An Analysis of a Healthy Housing Initiative and Its Implications for Public Policy

Jeffrey Colin Standen

A thesis submitted to fulfil the requirements for the degree of
Doctor of Philosophy

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Statement of Originality

This is to certify that to the best of my knowledge, the content of this thesis is my own work. This thesis has not been submitted for any degree or other purposes.

I certify that the intellectual content of this thesis is the product of my own work and that all the assistance received in preparing this thesis and sources have been acknowledged.

Mr Jeffrey Standen

30 August 2025

Dedication

I would like to dedicate this work to my mother, who instilled in me the value of continual life-long learning, gave encouragement along the way, but sadly did not live to proofread the final dissertation.

"Safe and functional housing is financially, socially and technically possible"

- Paul Pholeros (1953-2016)

Abstract

The New South Wales (NSW) Ministry of Health has been implementing the NSW Housing for Health (HfH) program since 1997, surveying and fixing hardware items in homes, such as plumbing and electrical items, that support householders to practice safe and healthy living. Using NSW HfH program data gathered from 1998-2017 and provided by NSW Health, this PhD thesis aimed to assess: if Aboriginal community housing in NSW functions to provide an environment that supports householders to practice safe and healthy living; if any changes in housing functionality over time are associated with the NSW HfH program; the financial cost of the NSW HfH program to bring Aboriginal community housing up to a minimum standard of functionality that supports householders to practice safe and healthy living; how a comprehensive economic analysis could be undertaken that includes the associated health, social, economic and intangible benefits generated from the NSW HfH program, and; the future challenges climate change presents for Aboriginal populations in NSW including implications for community housing and public policy.

The thesis describes the background to the NSW HfH program and reviews the literature to provide the context for the program as a NSW government strategy to address the inequity in Aboriginal health in NSW through targeting the living environment as a social determinant of health. The analyses presented quantify the contributions of the HfH program in improving housing conditions to achieve a minimum standard of house functionality that supports safe and healthy living practices. They also describe for the first time potentially influential social, demographic and geographic factors associated with the condition of housing in NSW, improvements in house functionality, and the fix-work costs associated with making improvements in house function over the 20-year period.

The thesis includes a scoping literature review to investigate methods for conducting a comprehensive economic assessment of the costs and benefits of the NSW HfH program. The review of international literature found that despite the scale of health concerns associated with physical housing considerations and the level of public investment, very few analyses of programs in housing explicitly consider health improvements. No economic evaluations appear to have been conducted to assess programs with the equivalent focus and breadth of the NSW Health HfH program. The thesis presents a protocol for an economic analysis comprising an ex-post cost-benefit analysis (CBA) that allows for a broad range of benefits potentially linked to the NSW Health HfH program to be quantified and monetised.

Using publicly available socio-demographic, meteorological and climate data, and future climate projections, the thesis quantified for the first time the impact of climate change on the exposure of Aboriginal populations in NSW and the future considerations for Aboriginal health and adaptation planning, including the role housing will play in supporting climate adaptation.

The thesis concludes by making a range of recommendations related to the NSW Health HfH program, the broader community housing sector, and the importance of strategies to support climate adaptation.

Authorship attribution statement

I collaborated with a range of co-authors on Chapters 4-8 of this thesis. Chapters 4, 7 & 8 and Appendix III have been published in peer-reviewed journals, and Chapters 5 & 6 were prepared as manuscripts for publication. I am the corresponding author on all published papers. I am the primary author on the publications in Chapters 4, 8 and Appendix III, and the manuscripts in Chapters 5 and 6. I am the supervising author on the publication in Chapter 7. The details of each author's contributions are listed with the preamble to each of those Chapters. Listed below are the details of the publications and manuscripts and a summary of my contributions to each.

Chapter 4 of this thesis is published as:

> Standen JC, Morgan GG, Sowerbutts T, Blazek K, Gugusheff J, Puntsag O, Wollan M and Torzillo P. "Prioritising Housing Maintenance to Improve Health in Indigenous Communities in NSW over 20 years". *International Journal of Environmental Research and Public Health*. 2020;*17*(16):5946. https://doi.org/10.3390/ijerph17165946

I conceived and designed the study; administered the study; oversaw the data management and statistical analysis and led the writing of the original draft and review and editing.

Chapter 5 of this thesis is written as a manuscript for publication:

> Standen JC, Ryan E, Mayne DJ, Sowerbutts T, Puntsag O, Matthews V, Spencer J, Barnett R, Torzillo P and Morgan GG. "Towards minimum standards for healthy housing in Aboriginal communities in New South Wales, Australia - are we there yet?" *Unpublished manuscript*.

I contributed to: Conceptualisation, Data Curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Validation, Visualisation, and led the writing of the original draft and review and editing.

Chapter 6 of this thesis is written as a manuscript for publication:

> Standen JC, Hedi J, Mayne DJ, Sowerbutts T, Puntsag O, Matthews V, Spencer J, Barnett R, Torzillo P and Morgan GG. "Bang for Buck: An analysis of costs associated with repairing housing for safe and healthy living in Aboriginal communities in NSW, Australia" *Unpublished manuscript*

I contributed to: Conceptualisation, Data Curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Validation, Visualisation, and led the writing of the original draft and review and editing.

Chapter 7 of this thesis is published as:

> Deeming S, Lawrence K, Standen JC. "The economic evaluation of a housing maintenance project to improve the health of Aboriginal housing tenants in NSW: A scoping literature review and protocol for an economic analysis". *Heliyon*. 2024;*10*(14). https://doi.org/10.1016/j.heliyon.2024.e34282

I supervised the project; assisted in acquiring project funding; conceptualised and co-designed the study; informed the literature search strategy; interpreted and validated the search results and proposed protocol; contributed original text and reviewed and edited drafts of the manuscript.

Chapter 8 of this thesis is published as:

> Standen JC, Spencer J, Lee GW, Van Buskirk J, Matthews V, Hanigan I, Boylan S, Jegasothy E, Breth-Petersen M, Morgan GG. "Aboriginal Population and Climate Change in Australia: Implications for Health and Adaptation Planning". *International Journal of Environmental Research and Public Health*. 2022;*19*(12):7502. https://doi.org/10.3390/ijerph19127502

I conceived and led the co-design of the study; acquired project funding; collaborated on the development of the methods, the implementation of the statistical analyses and interpretation of results; and led the writing of the original draft and review and editing. This is the final "corrected" version of the published paper (see below).

Appendix III of this thesis is a correction to the article in Chapter 8, published as:

> Standen JC, Spencer J, Lee GW, Van Buskirk J, Matthews V, Hanigan I, Boylan S, Jegasothy E, Breth-Petersen M, Morgan GG. "Correction: Standen et al. Aboriginal Population and Climate Change in Australia: Implications for Health and Adaptation Planning. *Int.J. Environ. Res. Public Health* 2022, *19*, 7502". *International Journal of Environmental Research and Public Health*. 2022;*19*(24):16378. https://doi.org/10.3390/ijerph192416378

As lead and corresponding author for the original publication, I supervised the corrections to the original manuscript with the co-authors and communicated with the

journal to ensure the corrections were published and the original electronic version was corrected.

Jeffrey Colin Standen

PhD Candidate

December 2025

As supervisor for the candidature upon which this thesis is based, I can confirm that the authorship attribution statements above are correct.

Professor Geoffrey Morgan

Supervisor

December 2025

Generative Artificial Intelligence

During the preparation of this thesis, I used *Grammarly* for text enhancements, including spelling and grammar checks and suggested paraphrasing of sentence structure. I confirm that where Grammarly suggested text modifications, the content was reviewed for possible errors, inaccuracies, and bias. I take full responsibility for the submitted thesis. I ensure the work is my own, and I have used generative AI within the parameters of the *University of Sydney Generative AI Guide for Researchers*

Disclosure of Interest Statement

As Manager of the NSW Health Aboriginal Environmental Health Unit, I have been responsible for the development and implementation of the NSW Health Housing for Health (HfH) Program for nearly 25 years. I have also delivered HfH projects interstate using the same HfH methodology. As NSW HfH Program Manager, I collaborated with the University of Sydney to develop a PhD proposal to review the first 20 years of the HfH Program and highlight future challenges for the program that would leverage both the strengths of academic research and the practicality of policy and program management.

To undertake the PhD, I have had to create a boundary between my roles as NSW Health Program Manager and University of Sydney PhD candidate. In my NSW Health role, I have access to the program data, and I supervised and led the cleaning and compilation of the NSW HfH project data into a single dataset. As a University of Sydney PhD candidate, I formally applied to the NSW Health data custodian for the release of the de-identified dataset for use in this research and publications that form part of my thesis. This PhD thesis is an analysis of the secondary data collected as part of the NSW HfH program.

My experience implementing the HfH methodology and managing the NSW HfH program has informed a deeper understanding of the data used in the studies and the results of the analyses related to the program. However, the potential also exists for my involvement in the program to influence the interpretation of the analyses. To address any potential bias, I worked closely with my University of Sydney lead supervisor and three co-supervisors to guide my research and ensure impartiality, and I have called upon external colleagues to review draft Chapters.

Reflectivity Statement

I came to this PhD later in life, having worked in Aboriginal public and environmental health for over 35 years. This PhD is a culmination of work by me and many others involved in the NSW Health Housing for Health (HfH) program over recent decades. After 20 years of implementing and evaluating the program, I felt I owed it to the people and communities that have opened their homes to HfH projects to use that information to the best of my ability to influence better policy, whilst respecting and protecting their confidentiality, and the confidentiality of the data. I elected to do this through a PhD to strengthen the quality and rigour of my work and to push myself to do the best I could. I deliberately chose a PhD by publication as I have come to believe that publishing peer-reviewed papers ensures a high standard of academic rigour and enables information sharing more effectively than relying solely on government reports.

In doing so, I draw from my experience working with Aboriginal communities across Australia, primarily in the Northern Territory and New South Wales, sharing experiences and listening to people's stories. Whilst I have learned much from my Aboriginal friends and colleagues over the years, I have learnt nothing more pertinent than to realise, as a non-Aboriginal male,-the extent to which I do not, and may never, understand Aboriginal culture from a lived experience perspective. Knowledge is not the same as understanding.

Acknowledging the bias and limitations of my own worldview and the potential for these to influence my research, I have increasingly sought to maximise input from Aboriginal people throughout the development of the NSW Health Housing for Health program and other programs I have been responsible for throughout my career. Through the development of training programs such as the NSW Aboriginal Environmental Health Officer Training Program (in parallel with the HfH program), the increasing input from a growing number of highly qualified Aboriginal environmental and public health practitioners continues to guide and improve the direction and cultural safety of my work and studies, including this thesis. To minimise any potential impact of cultural bias on my research, I have sought formal and informal input from Aboriginal environmental and public health practitioners, architects, policymakers, and researchers. My engagement with an Aboriginal Research Supervisor for this PhD and Aboriginal co-authors in the studies has been invaluable in guiding my learning and continuing to awaken me to subtle biases throughout the doctoral process.

Acknowledgements

The commitment to any PhD candidature is challenging enough. Combined with family, work, and community responsibilities, and a pandemic, my PhD journey over the past seven years has had its share of tribulations and disruptions. I am indebted to those around me, whose support, love and kindness encouraged and enabled me to persevere.

I would firstly like to acknowledge my primary supervisor, Professor Geoff Morgan, whose knowledge and mentorship have guided me throughout the course of my candidature. Geoff has been generously available, supportive, and understanding over the long journey. Along with my co-supervisors, Dr Darren Mayne, Associate Professor Veronica Matthews, and Clinical Professor Paul Torzillo, the knowledge, guidance, kind encouragement, and honest feedback from my supervisory team have been unequivocally invaluable.

I would like to acknowledge Professor Tess Lea, and the late Paul Pholeros AO, who both encouraged me to embark on this PhD many years ago, and the NSW Health Population and Public Health executive and management who were supportive of my PhD from its conception - particularly Dr Kerry Chant, Dr Jeremy McAnulty, Professor Wayne Smith, Dr Ben Scalley, Dr Richard Broome, and Dr Stephen Conaty.

To all my Aboriginal friends and colleagues, I am eternally grateful for your wisdom and guidance, and the magnanimity with which you have shared your knowledge and culture. I am particularly grateful to Professor Veronica Matthews, Jessica Spencer, Robert Barnett, Adam McEwen and Professor Gillian Barlow, who have shared their professional and cultural wisdom, given feedback and grounded my research.

Thanks also go to the co-authors and co-researchers who collaborated on my studies, for their involvement, subject matter expertise and dedication. Along with those already mentioned, this also includes Tim Sowerbutts, Otto Puntsag, Simon Deeming, Kerryn Lawrence, Grace Lee, Joe Van Buskirk, Ivan Hanigan, Sinead Boylan, Edward Jegasothy, Matilde Breth-Petersen and those biostatisticians on placement to my team from the NSW Health Biostatistics Training Program who assisted with components of data collation and analysis - Katrina Blazek, Jessica Gugusheff, Michael Wollan, Elizabeth Wilson, Ethan Ryan and Jordan Hedi.

This thesis is a small part of a much larger program of work that has been running for over two decades. Agencies and organisations often award new and innovative initiatives, and this has included the NSW Housing for Health program. Less acknowledged and rarely awarded are the continued efforts to routinely and devotedly implement those innovative initiatives. I acknowledge the NSW Health Environmental Health Program for its consistent efforts over 25 years, which have enabled the collection of a substantial body of novel and unique data used in this research. I would like to thank the Aboriginal community members, Project Managers, Team Leaders and others involved in delivering the NSW Housing for Health program - too many to list by

name - but who have worked tirelessly to improve the condition of houses. This includes the communities and families who opened their homes to the NSW HfH program survey teams. This thesis would not have been possible without everyone's trust, commitment and contributions.

To my friends and family, who I haven't seen much of in recent years, thanks for your understanding, and I hope to catch up with you all soon.

Finally, and most importantly, I want to acknowledge and thank unreservedly my family, Gus, Molly, and particularly Jenny, who have supported me throughout this long journey. You have endured my long absences along the way, allowed me the time to focus on writing, provided emotional and nutritional support, but most significantly, believed in me. I don't have words to express my gratitude. Thank you for your ongoing love, support and encouragement.

Scholarship Acknowledgement

This research was supported by an Australian Government Research Training Program (RTP) Scholarship.

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List of Abbreviations

ABS	Australian Bureau of Statistics
ACDP	Aboriginal Communities Development Program
ACHO	Aboriginal Community Housing Organisation
ACHP	Aboriginal Community Housing Provider
ACWSP	[NSW] Aboriginal Communities Water and Sewerage Program
AEHU	Aboriginal Environmental Health Unit
AHO	[NSW] Aboriginal Housing Office
AHURI	Australian Housing and Urban Research Institute
AIHW	Australian Institute of Health and Welfare
AP	Anangu Pitjantjatjara
ARF	Acute rheumatic fever
ARIA	Accessibility Remoteness Index of Australia
AWAP	Australian Water Availability Project
BOM	[Australian] Bureau of Meteorology
CALD	Culturally and Linguistically Diverse
CAR	Centre for Air pollution, energy and health Research
CBA	Cost-Benefit Analysis
CCA	Cost-Consequence Analysis
CEA	Cost-Effectiveness Analysis
CEE	Centre for Evidence and Evaluation
Census	Census of Population and Housing
CGE	Computable General Equilibrium
CHINS	Community Housing Needs Surveys
CHLP	Critical Healthy Living Practice
CMA	Cost-Minimisation Analyses
CNOS	Canadian National Occupancy Standard
CoESRA	Collaborative Environment for Scholarly Analysis and Synthesis
CPI	Consumer Price Index
CtG	[National Agreement on] Closing the Gap
CUA	Cost-Utility Analysis
DALY	Disability Adjusted Life Year
DCE	Discrete Choice Experiments
DPIE	[NSW] Department of Planning, Industry and Environment
ERP	Estimated Resident Populations

FFDI	Forest Fire Danger Index
FHBH	Fixing Houses for Better Health
GHQ-12	General Health Questionnaire-12
GNAF	Geocoded National Address File
HAS	Housing Affordability Stress
HfH	Housing for Health
HLP	Healthy Living Practice
HrQoL	Health related Quality of Life
ICD-10	International Statistical Classification of Diseases and Related Health Problems (ICD) Revision 10
IO	Input-Output Analysis
IRSD	Index of Relative Socioeconomic Disadvantage
LALC	Local Aboriginal Land Council
LYS	Life Years Saved.
MCDA	Multi-Criteria Decision Analysis
MFW	Major Fix Work
MLR	Multinomial Logistic Regression
NARCliM	NSW and ACT Climate Modelling
NATSIHS	National Aboriginal and Torres Strait Islander Health Survey
NATSISS	National Aboriginal and Torres Strait Islander Social Survey
NPARIH	National Partnership Agreement for Remote Indigenous Housing
NIHG	National Indigenous Housing Guide
NSW	New South Wales
PHU	Public Health Unit
QALY	Quality Adjusted Life Year
RA	Remoteness Area
RHD	Rheumatic heart disease
R&M	Repair and maintenance
SA	Statistical Area
SF	Survey-Fix
SF-36	36-Item Short Form Survey
SOMIH	State Owned and Managed Indigenous Housing
SWEMWBS	Short Warwick-Edinburgh Well-being Scale
TWT	Two Ways Together initiative
UPK	Uwankara Palyanyku Kanyinitjaku
USA	United States of America

USP	Usual Resident Populations
VOC	Volatile organic compound
VSLY	Value of a Statistical Life Year
WaSH	Water and Sanitation Hygiene
WA	Western Australia
WHO	World Health Organization

Glossary of Terminology

A glossary of terminology used to describe concepts and locutions unique to the content of this thesis has been provided in the table below.

Terminology	Description
Aboriginal	The original inhabitants of Australia (where the context does not also include the Torres Strait Islands). When referring to NSW, the term 'Aboriginal' is respectfully used in an inclusive way to refer to all Aboriginal and Torres Strait Islander people residing in NSW, in recognition that Aboriginal people are the original inhabitants of NSW.
Aboriginal and Torres Strait Islander	All original inhabitants of Australia, including the Torres Strait Islands.
Critical Healthy Living Practice (CHLP) Indicators	Refers to the 11 Indicators of house functionality that encompass safety, plus the first four most critical of the nine Healthy Living Practices, first published in 1986 in the Uwankara Palyanyku Kanyinitjaku (UPK) Report
First Nations	The original inhabitants of countries internationally. This term may include Australian First Nations people in this context
Fixing Houses for Better Health (FHBH) Program	A national program using the same methodology as the NSW Housing for Health program, which ran from 1999 to 2011.
Fix-work	Refers to the costs of trades and others to repair houses as part of a Housing for Health Project
Healthabitat	Means Healthabitat Ltd ACN 605 696 357, a company limited by guarantee and registered as a charity with the Australian Charities and Not-for-profits Commission (ACNC). All rights reserved. ABN 86 605 696 357
Health Hardware	The physical equipment needed to ensure housing and living environments support safe and healthy living, such as functioning taps, drains, electrical safety switches or hot water.
Healthy Living Practices (HLP)	Refers to the nine Healthy Living Practices first published in 1986 in the UPK Report
House condition	The physical condition of a house and its components.
House functionality	The capability of a house, or parts of a house, to function.
Housing for Health (HfH) Feasibility Assessment data	Community-level data collected at the start of a HfH project to plan and prepare for the implementation of a project. It includes general information on housing and infrastructure, housing management and logistics
Housing for Health (HfH) Financial data	Financial expenditure data on costs associated with the repairs to houses at each stage of a HfH project
Housing for Health methodology	The method developed and licensed by Healthabitat to survey and repair housing, using priorities intended to maximise safety and health benefits. The method includes the engagement of community members in the process and the immediate repair of any urgent items identified by the survey.
Housing for Health (HfH) Program	The NSW Housing for Health (HfH) Program, comprising many HfH projects and managed by NSW Health

Housing for Health (HfH) Program dataset	The consolidated dataset of NSW Health Housing for Health program and projects from 1998 to 2017. The Program data includes: • Survey-Fix data, • Financial expenditure data, • Feasibility Assessment data and • Community project metadata.
Housing for Health (HfH) Project	A single HfH project, comprising a before-and-after Survey-Fix of houses
Housing for Health (HfH) Survey data	The Results of the HfH house surveys
Indigenous	The original inhabitants of a country or countries internationally. In the Australian context, it includes Aboriginal and Torres Strait Islander Australians. (In this thesis, this term is used when directly referencing the literature or a title.)
NSW Health	The state health authority for the state of New South Wales (NSW), Australia
NSW Health Housing for Health Program	The Housing for Health Program, delivered in NSW by NSW Health.
NSW Housing for Health Program	The NSW Health Housing for Health Program
Survey-Fix	Refers to the process of surveying and repairing houses with community members. The process involves testing, recording, and fixing items in homes.
Survey-Fix 1 (SF1)	Refers to the first Survey-Fix in a HfH project. The data records survey results before any repair works commence.
Survey-Fix 2 (SF2)	Refers to the second Survey-Fix in a HfH project. The data records survey results after all repair works are completed.
UPK Report	The Uwankara Palyanyku Kanyinitjaku Report was a public and environmental health report of communities in North-Western South Australia
Visit	Refers to a complete HfH project in a community (which includes two surveys). Some communities had a project visit repeated some years later.

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Chapter 1
Introduction

1.0 Background

The association between the living environment and the health of populations has long been recognised, with poor housing described by the World Health Organisation (WHO) as one of the main social causes of ill health (1). Whilst Australians generally experience high standards of living and good health, such benefits are not always shared equitably. The policies and practices of colonisation and subsequent intergenerational trauma have had a fundamental and enduring impact (2) contributing to the large inequalities in housing and health experienced by Aboriginal people today in New South Wales (NSW) and across Australia (3, 4). Aboriginal people experience a disproportionately higher burden of disease than the non-Aboriginal population for many health indicators, including environmentally attributable infectious diseases, and related chronic conditions such as kidney and rheumatic heart disease (5, 6). They are also more likely to experience poor living environments, including substandard and overcrowded housing, poor water quality, sewerage infrastructure and other essential services (7). The functional state of housing infrastructure and health hardware – i.e., those items in the house that support safe and healthy living, such as electrical safety switches, taps, drains and hot water - has been identified as a key factor influencing the health of children in remote Aboriginal communities (8-11).

The condition of health hardware and the functionality of Aboriginal community housing in Australia to support safe and healthy living for residents has been previously studied and reported in the literature at a national level, and in remote and very remote jurisdictions of Australia (8-18). However, the condition of Aboriginal housing in NSW has not been specifically investigated, nor have any studies reported on the functionality of houses over an extended period, or where a project has been repeated in a community some years later. No extensive analysis has been undertaken of the cost to improve the functionality of houses over time or the impact of remoteness, and no previous studies have investigated the costs associated with differing levels of improvements in house functionality.

This thesis uses data collected by the NSW Health Housing for Health (HfH) Program over 20 years to examine the condition of Aboriginal community housing in NSW and the impact of the HfH Program over time, including associations with a range of geographic, social and other factors on house functionality not previously published. Financial data are linked to survey data to analyse changes over time and the influence of remoteness on expenditure, and to investigate the costs required to bring about varying levels of improvement in house functionality.

Building on this analysis of the NSW Health survey and financial data, the thesis examines the feasibility of conducting an economic analysis of the program to capture the broader cost-benefits and presents a protocol for future research. Looking forward, the thesis identifies for the first time the current and predicted impacts of climate on the Aboriginal population of NSW and discusses the implications for Aboriginal community housing.

1.1 The NSW Health Housing for Health (HfH) Program

Acknowledging the relationship between housing and health, the NSW state health authority, NSW Health, has been delivering Housing for Health (HfH) projects with NSW Aboriginal communities since 1997, applying a methodology developed in Central Australia by not-for-profit organisation, Healthabitat (19). HfH projects aim to identify, prioritise and repair items in houses that provide a physical living environment supportive of healthy living choices. The NSW HfH Program focuses on issues of housing design and functionality that support the health and safety of householders in the NSW Aboriginal community housing sector. NSW Health has delivered HfH projects across NSW in partnership with state and federal agencies and the Aboriginal community housing sector for more than 20 years (20, 21). Over this time, substantial administrative data has been generated primarily for prioritising the immediate repair of the most critical health hardware items in houses, managing program implementation and budgets, and informing evidence-based policy on the design and maintenance of Aboriginal housing. These data include information on over 300 items relating to design, repair and maintenance for each house collected before and after each project via a formalised survey. It also includes financial data on the cost of repairs to each house and other feasibility and metadata on each project. The survey data have been stored in electronic format by NSW Health since 1998.

Survey data from individual projects in NSW have demonstrated improvements against key indicators, and this information has been previously reported back to communities and funding providers by NSW Health. However, prior to this PhD project, collation and analysis of the HfH Program dataset by NSW Health had generally been ad hoc. With data available on over 100 projects across all parts of NSW from 1998 to 2017, collectively this data represents a potentially rich and valuable resource for providing insights into the condition of housing in the NSW Aboriginal community housing sector over time. The same HfH methodology, as implemented in NSW by NSW Health, has also been implemented in Aboriginal housing in other Australian states and the Northern Territory, but not as regularly or consistently as in NSW (20, 22). High-level descriptive analysis of this national HfH data has been previously presented (10, 18). However, the longevity, consistency and coverage of the NSW HfH data over more than 20 years allow for a more detailed and statistically robust analysis, providing an evidence base to improve program and project implementation (quality assurance) and influence future policy development for Aboriginal community housing in NSW for the public good.

1.2 Quantifying the Social and Economic Benefits

The HfH Program focuses on repairs to those aspects of houses associated with health improvement. A health outcomes study of the program after the first 10 years found significantly reduced hospitalisations for end-users of the program (23). Whilst this is likely to have an economic benefit for the health system, that evaluation did not include an appraisal of the program costings or other economic benefits. Additionally, there may be other less tangible outcomes that are likely to arise from the program, which may benefit families who could be juggling a range of other social demands within the home and extended family. Examples identified by project teams and communities include work opportunities, improved relationships between communities and local trades and local Public Health Units, or reduced stress from living in a functioning house. Such benefits have been postulated by community members and project and program managers, but not quantified (24), nor has any strategy or protocol been previously developed that identifies the best approach to achieve this. This thesis scopes the literature for economic analyses of physical housing interventions seeking to improve the health of residents. The thesis reviews alternative economic methods applied to

those relevant models and outlines a protocol for a cost-benefit analysis that accounts for the disparate health, social, economic and intangible benefits generated from the HfH Program (25).

1.3 Future Challenges for the HfH Program

Looking toward the future, temperatures in NSW are predicted to warm by 0.7°C by 2030 and 2.1°C by 2070 based on a medium CO_2 emissions scenario (26, 27), while the number of days over 35°C is expected to increase by approximately 20 days per year in coastal NSW and 40 days per year in north-western NSW by 2070 (26). Fire weather is expected to increase in western NSW in spring and summer, and rainfall is projected to decrease in spring and increase in autumn (26). The impact of these climate-related changes on Aboriginal people in NSW has not been previously quantified. Using publicly available data and modelling, this thesis identifies the impact climate change will have on the Aboriginal population of NSW, and discusses the implications for health and adaptation planning, including the role that housing and the NSW Housing for Health Program could play in climate adaptation in light of these predictions.

2.0 Thesis Aims and Research Questions

2.1 Thesis Development and Scope

This thesis is informed by my work with NSW Health over more than two decades implementing and developing the NSW Housing for Health (HfH) Program. As manager of the NSW HfH Program, I identified the need for more detailed and robust assessment of the program data and for more widespread peer review of the analysis, results and conclusions. Data from each of the projects over the first 20 years of the program were retrospectively collated into one dataset for review. I initiated discussions between the data custodian, Health Protection NSW (HPNSW), and the University of Sydney for a rigorous scientific review of this 20-year HfH dataset. These discussions informed the development of my PhD proposal and my application to HPNSW for the release of the deidentified HfH housing-related data to the University of Sydney for analysis and publication as part of this PhD thesis.

This thesis is not an evaluation of the Healthabitat Housing for Health methodology, which has been the subject of rigorous review and evaluation by communities, academics and government agencies since its development in the early 1990s and is considered an example of best-practice methodology in the field (23, 28-35). Rather, this thesis investigates more than 20 years of work with Aboriginal communities in NSW to improve the home living environments as a determinant of health, discusses the implications of the results of those investigations and considers future directions for Aboriginal housing over the coming decades.

The thesis includes two parts. Retrospectively, this thesis examines the data gathered by the NSW HfH Program during the process of repairing houses to improve health across NSW over 20 years. The NSW HfH dataset provides a rich source of information for the NSW Aboriginal community housing sector that, until this thesis, had not been available for analysis outside NSW Health. Prospectively, this thesis examines the key drivers and challenges for the program and Aboriginal community housing more broadly over the next 20 years and beyond.

This thesis aims to answer the following research questions:

1. Does Aboriginal community housing in NSW function to provide an environment that supports householders to practice safe and healthy living, and are any changes in housing functionality over time associated with the NSW Housing for Health program?
2. What is the financial cost of the NSW Housing for Health program to bring Aboriginal community housing up to a minimum standard of functionality that supports householders to practice safe and healthy living?
3. How could a comprehensive economic analysis be undertaken of the disparate health, social, economic and intangible benefits generated from the NSW Housing for Health program and the resources utilised to realise these benefits?
4. What future challenges does climate change present for Aboriginal community housing in NSW, and what are the implications for public policy?

3.0 Thesis Structure

This thesis contains nine chapters and three appendices. An outline of each is given below.

3.1 Chapter 1 Introduction

Chapter 1 provides the rationale for the thesis, including a brief introduction to the NSW Health Housing for Health (HfH) Program and the data generated by the program and defines the scope of this thesis. This chapter outlines the aims and research questions addressed by this thesis and provides an overview of each chapter.

3.2 Chapter 2 – Literature Review

Chapter 2 examines the national and international literature around health-related housing maintenance programs, prioritising literature relevant to Australian Aboriginal housing and health and NSW Health's Housing for Health (HfH) program. It provides an overview of the relationship between housing and health, Aboriginal population demographics in Australia and NSW, and social and cultural determinants of Aboriginal health in an historical context. The current literature around healthy housing is described in terms of housing security, suitability and affordability. An overview of the literature around economic analyses of housing and health initiatives (reviewed in more detail in Chapter 7) is also provided. The emerging impacts of climate change and the implications for the NSW Aboriginal population and Aboriginal community housing are also described.

3.3 Chapter 3 Data Collection, Data Consolidation & PhD Research Methods

Chapter 3 comprises two sections. Part 3.1 - NSW HfH Program Data Collection and Collation is provided to give context to the data collated by NSW Health through the HfH Program and analysed as part of this thesis. It provides an overview of the standardised Healthabitat HfH methodology used by NSW Health for data collection and prioritisation of maintenance work, over a 20-year period. It also includes an overview of the methods used by NSW Health to combine data from individual projects into a consolidated dataset of all available HfH projects over 20 years, from 1998 to 2017, which was provided to the University of Sydney. It should be noted that this PhD thesis is not an evaluation of the Housing for Health methodology, nor its implementation or administration. The thesis focuses on analysing data generated from HfH projects over a 20-year period. Part 3.2 - Research Methods provides an overview of the

descriptive analytical methods applied to analyse the consolidated HfH data used in this thesis to address the specific research questions. The methods for each separate analysis to address the research questions are described in more detail in Chapters 4 to 8.

3.4 Chapter 4 – Prioritising Housing Maintenance to Improve Health in Indigenous Communities in NSW over 20 years.

Chapter 4 was published in the *International Journal of Environmental Research and Public Health (IJERPH)*(36). It describes the development of the HfH Program in NSW, providing an overview of the program's methodology and implementation. The results from an initial analysis of program data over 20 years are presented, along with a discussion of the program's benefits and limitations. Descriptive analyses were used to describe the baseline condition of houses surveyed in participating Aboriginal communities *before* the Housing for Health (HfH) program was implemented and to compare the same houses *after* implementation to assess program effectiveness. Selected items from comprehensive before and after surveys of house hardware and design were used to define 11 Indicators of a house's ability to support occupiers to practice safe and healthy living. All survey items that comprise a Healthy Living Practice (HLP) Indicator must be fully compliant for an indicator to achieve a "pass". The study investigated whether there had been any change in these "pass/ fail" indicators over time. Using data from community houses that have received a repeat project, this chapter also investigates whether any program improvements in house functionality using the same "pass/ fail" indicators were sustained over time. (36)

3.5 Chapter 5 – Towards Minimum Standards for Healthy Housing in Aboriginal Communities in New South Wales, Australia – Are We There Yet?

Chapter 5 was prepared as a manuscript for future publication. It examines participation rates for Aboriginal Community Housing Providers (ACHP) and households in the NSW HfH projects over 20 years and describes the representativeness of the data to the NSW Aboriginal community housing sector. Using the same 20-year Survey-Fix dataset, a more nuanced classifier of house functionality than the "pass/ fail" indicator used in Chapter 4 was established. This was developed to determine (both *before* and *after* implementation): the extent of improvement required to achieve the minimum standard of house functionality prescribed by the Housing for Health priority indicators; whether there had been any change in house functionality over time; and whether Aboriginal community housing condition in NSW varied by survey, repeat projects, remoteness, evidence of housing maintenance activity, crowding (using occupancy ratios), and age of the house.

3.6 Chapter 6 – Bang for Buck: An Analysis of Costs Associated With Repairing Housing for Safe and Healthy Living in Aboriginal Communities in NSW, Australia.

Chapter 6 was prepared as a manuscript for future publication. Building on the previous analyses in Chapters 4 and 5, this study links the 20-year HfH Program survey data with financial expenditure data from 1998 to 2017 and examines the repair and maintenance fix-work costs (labour, materials, and on-costs) associated with improving house functionality in participating HfH projects. This novel analysis aimed to identify any change in fix-work cost over time and any associations by geographic remoteness. Using the same classifier of house functionality as that developed and described in Chapter 5, the analysis also aimed to identify

associations between fix-work costs and change in house functionality between project initiation and project completion.

3.7 Chapter 7 - The Economic Evaluation of a Housing Maintenance Project to Improve the Health of Aboriginal Housing Tenants in NSW: A Scoping Literature Review and Protocol for an Economic Analysis.

Chapter 7 was published as a review article in the journal *Heliyon* (25). Chapter 6 investigated the costs associated with improved house functionality through the HfH Program, but it was not intended to be an economic analysis of the overall HfH Program and did not attempt to quantify other social, economic and health benefits from the program. Chapter 7 considers whether and how to undertake a more detailed economic analysis of the HfH Program. Relevant economic evaluation policy is explored along with alternative economic models that may be applied to an economic analysis of a HfH project and to the whole program. It included a scoping literature review of economic evaluation methods applied to similar programs designed to improve the health of residents through improvements to physical housing assets associated with human health. Based on the insights from this review, discussions with HfH Program managers and the requirements of funding bodies and decision-makers, this Chapter presents a protocol for an economic evaluation of the Housing for Health program, taking into consideration other health, social, economic, and intangible benefits that may stem from the program (25).

3.8 Chapter 8 – Aboriginal Population and Climate Change in Australia: Implications for Health and Adaptation Planning

Chapter 8 was published in the *International Journal of Environmental Research and Public Health (IJERPH)* (37) and reviews the current evidence around the health risks of climate change for Aboriginal populations in NSW. Historical and projected climate data for NSW were mapped to NSW Aboriginal demographic data to describe the distribution of climate-related exposures for Aboriginal and non-Aboriginal populations in New South Wales (NSW), Australia. The Chapter describes the likely impact climate change will have on widening inequities in socio-economic outcomes, including health and housing, for NSW Aboriginal populations. The study identifies, with guidance from Aboriginal partner organisations, key challenges and issues associated with adaptation to these climate exposures and provides recommendations (37).

3.9 Chapter 9– Discussion and Conclusion

Chapter 9 summarises the key findings from Chapters 4- 8 in relation to the thesis aims and considers the implications for future public policy of housing initiatives to ensure safe and healthy home environments. It also describes the strengths and limitations of these studies; draws conclusions from the studies presented in this thesis, and makes a range of recommendations for public policy and further research.

3.10 Appendix I: Survey Items by Critical Healthy Living Practice Indicators

Appendix I presents a table of the Housing for Health (HfH) survey items from the NSW HfH Program data, used to calculate each of the Critical Healthy Living Practice Indicators described in Chapters 4, 5 and 6 of this thesis.

3.11 Appendix II: Release of the Housing Data

Appendix II contains the approval from the data custodian, Health Protection NSW, for the disclosure, use and publication of the housing data used in this thesis, including confidentiality undertakings. It also includes details of separate approvals by NSW Health to publish and cover costs of open-source publication for the published articles in Chapters 4, 7 and 8, and the prepared manuscript presented in Chapter 5.

The de-identified data used in the analyses in this thesis were collected by Health Protection NSW, NSW Ministry of Health, as part of their NSW Housing for Health (HfH) program. As part of the data release, Health Protection NSW advised that the HfH dataset did not require specific ethics approval as the data relate to house condition and do not include any personal or health information about individuals, nor identify specific houses or communities. Approval was received from the data custodian, Health Protection NSW, for the release of the housing data for analysis and publication under Health Administration Regulation 2020, Clause 16(2) – Disclosure of Information (Approval H23/56859; dated 8 August 2023).

3.12 Appendix III: Correction to Published Article

Appendix III of this thesis is a correction to the original version of the published article included in Chapter 8 of this thesis. The article included as Chapter 8 in this thesis, and available online, is the corrected version. The correction was published in the *International Journal of Environmental Research and Public Health (IJERPH)* (38). The minor correction pertains to an error that occurred during formatting changes of the accepted manuscript during copy editing, affecting some figures and a table. As the lead and corresponding author for the original publication, I supervised the corrections to the manuscript with the co-authors and communicated with the journal to ensure that the corrections were published, and the original electronic version of the full article was corrected.

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Chapter 2
Literature Review

1.0 Introduction

This Chapter examines the national and international literature around health-related housing maintenance programs, prioritising literature relevant to Australian Aboriginal housing and health and New South Wales (NSW) Health's Housing for Health (HfH) program. The review outlines the relationship between housing and health, and describes Aboriginal and Torres Strait Islander demographics, the social and cultural determinants of health in the context of colonisation, and the impact on Aboriginal health and housing. The current literature around healthy housing is described in terms of housing security, suitability and affordability. An overview of the literature around economic analyses of housing and health initiatives (described in more detail in Chapter 7), as well as the impacts of climate change on housing and health, is provided.

Throughout this Chapter, "First Nations" has been used to collectively describe the original inhabitants of countries internationally. "Aboriginal and Torres Strait Islander" has been used to describe all original inhabitants of Australia. Where a study only relates to Aboriginal people in Australia, the term "Aboriginal" has been used. As NSW is a focus of this thesis, and NSW Health delivers the NSW HfH program, the NSW Health communications and terminology policies have been used: when referring to NSW, the term 'Aboriginal' is respectfully used in an inclusive way to refer to all Aboriginal and Torres Strait Islander people residing in NSW, in recognition that Aboriginal people are the original inhabitants of NSW (1, 2).

2.0 Housing and Health

Since the early observations of physicians such as John Snow (3) and photojournalists such as Jacob Riis (4) in the mid to late 1800s, the inter-relationship between housing and health, the interconnection to socio-economic circumstances and the subsequent inequitable impacts on disadvantaged populations, has received considerable attention in the international literature (3-8). Historical and contemporary research suggests that housing conditions can have a significant impact on health, particularly among vulnerable populations, with numerous studies and systematic reviews highlighting the significant impact of housing on promoting well-being and preventing illness (6, 8-10).

Housing can impact health in several ways (11), and its importance is recognised in the United Nations Universal Declaration of Human Rights, signed in 1948. Article 25 recognises housing as a basic need and a fundamental human right to be universally protected (12). Improved housing conditions can protect and improve quality of life, prevent disease, reduce the risk of injury, and reduce poverty (13). Housing and basic amenities are recognised as social determinants of health by the World Health Organisation (14), and the importance of the relationship between housing and health underpins the WHO Housing and Health Guidelines (13). These guidelines also emphasise the growing importance of housing to health, particularly in light of global climatic and demographic changes. With increasing global populations,

changing weather patterns and increasing extreme weather events, the importance of safe and secure housing is ever-increasing (13). However, the relationship between housing and health is bi-directional, where one affects the other and vice versa (15). Figure 2.1 summarises the influence social determinants have over people's housing circumstances and the interrelationship between housing, health hazards and health outcomes. In turn, those adverse health outcomes affect people's capacity to earn and save, further impacting their economic determinants (16).

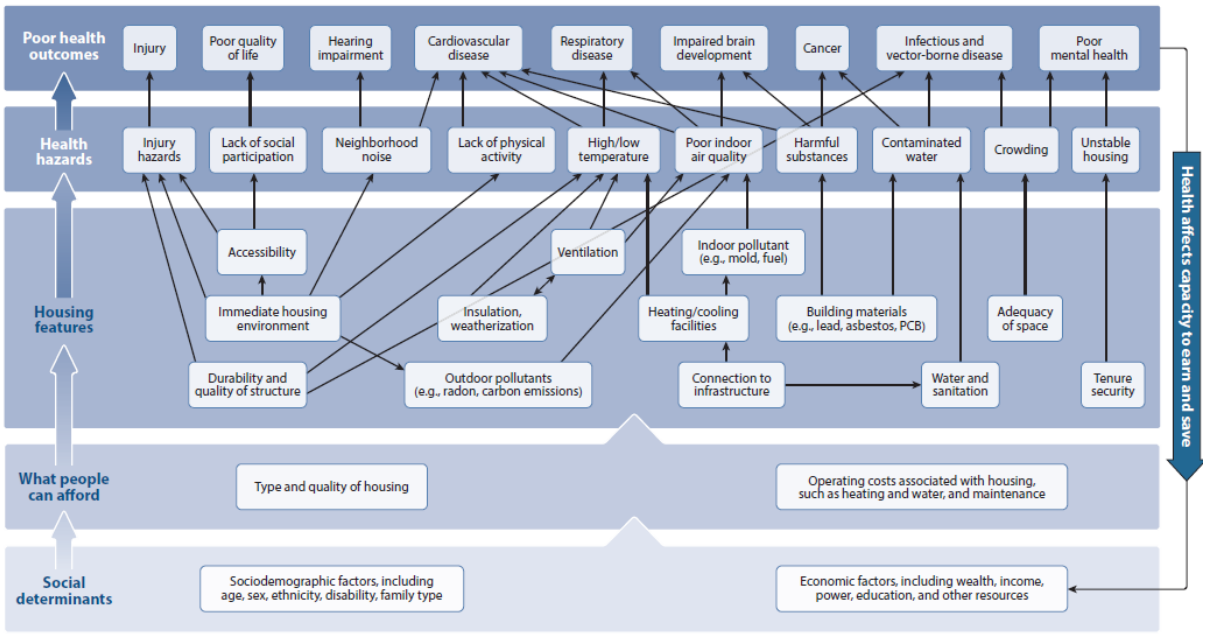

Figure 2.1: Housing pathways to health

Abbreviation: PCB, polychlorinated biphenyls.

Source: Philippa Howden-Chapman, et al., *Review of the Impact of Housing Quality on Inequalities in Health and Well-Being.* Annual Review of Public Health, 2023. **44**: p. 233-254

Despite substantial evidence of the association between housing and health, most published papers and systematic reviews on housing and health note the complexity of the relationship and acknowledge the difficulty in making causal links. Studies assessing the impacts of housing interventions on health face a range of difficulties, including controlling for confounding factors, relatively small intervention sample sizes, the quality of the underpinning evidence and lack of methodological rigour. This often limits attempts to accurately evaluate the precise influence of the impacts of housing interventions on health. As such, the literature recommends further research to strengthen the evidence (6, 8, 17-19). However, as early as the 1940s, Britten (1942) cautioned that this inability to demonstrate causality does not imply there is no influence of bad housing (5) and should not be an excuse for inaction in improving housing and living conditions (20).

Australia is a party to the International Covenant of Economic, Social and Cultural Rights, which enshrine the right to an adequate standard of living, including adequate food, clothing and housing (21). Australia has also expressed support for, but not yet ratified the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP), which affirms the rights of

Indigenous Peoples to the improvement of, and active involvement in developing their economic and social conditions, including housing (22). Australia is ranked among the top 12 economies in the world (23). However, despite these commitments and economic advantages, the benefits from housing are not shared equitably, and many Australians live with insecure, unaffordable or unsuitable housing (10, 24). With most of the Australian population living in good quality housing, Baker et.al. (2016) argue this leads to a dominance of a "good housing paradigm" whereby householders living in inadequate or unhealthy housing are doubly disadvantaged by the quality of their housing and the lack of acknowledgement by policy makers of the health effects of housing (25).

3.0 Aboriginal and Torres Strait Islander Population Demographics in Australia and NSW.

Using Australian Census of Population and Housing data, the Australian Bureau of Statistics (ABS) estimated there were 983,709 Aboriginal and Torres Strait Islander people living in Australia as at 30 June 2021 (26), representing 3.8% of the total Australian population (n=25,685,412) (27). This proportion has increased steadily from 2.4% in 2001 to 3.8% in the 2021 Census (27). Whilst more Aboriginal and Torres Strait Islander people (9.4%) live in very remote Australia than non-Aboriginal people (0.4%), over one-third of the Aboriginal and Torres Strait Islander population live in urban areas (n=401,674) (26). Around 1 in 5 Aboriginal people live in discrete Aboriginal communities (27) —usually former reserves and missions that, in NSW, are now designated Aboriginal land title under the NSW Land Rights Act 1983 (28).

