25.37	22.08
1-Jan	20.28	22.58	19.88	20.3	22.6	19.9	19.90	22.24	19.49	18.89	21.33	18.46
2-Jan	19.88	33.49	17.78	19.9	33.5	17.8	19.49	33.23	17.36	18.46	32.70	16.23
3-Jan	18.38	19.28	21.08	18.4	19.3	21.1	17.97	18.88	20.71	16.87	17.83	19.74
4-Jan	23.08	21.98	29.19	23.1	22	29.2	22.74	21.63	28.92	21.86	20.70	28.28
5-Jan	28.79	21.98	28.99	28.8	22	29	28.52	21.63	28.72	27.87	20.70	28.08
6-Jan	27.79	24.39	31.69	27.8	24.4	31.7	27.51	24.06	31.43	26.84	23.25	30.85
7-Jan	27.09	28.49	21.38	27.1	28.5	21.4	26.81	28.21	21.02	26.12	27.56	20.06
8-Jan	30.59	16.78	18.38	30.6	16.8	18.4	30.32	16.34	17.97	29.72	15.17	16.87

DATE	S1 1971-72	S1 1986-87	S1 2008-09	S2 1971-72	S1 1986-87	S2 2008-09	S3 1971-72	S3 1986-87	S3 2008-09	S4 1971-72	S4 1986-87	S4 2008-09
9-Jan	29.19	19.58	19.68	29.2	19.6	19.7	28.92	19.19	19.29	28.28	18.15	18.25
10-Jan	21.08	21.68	23.59	21.1	21.7	23.6	20.71	21.32	23.25	19.74	20.38	22.40
11-Jan	25.59	27.69	23.48	25.6	27.7	23.5	25.28	27.41	23.15	24.52	26.74	22.29
12-Jan	19.98	23.38	25.09	20	23.4	25.1	19.59	23.05	24.77	18.57	22.18	23.99
13-Jan	20.88	27.09	37.09	20.9	27.1	37.1	20.51	26.81	36.84	19.53	26.12	36.40
14-Jan	24.29	24.69	33.49	24.3	24.7	33.5	23.96	24.37	33.23	23.14	23.57	32.70
15-Jan	27.69	22.58	23.08	27.7	22.6	23.1	27.41	22.24	22.74	26.74	21.33	21.86
16-Jan	26.69	36.69	21.58	26.7	36.7	21.6	26.40	36.44	21.22	25.69	35.99	20.27
17-Jan	31.59	23.18	19.78	31.6	23.2	19.8	31.33	22.84	19.39	30.75	21.97	18.36
18-Jan	19.38	28.39	26.29	19.4	28.4	26.3	18.98	28.11	25.99	17.93	27.46	25.27
19-Jan	23.18	20.38	36.99	23.2	20.4	37	22.84	20.00	36.74	21.97	19.00	36.30
20-Jan	24.09	24.39	40.19	24.1	24.4	40.2	23.76	24.06	39.95	22.93	23.25	39.59
21-Jan	25.59	19.18	28.79	25.6	19.2	28.8	25.28	18.78	28.52	24.52	17.72	27.87
22-Jan	21.18	17.88	35.59	21.2	17.9	35.6	20.81	17.46	35.34	19.85	16.34	34.86
23-Jan	21.18	17.98	32.29	21.2	18	32.3	20.81	17.56	32.03	19.85	16.44	31.47
24-Jan	19.58	30.89	24.19	19.6	30.9	24.2	19.19	30.62	23.86	18.15	30.03	23.03
25-Jan	28.19	24.79	28.99	28.2	24.8	29	27.91	24.47	28.72	27.26	23.67	28.08
26-Jan	31.19	32.19	24.79	31.2	32.2	24.8	30.92	31.93	24.47	30.34	31.37	23.67
27-Jan	26.79	22.68	35.99	26.8	22.7	36	26.50	22.34	35.74	25.80	21.44	35.27
28-Jan	21.18	21.18	43.09	21.2	21.2	43.1	20.81	20.81	42.86	19.85	19.85	42.56
29-Jan	28.69	24.69	44.19	28.7	24.7	44.2	28.42	24.37	43.97	27.77	23.57	43.69