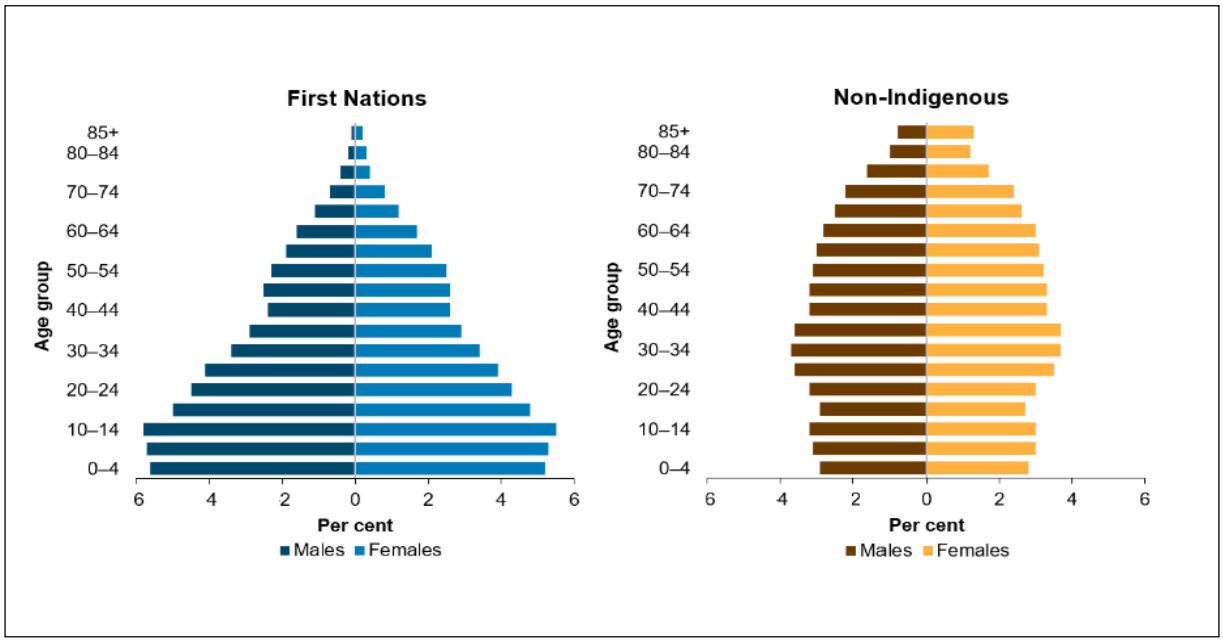

Figure 2.2: Australian population distribution by Aboriginal and Torres Strait Islander status, sex and age group, 2021

Source: Australian Institute of Health and Welfare. Aboriginal and Torres Strait Islander Health Performance Framework: Summary report March 2024. In: AIHW, editor. Canberra: Australian Government; 2024 (31)

Most of Australia's Aboriginal and Torres Strait Islander population (34.5%, n=339,710) live in New South Wales (NSW), where they represented 3.4% of the total NSW population (n=8,097,062) in 2021 (26). Similar to the Australian Aboriginal and Torres Strait Islander

population, the proportion of Aboriginal people in NSW has been increasing over recent decades (27). The geographical distribution of Aboriginal people in NSW is also similar to Australia, with higher proportions in regional and remote areas of NSW (particularly north-western NSW) than non-Aboriginal people, while most (40%, n=401,674) live in cities and urban areas (29, 30).

Figure 2.2 shows the age-sex population profiles of the Aboriginal and Torres Strait Islander population and the rest of the Australian population by 5-year age groups. The distribution of the non-Indigenous population shows similar proportions of the population in each age group and an increasingly large elderly population (31). Conversely, the Aboriginal and Torres Strait Islander population distribution shows a much younger population associated with higher rates of birth and mortality with age (31). This inequitable population distribution by age can be largely attributed to historical injustices and resultant socioeconomic disparities (30) described below.

4.0 Social and Cultural Determinants of Aboriginal Health

4.1 The Historical Context

Aboriginal culture is the oldest continuous culture in the world (32). Aboriginal knowledge systems have continued for more than 60,000 years, and sophisticated understandings of the world, including astronomy, geology and agriculture, caring for Country and living sustainably have been passed down between generations through storytelling, songs, dance, and ceremonies (33). These were actively disrupted by the arrival of European colonisers and the subsequent dispossession of Aboriginal populations across Australia (34). Foreign diseases, violent clashes and massacres decimated the Aboriginal population. The policies and actions of the colonising powers undermined the traditional mores and systems of law that underpin Aboriginal culture. Aboriginal people were forcibly removed from their traditional lands to government reserves and missions, used as slaves and forced labour, and traditional languages and cultural practices were banned. The ecological destruction of traditional lands for farming denied Aboriginal people access to traditional food sources. Children of mixed Aboriginal-European descent were forcibly separated from their Aboriginal parents, fragmenting kinship systems (34, 35). The legacy trauma of these historical injustices, along with ongoing structural and institutional racism, can be seen in the lasting and intergenerational impacts on the health, social, and economic circumstances, including housing, experienced by many Aboriginal and Torres Strait Islander Australians today (33, 36-38).

In contrast, cultural determinants of health can have a positive and protective influence on the health and well-being of First Nations people (39). These include maintaining cultural practices, language, relationships, identities, individual and community well-being, connection to land and waters and self-determination. (24, 40). Further studies of First Nations people's well-being aim to provide more evidence of the relationship of culture to health and well-being (41) and the need for long-term, coordinated, and place-based approaches that respect community priorities and embed participation (40, 42).

In its constitution, the World Health Organization (WHO) defines health as

> *"a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity"* (43).

This holistic approach to health and well-being aligns with Aboriginal knowledges and concepts described above. Recognising the importance of practising culture as a determinant of Aboriginal well-being, in 1989, the National Aboriginal Health Strategy defined Aboriginal health as

> *"a holistic concept which involves physical, emotional, spiritual, social, economic and cultural dimensions; it involves the notion that individual and community health cannot be separated from one another; it incorporates a central tenet of Aboriginal religion i.e. the cycle of life-death-life"* (44).

Both definitions acknowledge the influence of non-medical, social determinants on health, which the WHO describes as:

> *"the conditions in which people are born, grow, work, live, and age, and the wider set of forces and systems shaping the conditions of daily life".*

Determinants of health encompass economic, social, and political policies and systems that influence health. These determinants can influence health equity in both positive and negative ways and may be more important than access to healthcare services or genetics in influencing health (45). They include housing, basic amenities and the environment - the primary subject of this thesis - along with income, education, employment, childhood development, social inclusion, non-discrimination, and access to decent health services (14).

The health and corresponding social circumstances of Aboriginal people in Australia have been the subject of research and publication for over a century. In his 1932 dissertation, *Diseases of the Australian Aborigines,* Basedow (1932) summarised the extensive disease burden endured by Aboriginal Australians at the time (46). In the decades since, researchers and governments have continued to document the health and social circumstances of Aboriginal and Torres Strait Islander populations (24, 30, 47-49), identifying poorer outcomes for nearly all measures of health and social determinants compared to the rest of the Australian population (24). The more recent literature acknowledges the historical context described above and its impact on contemporary outcomes (50). The health, economic, social and political dimensions listed in the WHO's definition of social determinants are important drivers of the gap between the conditions in which Aboriginal people are born, grow, work, live, and age, and those of the wider Australian population (30). Higher proportions of Aboriginal people than non-Aboriginal people are born, but with double the infant mortality rate. As children grow, they are more likely to experience food insecurity and poorer nutrition, and present to health services with preventable diseases, including environmentally-related acute respiratory, gastrointestinal, skin, eye and ear infections. Aboriginal Australians are less likely to have post-school qualifications, employment, or own their own home. They are more likely to rent, live in multi-family households, live in crowded conditions, have no household internet connection, experience personal stressors (such as the death of a family member or mental illness), be incarcerated and/ or experience financial stress from limited household income. As they age, Aboriginal Australians experience higher rates of chronic diseases such as rheumatic heart disease, diabetes and kidney failure, and can expect to live around 8-9 years less than the rest of the Australian population (24, 42, 51).

The impact of social determinants such as racism and discrimination - either interpersonal (such as abuse, exclusion or stereotyping) or systemic (through policies and practices) - have been associated with poorer physical and mental health. Racism can impact health through

reduced access to social resources (including health care, education, employment, housing, and other services); psychological distress; an increased propensity for substance abuse and other risk-taking behaviours, or injury from assault (37, 38).

The Australian Institute of Health and Welfare (AIHW) estimates 35% of the total health gap between Aboriginal and Torres Strait Islander people and non-Indigenous Australians can be explained by social determinants, and an additional 30% by health risk factors such as smoking. The remaining 35% of the gap was unexplained, reflecting factors that may include cultural determinants such as access to affordable and culturally appropriate health care services, connection to Country and language, and effects of structural disadvantage and racism (31).

4.2 Comparison of Australian and Global First Nations Populations

The policies and practices of colonisation and subsequent intergenerational trauma have had a fundamental and enduring impact on health and disadvantage among First Nations peoples worldwide through social policies and systems that maintain disparities (35-37, 52). In economically developed countries like Australia, New Zealand, Canada, and the United States of America (USA), First Nations populations experience greater socio-economic disadvantage and poorer health outcomes than their corresponding mainstream populations.

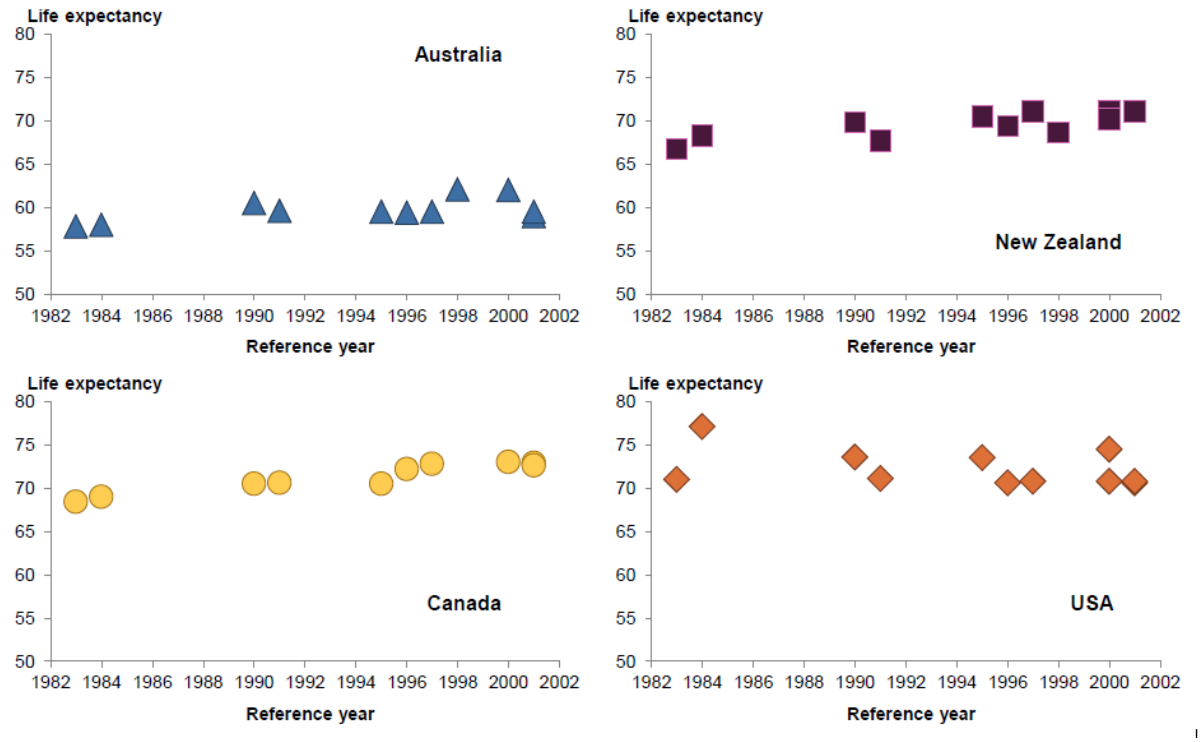

Figure 2.3: First Nations life expectancy estimates

Source: Australian Institute of Health and Welfare 2011. *Comparing life expectancy of Indigenous people in Australia, New Zealand, Canada and the United States: conceptual, methodological and data issues.* Cat. no. IHW 47. Canberra: AIHW.

However, comparisons of broad indicators of health, such as life expectancy, show First Nations Australians having lower life expectancy estimates than First Nations populations in those other countries (see Figure 2.3). Whilst caution is recommended when interpreting conclusions drawn from comparison studies between countries (due to differing concepts, definitions of

indigeneity, data and methods behind such estimates), the evidence indicates Australia has further to go to address its health inequities (53).

In addition to the social and health inequities discussed earlier, First Nations people, internationally and in Australia also face significant and ongoing housing and infrastructure challenges. These include limited access to affordable housing, overcrowding, and poor housing quality, including design, construction and maintenance, which can substantially elevate the risk of infectious diseases (54). These issues are more pronounced in remote and regional areas, but are also evident in urban settings (55-62) and highlight the need for adequate housing that supports the health and well-being of its occupants and inclusive housing policy that engages communities on housing design and needs (63, 64). These housing-related issues are explored in the following sections.

5.0 Healthy Housing

Healthy housing can be defined as housing that "sustains physical, mental and social health and well-being" (13, 14, 65) . This definition includes the physical structure of housing as well as its economic and social characteristics (65) and aligns closely with Aboriginal concepts and holistic definitions of health outlined in the National Aboriginal Health Strategy (1989) mentioned earlier (44).

5.0.1 Security, Suitability and Affordability

Mansour's conceptual model (Figure 2.4) organises housing and health concepts into three broad domains of Security, Suitability and Affordability (65). **Housing security** – often linked to tenure – relates to the assurance that occupants can live without fear of forced eviction, harassment and other threats. It includes issues of housing tenure, precariousness, homelessness, social housing, discrimination and displacement. **Housing suitability** refers to a house's ability to meet the needs of its occupants. It includes physical housing conditions, accessible, universal, and visitable housing, climate resilience, sustainability, and cultural

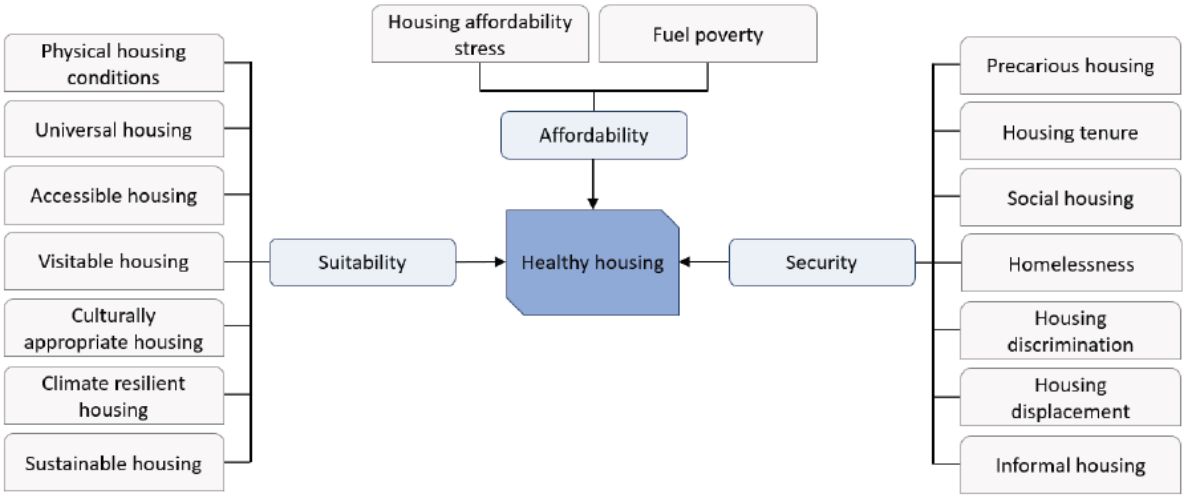

Figure 2.4: Conceptual model illustrating the organisation of the Housing and Health glossary

Source: Mansour, A., et al. (2022). *Housing and health: an updated glossary*. J Epidemiol Community Health **76**(9): 833-838.

appropriateness. **Housing affordability** relates to the cost of housing (including rent, mortgage repayments, repairs, maintenance and utility costs) relative to income.

The broad range of issues in Aboriginal housing, including those assessed in this thesis, are interrelated and cut across all three of these domains (65). The studies reported in this thesis relate largely to issues of:

- housing suitability - particularly in relation to the ability of housing to support safe and healthy living practices, and;
- housing affordability and housing security - in relation to climate change adaptation.

5.1 Housing Security

Colonisation, Discrimination and Housing Inequality

It's not possible to consider issues of housing security without considering the historical context and the policies that have, and still do, affect First Nations people globally. Many First Nations people describe structural barriers to accessing and maintaining adequate housing. Racism and discrimination persist as major barriers for many First Nations populations, compounding other social and health inequities. (36, 66). Native American and Māori populations describe frequently encountering discrimination in access to housing and healthcare, leading to disparities in housing and contributing to homelessness and decreased home ownership rates(52, 67-69). This context of discrimination is pivotal in understanding the barriers to housing stability and the subsequent effects on physical and mental health.

Aboriginal populations in Australia face unique challenges related to housing and health, intricately linked to historical and socio-cultural factors (70). Historical and contemporary policies and practices in Australia continue to contribute to a legacy of neglect, systemic disadvantage and structural racism that significantly affects Aboriginal peoples (71). The inter-generational impacts of colonisation have led to dispossession, displacement, and the disruption of traditional lifestyles, resulting in significant socio-economic disadvantages, including inadequate housing and infrastructure (66). The assimilation and protectionist policies of the government during the 19th and early 20th centuries marginalised Aboriginal communities (10, 36). These historical injustices have had lasting impacts, contributing to the current disparities in housing and health outcomes. Despite legislative advancements and commitments to improve housing conditions, these disparities persist (10, 36, 72, 73). Bailie and Wayte (2006) note that in rural and remote communities, these housing issues coalesce, exacerbating health inequities through a cycle of poverty and health disadvantage (10). The work of Andersen 2016-2018 found that similar frustrations and inequities exist for urban Aboriginal people (56, 57).

Stanton et al. describe how this historical trauma and social marginalisation have led to mental health challenges for Aboriginal populations, and why integrating mental health considerations into housing policy discussions is critical for fostering community resilience and improving overall health (74). Research suggests that incorporating First Nations cultural safety into housing support is crucial for maintaining housing stability (75, 76) and can significantly enhance health outcomes. The literature also emphasises the utility of culturally competent community-led initiatives that leverage traditional knowledge and practices. (77-80). Relevant services and programs that consider First Nations people's historical contexts and communal values are more likely to succeed (66, 79) highlighting calls for culturally competent services (81). Research also points to the necessity for holistic housing policy frameworks that

encompass intersecting health determinants—education, employment, and access to healthcare services—to address the broader socio-economic landscape faced by Aboriginal Australians (81, 82).

Housing Tenure

Another key determinant of housing security is the type of tenure. The three main types of tenure include homeownership, private rental, and social housing. Home ownership, usually considered the most secure tenure, provides occupants with a high level of protection from forced eviction or relocation. The security that private rental and social housing affords occupants in Australia varies jurisdictionally but generally offers less security to the occupants (65). Recent research in urban Aboriginal populations indicates these occupants are also more likely to experience the poorest dwelling conditions (58).

In Australia, Aboriginal and Torres Strait Islanders are less likely to own their own home and more likely to live in rental accommodation. The 2021 Census reports 42% of Aboriginal and Torres Strait Islanders owned their house, either with (28%), or without (14%) a mortgage, and home ownership has increased over the previous 20 years from 33% in 2001. However, most Aboriginal and Torres Strait Islanders (56%) live in rental accommodation, including 35% renting privately, 18% in social housing and 2.7% in another tenure arrangement. The proportion of Aboriginal and Torres Strait Islander households renting privately increased while the number in social housing decreased between 2001 and 2021. The Australian Institute of Health and Welfare (AIHW) National Housing Assistance Data Repository indicates there were around 79,166 First Nations households living in social housing as at 30 June 2022 (83).

Social Housing in Australia and NSW

This section describes the social housing sector in Australia and NSW, from which much of the data on the housing repair and maintenance component of this thesis is derived. Social housing has been defined as *low cost or subsidised rental housing provided by state and territory governments and the community sector…..to assist people who are unable to afford or access suitable rental accommodation in the private rental market* (83).

As of June 2023, there were around 446,000 social housing dwellings in Australia (84). There are generally four categories of social housing in Australia that are potentially accessible to Aboriginal people, as shown in Table 2.1. There are both public and community housing sectors, and within each, there is a sector of housing specifically allocated to Aboriginal people. Publicly owned social housing is the most common type of social housing, comprising both mainstream social housing (accessible to all people) and Aboriginal social housing. Publicly owned Aboriginal social housing is sometimes referred to as State Owned and Managed Indigenous Housing (SOMIH). The community housing sector is generally managed by not-for-profit organisations, which have both mainstream community housing and Aboriginal community housing (83). Aboriginal community housing in NSW includes housing owned by Local Aboriginal Land Councils (LALCs) and Aboriginal Community Housing Organisations (ACHOs). Some LALC housing is on discrete Aboriginal communities and predominantly located in rural and regional locations. Both LALCs and ACHOs may also own houses in country towns, regional centres and major cities.

Three-quarters of public housing dwellings in Australia are in major cities, and Aboriginal and Torres Strait Islander-specific housing is predominantly situated in very remote areas. Since 2006, there has been a gradual increase in community housing stock, while public housing has been declining in Australia (84). Transfer of ownership from public to community sectors may

have contributed to this change. The NSW social housing data shows a similar pattern of change to that throughout Australia (85, 86).

Table 2.1: Number of houses in each of the four social housing sectors potentially accessible to Aboriginal people in NSW in 2023 and 2024 (85, 86).

	Mainstream Housing (Aboriginal and non-Aboriginal tenants)	**Aboriginal Housing** (Aboriginal tenants only)
Public housing	Publicly owned and managed mainstream housing. *NSW Land and Housing Corporation* 95,765 houses (2023) 94,470 houses (2024) [-1295]	State Owned and Managed Indigenous Housing (SOMIH). *NSW Aboriginal Housing Office* 3737 houses (2023) 5380 Houses (2024) [+1643]
Community housing	Community Housing Organisations. *Non-government organisations* 49,275 houses (2023) 49,516 houses (2024) [+241]	Aboriginal Community Housing Sector *Local Aboriginal Land Councils and Aboriginal community organisations* 5504 houses (2023) 6,539 houses (2024) [+1035]

Sources: NSW Dept Communities and Justice (2024, 7 Apr 2025). "Social Housing Residential Dwellings Dashboard." Retrieved 18 May 2025, from: https://public.tableau.com/app/profile/dcj.statistics/viz/Social_Housing_Residential_Dwellings_17032188360200/Dashboard?publish=yes.

In NSW, around one-third of Aboriginal households live in social housing, compared to six per cent of non-Aboriginal households (87). NSW public housing is almost double the size of community housing in the mainstream housing sector, while community housing is larger than public housing in the Aboriginal community housing sector (Table 2.1). The numbers in each domain vary over time, as ownership can be transferred from one domain to another (for e.g., from government to community housing) in line with current policy or as houses are purchased, built, lost to fire, termites, extreme events, or reach the end of their economic life. This can be seen in the change of house numbers in the square brackets in Table 2.1, for the one-year period 30 June 2023 to 30 June 2024 (85, 86). The data provided by NSW Health and presented in Chapter 5 also shows a variation in house numbers in the Aboriginal community housing sector over the period 1998 and 2017, compared to the 2023 and 2024 data.

5.2 Housing Suitability

Several characteristics can determine the suitability of housing and its ability to meet the occupants' needs (65). Some items are general requirements for any occupants, such as safe and sustainable power, water and waste infrastructure and appropriate hygiene and sanitation facilities. Others may be specific to geography and climate, cultural mores or to specific individual needs such as disability access (65). The suitability of housing comprises more than just the house structure and the wider home living environment. It can also incorporate issues

of community planning, orientation, housing design and specification, construction quality, and the ongoing functionality of housing (88).

The Home Living Environment and Health

The World Health Organization's 2016 report on *Preventing disease through healthy environments*-estimated that around 22% of the global burden of disease is attributable to environmental factors, and 26% of child deaths could be prevented if environmental risks were removed (89). Housing and community are identified in this report as a key primary prevention opportunity. A study of primary health care attendance in the Kimberley Region of Western Australia (WA) found that over 20% of attendances were attributable to environmental factors. This was significantly higher for Aboriginal patients than for others, while for Aboriginal children 0-4 years old, the study estimated that over 25% of attendances could be prevented by addressing environmental factors (90).

A study comparing the time spent indoors in New Zealand to the USA, Canada, Germany and the United Kingdom, found that around two-thirds of a person's time was spent in the indoor home 'microenvironment' (91). The temperate climate in Australia (92) compared to New Zealand, may result in people spending more time outdoors than in the generally colder nations assessed in the study. Healthy housing extends beyond the walls of the home into surrounding environments (63, 65, 93) and the home living environment (indoors and outdoors) is where we spend most of our time (91, 94). Additionally, vulnerable groups such as infants, children, the elderly and those affected by chronic illness or living with disability spend even more of their time in the home environment (91). It should be noted that the New Zealand study (cited above), found that the estimated time spent indoors did not include time spent in 'other people's houses' (91). In communities with higher levels of unemployment, including Aboriginal communities (24), this exposure to the house and home environment would most likely be increased.

Housing and living environments are associated with a wide range of physical and mental health conditions and social well-being (8, 65, 95). It is widely documented that poor housing conditions, including overcrowding and inadequate sanitation, can lead to the spread of infectious diseases (13). A lack of adequate infrastructure such as power, water supply, sanitation and waste disposal in and around houses can lead to increased risk of environmentally attributable disease conditions, including gastroenteric, skin, and respiratory diseases, as well as eye and ear conditions such as trachoma and otitis media (5, 9, 13, 61-63, 90, 96-103). The physical living environment can also be associated with serious safety issues and injuries, including building structural defects, electrocution, fire egress and fall risks in disabled or frail aged residents and visitors (10, 13, 104-106). Housing can also expose occupants to physical contact with contaminants historically related to building products, such as lead or asbestos (107, 108), and volatile organic compounds (VOCs) found in contemporary products, such as adhesives and vinyls (13, 109). Mansour (2022) points out that all these interrelated aspects of housing can be either detrimental to or protective of health (65).

Globally, many First Nations communities experience overcrowding and other housing and living conditions that are considerably worse than the corresponding national average housing standards (110). Research in Australia documenting the condition of Aboriginal and Torres Strait Islander housing and the link to health (discussed below) is supported by similar international research, particularly in Canada (111-114), New Zealand (115-118) and to a lesser extent, the USA (52, 76, 119-121).

In New Zealand, the University of Otago's He Kāinga Oranga/Housing and Health Research Programme has led several studies that have demonstrated health and economic benefits from housing improvements with Māori and Pacifica communities. This work, spanning over 25 years and recently summarised by Howden-Chapman et al. (122), includes key studies by Howden-Chapman et al. (116, 117), Bennett et al. (123), Telfar-Barnard et al. (118, 124), and Chisholm et al. (125, 126). These studies have demonstrated health benefits, particularly for respiratory conditions, from improvements in insulation, heating, and other measures to reduce household cold and improve energy efficiency, as well as rectifying home hazards. They have also trialled systems to improve housing standards related to health, safety and energy efficiency, and called for the introduction and enforcement of basic minimum standards for housing through a "warrant of fitness" assessment, similar to a vehicle registration system (118, 123-125). The house assessment criteria used in these NZ studies are similar to those used in the NSW HfH assessments. In Canada, studies by Larcombe et al. (113), Shapiro et al. (114), Anwar et al.(112), Kirychuk et al. (111), and Hyslop et al. (127) have recorded crowding and inadequate conditions in First Nations housing, and described associations with self-reported respiratory health outcomes, including chronic bronchitis and tuberculosis. Similar to the New Zealand literature, the Canadian household surveys have focused mainly on issues related to crowding and/or housing conditions with a particular concern for issues associated with cold temperatures, such as mould and damp.

Several Australian studies of Aboriginal housing conditions and health outcomes have also identified unsuitable housing, particularly regarding crowding and the functionality of water and sanitation hardware and/or hygiene facilities in homes. Researchers, including Bailie et al. (59, 61, 128, 129), McDonald et al. (130) and Hall et.al. (131), investigated the impact of housing and hygiene interventions on common childhood illnesses in the NT, including skin, respiratory and diarrheal disease. National housing surveys have also identified poor housing conditions in Aboriginal and Torres Strait Islander housing across the country (26, 132-135). NSW Health's Aboriginal Environmental Health Unit investigated the impact of housing improvements from the NSW HfH program on skin, respiratory and gastrointestinal hospitalisations (136). More recently, Andersen et al. investigated associations between housing condition and gastroenteritis in a large urban population in NSW (55, 58). Housing conditions and housing quality are discussed in further detail in this section.

In addition to this literature describing the relationship between poor housing conditions and infectious disease, there is also considerable evidence acknowledging the mental health impacts of poor housing conditions and homelessness (137, 138). Canadian research on the psychosocial impacts of inadequate housing identifies elevated rates of stress, anxiety, and depression (139). Chronic stressors, including housing instability, have been associated with mental health differences in American Indian and Alaskan Natives (69, 76), a finding echoed by Haitana et al., who found that inadequate living conditions and housing discrimination impair the overall mental and physical health of Māori populations in New Zealand (140). Aboriginal people in Australia are more likely than other Australians to suffer from life stressors (such as the death of a family member, chronic illness, inability to find employment and mental illness) (24), which can be exacerbated by poor housing conditions (137, 141). The NSW Housing and Mental Health Agreement implementation guidelines acknowledge that not only does housing affect mental health, but people with mental health disorders often experience difficulties in accessing safe, affordable and stable housing (142). For example, the guidelines report that a greater proportion of people in social housing in NSW have mental/behavioural conditions than in the mainstream population. Conversely, policies and programs aimed at improving housing

also serve as mental health interventions. (74) Firestone et al., found that culturally relevant housing programs integrated with health services in Canada fostered supportive community environments and significantly improved mental health outcomes (79).

Crowding and Health

Crowding in Aboriginal housing in Australia is often defined using the Canadian National Occupancy Standard (CNOS) (143) including by the AIHW (144). The CNOS was created by Canadian federal, provincial and territorial governments in the mid-1980s to provide a common reference point for "suitable" housing based on how many people a given dwelling unit might accommodate, given the number of bedrooms.

Under the Canadian National Occupancy Standard, suitable housing is based on the following criteria:

- *A maximum of 2 persons per bedroom*.
- *Household members, of any age, living as part of a married or common-law couple share a bedroom with their spouse or common-law partner*.
- *Lone parents, of any age, have a separate bedroom from their children*.
- *Household members aged 18 or over have a separate bedroom, except those living as part of a married or common-law couple*.
- *Household members under 18 years of age of the same sex may share a bedroom, except lone parents and those living as part of a married or common-law couple*.
- *Household members under 5 years of age of the opposite sex may share a bedroom if doing so would reduce the number of required bedrooms (143)*.

In Australia, low-income families, Aboriginal and Torres Strait Islanders and those from Culturally and Linguistically Diverse (CALD) backgrounds, specifically recent migrants, are disproportionately affected by household crowding (145). Overcrowding has been linked to negative impacts on health and well-being, such as increased incidences of infectious diseases (particularly respiratory conditions including asthma), chronic diseases, lead poisoning, injuries, stress and mental health, lack of privacy, noise and antisocial behaviour (54, 145-147). A scoping review by Lorentzen found that hazardous dwelling condition characteristics of relevance to health (e.g. mould, lead, rodent or cockroach infestation, leaking plumbing) often coincide with overcrowded dwellings (148). The review found that while overcrowding can be associated with a range of social and other circumstances that may affect health, the epidemiological attribution of causality is difficult, and called for more research on the effects of overcrowding on dwelling conditions. Despite this, numerous primary studies and reviews indicate that environmentally attributable infectious disease conditions can be exacerbated in crowded housing (54, 145, 147, 149). Not only is disease transmission increased in crowded conditions, but the infrastructure and hardware that support healthy living in houses are also put under additional pressure in crowded conditions. The "health hardware" i.e. the physical equipment needed to ensure housing and living environments support good health (150) (such as taps, toilets, stoves and other fixtures and fittings), are being used more often, by more occupants and therefore more likely to reach the end of their functional life sooner (54, 93, 131, 148).

However, crowding does not always have a negative impact on occupants (145), and whilst the CNOS provides a useful measure for overcrowding in dwellings, it does not necessarily reflect a household's experience of overcrowding (144). Living in a large, well-functioning household has also been self-reported to have a positive impact, with respondents citing the benefits of close family networks, strengthening family ties, allowing for care of relatives, promoting cultural identity and financial benefits. Dockery notes that the use of the CNOS to classify overcrowding doesn't consider cultural differences in living and sleeping arrangements and therefore may not reflect the experiences of Aboriginal households (145) where connection to family is an underpinning value of Aboriginal culture (35). However, whilst there may be cultural preferences for living with extended families, mainstream nuclear family housing design doesn't fit with these preferences (54, 88, 151). Aboriginal or CALD populations may not necessarily choose to be 'overcrowded' as per the CNOS definition; they just may not have a choice.

In First Nations communities internationally, crowding is often identified as a form of housing inadequacy (110). Surveys of rural First Nations communities in Saskatchewan demonstrate they experience significantly higher rates of overcrowding compared to Canadian national averages, with associated respiratory health risks that exacerbate existing health disparities among community members (111, 112, 127). A systematic review by the New Zealand Ministry of Health reported disproportionately high rates of rheumatic heart disease in the Māori and Pacific populations of New Zealand have also been linked to overcrowding, contributing to increased rates of Group A Streptococcal throat infections (152) More contemporary research in New Zealand by Baker et al. in 2022 supports these findings, identifying the importance of household crowding, along with access to primary health care, as strong modifiable causal factors in the development of acute rheumatic fever (153).

Across Australia, overcrowding is a widespread issue affecting many Aboriginal and Torres Strait Islander communities, with households three times more likely to experience overcrowding compared to non-Indigenous households (83). While Census data indicate an improvement over the last 20 years in the number of Aboriginal and Torres Strait Islander people living in crowded housing (83), studies reveal that the impact of overcrowded housing conditions on health in Aboriginal communities remains substantial (10, 24, 54). The Australian literature demonstrates significant health challenges from overcrowding through greater susceptibility to household transmission of respiratory, skin and other communicable diseases, leading to severe chronic complications such as rheumatic heart disease (154-158). Overcrowding in Aboriginal communities can also lead to reduced privacy, sleep deprivation and increased stress and mental health issues (103). Although overcrowding is higher in remote and rural communities (83), studies focusing on urban Aboriginal families in NSW highlighted a high prevalence of housing problems, including overcrowding in these settings (57, 58).

A scoping review of homelessness among First Nations peoples in Australia, Canada and New Zealand revealed that they are overrepresented within homeless populations in all three countries and identified that addressing temporary housing needs for mobile First Nations populations forms a critical gap in current housing policies (159). With 3% of Aboriginal and Torres Strait Islanders homeless, representing 20% of homeless Australians, temporary homelessness in Aboriginal and Torres Strait Islanders communities is an overlooked area of housing need(160). It can be associated with cultural mobility (such as for funerals or ceremony business), resistance to engaging with mainstream services or involuntary exclusion. Habibis (2011) highlights the necessity of creating responsive housing strategies for Aboriginal and

Torres Strait Islander peoples who experience temporary homelessness and cultural mobility, which significantly affects their access to stable and adequate housing (160).

Occupancy ratios may be reduced through the construction of new housing or the addition of bedrooms to existing housing (81, 161). Various governments in Australia have invested heavily, albeit sporadically, in these initiatives over several decades (161-164). However, Pholeros et al. argue that the focus should not solely be on increasing the number of houses but on ensuring that essential health infrastructure, such as clean water and waste management systems and functional housing are adequately addressed within communities (165). Functioning health infrastructure and hardware in a house are likely to relieve some health impacts of crowding by ensuring all residents can practice healthy living, such as washing, toileting and cooking (54, 131, 161). The specification of high-quality health hardware (such as plumbing and electrical parts) that can withstand higher usage can reduce the failure rates of this critical hardware due to overuse. Consideration of the appropriate design of housing and yard areas - including external living areas such as verandas and externally accessible water and ablutions - can also contribute to overcoming the impact of crowding, particularly from temporary crowding in houses (100, 105). Analysis in Chapter 5 of this thesis investigates the impact that occupancy ratios may have on maintaining and improving housing conditions in Aboriginal Housing in NSW.

Housing Conditions and Housing Quality

Extensive international literature demonstrates an association between housing conditions and health outcomes, particularly in socially and economically disadvantaged populations (6). Whilst establishing causal links in such epidemiological studies is challenging, there is clear evidence that housing conditions can impact both physical and mental health (6, 9, 165, 166). In Australia, some Aboriginal and Torres Strait Islander health and housing literature calls for further research to measure health status and demonstrate improved health outcomes from housing improvements (19). Baker (2016) describes how research into the relationship between housing and health has moved away from focusing on basic housing and sanitary conditions as a determinant of health to a more complex understanding of the relationship (25). This is largely because, as a whole, there is little evidence of the negative effects of poor-quality dwellings for the non-Aboriginal population of Australia, as most Australians live in good-quality housing. Pholeros et al.(2013) maintain that whilst a deeper understanding of the relationship between housing and health is of interest, for Aboriginal and Torres Strait Islander communities in Australia who do not have basic housing and sanitary conditions, it may not lead to the desired health benefits without firstly ensuring access to this basic hygiene and sanitation hardware. (165).

Despite geographic, cultural and climatic differences, First Nations groups globally share similar challenges and generic housing issues (165). Similar to the situation with overcrowding, First Nations communities internationally also experience poor quality housing. While housing quality research in colder climates such as NZ and North America have a strong focus on mould, damp, insulation, temperature control, and structural deficiencies (16, 94, 111-113, 116, 117, 122), studies seldom assess the availability and functionality of hygiene and sanitation facilities to support healthy living. Where they do, the research often uses self-reported rather than objective assessments of health-related hardware functionality (55, 111, 112, 116).

Aboriginal Australians also experience housing and living conditions far worse than the general population, and this has been widely documented over several decades (46, 151, 167). In the

early 1980s, Waterford noted the link between the living environment and health and described the irrationality of the health care system, continually providing medical treatment without addressing the wider social and public health issues within Aboriginal communities (167). Waterford also noted that public health measures do not necessarily entail European patterns of socialisation and housing.

In the mid-1980s, the Nganampa Health Council Inc., the South Australian Health Commission, and the Aboriginal Health Organisation of SA commissioned a landmark report on the state of public health in the Anangu Pitjantjatjara (AP) Lands in the North-West corner of South Australia. The report, known as the *Report of Uwankara Palyanyku Kanyinitjaku: An Environmental and Public Health Review within the Anangu Pitjantjatjara (AP) Lands* (or *UPK Report*), considered the broader social determinants of health and provided a strategy to address the extensive environmental and public health needs of the Aboriginal communities on the AP Lands (63). The report outlined a list of nine evidence-based Healthy Living Practices (HLPs) that individuals need to maintain a healthy lifestyle, while also highlighting that the poor condition of existing environmental and public health infrastructure fails to support these practices. The nine HLPs were prioritised with the first being the most critical:

1. Washing People
2. Washing clothes and bedding
3. Removing wastewater safely
4. Improving nutrition, the ability to store prepare and cook food
5. Reducing the negative impacts of crowding
6. Reducing the negative effects of animals, insects and vermin
7. Reducing the health impacts of dust
8. Controlling the temperature of the living environment
9. Reducing hazards that cause trauma (63).

At the time of the UPK Report, little to no work existed that detailed the elements of the living environment that contribute to poor health, nor prioritised their repair to maximise health benefit in a limited fiscal environment (165). Building upon the work of the UPK Report, a not-for-profit non-government organisation, Healthabitat[1] was established and subsequently prescribed the materials and infrastructure necessary to support the nine HLPs. They listed the essential "health hardware" items that supported the nine HLPs, such as safe hot and cold water supplies, taps, drains, toilets, waste disposal systems, and safe food preparation areas (93). From this, they developed a survey instrument to measure these items in each house objectively, and trialled their first "Housing for Health" (HfH) project in a remote community in Central Australia. The model steered away from merely describing the poor state of environmental health in Aboriginal living environments, instead adopting a "no survey without service" ethos: testing, recording, repairing and reporting at each survey (20, 93, 168).

[1] "Healthabitat" is a company limited by guarantee and is registered as a charity with the Australian Charities and Not-for-profits Commission (ACNC).

In addition to the variables often measured in First Nations communities internationally (such as mould, dampness, insulation, temperature control and structural deficiencies), the HfH methodology included a detailed, objective assessment of electrical and plumbing hardware to ensure houses were safe and enabled residents to practice healthy living, as defined by the nine HLPs (93). The HfH surveys in the Central Australia study were initially implemented quarterly over one year, and items fixed as failures were identified. The HfH project found that when the health hardware in the homes was working, the residents used it enthusiastically (93).

The HfH method developed by Healthabitat was subsequently refined after the Central Australia project and implemented in a tropical community in Far-North Queensland in the mid-1990s (169). Soon after, it was then trialled in a North Coast community in New South Wales (NSW) in 1997-98 as part of a NSW cross-government initiative (164, 170). Based on the success of that trial, the NSW government implemented the NSW Housing for Health program, managed by NSW Health. It expanded the projects into other Aboriginal communities across NSW. The program has been ongoing since 1998, primarily within the Aboriginal community housing sector. The data from that program is the subject of studies reported in Chapters 4, 5 and 6 of this thesis.

Throughout much of the 2000s, the Australian government also funded a National "Fixing Houses for Better Health" (FHBH) program in parallel to NSW, using the same HfH methodology and principles, with only the funding source and amount differing (105, 106, 171).

Both Healthabitat's methodology and national and jurisdictional programs applying the method have been reviewed and evaluated several times over three decades, consistently describing it as a best practice model (136, 170-179). Notably, the rigour applied to reviewing the HfH methodology has been disproportionate to that applied to capital housing programs with funding on a scale magnitudes greater (172). This includes calls for programs implementing the HfH methodology to demonstrate improved health outcomes, possibly because 'health' is explicit in the program name.

Since the 1980s, the Australian literature has consistently acknowledged the link between poorer housing in Aboriginal communities and adverse health and well-being (77). It also indicates that housing has largely remained inadequate and unchanged for most Aboriginal communities, with numerous Australian studies concluding that the condition of Aboriginal and Torres Strait Islander housing is inadequate in both quality and quantity, and is unable to consistently provide healthy and comfortable living environments (10, 20, 54, 59-62, 70, 72, 81, 93, 100, 105, 106, 128, 130, 131, 161, 165, 177, 180-186). Australian Bureau of Statistics (ABS) data released in 2023 (83) shows that in 2018–19, Aboriginal and Torres Strait Islander households were living in dwellings where:

- 20% did not meet an acceptable standard, i.e. one or more basic household facilities were unavailable or more than two major structural problems;
- 33% had at least one major structural problem, such as major cracks in walls/floors, walls or windows that were not straight, or major plumbing problems (46% in remote areas and 31% in non-remote areas);
- 9.1% had no access to working facilities for food preparation;
- 4.5% had no access to working facilities to wash clothes and bedding;
- and 2.8% had no access to working facilities to wash household residents.

Whilst extensive literature referenced above reaffirms the huge inequity in the condition of Aboriginal housing in Australia, much of the data used to support these findings is largely subjective, relying on cross-sectional self-reported data. (25, 57). It is clear from reviewing the literature that there is much less objective, detailed and longitudinal data reported on housing conditions in Aboriginal communities in Australia, particularly in NSW, and none with the extent or breadth of that collected by NSW Health and studied in this thesis. While self-reported data are often an economical way to gather data on housing quality from large numbers of people, evidence suggests that residents tend to underreport problems with their housing, which impacts the validity of assessments based on these data (187). Self-report data are less reliable than assessments carried out by building or environmental health professionals (188).

Over recent decades, the ABS have collected data on the status of Aboriginal and Torres Strait Islander housing and infrastructure from several sources including the Census of Population and Housing (Census), the National Aboriginal and Torres Strait Islander Health Survey (NATSIHS), the National Aboriginal and Torres Strait Islander Social Survey (NATSISS) and the Community Housing Needs Surveys (CHINS) data. (132, 134, 135). While these high-level data cover all Aboriginal communities in Australia, they appear to lack the granularity and objectivity to accurately reflect the condition of housing and key areas of need in any detail.

Studies based on national HfH and FHBH data collections have been previously published in the peer-reviewed literature and consistently report the survey results as 11 aggregated critical safety and HLP indicator measures before and after the implementation of projects (20, 100, 105, 165). Healthabitat developed these critical safety and HLP indicators to measure whether a house was safe and enabled householders to adopt the most critical healthy living practices. Each is a compound indicator derived from a number of HfH survey items, unique to each of the 11 indicators. Current national aggregated data summaries are also available on the Healthabitat website (189) and for NSW on the NSW Healthstats website (190). Although the house survey data collected in the HfH projects are very detailed, the aggregated HLP indicator data previously reported don't specify which survey items are used to define each of the HLP indicators (20, 100, 105, 106, 165). Healthabitat, the owner of that information, has not previously released this publicly. Therefore, while the HLP indicators offer benchmark measures of housing condition, it is difficult for others to critique the benchmark without knowing the methods used to develop them. The indicators and their components are described in studies in this thesis, with permission from Healthabitat (see Appendix I).

House survey data collected by the NT government since 2000 used a separate survey instrument and process to measure house function (62). NT-based research of that data also used the nine HLPs in the UPK report to develop benchmark indicators of house function. However, in the absence of details on the available criteria used by Healthabitat, the authors used slightly different survey items to create each of their HLP indicators (62) from that used by the Healthabitat methodology. This research by Bailie et al. has used objective and subjective data to measure associations between house improvements, hygiene and skin and other infectious diseases, particularly in children (10, 59-62, 128). Other reports (191) have referenced the HLPs as indicators of house function, but the criteria used to define the indicators are not clear and may also differ from those used by Healthabitat. Therefore, comparison between studies is limited.

Building on Bailie et al.'s work, McDonald et al. (130) acknowledge the factors contributing to living conditions and poor hygiene in Aboriginal communities are outside the control of the health system, and that intersectoral collaboration and action are required. Additional research

by McDonald et al. (144, 145, 159, 160) concludes that gains in child health are unlikely to be achieved solely through infrastructure improvements, and that behavioural changes in hygiene are also required. In contrast, a 10-year linked data health outcomes evaluation of 2230 houses across 71 community projects in the NSW Housing for Health program, which does not include hygiene behavioural change interventions, found a significant 40% reduction in hospital admissions for infectious respiratory, skin and diarrhoeal diseases for residents in NSW after receiving the HfH program compared to a control population (136). (See Appendix A of Chapter 4 for further details about this study.) Delivering hygiene behavioural change as suggested by McDonald et al. (130) is complex. Hygiene education has historically been the narrative of missionaries and colonising policies (192), and resistance to hygiene behavioural change has been associated with perceptions of hygiene practices being a Western health concept, and not necessarily being considered a part of the Aboriginal cultural domain (193). Any attempt to provide hygiene or other health education should be co-designed with Aboriginal or Torres Strait Islander people if it is to be appropriate or effective (81). Evidence on the capability of Aboriginal housing to support healthy living suggests hygiene education cannot come before ensuring the infrastructure, hardware and service delivery precursors that support healthy living behaviours are in place.

Much of the research on Aboriginal housing conditions in Australia focuses on regional and remote Australia (20, 54, 70, 106, 161, 177, 181, 194-196). However, studies focusing on urban Aboriginal families in NSW highlighted a high prevalence of housing problems, including structural issues and inadequate facilities (57, 58), suggesting the problems of inadequate Aboriginal housing are not unique to rural and remote areas. Unfortunately, while the NSW HfH program has served communities in major cities, inner and outer regional, and remote areas, it has not previously presented data at a geographic level, so it is unclear whether regional variations in Aboriginal community housing functionality exist in NSW. This is addressed in Chapter 5 of this thesis.

One consistency across nearly all the research into Aboriginal housing conditions in Australia is the need for more comprehensive investment in Aboriginal housing to address the extreme disadvantage experienced in Aboriginal communities (54, 60, 61, 70, 72, 81, 128, 131, 161, 177, 185, 197, 198). Yet, other than high-level reporting of expenditure on Aboriginal housing from government reports (199), there is little or no detail on the cost required to improve houses to a reasonable standard that supports health and safety. Chapter 6 of this thesis addresses this gap in the literature in some detail.

Improving Housing Quality

The complexity of housing constructed in Aboriginal communities in Australia has increased substantially over the past 50 years. Most of the self-constructed, dirt-floor tin humpies sheltering Aboriginal people were replaced by modern housing during the 1990s and 2000s as part of a program by the then Aboriginal and Torres Strait Islander Commission (151). However, overcrowding and poor housing quality persist in many Aboriginal and Torres Strait Islander communities (66). The literature identifies key areas where housing fails to support health and proposes strategies to address these issues. These include reducing overcrowding (54), the application of housing design and specification standards for new housing and refurbishments, and the need for cyclical repair and maintenance programs to ensure house functionality (15, 165, 180). Whilst the literature widely and consistently calls for improved maintenance programs (15, 20, 161, 165, 180), the impact of housing management systems on the condition of houses has not been widely studied. Chapter 5 of this thesis addresses this gap, assessing

the association between the presence of a housing management system and the age of the assets on house functionality.

The importance of improving housing is highlighted by Ige et al., who systematically reviewed 39 studies assessing the impact of buildings on health (8). They showed that housing refurbishment and modifications, provision of adequate heating, and improvements to ventilation and water supply were consistently associated with improved-respiratory outcomes, mental health and quality of life. Bailie et al describe how in Aboriginal communities in the NT, the nature of extended families, high levels of crowding and generally poor quality existing housing meant that as new houses become available in Aboriginal communities, there is a complex movement of people from pre-existing to new houses and, for others, between pre-existing houses in search of housing in better condition (59). Pholeros et al. (2013) argue that building new housing alone is not the answer and that maintenance must be a critical part of any housing program to prevent the failure of the existing housing (165).

Howden-Chapman et al. describe how, despite extensive research demonstrating that constructing and retrofitting high-quality housing can reduce respiratory, cardiovascular, and infectious diseases, housing standards globally are unevenly developed, implemented, and monitored (200). They argue this contributes to cumulative disadvantage for First Nations people and other marginalised populations. This paper preceded the release of the 2018 *WHO Housing and Health guidelines* (13), and while this 2018 WHO report is an important overarching global document, it doesn't address the specific needs for Aboriginal housing in Australia.

In Australia, the National Construction Code (NCC) and associated Australian Standards (AS) should underpin the construction of all new housing and housing refurbishments to ensure a minimum standard. In addition to the NCC and AS, many jurisdictions, including NSW, have developed their own guidelines for Aboriginal housing, some of which include governance as well as design and management criteria (201, 202). In 1999 Australian Commonwealth, State and Territory government Housing Ministers released the *National framework for the design, construction and maintenance of Indigenous housing*(203). The framework recognised housing issues cross all jurisdictions and aimed to achieve safe, healthy and sustainable houses for Indigenous people. It was underpinned by four principles: that houses for Aboriginal and Torres Strait Islander peoples would be designed, constructed and maintained for safety; support healthy living practices; adopt quality control measures; and be sustainably designed and constructed for long-term function and ease and economy of maintenance (203). The framework included the development of the National Indigenous Housing Guide (NIHG) (204). However, following the release of a third edition of the NIHG in 2007 and a change of government that same year, no further editions were published, and the framework appears to have been discontinued.

The Australian Housing and Urban Research Institute (AHURI) acknowledge there are some exemplary models of design, procurement and delivery of Aboriginal housing in many parts of Australia (205). However, despite these and the existence of national and jurisdictional standards and guidelines for housing construction, AHURI concludes that current patterns of housing design and provision are failing to meet the functional needs and personal and cultural aspirations of Aboriginal people. Further research into whether national and jurisdictional standards remain unimplemented, and identifying any barriers or facilitators to their uptake, is required.

The importance of repairs and maintenance of Aboriginal housing has been consistently identified in the literature (15, 161, 162). Specifically, there are calls for systems of cyclical, rather than responsive maintenance systems, and the recognition that maintenance is an investment in the life of the housing and in the health of the occupants (146, 161, 168, 177). Responsive maintenance systems reliant on self-reporting by tenants have been shown to be less effective, as barriers to reporting often exist, including long wait times, indifference due to previous experiences of inaction, and an acceptance of dysfunctional house infrastructure by occupants (130). Small items left unchecked, such as a leaking tap, can become a more serious and expensive issue if not addressed. Under-resourced repairs and maintenance management have led to significant backlogs of essential items in some communities (130).

Culturally responsive housing policy is a critical area of focus in the literature. A lack of local input into housing management can add to the disempowerment of communities (77). International and domestic evidence suggests that collaborative, community-driven housing programs and the engagement of First Nations communities in co-designing and leading housing can enhance health outcomes, well-being and housing stability (81, 206). Integrating First Nations knowledge systems has been shown to enhance the efficacy of housing initiatives, aligning with culturally appropriate practices that respect and incorporate their perspectives (207). Housing programs must prioritise the needs of First Nations families, taking into account cultural practices and systemic barriers that reflect historical injustices (208).

To deliver culturally and climatically responsive housing that is quality assured and supported by ongoing management systems requires long-term ongoing investment (70). The resources invested in the construction and, as importantly, the maintenance of houses, do not adequately meet the demands of delivering adequate social housing (209, 210). Poor housing is a cost borne ultimately by the health sector (211), and the cost of housing construction and maintenance should be seen as an investment in health with flow-on effects for society.

5.3 Housing Affordability

The third domain of healthy housing is housing affordability (65). It is a global issue affecting high, middle and low-income countries differently and is inextricably linked to the social determinants of health (14, 40). Measuring housing affordability is complex, but one common measure is to compare housing costs to gross household income. A benchmark threshold of housing cost-to-income ratio is 30%, beyond which housing is considered unaffordable and can lead to Housing Affordability Stress (HAS) and energy poverty in households (65).

People living in owner-occupied homes appear to have better health and longer life expectancy than those who live in rented accommodation. (212). However, Aboriginal and Torres Strait Islanders are less likely to own their own home (83). The 2021 Australian Census identified that, among Aboriginal and Torres Strait Islander households with a mortgage, 14% (11,765 dwellings) were spending more than 30% of their gross income on mortgage repayments. The Census also found that 35% (58,867 dwellings) of those Aboriginal and Torres Strait Islander households that were renting were spending more than 30% of their gross income on rent payments (83).

There is a considerable amount of Australian research investigating the relationship between housing affordability, often referred to as Housing Affordability Stress (HAS), and mental health. Bentley et al. found that the impact of unaffordable housing for individuals residing in low-to-moderate income households is detrimental to mental health, but not for those in higher-

income households (213). Other studies of the mental health effects of exposure to HAS found that both prolonged and intermittent exposure to HAS negatively impacted mental health, irrespective of baseline mental health (25, 214, 215). These studies conclude that interventions targeting affordable housing benefit population mental health, and such interventions should be designed with people's housing context in mind.

Energy Poverty

Affordability is not limited to mortgages and rental payments but also includes the energy and resources to run a household (216). Energy poverty or fuel poverty refers to the inability to secure a healthy internal temperature in the home due to unaffordable energy costs of heating and/or cooling. This can be caused by a combination of low household income, high energy costs, and thermally (i.e. energy) inefficient housing. Energy poverty is measured as a ratio where household energy cost-to-disposable income exceeds 10% (216). Direct health impacts of energy poverty include respiratory effects associated with living in a cold and damp environment or the use of poor indoor heating appliances (e.g. unflued gas heating), or cardiovascular effects due to high temperatures (65). Indirect impacts on health can include increased stress and reduced emotional well-being through increased financial burden. Bentley et al. state that when people can no longer afford to warm their homes, their mental health declines significantly (217). They argue that with energy becoming increasingly expensive, there is emerging evidence for a sizable burden on population health.

In some regions of Australia, cooling housing is a growing issue with increasing hot weather predicted over the coming decades (88, 218). Extreme heat is limiting the capacity to cool houses to a comfortable temperature with passive measures alone (88). Active cooling measures such as air conditioning are becoming necessary, which puts an increasing burden on household economies and risks sending more families into energy poverty.

An Australian study by Buergelt et al. into the use of power in homes of Yolgnu people in East Arnhem communities revealed that the design of houses in remote communities was both climatically and culturally inappropriate (149). Combined with insufficient and overcrowded housing, this contributed to power being used inefficiently in homes, along with a range of other intertwined social, economic and health challenges. The impacts of climate change on housing are likely to exacerbate energy poverty.

6.0 Housing, Health and Climate Change

The latest report of the Intergovernmental Panel on Climate Change (IPCC) acknowledges the unequivocal human influence on warming of the atmosphere, oceans and land, and highlights the effect this is already having on many weather and climate extremes across the planet (219). The report describes the possibility of reaching the 1.5 °C global warming threshold as early as 2030. In Australia, a 1.4 ◦C warming since 1910 has already been observed, and this is causing more severe heatwaves and fire weather, reduced rainfall, and severe droughts in parts of Australia (220). In NSW, temperatures in 2020 are predicted to warm 0.7 °C by 2030 and 2.1 ˚C by 2070, with the number of days per year greater than 35 °C expected to increase by up to 40 days in some regions by 2070 (221, 222). Rainfall is projected to increase in autumn and decrease in spring, with regional variation and fire weather expected to increase in western NSW (221).

The pathways through which climate change can affect health have been well documented (223). Injury and death can result directly from extreme events such as floods, storms and

bushfires, while heatwaves can increase cardiovascular morbidity and mortality. Human health can be indirectly impacted by altered environmental and ecological systems (223, 224). Warmer conditions can encourage water and food-borne pathogens and increase mosquito-borne disease transmissions. Increased air pollutants, such as bushfire smoke and dust, can exacerbate respiratory diseases, and increasing drought severity can lead to food and water insecurity (92, 223-225). Mental health and social and emotional well-being can also be adversely impacted by the social, economic and demographic disruptions caused by climate change (223, 224). Climate can further impact crowding when only one room has heating or cooling, and families congregate (88, 226).

People with pre-existing health sensitivities, who are poorly resourced and living in areas more exposed to these climate extremes, will be most affected (225), including Aboriginal and Torres Strait Islander communities. However, prior to this thesis, the extent of this exposure to climate change for the Aboriginal population of NSW was not defined in the literature. The impacts of climate change on a range of environmental health hazards affecting the Aboriginal population of NSW are presented in Chapter 8.

The capacity of housing to adapt to extreme climate events such as floods, fire intensity and heat is emerging as an important consideration for housing over the coming decades (227). Housing modifications to reduce exposure to changing weather conditions and extreme events can potentially improve health outcomes. A 2025 scoping review by Cartwright et al. examined the evidence from 38 articles on the contribution of housing conditions to the impacts of climate change on health (228). The authors observed that heat-health impacts were the most common focus in the literature. The review found housing conditions that improve heat-related health outcomes included air conditioning, window shading and ventilation. Excessive air tightness and inappropriate insulation were reported to increase indoor heat and reduce indoor air quality. The authors concluded that housing adaptations that were multifaceted rather than single fixes were more effective.

Quilty et al. state that the convergence of excessive heat, poor housing, energy insecurity and chronic disease in Aboriginal communities has reached critical levels (218). They describe how in areas of Australia where temperature extremes now extend for months, Aboriginal community houses become “heat caves, much like a car parked in the hot sun” (218), and current building codes provide little protection for residents against environmental harm. Where air conditioning is available, poorly designed and uninsulated houses in Aboriginal communities are far more expensive to cool than better quality dwellings (218, 229). The higher energy requirements mean the power infrastructure is more likely to disconnect when the power is most needed to keep people safe from extreme heat.

Architecture can be an influential enabler of health and well-being. Elements of the built environment, including location, aspect, design, construction quality, materials specified, and the efficacy of maintenance, will all contribute to the performance of a house during extreme weather events (88). However, as identified earlier in this chapter, for much of the existing Aboriginal housing across Australia, including NSW, these architectural elements are deficient. Memmott et al. acknowledge how the current climate-related vulnerabilities experienced by Aboriginal Australians stem from the trauma and displacement over more than two centuries of colonisation. (88) The authors recommend that Indigenous-led, co-designed and multifaceted approaches to addressing the social determinants of health are needed to improve climate adaptation for Aboriginal people.

7.0 The NSW Housing for Health Program

7.1 Investigating Changes in Aboriginal Community House Functionality

The development of the Housing for Health (HfH) methodology has been summarised above, and a more detailed context is given in the Methods chapter (Chapter 3). NSW Health purchased a non-commercial license from Healthabitat to implement the HfH methodology in each project. The NSW HfH program is administered by NSW Health and implemented by NSW Health in partnership with Aboriginal communities. The program aims "to improve the health of Aboriginal people and communities in NSW by improving their living environment" (230). A primary focus of the program is testing and fixing housing to ensure critical health hardware in a house functions adequately to protect the safety of occupants and enables healthy living to be practised. The NSW Health program collects data on the condition of houses and the cost of fix-work before and after each project and reports this data back to each community at the end of a HfH project. As the number of projects has grown, a large dataset on the state of health hardware in Aboriginal housing and the cost of repairs has been collected over the 20-year life of the NSW Health program. Given the longevity of the program, some communities have had repeat HfH projects some years later.

This thesis will investigate the state of Aboriginal housing in NSW using the NSW HfH Program housing repair and maintenance data over the first 20 years of the NSW Health HfH Program. The investigation will focus on the before and after house survey repair and maintenance data, as well as the fix work expenditure data. The NSW HfH program is the only implementation of the HfH methodology that has maintained consistent longevity and fidelity to the methods for over two decades, including repeat projects. However, no detailed analysis of this increasingly large and detailed housing repair and maintenance dataset has been undertaken prior to this thesis.

7.2 Health Economic Analyses

In a 2012 New Zealand scoping study of the cost of child health inequalities, Mills et al. described the significant economic cost of "doing nothing" and identified potential significant economic benefits from investment in programs to reduce health inequities, including better housing (115). Previous reviews of projects implementing the HfH methodology have considered improvements in house condition and/or health outcomes in communities (136, 171, 179). These reviews also identified other less tangible benefits emerging from projects that extend beyond the direct and more easily quantifiable impacts, influencing other social determinants of health. These emerge from the application of principles ingrained in the HfH method including: community engagement; working in partnership with housing providers; training and employment of Aboriginal community workers to complete surveys and fix work; consistent and standardised testing and data collection; applying a "no survey without service" ethos incorporating immediate fix of urgent items; maximising the use of local tradespeople and other business to strengthen local capacity; and use of an evidence-based health-focused priorities (173). The application of these principles has been identified as best practice for program implementation (171, 173) and effective intervention research (231).

Economic evaluation of public policy is advocated but rarely undertaken. Fenwick et al. assert that, when done appropriately, economic evaluation provides the potential to make substantial contributions to housing policy (232). Studies quantifying the disparate health, social, cultural, economic and other intangible benefits generated from programs implementing the HfH

methodology have not yet been conducted. An economic analysis of the HfH program could achieve this and evaluate the relative merit of the initiative.

Cost-benefit analysis (CBA) is the preferred method of economic evaluation by NSW Treasury (233, 234), but there are other models that may be better suited to the HfH program. Chapter 7 is a published paper that includes a scoping review of the literature exploring the merits of various methods of economic analysis. Chapter 7 also reviews economic analyses of physical housing interventions, similar to the NSW Health HfH program, in OECD countries since 1996, seeking to improve residents' health. The review found 58 studies that included modifications also addressed by the HfH Program, (such as falls prevention, ventilation, smoke alarms), but no economic evaluations assessed a program with the equivalent focus and breadth of HfH. Informed by the scoping review, an economic protocol is proposed that could be used to evaluate HfH and capture those intangible benefits effectively. Undertaking such an economic analysis of the NSW Health HfH program is a complex undertaking and beyond the scope of this thesis.

8.0 Conclusion

This literature review chapter describes the well-recognised connection between housing and health and highlights the importance of housing as a social determinant of health, particularly for First Nations populations globally. The condition of Australian Aboriginal housing continues to be inadequate, contributing to poor health, and those health impacts are likely to be exacerbated by climate change. Several surveys and studies have been undertaken of housing and health in Aboriginal communities over recent decades. These are often short-lived projects aimed at answering research questions (usually attempting to demonstrate a health outcome associated with an initiative) or larger self-reported national census-type data that is more general in nature. No objective data could be found in the literature with a similar level of detail on Aboriginal housing conditions, collected as consistently, and with the longevity of the NSW Housing for Health program dataset, which forms the basis of the analyses conducted in Chapters 4, 5 and 6 of this thesis.

Previous analyses of HfH data in NSW have been limited to reporting on the proportion of houses that achieve the maximum score for critical safety and healthy living practice indicators at a state-wide level. That analysis does not indicate the extent of repairs required to improve those houses, nor the cost to do so. Changes in housing conditions over time and the impact of other social and geographic variables on housing conditions in NSW, such as occupancy or remoteness, have not been previously studied. No evidence was found in the literature of repeat surveys of housing conditions in identical houses, some years later. Using the 20-year NSW Health HfH program dataset, this thesis will address these gaps in the current literature and identify factors that enhance or hinder improvement in Aboriginal housing in NSW, informing future policy development.

Economic analysis methods have been identified (in Chapter 7) that could be implemented to quantify the intangible benefits of the NSW Health HfH program and contribute to improving policy. Understanding the impacts of climate change for Aboriginal people in NSW, presented in Chapter 8 will help to identify future risks and areas for improvement, including the role housing may play in climate adaptation.

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Chapter 3
Housing for Health Background & Research Methods

1.0 Context and Scope

A major focus of this thesis was to examine changes in the functionality of Aboriginal Community Housing between 1997 and 2017 associated with the NSW Housing for Health (HfH) Program. It did this using data collected as part of the standard NSW HfH Program delivery. The thesis also reviewed the literature on approaches for conducting a comprehensive health economics evaluation of the NSW HfH Program. The final study used publicly available demographic and climatology data to assess the implications of climate change for health and adaptation planning for Aboriginal communities and peoples in NSW, including the implications for housing.

This chapter broadly describes the data and methods used in the specific studies reported in this thesis. More detailed descriptions of the methods applied to address each of the research questions are provided in the corresponding Chapters 4—8). Whilst not the subject of the thesis, a summary of the HfH methodology that NSW Health used to collect the NSW HfH Program data over a 20-year period, as well as the process used to consolidate that dataset, is provided to give additional context to the data.

This Methods chapter has been separated into two sections:

Part A: NSW HfH Program Data - Collection and Collation
Part B: Research Methods

2.0 Part A – Data Collection and Collation

2.1 Project Data Collection by NSW Health

The Housing for Health (HfH) Methodology

Housing for Health (HfH) is a structured and comprehensive process for surveying and repairing homes to improve safety and health for their residents. The methodology was developed and licenced by Healthabitat, a not-for-profit non-government organisation, and has been used around Australia and internationally since the early 1990s. The methods for the collection of HfH Program data have been previously published (1-4). An overview of the HfH methodology is provided to give context for the Program dataset analysed in this thesis. The standardised process followed in each Housing for Health project involves seven main stages, described below.

Stage 1: Project Establishment and Community Selection

To establish a project, a funding source needs to be secured. The funding provider is typically involved in selecting the communities invited to participate in Housing for Health. It is primarily

based on need, availability of project resources and other administrative requirements. Communities are not randomly selected.

Stage 2: Community Consultation and Feasibility

Once a project is established, a meeting is held with the Aboriginal Community Housing Provider (ACHP) and the community to explain the process and seek their consent to participate. The collection of HfH data to repair houses, evaluate the program, and inform future policy is explained during the consultation. The HfH data collection includes two related surveys. Survey-Fix 1 (SF1) assesses the functionality of the houses prior to any fix-works being conducted. This information is used to identify and prioritise repair and maintenance work for each house. Survey-Fix 2 (SF2) is conducted after the house fix-works have been completed to inspect the works and assess the post-fix-work functionality of the houses. If the ACHP consents to the project, a feasibility assessment is conducted to confirm the project scope and identify existing community housing and infrastructure management systems, as well as any logistical issues that may influence the program. The ACHP can cancel a project at any time.

Stage 3: Preparation for Survey-Fix 1

The preparation stage involves establishing all the logistics for Survey-Fix 1 and ensuring that residents are informed of the project, including its benefits and limitations. Each house is visited to explain the project and invite community members to participate in the survey teams. The logistics of employing and insuring community workers are arranged, tools and consumables purchased, and plumbing and electrical trades are engaged. The preparation stage is crucial for ensuring local employment and addressing immediate repair and maintenance issues, both of which are program priorities during and after the project stages.

A de-identified project number is assigned to the community project, and each house is allocated a de-identified house identification number to maintain the confidentiality of the Survey-Fix data. A separate master list of de-identified house numbers and street addresses is used by the project manager, the trades, the ACHP, and the HfH Program administrators to implement the project and manage future maintenance. Only the community and NSW Health retain the master list linking the house back to the address.

Stage 4: Survey-Fix 1 (SF1)

Survey Fix 1 marks the beginning of the project implementation. The first day is dedicated entirely to employing and training local Aboriginal community members to safely conduct housing repair and maintenance survey tests, record survey data accurately, and make minor repairs. On the first day, each team surveys one house as part of the training. Depending on the number of community houses in a project, there are usually between one and four survey teams, each comprising around four Aboriginal community members, supported by an experienced technical team leader. A paper-based system is used to record results, allowing teams to survey different parts of the house concurrently. Survey data criteria are based on Australian design and construction standards (such as plumbing and drainage, electrical installation and hot water temperatures) or current best practice guidelines (such as the National Indigenous Housing Guide) (5).

Participation by each household is voluntary, and verbal consent to enter the property to survey and fix the houses is provided by householders prior to entering the premises. Consent can be withdrawn at any time during the survey. Survey teams carry a toolbox with testing equipment (thermometers, power point testers, etc) and tools and materials to undertake some minor repairs immediately. Depending on house size and condition, a survey team takes about one

hour to survey a house, make minor repairs, check all sheets for accuracy and missing data, and report back to the householder.

Standardised tests are performed on over 268 survey items in each house, and the paper-based results are entered into a Microsoft Access field database as they are completed. The survey database performs missing data and data validity checks during data entry. Any discrepancies are followed up with the Survey Team Leaders. If the survey team is unable to collect data for logistical reasons - for example, a solar hot water system mounted on a roof cannot be accessed by the survey team - these checks are referred to the trades to complete as part of their work. These quality checks ensure minimal missing HfH survey data on a house.

The database is used to allocate urgent jobs for plumbers and electricians who follow behind the teams carrying out repairs. Upon completion, trades record the work status and the cause of the repair for each job – either routine maintenance, faulty workmanship or materials, or tenant damage. This is entered into the database for the related survey item. For each project, tradespeople are required to invoice separately for the work undertaken on each house. This expenditure is recorded by house and by trade for each project in a separate Microsoft Access financial management database.

Stage 5: Major Repairs

Once urgent works are completed as part of Survey-Fix 1, the job sheets returned from the trades are entered into the survey database, and invoices are entered into the financial management database. The project manager then inspects the repairs and prepares a schedule of works for any larger or less urgent items identified by the survey teams that can be prepared within budget. This stage may involve other trades such as builders and carpenters, or other health professionals such as occupational therapists if there are elderly or disabled tenants.

Stage 6: Survey-Fix 2 (SF2)

Once the major repairs are completed, a second survey and fix is undertaken. This Survey-Fix 2 (SF2) repeats the employment, training and data collection on house functionality assessed at SF1. The data collected at this stage provides a comparison of SF1 data (before any work) and SF2 data (after all work is completed).

Stage 7: Project Reporting

Throughout a project, the project manager works closely with the community housing provider(s) to coordinate any planned repairs and report on the progress of the HfH project. Once the second survey is completed and all job sheets and invoices returned, a report is compiled for the community and funding providers on the works completed and any recommended future works beyond the scope of the HfH project. Project-related data, shared and discussed throughout by the project manager, are reported back to the community at the end of each project. Where possible, electronic data are made available to the community to update any existing management systems. The project is then closed.

Quality Assurance and Prioritisation

Several processes are in place to ensure quality and validate the Survey-Fix data. Technical Team Leaders check the data collected by teams before leaving each house. Missing and data validation checks are run during data entry. Healthabitat also audits the management of each project to ensure compliance with the HfH methodology. Copies of the survey and financial management databases are provided to NSW Health by the project manager at critical stages

throughout the process, and a final copy of each database is provided to NSW Health upon project completion.

The program has limited funding to carry out repairs, and the need almost always exceeds the available budget. Therefore, all works are prioritised to maximise safety and health benefits to the householders. Electrical, fire, gas, and structural safety are addressed as the highest priority, followed by the nine healthy living practices (HLPs) described in Chapter 2. Given funding limitations, not all priorities may be met for a project. Safety and the top four HLPs (i.e. the ability to wash people (particularly children); wash clothes and bedding; remove wastewater safely, and store, prepare and cook food) are referred to as *Critical* Healthy Living Practices (CHLPs). Before and after survey data relating to these priorities are reported routinely in the results for each project. Over the life of the NSW HfH Program, there have been four generations of the HfH survey instrument. However, the items used to calculate indicators of these CHLPs have remained consistent across generations, allowing comparability of survey results over time. The items comprising each CHLP are presented in Appendix I of this thesis.

Aboriginal Governance of HfH Implementation by NSW Health

The HfH methodology was initially co-designed with Aboriginal community members in the Pitjantjatjara Lands of South Australia, and technical experts in housing and health. The licensed HfH methodology, including the process, survey instrument, testing methods, data collection and healthy living priorities, is standardised to maintain consistency across projects. The governance over project implementation in the NSW HfH program is tailored to each community's local arrangements with the Aboriginal Community Housing Providers (ACHPs) having oversight and providing consent prior to, and throughout a project. Formal meetings with ACHPs, their members and/ or the community are established at the consultation and reporting stages of the project, and throughout the project as required by the community. Project managers work closely with ACHP staff during implementation. Local Aboriginal community members are engaged in project data collection and the associated fix work of houses. The second survey provides community participants with an opportunity to audit the project.

The NSW HfH Program has developed in parallel with the Aboriginal Environmental Health Officer Training Program (AEHOTP) - a workforce development initiative of the NSW Aboriginal Environmental Health program. The AEHOTP supports Aboriginal people to study an environmental health bachelor's degree whilst working in a relevant state or local government organisation. As part of the program requirements, Aboriginal trainees and graduates participate in HfH projects initially as Assistant Team Leaders, progressing to Team Leaders and Data Managers, developing and providing increasing technical expertise. Some graduates of the program are now HfH Project Managers. The increasing participation of Aboriginal environmental health practitioners, alongside community members, over more than two decades has further strengthened Aboriginal involvement and governance in the program.

2.2 – HfH Program Data Consolidation by NSW Health

NSW Health has been continuously collecting standardised and validated Survey-Fix data with Aboriginal communities across NSW since 1997. NSW HfH projects that are the basis of the HfH Program data assessed in this thesis have been predominantly delivered within the Aboriginal community housing sector. NSW Health staff consolidated all available HfH Program data from HfH projects completed between 1998 and 2017 into a single dataset. This included:

- Survey-Fix data on the condition of houses at SF1 and SF2, extracted from Microsoft Access survey databases for each project,
- Financial data on the cost of repairs by trades and by project stage for each house linked at the house level, extracted from Microsoft Access databases and Microsoft Excel financial management files,
- Other program metadata collected by NSW Health for program management and project implementation, including project feasibility assessment data and community characteristics (such as survey dates, remoteness classification, evidence of repair and maintenance programs, and the total number of eligible houses for each project). These were extracted from a Microsoft Access program management database. Some data were manually extracted from paper-based reports, particularly for earlier projects and electronic Word documents.

NSW Health advised fix-work expenditure data were incomplete or missing for some early projects. As HfH projects were gradually rolled out across NSW, most discrete Aboriginal communities and many other Aboriginal community housing providers had received the program over the 20-year study period. Given the extended timeframe, some communities had received a second, and in one case, a third project, some years later. These repeat projects are identified in the dataset. Program management data on the total number of eligible housing providers and houses in the Aboriginal community housing sector, the numbers that were approached by the program and the numbers that participated were included with the NSW Health HfH dataset. Each HfH project location had been classified by Australian Remoteness category (Major Cities, Inner Regional, Outer Regional, and Remote & Very Remote) using the 2011 Australian Bureau of Statistics (ABS) remoteness structure (6). A data dictionary was compiled by NSW Health to define the meaning of each data field. All data were deidentified prior to release by the data custodian to the University of Sydney.

2.3 Data Release from NSW Health

The HfH Program data used in the analyses in this thesis were collected, collated, and consolidated by Health Protection NSW, a division of the New South Wales (NSW) Ministry of Health, as part of its NSW Housing for Health (HfH) program. Health Protection NSW is the data custodian of that project data.

In consultation with my PhD supervisors, a formal process was undertaken by the University of Sydney and myself as the PhD Candidate to request the release of the NSW Health HfH dataset for this PhD thesis. A copy of the data release documentation is provided in Appendix II. As part of the data release, Health Protection NSW advised that the HfH dataset did not require specific ethics approval as the HfH data relates to housing and does not include personal health information about individuals, nor identify specific houses or communities. As the data custodian, Health Protection NSW approved the release of the data for analysis and publication.

3.0 Part B – PhD Research Methods

3.1 Research Methods

The detailed methods applied to address each of the PhD thesis research questions are described in detail within the individual Chapters 4-8. The analytical approach applied in Chapters 4, 5, and 6 of this thesis involves analysing the HfH Program dataset collected by the HfH Program over the past 20 years. The analyses are primarily descriptive, with the overall aim of investigating the impact of NSW Health's HfH Program on housing functionality, including implications for public policy.

The HfH Program dataset provided by NSW Health included HfH survey data from 113 projects. The HfH Program dataset also included financial data from 107 of those communities. The analysis of the data included investigating any impact of repeat visits by the program over time. First and second projects were included in the analysis, but third visit projects were excluded because there was only one within the study period.

Aboriginal Governance of this Research

Aboriginal governance and sovereignty of programs and data relating to Aboriginal people is an area that has rapidly evolved over the course of this thesis (7). In parallel, the Aboriginal governance of this PhD research has also evolved over this time. My PhD research team, including my Aboriginal academic co-supervisor and two Aboriginal colleagues and peers with community and HfH program experience and environmental health expertise, strengthened Aboriginal sovereignty and governance over the research, to prioritise Aboriginal perspectives and accurately reflect community context, and to improve the quality, accuracy and cultural safety of the research. The research team was responsible for co-developing research questions, managing and analysing data, interpreting and writing up results, and developing recommendations for translating this research into action. Thesis results were presented to NSW Health HfH program team members, including three Aboriginal staff members (who are co-authors on the papers), to discuss analyses and results and to receive feedback on their interpretation throughout the course of the research. In addition, informal input was also sought from Aboriginal community members, health and building practitioners, policymakers, and researchers to further inform the interpretation of results, understand the implications and develop appropriate recommendations. Where appropriate, these contributions were acknowledged in the research outputs with co-authorship and acknowledgements.

Chapter 4 aims to answer the question: Does Aboriginal community housing in NSW function to provide an environment that supports householders to practice safe and healthy living, and are any changes in housing functionality over time associated with the NSW Housing for Health program? The analysis provides a broad description of the program data and a descriptive analysis of the HfH survey data from 3593 houses in 112 HfH projects from 1998–2017 using SAS Enterprise Guide Version 9.4 (8). A comparative analysis was undertaken of the condition of houses before the program was implemented (a sentinel indicator of housing condition across the Aboriginal community housing sector) and changes in house functionality associated with the NSW HfH Program after implementation. Consistent with historical reporting of single projects in NSW, 11 fundamental indicators of whether houses are considered safe and able to support the four critical Healthy Living Practices (CHLPs) (described above and in Chapter 2) were reported in this analysis. From the SF1 and SF2 survey data, 79 data items are used to calculate the following 11 CHLP indicators:

1. Power, water, and waste connected
2. Electrical safety
3. Gas safety
4. Structure and access
5. Fire safety
6. Shower working adequately
7. Facilities to wash children
8. Laundry services
9. Flush toilet working
10. All drains working
11. Facilities to store, prepare and cook food

Each indicator is comprised of between 1 and 17 survey items (see Appendix I). This analysis allocated a score for each indicator (standardised to 10), based on the number of items working. Scores were dichotomised into binary categories where 1 = 100% of key items for each CHLP indicator working, and 0 <100% of items working for each CHLP indicator. This approach is consistent with historical reporting of individual projects by NSW Health and Healthabitat. Summary statistics of the percentage of houses with a score of 1 (all items working) at SF1 and SF2 were calculated and compared for all 11 indicators, and 95% confidence level intervals were calculated. A separate analysis of the 24 communities (802 houses) that had received a second project was conducted, whereby the percentage of houses with all items working at SF1 and SF2 at the initial and the repeat projects was compared.

A single house score was also calculated to describe the average percentage of CHLP indicators that fully met the criteria at Survey-Fix 1 and Survey–Fix 2 over time. Results were stratified by five-year epochs (1998–2002; 2003–2007; 2008–2012, and 2013–2017) to demonstrate changes in SF1 and SF2 house scores over the 20-year study period, and a trend test statistic at a 95% confidence level was applied.

Chapter 5 further develops the analysis conducted in Chapter 4. The binary score categorisation applied in Chapter 4 (with a 100% pass threshold for each CHLP Indicator) can be insensitive to potentially meaningful improvements in the functionality of the house to support healthy living. Chapter 5 conducted a more nuanced analysis to ascertain the amount of improvement required to achieve the minimum standards prescribed by the CHLP indicators before and after projects. Consistent with the analysis in Chapter 4, the same survey items were used to calculate a score for each of the 11 CHLPs for each house survey. These house functionality scores were classified into four categories. A 100% pass threshold was retained (as in Chapter 4), and three additional categories were created based on the tertiles of the house functionality scores <10, categorised as: 10 (Functional); 8.5 to <10 (Almost Functional); 7.5 to <8.5 (Low Function), and 0 to <7.5 (Very Low Function). Changes in before-and-after house functionality over the 20 years were calculated using 5-year epochs consistent with the previous analysis. The analysis also considered the potential effect of a repeat project and of geographical and socio-demographic factors that may impact Aboriginal community housing conditions in NSW, including house age, occupancy ratios, evidence of maintenance activity, and remoteness. Chapter 5 also investigated coverage and participation rates for Aboriginal

Community Housing Providers (ACHPs) and households in the NSW HfH Program between 1997 and 2017. To be eligible to participate in the program, NSW Health required ACHPs to have more than two houses. Coverage rates were calculated by dividing the number of ACHPs and households invited to participate in a HfH project during the study period by the total number of ACHPs and households provided by NSW Health, respectively. Participation rates were calculated by dividing the number of participating ACHPs and households by the number of ACHPs and households invited, respectively. Coverage and participation rates were calculated separately for initial and return HfH projects. Further detail is provided in Chapter 5.

Chapter 6 aims to address the research question: What is the financial cost of the NSW Housing for Health program to bring Aboriginal community housing up to a minimum standard of functionality that supports householders to practice safe and healthy living? The financial data provided by NSW Health were adjusted to March 2022 Consumer Price Index (CPI) values to enable effective historical and comparative analyses over the 20-year study period. The CPI series "Maintenance and repair of the dwelling; Sydney (ID A2328056R)" was used for these adjustments as it provided the closest approximation to price changes that would have occurred in NSW, Australia, over the study period. As this study aimed to link the expenditure per house to the level of change in house functionality using the same CHLP indicator classifications generated in Chapter 5, only fix-work expenditure line items that could be attributed to influencing the critical Healthy Living Practice criteria (e.g. plumbing and electrical costs) were included in the analysis. A descriptive analysis of the HfH survey fix-work costs per house was conducted, including stratifying the data over time and by remoteness. HfH Survey-Fix Financial data were available for 3,025 houses from 107 projects included in the NSW HfH Program between 1998 and 2017. Using the same house score categories developed in Chapter 5, a descriptive analysis of the house Survey-Fix Financial data was undertaken to ascertain the median costs to improve house condition from one category of house functionality to another.

Chapter 7 aims to answer the research question: How could a comprehensive economic analysis be undertaken of the disparate health, social, economic and intangible benefits generated from the Housing for Health program and the resources utilised to realise these benefits? To complement the financial analysis of fix-work expenditure, a scoping literature review explored potential economic evaluation methods relevant to NSW and Australian government policy contexts, identifying models for future economic analyses of HfH. The review focused on similar programs to inform a protocol for a more comprehensive economic analysis than the direct costs considered in Chapter 6. The scoping review was conducted in line with PRISMA-ScR guidelines and incorporated grey literature, including policy documentation and non-peer-reviewed publications. Details on eligibility criteria, information sources, search strategy, selection of evidence sources, and the protocol for economic analysis are presented in Chapter 7.

Chapter 8 aimed to address the research question: What future challenges does climate change present for Aboriginal community housing in NSW, and what are the implications for public policy? Using publicly available demographic data, historical meteorological data, and future climate modelling data, the research in Chapter 8 assessed the exposure of Aboriginal communities to climate-related risks, including heatwaves, floods, droughts, and bushfires. Population data, based on counts from the Australian Bureau of Statistics (ABS) 2016 Census for Population and Housing for Statistical Areas Level 1 (SA1) (9) and ABS 2016 population grids (10) were used to calculate population-weighted exposure estimates by SA1. Historical climate exposure data for NSW at a 25 km^2 resolution were sourced from the NSW Department of Planning, Industry and Environment (DPIE) as well as the Australian Bureau of Meteorology

(BoM) Australian Water Availability Project (AWAP) (11) for the period 1990 - 2019 and aggregated to annual averages for regions. Future prediction data, sourced from the NSW DPIE NSW and ACT Climate Modelling (NARCliM) project (12), were used at a 10 km^2 resolution. Selected key climate-related exposures relevant to the NSW context included heat, rainfall, drought and fire danger. Odds ratios were calculated by comparing the proportion of Aboriginal populations with non-Aboriginal populations living in areas classified as high risk using the Wald method, and confidence intervals were calculated accordingly. A sensitivity analysis, stratifying odds ratios by the ABS Index of Relative Socioeconomic Disadvantage (IRSD) quintile (13) was done to assess whether differential exposures could be explained by socioeconomic status. Descriptive analyses were performed to describe population vulnerabilities and inform policy implications for housing and public health. Acknowledging the cultural determinants underpinning Aboriginal health and well-being (14), a framework of climate vulnerability (15) was adapted to articulate direct and indirect health impacts from climate-related hazards (based on exposure and pre-existing sensitivities to climate events) balanced against the adaptive capacity of communities and populations to minimise the net susceptibility of Aboriginal people to climate change.

Further details of these methods are provided in the respective chapters.

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Chapter 4
Prioritising Housing Maintenance to Improve Health in Indigenous Communities in NSW over 20 years

Preamble

This chapter aims to address the first research question of this thesis: "Does Aboriginal community housing in NSW function to provide an environment that supports householders to practice safe and healthy living, and are any changes in housing functionality over time associated with the NSW Housing for Health program?"

The chapter describes the analysis of a NSW Health dataset compiled from before (Survey-Fix1) and after (Survey-Fix2) survey data from Housing for Health (HfH) projects conducted from 1998 to 2017. The article summarises the background to the NSW Housing for Health (HfH) program, the methodology of the program, the safety and healthy living priorities that guide the implementation of the program and the method used to score houses for each project against Critical Healthy Living Practice (CHLP) Indicators to evaluate change. Using a binary (pass/ fail) scoring system, where houses that meet *all* criteria for a CHLP Indicator are scored as a pass, this paper presents a snapshot of the condition of houses in the broader Aboriginal community housing sector from the SF1 data before any repairs undertaken, and the impact of the NSW Health program on those same indicators from the SF2 data after repairs are completed. The items comprising each CHLP indicator are reported in Appendix I of the thesis. The geographical distribution of projects, any changes over time, the primary causes for repair works, and the impact of returning to communities for a 2nd project are also described in this paper.

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[1] Health Protection NSW, St Leonards NSW 2065, Australia
[2] School of Public Health, Faculty of Medicine and Health, University of Sydney, Camperdown NSW 2006, Australia
[3] University Centre for Rural Health, Faculty of Medicine and Health, University of Sydney, Lismore NSW 2480, Australia
[4] Q Social Research Consultants Pty Ltd., Broadway NSW 2007, Australia
[5] NSW Ministry of Health, St Leonards NSW 2065, Australia
[*] Author to whom correspondence should be addressed.

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Author	Contributions
JCS	Conceived and designed the study, oversaw the data management and statistical analysis, and led the write-up of the paper.
GGM	Contributed to the design of the study and commented on drafts of the paper.
TS	Assisted with the data management, validation and statistical analysis, and commented on drafts of the paper.
KB	Assisted with the data management, validation and statistical analysis, and commented on drafts of the paper.
JG	Assisted with the data management, validation and statistical analysis, and commented on drafts of the paper.
OP	Assisted with the data management, validation and statistical analysis, and commented on drafts of the paper.
MW	Assisted with the data management, validation and statistical analysis, and commented on drafts of the paper.
PT	Contributed to the development of the original survey tool and commented on drafts of the paper.

All authors read and agreed to the published version of the manuscript.

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Article

Prioritising Housing Maintenance to Improve Health in Indigenous Communities in NSW over 20 years

Jeffrey C. Standen [1,2,*], Geoffrey G. Morgan [2,3], Tim Sowerbutts [4], Katrina Blazek [5], Jessica Gugusheff [5], Otto Puntsag [1], Michael Wollan [5] and Paul Torzillo [2]

1 Health Protection NSW, St Leonards NSW 2065, Australia; Otto.Puntsag@health.nsw.gov.au
2 School of Public Health, Faculty of Medicine and Health, University of Sydney, Camperdown NSW 2006, Australia; geoffrey.morgan@sydney.edu.au (G.G.M.); Paul.torzillo@sydney.edu.au (P.T.)
3 University Centre for Rural Health, Faculty of Medicine and Health, University of Sydney, Lismore NSW 2480, Australia
4 Q Social Research Consultants Pty Ltd., Broadway NSW 2007, Australia; sbutts@qsrc.com.au
5 NSW Ministry of Health, St Leonards NSW 2065, Australia; katrina.blazek@sydney.edu.au (K.B.); Jessica.Gugusheff@health.nsw.gov.au (J.G.); Michael.Wollan@health.nsw.gov.au (M.W.)
* Correspondence: Jeff.Standen@health.nsw.gov.au; Tel.: +61-2-9391-9627

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Abstract: Many studies document the relationship between housing quality and health status. Poor housing in Aboriginal communities continues to be linked to the compromised health status of Aboriginal Australians. The New South Wales (NSW) Housing for Health (HfH) program has been assessing and repairing Aboriginal community housing across the state for 20 years using a standardised intervention methodology that aims to improve the health of Aboriginal people in NSW by improving their living environments. Items are tested and repairs are prioritised to maximise safety and health benefits and measured against 11 Critical Healthy Living Priorities (e.g., safety, facilities for washing people and clothes, removing waste and preparing food). Descriptive analysis of data collected pre- and post-intervention from 3670 houses was conducted to determine the effectiveness of the program. Analysis demonstrated statistically significant improvements in the ability of the houses to support safe and healthy living for all critical healthy living priorities post-interventions. Trend analysis demonstrated the magnitude of these improvements increased over 20 years. In 24 communities (n = 802 houses) where projects were repeated (5–17 years later), results indicate sustainability of improvements for 9 of 11 priorities. However, the overall condition of health-related hardware in Aboriginal community housing across NSW pre-intervention has not significantly changed during the program's 20 years. Results suggest a systematic lack of routine maintenance and quality control continues to be the overwhelming cause for this lack of improvement pre-intervention. Our evaluation of the HfH program demonstrated that fidelity to a standardised housing testing and repair methodology to improve residents' safety and health can have sustainable effects on housing infrastructure and associated health benefits, such as a 40% reduction in infectious disease hospital separations. Housing and health agencies should collaborate more closely on social housing programs and ensure programs are adequately resourced to address safety and health issues.