DATE	S1 1971-72	S1 1986-87	S1 2008-09	S2 1971-72	S1 1986-87	S2 2008-09	S3 1971-72	S3 1986-87	S3 2008-09	S4 1971-72	S4 1986-87	S4 2008-09
30-Jan	31.79	27.69	44.19	31.8	27.7	44.2	31.53	27.41	43.97	30.95	26.74	43.69
31-Jan	29.39	36.39	31.59	29.4	36.4	31.6	29.12	36.14	31.33	28.49	35.68	30.75
1-Feb	36.89	22.18	34.09	36.9	22.2	34.1	36.64	21.83	33.83	36.19	20.91	33.32
2-Feb	34.29	39.59	28.79	34.3	39.6	28.8	34.03	39.35	28.52	33.52	38.97	27.87
3-Feb	20.48	21.38	28.69	20.5	21.4	28.7	20.10	21.02	28.42	19.10	20.06	27.77
4-Feb	23.79	18.98	31.59	23.8	19	31.6	23.45	18.58	31.33	22.61	17.51	30.75
5-Feb	31.29	23.38	32.19	31.3	23.4	32.2	31.02	23.05	31.93	30.44	22.18	31.37
6-Feb	33.79	30.69	33.49	33.8	30.7	33.5	33.53	30.42	33.23	33.01	29.82	32.70
7-Feb	30.19	39.29	46.79	30.2	39.3	46.8	29.92	39.05	46.58	29.31	38.66	46.37
8-Feb	26.29	20.28	20.88	26.3	20.3	20.9	25.99	19.90	20.51	25.27	18.89	19.53
9-Feb	33.39	26.09	20.28	33.4	26.1	20.3	33.13	25.79	19.90	32.60	25.05	18.89
10-Feb	31.59	24.19	19.68	31.6	24.2	19.7	31.33	23.86	19.29	30.75	23.03	18.25
11-Feb	30.79	21.58	17.68	30.8	21.6	17.7	30.52	21.22	17.26	29.93	20.27	16.13
12-Feb	33.39	22.18	22.88	33.4	22.2	22.9	33.13	21.83	22.54	32.60	20.91	21.65
13-Feb	22.78	34.09	26.39	22.8	34.1	26.4	22.44	33.83	26.10	21.55	33.32	25.37
14-Feb	21.78	36.99	27.29	21.8	37	27.3	21.42	36.74	27.01	20.48	36.30	26.33
15-Feb	28.29	22.38	27.49	28.3	22.4	27.5	28.01	22.03	27.21	27.36	21.12	26.54
16-Feb	19.68	28.09	28.99	19.7	28.1	29	19.29	27.81	28.72	18.25	27.15	28.08
17-Feb	23.38	28.09	31.19	23.4	28.1	31.2	23.05	27.81	30.92	22.18	27.15	30.34
18-Feb	23.28	31.39	29.99	23.3	31.4	30	22.95	31.12	29.72	22.08	30.54	29.10
19-Feb	20.78	36.39	30.39	20.8	36.4	30.4	20.41	36.14	30.12	19.42	35.68	29.52

DATE	S1 1971-72	S1 1986-87	S1 2008-09	S2 1971-72	S1 1986-87	S2 2008-09	S3 1971-72	S3 1986-87	S3 2008-09	S4 1971-72	S4 1986-87	S4 2008-09
20-Feb	21.38	21.78	25.89	21.4	21.8	25.9	21.02	21.42	25.59	20.06	20.48	24.84
21-Feb	18.28	21.98	22.88	18.3	22	22.9	17.87	21.63	22.54	16.76	20.70	21.65
22-Feb	19.78	18.98	26.39	19.8	19	26.4	19.39	18.58	26.10	18.36	17.51	25.37
23-Feb	20.08	26.79	34.99	20.1	26.8	35	19.70	26.50	34.74	18.68	25.80	34.24
24-Feb	24.59	28.79	20.38	24.6	28.8	20.4	24.27	28.52	20.00	23.46	27.87	19.00
25-Feb	30.29	18.38	21.68	30.3	18.4	21.7	30.02	17.97	21.32	29.41	16.87	20.38
26-Feb	25.09	26.19	30.59	25.1	26.2	30.6	24.77	25.89	30.32	23.99	25.16	29.72
27-Feb	29.79	31.59	35.49	29.8	31.6	35.5	29.52	31.33	35.24	28.90	30.75	34.76
28-Feb	29.89	15.18	22.68	29.9	15.2	22.7	29.62	14.72	22.34	29.00	13.47	21.44
29-Feb	31.39			31.4			31.12			30.54		