Keywords: housing for health; health hardware; housing quality; Indigenous housing; Aboriginal housing; health; evaluation; housing standards; home health and safety; healthy living priorities

1. Introduction

The World Health Organization (WHO) recognises poor housing as one of the main social causes of ill health [1,2] and extensive evidence has demonstrated improvements in health associated with improvements in housing and living environments since the late 1800s [3–5].

While Australia is an economically developed country with a high standard of living [6–8], poor housing in Aboriginal communities continues to be linked to the compromised health status of Aboriginal Australians since early last century [9–18].

There are around 800,000 Aboriginal and Torres Strait Islander people in Australia, representing 3.3% of the total Australian population. Whilst in remote areas there are higher proportions of Aboriginal Australians, one-third of the Australian Aboriginal population lives in New South Wales (NSW), the most populous state in Australia [19,20]. The NSW state health authority (NSW Health) has been delivering Housing for Health (HfH) projects with Aboriginal communities across NSW since 1997. HfH aims to improve the health status of Aboriginal people, particularly children, by assessing, repairing or replacing "health hardware" (particularly plumbing and electrical items) in houses to ensure they are safe and support occupants to practice healthy living. Health hardware in the context of HfH is defined as "the physical equipment needed to give people access to the health giving services of housing" [21].

HfH is a structured process for surveying and fixing houses, developed by Healthabitat, a not-for profit organisation, in the early 1990s [22,23]. It has since been used throughout Australia and internationally [9,24] and adopts a "no survey without service" approach to testing, recording, repairing and reporting at each survey. The "no survey without service" approach means no survey data is collected without a service being provided, such as making immediate repairs to items that require urgent attention [22].

In 1997 an interagency environmental health committee of NSW government agencies funded a trial HfH project in one discrete Aboriginal community in Northern NSW that demonstrated measurable improvement in the condition of those houses and ability to support healthy living. Consequently, a jointly funded program by NSW Health and the NSW Governments' 10-year Aboriginal Communities Development Program (ACDP) expanded HfH to other NSW Aboriginal communities—usually a small town or a neighbourhood in a larger town [25]. An evaluation at the end of the ACDP funding cycle demonstrated positive health outcomes and subsequently the program was recurrently funded by NSW Health and funding increased. The NSW HfH program is managed centrally by NSW Health's Aboriginal Environmental Health Unit and delivered jointly with regional NSW Public Health Units (PHUs), in partnership with the Aboriginal communities. The HfH program and financial management is guided by NSW state government policies and procedures.

This paper aims to describe the development of the HfH program in NSW, provide an overview of the program methodology and an analysis of program data over 20 years, and discuss the benefits and limitations of the program.

2. Methods

2.1. Data Collection

Housing for Health (HfH) projects (also referred to as the intervention) are run according to a standardised seven stage process [26,27] which involves the collection of data on house condition, remediation works completed and associated expenditure.

2.1.1. Stages 1-3: Community Selection and Project Establishment

In NSW, projects are delivered continuously, and at any given time there are around 10–15 projects at various stages of implementation across the state. The selection of Aboriginal communities invited to participate in HfH (Stage 1) is primarily based on need determined from information on housing

condition provided by PHUs, communities and government reports—and the availability of project resources at the time. Communities are not randomly selected.

Community consultation and a feasibility assessment (Stage 2) is undertaken to consider logistical issues in delivering the project—such as employment of local workers, insurances and accommodation—and to obtain community consent prior to proceeding. Consultation is undertaken with the housing providers, community leaders and each household. Project establishment (Stage 3) informs residents, arranges local work opportunities by employing local community workers and tradespeople, purchases consumables, and prepares for the immediate fix during the next stages.

2.1.2. Stage 4: Baseline Survey and Urgent Repairs

Teams of trained community workers led by qualified team leaders, usually from local PHUs, undertake the initial baseline survey and fix (SF1). SF1 tests and records 268 items in each house using standardised, repeatable tests based on Australian standards and current best practice. The raw survey items provide useful information on specific issues in houses such as number of residents, number of taps working and hot water temperatures, and guides the repair works. Teams carry out minor repairs immediately such as replacing light globes and shower heads or unblocking sinks. The tradespeople—licenced plumbers and electricians—follow the teams within the next few hours repairing urgent and more complex items identified by the survey such as replacing hot water systems. There are some widely held beliefs about social housing being poorly looked after by the tenants, so the tradespeople are required to identify and record the cause for each repair being either:

- *Routine* (maintenance reasonably expected in a house);
- *Faulty* (the item isn't present or installed incorrectly), or
- *Damage* (by people, and not by ants, vermin, poor water quality or other factors outside of the residents' control).

2.1.3. Stage 5: Major Repairs

Larger, more complex works such as re-waterproofing showers or improving accessibility for elderly or disabled tenants are implemented over the next 4 to 18 months following SF1, with the length determined by the number and condition of houses.

2.1.4. Stages 6 and 7: Follow-Up Survey and Final Report

Following the completion of the major repairs, a second survey and fix (SF2) is undertaken using the same survey instrument as SF1. This second survey and fix provides a data driven comparison between SF1 conducted *before* any works completed and SF2 conducted *after* all works are completed. This is usually between six and 18 months later, depending on the amount of work required. SF2 facilitates repairs to any outstanding items since SF1 and enables an audit of the works in Stage 4 and Stage 5 by community teams. A report of the housing condition before and after each project, and a list of all works undertaken—by house and by trade—is compiled for each HfH project and provided to the community organisations at the completion of the project.

2.1.5. Repeat HfH Projects

As the program has been continuously delivered around the state of NSW for two decades, most of the larger Aboriginal community housing providers in both discrete and non-discrete Aboriginal communities have received a HfH project. In the second decade, some communities received a repeat HfH project. The time between first and second HfH projects ranges from five to 17 years, and timing was dependent on specific issues in those communities.

2.1.6. Methods of Prioritising Repairs

The program has a limited budget, so all works are prioritised to maximise the safety and health benefit to householders. Immediate life-threatening dangers are addressed as the highest priority, followed by repairs that ensure the house structure and hardware can support healthy living by the residents. Based on the literature, Healthabitat developed a practical implementation of evidence-based practices that support healthy living [11,22]. These included 11 Critical Healthy Living Priorities (CHLPs) which are reported in this analysis:

1. Power, water, and waste connected
2. Electrical safety
3. Gas safety
4. Structure and access
5. Fire safety
6. Shower working adequately
7. Facilities to wash children
8. Laundry services
9. Flush toilet working
10. All drains working
11. Facilities to store, prepare and cook food

Work is allocated in accordance with these priorities, but not all may be met at the completion of a HfH project given funding limitations.

2.2. Statistical Analysis

There are 268 raw items collected at survey and 41 items calculated based on the survey items, giving a total of 309 items per house. These items have response codes assigned to them with a score for each response: typically, 1 for a pass and 0 for a fail, although some items have slightly more complex scores.

Each CHLP is measured by assigning a set of data items from the survey. For example, for a house to enable residents to wash effectively and to maintain hygiene and health, a shower in a house requires the following minimum seven items to be functioning: hot water; cold water; hot water at a safe but effective temperature; hot and cold water taps; a shower hose and adequate drainage [9]. The CHLP score is calculated as the sum of scores for each item, with the maximum score being the sum of maximum possible scores for those items. (Figure A2 in Appendix B shows similar criteria to store, prepare and cook food.)

Two methods were used to calculate summary statistics for a set of houses:

1. The percentage of houses where CHLPs were fully met, i.e., a house's score for a CHLP equaled the maximum possible CHLP score, therefore fully meeting the standard.
2. The percentage of houses where CHLP scores were within specified ranges i.e., Good (100% of maximum score); Fair (50% to 99% score) and Poor (less than 50%). This method was used for analysis in Appendix C.

Survey data from 112 HfH projects from 1998–2017 were analysed using SAS Enterprise Guide software, Version 9.4 [28]. Descriptive analyses were conducted of these CHLP summary measures collected at SF1 and SF2 to compare before and after house function within all 112 HfH projects and assess changes over 20 years.

The percentage of houses where a CHLP was fully met was calculated as a binomial proportion for all HfH projects in the relevant time period. A 95% confidence level interval for the binomial proportion was constructed using the normal approximation. To compare the percentages of CHLPs fully met between SF1 and SF2, the proportions of houses before and after intervention were tested for

marginal homogeneity for matched pairs using the McNemar test statistic at 95% confidence level [29]. A matched-pairs method compares categorical responses for two samples when each observation (i.e., the house that received HfH) in one sample pairs with an observation in the other sample.

The HfH projects were grouped into 5-year intervals based on completion dates for each project and an average across the CHLP scores was calculated to determine trends over time. For each CHLP we assessed whether there was a linear trend in the percentage fully met across an ordered factor (5-year intervals). This analysis was applied separately at SF1 and SF2 and the Cochran–Armitage trend test statistic was used at 95% confidence level [29].

Separate analysis was undertaken for those communities that had a repeat HfH project (n = 802 houses, n = 24 projects) to compare CHLP scores over time within the same community.

3. Results

Over the 20-year period (1998–2017), the NSW Housing for Health (HfH) program conducted 113 HfH community projects (or interventions) in 3670 houses with a resident population of 14,609 people. In total, 88 communities (2791 houses) received at least one HfH project from 1998 to 2017. Of these 88 communities, 24 (802 houses) had a second project between five and 17 years later. One community had a third project implemented but it is not included in this analysis.

Figure 1 shows the distribution of communities where HfH projects were conducted across NSW from 1998 to 2017, including those communities visited more than once. There is a wide distribution of HfH projects in communities across the state in urban, rural and remote areas. The HfH program has reached around 70% of houses in the NSW Aboriginal community housing sector over this time.

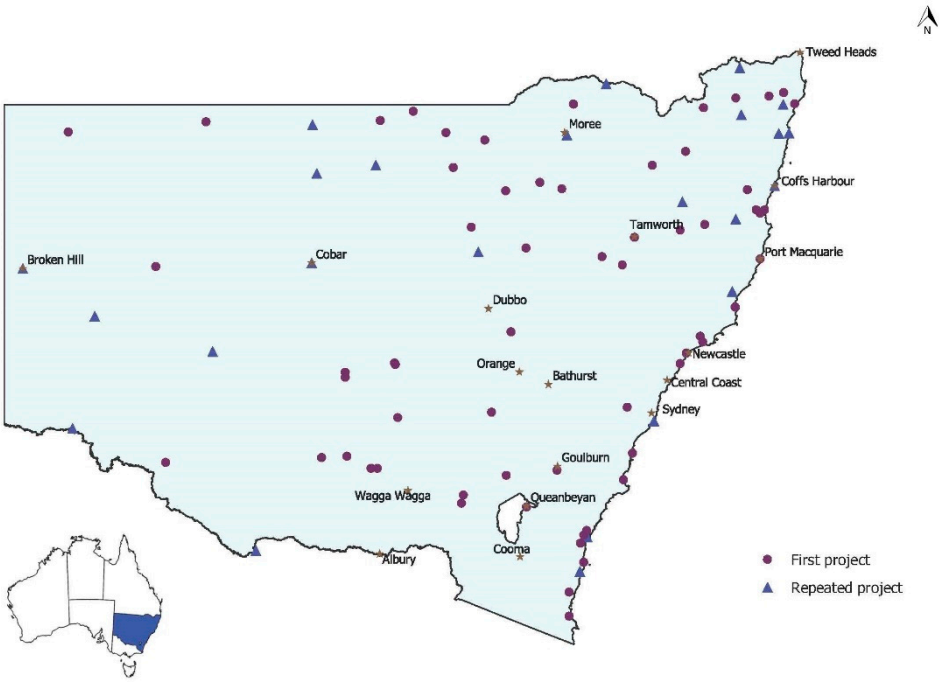

Figure 1. Location of New South Wales (NSW) Housing for Health Projects[+] from 1998 to 2017. Note: [+] where two projects are in close proximity (e.g., in the same town), they may be represented by one triangle or circle.

Table 1 summarises this information by five-year intervals. The results show the number of projects, houses and residents (recorded at SF1) in communities that received one or more HfH projects.

Table 1. Summary results of Housing for Health program data by 5-year intervals.

Period		Project	Houses	Residents *
1998–2002	Visit 1	35	1141	5021
	Visit 2	0	0	0
	Total	35	1141	5021
2003–2007	Visit 1	28	911	3621
	Visit 2	1	16	51
	Total	29	927	3672
2008–2012	Visit 1	11	356	1335
	Visit 2	8	327	1339
	Total	19	683	2674
2013-2017	Visit 1	14	383	1385
	Visit 2	15	459	1507
	Total	29	842	2892
All years	Visit 1	88	2791	11,362
	Visit 2	24	802	2897
	Total	112	3593	14,259

* The number of people living in a house is recorded during the Survey Fix 1.

Figure 2 shows the average percentage of houses where all CHLPs were fully met at SF1 and SF2 for all NSW projects by 5-year intervals. (Table A6 in Appendix E summarises data for Figure 3). Trend analysis shows increasing improvement at SF2 over time. However, the CHLP related condition of houses before the project (SF1) remained consistently low (below 40% average across CHLPs) over the past 20 years. This general trend is reflected in nearly all the critical HLPs (represented in Appendix D).

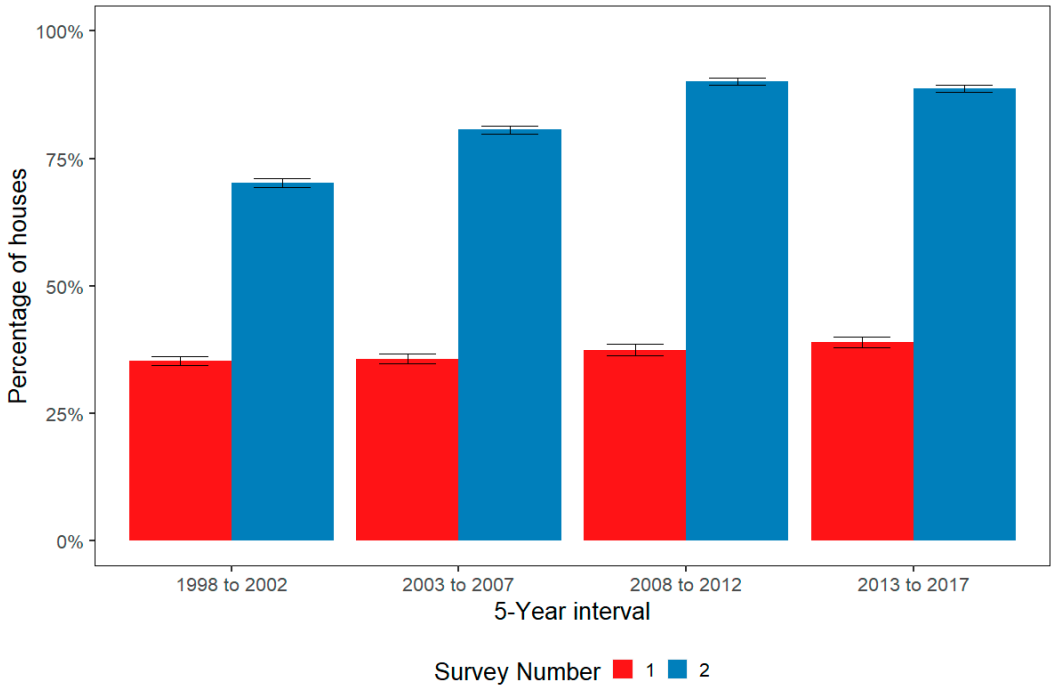

Figure 2. Average Percentage of houses with Critical Healthy Living Priorities fully met at Survey-Fix 1 and Survey–Fix 2 for all NSW projects 1998–2017 by 5-year intervals.

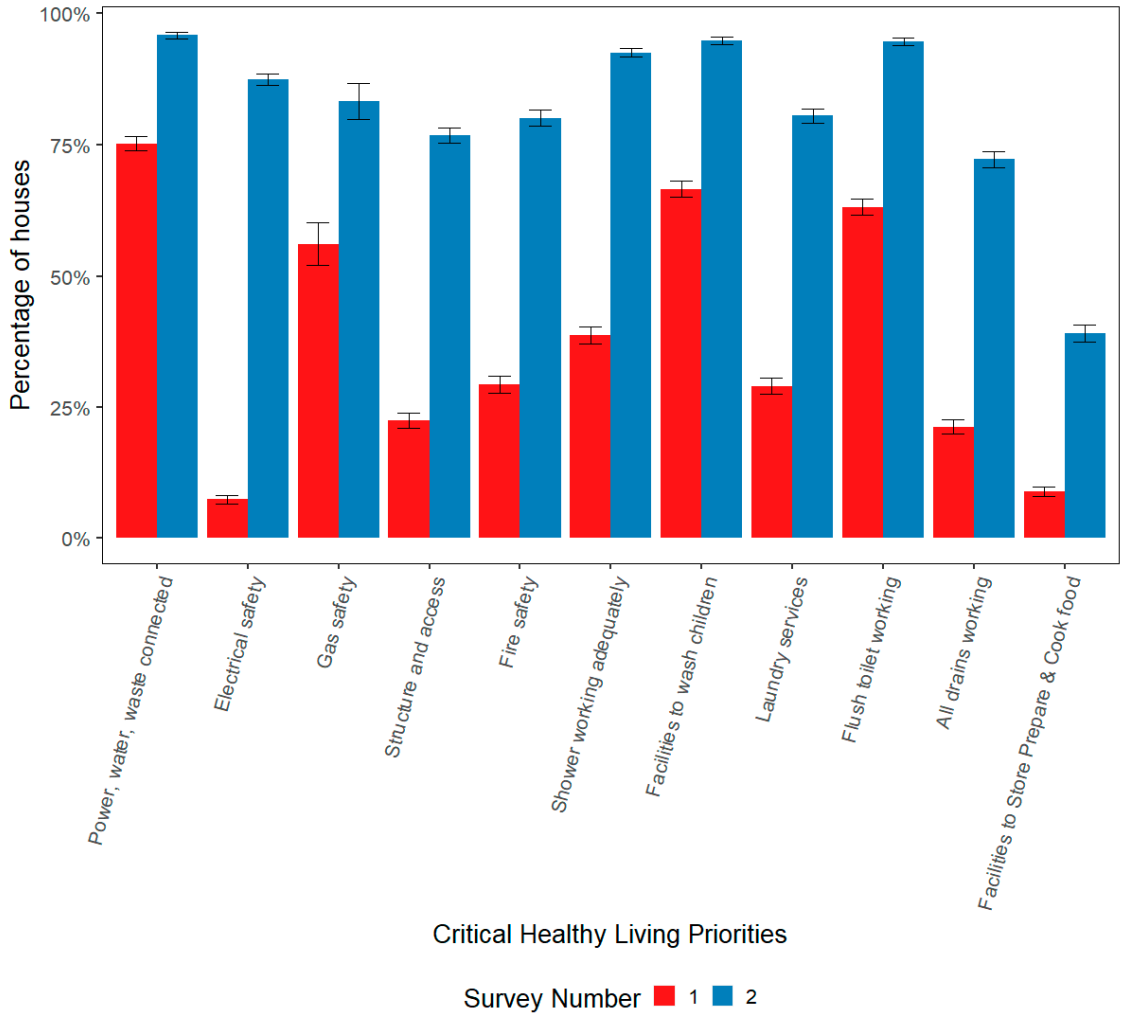

Figure 3. Percentage of houses with Critical Healthy Living Priorities fully met at Survey-Fix 1 and Survey–Fix 2 for all NSW projects (n = 112) from 1998–2017.

Figure 3 shows changes in the CHLPs (the most important items needed to support safe and healthy living) between SF1 (red bars) and SF2 (blue bars) for all projects completed in NSW over the past 20 years. The CHLP categories are prioritised from left (highest) to right. (See Appendix E Table A5 for data tables for Figure 3). The columns represent the percentage of houses that met all criteria (100% score) for each CHLP category in all HfH projects (n = 112). If one or more criteria failed in a house, the house was not considered to adequately support that CHLP item.

At the initial survey (SF1), safety in houses was low, particularly electrical safety (7.5%), structure and access (23%) and fire safety (29%). For those houses with gas, just over half (56%) met the safety requirements. With regard to washing people, only 39% of all houses had all items in the shower working and two thirds of houses had a place to wash a small child with all hardware working (such as a bath, large basin or laundry tub with washing machine by-pass). Only 29% of houses had laundry facilities to support the washing of clothes and bedding. This includes the hardware and space to install a washing machine safely but does not include the washing machine itself as this is considered a tenant responsibility in social housing. Only two thirds of houses had flush toilets working properly, and 21% had all drainage working. Improving nutrition is assessed by whether houses support the ability of residents to prepare, cook and store food safely. Only 9% of houses had all items in this CHLP category working at SF1.

Chi-squared analysis ($P < 0.01$) revealed significant improvement in the percentage of houses meeting each CHLP from SF1 to SF2 in all categories. Following SF2, a score of at least 75% was attained

for all but two of the CHLPs, with four CHLPs exceeding a score of 90%. The biggest improvement was in electrical safety, with only 7% meeting this CHLP at SF1 and 87% at SF2. Whilst the ability to store, prepare, and cook food was improved more than 4-fold, only 39% of houses had all items working at the end of the projects.

Figure 4 presents data on the reasons tradespeople recorded for repairing 63,648 items identified by the survey during the 20-year study period. Across NSW Aboriginal community housing, 84% of items repaired were routine maintenance issues. Faulty design or workmanship accounted for 11% of failures, with 5% of items fixed as a result of damage by the tenants.

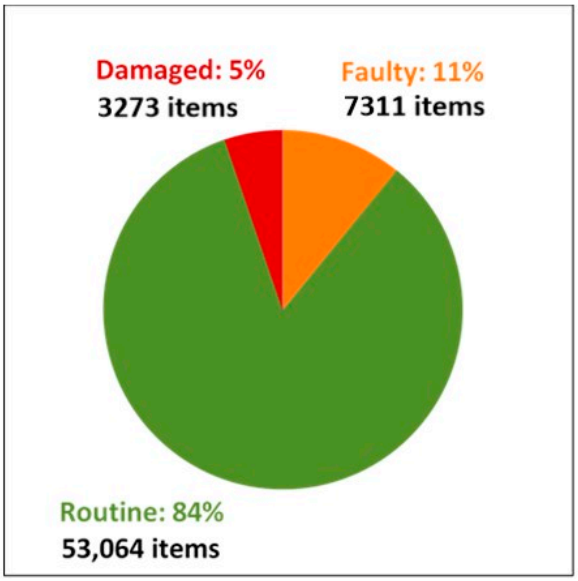

Figure 4. Percentage of items fixed under the NSW Housing for Health Program (n = 63,648) by the reason for repair from 1998–2017.

Figure 5 shows the CHLPs for 24 communities where a repeat project was implemented in the second decade of the program. The red and dark blue bars show the percentage of houses meeting each CHLP at the first project SF1 and SF2, respectively. The orange and light blue bars show the percentage of houses meeting each CHLP at the second project SF1 and SF2, respectively. (See Table A7 in Appendix E for Data Tables for Figure 5).

In both visits, significant improvements in houses were made between SF1 and SF2. The SF2 results for all CHLPs in the second HfH projects within the same community were higher than SF2 in the first HfH projects in those communities. All CHLPs except *Gas Safety* and *Structure and Access* followed a similar pattern: the lowest house function was recorded at SF1 of the first HfH project. These increased significantly by SF2. In the five to 17 years between the first and second HfH projects in these communities, the functionality of the houses dropped, but overall not to the level of the first HfH project in these communities, indicating some of the improvements from the first project may have been sustained in these 24 communities that had a second HfH project.

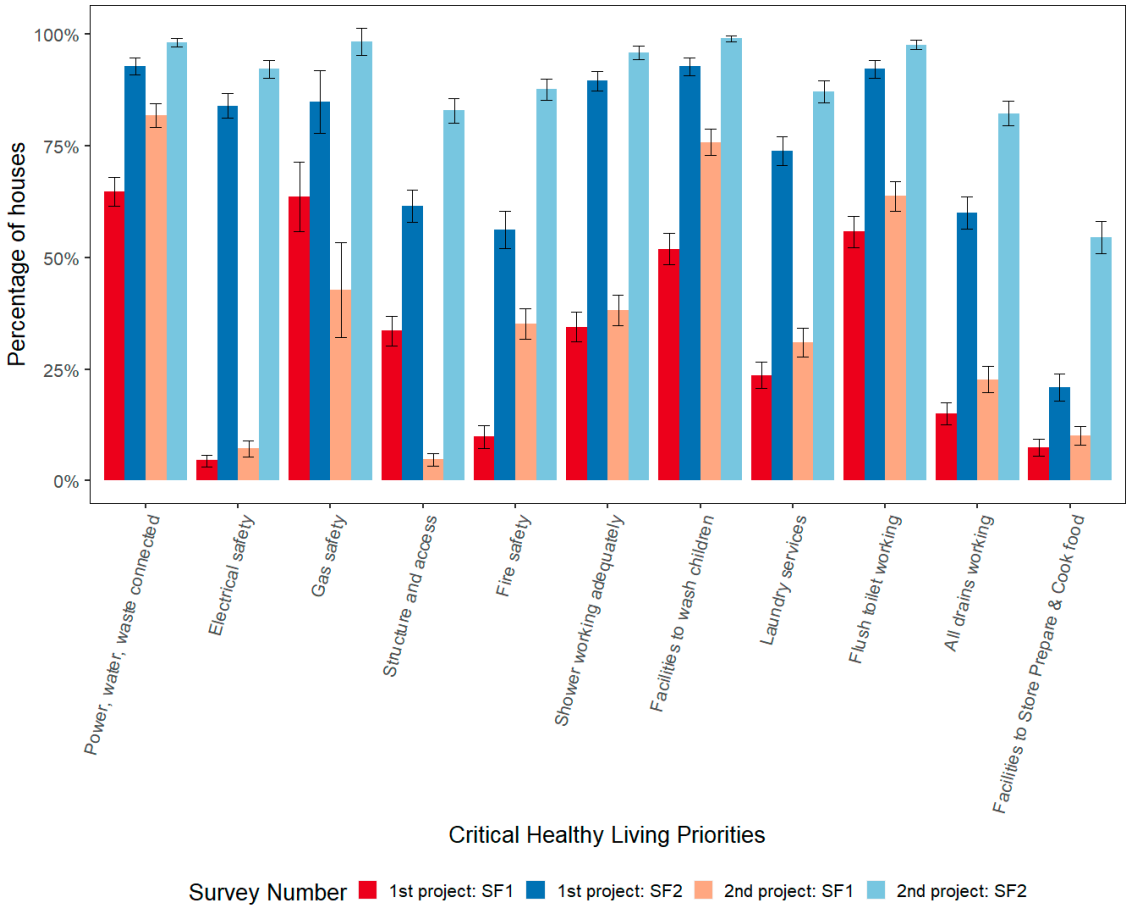

Figure 5. Percentage of houses with Critical Healthy Living Priorities fully met for NSW projects with repeat visits at First Project SF1 (n = 802) and SF2 (n = 722); and at Second Project SF1 (n = 788) and SF2 (n = 734) from 1998–2017.

4. Discussion

This report highlights the sustained improvements to housing within NSW Aboriginal communities as a result of the NSW Housing for Health (HfH) program over a 20-year period from 1998 to 2017. The research demonstrated significant improvements in the condition of houses and the ability to meet critical healthy living priorities (CHLPs) due to the HfH project intervention (Figure 3). Not all houses reached 100% for all the CHLPs reported in this paper, but more detailed analysis of the data showed there were still measurable improvements in each house (see Appendix C).

Most CHLPs achieved greater than 75% compliance after the HfH project intervention. However, results are generally lower for the lower priority CHLPs largely because of HfH program budgetary constraints restricting improvement on expensive items.

Each CHLP comprises a set number of items and a house must pass all these items to achieve that CHLP goal. Occasionally, achieving a maximum score for all CHLP items is beyond the scope of the HfH program funding and not all items are fixed. For example, fire safety in all houses was upgraded to current standards for smoke detection, but in some houses, security screens had been permanently fixed to the building frame, increasing security but preventing egress (fire escape) from windows.

Whilst the facilities to store, prepare and cook food were improved more than four-fold due to the HfH project intervention, only 39% of houses had all items working after the intervention. Budgetary constraints limited the ability to improve all items within this CHLP, particularly in the first decade of the program. Appendix B shows the separate criteria for this CHLP in more detail.

Increased HfH funding allocation in the second decade of the program is likely to have contributed to the measurable improvement in this category over time (as shown in Appendix D).

The results of Survey-Fix2 (SF2) are a measure of the effectiveness of the HfH project intervention to improve house function over the past 20 years. Trend analysis of the overall SF2 data post-intervention (Figure 2) indicates the HfH program has become more effective over time. This is most likely a result of improved targeting of items for repair by HfH project managers and some increased funding. Appendix E shows that this same trend of program efficiency is consistent across each of the CHLPs.

Evaluation of house function is built into the methodology of the NSW HfH program for each HfH project but quantifying the impact of the HfH program on health outcomes is challenging. A 10-year evaluation of the program assessed changes in hospital admissions before and after each project. The analysis linked hospital admissions data to all houses in the HfH program over the first decade and demonstrated a 40% reduction in hospital separations for environmentally related infectious diseases for those residents of houses included in the HfH program compared to a control population [30]. A summary of this evaluation and these results is presented in Appendix A. Whilst this analysis cannot demonstrate causality between the HfH intervention and reduced disease, it does demonstrate a strong association between these improved house function measures and improved health outcomes [30]. The significant reductions in hospitalisations found in this assessment occurred in the context of significant improvement in targeted safety and healthy living practice measures over the first decade of the HfH program. Figure 2 demonstrates even greater improvements in house function over the second decade of the HfH program (2008 to 2017) compared to the first decade (1998 to 2007), indicating the same or possibly better health outcomes would likely be continued over the life of the HfH program.

Survey-Fix 1 (SF1) data describes of the condition of housing before any work was undertaken as part of the HfH intervention. The HfH program has surveyed and fixed around 70% of the NSW Aboriginal community housing sector, presenting a picture of the housing condition in the sector over 20 years. The ability of Aboriginal community housing in NSW to support basic safety and healthy living priorities prior to a HfH project was below 40% across all houses (Figure 2) and trend analysis indicates a lack of significant improvement in the condition of houses in the sector over the last two decades.

The failure of housing management systems is a likely reason for this lack of improvement in house function in Aboriginal communities over the past two decades (see Figure 4). NSW HfH program data indicates 95% of the repairs made on these houses resulted from a failure of systems to ensure routine maintenance (84%) and adequate checks on the quality of workmanship (11%). Focusing on tenancy management to reduce tenant damage will only address 5% of the issues related to house function in NSW community housing. Our results are consistent with previously published national data (2006) which showed, whilst there were slightly higher rates of tenant damage (10%), the primary cause for house function failure stemmed from a failure of maintenance regimes and quality control [9].

Although the average condition of houses at SF1 across all 112 HfH projects shows very little change over 20 years, (Figure 2) the 24 locations that have received a second HfH project have maintained higher house function (at the second project SF1) for most CHLPs (Figure 5), suggesting a sustainable benefit of the HfH program over time. This finding is consistent with results reported in the 10-year review which showed one community in 2003 where a third survey and fix had been undertaken 2–3 years later to gauge the sustainability of the program, house function had deteriorated slightly since SF2, but only 5% of the original funding was required to bring the houses back to the same standard [30]. Anecdotally, HfH project managers have reported that higher quality health hardware (e.g., taps) specified by the program was still functioning at the return visit. Whilst high quality materials may cost a little extra, they are likely an investment in sustainable health hardware. Further analysis of the survey and financial data for these 24 projects is planned to identify the sustainability of improvements in individual items.

Data from communities that received a repeat HfH project demonstrates significant improvement in the condition of the houses after each intervention (from SF1 to SF2). The improvement between SF2

results at the end of the first and second interventions is consistent with the general improvements in project delivery over the life of the program, illustrated in Figure 2.

The results of the HfH program assessment of evidence-based housing safety and health priorities presented here demonstrates significant improvements in the home environments over two decades. For disadvantaged families where unemployment is high, the home environment is often the environment where people spend most of their time. Ensuring the homes' ability to support health is associated with significant reduction in the rates of infectious diseases, which in turn can reduce the risk factors for many chronic diseases, such as renal and cardiac disease, both of which are overrepresented in the Aboriginal population [17,20,31]. The HfH program also helps ensure the home environment supports practices delivered by health messages through clinical and population health services.

Improving health outcomes should reduce health expenditure on preventable conditions. "The cost of poor housing is borne by the health system" [32] and, while the extent of the financial benefit to health from the NSW HfH program is yet to be quantified, the relatively small amounts of HfH program funding that supports healthy living is likely to be an investment in health into the future. The benefits of the HfH program are not limited to improvements in house function and health outcomes. The strong engagement with Aboriginal communities throughout the process builds relationships between the communities and the NSW state health authority, as well as local Public Health Units. On the strength of these relationships, other issues of concern to the community, such as drinking water quality or waste management, have been raised and addressed by separate programs. Socioeconomic disadvantage covers a wide range of factors of which a functioning house may only be one. However, for a householder juggling many issues in the home, it can mean one less cause of stress and disempowerment in their life, allowing them the energy to focus on other issues including their health and the health of their family.

Much has been published on the connection of housing and health in the international literature. In the context of industrialised economies, much of the modern literature relates to urbanisation, energy efficiency, temperature control (particularly in cold environments), and indoor air quality issues such as mould and chemical exposures [33–36]. There is also a considerable body of literature on improving drinking water, sanitation and hygiene (WaSH) in the developing country context [37–42]. There is less published internationally on the capability of modern housing to support issues such as safety and WaSH principles. In the Australian context, a number of housing-related papers in the published and grey literature reference safety and healthy living practices as a measure or a best practice standard for housing [17,43–48], but the findings of this paper suggest no assumptions can be made that are adequately addressed in modern public housing, especially in Indigenous communities.

5. Strengths and Limitations

A strength of the HfH program has been the consistent collection of detailed data on houses in Aboriginal communities over an extended period. Whilst the primary purpose of the data is to guide repair work for each HfH project, the consolidated data provides evidence that can inform social housing policy and program delivery. Despite the gains demonstrated over the past 20 years, the HfH program does not address all issues in the homes. An average budget of only $9220 per house (Consumer Price Index (CPI) adjusted) has limited the HfH program's ability to improve all items in houses, and more detailed analysis of the HfH program data may help identify specific items for repair that provide further improvements to the CHLPs.

The HfH program does not focus on social housing issues such as tenancy and long-term asset management. Its primary focus is on improving health by providing a level of attention to detail on hardware items that improve safety and health in houses, and these items are a basic standard that could be applied to all social housing. Telfar-Barnard et al. described a household "warrant of fitness" assessment for all rental housing in New Zealand to ensure basic measures of habitability are met, [49] similar to a basic standard of testing applied to car registrations in many jurisdictions. A

similar approach could be applied to social housing in Australia to include criteria that ensure houses support basic healthy living practices in any handover or annual inspection processes.

6. Conclusions

Analysis of the Housing for Health (HfH) program data has demonstrated significant improvements in critical healthy living priorities in Aboriginal community housing in NSW where the program has been implemented. The magnitude of these improvements has increased over 20 years and results indicate sustainability of improvements for most priorities. The NSW HfH program's collection of consistent data over this time provides a repository of information which can guide future policy and program development. Despite the benefits from the HfH program, across NSW there has been little change over two decades in the poor standard of safety and health hardware in Aboriginal homes prior to the HfH projects. A lack of routine maintenance and faulty design or construction is overwhelmingly the key cause identified for the failure of items repaired under the program. This data suggests the systems for maintenance of health hardware in Aboriginal community housing over the past 20 years have not improved healthy living priorities. This lack of improvement may be contributing to the gap in Aboriginal health compared to the rest of the Australian population. The specification of quality health hardware in maintenance programs is likely to be a cost-effective investment in both housing and health in the long term. Fidelity to a detailed HfH program methodology of standardised testing and repair of defined items that improve safety and health has led to these significant and sustainable improvements in house function in Aboriginal communities over the past 20 years of the HfH program in NSW. The effectiveness of the HfH program has improved significantly over the second decade, suggesting the substantial improvements in health outcomes associated with the first decade of the HfH program [30] will likely be sustained or increased. The program should be expanded to communities that have not yet received the program, and the program principles should be embedded into larger social housing repair and maintenance programs.

Author Contributions: J.C.S.: conceived and designed the study, oversaw the data management and statistical analysis, an led the writeup of the paper. T.S., O.P., K.B., J.G. and M.W.: assisted with the data management, validation and statistical analysis, and commented on drafts of the paper. P.T. contributed to the development of the original survey tool and commented on drafts of the paper. G.G.M. contributed to the design of the study and commented on drafts of the paper. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The Housing for Health tool implemented in this report was provided under license to Health Protection NSW by Healthabitat Ltd. J. Standen is the Manager of the Aboriginal Environmental Health Unit in Health Protection NSW and manages the HfH program. P. Torzillo is a Director of Healthabitat Ltd. but had no influence in the design of the study; in the collection, analyses, or interpretation of data, or in the decision to publish the results.

Appendix A. Health Outcomes Evaluation of the NSW Housing for Health Program

A health linkage evaluation of the New South Wales (NSW) Housing for Health (HfH) program was conducted after the first 10 years of the program. The evaluation looked at the impact of the HfH program on World Health Organization's (WHO) International Statistical Classification of Diseases and Related Health Problems (ICD) Revision 10 (ICD-10) disease classifications attributed to changes to the home environment.

Table A1. List of International Statistical Classification of Diseases and Related Health Problems Revision 10 (ICD-10) codes for diseases related to the home environment (used for evaluation of health outcomes from Housing for Health).

Diseases	ICD-10 Codes
Acute respiratory Infections	J00-J22
Hepatitis—Viral	B15-B19 O98.4, P35.3
Intestinal Infectious Diseases	A01-A09
Otitis media	H65.1, H65.2, H65.3, H66, H67.0, H67.8
Skin infections	L00-L08

The evaluation linked the location of houses that received a HfH project between 1998 and 2008 to usual residential addresses data in the NSW Health routinely collected hospital admissions data. The rate of disease-specific hospital admission was calculated for each month in each community over the 10-year study period. Descriptive analysis assessed the rate of hospitalisations before and after each HfH project by calculating disease-specific rate ratios for each project and collectively for the whole program. The same process was used to calculate the disease-specific rate ratios for the control population (defined as the NSW rural Aboriginal population that did not receive the HfH intervention). The ratio of the two rate ratios was then calculated to assess any impact the program had on the selected hospitalisations over the 10 years [30]. Figure A1 shows these rate ratios for both case and control groups by grouped categories: All studied disease groups; Respiratory; Skin; Intestinal infections (including hepatitis) and Otitis media [30].

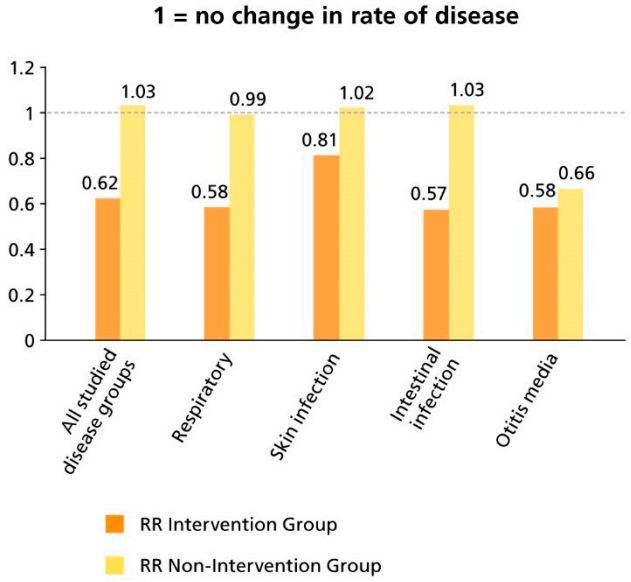

Figure A1. Before and after rate ratios for disease conditions in HfH intervention and non-intervention groups during a Health Outcomes Evaluation of Housing for Health.Source: Aboriginal Environmental Health Unit, Closing the Gap: 10 Years of Housing for Health in NSW—An evaluation of a healthy housing intervention. 2010: Sydney, NSW.

Routinely collected hospital separations data were used in the analysis due to its availability; however, it should be noted that for many home environment-related infections, hospital admissions would only represent the most serious of cases. Some symptoms may not be treated, and most infectious eye, ear, skin, respiratory or gastro-intestinal conditions would likely be treated at a primary health service such as a medical service or local general practitioner. As only the most serious cases would require hospital admission, these data may only represent a small portion of the overall burden of environmentally related diseases associated with Aboriginal community housing.

Appendix B. Criteria for the Critical Healthy Living Priority, *Improving Nutrition: Ability to Store, Prepare and Cook Food*

Each of the critical Healthy Living Priorities (CHLP) presented in the Housing for Health program results are measured by assigning a set of data items for that particular CHLP. Figure A2 shows the separate items for the CHLP: *Improving Nutrition: Ability to Store, Prepare and Cook Food* in more detail. The plumbing and electrical components of storing, preparing and cooking food (such as sinks taps, hot water and stoves and ovens) all achieved between 90–100% compliance by the end of the project. Less improvement was made in areas where kitchen benches and cupboards required replacement (primarily a financial restriction) and in refrigeration (which is considered a tenant responsibility in social housing in NSW).

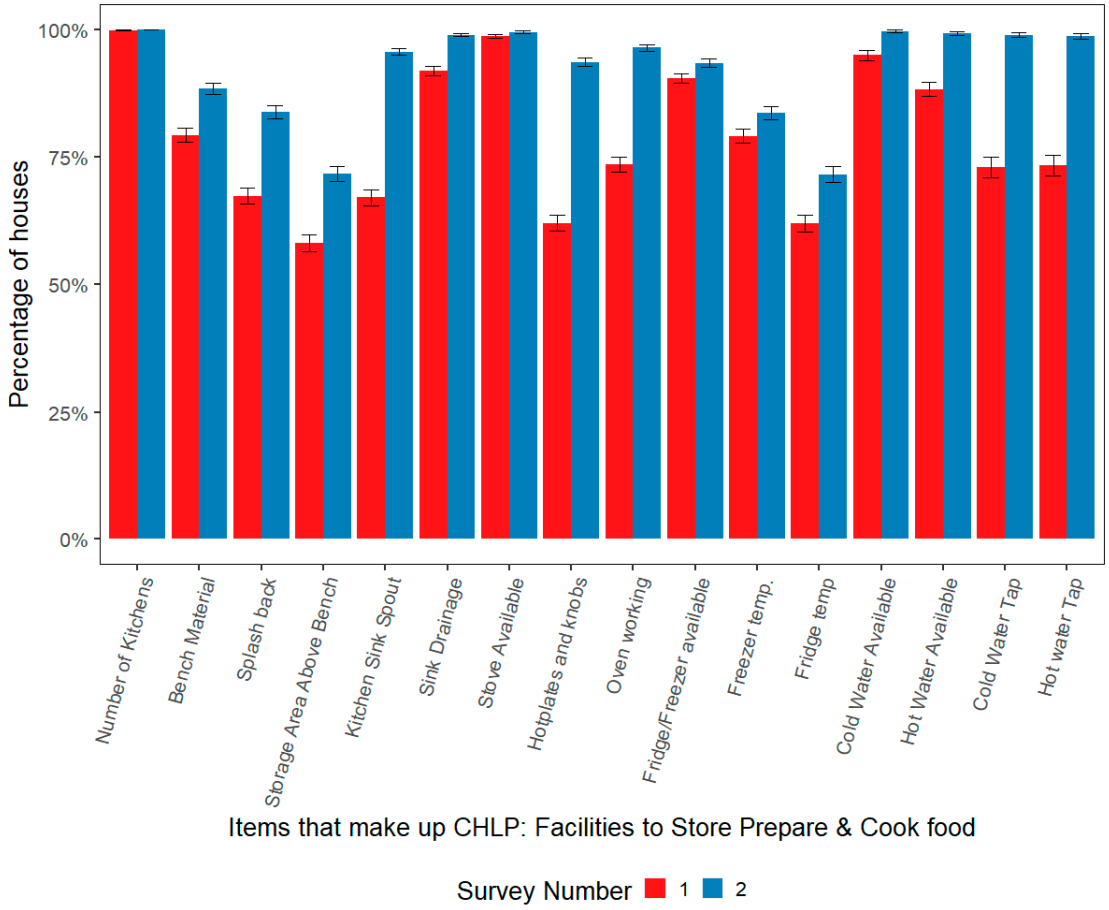

Figure A2. Percentage of houses where Critical Healthy Living Priority: *Improving Nutrition: Ability to Store, Prepare and Cook Food* was fully met for all NSW projects from 1998–2017.

Table A2. Percentage of houses where Critical Healthy Living Priority: *Improving Nutrition: Ability to Store, Prepare and Cook Food* was fully met for all NSW projects from 1998–2017.

	Survey ID 1		Survey ID 2	
Healthy Living Priority	**Per cent**	**95% CI**	**Per cent**	**95% CI**
Number of Kitchens	99.9	(99.8, 100)	100	(100, 100)
Bench Material	79.3	(78.0, 80.6)	88.4	(87.3, 89.5)
Splash back	67.4	(65.9, 68.9)	83.9	(82.7, 85.1)
Storage Area Above Bench	58.2	(56.6, 59.8)	71.8	(70.3, 73.3)
Kitchen Sink Spout	67.1	(65.6, 68.6)	95.7	(95.0, 96.4)
Sink Drainage	91.9	(91.0, 92.8)	99.0	(98.7, 99.3)
Stove Available	98.8	(98.4, 99.2)	99.6	(99.4, 99.8)

Table A2. *Cont.*

Healthy Living Priority	Survey ID 1		Survey ID 2	
	Per cent	95% CI	Per cent	95% CI
Hotplates and knobs	62.1	(60.5, 63.7)	93.6	(92.8, 94.4)
Oven working	73.6	(72.1, 75.1)	96.5	(95.9, 97.1)
Fridge/Freezer available	90.5	(89.5, 91.5)	93.5	(92.7, 94.3)
Freezer temp.	79.1	(77.7, 80.5)	83.7	(82.4, 85.0)
Fridge temp	62.1	(60.5, 63.7)	71.6	(70.1, 73.1)
Cold Water Available	95.0	(94.0, 96.0)	99.7	(99.4, 100)
Hot Water Available	88.4	(86.9, 89.9)	99.3	(98.9, 99.7)
Cold Water Tap	73.1	(71.1, 75.1)	99.0	(98.5, 99.5)
Hot water Tap	73.4	(71.4, 75.4)	98.7	(98.2, 99.2)

Appendix C. Changes in House Condition between Survey Fix 1 and Survey Fix 2 for Each of the Critical Healthy Living Priorities by Category of House Condition (Good, Fair or Poor)

Figure A3 presents the results of 112 Housing for Health projects by critical Healthy Living Priorities (CHLP) for Survey-Fix 1 (SF1) and Survey-Fix 2 (SF2) between 1998 and 2017. The scores for each priority are measured by performance score categories rather than just the percentage of houses that were all OK (i.e., achieved a 100% score). The categories (and scores) are: Good (100%) shown in dark green; Fair (51–99%) shown in light green and Poor (<50%) shown in yellow. It demonstrates that whilst not all houses achieved a 100% score for the HLP criteria at SF2, there was still measurable improvement in each house after the HfH intervention. Notably, after SF2 there is a significant reduction ($P < 0.01$) in the percentage of houses only achieving 50% or less of the possible score (in yellow).

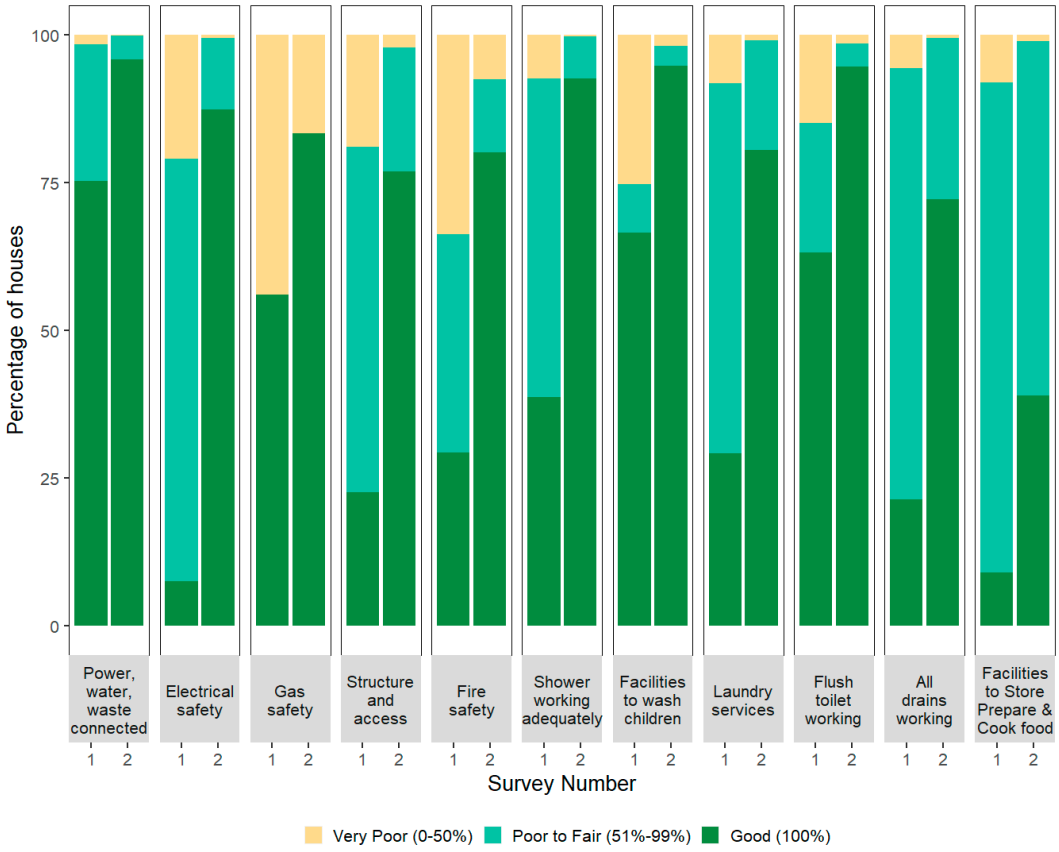

Figure A3. Comparison of Survey-Fix 1 and Survey-Fix 2 data for each critical Healthy Living Priority by category of house condition (Good, Fair or Poor) based on house function from 1998–2017.

Table A3. Comparison of Survey-Fix 1 and Survey-Fix 2 data for each critical Healthy Living Priority by category of house condition (Good, Fair or Poor) based on house function from 1998–2017.

Critical Health Living Priority	Category of House Condition	Per Cent	
		Survey ID 1	Survey ID 2
Power, water, waste connected	Very Poor (0–50%)	1.7	0.1
	Poor to Fair (51–99%)	23.1	4.0
	Good (100%)	75.2	95.9
Electrical safety	Very Poor (0–50%)	21.0	0.5
	Poor to Fair (51–99%)	71.5	12.1
	Good (100%)	7.5	87.4
Gas safety	Very Poor (0–50%)	43.8	16.7
	Good (100%)	56.2	83.3
Structure and access	Very Poor (0–50%)	18.9	2.1
	Poor to Fair (51–99%)	58.6	21.0
	Good (100%)	22.5	76.9
Fire safety	Very Poor (0–50%)	33.6	7.5
	Poor to Fair (51–99%)	37.1	12.4
	Good (100%)	29.3	80.1
Shower working adequately	Very Poor (0–50%)	7.3	0.3
	Poor to Fair (51–99%)	53.8	7.1
	Good (100%)	38.8	92.6
Facilities to wash children	Very Poor (0–50%)	25.2	1.9
	Poor to Fair (51–99%)	8.2	3.3
	Good (100%)	66.6	94.8
Laundry services	Very Poor (0–50%)	8.2	0.9
	Poor to Fair (51–99%)	62.6	18.5
	Good (100%)	29.1	80.6
Flush toilet working	Very Poor (0–50%)	14.9	1.5
	Poor to Fair (51–99%)	21.9	3.9
	Good (100%)	63.2	94.7
All drains working	Very Poor (0–50%)	5.6	0.6
	Poor to Fair (51–99%)	73.0	27.2
	Good (100%)	21.3	72.2
Facilities to Store, Prepare & Cook food	Very Poor (0–50%)	8.1	1.0
	Poor to Fair (51–99%)	82.9	59.9
	Good (100%)	9.0	39.1

Appendix D. Changes in House Function in Housing for Health (HfH) Projects over Time

Figure A4 shows changes in each of the critical Healthy Living Priorities (CHLP) between Survey –Fix 1 (SF1) and Survey-Fix 2 (SF2), separated into four five-year intervals to assess differences in house function and improvement over time for each CHLP.

The condition of houses pre-HfH intervention (represented by the SF1 data) improved slightly over time for some criteria. Trend analysis showed over the two decades that there were positive trends across five-year periods in: *Power, water, waste connected*; *Fire safety*; *Facilities to wash children (basin/bath/tub)*, and *Store, prepare & cook food*. There was a 'minimal' positive trend in: *Flush toilet working*, and *All drains working*, and no trend in: *Shower working adequately* and *Laundry services.*

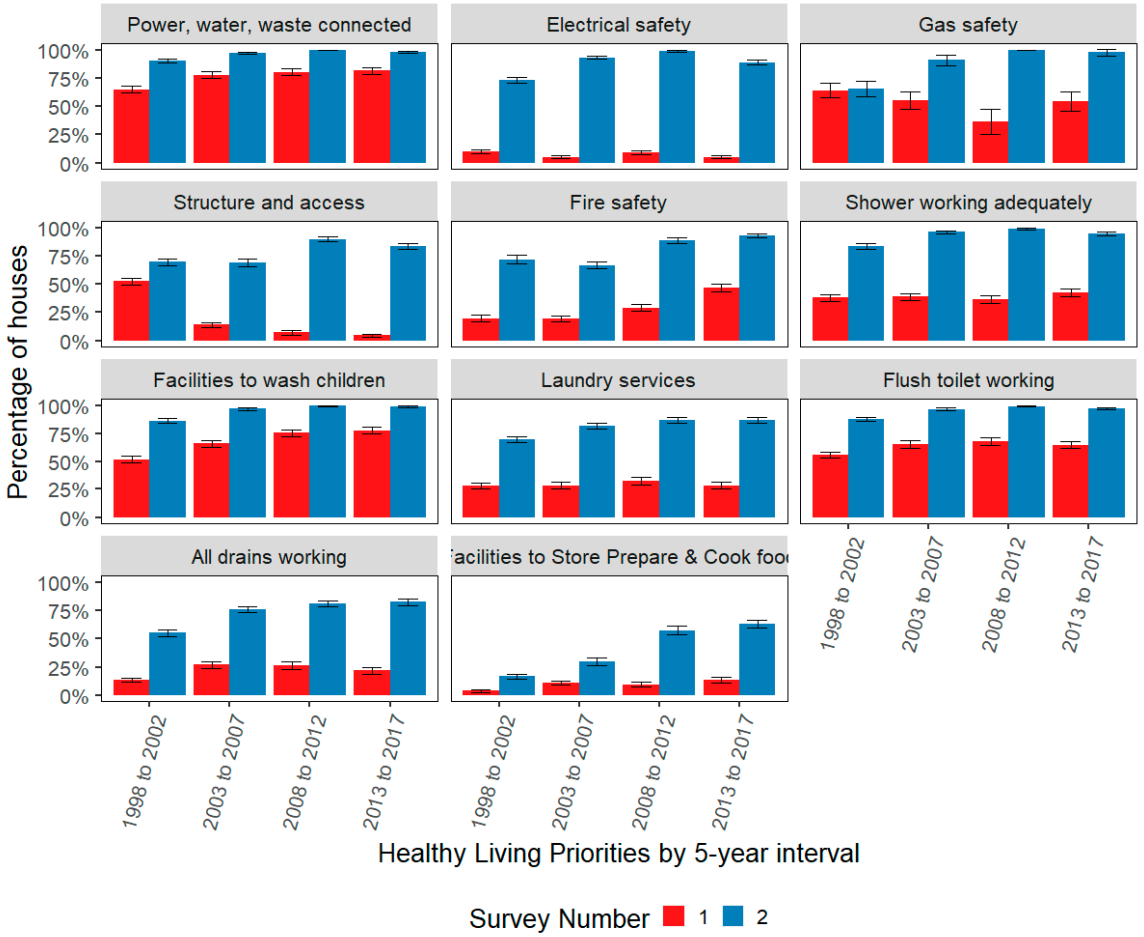

Figure A4. Percentage of houses where Critical Healthy Living Priorities were fully met at Survey-Fix1 and Survey–Fix 2 by 5-year intervals from 1998–2017.

At SF2 there were positive trends toward improvement post-intervention across five-year intervals in all CHLPs, particularly after 2002. This trend toward improvement in CHLP scores at SF2 after 2002 was true for *Power, Water and Waste Connected*; *Electrical Safety*; *Gas safety*; *Shower working* adequately, and *Facilities to wash children (basin/bath/tub)*. There was also a significant improvement in the percentage of houses meeting the *Fire Safety*; *Structure and Access*, and *Store, Prepare and Cook Food* criteria in the second decade of the program compared to the first.

The data for Figure A4 is shown below in Table A4.

Table A4. Critical Healthy Living Priorities at Survey-Fix1 and Survey–Fix 2 by 5-year intervals from 1998-2017.

		Survey ID 1		Survey ID 2	
Healthy Living Priority	**5-Year Period**	**Per cent**	**95% CI**	**Per cent**	**95% CI**
Power, water, waste connected	1998 to 2002	65.1	(62.3, 67.9)	90.3	(88.5, 92.1)
	2003 to 2007	77.9	(75.2, 80.6)	97.2	(96.1, 98.3)
	2008 to 2012	80.5	(77.6, 83.4)	99.9	(99.6, 100)
	2013 to 2017	81.5	(78.9, 84.1)	98.1	(97.1, 99.1)
Electrical safety	1998 to 2002	10.1	(8.3, 11.9)	73.2	(70.5, 75.9)
	2003 to 2007	5.1	(3.7, 6.5)	93.4	(91.8, 95)
	2008 to 2012	9.1	(7.0, 11.2)	98.9	(98.1, 99.7)
	2013 to 2017	5.2	(3.7, 6.7)	89.1	(86.9, 91.3)

Table A4. *Cont.*

Healthy Living Priority	5-Year Period	Survey ID 1		Survey ID 2	
		Per cent	95% CI	Per cent	95% CI
Gas safety	1998 to 2002	64.3	(58.1, 70.5)	65.8	(59.1, 72.5)
	2003 to 2007	55	(47.3, 62.7)	91.2	(86.5, 95.9)
	2008 to 2012	36.5	(25.5, 47.5)	100	
	2013 to 2017	54.5	(46.0, 63.0)	97.8	(94.9, 100)
Structure and access	1998 to 2002	52.7	(49.8, 55.6)	69.5	(66.7, 72.3)
	2003 to 2007	14.0	(11.8, 16.2)	69.1	(66.0, 72.2)
	2008 to 2012	7.0	(5.2, 8.8)	89.8	(87.6, 92.0)
	2013 to 2017	4.6	(3.2, 6.0)	83.5	(80.9, 86.1)
Fire safety	1998 to 2002	19.8	(16.5, 23.1)	71.8	(68.0, 75.6)
	2003 to 2007	19.3	(16.7, 21.9)	66.7	(63.6, 69.8)
	2008 to 2012	29.1	(25.8, 32.4)	88.8	(86.5, 91.1)
	2013 to 2017	46.9	(43.5, 50.3)	93.0	(91.2, 94.8)
Shower working adequately	1998 to 2002	37.9	(35.1, 40.7)	83.6	(81.3, 85.9)
	2003 to 2007	38.8	(35.6, 42.0)	96.3	(95.0, 97.6)
	2008 to 2012	36.2	(32.7, 39.7)	98.9	(98.1, 99.7)
	2013 to 2017	42.4	(39.0, 45.8)	94.6	(93.0, 96.2)
Facilities to wash children	1998 to 2002	52.1	(49.1, 55.1)	86.2	(84.1, 88.3)
	2003 to 2007	66.1	(63.0, 69.2)	97.0	(95.9, 98.1)
	2008 to 2012	75.7	(72.6, 78.8)	99.7	(99.3, 100)
	2013 to 2017	78.0	(75.2, 80.8)	98.8	(98.0, 99.6)
Laundry services	1998 to 2002	28.1	(25.5, 30.7)	69.8	(67.0, 72.6)
	2003 to 2007	28.4	(25.5, 31.3)	82.1	(79.6, 84.6)
	2008 to 2012	32.7	(29.3, 36.1)	87.1	(84.6, 89.6)
	2013 to 2017	28.1	(25.0, 31.2)	87.1	(84.7, 89.5)
Flush toilet working	1998 to 2002	56.3	(53.4, 59.2)	87.9	(85.9, 89.9)
	2003 to 2007	65.7	(62.6, 68.8)	96.7	(95.5, 97.9)
	2008 to 2012	68.2	(64.8, 71.6)	99.3	(98.7, 99.9)
	2013 to 2017	65.2	(62.0, 68.4)	97.3	(96.2, 98.4)
All drains working	1998 to 2002	13.4	(11.4, 15.4)	55.2	(52.2, 58.2)
	2003 to 2007	26.9	(24.0, 29.8)	75.9	(73.1, 78.7)
	2008 to 2012	26.3	(23.1, 29.5)	81.2	(78.3, 84.1)
	2013 to 2017	21.7	(18.9, 24.5)	82.5	(79.8, 85.2)
Facilities to Store Prepare & Cook food	1998 to 2002	3.8	(2.7, 4.9)	16.5	(14.2, 18.8)
	2003 to 2007	10.9	(8.9, 12.9)	29.7	(26.7, 32.7)
	2008 to 2012	9.5	(7.4, 11.6)	57.4	(53.8, 61.0)
	2013 to 2017	13.5	(11.2, 15.8)	62.9	(59.5, 66.3)

Appendix E. Data Tables for Figures 2, 3 and 5

Table A5 provides the data for Figure 3: Percentage of houses with Critical Healthy Living Priorities fully met at Survey-Fix1 and Survey–Fix 2 for all NSW projects (n = 112) from 1998–2017 in the main text.

Table A5. Percentage of houses with Critical Healthy Living Priorities fully met at Survey-Fix1 and Survey–Fix 2 for all NSW projects (n = 112) from 1998–2017.

	Survey ID 1		Survey ID 2	
Healthy Living Priority	**Per cent**	**95% C.I.**	**Per cent**	**95% C.I.**
Power, water, waste connected	75.2	(73.8, 76.6)	95.9	(95.2, 96.6)
Electrical safety	7.5	(6.6, 8.4)	87.4	(86.3, 88.5)
Gas safety	56.2	(52.2, 60.2)	83.3	(79.9, 86.7)
Structure and access	22.5	(21.1, 23.9)	76.9	(75.5, 78.3)
Fire safety	29.3	(27.7, 30.9)	80.1	(78.6, 81.6)
Shower working adequately	38.8	(37.2, 40.4)	92.6	(91.7, 93.5)
Facilities to wash children	66.6	(65.1, 68.1)	94.8	(94.0, 95.6)
Laundry services	29.1	(27.6, 30.6)	80.6	(79.3, 81.9)
Flush toilet working	63.2	(61.6, 64.8)	94.7	(93.9, 95.5)
All drains working	21.3	(20.0, 22.6)	72.2	(70.7, 73.7)
Facilities to Store Prepare & Cook food	9.0	(8.1, 9.9)	39.1	(37.5, 40.7)

Table A6 provides the data for Figure 2: Average Percentage of houses with Critical Healthy Living Priorities fully met at Survey-Fix1 and Survey–Fix 2 for all NSW projects 1998–2017 by five-year intervals.

Table A6. Average Percentage of houses with Critical Healthy Living Priorities fully met at Survey-Fix1 and Survey–Fix 2 for all NSW projects 1998-2017 by 5-year intervals.

	Survey ID 1		Survey ID 2	
5-Year Period	**Per cent**	**95% C.I.**	**Per cent**	**95% C.I.**
1998 to 2002	35.2	(34.3, 36.1)	70.2	(69.3, 71.1)
2003 to 2007	35.7	(34.7, 36.7)	80.6	(79.8, 81.4)
2008 to 2012	37.4	(36.3, 38.5)	90.2	(89.5, 90.9)
2013 to 2017	39.0	(38.0, 40.0)	88.8	(88.1, 89.5)

Table A7 provides the data for Figure 5: Percentage of houses with Critical Healthy Living Priorities fully met for NSW projects with repeat visits at First Project SF1 (n = 802) and SF2 (n = 722); and at Second Project SF1 (n = 788) and SF2 (n = 734) from 1998–2017 in the main text.

Table A7. Percentage of houses with Critical Healthy Living Priorities fully met for NSW projects with repeat visits at First Project SF1 (n = 802) and SF2 (n = 722); and at Second Project SF1 (n = 788) and SF2 (n = 734) from 1998–2017.

		Survey ID 1		Survey ID 2	
Healthy Living Priority	**Visit**	**Per cent**	**95% C.I.**	**Per cent**	**95% C.I.**
Power, water, waste connected	1st visit	64.8	(61.5, 68.1)	92.9	(91, 94.8)
	2nd visit	81.9	(79.2, 84.6)	98.2	(97.2, 99.2)
Electrical safety	1st visit	4.5	(3.1, 5.9)	84.1	(81.4, 86.8)
	2nd visit	7.4	(5.6, 9.2)	92.2	(90.3, 94.1)
Gas safety	1st visit	63.7	(55.9, 71.5)	85.0	(78.0, 92.0)
	2nd visit	42.9	(32.3, 53.5)	98.4	(95.3, 100)
Structure and access	1st visit	33.7	(30.4, 37.0)	61.6	(58.1, 65.1)
	2nd visit	4.8	(3.3, 6.3)	83.0	(80.3, 85.7)
Fire safety	1st visit	10.0	(7.5, 12.5)	56.3	(52.1, 60.5)
	2nd visit	35.3	(32.0, 38.6)	87.7	(85.3, 90.1)

Table A7. *Cont.*

		Survey ID 1		Survey ID 2	
Healthy Living Priority	**Visit**	**Per cent**	**95% C.I.**	**Per cent**	**95% C.I.**
Shower working adequately	1st visit	34.6	(31.3, 37.9)	89.6	(87.4, 91.8)
	2nd visit	38.3	(34.9, 41.7)	95.9	(94.5, 97.3)
Facilities to wash children	1st visit	52.0	(48.5, 55.5)	92.8	(90.9, 94.7)
	2nd visit	75.9	(72.9, 78.9)	99.0	(98.3, 99.7)
Laundry services	1st visit	23.8	(20.9, 26.7)	74.0	(70.8, 77.2)
	2nd visit	31.1	(27.9, 34.3)	87.2	(84.8, 89.6)
Flush toilet working	1st visit	55.8	(52.4, 59.2)	92.2	(90.2, 94.2)
	2nd visit	63.8	(60.4, 67.2)	97.7	(96.6, 98.8)
All drains working	1st visit	15.2	(12.7, 17.7)	60.1	(56.5, 63.7)
	2nd visit	22.8	(19.9, 25.7)	82.3	(79.5, 85.1)
Facilities to Store Prepare & Cook food	1st visit	7.6	(5.8, 9.4)	21.1	(18.1, 24.1)
	2nd visit	10.3	(8.2, 12.4)	54.6	(51.0, 58.2)

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Chapter 5

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Chapter 6

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Chapter 7
The Economic Evaluation of a Housing Maintenance Project to Improve the Health of Aboriginal Housing Tenants in NSW: A Scoping Literature Review and Protocol for an Economic Analysis.

Preamble

Chapter 7 aims to answer the research question: "How could a comprehensive economic analysis be undertaken of the disparate health, social, economic and intangible benefits generated from the Housing for Health program and the resources utilised to realise these benefits?"

The previous chapter investigated expenditure by the NSW Housing for Health (HfH) Program on repair works related to the Critical Healthy Living Practice (CHLP) indicators in NSW Aboriginal community housing over 20 years. The influence of other parameters, including time and remoteness, was explored along with associations between expenditure and the level of improvement in health hardware functionality for each house. That analysis demonstrated that major improvements to house functionality can be achieved with relatively minimal investment. Whilst this analysis provided valuable insights into the costs associated with improving house functionality, it was not an economic analysis of the HfH Program and did not consider the health, social, economic, and other intangible benefits that may stem from its implementation. Such an assessment would require a more detailed health economic analysis, of which several models could be utilised for an economic evaluation of the HfH Program.

This chapter explores the various options for economic analyses and the strengths and limitations of each in their application to an assessment of the NSW HfH Program. It reviews the literature for previous examples of economic analyses of housing and health-related initiatives and proposes a high-level protocol for the most appropriate model for a future economic evaluation of a HfH project and/or the broader HfH Program, including strategies such as sensitivity analyses to address some of the limitations of the proposed model.

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a Hunter Medical Research Institute, Lot 1, Kookaburra Crescent, New Lambton Heights, NSW, Australia
b School of Medicine and Public Health, University of Newcastle, Callaghan, NSW, 2308, Australia
c Health Protection NSW, Locked Mail Bag 2030, St Leonards, NSW, 1590, Australia
d School of Public Health, Faculty of Medicine and Health, University of Sydney, Camperdown, NSW, 2006, Australia

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Author	Contributions
SD	Investigation, Methodology, Visualisation, Writing – review & editing.
KL	Conceptualisation, Funding acquisition, Project administration, Validation, Writing – review & editing.
JCS	Conceptualisation, Funding acquisition, Supervision, Validation, Writing – review & editing.

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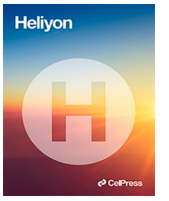

Review article

The economic evaluation of a housing maintenance project to improve the health of Aboriginal housing tenants in NSW: A scoping literature review and protocol for an economic analysis

Simon Deeming [a,b], Kerryn Lawrence [c], Jeffrey C. Standen [c,d,*]

[a] Hunter Medical Research Institute, Lot 1, Kookaburra Crescent, New Lambton Heights, NSW, Australia
[b] School of Medicine and Public Health, University of Newcastle, Callaghan, NSW, 2308, Australia
[c] Health Protection NSW, Locked Mail Bag 2030, St Leonards, NSW, 1590, Australia
[d] School of Public Health, Faculty of Medicine and Health, University of Sydney, Camperdown, NSW, 2006, Australia

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ABSTRACT

Considerable evidence exists regarding the role housing plays in the determination of health and well-being outcomes. Despite the scale of health concerns arising from housing considerations, there are very few economic analyses of housing programs that seek to improve health outcomes by addressing the physical infrastructure of the living environment. The NSW *Housing for Health* (HfH) program is an environmental health initiative funded and administered by NSW Health, that addresses health-related hardware in residential accommodation to ensure the home environment supports healthy living practices to ultimately improve health outcomes for residents. This study reviews the economic methods that have been applied to comparable programs and identifies relevant costs and benefits that should be addressed. Founded on the requirement from decision makers, and the insights from the review, the paper outlines a protocol for a cost-benefit analysis that accounts for the disparate health, social, economic and intangible benefits generated from the HfH program and the resources utilised to realise these outcomes.

1. Background and objectives

Social determinants, such as access to clean water and sanitation, food, health and social services, income levels, employment, education, transport and housing, have long been acknowledged for their role in health and well-being [1–3]. Significant evidence exists regarding the role housing specifically plays in the determination of health and well-being outcomes [3–7].

Australia's Aboriginal and Torres Strait Islander population has suffered from long-term disadvantage. In response, various Governments have undertaken program and policy initiatives to close the gap between Australia's Aboriginal and Torres Strait Islander and non-Aboriginal population in terms of health, education, economic development, justice, families and young people, culture and heritage, and housing [8,9]. One initiative seeking to reduce this inequality is the *Housing for Health* program.

The broad purpose of this paper is to review the literature to determine the most appropriate method for economic analysis of the New South Wales (NSW) *Housing for Health* program.

* Corresponding author. Health Protection NSW, Locked Mail Bag 2030, St Leonards, NSW, 1590, Australia.
E-mail addresses: simon.deeming@hmri.org.au (S. Deeming), kerryn.lawrence@health.nsw.gov.au (K. Lawrence), jeff.standen@health.nsw.gov.au (J.C. Standen).

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1.1. The Housing for Health program

The *Housing for Health* (HfH) program is an environmental health initiative that comprises a licensed, multi-stage process of consultation, surveys and housing works. The process aims to assess, repair, or replace health hardware in residential accommodation to enable the residents to conduct healthy living practices (HLPs) in a safe environment. The NSW HfH Program has been predominantly undertaken with Aboriginal community housing providers in remote, regional and urban NSW for over 20 years. The current program is funded by NSW Health and managed by the Aboriginal Environmental Health Unit (AEHU). Previous projects have been funded jointly by NSW Health and the Aboriginal Communities Development Program (ACDP) the Two Ways Together (TWT) initiative, and a variety of other state or Federal programs [10].

The HfH process consists of seven main stages, summarised as.

- Project establishment - Securing funding and working with stakeholders to identify priority communities for project delivery;
- Community consultation and feasibility assessment – Clarification of expectations for the program i.e. includes plumbing, excludes painting; obtain community agreement to implement the HfH project, including a communication plan for unavailable tenants; Completion of a feasibility plan with the relevant social housing provider/s to define the parameters of the project;
- Project preparation – involves informing residents, engaging community workers and arranging consumables and logistics for immediate repair of houses by trades following survey.
- First survey and fix (SF1) – SF1 involves surveying and testing 268 essential safety and health hardware items for every house and yard area using a standardised repeatable and validated survey instrument. The work is completed by teams of local tenants, led by Team Leaders (often from the local Public Health Units). The team members receive prior safety, testing and tool training. During SF1 teams immediately fix any minor repairs not requiring a licensed trade. Works identified as urgent are completed by licensed plumbers and electricians within 1–2 days of the survey.
- Major repairs – Larger or less urgent jobs are prioritised, in accordance with HfH priorities. The Major repairs stage commonly requires a range of service providers, such as a hot water service agent, carpenter, builder, occupational therapist, electrician, plumber, etc.
- Second survey and fix (SF2) - Following the Major repairs stage, SF2 uses the same surveying and repair process as SF1 to audit the works completed, identify any works outstanding or that subsequently arose since SF1 and provide comparative data.
- Reporting and closure – On completion of SF2 works, a HfH final report is submitted to the housing provider containing a list of the work undertaken per house, a forward works list (prioritised in terms of safety and the nine HLPs), project expenditure, and a graph summarising dwelling functionality by defined Healthy Living Indicators at SF1 and SF2 [11].

In the 20 years from 1998 to 2017, 112 HfH projects have been delivered across NSW using this methodology to a total of 3593 houses, including repeat projects in 24 projects (802 houses) [11].

1.2. Housing for Health study project

The discrete HfH project that represents the subject investment for the proposed economic evaluation comprises the implementation of the HfH process with a national Tier 1 registered community housing provider managing 127 residential dwellings, in the form of houses and units distributed throughout a rural town in northern NSW. The specific location and name of the study project has been deidentified.

1.2.1. Relevant economic evaluation policy

Funding for the HfH program has been sourced from the NSW Government and Federal Government and directed through NSW Health (AEHU) and delivered in partnership with community housing providers. Consequently, interested decision makers include the respective departments of Health, Social Services and Treasury within both the state and Federal governments. The purpose of an economic evaluation is to inform decision makers regarding the merits of new, recurrent or qualified/refined funding, or to provide grounds for disinvestment. Consequently, the choice of economic method should meet the requirements of the varied decision-makers.

The economic evaluation methods accepted by the NSW government, in common with their national counterparts, include Multi-Criteria Decision Analysis (MCDA), Discrete Choice Experiments (DCE), Cost analysis, Cost-Consequence Analysis (CCA), Cost-Effectiveness Analysis (CEA) including Cost-Utility Analysis (CUA), Cost-Benefit Analysis (CBA), Input-Output Analysis (IO) and Computable General Equilibrium (CGE) modelling [12]. CGE modelling is not insightful for this scale of investment and IO modelling only addresses implications for economic activity. MCDA and DCE are not relevant to ex-ante program evaluation and cost analyses fail to account for the program outcomes. Of the remaining options, CEA/CUA was developed for health economic evaluation. This form of analysis is suitable for economic evaluation of health interventions or programs where the outcomes can be reflected within a single measure, typically a clinical or Health-related Quality of Life outcome. Reference to a single health outcome would not fully reflect the beneficial outcomes from the HfH program. CCA addresses this challenge by reporting multiple outcomes in natural units alongside incremental costs. CCA precludes objective comparison, and consequently assessment against pre-determined thresholds, but is often sufficient for health service decisions. However, the absence of clear decision rules undermines its value for the independent decision makers, such as for treasuries' common requirement for inter-departmental comparison.

CBA is the preferred method for investment/program/policy evaluation by the Australian Commonwealth and NSW Treasury. CBA is considered a relatively value-free and more comprehensive method with capacity to incorporate overall welfare effects to society,

including social, environmental, and economic impacts. CBA is also readily scale-able, to compare different project options and to rank proposals across different policy areas. In addition, NSW Government policy for program evaluation more broadly is shifting from process evaluation to outcomes-based budgeting, where measures of activity levels are only relevant to the extent that they generate measurable benefits [13]. This rationale aligns closely with CBA.

As a consequence of this evaluation policy context, the premise prior to the scoping literature review is that CBA comprises the appropriate form of economic analysis. The results of the literature review sought to inform whether this approach was merited and viable, or whether alternatives provide a more advantageous approach. The literature review also serves to identify considerations that should be addressed and factors that should be incorporated within an economic analysis of such programs.

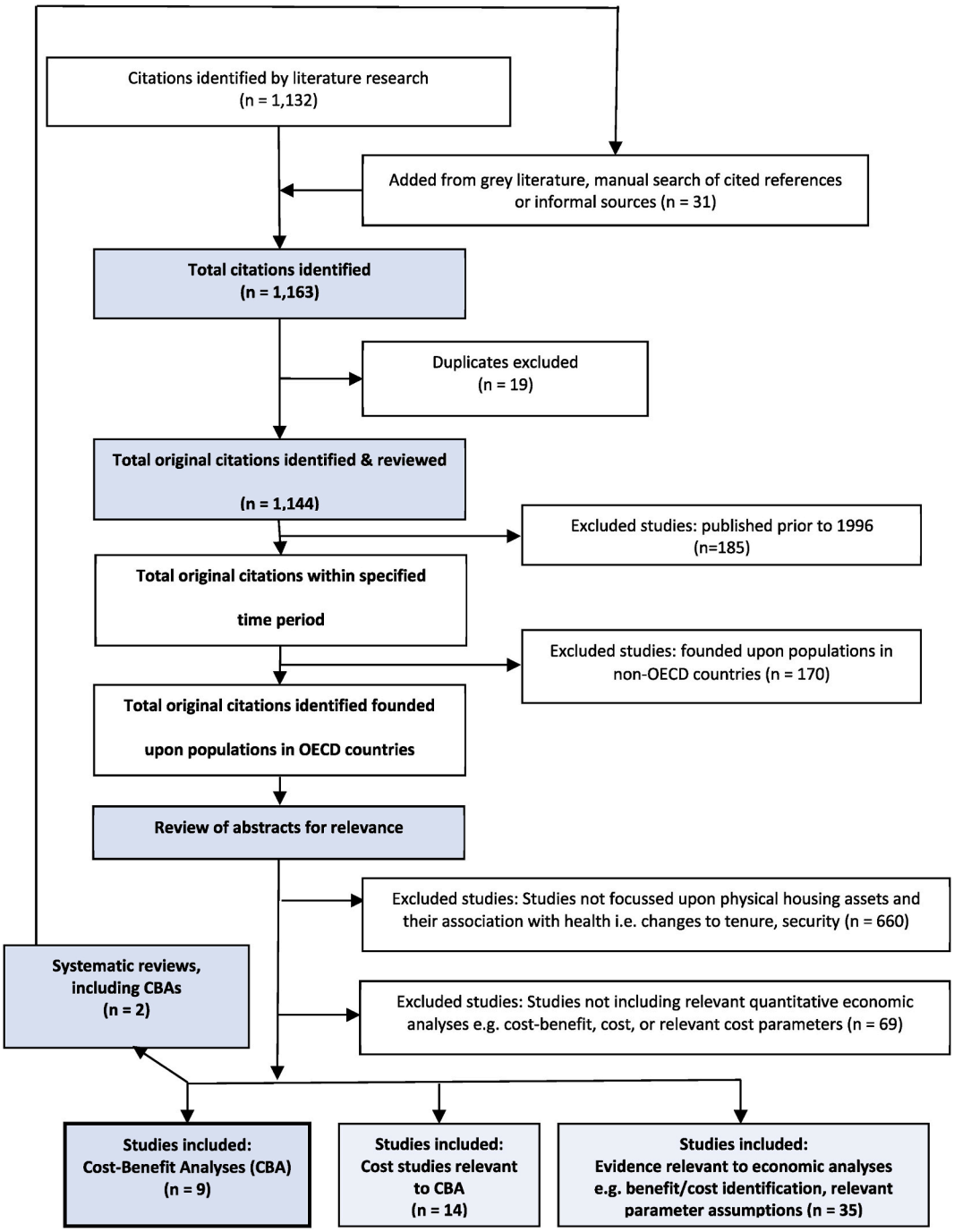

Fig. 1. PRISMA-ScR diagram – Literature selection protocol.

Guidance from the NSW Treasury recommends that a cost benefit analysis should be completed for capital expenditure exceeding $10 million or more [14]. Investment in the HfH program across NSW totals approximately $2.6 million per year, while the study project totalled approximately $1.0 million over three years. The protocol for the economic evaluation will reflect this discrete study investment but will also demonstrate relevance of an economic evaluation of the statewide HfH program.

The aims for this study were.

- To conduct a scoping literature review: to examine alternative economic evaluation methods applied to programs or interventions designed to improve the health of residents through improvements to physical housing assets associated with human health; to identify key characteristics or factors to be considered within such analyses; and to examine the requirement for relevant evidence given the existing knowledge base. This review is focussed on economic evaluation methods and potential components of these analyses, rather than the identification of specific parameter estimates e.g., effect sizes.
- Founded on the insights from the literature review and prior knowledge of the government policy and program context, prepare a protocol for the economic evaluation of the *Housing for Health* study project.

2. Methods

2.1. Literature review

To inform the economic analysis, a scoping literature review was conducted in line with PRISMA-ScR guidelines [15]. The appropriate form of literature review was determined using the guidance in Munn, Peters [16]. A scoping review provides for inclusion of policy documentation and relevant non-peer-reviewed publications. Outside of medical and health research, systematic reviews are rarely conducted for most government program evaluations. If the proposed economic analyses demonstrate that the results are critically dependent on key assumptions, such as an improvement in health or reduced hospital admissions, then a systematic review would be appropriate to inform specific parameter assumptions.

Eligibility criteria – The search strategy included publications published in English from 1996 to 2019, including Daily, Ahead of Print, In-Process & Other Non-Indexed Citations.

Information sources – The bibliographic database/article index *Ovid MEDLINE(R)* was searched. Additional sources were identified from the program managers and through hand searching of references.

Search strategy – The search strategy (Appendix A) was conducted on October 2, 2019. Manual follow-up of references and other hand searching was conducted through Calendar Year 2020.

Selection of sources of evidence – A more inclusive/heterogeneous approach was used to capture different types of evidence or data sources e.g. peer-reviewed academic papers, government policy documents, third sector reports, etc.

Protocol for economic analysis – The protocol was determined with respect to: the need for the economic analysis to provide evidence suitable for the HfH Program Managers, NSW Health and the NSW and Commonwealth Treasuries; and best practice guidelines for the appropriate economic evaluation method.

3. Results

3.1. Scoping literature review

The PRISMA diagram for the scoping literature review is provided in Fig. 1. The abstracts were reviewed for relevance to exclude: studies not focussed on physical housing assets and their association with health; and studies not incorporating quantitative economic analyses; or methods directly relevant to the conduct of quantitative economic analyses of *Housing for Health*, or similar programs. The search strategy and manual search captured 1163 potentially relevant citations. The review process identified nine documents containing relevant information regarding cost-benefit analyses of these programs, 14 studies that included cost analyses, and 35 studies that either identified relevant benefit or cost considerations, or information relevant to the method for parameter estimation within an economic analysis.

3.2. Physical housing interventions seeking to improve residential health

The economic analyses identified through the literature review which met the intervention criteria included physical modifications to prevent falls, improved ventilation, removal of lead paint, retrofitted insulation to improve domestic temperatures, and smoke alarm installation. These interventions included modifications addressed by the HfH program, but do not include the full range of potential improvements and according benefits. There were no economic evaluations that assessed a program with equivalent focus and breadth.

3.3. Economic methods

The literature review identified a range of alternative economic methods applied to relevant programs, including cost-benefit analyses (CBA), cost-utility analyses (CUA), cost-offset analyses, cost-minimisation analyses (CMA) and cost studies. The review identified two relevant systematic reviews. Fenwick, Macdonald [17] conducted a systematic review regarding the economic analysis

of the health impacts of housing improvement studies. They identified four CBAs and 25 studies that included costs but had not progressed to an economic analysis. Pega and Wilson [18] conducted a systematic review regarding health economic analyses of housing improvement interventions and insecticide-treated bed nets in the home. They identified 15 CBAs and a further 20 CEA/CUAs. Many of the CBA studies did not meet the specifications of this scoping review because they were either incorrectly termed CBAs or they were conducted in countries outside the search requirement.

Additional studies identified in the systematic reviews were added to the manual search (see Fig. 1 - PRISMA-Scr diagram). In total, eight CBAs were identified for physical housing interventions to address lead poisoning (n = 4), housing insulation (n = 2), risk of falls (n = 1) and smoke detectors (n = 1), and one study addressed the methodological issues of applying CBA to relevant interventions. These evaluations range from poor to excellent quality with respect to formal methods [14,19,20].

Two of the studies were produced by the same research group in New Zealand. The New Zealand studies both assessed the insulation of housing to generate health and other benefits, including an ex-ante CBA of a trial and an ex-post CBA of a government program [21,22]. Their choice of CBA appears driven by OECD and government evaluation policy. The investigators also authored the paper regarding the methodological strengths and limitations of CBA for such interventions. Aside from the policy requirement, CBA was acknowledged for its capacity to counteract narrow government thinking and special interest lobbying, for its applicability irrespective of scale, for its inclusion of disparate costs and benefits that may otherwise be ignored, and as a framework to articulate value [23]. Their application of CBA identified a number of specific challenges including the theoretical assumption that utility can be transferred from winners to losers, the risk of bias towards considerations for which strong evidence is available, particularly for impacts with low population rates e.g. hospitalisation, the valuation of health, well-being and mortality, and the treatment of inter-generational and societal equity considerations [23].

A CBA was also conducted by Nevin, Jacobs [24] to evaluate an intervention to remove indoor lead paint. The implications of lead paint poisoning are broad, particularly for children, and consequently, their analysis (and the update by Dixon, Jacobs [25]) accounts for potential health service, social and economic benefits.

Gould [26] conducted a model-based CBA of indoor lead paint removal. As per Nevin, Jacobs [24], a CBA framework enabled the analysis to account for a wider range of healthcare, economic and social impacts, although they did not incorporate a value for health outcomes. The Pichery, Bellanger [27]'s partial CBA of lead hazard control valued similar societal benefits. Their analysis sought to value imposts on quality of life via a judicially-determined compensation methodology.

Ling, Henderson [28] accounted for costs and benefits of a home modification program to prevent falls. The formal quality of the CBA was low. Their study included reductions in aged care admissions, which represents a potential benefit from the HfH program, due to the inclusion of this factor within the survey/modifications. Finally, Liu, Mack [29] evaluated a smoke alarm intervention using a CBA. Their evaluation adopted a CEA framework, but sought to monetise health outcomes, via quality of life loss, as well as tangible cost savings, such as health care savings, economic productivity gains and property savings. As per Pichery et al., their valuation of health-related quality of life, utilised evidence from jury verdicts and settlements for fire injuries. A Markov state transition model was used to estimate the home fire incidence rates, mortality rate per fire and accordingly the mortality risk reduction from smoke alarms. A value was placed on mortality using estimates for Life Years Saved (LYS) and the Value of a Statistical Life Year (VSLY).

Preval, Chapman [30] also conducted a CBA that met the search criteria, but the intervention, provision of residential heaters, is not a component of the HfH program. Laing and Baker [31] were categorised as a CBA in Fenwick, Macdonald [17], but no evidence of the outcome methods, measures or values could be sourced.

The primary conclusions arising from the Fenwick systematic review were that public health initiatives regarding housing interventions should, but rarely, include economic evaluations. It also identified the need to collect data over an extended period to capture longer term impacts, the need to plan for economic data collection from commencement of the program, and the need to adopt a broad perspective to capture the disparate costs and benefits that may arise from housing interventions [32].

Alternative economic evaluation methods identified through the scoping review included: cost studies that seek to estimate the

Table 1
Potential incremental costs associated with health/physical housing initiatives and corresponding source for methods/parameter estimation.

Attribute	Attribute source	Relevant considerations
Program management (incl admin)	All (explicit only in some)	Majority of studies utilised primary data source for subject program cost
Project management	All (explicit only in some)	Majority of studies utilised primary data source for subject program cost
Capital costs of physical infrastructure	All	Majority of studies utilised primary data source for subject program cost
Contracted specialist services	Explicit only in Haddix, Mallonee [38]	Primary data source
Producer surplus benefits arising from public expenditure	Grimes, Denne [22]	Deducted from program costs to derive a net cost in Grimes, Denne [22]
Volunteer time (residents)	Liu, Mack [29], Haddix, Mallonee [38]	Lost leisure time; potentially valued at $0 for excess leisure time
Paid employment (residents)	Haddix, Mallonee [38]	
Deadweight loss from taxation	Grimes, Denne [22]	Relevant to all programs; included in few
Administration of taxation/public insurance	Grimes, Denne [22], Liu, Mack [29]	Relevant to all programs; included in few
Educational material	Haddix, Mallonee [38], Phillips, Humphreys [39]	Example of implementation costs

Table 2
Potential incremental benefits associated with health/physical housing initiatives and corresponding source for methods/parameter estimation.