Table 16: Minimum daily summer temperature by scenario and year

DATE	S1 1971-72	S1 1986-87	S1 2008-09	S2 1971-72	S1 1986-87	S2 2008-09	S3 1971-72	S3 1986-87	S3 2008-09	S4 1971-72	S4 1986-87	S4 2008-09
1-Dec	10.00	8.30	8.90	10	8.3	8.9	10.11	8.45	9.03	10.17	8.59	9.15
2-Dec	12.90	11.60	8.90	12.9	11.6	8.9	12.93	11.67	9.03	12.86	11.65	9.15
3-Dec	10.00	16.30	13.40	10	16.3	13.4	10.11	16.25	13.42	10.17	16.01	13.32
4-Dec	12.30	12.90	7.40	12.3	12.9	7.4	12.35	12.93	7.57	12.30	12.86	7.76
5-Dec	6.60	10.80	13.90	6.6	10.8	13.9	6.79	10.89	13.91	7.02	10.91	13.78
6-Dec	11.80	14.60	12.90	11.8	14.6	12.9	11.86	14.59	12.93	11.84	14.43	12.86
7-Dec	9.20	18.39	7.80	9.2	18.4	7.8	9.33	18.32	7.96	9.43	18.03	8.13
8-Dec	11.80	9.70	6.80	11.8	9.7	6.8	11.86	9.81	6.99	11.84	9.89	7.20
9-Dec	17.19	9.90	7.70	17.2	9.9	7.7	17.12	10.01	7.87	16.84	10.08	8.04
10-Dec	12.30	9.00	11.60	12.3	9	11.6	12.35	9.13	11.67	12.30	9.24	11.65
11-Dec	8.10	9.80	7.70	8.1	9.8	7.7	8.26	9.91	7.87	8.41	9.98	8.04
12-Dec	8.20	10.70	12.00	8.2	10.7	12	8.35	10.79	12.06	8.50	10.82	12.02
13-Dec	10.30	10.80	15.00	10.3	10.8	15	10.40	10.89	14.98	10.45	10.91	14.80
14-Dec	11.40	6.90	10.90	11.4	6.9	10.9	11.47	7.09	10.98	11.47	7.30	11.00
15-Dec	7.90	4.11	11.20	7.9	4.1	11.2	8.06	4.36	11.28	8.22	4.70	11.28
16-Dec	7.20	12.30	10.70	7.2	12.3	10.7	7.38	12.35	10.79	7.58	12.30	10.82
17-Dec	12.30	11.10	12.50	12.3	11.1	12.5	12.35	11.18	12.54	12.30	11.19	12.49
18-Dec	9.60	8.00	12.80	9.6	8	12.8	9.72	8.16	12.84	9.80	8.32	12.76
19-Dec	10.70	8.60	8.90	10.7	8.6	8.9	10.79	8.74	9.03	10.82	8.87	9.15
20-Dec	9.10	7.80	7.60	9.1	7.8	7.6	9.23	7.96	7.77	9.34	8.13	7.95

DATE	S1 1971-72	S1 1986-87	S1 2008-09	S2 1971-72	S1 1986-87	S2 2008-09	S3 1971-72	S3 1986-87	S3 2008-09	S4 1971-72	S4 1986-87	S4 2008-09
21-Dec	12.50	9.80	10.00	12.5	9.8	10	12.54	9.91	10.11	12.49	9.98	10.17
22-Dec	16.30	7.20	18.29	16.3	7.2	18.3	16.25	7.38	18.22	16.01	7.58	17.93
23-Dec	18.59	7.30	13.80	18.6	7.3	13.8	18.52	7.48	13.81	18.25	7.67	13.69
24-Dec	13.10	12.30	10.20	13.1	12.3	10.2	13.13	12.35	10.30	13.04	12.30	10.36
25-Dec	13.70	7.20	11.10	13.7	7.2	11.1	13.71	7.38	11.18	13.60	7.58	11.19
26-Dec	21.00	12.80	11.40	21	12.8	11.4	20.95	12.84	11.47	20.78	12.76	11.47
27-Dec	9.90	13.10	13.80	9.9	13.1	13.8	10.01	13.13	13.81	10.08	13.04	13.69
28-Dec	8.90	12.40	11.20	8.9	12.4	11.2	9.03	12.45	11.28	9.15	12.39	11.28
29-Dec	10.10	10.10	11.80	10.1	10.1	11.8	10.20	10.20	11.86	10.26	10.26	11.84
30-Dec	14.70	9.20	13.30	14.7	9.2	13.3	14.69	9.33	13.32	14.52	9.43	13.23
31-Dec	11.20	18.19	12.00	11.2	18.2	12	11.28	18.11	12.06	11.28	17.82	12.02
1-Jan	9.40	9.00	11.20	9.4	9	11.2	9.52	9.13	11.28	9.61	9.24	11.28
2-Jan	12.50	11.30	7.80	12.5	11.3	7.8	12.54	11.37	7.96	12.49	11.37	8.13
3-Jan	12.50	14.40	6.30	12.5	14.4	6.3	12.54	14.39	6.50	12.49	14.25	6.74
4-Jan	11.90	14.20	8.10	11.9	14.2	8.1	11.96	14.20	8.26	11.93	14.06	8.41
5-Jan	12.90	15.10	9.70	12.9	15.1	9.7	12.93	15.08	9.81	12.86	14.89	9.89
6-Jan	13.90	15.30	13.50	13.9	15.3	13.5	13.91	15.27	13.52	13.78	15.08	13.41
7-Jan	14.90	14.70	15.80	14.9	14.7	15.8	14.88	14.69	15.76	14.71	14.52	15.54
8-Jan	18.09	8.20	9.70	18.1	8.2	9.7	18.01	8.35	9.81	17.72	8.50	9.89
9-Jan	19.59	6.80	10.20	19.6	6.8	10.2	19.53	6.99	10.30	19.30	7.20	10.36
10-Jan	17.69	9.80	10.70	17.7	9.8	10.7	17.61	9.91	10.79	17.30	9.98	10.82

DATE	S1 1971-72	S1 1986-87	S1 2008-09	S2 1971-72	S1 1986-87	S2 2008-09	S3 1971-72	S3 1986-87	S3 2008-09	S4 1971-72	S4 1986-87	S4 2008-09
11-Jan	17.19	11.70	10.70	17.2	11.7	10.7	17.12	11.76	10.79	16.84	11.74	10.82
12-Jan	18.09	9.00	10.40	18.1	9	10.4	18.01	9.13	10.50	17.72	9.24	10.54
13-Jan	11.90	10.50	11.50	11.9	10.5	11.5	11.96	10.59	11.57	11.93	10.63	11.56
14-Jan	7.20	15.30	24.90	7.2	15.3	24.9	7.38	15.27	24.91	7.58	15.08	24.90
15-Jan	11.60	8.90	13.80	11.6	8.9	13.8	11.67	9.03	13.81	11.65	9.15	13.69
16-Jan	13.60	9.80	12.70	13.6	9.8	12.7	13.62	9.91	12.74	13.51	9.98	12.67
17-Jan	15.70	12.70	12.50	15.7	12.7	12.5	15.66	12.74	12.54	15.45	12.67	12.49
18-Jan	15.00	10.00	7.50	15	10	7.5	14.98	10.11	7.67	14.80	10.17	7.85
19-Jan	11.10	8.40	11.90	11.1	8.4	11.9	11.18	8.55	11.96	11.19	8.69	11.93
20-Jan	9.60	9.30	18.39	9.6	9.3	18.4	9.72	9.42	18.32	9.80	9.52	18.03
21-Jan	11.10	11.90	12.80	11.1	11.9	12.8	11.18	11.96	12.84	11.19	11.93	12.76
22-Jan	13.60	8.50	15.10	13.6	8.5	15.1	13.62	8.65	15.08	13.51	8.78	14.89
23-Jan	15.30	11.30	9.80	15.3	11.3	9.8	15.27	11.37	9.91	15.08	11.37	9.98
24-Jan	12.80	8.90	15.30	12.8	8.9	15.3	12.84	9.03	15.27	12.76	9.15	15.08
25-Jan	13.90	12.40	9.20	13.9	12.4	9.2	13.91	12.45	9.33	13.78	12.39	9.43
26-Jan	15.80	14.70	11.40	15.8	14.7	11.4	15.76	14.69	11.47	15.54	14.52	11.47
27-Jan	16.39	9.50	14.90	16.4	9.5	14.9	16.34	9.62	14.88	16.10	9.71	14.71
28-Jan	15.50	8.20	16.59	15.5	8.2	16.6	15.47	8.35	16.54	15.27	8.50	16.28
29-Jan	12.90	8.10	30.50	12.9	8.1	30.5	12.93	8.26	30.59	12.86	8.41	30.81
30-Jan	13.50	8.80	23.90	13.5	8.8	23.9	13.52	8.94	23.89	13.41	9.06	23.84
31-Jan	16.20	13.60	19.59	16.2	13.6	19.6	16.15	13.62	19.53	15.91	13.51	19.30