Attribute	Attribute source[a]	Relevant considerations
Healthcare – Primary care (General practitioners) services	Chapman, Howden-Chapman [21], Grimes, Denne [22], Nevin, Jacobs [24], Gould [26], Pichery, Bellanger [27], Liu, Mack [29], Preval, Chapman [30], Chenoweth, Estes [33], Bray, Burns [37], Barton, Basham [41], Salkeld, Cumming [42], Brown [50]	Barton, Basham included health service saving on Cost side; Grimes, Denne [22] modelled estimates based on other studies
Healthcare – Reduced hospitalisations/ Emergency Department attendance	Chapman, Howden-Chapman [21], Grimes, Denne [22], Nevin, Jacobs [24], Gould [26], Pichery, Bellanger [27], Liu, Mack [29], Chenoweth, Estes [33], Bray, Burns [37], Haddix, Mallonee [38], Phillips, Humphreys [39], Barton, Basham [41], Salkeld, Cumming [42], Ginnelly, Sculpher [49], Han, Ungar [51], Nicol, Roys [52]	Barton, Basham [41] included health service saving on Cost side
Healthcare – Medication (explicit from health services)	Liu, Mack [29], Preval, Chapman [30], Barton, Basham [41], Salkeld, Cumming [42]	Medication costs not separated but incorporated into healthcare cost estimates for many projects
Health & Well-being – Health-related Quality of Life improvements/Morbidity averted	Chapman, Howden-Chapman [21], Pichery, Bellanger [27], Chenoweth, Estes [33], Frick, Kung [36], Bray, Burns [37], Church, Goodall [40], Barton, Basham [41], Salkeld, Cumming [42], Lawson, Kearns [43], Keall, Ormandy [44], Franchimon [45], Jutkowitz, Gitlin [46], Coskeran, Denman [53]	EQ-5D: Coskeran, Denman [35], Bray, Burns [37], Church, Goodall [40] Short Warwick-Edinburgh Well-being Scale (SWEMWBS): Bray, Burns [37] SF36: Barton, Basham [41], Salkeld, Cumming [42], Lawson, Kearns [43] GHQ12: Barton, Basham [41] Literature-derived Quality Adjusted Life Years (QALYs): Liu, Mack [29], Frick, Kung [36], Phillips, Humphreys [54] Financial compensation method: Pichery, Bellanger [27] Disability Adjusted Life Years (DALYs): Chenoweth, Estes [33], Keall, Ormandy [44], Franchimon [45]
Health – Reduced mortality/Life Years Saved	Chapman, Howden-Chapman [21], Grimes, Denne [22], Liu, Mack [29], Jutkowitz, Gitlin [46]	Life Years Saved (LYS) (no. of days to death; difference in area under Kaplan-Meier survival curve estimated LYS); Double-counting must be avoided if long-term productivity losses/gains incorporated
Social – Reduced demand on emergency services, coroner services, funeral costs (e.g. fire)	Liu, Mack [29], Haddix, Mallonee [38], Ginnelly, Sculpher [49]	
Social – Informal care (e.g. fall related; childcare)	Preval, Chapman [30], Salkeld, Cumming [42]	Double counting must be avoided with any well-being benefits
Social – Reduction in long term care (e.g. fall related)	Kochera [48]	Predominantly falls related, with other long term benefits less directly attributable to the intervention
Social – Reduced aged care admissions	Ling, Henderson [28]	Predominantly falls related, with other long term benefits less directly attributable to the intervention
Social – Reduced crime	Nevin, Jacobs [24], Gould [26], Pichery, Bellanger [27]	Related to education outcomes
Social – Education: Days off school/value of lost education/economic productivity loss to children's parents	Chapman, Howden-Chapman [21], Grimes, Denne [22], Preval, Chapman [30], Barton, Basham [41], Brown [50]	Predominantly modelled analysis founded on parameter estimates from other studies
Social – Education: Reduction in Special education costs	Gould [26], Pichery, Bellanger [27], Brown [50]	
Economic – Utilities savings (electricity, water)	Chapman, Howden-Chapman [21], Nevin, Jacobs [24]	
Economic – Changed asset management/ maintenance costs	Franchimon [45]	Inclusion in costs or benefits dependant on program intervention
Economic – Patient & carer transportation and lost time	Nevin, Jacobs [24], Ginnelly, Sculpher [49]	Double counting must be avoided with any well-being benefits
Economic – Additional employment (direct investment stimulus)	Grimes, Denne [22]	Need to ensure incremental to counterfactual i.e. alternative investment in other economic activity that may generated employment; Probably list as intangible for study project
Economic – Productivity loss/gain (short term due to health interruption to employment, employer borne; value of lost housework)	Liu, Mack [29], Haddix, Mallonee [38]	
Economic – Productivity loss/gain (lifetime earnings, excl education)	Nevin, Jacobs [24], Gould [26], Pichery, Bellanger [27], Haddix, Mallonee [38]	Double-counting must be avoided if mortality valued using LYS/VSLY method
Economic - Additional tax revenue	Gould [26]	Double counting must be avoided if producer surplus considerations included
Environmental – CO_2e savings	Chapman, Howden-Chapman [21]	Within a societal perspective, relevant to renovations that affect heating and/or air-conditioning

[a] Notes: Sources represent examples of the inclusion of the respective attribute within the broader literature review results, including studies adopting non-CBA methods.

economic costs arising from poor housing e.g. Chenoweth, Estes [33]; cost-offset studies, which estimate the costs of public housing investment net of potential fiscal savings e.g. Davidson, Nicol [34]; cost-effectiveness analyses (CEA), which estimate an incremental cost per change in a single health outcome arising from an intervention e.g. Coskeran, Denman [35]; cost-utility analysis (CUA), a CEA for which the Health related Quality of Life (HrQoL) outcome measure has been converted to a Quality Adjusted Life Year (QALY) e.g. Frick, Kung [36], and cost-consequence analyses (CCA) e.g. Bray, Burns [37], which report multiple outcomes in natural units, alongside the costs for an intervention. The results of most of these analyses were presented as evidence to inform program funding. However, the selected methods were not ostensibly determined by the funders' preferred methods.

3.4. Relevant economic cost considerations

Table 1 lists the cost categories identified within all the economic studies found through the broader literature search. The capital costs of physical interventions were included in all the studies. Program and project management costs were included in all studies, albeit often incorporated within aggregate program costs. Privately contracted specialist components were detailed for few studies [38]. Grimes, Denne [22] included the producer surplus estimate arising from the additional public expenditure, the value of which they deducted to derive net program costs. This economic cost consideration is only relevant for CBAs.

Two studies accounted for costs attributable to roles within the intervention conducted by residents, either paid or volunteered [29, 38]. These costs were not relevant to every program intervention. However, the formal scope/study boundary for many of these studies was poorly defined and consequently, the grounds for exclusion was often unclear. Implementation costs, such as the provision of educational materials, were only identified in two studies [38,39].

Economic cost considerations such as the deadweight loss/excess burden of taxation and the cost of administering taxation/public insurance were included in two of the 12 CBAs [22,29]. These economic costs are only relevant to CBAs.

3.5. Relevant benefits

The literature review identified 19 potential benefit categories across all the identified studies (Table 2). The respective studies demonstrate methods potentially relevant to estimate the value of equivalent benefits from the HfH program.

3.5.1. Healthcare service benefits

Healthcare, particularly net health service savings, dominated the potential benefits within most studies, demonstrating the importance of this component within economic analyses of comparable housing interventions (full reference list in Table 2). Methods to estimate the impact upon primary healthcare services e.g. general practitioners, changes in hospital admissions and Emergency Department attendances, and medication use (often incorporated within health service costs) varied from primary studies to model-based analyses using secondary data.

3.5.2. Health benefits

CEA/CUA frameworks provide a stronger theoretical bases for the inclusion of health outcomes within economic analyses. Consequently, the majority of studies that estimated program benefits for HrQoL, well-being, pain and suffering, or morbidity effects were conducted using these methods. For the studies identified through the review, a number of different instruments were used to measure these health outcomes, including EuroQoL EQ-5D [35,37,40], 36-Item Short Form Survey (SF-36) [41–43], General Health Questionnaire-12 (GHQ-12) [41], and the Short Warwick-Edinburgh Well-being Scale (SWEMWBS) [37]. Some studies used these instruments to estimate gains in QALYs, while others applied estimated QALY gains evidenced within the published literature.

Three studies utilised Disability Adjusted Life Years (DALYs) to estimate morbidity effects [33,44,45]. These analyses typically utilise environmental attributable fractions to estimate both the direct and indirect health service costs, and the DALYs, associated with environmental conditions.

Some studies directly accounted for a reduction in mortality attributed to the respective interventions [21,22,29,46]. Evidence of reductions in mortality attributable to the intervention were combined with assumptions regarding respective survival curves for the control and intervention to estimate the number of Life Years Saved. One study, Barton, Basham [41], measured a range of clinical respiratory and musculoskeletal health outcomes that were reported alongside HrQoL outcomes in a CCA format.

3.5.3. Social benefits

The social benefits included within the identified studies fall into four categories: short term benefits that arise from improved health, including reduced childcare demands, days off school [21,22,30,41,47]; positive long term benefits that arise from improved health, such as reduced special education needs, improved educational outcomes, reduced crime and the economic productivity gains that arise from improved life trajectories [21,22,26,27,29,46,47]; benefits from reduced falls, including informal and formal aged care demands, reduced aged care admissions [28,48]; and benefits from a lower probability of fire, such as the reduced resources required for emergency services, coroner services and funerals [29,38,49].

3.5.4. Economic benefits

The economic benefits within the identified studies included direct impacts, such as utilities savings (electricity, water) [21], reduced asset management/maintenance costs [45], and the additional employment arising from the program investment [22]. The indirect economic benefits include the productivity gains arising from reduced workplace absence [29], net gains to domestic work [38], and the societal gains reflected in improved lifetime earnings resulting from improved health outcomes [24,26,27,38].

Two studies also accounted for reductions in out-of-pocket patient & carer transport costs and the time lost attending health services [24,49].

3.5.5. Other benefits

The environmental benefit from improved housing insulation comprised a significant ancillary benefit for interventions seeking to improve health via improvement in indoor temperatures [21].

3.6. Benefit valuation

Many of the potential benefits identified in the literature were not valued, but reported as changes in natural units, consistent with the CUA, CEA or CCA framework. Exceptions include the cost-offset studies, which valued projected net health service savings to offset against investment costs [34]. Some of the CUA studies introduce an assumed value per QALY/DALY to inform an investment decision rule, but this approach only informs investment decisions against comparators evaluated using the same theoretical framework.

Within the CBA studies, five excluded the potential value of health benefits due to either a lack of data regarding potential changes in quality of life, well-being or morbidity, or the methodological challenges associated with their valuation and inclusion within this theoretical framework. Of the three studies that quantified values for health benefits, Pichery, Bellanger [27] utilised a legal compensation method to value potential gains in morbidity, Grimes, Denne [22] valued projected gains in mortality using the Value of a Statistic Life applied to LYS, while Liu, Mack [29] incorporated values for both mortality and morbidity using both methods.

3.7. Equity

The results demonstrate that most of the identified studies were positioned within an equity policy context that seeks to improve outcomes for marginalised and low socio-economic status community cohorts. However, none of the relevant economic evaluations specifically accounted for equity within the quantitative component of the analysis.

3.8. Protocol for the economic evaluation of the HfH study project investment

Founded on discussions with the project delivery team within the Public Health Unit of the relevant Local Health District, the Program's managers (the Aboriginal Environmental Health Unit within NSW Health), the respective Centres for Evidence and Evaluation (CEE) within NSW Health and the NSW Treasury, and the insights from the literature review, the following section outlines a protocol for the economic evaluation of the HfH study project.

Title: Prioritising housing maintenance to improve health in Aboriginal communities in NSW: an ex-post cost benefit analysis of a *Housing for Health* Project

Purpose – The primary stakeholders for the economic analysis are the Program Managers within the AEHU, the community housing provider, NSW Health and the NSW Treasury. The purpose is to conduct an economic evaluation of the project/program to inform decision makers regarding the relative merits of on-going funding.

Target population and setting – Given that the costs and benefits from the HfH study project extend beyond the resident population, the target population comprises the broader community within the Local Health District catchment.

Choice of economic framework – The proposed economic analysis will comprise an ex-post cost benefit analysis (CBA). The choice of economic framework is informed by the format required by the decision makers to optimise the outcomes from public investment into public health [12].

Study perspective – the economic analysis will adopt a societal perspective consistent with a social welfare cost-benefit framework.

Program/project comparator – Application of the seven-stage HfH program to the study project for the period from July 2018 to June 2020. The study project addressed 127 dwellings providing housing for 302 residents. The project identified and repaired 2467 items.

Baseline comparator – An ex-post CBA requires a counterfactual reflecting the baseline against which the incremental changes in societal outcomes and costs can be referenced. The baseline will reflect a modelled scenario in the absence of the implemented HfH program. Evidence for the counterfactual will be derived from the available pre and post intervention data for the affected residents and from the available literature.

Study design/model – The extent to which the effects can be attributed to the program will be primarily examined via a marginal analysis using a pre-post design.

3.9. Benefit estimation

Potential economic benefits identified through the literature review will each be considered for inclusion founded on: the relative size of the potential benefits; the strength of evidence, primary or secondary, attributing the outcome to the program intervention; and the potential magnitude of the benefits relative to the research cost of deriving the estimate. Impacts on healthcare service use will be

explicitly incorporated. Where evidence exists, mortality gains will be included, but any potential health, well-being and morbidity effects will be addressed within the sensitivity analyses.

To retain consistency with costs, productivity gains will be valued using the human capital method. To retain the confidence of primary stakeholders in the results, a conservative approach will be adopted to the inclusion and valuation of any benefits, and transparency will be provided to the evidence base.

Components not monetised will be retained as intangible outcomes alongside the reported results. For example, the capacity for Aboriginal elders to remain in community carries significant cultural and social value. It is critical that such intangible values are acknowledged with equivalent merit to the elements more readily monetised.

3.10. Resource and cost estimation

The resource components required to generate the benefits include: program management, project management and administration, contract management, coordination, training, work audits, reporting and closure; survey conduct and data administration; team repairs; licensed trade repairs; tasks conducted by residents, including both paid and volunteered time; and investment in the hardware. The opportunity cost of in-kind support from AEHU, the LHD, the community housing provider, the local Aboriginal medical service and the local government council will also be incorporated. Any additional resources will be identified through the CBA process. The costs will be derived from shadow prices for labour and equipment, and market prices for materials and outsourced contracts e.g. licensed repairs. Estimates for the resource utilisation will be derived from records of direct expenditure, administration records or manager estimates for opportunity costs.

The resources required to derive estimates for some components, such as the beneficial offset from additional producer surplus, prohibit inclusion within the project evaluation, but could be incorporated within a wider evaluation of the whole HfH program.

Time horizon - The time horizon for the economic analysis will comprise ten years from approval of the memorandum of understanding between AEHU and the community housing provider in July 2018. This period will account for the resources required to prepare and consult with the community, as well as the period of investment into housing maintenance through to the reporting and closure stage of the program. The time horizon extends beyond this period to account for the generation of downstream benefits and any costs that may be necessary for the realisation of on-going benefits.

Discount rate - NSW Treasury recommend the application of the social opportunity cost of capital, which is currently estimated at 7 %. NSW Treasury are also keen to maintain consistency across past and present economic evaluations, which utilised a 7 % discount rate [12]. There is concern that the adoption of this discount rate discriminates against projects with longer term benefits, particularly where greater uncertainty exists regarding higher long-term benefits and/or costs. Consequently, this evaluation will conduct sensitivity analyses with 3 %, 5 %, 7 % and 10 % discount rates.

Currency and price date – Specification of the currency and price date represents good practice but will also contribute to NSW Treasury's goal to build the comparable evidence base over time.

Analysis and reporting – The analysis will report a Benefit Cost Ratio and Net Present Value of the HfH study project. Sensitivity analyses will be conducted to identify the key assumptions and their impact on the decision rule. In line with the purpose to inform key stakeholders, the economic evaluation will be reported according to the NSW Government guidelines for CBA.

Accounting for equity – Equity is an important consideration for this HfH program, given the highly disadvantaged profile of the resident population. Equity considerations will not be incorporated directly into the quantitative analysis, due to the absence of a commonly accepted method. Rather, the results of the economic analysis will be positioned within wider distributional policies to provide for comparison to alternative programs or investments seeking to realise similar equity objectives.

4. Discussion

To optimise the public benefits generated through investment in publicly-funded programs, policy makers and public treasuries are increasingly focussed on a program's outcomes rather than demonstration of activities [13]. This policy is commonly accompanied by a requirement to conduct appropriate economic analyses that provide transparency to the value generated from the investment to enable comparison and optimisation across public budgets [12,55]. The requirement for such economic analyses is likely to increase as fiscal budgets are constrained to recover from the public debts incurred as a result of the Global Financial Crisis and COVID-19 recession.

With respect to the study aims, this review supports the requirement for an economic analysis of the HfH study project. Despite the scale of health concerns arising from physical housing considerations, and despite the scale of public investment directed towards this issue, the literature review identified very few economic analyses of housing programs that seek to improve the physical infrastructure for health reasons.

The review identified that a range of economic evaluation methods have been applied to comparable program investments. With respect to the program's stakeholders, treasuries prefer CBA to inform resource allocation between alternative public investments [12,19,20,23]. Where health outcomes can be reflected in a single measure, health departments more commonly utilise CEA/CUA to inform on resource decisions for alternative health investments [36,56].

The scoping review of the literature identified nineteen potential benefits from the HfH study project. Of the alternative economic evaluation methods utilised only CBA or CCA provide a consistent framework to include these disparate outcomes. While accepted methods exist to incorporate mortality gains within CBA, challenges exist with the valuation of health, well-being, or morbidity gains. The compensation approach utilised by Pichery, Bellanger [27] and Liu, Mack [29] is not supported within the government guidelines

relevant to the program [57]. CUA/CEA was designed to evaluate health outcomes but excludes most other benefits from the quantitative analysis. The review identified net health services gains as a large potential benefit, but this is readily incorporated within most methods. Given these considerations, the protocol retains a CBA framework providing the capacity to scale the analysis to an evaluation of the wider HfH program.

The primary challenge arising from the application of CBA lies with the exclusion of potential health gains from the evaluation of a health program. Some government guidelines outline accepted methods to value health [57], although these are often inconsistent with the social welfare theory foundations of CBA [58]. Consequently, to account for any evidence demonstrating improvements in residents' health, well-being or morbidity, relevant values will be included within the sensitivity analysis. This approach can inform the decision rule, as per CUA, without undermining theoretical consistency within the central analysis.

A second challenge arises with the number of potential benefits that represent improvements in low probability but high value events, such as hospital admissions, mortality from fire, falls and aged care admissions. Primary data is required to demonstrate a program effect on lower probability events, preferably from commencement of the program, and preferably over a long period [32]. Such evidence is unlikely for small investments like the HfH project. To capture these benefits, evidence will be required from either the wider HfH program or the literature. Long term collection of a minimum data set for all potential costs and benefits, but specifically for low-probability high-value events would assist the economic evaluation of HfH and similar programs, such as the NSW Aboriginal Communities Water and Sewerage Program (ACWSP) [59].

Quantitative evidence of the program's effect will not be available for all potential benefits. For example, affirmative enquiry undertaken with the tenant workers described personal benefits of "improved self-esteem, new personal relationships, enhanced work ethic, enjoyment out of working and helping others on a worthwhile project" [60], clearly reflecting a potential well-being benefit. Informal evidence also supports the probability of positive well-being benefits arising from tenants' improved sense of self-worth, reduced stress from safety improvements, reduced financial stress from improved energy efficiency, etc. In the absence of a validated instrument to capture these benefits, such outcomes should be acknowledged as intangible benefits of the HfH study project.

The review demonstrated that program costs are more readily and consistently incorporated within economic analyses due to the availability of expenditure data, although issues remain. Implementation costs are neglected in economic analyses of public health interventions, despite their relevance within most programs [61]. The participatory and community-partnered implementation of the HfH program represents a strength that is fully costed, in contrast to many alternative programs. Similarly, another strength of the program is that it does not require on-going support to deliver the intervention. Once the physical infrastructure is upgraded the marginal benefits should be realised. This lies in contrast to behavioural interventions, such as smoking or nutrition, that often require support following an intervention for the assumed benefits to be realised [62,63]. This consideration carries implications for the respective decay rate (dissipation) of their assumed benefits. It is important that the results of the program's economic evaluation reflect the relative sustainability of the benefits from the HfH program, particularly in comparison to alternative programs requiring on-going expenditure.

The economic analyses identified through the review were positioned within an equity policy framework but did not incorporate equity within quantification of any benefit estimates. This is consistent with the immaturity of research methods in this field [64,65] and the absence of definitive and accepted government guidance in this regard [14,19,20,55]. Equity will be addressed through comparison *to* alternative programs or investments seeking to realise comparable objectives. The NSW Treasury supports this approach [12].

This study has limitations. Scoping literature reviews risk selection bias and may not identify all relevant studies, nor do they provide a formal evaluation of evidence quality. Nevertheless, the review is considered a proportionate approach to address the aims and inform the economic protocol. The conduct of the outlined economic evaluation is not funded at time of publication. If policy makers promote the requirement for economic evaluation, it is imperative that independent funding is made available for this task or a percentage of the program funding is quarantined for such activities in the original funding approval.

5. Conclusion

Considerable evidence exists regarding the role housing plays in the determination of health and well-being outcomes. The HfH program represents an environmental health initiative funded and administered by NSW Health, that addresses health-related hardware in residential accommodation to improve the potential health outcomes for residents. The purpose of an economic analysis is to provide evidence regarding the relative value of this program, to enable comparison and optimisation of investment into public health.

The results of the review demonstrated that relatively few economic analyses of housing/health programs have been conducted. Of those identified, a wide array of economic methods have been applied, capturing a disparate and often partial mix of costs and benefits. As a result, the economic evidence of the relative value of alternative initiatives lacks clarity and inhibits comparison. Founded on the requirement for decision makers, and the insights from the literature review, the paper outlines a protocol for a cost-benefit analysis that accounts for the disparate health, social, economic and intangible benefits potentially generated from the HfH program. The review and the protocol consequently also establish a more consistent and comprehensive framework for the economic evaluation of comparable housing/health programs going forward.

Ethics declaration

Review and/or approval by an ethics committee was not needed for this study because the paper reviews economic evaluation

methods for interventions designed to improve the health of residents through improvements to housing assets. There were no data collected on human subjects.

Data availability Statement

No data was collected for the research described in the article.

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CRediT authorship contribution statement

Simon Deeming: Investigation, Methodology, Visualization, Writing – review & editing. **Kerryn Lawrence:** Conceptualization, Funding acquisition, Project administration, Validation, Writing – review & editing. **Jeffrey C. Standen:** Conceptualization, Funding acquisition, Supervision, Validation, Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Jeffrey Standen and Kerryn Lawrence are employed by NSW Ministry of Health and manage and implement the Housing for Health program in NSW.

NSW Ministry of Health engaged Simon Deeming Hunter Medical Research Institute to undertake the scoping literature review.

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Appendix A. Literature search strategy

Database: Ovid MEDLINE(R) and Epub Ahead of Print, In-Process & Other Non-Indexed Citations and Daily <1946 to September 23, 2019>

Search Strategy.

1 Public housing/or Housing/st
2 ((public or affordable or social or community) adj1 housing). ti,ab,kw,kf.
3 ("low income housing" or "low cost housing"). ti,ab,kw,kf.
4 (health adj2 hous*). ti,ab,kw,kf.
5 ((housing or household*) adj10 (indigenous or aboriginal* or First Nation*)). ti,ab,kw,kf.
6 1 or 2 or 3 or 4 or 5
7 exp Continental Population Groups/
8 (aborigin* or indigenous or torres strait or first nation* people*). ti,ab,kw,kf.
9 7 or 8
10 6 and 9
11 Housing/ec
12 exp "Costs and cost analysis"/
13 (economic* adj1 (evaluat* or analys*)). ti,ab,kw,kf.
14 (cost* adj (effectiv* or utilit* or benefit* or minimi* or analy* or offset* or stud* or consequence or outcome or outcomes)). ti,ab,kw,kf.
15 Program evaluation/
16 (housing adj2 economic*). ti,ab,kw,kf.
17 (economic* adj1 benefit*). ti,ab,kw,kf.
18 11 or 12 or 13 or 14 or 15 or 16 or 17
19 6 and 18
20 Health status/
21 Health status indicators/
22 health status. ti,ab,kw,kf.
23 health impact assessment*.ti,ab,kw,kf.
24 Population health/or Public health/

25 (health adj1 outcome*). ti,ab,kw,kf.
26 20 or 21 or 22 or 23 or 24 or 25
27 6 and 26
28 10 or 19 or 27
29 Developing Countries. sh,kf.
30 (Africa or Asia or Caribbean or “West Indies" or “South America" or “Latin America" or “Central America"). hw,kf,ti,ab,cp.
31 (Afghanistan or Albania or Algeria or Angola or Antigua or Barbuda or Argentina or Armenia or Armenian or Aruba or Azerbaijan or Bahrain or Bangladesh or Barbados or Benin or Byelarus or Byelorussian or Belarus or Belorussian or Belorussia or Belize or Bhutan or Bolivia or Bosnia or Herzegovina or Hercegovina or Botswana or Brasil or Brazil or Bulgaria or Burkina Faso or Burkina Fasso or Upper Volta or Burundi or Urundi or Cambodia or Khmer Republic or Kampuchea or Cameroon or Cameroons or Cameron or Camerons or Cape Verde or Central African Republic or Chad or Chile or China or Colombia or Comoros or Comoro Islands or Comores or Mayotte or Congo or Zaire or Costa Rica or Cote d’Ivoire or Ivory Coast or Croatia or Cuba or Cyprus or Czechoslovakia or Czech Republic or Slovakia or Slovak Republic or Djibouti or French Somaliland or Dominica or Dominican Republic or East Timor or East Timur or Timor Leste or Ecuador or Egypt or United Arab Republic or El Salvador or Eritrea or Estonia or Ethiopia or Fiji or Gabon or Gabonese Republic or Gambia or Gaza or Georgia Republic or Georgian Republic or Ghana or Gold Coast or Greece or Grenada or Guatemala or Guinea or Guam or Guiana or Guyana or Haiti or Honduras or Hungary or India or Maldives or Indonesia or Iran or Iraq or Isle of Man or Jamaica or Jordan or Kazakhstan or Kazakh or Kenya or Kiribati or Korea or Kosovo or Kyrgyzstan or Kirghizia or Kyrgyz Republic or Kirghiz or Kirgizstan or Lao PDR or Laos or Latvia or Lebanon or Lesotho or Basutoland or Liberia or Libya or Lithuania or Macedonia or Madagascar or Malagasy Republic or Malaysia or Malaya or Malay or Sabah or Sarawak or Malawi or Nyasaland or Mali or Malta or Marshall Islands or Mauritania or Mauritius or Agalega Islands or Mexico or Micronesia or Middle East or Moldova or Moldovia or Moldovian or Mongolia or Montenegro or Morocco or Ifni or Mozambique or Myanmar or Myanma or Burma or Namibia or Nepal or Netherlands Antilles or New Caledonia or Nicaragua or Niger or Nigeria or Northern Mariana Islands or Oman or Muscat or Pakistan or Palau or Palestine or Panama or Paraguay or Peru or Philippines or Philipines or Phillipines or Philippines or Poland or Portugal or Puerto Rico or Romania or Rumania or Roumania or Russia or Russian or Rwanda or Ruanda or Saint Kitts or St Kitts or Nevis or Saint Lucia or St Lucia or Saint Vincent or St Vincent or Grenadines or Samoa or Samoan Islands or Navigator Island or Navigator Islands or Sao Tome or Saudi Arabia or Senegal or Serbia or Montenegro or Seychelles or Sierra Leone or Slovenia or Sri Lanka or Ceylon or Solomon Islands or Somalia or South Africa or Sudan or Suriname or Surinam or Swaziland or Syria or Tajikistan or Tadzhikistan or Tadjikistan or Tadzhik or Tanzania or Thailand or Togo or Togolese Republic or Tonga or Trinidad or Tobago or Tunisia or Turkey or Turkmenistan or Turkmen or Uganda or Ukraine or Uruguay or USSR or Soviet Union or Union of Soviet Socialist Republics or Uzbekistan or Uzbek or Vanuatu or New Hebrides or Venezuela or Vietnam or Viet Nam or West Bank or Yemen or Yugoslavia or Zambia or Zimbabwe or Rhodesia). hw,kf,ti,ab,cp. (3559809)
32 ((developing or less* developed or under developed or underdeveloped or middle income or low* income or underserved or under served or deprived or poor*) adj (countr* or nation? or population? or world)). ti,ab.
33 ((developing or less* developed or under developed or underdeveloped or middle income or low* income) adj (economy or economies)). ti,ab.
34 (low* adj (gdp or gnp or gross domestic or gross national)). ti,ab.
35 (low adj3 middle adj3 countr*). ti,ab.
36 (lmic or lmics or third world or lami countr*). ti,ab.
37 transitional countr*.ti,ab.
38 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37
39 28 not 38
40 (developed countries or european union). af.
41 europe/or andorra/or austria/or belgium/or exp france/or exp germany/or exp united kingdom/or greece/or ireland/or exp italy/or liechtenstein/or luxembourg/or monaco/or netherlands/or portugal/or exp “scandinavian and nordic countries"/or spain/or switzerland/or exp australia/or new zealand/
42 north america/or exp canada/or exp united states/(1456761)
43 (united kingdom or england or scotland or wales or denmark or finland or iceland or norway or sweden). af.
44 (north america or canada or oecd or united states). af.
45 (europe or andorra or austria or belgium or france or germany or greece or ireland or italy or liechtenstein or luxembourg or monaco or netherlands or portugal or spain or switzerland or australia or new zealand). af.
46 40 or 41 or 42 or 43 or 44 or 45
47 39 and 46
48 limit 47 to (english language and yr = "1996 -Current")
49 limit 48 to (comment or editorial or letter or news)
50 48 not 49

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Chapter 8
Aboriginal Population and Climate Change in Australia: Implications for Health and Adaptation Planning

Preamble

The studies in Chapters 4, 5 and 6 of this thesis analysed the unique and extensive dataset compiled by NSW Health for the Housing for Health (HfH) Program over more than two decades. These chapters examined the performance of housing in the NSW Aboriginal community housing sector between 1998 and 2017 and the impact the HfH Program has had on house functionality in this sector over that time. The studies conclude that the HfH Program made substantial and increasing improvements in house functionality over the past 20 years for a minimal financial investment.

Chapter 7 investigated how a more comprehensive health economics analysis of the direct and indirect benefits of the HfH Program may be undertaken to assess the economic efficacy of the program and identify broader implications for future public policy. However, in considering prospective implications for public policy, future housing-related risks need to be identified and understood.

Chapter 8 aims to address the research question: "What future challenges does climate change present for Aboriginal communities in NSW, and what are the implications for public policy?" This study investigates the impact of climate-related health risks on the Aboriginal population of NSW, quantifying for the first time the current and predicted exposures to climate-related hazards, including heatwaves, floods, droughts, and bushfires. Acknowledging the cultural determinants underpinning Aboriginal health and well-being, a framework of climate vulnerability is used to articulate direct and indirect health impacts from climate-related hazards. These are balanced against the adaptive capacity of Aboriginal people and communities to limit their net susceptibility to climate change. The implications for health and adaptation planning, including for the Aboriginal community housing sector, are discussed. These impacts will be highly relevant for the ongoing work of the NSW HfH Program into the future.

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1 Health Protection NSW, St Leonards, NSW 2065, Australia

2 School of Public Health, Faculty of Medicine and Health, University of Sydney, Camperdown, NSW 2006, Australia

3 University Centre for Rural Health, Faculty of Medicine and Health, University of Sydney, Lismore, NSW 2480, Australia

***** Correspondence: jeff.standen@health.nsw.gov.au; Tel.: +61-2-9391-9627

† Affiliation to Aboriginal country: Jessica Spencer Wiradjuri; Veronica Matthews Quandamooka.

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Author contributions are listed in the published article and in the table below:

Author	Contributions
JCS	Conceived and led the design of the study with collaborators; collaborated on the development of the methods; the implementation of the statistical analyses and interpretation of results; and led the write-up of the paper.
JS	Assisted with the study design, interpretation of results and contributed to the write-up of the paper. JS is from the Wiradjuri community and is an Environmental Health Project Officer in Central West New South Wales.
GWL	Contributed to the review of literature, the interpretation of results and the write-up of the paper.
JVB	Collaborated on the development of the methods; led the identification of the environmental data metrics and the statistical analysis; collaborated on the interpretation of results; and commented on drafts of the paper.
VM	Assisted with development of the project and commented on drafts of the paper. VM is from the Quandamooka community in Southeast Queensland and leads the Centre for Research Excellence in Strengthening Systems for Indigenous Health Care Equity.
IH	Collaborated on the development of the methods; led the identification of the environmental data metrics and the statistical analysis; collaborated on the interpretation of results; and commented on drafts of the paper.
SB	Assisted with development of the project and commented on drafts of the paper.
EJ	Collaborated on the development of the methods; led the identification of the environmental data metrics and the statistical analysis; collaborated on the interpretation of results; and commented on drafts of the paper.

MB-P	Assisted with the development of the project and commented on drafts of the paper
GGM	Contributed to the design of the study and commented on the interpretation of results and drafts of the paper.

All authors have read and agreed to the published version of the manuscript.

Note: Formatting changes made to the accepted manuscript during copy editing resulted in errors in some of the figures and tables that were not identified prior to the initial publication. A formal Correction was subsequently published, and the original publication was updated. The details and the published Correction are attached as **Appendix III** to this thesis. The online version available here is the corrected version.

International Journal of
Environmental Research and Public Health

MDPI

Article

Aboriginal Population and Climate Change in Australia: Implications for Health and Adaptation Planning

Jeffrey C. Standen [1,2,*], Jessica Spencer [1,†], Grace W. Lee [1,2], Joe Van Buskirk [2], Veronica Matthews [3,†], Ivan Hanigan [2], Sinead Boylan [2], Edward Jegasothy [2,3], Matilde Breth-Petersen [2] and Geoffrey G. Morgan [2,3]

1 Health Protection NSW, St Leonards, NSW 2065, Australia; jessica.spencer@health.nsw.gov.au (J.S.); g.lee@sydney.edu.au (G.W.L.)
2 School of Public Health, Faculty of Medicine and Health, University of Sydney, Camperdown, NSW 2006, Australia; joseph.vanbuskirk@sydney.edu.au (J.V.B.); ivan.hanigan@sydney.edu.au (I.H.); sinead.boylan@csiro.au (S.B.); edward.jegasothy@sydney.edu.au (E.J.); matilde.petersen@sydney.edu.au (M.B.-P.); geoffrey.morgan@sydney.edu.au (G.G.M.)
3 University Centre for Rural Health, Faculty of Medicine and Health, University of Sydney, Lismore, NSW 2480, Australia; veronica.matthews@sydney.edu.au
* Correspondence: jeff.standen@health.nsw.gov.au; Tel.: +61-2-9391-9627
† Affiliation to Aboriginal country: Jessica Spencer Wiradjuri; Veronica Matthews Quandamooka.

Abstract: The health impacts of climate are widely recognised, and extensive modelling is available on predicted changes to climate globally. The impact of these changes may affect populations differently depending on a range of factors, including geography, socioeconomics and culture. This study reviewed current evidence on the health risks of climate change for Australian Aboriginal populations and linked Aboriginal demographic data to historical and projected climate data to describe the distribution of climate-related exposures in Aboriginal compared to non-Aboriginal populations in New South Wales (NSW), Australia. The study showed Aboriginal populations were disproportionately exposed to a range of climate extremes in heat, rainfall and drought, and this disproportionate exposure was predicted to increase with climate change over the coming decades. Aboriginal people currently experience higher rates of climate-sensitive health conditions and socioeconomic disadvantages, which will impact their capacity to adapt to climate change. Climate change may also adversely affect cultural practices. These factors will likely impact the health and well-being of Aboriginal people in NSW and inhibit measures to close the gap in health between Aboriginal and non-Aboriginal populations. Climate change, health and equity need to be key considerations in all policies at all levels of government. Effective Aboriginal community engagement is urgently needed to develop and implement climate adaptation responses to improve health and social service preparedness and secure environmental health infrastructure such as drinking water supplies and suitably managed social housing. Further Aboriginal-led research is required to identify the cultural impacts of climate change on health, including adaptive responses based on Aboriginal knowledges.

Keywords: Aboriginal health; Aboriginal population; adaptation; climate exposure; climate and health; climate vulnerability; equity; health policy; indigenous health

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1. Introduction

Climate change is a complex global phenomenon that influences environmental conditions that, in turn, affect human health [1,2]. Although it is difficult to attribute accurately the magnitude of health impacts caused by the anthropogenic change in the climate, evidence of health changes can nonetheless be inferred from the more robust data that links particular climate-related hazards with health outcomes [1]. The pathways by which climate change can affect health have been well described: extreme events such as bushfires,

floods and storms can inflict injury and death directly, whilst heatwaves can increase cardiovascular morbidity and mortality [2,3]. Climate change can degrade environmental and ecological systems and affect human health indirectly: warmer conditions can encourage pathogen proliferation that causes water and food-borne diseases; increased sources of air pollutants such as bushfire smoke and dust can exacerbate respiratory diseases; ecological environments can become more conducive to mosquito-borne disease transmissions; and droughts can become more severe leading to food and water insecurity [2–5]. The social, economic and demographic disruptions caused by climate change can adversely impact livelihoods, including mental health and social and emotional well-being [2,3].

In Australia, an observed 1.4 °C of warming since 1910 has already caused more severe heatwaves and fire weather, reduced rainfall and severe droughts in parts of Australia [6]. People with existing climate-sensitive conditions, who are poorly resourced and living in areas more severely impacted by climate extremes, are most affected by climate change [5]. In Australia, this includes Aboriginal and Torres Strait Islander communities. The term "Aboriginal" is used to describe the original inhabitants of Australia and their descendants. The term "Torres Strait Islander" is used to describe the original inhabitants and their descendants from the Torres Strait Islands located to the north of mainland Australia. As the focus of this study is on NSW, "Aboriginal" is respectfully used in an inclusive way to refer to all Aboriginal and Torres Strait Islander people residing in NSW.

Aboriginal people have historically been managing land and water resources sustainably for ongoing farming practices, drinking water and cultural practices [7]. As the natural environment is increasingly impacted by climate change, Aboriginal communities will continually be disproportionately affected due to their close physical and spiritual relationships with their Country (traditional homelands) and dependence on land and water resources. Climate change is seen as another component of ongoing colonisation, where Aboriginal people have been dispossessed, communities decimated and culture suppressed [8,9]. Aboriginal people bear greater proportions of ill health, including cardiovascular and respiratory diseases, diabetes and mental health conditions [10,11] and poorer status across the social determinants, including education, employment, income and housing conditions, compared with non-Aboriginal populations [12].

Climate change also presents an opportunity for redress. Aboriginal communities are humanity's oldest continuing culture, having adapted to gradual and abrupt changes over millennia, including colonisation [13]. The application of Aboriginal knowledges and cultural practices has shown enormous environmental, health and well-being benefits. This has been demonstrated by Aboriginal rangers participating in caring for Country activities showing lower rates of obesity, diabetes and cardiovascular diseases [14,15]. Resourcing and empowering Aboriginal communities to lead place-based climate adaptation and mitigation processes will be critical to addressing current and future climate challenges in Australia.

New South Wales (NSW) is the fifth largest and most populated state on the continent, situated on the east coast of Australia with an area of 801,137 km^2 and a coastline of 2101 km [16]. NSW is geographically diverse, influencing climate and population patterns. Temperatures get progressively hotter moving inland towards the west and north-west of the state, where the north-west receives highly variable rainfall and very high temperatures [17]. The elevated mountainous areas of the Great Dividing Range separate the east coast from the inland. The range enhances rainfall near the coast, where temperatures are moderate [17]. The flat, western side of the range covers two-thirds of the state and includes much of the state's agricultural land, with inland rivers forming part of the Murray–Darling River network flowing towards South Australia. In 2021, 8,186,800 residents lived in major cities, regional centres and rural areas across NSW [18]. In 2016, one-third of Australia's Aboriginal people were estimated to live in NSW (n = 265,685, 33%) and within NSW, 46.3% were estimated to live in major cities (n = 123,099) [19]. However, as a proportion, Aboriginal people in NSW are more likely to live outside of major urban areas than non-Aboriginal populations and some in discrete Aboriginal communities—former reserves and missions that are now designated Aboriginal land title and mostly located in rural and regional locations.

Temperatures in NSW are predicted to warm by 0.7 °C by 2030 and 2.1 °C by 2070 based on a medium CO_2 emissions scenario [17,20]. The number of days greater than 35 °C is expected to increase by approximately 20 and 40 extra days per year in coastal and north-western NSW, respectively, by 2070 [17]. Fire weather is expected to increase in western NSW in spring and summer, whilst rainfall is projected to decrease in spring and increase in autumn with regional variations [17].

This study reviewed current evidence on the health risks of climate change for Aboriginal populations in NSW and described historical and future exposure to a range of climate-related factors in the Aboriginal compared to non-Aboriginal populations. Guided by Aboriginal partner organisations, this study further identified key challenges and issues associated with adaptation to these climate exposures.

2. Materials and Methods

Project partners from Aboriginal government and non-government agencies working in the NSW Aboriginal community and health sectors guided the development and implementation of the study. Detailed population data on usual resident populations (URPs), based on counts from the Australian Bureau of Statistics (ABS) 2016 Census for Population and Housing, were obtained [21]. The ABS divides Australia into Statistical Areas of different levels based on population size. URPs were obtained for Statistical Areas Level 1 (SA1), which contain between 200 and 800 usual residents [22]. To account for spatial variability of exposures within SA1s, ABS 2016 population grids [23] were extracted by SA1 and were used to calculate population weighted estimates by SA1. URPs are known to undercount Aboriginal populations in Australia, and so estimates are aggregated to the state level with overall proportions reported. While the ABS estimated resident populations (ERPs) have been corrected for the known undercounting of Aboriginal people [24], these population data are only available at the Statistical Area 2 (SA2) level, a spatial unit many times larger than the smaller SA1 spatial unit (containing between 3000 and 25,000 people). In order to assess the suitability of using URPs versus ERPs, estimates were obtained using both methods in a sensitivity analysis, with negligible differences in proportions found across methods. As such, the smaller geographical unit (i.e., SA1 level geography using URP estimates) was used for the primary analyses.

Discrete Aboriginal communities across NSW were also mapped using data identified by various government programs and compiled by the NSW Health Environmental Health Branch. The data have been validated by on-site field visits and mapping using the G-NAF (Geocoded National Address File), a trusted index of Australian address information. G-NAF contains the state, suburb, street, number and coordinate reference (or "geocode") for street addresses in Australia. G-NAF does not contain any personal information or details relating to an individual or business [25].

2.1. Historical and Projected Climate Data

Selected historical climate exposure data were obtained from the NSW Department of Planning, Industry and Environment (DPIE) through the Australian Bureau of Meteorology (BoM) Australian Water Availability Project (AWAP) [26] for NSW at a resolution of 25 km by 25 km over the 1990 to 2019 period. All data were aggregated to annual averages for the region. Future predictions for data on selected climate parameters were sourced from the NSW and ACT Climate Modelling (NARCliM) project. The NARCliM modelling was able to draw from global climate model outputs and downscaled them to finer 10 km by 10 km resolutions for the period from 2020 to 2039 [20,27]. This study selected key climate-related exposures based on publicly available data relevant to the NSW context, including heat, rainfall, drought and fire danger.

NSW climate data were obtained from the AWAP [26] to estimate population exposures to extreme heat and heatwaves. Average annual days with daily mean temperatures of 35 °C or above were calculated, as well as an estimate of annual average maximum heatwave duration in days, as estimated by the Excess Heat Factor metric [28]. This metric identifies

the longest heatwave duration where the day's rolling three-day mean temperature both exceeds the 95th percentile of historical temperatures and the recent 30-day average for that region [28].

Rainfall variability and average rainfall estimates were obtained for NSW from AWAP [26]. Daily rainfall estimates were used to calculate annual averages. Rainfall variability was also calculated as the 90th rainfall percentile minus the 10th rainfall percentile divided by the 50th rainfall percentile (i.e., median). This metric provides an indication of how much rainfall varies from low to extreme.

Drought exposure was calculated using the Standard Precipitation Evapotranspiration Index with a six-month rolling sum of rainfall, and evapotranspiration, between 1950 and 2020, sourced from the AWAP. In this method, cumulative six-month estimates of precipitation were fitted to a standard gamma probability distribution with z scores calculated for each six-monthly rolling sum. Negative z scores indicate drought, with values of −1.3 or lower indicating at least moderate drought. Evapotranspiration was estimated using the Thornthwaite method due to a lack of windspeed data [29]. The proportion of months in drought per period was compared between the period of 1990 to 2006 and 2007 to 2020 to provide an estimate of the relative increase in drought-affected months between these two periods.

Bushfire vulnerability was estimated using the McArthur Forest Fire Danger Index (FFDI), a composite measure of the area's drought factor, daily maximum temperature, daily afternoon humidity and wind speed [30]. Higher values of FFDI indicate a higher likelihood of fires starting and spreading, with values between 25 and 49 indicating very high danger and values of 50 or over indicating severe fire danger. Historical (1990–2009) and projected FFDI values were sourced from NARCliM.

2.2. Statistical Analysis

Exposure grids for each of the climate metrics were averaged across ABS Statistical Area 1 (SA1) boundaries for 2016 [22]. Population-weighted exposure estimates were then calculated by SA1, with categories informed by the distribution of each exposure. Aboriginal and non-Aboriginal populations were then summed by exposure category for each population. In order to calculate the odds of each population living in areas with a higher risk exposure, exposure estimates were further categorised into "high" versus "lower" risk, with dichotomisation informed by the categories identified by the distributions. For example, average annual days over 35 °C were categorised into <5 days; 5–<10 days; 10–<20 days; 20–<50 days and 50+ days above 35 °C. This categorisation was dichotomised to <20 days indicating "lower risk" and 20 or greater days above 35 °C indicating "high risk". Odds ratios were calculated by comparing the proportion of Aboriginal populations living in areas classified as high risk with non-Aboriginal populations living in those same areas, using the Wald method with confidence intervals calculated accordingly.

As a sensitivity analysis, odds ratios were stratified by the ABS Index of Relative Socioeconomic Disadvantage (IRSD) quintile [31] to assess whether differential exposures could be explained by socioeconomic status. The IRSD is a general socioeconomic index that includes measures of the relative disadvantage of people and households within an area, such as low-income or low-skilled occupations. A low score indicates a relatively greater disadvantage [32].

All data processing and visualisation were performed using RStudio (Version 4.1.3) (RStudio Inc., Boston, MA, USA, 2019). This study used publicly available data on climate modelling and Aboriginal demographics.

3. Results

Figure 1 shows the distribution of Aboriginal populations and locations of discrete Aboriginal communities in NSW. Most Aboriginal people (46%) lived in major cities; however, Aboriginal people made up a greater proportion of the population in regional and remote areas.