DATE	S1 1971-72	S1 1986-87	S1 2008-09	S2 1971-72	S1 1986-87	S2 2008-09	S3 1971-72	S3 1986-87	S3 2008-09	S4 1971-72	S4 1986-87	S4 2008-09
1-Feb	16.20	14.60	18.09	16.2	14.6	18.1	16.15	14.59	18.01	15.91	14.43	17.72
2-Feb	24.40	10.90	18.69	24.4	10.9	18.7	24.40	10.98	18.62	24.37	11.00	18.35
3-Feb	11.60	9.40	18.79	11.6	9.4	18.8	11.67	9.52	18.72	11.65	9.61	18.46
4-Feb	10.90	9.80	17.89	10.9	9.8	17.9	10.98	9.91	17.81	11.00	9.98	17.51
5-Feb	12.30	8.50	16.99	12.3	8.5	17	12.35	8.65	16.93	12.30	8.78	16.66
6-Feb	21.70	12.20	17.59	21.7	12.2	17.6	21.66	12.25	17.51	21.52	12.21	17.21
7-Feb	16.89	13.50	18.79	16.9	13.5	18.8	16.83	13.52	18.72	16.56	13.41	18.46
8-Feb	16.89	15.60	16.89	16.9	15.6	16.9	16.83	15.56	16.83	16.56	15.36	16.56
9-Feb	14.60	9.20	14.30	14.6	9.2	14.3	14.59	9.33	14.30	14.43	9.43	14.15
10-Feb	17.19	13.20	11.50	17.2	13.2	11.5	17.12	13.23	11.57	16.84	13.13	11.56
11-Feb	19.70	8.70	11.60	19.7	8.7	11.6	19.64	8.84	11.67	19.41	8.97	11.65
12-Feb	17.19	11.80	12.90	17.2	11.8	12.9	17.12	11.86	12.93	16.84	11.84	12.86
13-Feb	15.00	10.50	6.90	15	10.5	6.9	14.98	10.59	7.09	14.80	10.63	7.30
14-Feb	9.70	12.70	10.50	9.7	12.7	10.5	9.81	12.74	10.59	9.89	12.67	10.63
15-Feb	12.80	15.60	11.80	12.8	15.6	11.8	12.84	15.56	11.86	12.76	15.36	11.84
16-Feb	16.69	13.40	13.20	16.7	13.4	13.2	16.64	13.42	13.23	16.38	13.32	13.13
17-Feb	14.50	14.60	13.00	14.5	14.6	13	14.49	14.59	13.03	14.34	14.43	12.95
18-Feb	16.20	14.10	13.70	16.2	14.1	13.7	16.15	14.10	13.71	15.91	13.97	13.60
19-Feb	12.80	16.59	13.70	12.8	16.6	13.7	12.84	16.54	13.71	12.76	16.28	13.60
20-Feb	11.30	20.40	15.90	11.3	20.4	15.9	11.37	20.35	15.86	11.37	20.15	15.64
21-Feb	9.60	9.50	14.30	9.6	9.5	14.3	9.72	9.62	14.30	9.80	9.71	14.15

DATE	S1 1971-72	S1 1986-87	S1 2008-09	S2 1971-72	S1 1986-87	S2 2008-09	S3 1971-72	S3 1986-87	S3 2008-09	S4 1971-72	S4 1986-87	S4 2008-09
22-Feb	10.40	8.50	16.10	10.4	8.5	16.1	10.50	8.65	16.05	10.54	8.78	15.82
23-Feb	13.90	6.20	13.40	13.9	6.2	13.4	13.91	6.40	13.42	13.78	6.65	13.32
24-Feb	15.10	9.70	9.50	15.1	9.7	9.5	15.08	9.81	9.62	14.89	9.89	9.71
25-Feb	13.90	8.80	12.10	13.9	8.8	12.1	13.91	8.94	12.15	13.78	9.06	12.12
26-Feb	15.30	6.90	12.70	15.3	6.9	12.7	15.27	7.09	12.74	15.08	7.30	12.67
27-Feb	14.90	11.70	14.60	14.9	11.7	14.6	14.88	11.76	14.59	14.71	11.74	14.43
28-Feb	14.80	13.40	14.20	14.8	13.4	14.2	14.78	13.42	14.20	14.62	13.32	14.06
29-Feb	17.89			17.9			17.81			17.51		