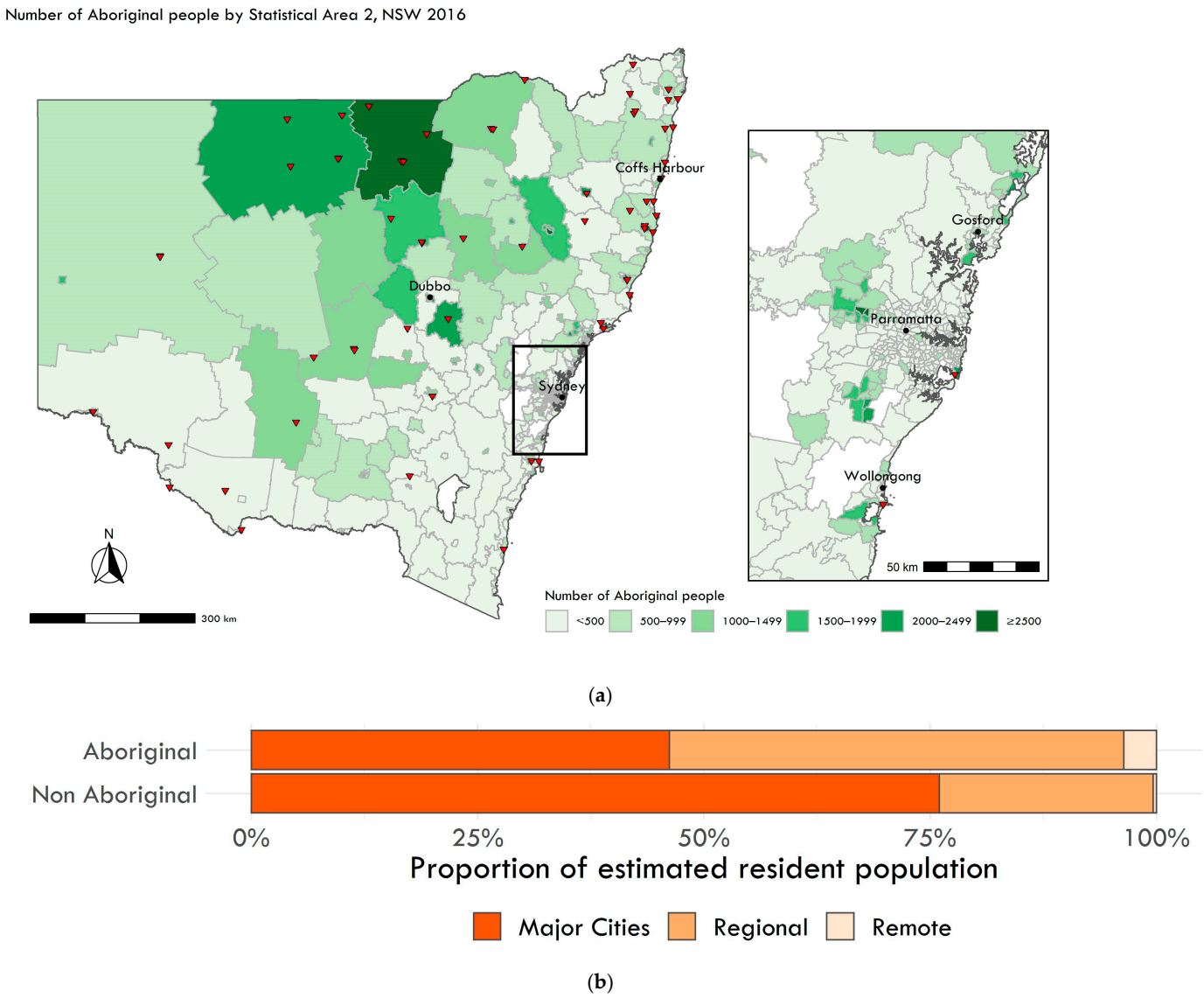

Figure 1. Distribution of Aboriginal people in NSW, 2016: (**a**) Number of Aboriginal people by Statistical Area 2 in NSW and the Greater Sydney Regions, 2016. Triangle markers indicate discrete Aboriginal communities with populations between 10–1000 people. (**b**) Proportion of Aboriginal versus non-Aboriginal populations by rurality. Source: Australian Bureau of Statistics [22] and NSW Ministry of Health, Environmental Health Branch.

3.1. Comparison of Climate Exposure Levels between Aboriginal and Non-Aboriginal Populations

Across all climate indicators, higher proportions of Aboriginal populations compared to non-Aboriginal populations were found to live in areas with more extreme climate-related exposures. All climate exposure risk indicators are summarised by exposure categories in Table 1, with additional descriptive statistics included in Appendix A Table A1.

For periods of excessive heat (i.e., the average of the longest annual heatwave duration), 26% of NSW Aboriginal populations lived in areas with seven or greater maximum number of heatwave days annually, compared with 9% of non-Aboriginal populations (OR 3.79, 95% CI 3.75–3.83). Aboriginal populations had 4.3 times the odds of living in areas with a high number of annual average days exceeding 35 °C (20% vs. 5%; 95% CI 4.3 to 4.4) and were predicted to have 3.5 times the odds of living in areas with five or more additional days exceeding 35 °C in the next 20 years (32% vs. 12%; 95% CI 3.4 to 3.5).

Table 1. Annual climate exposure estimates by Aboriginal versus non-Aboriginal URPs, population weighted at the Statistical Area 1 level for historical (1990–2019) and projected (2020–2039) periods.

Climate Exposure	Exposure Category	Aboriginal URP [i]		Non-Aboriginal URP [i]		Binary Risk Category	Higher-Risk Exposed Population (%)		Odds Ratio
		n	%	*n*	%		Aboriginal	Non-Aboriginal	
Historical annual average maximum heatwave days [ii]	0–4	12,882	6.2%	712,057	10.0%	Lower	26.4%	8.7%	3.79 [3.75–3.83] **
	5	101,001	48.9%	5,109,987	71.6%	Lower			
	6	38,193	18.5%	696,651	9.8%	Lower			
	7	37,112	18.0%	496,711	7.0%	Higher			
	>7	17,514	8.5%	121,239	1.7%	Higher			
Historical annual days above 35 °C	<5	61,112	29.3%	1,768,115	24.5%	Lower	19.5%	5.3%	4.34 [4.29–4.39] **
	5–9.9	64,413	30.9%	4,122,137	57.2%	Lower			
	10–19.9	42,504	20.4%	932,265	12.9%	Lower			
	20–49.9	34,536	16.6%	360,230	5.0%	Higher			
	≥50	6101	2.9%	19,784	0.3%	Higher			
Projected additional days above 35 °C	<2	59,097	28.0%	1,842,597	25.4%	Lower	31.8%	11.9%	3.45 [3.42–3.48] **
	2–4.9	84,608	40.1%	4,536,671	62.6%	Lower			
	5–9.9	45,609	21.6%	760,717	10.5%	Higher			
	≥10	21,470	10.2%	102,944	1.4%	Higher			
Historical annual rainfall variability	Low	25,477	12.2%	1,920,044	26.7%	Lower	13.3%	3.2%	4.67 [4.61–4.73] **
	Low to moderate	155,450	74.5%	5,053,399	70.2%	Lower			
	Moderate	23,201	11.1%	204,412	2.8%	Higher			
	Moderate to high	2864	1.4%	7912	0.1%	Higher			
	High	1674	0.8%	16,764	0.2%	Higher			
Historical annual average rainfall (mm)	≤400	8138	3.9%	129,981	1.8%	Higher	35.6%	16.6%	2.77 [2.75–2.80] **
	400–799	66,068	31.7%	1,065,592	14.8%	Higher			
	800–1199	110,212	52.8%	5,243,879	72.8%	Lower			
	≥1200	24,248	11.6%	763,079	10.6%	Lower			
Projected change in annual rainfall (%)	<−1%	23,675	11.2%	412,395	5.7%	Higher	23.3%	12.4%	2.14 [2.12–2.16] **
	−0.01	25,384	12.0%	487,009	6.7%	Higher			
	0–0.9%	17,531	8.3%	491,761	6.8%	Lower			
	1–1.9%	71,977	34.1%	3,863,646	53.3%	Lower			
	≥2%	72,211	34.3%	1,987,405	27.4%	Lower			
Historical annual days with FFDI ≥ 50 [iii]	0–0.9	109,645	52.8%	4,779,751	66.9%	Lower	20.4%	5.7%	4.26 [4.21–4.31] **
	1–1.9	55,888	26.9%	1,962,018	27.5%	Lower			
	2–4.9	31,580	15.2%	329,493	4.6%	Higher			
	≥5	10,731	5.2%	74,910	1.0%	Higher			
Projected additional annual days FFDI ≥50	0–0.24	161,178	77.8%	6,659,154	93.5%	Lower	12.4%	3.1%	4.35 [4.29–4.41] **
	0.25–0.49	20,318	9.8%	236,287	3.3%	Lower			
	0.5–0.9	20,991	10.1%	198,057	2.8%	Higher			
	≥1	4599	2.2%	25,478	0.4%	Higher			

Table 1. *Cont.*

Climate Exposure	Exposure Category	Aboriginal URP [i]		Non-Aboriginal URP [i]		Binary Risk Category	Higher-Risk Exposed Population (%)		Odds Ratio
		n	%	*n*	%		Aboriginal	Non-Aboriginal	
Change in drought-affected months (1990–2006 vs. 2007–2020)	≤−10%	40,473	20.1%	2,409,632	35.8%	Lower			2.35 [2.33–2.37] **
	−9.9–−5%	58,985	29.3%	2,436,940	36.2%	Lower			
	−4.9–−2.5%	19,621	9.7%	435,573	6.5%	Lower			
	−2.4–0%	17,825	8.9%	333,644	5.0%	Lower			
	0.01–5%	39,283	19.5%	753,751	11.2%	Higher	32.0%	16.7%	
	>5%	25,159	12.5%	370,407	5.5%	Higher			

Notes: (i) URP = usual resident populations from the 2016 Australian Bureau of Statistics Census of Population and Housing; ** $p < 0.001$; (ii) Annual average maximum heatwave days refer to the average longest heatwave duration (in days), where each day's rolling three-day mean temperature both exceeds the 95th percentile of historical temperatures and the recent 30-day average for that region; Historical period is from 1990 to 2019 except (iii) Historical FFDI where the time period is 1990–2009. Projected period is from 2020 to 2039.

For rainfall variability, 13% of the Aboriginal population in NSW lived in areas with moderate, moderate to high or high rainfall variability (11%, 1% and 1%, respectively), compared with 3% of the non-Aboriginal population in NSW (3%, 0.1% and 0.2%, respectively). That is, Aboriginal populations had 4.7 times the odds of living in areas with higher exposure to rainfall variability (95% CI 4.6 to 4.7) and likely more prone to drought or flooding issues. For rainfall, 36% of the Aboriginal population in NSW lived in areas with less than 800 mm annual average rainfall (4% ≤400 mm and 32% between 400 and less than 800 mm) compared with 17% of non-Aboriginal populations (2% ≤400 mm and 15% between 400 and less than 800 mm; OR 2.77, 95% CI 2.75 to 2.80). Aboriginal populations were also more likely to live in areas with projected decreases in rainfall, with 23% of Aboriginal populations living in these areas, compared with 12% of non-Aboriginal populations in the next 20 years (OR 2.1, 95% CI 2.1 to 2.2).

Aboriginal populations were 4.3 times (95% CI 4.2 to 4.3) more likely to live in areas with an average of three or more days annually where Forest Fire Danger Index (FFDI) exceeded 50 (extreme fire danger) compared with non-Aboriginal populations (20% vs. 6%). In addition, Aboriginal populations were predicted to have 4.4 times (95% CI 4.3 to 4.4) the odds of living in areas with 0.5 or greater additional days annually where FFDI exceeds 50 in the next 20 years (12% vs. 3%).

Aboriginal people were also more likely to live in areas with increased months of drought between 2007 and 2020 compared with the previous period, 1990–2006. Specifically, Aboriginal people were 2.4 times (95% CI 2.3 to 2.4) more likely to live in areas with increases in drought-affected months than non-Aboriginal people (32% vs. 17%). Drought frequency and intensity were expected to increase in the future; however, future drought changes were not included in this analysis due to the level of uncertainty in its projection.

Figures 2 and 3 show the levels of historical and projected climate exposure for heat, rainfall and fire danger in categories of increasing severity across NSW. The proportions of Aboriginal versus non-Aboriginal populations exposed to each category of climate exposure are provided in the histograms for each exposure map.

Figure 2a,b respectively shows the current impact of heatwaves and high temperatures (days exceeding 35 °C) across NSW, particularly affecting the north-west of the state. Figure 2c shows north-west NSW was also predicted to experience more than 10 additional days over 35 °C. The histograms associated with each figure show the disproportionate impact of these exposures on Aboriginal populations.

Figure 2d shows that rainfall variability was greatest in the west of the state, which also experiences the lowest annual rainfall (Figure 2e). The projected change in rainfall shown in Figure 2f was predicted to decrease in the southern parts of the state and increase across the north of the state, including coastal and inland areas. The histograms associated with Figure 2d,e shows that Aboriginal people disproportionately resided in areas of both lower and higher annual rainfall and experienced greater rainfall variability than the non-Aboriginal population of NSW. The histogram in Figure 2f shows that predicted changes in rainfall would disproportionately impact Aboriginal populations who would experience periods of both higher and lower rainfall over the next 20 years.

Figure 3a,b respectively shows the observed and predicted days of greater fire danger risk increased towards the west of the state. The histograms that show a higher proportion of the NSW Aboriginal populations historically resided in areas of greater fire danger risk compared to the non-Aboriginal population, and this was predicted to increase as the fire danger risk increases over the next 20 years.

3.2. Comparative Climate Exposure Levels by Index of Relative Socioeconomic Disadvantage (IRSD) between Aboriginal and Non-Aboriginal Populations

Sensitivity analyses revealed that Aboriginal people were at a disproportionately higher risk of exposure to all study climate parameters, regardless of socioeconomic status. In fact, for most exposures, Aboriginal people living in the highest IRSD quintile (i.e., the least disadvantaged) had higher odds of living in areas exposed to higher risk compared

to non-Aboriginal populations in the same IRSD quintile. These results indicated that socioeconomic status alone did not account for the differential climate risk exposures for Aboriginal populations identified above. These results are displayed in Appendix A.

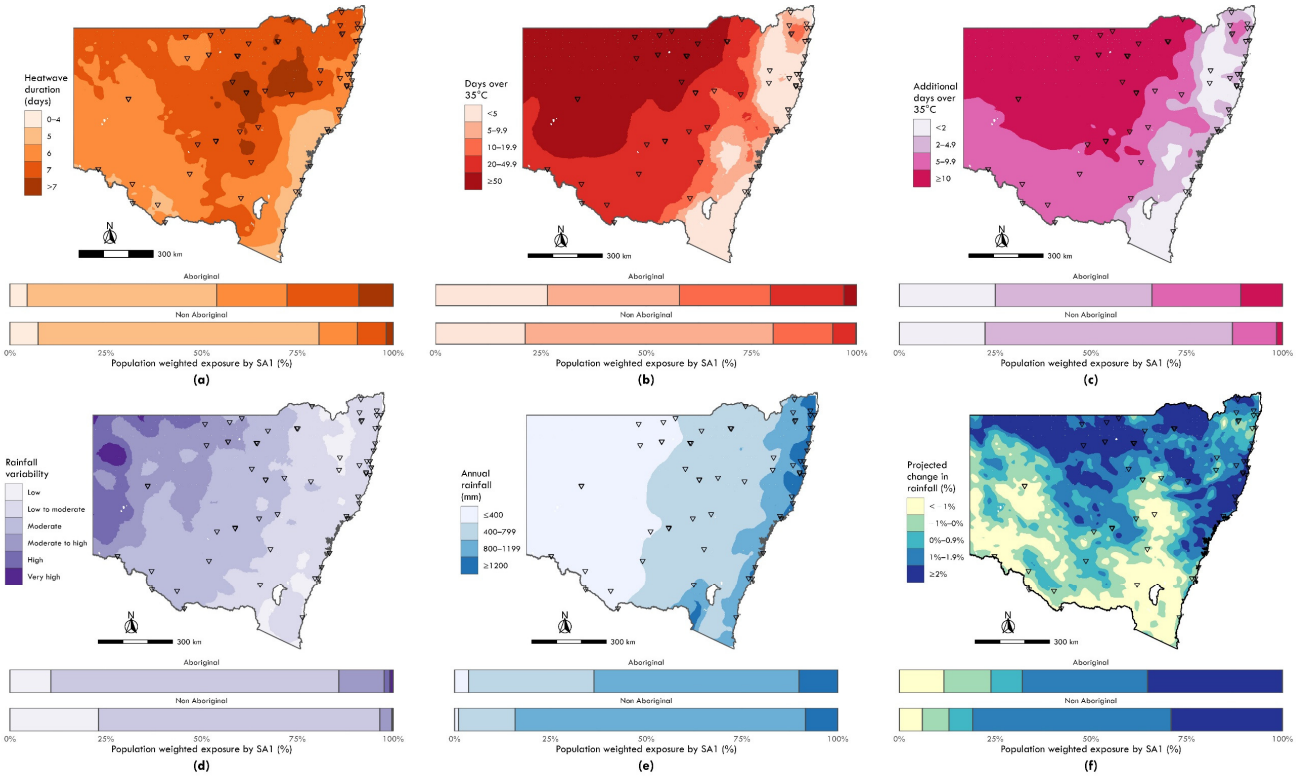

Figure 2. Maps of climate exposures with bar charts indicating relative exposure by category across Aboriginal and non-Aboriginal populations. Exposures include: (**a**) Historical annual average maximum heatwave duration (days), 1990–2019; (**b**) Historical annual days exceeding 35 °C, 1990–2019; (**c**) Projected additional days exceeding 35 °C annually, 2020–2039; (**d**) Historical annual rainfall variability, 1990–2019; (**e**) Historical annual rainfall in millimetres (mm), 1990–2019; (**f**) Projected relative change in annual rainfall, 2020–2039. Triangle markers denote identified discrete Aboriginal communities. See Appendix A for a summary of descriptive statistics for selected climate exposure estimates on a continuous scale.

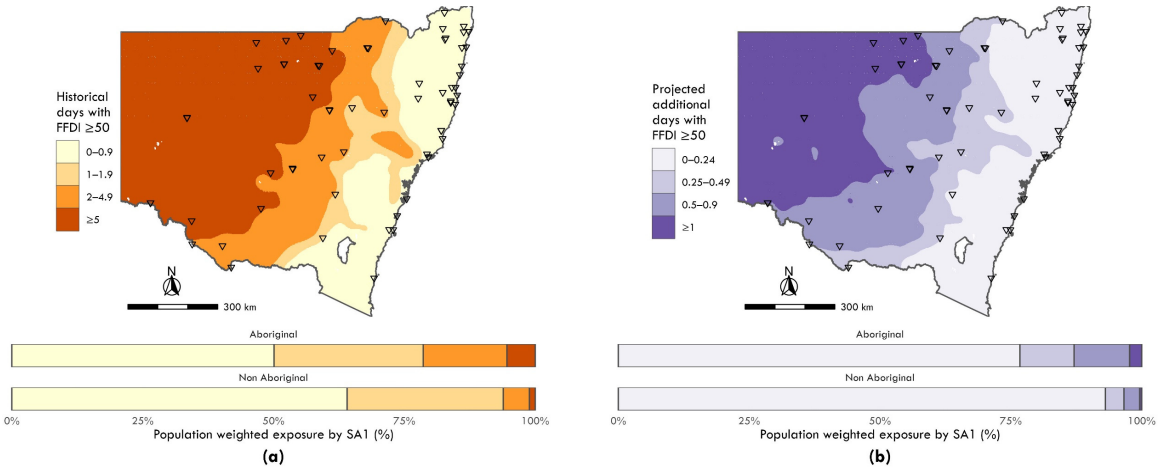

Figure 3. Maps of annual days with Macarthur Forest Fire Danger Index exceeding 50 (i.e., "severe" fire danger), with bar charts indicating relative exposure by category across Aboriginal and non-Aboriginal populations: (**a**) historical between 1990 and 2009; and (**b**) projected for 2020–2039. See Appendix A for a summary of descriptive statistics.

4. Discussion

Through the analysis of publicly available data and exposure mapping of climate hazards, this study confirmed what has been suspected anecdotally—that Aboriginal populations are disproportionately exposed to climate hazards, and this disparity is predicted to become more pronounced in the coming decades due to the projected impacts of climate change. The study quantified the different exposures for Aboriginal and non-Aboriginal populations in NSW, which include greater rainfall variability that can lead to more floods and droughts and higher temperatures and longer heatwaves that can result in greater risks of fire weather and bushfires. The Australian continent was romantically described by non-Aboriginal poet Dorothea Mackellar in her famous 1908 poem "My Country" as "a land of droughts and flooding rains" [33]. Anthropogenic changes in climate since this time have seen an amplification of these harsh extremes, and the health implications on Aboriginal populations, in particular, will depend on the effectiveness of the adaptation responses implemented today. The key issues and challenges faced by Aboriginal people under each study climate hazard are discussed below.

4.1. Increased Temperatures and Heatwaves

The analysis identified that a larger proportion of Aboriginal than non-Aboriginal people in NSW reside in areas that experienced greater numbers of hot days. These trends will continue as temperatures are predicted to increase with climate change.

Sensitivities to heat can be exacerbated by inadequate housing conditions, which is a key contributor to the health gap between Aboriginal and non-Aboriginal populations [34–36]. Housing issues are most prevalent in social housing, the dominant tenure type for Aboriginal communities [37,38]. Recent analysis of NSW housing condition data from 1998 to 2017 has indicated that housing conditions are unable to support basic healthy living practices (such as electrical safety, ablutions and food preparation) in the majority of Aboriginal community housing, and Aboriginal housing often lacks adequate thermal regulation, which puts older adults (particularly those with chronic disease) and children at risk of extreme temperature events [39,40]. Overcrowded conditions, together with poor housing amongst Aboriginal communities across Australia, have been recorded over many decades [38,40–43]. Overcrowding encourages the spread of infectious diseases, which can be intensified where only part of the house effectively regulates thermal comfort [44].

For NSW Aboriginal people already living in poor housing conditions, the projected impacts of climate change will add an additional level of complexity. As a key determinant of health and well-being, housing has the potential to either protect residents against or expose them to increased risk of climate-related harm [45].

Providing a cool living environment will be a key supportive factor in climate adaptability. Cooling housing can be achieved through a combination of passive design measures such as insulation, roof space ventilation or window shading and through active cooling measures such as air-conditioning or fans, which require ongoing running costs. A temperature control study in an Aboriginal community in north-western NSW in 2003 found the summer temperatures inside the houses exceeded 35 °C for up to 15 h of the day, including after 9 pm when children were trying to sleep [46]. Many houses had some form of active cooling but usually only in one room. As a result, families slept in the one cooled room at night, increasing the effects of crowding in the house. Passive cooling measures retrofitted to houses as part of the project reduced temperatures within the living space and improved the efficiency of mechanical cooling systems, but alone were unable to achieve thermal comfort [46]. Food security may also be affected by increased and prolonged temperatures. In NSW, Housing for Health data reported that 62% of Aboriginal homes surveyed between 1998 and 2017 had adequate refrigeration, and only 9% had adequate facilities to store, prepare and cook food [47]. The impact of inadequate housing design on Aboriginal health in NSW has been previously documented [40,46,48], and our mapping and projections show that this will likely be exacerbated by climate change.

Passive and active technical solutions exist to assist adaptive capacity to climate change, but any capital investment in social housing to cope with climate change needs to be supplemented by a robust and effective system of repair and maintenance. The NSW Housing for Health program identified that the overwhelming reason items failed in Aboriginal community housing was due to a lack of systematic maintenance (84%) and quality control (11%) [40].

Adaptation strategies must also be affordable so as not to burden social housing tenants already under financial stress with an additional economic demand beyond their capacity to pay [49]. Installation of active air cooling must also be supported by passive cooling measures to improve efficiency and minimise running costs. Adaptation strategies also need to consider impacts on utilities. High water consumption by evaporative cooling can impact water supplies [46], and increased use of air-conditioning over recent years has impacted the electricity grid in major cities, with substations overheating on days of high consumption [50–52]. Improvements in solar power technology over recent decades can reduce running costs and the impact on the electricity grid; however, these solutions require community engagement, robust systems of quality control and ongoing maintenance and monitoring so as not to provide an additional burden on communities.

4.2. Rainfall Variability and Risks of Flooding and Drought

A larger proportion of Aboriginal than non-Aboriginal people reside in areas that currently experience higher rainfall variabilities and risks of flooding and drought. The historical location of discrete Aboriginal communities near rivers will make those communities more susceptible to flooding and associated health issues. A survey conducted following the devastating floods of 2017 in Northern NSW showed that Aboriginal respondents had four times the odds of reporting flooded homes compared to non-Aboriginal respondents [53]. They were also more likely to report symptoms of anxiety, depression and post-traumatic stress disorder [53]. Other health risks associated with flood events are damages to sewage and water supply infrastructure leading to pathogen proliferation and water-borne diseases [36]. More extreme flooding in the same region in early 2022 is likely to lead to a cumulative impact from these climate risk factors.

Increased flooding events will impact communities along coastal and river systems, and the need for adequate flood mitigation strategies and disaster management preparedness will be crucial adaptation responses for these communities to protect against the loss of lives and assets. Increased flooding may also increase the risk to food and medication supply chains for regional and remote communities and transport logistics for agriculture, thus impacting food security and rural economies and increasing the need for support services in these communities.

Warmer temperatures and changed geographical patterns of intense rainfall or flooding, especially where "re-wetting" of an environment occurs, may promote breeding conditions for mosquitos and the transmission of vector-borne diseases [54]. Aboriginal people living in regional and remote areas can be disproportionately affected. The 2022 summer has seen the first incursion of Japanese encephalitis into south-eastern Australia [55,56].

Extremes of flooding and drought are also likely to have long-term impacts on agricultural production and local economies. Food insecurity may be exacerbated directly via crop damage or via scarcity-related food price increases [57]. The collapse of smaller local producers unable to survive prolonged droughts can lead to population decline in smaller regional centres, and the mental health impacts for residents of these towns should also be considered.

On average, a larger proportion of Aboriginal people than non-Aboriginal people resided in areas that experienced additional drought events in the past decade. Rivers are not just a source of water but also a source of food, recreation and connection and often hold the stories of the land integral to the maintenance and protection of Aboriginal cultures and practices. Reduced water flows during extended droughts will see more frequent drying

up of river systems and increased algal blooms, affecting water supplies, diminishing fish and crayfish food sources and impacting swimming holes and other recreational activities.

Periods of extended drought can also affect the size and distribution of many native plants and animals that provide a traditional food source to many Aboriginal people and may represent cultural totems. Prolonged periods of drought are likely to reduce the availability of bush fruits, numbers of kangaroos and other animals, or the laying of emu eggs, for example, impacting food security. Collecting bush tucker not only supplements diet and provides an affordable food source, but it also reaffirms connection to Country.

With reduced water flows predicted during increasing drought conditions, water will become a scarcer commodity for rural communities dependent upon it for drinking, irrigation, agriculture and tourism. There may be engineering solutions that can assist with securing drinking water supplies in larger towns and communities in these regions, but few water utilities in regional and remote NSW have the financial capacity to upgrade systems without subsidy. Blending bore water with river water in periods of reduced river flow is common, but whilst this water meets potable guidelines, it may be far less palatable for drinking and bathing with higher levels of salts and other chemicals and a high alkaline texture. Reduced river water flows will also impact the ability to meet closing the gap targets for employment in regional areas where employment relies on agriculture and tourism.

In Australia, the Murray–Darling Basin catchment and tributaries cover 75% of NSW and are home to approximately 40 Aboriginal Nations or 15% of the total Aboriginal and Torres Strait Islander population [58]. To all Aboriginal groups, it is vitally important that the basin functions as a healthy, living river with natural flows and cycles. However, the basin also provides drinking water for over 3 million people and supports 45% of Australia's agricultural output, resulting in water over-extraction and reversal of cultural flows [58]. For improved sustainability, Aboriginal cultural and spiritual values should be considered in the allocation of water alongside market value [59,60]. There is a need to engage now with Aboriginal communities all along the river systems in developing river water management solutions that consider the predicted impacts of climate change.

4.3. Fire Danger

A higher proportion of Aboriginal people reside in areas exposed to higher fire danger days than non-Aboriginal people. During the summer bushfires of 2019/2020, 7% or 5 million hectares of land on the eastern seaboard were burnt [61]. Of the total Aboriginal population living in NSW and Victoria, greater than 25% lived in fire-affected areas, of which 36% were Aboriginal children [62]. Smoke inhalation, as an indirect health impact of bushfires, is particularly harmful to children's respiratory health [63]. Bushfires also contribute to trauma-related anxiety and loss of homes, traditional resources and cultural sites. The Aboriginal experience of a bushfire disaster is distinctively intimate and akin to the burning up of memories, sacred places and "someone far older and wiser" [64]. Increased bushfires in water supply catchments will also impact drinking water quality management.

Climate change will likely increase the frequency and intensity of bushfires, and more Aboriginal people will be disproportionately affected. Given that Aboriginal people hold valuable knowledge on restorative traditional fire practices and significant legal rights and cultural heritage in lands and waters in fire-prone areas, it is important to recognise their place in the planning and implementation of bushfire disaster response strategies and policies, as well as cultural heritage protection and Indigenous fire management [64].

4.4. Culturally Centred Approach toward Climate Adaptation

Figure 4 summarises factors that contribute to the experience of climate vulnerability for Aboriginal people in the context of exposure, sensitivity and adaptive capacities. Living in areas prone to extreme heat, fire weather, floods and droughts under climate change will impact the health and well-being of Aboriginal populations directly and indirectly. These health impacts are exacerbated by existing ill-health amongst Aboriginal communities and

compounded by factors such as poor housing and food insecurity. Capacities to reduce climate exposures and sensitivities will depend on effective technologies, adequate financial resources and supportive institutions and governance [65]. Informed by NSW Aboriginal agency stakeholders working in the Aboriginal community and health sectors, it became evident that undermining Aboriginal cultures impacts adversely Aboriginal health and well-being, which will, in turn, increase climate vulnerability. Cultural determinants add an additional layer to the framework in its application to NSW Aboriginal communities. This is consistent with previous findings described in the literature that have identified the impact of climate change on Indigenous cultures in Australia and internationally [66] and our sensitivity analysis, which suggested a higher exposure to climate-related hazards for Aboriginal populations in NSW over and above socioeconomic disadvantage compared to the broader, non-Aboriginal population.

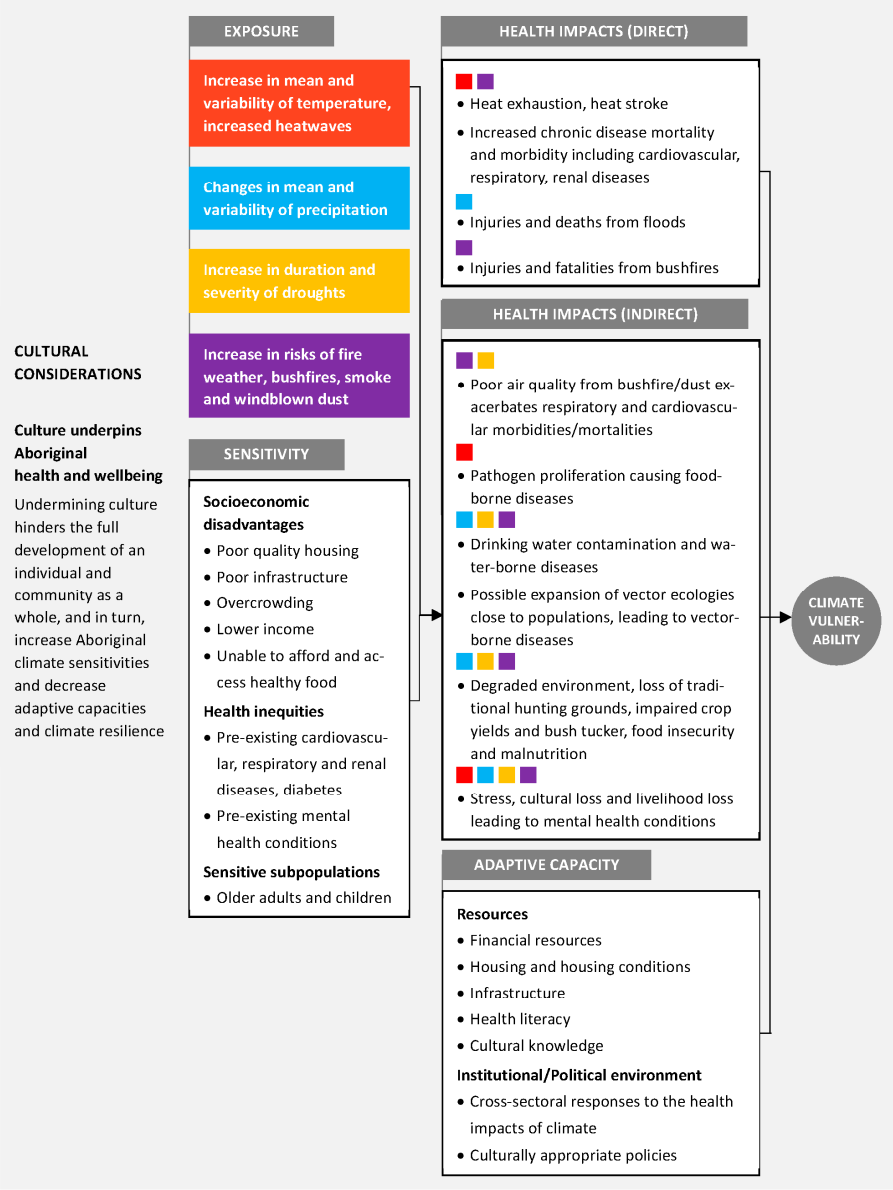

Figure 4. Summary of the components of climate vulnerability, where exposure to climate-related hazards and sensitivity factors contribute to the susceptibility of Aboriginal people to a range of direct and indirect health outcomes. Capacity to manage the influence of exposure and sensitivities to climate-related hazards can reduce the net vulnerability to climate change. (Adapted from [67]). Underpinning the components of climate vulnerability are the complex and important cultural determinants [68] of Aboriginal health and well-being.

4.5. Policy Implications

The recognition that culture is an underlying determinant of good health is in line with the national "Closing the Gap" strategy, which advocates for an Aboriginal- and Torres Strait Islander-driven approach to health policy and program reform [68]. This strength-based approach is key to building resilience to the impacts of climate on Aboriginal health, and action is needed now to develop effective Aboriginal-led adaptation responses to the current and future impacts of climate on health.

The increased exposures identified in this analysis, along with climate sensitivities already experienced by Aboriginal populations in NSW, such as socioeconomic and health inequalities, indicate that the potential health impacts of climate change are even more significant for those populations than it is for the non-Aboriginal populations in NSW. This combination of inequities in exposure, sensitivity and adaptive capacity to climate-related hazards in Aboriginal populations can be described as both climate and racial injustice [69,70], particularly as susceptibility to these is linked to structural inequalities in society. These injustices identified within Australia are analogous to those seen between countries whereby climate risks are inequitably borne by post-colonial lower-income countries and other First Nations communities [66,71,72]. The Australian government has set 17 "Closing the Gap" targets aimed at improving socioeconomic outcomes for Aboriginal and Torres Strait Islander people, including health and well-being, education, employment, justice, safety, housing, land and waters, languages and digital inclusion outcomes [73]. Climate change is likely to widen the inequities that currently exist in relation to many of these factors.

Undermining Aboriginal cultures in responding to climate change not only increases sensitivity but decreases adaptive capacity. As climate change progresses, the capacity to adapt to these greater potential health impacts is further compounded by several non-climatic stressors already experienced by Aboriginal populations related to socioeconomics (such as financial inequity, health literacy and the condition of housing and infrastructure), and factors in the institutional and political environments (such as government policy related to allopathic approaches to health service delivery, management of social housing and infrastructure, or water allocations). In addition, these stressors exist within historical experiences of disempowerment of Aboriginal people in Australia, such as colonisation and land dispossession, experiences that have been shared by other First Nations people globally [66,71,72]. Conversely, policies that seek to address the underlying determinants of health, such as reducing financial inequity, improving health literacy and housing and further empowering Aboriginal communities, may improve adaptive capacity to climate-related health risks.

Connection to Country was identified by Aboriginal agency stakeholders as a key component of Aboriginal identity, with many NSW Aboriginal people living where they do because of cultural and ancestral connections to the land and waters of those places going back for tens of thousands of years. Whilst changes to the climate will impact many of those places with more extreme, harsher living conditions predicted and increased fire danger, simply moving "off Country" would have additional cultural, health and well-being implications [74].

What is lesser understood is the role traditional Aboriginal knowledges play in climate adaptation. Aboriginal people have inhabited the Australian continent for tens of thousands of years, and learnings from traditional knowledges could benefit the wider population [72]. Traditional, cooler burning practices, for example, are being incorporated into fire management in some areas, and researchers are working with traditional owners to understand these practices and their benefits for managing fires now and into the future [75–77].

The NSW government recognises the potential impact climate change may have on government assets and service delivery and their ability to meet policy objectives and is in the process of developing a NSW climate change adaptation strategy [78]. It has identified benefits for the state from the economic and employment opportunities adaptation offers

and claims the strategy will "give NSW families and communities confidence the challenges posed by climate change can be solved by improving–not eroding their prosperity". How this strategy will engage the Aboriginal people of NSW has not yet been defined, but history would indicate there is a very tangible risk that Aboriginal communities may be left out of these discussions, with unintended consequences exacerbating health inequities. Now is the time to be engaging with Aboriginal communities to ensure Aboriginal knowledges are incorporated and climate change adaptation offers opportunities for all.

The US Public Health Institute's statement on climate change describes the concept of "Health, Equity and Climate in All Policies" and calls on federal agencies to consider the impact of their decisions on climate, health and equity [79]. NSW Health requires an Aboriginal Health Impact Statement to be applied to all health policies, programs and strategies to ensure the health and well-being of Aboriginal people have been adequately considered [80]. Given many environmental factors that impact health sit within the responsibility of other agencies such as housing or infrastructure, a similar systematic approach should be applied more broadly to all agencies at all levels of government to ensure appropriate Aboriginal community engagement and consideration of climate, health and equity impacts for all government policies, planning and developments.

The timely implementation of strategies is critical. Aboriginal people in NSW were identified early in the COVID-19 pandemic response as a sensitive population to the disease given existing health co-morbidities, housing conditions and socioeconomic factors. However, until there was an outbreak in the Aboriginal community, limited resources were directed towards this population, compromising an effective response. The same approach cannot afford to be taken to address climate change.

4.6. Strengths and Limitations

All population data used in this study was from 2016 populations, both the URPs at the SA1 level and overall populations from the Australian population grid. This means that projection estimates assume that the proportions of Aboriginal vs. non-Aboriginal people at the SA1 level will remain static. While changes in these populations are to be expected [81], especially into the future, overall proportions are unlikely to change substantially. Indeed, analysis of 2006, 2011 and 2016 censuses revealed only small changes in the proportions of Aboriginal vs. non-Aboriginal populations at the SA1 level, with very little internal migration observed across rural and regional areas. As such, these estimates should be indicative of the population proportions in the near future.

The preliminary consultations in this paper were far from exhaustive, and for a population that stands to be disproportionately impacted by climate change, further work needs to be done to engage the Aboriginal community in developing and implementing appropriate adaptation strategies.

While mitigation is recognised as an essential component of effective adaptation, this paper focuses on climate change adaptation. Further development of this work should include a combined focus on mutually reinforcing mitigation and adaptation actions to reduce the burden of Aboriginal ill health, boost community resilience and lessen poverty and inequity.

5. Conclusions

This analysis demonstrates that the Aboriginal population of NSW are currently disproportionally exposed to extreme climate events, and this disproportionate exposure will increase in the future with predicted changes in climate. Pre-existing health sensitivities (such as chronic diseases and psychosocial distress) and factors limiting adaptive capacity (such as socioeconomic disadvantage and political environments) already put Aboriginal populations in NSW at greater risk of the impacts of climate change, and this will continue unless significant challenges are addressed.

Based on guidance, stories and experiences from the Aboriginal stakeholders and authors involved in the project, the following recommendations are proposed to assist local

communities and all levels of government in guiding the development and implementation of adaptation policies and strategies underpinned by Aboriginal cultural considerations.

1. Opportunities for communities

Effective engagement with Aboriginal communities, supported by active investment, is urgently needed to identify and maximise the opportunities climate adaptation may offer to improve health and socioeconomic equity for communities.

2. Adaptation Strategies

Climate change needs to be a key consideration in all future planning by policymakers and program implementers across all tiers of government. A "Climate Change, Health and Equity Impact Statement" should accompany any future policies, strategies or planning developments at all levels of government, identifying impacts (both positive and negative) on climate change, health and equity, including mitigation and adaptation strategies, particularly on populations vulnerable to climate change. This should be a consideration of all policies, standards and guidelines, from the design of housing through to the strategic energy needs of the nation.

3. Implementation and management

Climate adaptation strategies are needed now that ensure responses to health and social service preparedness, including housing, water supplies, infrastructure and food security are effectively implemented and managed. Quality control and maintenance systems for these services, particularly social housing, must be adequately supported and resourced to be implemented effectively.

4. Communication and cultural adaptation strategies

The true impact of climate on NSW Aboriginal populations and cultural practices is not clearly understood. A better understanding of current health impacts and adaptation responses among Aboriginal populations and communities in NSW is required to develop culturally appropriate adaptation strategies and resilient communities in the face of climate change. Further quantitative and qualitative participatory-based research to identify cultural impacts of climate change on health and explore adaptive responses, including those based on Aboriginal knowledges, should be supported.

Author Contributions: J.C.S.: conceived and led the design of the study with collaborators; collaborated on the development of the methods; the implementation of the statistical analyses and interpretation of results, led the write up of the paper. J.S.: assisted with the study design, interpretation of results and contributed to the write-up of the paper. J.S. is from the Wiradjuri community and is an Environmental Health Project Officer in Central West New South Wales. V.M. is from the Quandamooka community in Southeast Queensland and leads the Centre for Research Excellence in Strengthening Systems for Indigenous Health Care Equity. All other authors are non-Indigenous. G.W.L.: contributed to the review of literature, the interpretation of results and the write-up of the paper. V.M., S.B. and M.B.-P.: assisted with development of the project and commented on drafts of the paper. J.V.B., I.H. and E.J.: collaborated on the development of the methods; led the identification of the environmental data metrics and the statistical analysis; collaborated on the interpretation of results; and commented on drafts of the paper. G.G.M. contributed to the design of the study and commented on interpretation of results and drafts of the paper. All authors have read and agreed to the published version of the manuscript.

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Appendix A

Table A1 presents a summary of descriptive statistics for selected climate exposure estimates on a continuous scale. Table A2 and Figure A1 present the results of the sensitivity analysis. In these analyses, odds ratios of high-risk environmental exposure are recalculated and stratified by the Australian Bureau of Statistics Index of Relative Socioeconomic Disadvantage (IRSD) quintiles. An IRSD of 1 represents the level of greatest disadvantage, and 5 the lowest level of disadvantage.

Table A1. Descriptive statistics for selected climate exposure estimates on a continuous scale.

Exposure	Mean	Standard Deviation%	Minimum	Median	25th Percentile	75th Percentile	Maximum
Historical annual maximum heatwave duration (days)	4.50	1.02	0.00	4.08	4.25	4.56	8.02
Historical annual days over 35 °C (days)	8.51	8.19	0.00	4.92	6.80	9.35	84.17
Projected additional days over 35 °C (days)	3.35	2.22	0.00	1.93	2.87	4.05	15.22
Historical average annual rainfall (mm)	968.43	255.24	0.00	834.57	993.16	1132.05	1779.36
Projected change in annual rainfall (%)	1.36	1.18	−4.10	1.19	1.66	2.01	3.97
Historical annual days with FFDI $\geq$ 50 (days)	0.94	1.15	0.00	0.42	0.72	1.13	16.05
Projected additional annual days with FFDI $\geq$ 50 (days)	0.09	0.17	−0.05	0.01	0.04	0.08	1.71

Table A2. Climate exposure estimates by Aboriginal versus non-Aboriginal usual resident populations stratified by the Index of Relative Socioeconomic Disadvantage (IRSD). Small cell counts for either population have been aggregated.