Table 17: Mean daily summer temperature by scenario and year

DATE	S1 1971-72	S1 1986-87	S1 2008-09	S2 1971-72	S1 1986-87	S2 2008-09	S3 1971-72	S3 1986-87	S3 2008-09	S4 1971-72	S4 1986-87	S4 2008-09
1-Dec	16.74	19.49	14.99	16.75	19.5	15	16.57	19.39	14.87	16.03	19.04	14.44
2-Dec	15.14	21.69	17.79	15.15	21.7	17.8	15.00	21.53	17.62	14.53	21.06	17.11
3-Dec	21.39	21.14	14.34	21.4	21.15	14.35	21.28	21.03	14.24	20.96	20.67	13.86
4-Dec	13.34	16.04	19.74	13.35	16.05	19.75	13.24	15.90	19.60	12.85	15.43	19.15
5-Dec	17.89	20.69	22.29	17.9	20.7	22.3	17.76	20.55	22.18	17.33	20.11	21.85
6-Dec	14.04	24.64	17.50	14.05	24.65	17.5	13.90	24.47	17.44	13.41	24.03	17.18
7-Dec	17.54	16.74	12.89	17.55	16.75	12.9	17.40	16.63	12.78	16.96	16.25	12.36
8-Dec	23.64	13.14	15.19	23.65	13.15	15.2	23.47	12.97	15.10	23.02	12.41	14.74
9-Dec	21.44	14.39	15.39	21.45	14.4	15.4	21.34	14.26	15.22	21.01	13.80	14.69
10-Dec	14.59	18.39	12.84	14.6	18.4	12.85	14.48	18.31	12.71	14.07	18.00	12.24
11-Dec	14.69	14.19	17.34	14.7	14.2	17.35	14.58	14.02	17.20	14.17	13.47	16.73
12-Dec	18.24	14.39	18.69	18.25	14.4	18.7	18.15	14.22	18.51	17.80	13.68	17.96
13-Dec	20.34	13.19	13.74	20.35	13.2	13.75	20.24	13.09	13.56	19.93	12.67	12.98
14-Dec	12.79	9.99	14.69	12.8	10	14.7	12.66	9.89	14.52	12.17	9.46	13.97
15-Dec	12.94	18.54	15.54	12.95	18.55	15.55	12.83	18.41	15.39	12.38	17.99	14.91
16-Dec	16.39	16.19	15.89	16.4	16.2	15.9	16.22	16.05	15.71	15.70	15.57	15.16
17-Dec	14.39	13.84	15.99	14.4	13.85	16	14.25	13.72	15.81	13.76	13.28	15.24
18-Dec	14.14	14.29	14.64	14.15	14.3	14.65	13.97	14.17	14.52	13.42	13.72	14.07
19-Dec	14.34	16.39	12.64	14.35	16.4	12.65	14.21	16.32	12.51	13.74	16.01	12.04
20-Dec	20.04	14.44	15.69	20.05	14.45	15.7	19.93	14.30	15.56	19.56	13.80	15.11

DATE	S1 1971-72	S1 1986-87	S1 2008-09	S2 1971-72	S1 1986-87	S2 2008-09	S3 1971-72	S3 1986-87	S3 2008-09	S4 1971-72	S4 1986-87	S4 2008-09
21-Dec	23.54	13.44	23.69	23.55	13.45	23.7	23.38	13.33	23.52	22.97	12.91	23.05
22-Dec	26.39	12.74	24.14	26.4	12.75	24.15	26.23	12.62	24.02	25.83	12.16	23.71
23-Dec	22.34	16.24	14.94	22.35	16.25	14.95	22.23	16.07	14.80	21.90	15.54	14.30
24-Dec	22.34	13.19	17.14	22.35	13.2	17.15	22.22	13.08	17.01	21.87	12.65	16.58
25-Dec	25.14	19.74	17.59	25.15	19.75	17.6	24.99	19.62	17.46	24.58	19.23	17.04
26-Dec	20.35	17.54	21.74	20.35	17.55	21.75	20.27	17.38	21.61	20.00	16.87	21.24
27-Dec	15.79	16.04	20.19	15.8	16.05	20.2	15.69	15.87	20.10	15.30	15.32	19.78
28-Dec	16.14	17.04	20.14	16.15	17.05	20.15	16.02	16.93	20.04	15.59	16.54	19.70
29-Dec	21.39	15.44	17.79	21.4	15.45	17.8	21.25	15.32	17.63	20.84	14.90	17.12
30-Dec	16.39	26.29	17.74	16.4	26.3	17.75	16.25	26.12	17.60	15.78	25.72	17.16
31-Dec	13.89	17.69	17.24	13.9	17.7	17.25	13.75	17.61	17.11	13.24	17.31	16.68
1-Jan	16.39	16.94	13.84	16.4	16.95	13.85	16.22	16.80	13.73	15.69	16.35	13.30
2-Jan	16.19	23.94	12.04	16.2	23.95	12.05	16.02	23.81	11.93	15.47	23.47	11.49
3-Jan	15.14	16.74	14.59	15.15	16.75	14.6	14.96	16.54	14.48	14.40	15.94	14.07
4-Jan	17.99	18.54	19.44	18	18.55	19.45	17.84	18.35	19.37	17.36	17.80	19.09
5-Jan	21.34	18.64	21.24	21.35	18.65	21.25	21.21	18.45	21.12	20.83	17.89	20.74
6-Jan	21.34	19.54	23.74	21.35	19.55	23.75	21.20	19.38	23.59	20.78	18.89	23.20
7-Jan	22.59	18.35	15.54	22.6	18.35	15.55	22.41	18.28	15.42	21.92	18.03	14.97
8-Jan	25.09	11.79	14.29	25.1	11.8	14.3	24.93	11.67	14.13	24.51	11.19	13.61
9-Jan	23.44	14.69	15.19	23.45	14.7	15.2	23.26	14.55	15.04	22.79	14.06	14.53
10-Jan	19.14	16.69	17.14	19.15	16.7	17.15	18.92	16.54	17.02	18.29	16.06	16.61

DATE	S1 1971-72	S1 1986-87	S1 2008-09	S2 1971-72	S1 1986-87	S2 2008-09	S3 1971-72	S3 1986-87	S3 2008-09	S4 1971-72	S4 1986-87	S4 2008-09
11-Jan	21.84	18.35	16.94	21.85	18.35	16.95	21.65	18.27	16.82	21.12	17.99	16.42
12-Jan	15.94	16.94	18.29	15.95	16.95	18.3	15.78	16.82	18.17	15.25	16.41	17.77
13-Jan	14.04	21.19	30.99	14.05	21.2	31	13.94	21.04	30.88	13.55	20.60	30.65
14-Jan	17.94	16.79	23.64	17.95	16.8	23.65	17.81	16.70	23.52	17.40	16.36	23.20
15-Jan	20.64	16.19	17.89	20.65	16.2	17.9	20.51	16.07	17.74	20.12	15.66	17.27
16-Jan	21.19	24.69	17.04	21.2	24.7	17.05	21.03	24.59	16.88	20.57	24.33	16.38
17-Jan	23.29	16.59	13.64	23.3	16.6	13.65	23.15	16.48	13.53	22.78	16.07	13.11
18-Jan	15.24	18.40	19.09	15.25	18.4	19.1	15.08	18.33	18.98	14.56	18.07	18.60
19-Jan	16.39	14.84	27.69	16.4	14.85	27.7	16.28	14.71	27.53	15.89	14.26	27.17
20-Jan	17.59	18.14	26.49	17.6	18.15	26.5	17.47	18.01	26.39	17.06	17.59	26.17
21-Jan	19.59	13.84	21.94	19.6	13.85	21.95	19.45	13.71	21.80	19.01	13.25	21.38
22-Jan	18.24	14.59	22.70	18.25	14.6	22.7	18.04	14.42	22.63	17.46	13.86	22.42
23-Jan	16.99	13.44	23.79	17	13.45	23.8	16.82	13.30	23.65	16.30	12.80	23.27
24-Jan	16.74	21.64	16.69	16.75	21.65	16.7	16.55	21.53	16.59	15.96	21.21	16.23
25-Jan	21.99	19.74	20.19	22	19.75	20.2	21.84	19.58	20.09	21.40	19.10	19.77
26-Jan	23.79	20.85	19.84	23.8	20.85	19.85	23.63	20.77	19.68	23.22	20.54	19.19
27-Jan	21.14	15.44	26.29	21.15	15.45	26.3	20.98	15.34	26.14	20.53	14.97	25.78
28-Jan	17.04	14.64	36.80	17.05	14.65	36.8	16.87	14.53	36.73	16.35	14.13	36.69
29-Jan	21.09	16.74	34.05	21.1	16.75	34.05	20.97	16.65	33.93	20.59	16.31	33.77
30-Jan	23.99	20.64	31.89	24	20.65	31.9	23.84	20.51	31.75	23.43	20.12	31.50
31-Jan	22.79	25.49	24.84	22.8	25.5	24.85	22.63	25.37	24.67	22.20	25.06	24.23

DATE	S1 1971-72	S1 1986-87	S1 2008-09	S2 1971-72	S1 1986-87	S2 2008-09	S3 1971-72	S3 1986-87	S3 2008-09	S4 1971-72	S4 1986-87	S4 2008-09
1-Feb	30.64	16.54	26.39	30.65	16.55	26.4	30.52	16.41	26.23	30.28	15.96	25.83
2-Feb	22.94	24.50	23.79	22.95	24.5	23.8	22.85	24.44	23.62	22.59	24.29	23.16
3-Feb	15.69	15.59	23.29	15.7	15.6	23.3	15.54	15.46	23.11	15.05	15.02	22.64
4-Feb	18.04	13.74	24.29	18.05	13.75	24.3	17.90	13.61	24.13	17.45	13.14	23.70
5-Feb	26.49	17.79	24.89	26.5	17.8	24.9	26.34	17.65	24.72	25.98	17.20	24.29
6-Feb	25.34	22.09	26.14	25.35	22.1	26.15	25.18	21.97	25.98	24.79	21.62	25.58
7-Feb	23.54	27.44	31.84	23.55	27.45	31.85	23.38	27.31	31.70	22.94	27.01	31.46
8-Feb	20.44	14.74	17.59	20.45	14.75	17.6	20.29	14.61	17.40	19.85	14.16	16.84
9-Feb	25.29	19.64	15.89	25.3	19.65	15.9	25.13	19.51	15.73	24.72	19.09	15.22
10-Feb	25.64	16.44	15.64	25.65	16.45	15.65	25.48	16.35	15.48	25.08	16.00	14.95
11-Feb	23.99	16.69	15.29	24	16.7	15.3	23.82	16.54	15.09	23.38	16.05	14.49
12-Feb	24.19	16.34	14.89	24.2	16.35	14.9	24.06	16.21	14.81	23.70	15.77	14.47
13-Feb	16.24	23.39	18.44	16.25	23.4	18.45	16.13	23.29	18.34	15.72	22.99	18.00
14-Feb	17.29	26.29	19.54	17.3	26.3	19.55	17.13	26.15	19.44	16.62	25.83	19.08
15-Feb	22.49	17.89	20.34	22.5	17.9	20.35	22.33	17.73	20.22	21.87	17.22	19.84
16-Feb	17.09	21.34	20.99	17.1	21.35	21	16.89	21.20	20.87	16.30	20.79	20.51
17-Feb	19.79	21.09	22.44	19.8	21.1	22.45	19.60	20.96	22.32	19.05	20.56	21.97
18-Feb	18.04	23.99	21.84	18.05	24	21.85	17.89	23.83	21.72	17.42	23.41	21.35
19-Feb	16.04	28.39	23.14	16.05	28.4	23.15	15.89	28.24	22.99	15.40	27.91	22.58
20-Feb	15.49	15.64	20.09	15.5	15.65	20.1	15.37	15.52	19.94	14.93	15.09	19.50
21-Feb	14.34	15.24	19.49	14.35	15.25	19.5	14.18	15.14	19.30	13.65	14.74	18.74

DATE	S1 1971-72	S1 1986-87	S1 2008-09	S2 1971-72	S1 1986-87	S2 2008-09	S3 1971-72	S3 1986-87	S3 2008-09	S4 1971-72	S4 1986-87	S4 2008-09
22-Feb	16.84	12.59	19.89	16.85	12.6	19.9	16.65	12.49	19.76	16.07	12.08	19.35
23-Feb	17.59	18.24	22.25	17.6	18.25	22.25	17.39	18.16	22.18	16.79	17.84	21.97
24-Feb	19.24	18.80	16.24	19.25	18.8	16.25	19.09	18.73	16.08	18.62	18.46	15.56
25-Feb	22.79	12.64	17.19	22.8	12.65	17.2	22.65	12.53	17.03	22.25	12.08	16.52
26-Feb	19.99	18.94	22.59	20	18.95	22.6	19.83	18.83	22.46	19.35	18.45	22.08
27-Feb	22.29	22.49	24.84	22.3	22.5	24.85	22.15	22.37	24.72	21.76	22.03	24.41
28-Feb	23.89			23.9			23.72			23.25		

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