Climate Exposure	IRSD Quintile	Exposure Category	Aboriginal URP		Non-Aboriginal URP		Binary Risk Category	High-Risk Exposure Population (%)		Odds Ratio
			n	%	n	%		Aboriginal	Non-Aboriginal	
Historical annual average maximum heatwave duration (day)	1	0–4	3658	4.0%	67,183	4.5%	Lower	35.3%	14.4%	3.24 [3.19–3.28]
		5	36,193	39.3%	1,006,257	67.0%	Lower			
		6	19,776	21.4%	210,839	14.0%	Lower			
		7	22,740	24.7%	180,293	12.0%	Higher			
		>7	9831	10.7%	36,434	2.4%	Higher			
	2	0–4	2990	6.3%	90,031	6.4%	Lower	23.2%	11.0%	2.45 [2.40–2.50]
		5	24,199	51.3%	978,283	69.5%	Lower			
		6	9025	19.1%	184,468	13.1%	Lower			
		7	7033	14.9%	125,239	8.9%	Higher			
		>7	3881	8.2%	28,956	2.1%	Higher			
	3	0–4	2150	7.2%	93,278	7.5%	Lower	20.0%	9.0%	2.54 [2.46–2.61]
		5	17,155	57.1%	908,316	72.6%	Lower			
		6	4731	15.7%	136,558	10.9%	Lower			
		7	4054	13.5%	89,254	7.1%	Higher			
		>7	1965	6.5%	23,086	1.8%	Higher			
	4	0–4	1801	8.7%	133,554	10.9%	Lower	15.6%	7.1%	2.40 [2.31–2.49]
		5	13,301	64.3%	916,272	74.5%	Lower			
		6	2364	11.4%	91,407	7.4%	Lower			
		7	2066	10.0%	67,511	5.5%	Higher			
		>7	1161	5.6%	20,335	1.7%	Higher			
	5	0–4	1957	14.9%	320,458	18.6%	Lower	9.3%	2.6%	3.82 [3.60–4.06]
		5	8736	66.5%	1283,494	74.7%	Lower			
		6	1232	9.4%	69,650	4.1%	Lower			
		7	548	4.2%	32,345	1.9%	Higher			
		>7	670	5.1%	12,362	0.7%	Higher			

Table A2. *Cont.*

Climate Exposure	IRSD Quintile	Exposure Category	Aboriginal URP		Non-Aboriginal URP		Binary Risk Category	High-Risk Exposure Population (%)		Odds Ratio
			n	%	n	%		Aboriginal	Non-Aboriginal	
Historical annual days above 35 °C	1	<5	25,453	27.4%	349,476	23.1%	Lower	26.8%	8.8%	3.79 [3.73–3.85]
		5–9.9	22,351	24.1%	792,040	52.4%	Lower			
		10–19.9	20,087	21.6%	235,915	15.6%	Lower			
		20–49.9	20,533	22.1%	125,376	8.3%	Higher			
		≥50	4367	4.7%	7809	0.5%	Higher			
	2	<5	16,297	34.2%	402,935	28.3%	Lower	16.4%	6.6%	2.79 [2.72–2.86]
		5–9.9	14,152	29.7%	705,818	49.6%	Lower			
		10–19.9	9375	19.7%	221,492	15.6%	Lower			
		20–49.9	6625	13.9%	87,296	6.1%	Higher			
		≥50	1187	2.5%	6169	0.4%	Higher			
	3	<5	9335	30.6%	307,539	24.3%	Lower	14.5%	5.9%	2.69 [2.60–2.78]
		5–9.9	10,624	34.9%	712,058	56.2%	Lower			
		10–19.9	6093	20.0%	172,158	13.6%	Lower			
		20–49.9	4094	13.4%	72,327	5.7%	Higher			
		≥50	319	1.0%	2808	0.2%	Higher			
	4	<5	5657	26.9%	293,237	23.5%	Lower	9.8%	4.2%	2.50 [2.39–2.62]
		5–9.9	8789	41.8%	740,170	59.4%	Lower			
		10–19.9	4531	21.5%	160,069	12.9%	Lower			
		20–49.9	1897	9.0%	48,930	3.9%	Higher			
		≥50	158	0.8%	2766	0.2%	Higher			
	5	<5	3316	25.0%	405,768	23.5%	Lower	6.4%	1.5%	4.57 [4.26–4.91]
		5–9.9	7351	55.4%	1,154,813	66.9%	Lower			
		10–19.9	1748	13.2%	139,522	8.1%	Lower			
		20–49.9	832	6.3%	25,023	1.5%	Higher			
		≥50	10	0.1%	191	0.0%	Higher			

Table A2. *Cont.*

Climate Exposure	IRSD Quintile	Exposure Category	Aboriginal URP		Non-Aboriginal URP		Binary Risk Category	High-Risk Exposure Population (%)		Odds Ratio
			n	%	n	%		Aboriginal	Non-Aboriginal	
Projected additional days above 35 °C	1	<2	24,079	25.7%	365,971	24.0%	Lower	39.1%	16.5%	3.26 [3.21–3.30]
		2–4.9	32,962	35.2%	907,961	59.5%	Lower			
		5–9.9	22,451	24.0%	211,402	13.9%	Higher			
		≥10	14,164	15.1%	39,770	2.6%	Higher			
	2	<2	16,131	33.4%	417,526	29.0%	Lower	27.8%	13.4%	2.48 [2.43–2.53]
		2–4.9	18,751	38.8%	827,918	57.6%	Lower			
		5–9.9	9344	19.3%	168,441	11.7%	Higher			
		≥10	4074	8.4%	24,698	1.7%	Higher			
	3	<2	8952	28.9%	325,981	25.5%	Lower	28.2%	13.7%	2.47 [2.41–2.54]
		2–4.9	13,308	42.9%	779,115	60.9%	Lower			
		5–9.9	6922	22.3%	156,139	12.2%	Higher			
		≥10	1809	5.8%	19,137	1.5%	Higher			
	4	<2	4763	24%	260,312	23%	Lower	25.6%	12.5%	2.42 [2.35–2.50]
		2–4.9	9484	48%	727,159	64%	Lower			
		5–9.9	4516	23%	141,911	12%	Higher			
		≥10	891	5%	13,413	1%	Higher			
	5	<2	3473	26.2%	403,194	23.4%	Lower	15.4%	5.0%	3.46 [3.29–3.62]
		2–4.9	7749	58.4%	1,231,131	71.6%	Lower			
		5–9.9	1685	12.7%	80,360	4.7%	Higher			
		≥10	360	2.7%	5839	0.3%	Higher			

Table A2. *Cont.*

Climate Exposure	IRSD Quintile	Exposure Category	Aboriginal URP		Non-Aboriginal URP		Binary Risk Category	High-Risk Exposure Population (%)		Odds Ratio
			n	%	n	%		Aboriginal	Non-Aboriginal	
Historical annual rainfall variability	1	Low	8486	9.1%	177,202	11.7%	Lower	18.9%	6.1%	3.55 [3.49–3.62]
		Low to moderate	66,796	72.0%	1,240,577	82.1%	Lower			
		Moderate	14,004	15.1%	77,837	5.2%	Higher			
		Moderate to high	2045	2.2%	2508	0.2%	Higher			
		High	1460	1.6%	12,492	0.8%	Higher			
	2	Low	5181	10.9%	289,093	20.3%	Lower	11.0%	3.9%	3.05 [2.96–3.14]
		Low to moderate	37,225	78.1%	1,079,304	75.8%	Lower			
		Moderate	4468	9.4%	49,810	3.5%	Higher			
		Moderate to high	646	1.4%	3447	0.2%	Higher			
		High	116	0.2%	2056	0.1%	Higher			
	3	Low	4082	13.4%	337,452	26.6%	Lower	10.2%	3.6%	3.08 [2.97–3.21]
		Low to moderate	23,270	76.4%	884,359	69.8%	Lower			
		Moderate	2903	9.5%	42,098	3.3%	Higher			
		Moderate to high	120	0.4%	1189	0.1%	Higher			
		High	90	0.3%	1792	0.1%	Higher			
	4	Low	3404	16.2%	362,383	29.1%	Lower	5.4%	2.2%	2.60 [2.45–2.76]
		Low to moderate	16,482	78.4%	855,795	68.7%	Lower			
		Moderate	1085	5.2%	25,904	2.1%	Higher			
		Moderate to high	53	0.3%	727	0.1%	Higher			
		High	8	0.0%	363	0.0%	Higher			
	5	Low	3938	29.7%	743,085	43.1%	Lower	3.3%	0.5%	6.70 [6.08–7.39]
		Low to moderate	8882	67.0%	973,498	56.4%	Lower			
		Moderate	437	3.3%	8673	0.5%	Higher			
		Moderate to high	0	0.0%	0	0.0%	Higher			
		High	0	0.0%	61	0.0%	Higher			

Table A2. *Cont.*

Climate Exposure	IRSD Quintile	Exposure Category	Aboriginal URP		Non-Aboriginal URP		Binary Risk Category	High-Risk Exposure Population (%)		Odds Ratio
			n	%	n	%		Aboriginal	Non-Aboriginal	
Historical annual average rainfall (mm)	1	≤400	5377	5.8%	33,291	2.2%	Higher	42.0%	18.3%	3.24 [3.20–3.29]
		400–799	33,630	36.2%	242,707	16.1%	Higher			
		800–1199	44,544	48.0%	1,094,131	72.4%	Lower			
		≥1200	9240	10.0%	140,487	9.3%	Lower			
	2	≤400	1460	3.1%	22,859	1.6%	Higher	33.4%	18.1%	2.26 [2.22–2.30]
		400–799	14,431	30.3%	235,298	16.5%	Higher			
		800–1199	25,028	52.5%	998,470	70.1%	Lower			
		≥1200	6717	14.1%	167,083	11.7%	Lower			
	3	≤400	594	1.9%	15,759	1.2%	Higher	29.4%	16.0%	2.18 [2.13–2.24]
		400–799	8365	27.5%	187,141	14.8%	Higher			
		800–1199	17,321	56.9%	924,890	73.0%	Lower			
		≥1200	4185	13.7%	139,100	11.0%	Lower			
	4	≤400	286	1.4%	17,820	1.4%	Higher	29.0%	16.7%	2.03 [1.97–2.09]
		400–799	5815	27.6%	190,745	15.3%	Higher			
		800–1199	12,465	59.3%	902,392	72.5%	Lower			
		≥1200	2466	11.7%	134,215	10.8%	Lower			
	5	≤400	213	1.6%	40,008	2.3%	Higher	24.5%	14.1%	1.98 [1.90–2.06]
		400–799	3033	22.9%	202,899	11.8%	Higher			
		800–1199	8483	64.0%	1,301,490	75.4%	Lower			
		≥1200	1528	11.5%	180,920	10.5%	Lower			

Table A2. *Cont.*

Climate Exposure	IRSD Quintile	Exposure Category	Aboriginal URP		Non-Aboriginal URP		Binary Risk Category	High-Risk Exposure Population (%)		Odds Ratio
			n	%	n	%		Aboriginal	Non-Aboriginal	
Projected change in annual rainfall (%)	1	<−1%	11,296	12.1%	108,364	7.1%	Higher	25.4%	15.5%	1.86 [1.83–1.89]
		−1–0%	12,524	13.4%	128,238	8.4%	Higher			
		0–0.9%	8824	9.4%	102,000	6.7%	Lower			
		1–1.9%	25,290	27.0%	825,439	54.1%	Lower			
		≥2%	35,722	38.1%	361,063	23.7%	Lower			
	2	<−1%	5593	11.6%	103,775	7.2%	Higher	24.3%	15.9%	1.69 [1.65–1.73]
		−1–0%	6122	12.7%	125,318	8.7%	Higher			
		0–0.9%	3458	7.2%	103,196	7.2%	Lower			
		1–1.9%	17,570	36.4%	761,097	52.9%	Lower			
		≥2%	15,557	32.2%	345,197	24.0%	Lower			
	3	<−1%	3217	10.4%	74,245	5.8%	Higher	20.8%	13.0%	1.77 [1.72–1.82]
		−1–0%	3238	10.4%	91,787	7.2%	Higher			
		0–0.9%	2541	8.2%	97,250	7.6%	Lower			
		1–1.9%	12,187	39.3%	699,735	54.7%	Lower			
		≥2%	9808	31.6%	317,355	24.8%	Lower			
	4	<−1%	1866	8.8%	64,896	5.2%	Higher	18.6%	11.7%	1.71 [1.65–1.78]
		−1–0%	2046	9.7%	81,399	6.5%	Higher			
		0–0.9%	1612	7.6%	89,818	7.2%	Lower			
		1–1.9%	9234	43.8%	651,410	52.2%	Lower			
		≥2%	6327	30.0%	359,622	28.8%	Lower			
	5	<−1%	1211	9.1%	59,157	3.4%	Higher	16.4%	6.8%	2.70 [2.57–2.82
		−1–0%	962	7.3%	57,422	3.3%	Higher			
		0–0.9%	949	7.2%	98,508	5.7%	Lower			
		1–1.9%	6715	50.6%	908,782	52.8%	Lower			
		≥2%	3424	25.8%	596,231	34.7%	Lower			

Table A2. *Cont.*

Climate Exposure	IRSD Quintile	Exposure Category	Aboriginal URP		Non-Aboriginal URP		Binary Risk Category	High-Risk Exposure Population (%)		Odds Ratio
			n	%	n	%		Aboriginal	Non-Aboriginal	
Historical annual days with a Forest Fire Danger Index (FFDI) ≥ 50	1	0–0.9	42,363	45.8%	815,518	54.2%	Lower	26.9%	8.9%	3.76 [3.70–3.82]
		1–1.9	25,227	27.3%	555,757	36.9%	Lower			
		2–4.9	17,140	18.5%	100,019	6.6%	Higher			
		≥5	7769	8.4%	34,516	2.3%	Higher			
	2	0–0.9	27,506	58.0%	924,217	65.2%	Lower	18.3%	7.4%	2.81 [2.75–2.88]
		1–1.9	11,242	23.7%	388,921	27.4%	Lower			
		2–4.9	7040	14.8%	87,514	6.2%	Higher			
		≥5	1652	3.5%	17,233	1.2%	Higher			
	3	0–0.9	17,027	56.1%	826,286	65.7%	Lower	15.4%	6.2%	2.76 [2.67–2.85]
		1–1.9	8645	28.5%	352,969	28.1%	Lower			
		2–4.9	3898	12.9%	62,477	5.0%	Higher			
		≥5	763	2.5%	15,048	1.2%	Higher			
	4	0–0.9	11,881	56.6%	866,053	70.0%	Lower	11.7%	4.7%	2.71 [2.60–2.83]
		1–1.9	6629	31.6%	313,273	25.3%	Lower			
		2–4.9	2184	10.4%	50,300	4.1%	Higher			
		≥5	279	1.3%	7613	0.6%	Higher			
	5	0–0.9	8726	66.5%	1,324,281	78.0%	Lower	7.4%	1.7%	4.71 [4.40–5.03]
		1–1.9	3417	26.1%	345,003	20.3%	Lower			
		2–4.9	968	7.4%	27,970	1.6%	Higher			
		≥5	3	0.0%	399	0.0%	Higher			

Table A2. *Cont.*

Climate Exposure	IRSD Quintile	Exposure Category	Aboriginal URP		Non-Aboriginal URP		Binary Risk Category	High-Risk Exposure Population (%)		Odds Ratio
			n	%	n	%		Aboriginal	Non-Aboriginal	
Projected additional annual days with FFDI ≥ 50	1	0–0.24	65,220	70.7%	1,347,359	89.7%	Lower	17.4%	5.2%	3.80 [3.73–3.87]
		0.25–0.49	11,024	11.9%	76,160	5.1%	Lower			
		0.5–0.9	12,321	13.3%	61,945	4.1%	Higher			
		≥1	3731	4.0%	16,917	1.1%	Higher			
	2	0–0.24	37,683	79.8%	1,286,023	91.4%	Lower	10.4%	3.8%	2.99 [2.90–3.08]
		0.25–0.49	4589	9.7%	68,509	4.9%	Lower			
		0.5–0.9	4403	9.3%	48,374	3.4%	Higher			
		≥1	523	1.1%	4409	0.3%	Higher			
	3	0–0.24	25,169	83.2%	1,167,109	93.1%	Lower	7.7%	3.3%	2.46 [2.35–2.57]
		0.25–0.49	2748	9.1%	45,934	3.7%	Lower			
		0.5–0.9	2139	7.1%	38,021	3.0%	Higher			
		≥1	193	0.6%	3204	0.3%	Higher			
	4	0–0.24	18,091	87.1%	1,159,839	94.6%	Lower	5.5%	2.4%	2.36 [2.22–2.51]
		0.25–0.49	1538	7.4%	37,218	3.0%	Lower			
		0.5–0.9	1112	5.4%	28,621	2.3%	Higher			
		≥1	29	0.1%	823	0.1%	Higher			
	5	0–0.24	12,145	92.8%	1,669,391	98.3%	Lower	4.6%	1.2%	3.99 [3.67–4.34]
		0.25–0.49	346	2.6%	8289	0.5%	Lower			
		0.5–0.9	597	4.6%	20,020	1.2%	Higher			
		≥1	0	0.0%	61	0.0%	Higher			

Table A2. *Cont.*

Climate Exposure	IRSD Quintile	Exposure Category	Aboriginal URP		Non-Aboriginal URP		Binary Risk Category	High-Risk Exposure Population (%)		Odds Ratio
			n	%	n	%		Aboriginal	Non-Aboriginal	
Relative change in drought-affected months (1990–2006 vs. 2007–2020)	1	≤−10%	13,856	15.3%	344,184	23.3%	Lower			2.12 [2.09–2.15]
		−9.9–−5%	25,938	28.6%	609,131	41.2%	Lower			
		−4.9–−2.5%	9507	10.5%	135,713	9.2%	Lower			
		−2.4–0%	8878	9.8%	80,167	5.4%	Lower			
		0.01%–5%	17,490	19.3%	178,228	12.1%	Higher	35.9%	20.9%	
		>5%	15,134	16.7%	130,805	8.8%	Higher			
	2	≤10%	8460	18.5%	418,629	30.7%	Lower			1.76 [1.72–1.79]
		−9.9–−5%	13,802	30.2%	452,136	33.1%	Lower			
		−4.9%–−2.5%	4331	9.5%	109,654	8.0%	Lower			
		−2.4–0%	3622	7.9%	77,300	5.7%	Lower			
		0.01–5%	10,035	22.0%	202,484	14.8%	Higher	33.9%	22.5%	
		>5%	5427	11.9%	105,395	7.7%	Higher			
	3	≤−10%	6724	23.1%	459,306	38.2%	Lower			1.70 [1.66–1.75]
		−9.9–−5%	8323	28.6%	365,938	30.4%	Lower			
		−4.9–−2.5%	3383	11.6%	87,006	7.2%	Lower			
		−2.4–0%	2549	8.8%	68,078	5.7%	Lower			
		0.01–5%	5718	19.7%	153,570	12.8%	Higher	27.9%	18.5%	
		>5%	2401	8.3%	69,538	5.8%	Higher			
	4	≤−10%	6010	29.9%	526,829	45.0%	Lower			1.89 [1.83–1.96]
		−9.9–−5%	5613	27.9%	335,048	28.6%	Lower			
		−4.9–−2.5%	1503	7.5%	61,476	5.3%	Lower			
		−2.4–0%	1847	9.2%	66,667	5.7%	Lower			
		0.01–5%	3834	19.0%	134,397	11.5%	Higher	25.6%	15.4%	
		>5%	1324	6.6%	45,693	3.9%	Higher			
	5	≤−10%	4192	34.4%	645,501	43.2%	Lower			2.65 [2.53–2.79]
		−9.9–−5%	4677	38.4%	669,733	44.8%	Lower			
		−4.9–−2.5%	697	5.7%	39,584	2.6%	Lower			
		−2.4–0%	693	5.7%	40,711	2.7%	Lower			
		0.01–5%	1528	12.5%	81,108	5.4%	Higher	15.9%	6.6%	
		>5%	405	3.3%	17,986	1.2%	Higher			

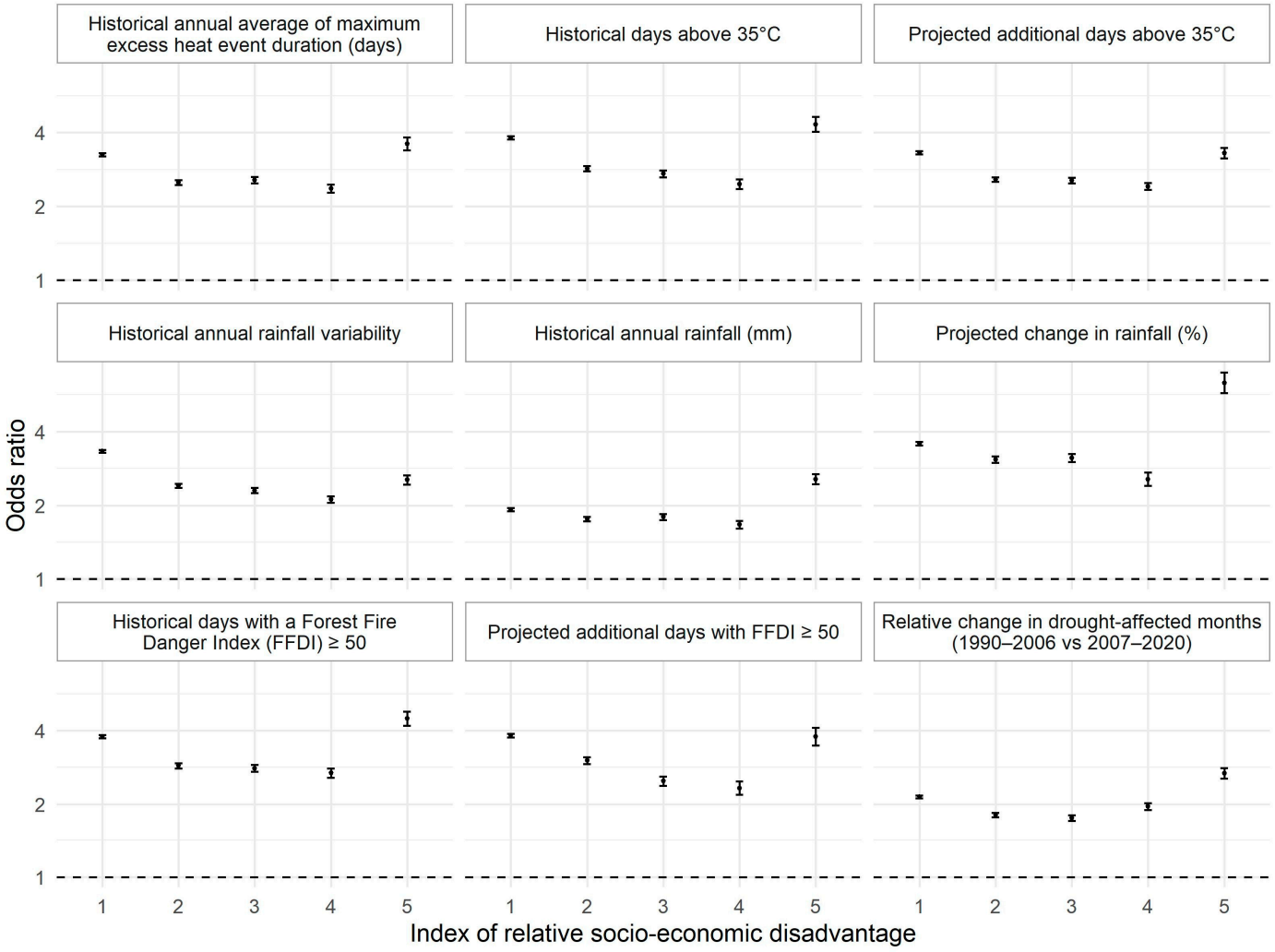

Figure A1. Climate exposure estimates by Aboriginal versus non-Aboriginal usual resident populations stratified by the Index of Relative Socioeconomic Disadvantage (IRSD).

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Chapter 9
Discussion and Conclusion

1.0 Introduction

This chapter summarises the main findings of the thesis and discusses how they address the research questions. The discussion also outlines the strengths, limitations and implications of the thesis for policy and practice.

The aim of this thesis was to answer the following research questions:

1. Does Aboriginal community housing in NSW function to provide an environment that supports householders to practice safe and healthy living, and are any changes in housing functionality over time associated with the NSW Housing for Health program?
2. What is the financial cost of the NSW Housing for Health program to bring Aboriginal community housing up to a minimum standard of functionality that supports householders to practice safe and healthy living?
3. How could a comprehensive economic analysis be undertaken of the disparate health, social, economic and intangible benefits generated from the NSW Housing for Health program and the resources utilised to realise these benefits?
4. What future challenges does climate change present for Aboriginal community housing in NSW, and what are the implications for public policy?

This thesis makes novel and important contributions to the Aboriginal housing literature through the review and methodological analysis of a unique and comprehensive dataset of quantitative housing maintenance and expenditure data from NSW Health's Housing for Health (HfH) program over 20 years. The thesis described the background to the NSW HfH Program and reviewed the literature to provide context for the program as a strategy of the NSW government to address inequities in Aboriginal Health in NSW, targeting the living environment as a social determinant of health.

The contributions of this thesis not only support the evidence reported in the published literature and government reports but also provide new and unique insights into the condition of Aboriginal community housing in NSW over two decades. The thesis quantified the contributions of the HfH Program in improving the condition of housing to achieve a minimum standard of house functionality that supports safe and healthy living practices. It also describes for the first time. potentially influential social, demographic and geographic factors associated with the condition of housing in NSW, the effectiveness of the HfH Program in achieving its goals, and the fix-work costs associated with making improvements in healthy house functionality.

Building on this analysis, the thesis identified that there were no health economic analyses of a similar program to the NSW HfH Program in the literature and presented a model of cost-benefit analysis as the most appropriate design to weigh the benefits generated from the HfH Program against the resources utilised to realise these outcomes. Finally, this research quantifies for the first time the impact of climate change on related exposures for the Aboriginal populations of NSW and the future considerations for Aboriginal health and adaptation planning, including the role housing plays in supporting climate adaptation.

2.0 Summary of Findings

2.1 Prioritising Housing Maintenance to Improve Health in Indigenous Communities in NSW Over 20 Years

Chapter 4 provided an overview of the first 20 years of the NSW Health HfH Program and analysed Survey-Fix (SF) data on 3,593 houses from 112 HfH projects across NSW between 1998 and 2017, including 802 houses that received a repeat project between five and 17 years later. The Chapter described house performance before and after project implementation against the HfH Program's 11 most critical safety and Healthy Living Practice (HLP) Indicators using binary pass/fail categories, whereby 100% of indicator items must be met to pass that indicator. The 100% threshold is set as those items that constitute each indicator are considered the *minimum* requirements for a house to support safe and healthy living. The average condition of houses before project initiation was poor across all indicators, particularly in terms of electrical, fire, and structural safety; adequate shower and laundry facilities; all drainage working; and adequate food preparation, storage, and cooking facilities. However, the HfH Program was highly effective in achieving significant changes across all 11 critical HLP indicators after each project was completed.

Using a single house metric derived from the average percentage of indicators that passed, this analysis showed the condition of Aboriginal community housing in NSW before a HfH project (i.e. at Survey-Fix 1) to be consistently low across the 20-year study period, with only negligible improvement in the percentage of indicators that passed over that time. However, the HfH Program was increasingly effective across the 20 years, showing consistent, significant improvements in house functionality at the post-fix survey (Survey-Fix 2). Where repeat projects were implemented in the same community, the condition of houses before the second project remained higher than before the first project, indicating some sustained benefit from the initial project. This is the first time this or similar data has been presented over an extended period for Aboriginal housing. The analysis also identifies that the primary cause for the failure of items repaired by trades (95%) was systematic issues, primarily a lack of maintenance and faulty design, material, or workmanship.

2.2 Towards Minimum Standards for Healthy Housing in Aboriginal Communities in New South Wales, Australia – Are We There Yet?

Chapter 5 built upon the survey data analysis in Chapter 4. A more nuanced analysis of the survey data was conducted based on a single house functionality score, which classified houses into four categories to indicate how far the houses were from achieving the minimum standards prescribed by the Housing for Health methodology, where the minimum standard was defined as all items for all Critical Healthy Living Practice (CHLP) Indicators being operational. This was done for both the before and after survey data. This analysis

demonstrated that no houses met the minimum standard of house functionality set by the CHLP indicators prior to implementing a HfH project. Over the 20-year study period, there was only a modest improvement in Aboriginal community housing, with nearly 60% of houses still classified as either Low or Very Low Functionality at SF1 in the last five-year epoch of the 20-year study period.

Following the house fix component of the project, houses improved consistently over the 20 years with nearly all houses meeting the program standard (Functional) (48.5%) or Almost Functional (48.6%) in the last 5-year epoch. The presence of housing maintenance activity in a community or a previous HfH project was associated with improved house functionality before the project and led to greater improvements after the project. Outside of the major cities, remoteness classification was not substantially associated with the condition of houses either before or after project implementation. Where Occupancy ratios exceeded 2 people per bedroom, the condition of houses was lower before project initiation and the level of improvement achieved was also lower. Whilst the age of the house was strongly associated with functionality prior to a project (likely a reflection of a lack of adequate maintenance over time), the house age was not associated with the ability to make improvements.

Chapter 5 also demonstrated that whilst the data are primarily collected for program administration, and communities are not randomly selected, the very high participation rates and high proportion of Aboriginal community housing reached by the NSW HfH Program over 20 years mean the results of these analyses are likely generalisable across the broader NSW Aboriginal Housing sector.

2.3 Bang for Buck: Analysis of Costs Associated with Repairing Housing for Safe and Healthy Living in Aboriginal Communities in NSW, Australia

Chapter 6 presented the costs associated with CHLP-related repairs to each house in the HfH Program over the 20-year study period. As the program aims to bring houses to an equivalent standard of functionality, fix-work expenditure varied between houses. For some houses, these costs varied substantially if considerable repairs were required. The HfH Program has made substantial gains in Aboriginal community housing functionality for a median fix-work spend of $6,509 per house after adjusting to March 2022 dollars using the *maintenance and repair of the dwelling – Sydney* Consumer Price Index (CPI) series.

Median fix-work expenditure was significantly higher per house in Outer Regional areas compared to both Major Cities and Inner Regional areas. While Chapters 4 and 5 demonstrated consistent house functionality improvements across four five-year epochs, Chapter 6 showed an overall trend in expenditure per house that decreased from $7,945 in 1998–2002 to $4,835 in 2013-2017, suggesting improvements in program efficiency over time.

Chapter 6 also presented the trends in fix-work expenditure associated with changes in house functionality from one category to another before and after projects. Consistent with findings in Chapter 5 that higher baseline house functionality before work was associated with higher house functionality after, the cost required to repair items in a house was also influenced by initial house condition. Higher median expenditure was required on houses categorised as Very Low functionality ($9,509) than those in the Low Functionality ($6,440) or Almost Functional ($4,850) categories at Survey-Fix 1 (SF1).

2.4 The Economic Evaluation of a Housing Maintenance Project to Improve the Health of Aboriginal Housing Tenants in NSW: A Scoping Literature Review and Protocol for an Economic Analysis

Chapter 7 investigates how the fix-work costs in the previous chapter and other inputs that potentially impact socioeconomic determinants of health associated with the program, previously described (1) but not quantified, could be assessed as part of an economic review of HfH. A systematic review was undertaken of other programs addressing physical housing assets associated with health improvement to provide supporting evidence for the development of a protocol for an economic analysis of the program. The review found that despite the scale of health concerns associated with physical housing considerations and the level of public investment, very few programs in housing explicitly aimed to improve health. Further, no economic evaluations were found that assessed a program with the equivalent focus and breadth of repairs as HfH projects. This review supports the need for an economic analysis of the HfH Program, and the chapter presents a high-level protocol that provides the framework for an economic analysis comprising an ex-post cost-benefit analysis that allows for the various health, social, economic and intangible benefits of the HfH Program to be quantified and monetised.

2.5 Aboriginal Population and Climate Change in Australia: Implications for Health and Adaptation Planning

Chapter 8 explored the current and future impacts of climate on the Aboriginal populations of NSW and the implications for Aboriginal health, adaptation planning and public policy, including the NSW HfH Program. Analysis linking NSW demographic data and NSW and Australian Regional Climate Modelling (NARCliM) projections found Aboriginal populations in NSW are already disproportionately exposed to a range of climate extremes in heat, fire danger, rainfall and drought, and that this disproportionate exposure is predicted to increase with climate change over the next decades. This finding is novel in the research and policy literature and has implications for Aboriginal housing, including the HfH Program.

In addition to exposure, Aboriginal people presently experience higher rates of climate-sensitive health conditions such as cardiovascular, respiratory and renal diseases, compounding the impact of these exposures. Additionally, socioeconomic disadvantages - including poor housing, overcrowding and lower income - will impact their capacity to adapt to climate change. Cultural practices may also be adversely affected by climate change.

3.0 Implications for Policy and Practice

The NSW Housing for Health (HfH) Program grew out of a need to understand and improve the living environment for Aboriginal people in NSW. This thesis tells an important story of the effectiveness of the NSW HfH Program, and the NSW Aboriginal Community Housing Sector more broadly, over the 20-year study period. The thesis findings have lessons and implications for the NSW HfH Program, as well as for public policy in NSW, Australia, and internationally. These implications are discussed in this section.

The findings in this thesis support existing evidence on the effectiveness of the Housing for Health methodology as a process to improve the living conditions for residents whose houses received a HfH project (2-6), and presents new evidence demonstrating consistent improvement in program outcomes in NSW over 20 years. This thesis also describes for the first

time information on the baseline condition of Aboriginal community housing in NSW prior to any visit by the HfH Program between 1998 and 2017. With no houses meeting the standard of the HfH Program at Survey-Fix 1, the findings add to the growing body of evidence calling for greater investment in this sector. The findings support previous reports and publications on similar Aboriginal housing data, highlighting the inadequacy of Aboriginal housing conditions in supporting householders to practice safe and healthy living (3, 5, 7-12). A strength of the results presented in this thesis is that these findings are based on rigorous statistical analysis of a large dataset collected consistently and methodically with Aboriginal community members over two decades. Whereas the existing literature largely focuses on the condition of Aboriginal housing in remote Australia, particularly central and northern Australia, this analysis focuses on the NSW context and includes a cross-section of housing across urban, regional and remote NSW.

3.1 The NSW Housing for Health Program

One clear finding of this program is the significant improvement in house functionality associated with HfH project visits. Measured against the CHLP Indicators, the program has made substantial gains in house functionality, and these gains have increased over time, whilst the cost to achieve those outcomes has decreased. The findings demonstrate that reaching a minimum standard of safe and healthy housing in Aboriginal communities is a cost-effective and achievable target. However, this will require additional investment in the Aboriginal community housing sector.

The longevity of the program and longitudinal nature of the data have allowed for trend analysis, presenting for the first time the condition of housing in NSW before and after the NSW HfH projects over two decades. The potential health benefits of the program have been identified in previous evaluations (6), and this new evidence strengthens the argument for expanding the focus on safety and health-related repairs and maintenance to all housing across the sector. Continuing the NSW HfH Program and updating the consolidated HfH dataset would maintain the continuity and currency of the data, enabling further research and providing evidence that could guide improved policies and programs. The consolidated data also provide useful sentinel surveillance of the Aboriginal community housing sector, allowing for the evaluation of changes in housing policy and program initiatives over time, and strengthening arguments for better resourcing. The data may also enable further valuable research, such as the impact of the COVID-19 pandemic on program delivery and house functionality. Recommended future research is discussed further in section 5.0.

Continued implementation of the NSW HfH Program would support Aboriginal Community Housing Providers (ACHPs) to improve their houses to a minimum standard of functionality, making their maintenance load more manageable, at least in the short term. This does not take away from the need to adequately resource Aboriginal Community Housing Providers (ACHPs) to sustainably maintain ongoing repair and maintenance programs. Expanding the scope of the NSW HfH Program to work with ACHPs to co-design models that embed the principles of the program into existing housing management systems could also provide more sustainable benefits from HfH projects and contribute to the Closing the Gap Priority Reforms, which call for greater community control and self-determination.

Whilst the NSW HfH Program does not address all the issues of managing social housing, the findings in Chapters 4 and 5 of this thesis demonstrate a continued need for improvement of current standards of house functionality that support minimum standards of safety and healthy living, such as those identified by the CHLPs. The findings demonstrate this is an achievable

target, but the sector has not been able to attain this over the past decades, most likely due to inadequate resourcing. The findings of this thesis provide for the continuation of the NSW HfH Program whilst the sector is strengthened to maintain these minimum standards.

3.2 Turning Policy into Practice

Despite the acknowledgement of the importance of housing and the implementation of housing programs nationally, there are few published examples of "how to" improve housing and living environments in Aboriginal communities. The research literature often acknowledges the importance of the social determinants of health, including housing, in managing acute and chronic disease conditions such as trachoma, rheumatic heart disease, or post-streptococcal glomerulonephritis (13-17), but often as a one-line statement in the conclusion of the paper or the report. Far less research is published describing tangible initiatives to translate social determinants of health policy into action, particularly in the case of housing and Aboriginal communities.

The importance of housing as a determinant of health is also recognised in previous and current reports and government policy, (18, 19) and the aims of the NSW Health HfH Program align with those aspirations of governments since it was first established in NSW in 1997 (20). Whilst the NSW HfH Program predates the launch of the "Closing the Gap" campaign in 2007, (21) its' aims align with the current Closing the Gap priorities and support some of the high-level outcomes, specifically Outcome 9: "*Aboriginal and Torres Strait Islander people secure appropriate, affordable housing that is aligned with their priorities and need"* (22), and its associated targets:

> *"9a: By 2031, increase the proportion of Aboriginal and Torres Strait Islander people living in appropriately sized (not overcrowded) housing to 88 per cent.*
>
> *9b: By 2031, all Aboriginal and Torres Strait Islander households:*

- *within discrete Aboriginal and Torres Strait Islander communities receive essential services that meet or exceed the relevant jurisdictional standard*
- *in or near to a town receive essential services that meet or exceed the same standard as applies generally within the town (including if the household might be classified for other purposes as a part of a discrete settlement such as a "town camp" or "town based reserve".)"* (22).

However, the findings from this thesis indicate that, in NSW at least, the condition of housing falls well short of this target and improvements in the most basic items of house functionality - those that support safe and healthy living – have only been very modest over 20 years, including the 10 years since Closing the Gap and the National Partnership Agreements on Remote Indigenous Housing (NPARIH) (23) were announced.

A gap remains between the high-level targets of government housing policy and the on-the-ground reality of Aboriginal community housing. Government policy falls short of outlining specific actions to transform aspirations into reality. Qualitative research by Flinders University on the uptake of social determinants of health in government policies found that while the importance of social determinants of health and health inequities are widely recognised, policies often focus on biomedical strategies to treat or prevent disease, or on behavioural strategies targeting individuals. This has been described as 'lifestyle drift' (1). The findings from this thesis indicate that programs focusing on behavioural change may be significantly compromised by the inability of housing to support healthy living practices.

McGuffog et al. claim "[h]igh quality intervention research is needed to inform evidence-based practice and policy for Aboriginal and Torres Strait Islander communities." (24) Whilst this may be the case, it is not just a lack of evidence that has prevented changes in the sector. Housing policy and practice is complex and often described as incorporating a diversity of issues relating to housing, security, affordability and suitability (25). The additional complexities of historical mistreatment of Aboriginal people over centuries and the subsequent intergenerational impacts of colonisation, compounded by continuing inequities (26) have seen Aboriginal housing characterised as a 'wicked' problem, and the impact of political and other forces on housing policy cannot be underrated (27).

Repair and maintenance is only one component of the housing story, but clearly, from the evidence in this thesis, a significant one. The thesis also demonstrates that repair and maintenance is not so wicked and achieving a basic level of "safe and functional housing is financially, socially and technically possible" (28).

3.3 Scaling the Benefits of HfH to the Broader Social Housing Sector

As evidenced by the thesis findings, the NSW HfH Program is an example of translating government targets into concrete action, engaging with communities to make tangible and effective improvements in housing and living environments to reduce the burden of disease in Aboriginal communities in NSW (29). The NSW HfH Program does not address all issues in social housing management and is not intended as a comprehensive asset management program. However, there are fundamental principles underpinning the program methodology that have contributed to the findings of this thesis about housing improvements and facilitated the high participation rates by NSW Aboriginal communities. These principles may be transferable to other social housing repair and maintenance programs. Proactive audits of houses with immediate repairs, involvement and employment of community members, evidence-based prioritisation of safety and health repairs, and collecting evidence to improve policy and program management are examples of principles that could be embedded into other repair and maintenance programs and jurisdictions.

The NSW HfH Program has achieved significant improvements in house functionality, but in a relatively small number of houses each year. Working with ACHPs to incorporate some of the principles of the methodology into existing repair and maintenance programs in the Aboriginal housing sector more broadly could make similar improvements to housing, but potentially on a much larger scale, which may contribute to an overall improvement in Aboriginal health.

3.4 Investment in Repair & Maintenance Systems

This thesis suggests that despite the efforts of many in the sector working to improve the lives of communities, the policies and resources allocated to Aboriginal community housing by successive NSW and Australian governments have failed to address the inadequate quality and quantity of housing in Aboriginal communities in NSW. The findings of this thesis for the NSW HfH Program are comparable to similar work in other jurisdictions across Australia (23, 30). With the cost of poor housing ultimately being borne by householders and the health system (31), expenditure on housing repairs and maintenance should be seen as an investment in protecting both assets and the health of the residents.

The finding from this thesis that 95% of jobs repaired by the trades were due to systematic issues of a lack of maintenance (84%) and quality control (11%), supports the program's focus on safety and health-related repair and maintenance and adds to existing literature identifying

the need for prioritised health-focused maintenance systems. Whilst tenancy support is an important part of housing management, damage by tenants accounted for only 5% of the safety and health-related jobs completed as part of HfH over a 20-year period. Any focus on reducing tenant-related damage largely puts the onus on the tenant, rather than those organisations responsible for housing management systems. These findings indicate greater emphasis needs to be placed on improving routine maintenance systems and quality assurance across the Aboriginal Community Housing sector.

The thesis also presents new data demonstrating that house functionality is improved in houses where there is evidence of existing housing maintenance activity, and where not, the capacity for improvement is hindered. However, over 40% of houses studied in the NSW HfH Program had no evidence of existing housing maintenance. The NSW HfH Program was not intended to be a proxy cyclical maintenance program for the NSW Aboriginal housing sector, but the NSW HfH Program has returned to some communities, and the data shows that where there were second HfH projects, the condition of houses had deteriorated, but were still better than at the first visit. Further analysis of any association between house condition and the time between repeat projects could give insight into the minimum frequency of cyclical maintenance audits required to sustain house functionality cost-effectively.

The lack of routine repair and maintenance likely explains the NSW HfH findings around the impact of the age of the house at SF1, whereby the condition of houses was poorer for older houses, but house age was no impediment to repairing them to the minimum standard. As with the NSW HfH Program, robust cyclical maintenance systems could adequately maintain the condition of existing housing stock. Many housing management systems (where they exist) rely on self-reported maintenance programs, where tenants are required to report problems. These systems are unreliable as they depend on tenants having the means and motivation to report issues and generally only capture the most pressing issues for the tenants (such as a blocked toilet) (32) and don't capture the routine maintenance checks (such as Hot Water System valves), that could increase the life of assets and avert major expenditure (4, 33).

No houses in the NSW HfH Program met the Programs' minimum standard criterion at the start of a community project, and while the condition of houses in metropolitan areas was marginally better than in regional and remote locations of NSW, more than half were low or very low functionality. This is consistent with Aboriginal people's perceptions of housing in urban and suburban areas (34). The findings in this thesis did show an association between rurality and house condition, with greater improvements possible in metropolitan areas. Qualitative data could shed more light on these patterns, but incentives to improve access to trades, including encouraging more trades in rural and remote NSW, could be beneficial. There was little difference in the condition of housing in regional and remote areas, suggesting the remote area focus of previous housing programs such as NPARIH, (23) could have been broadened to include regional housing.

Crowding in houses has long been associated with poor health outcomes (30). Using occupancy ratio as a proxy measure for crowding, the NSW HfH evidence in this thesis strengthens the existing literature, demonstrating a relationship between increased crowding in NSW Aboriginal community housing and a decreased condition of health hardware, particularly once the occupancy ratio exceeded 2 people per bedroom. In addition, the occupancy ratio also impacted the ability of the HfH Program to improve house functionality, where less improvement was made in houses with higher occupancy ratios, supporting the continued need to prioritise reducing crowding in future housing programs

3.5 Re-Prioritise Existing Funding to Repairs & Maintenance

Historically, governments have often tried to address housing supply and quality issues for Aboriginal communities by constructing new housing, often at significant cost. However, new housing alone does not lead to an overall increase in safe and habitable houses without adequately maintaining the current housing stock (3, 35, 36). The NSW statewide average cost of constructing a new house in 2022 was approximately $400,000 (37), and given that most construction would be in the metropolitan areas, this figure would likely be higher in regional and remote areas. Using the NSW HfH financial data (CPI adjusted to March 2022) presented in this thesis, an expenditure of $400,000 to build one house would be comparable to the NSW HfH Program undertaking housing repair and maintenance fix-work in around 60 houses (excluding project management costs that are provided in-kind by the program). Adequate resourcing of ongoing house repair and maintenance programs is complicated by a range of factors, including that the political optics of constructing a new house could outweigh a repair and maintenance system for many more houses. It is well documented that the Aboriginal housing sector requires major upgrades of existing assets and construction of new housing stock to replace houses beyond economic repair and address the shortage of housing across Aboriginal communities(35). However, this should not occur in the absence of, or before, ensuring existing houses are safe and support householders to practice the most basic healthy living activities.

This analysis found the median fix-work cost of improvements in house functionality over the 20-year study period was $6,509 per house (CPI adjusted to March 2022), with fix-work costs decreasing over the 20 years and house functionality improvements increasing, suggesting efficiencies in NSW Health HfH Program delivery over time. House functionality in communities that received a second NSW Health HfH project (5-17 years later) had decreased between projects but remained higher than the start of the first project, indicating possible sustained benefits from previous HfH projects in the same community. This finding supports calls for cyclical maintenance (33, 35). If all 4729 estimated Aboriginal community houses in NSW received a Housing for Health project, the total cost for fix-work would be around $30.1 million (excluding project management costs). If implemented on a 3 to 5-year cyclical basis, for example, this would amount to approximately $6—10 million per year, a relatively minor investment by governments towards improving the lives of Aboriginal people.

With an increasing Aboriginal population in NSW (38), housing need will likely continue to outstrip available funding, maintaining pressure on health hardware in houses and reaffirming the need to prioritise available resources. In 2023–24, the NSW Government allocated $251.9 million to the NSW Aboriginal Housing Office (AHO), including:

- $139.2 million towards managing and coordinating capital and maintenance works for First Nations social and community housing, and
- $60.0 million for ‘Closing the Gap – Housing Solutions’ - An initiative seeking to deliver new homes, improve living conditions, provide stable housing for women and families, support the First Nations community housing provider sector, and create jobs for First Nations people (39).

Without further detail available on the distribution of these funds, these high-level figures suggest that a reprioritisation of funding toward safety and health-focused repairs and maintenance, may be feasible within current resourcing. Consultation within the Aboriginal

Housing sector should consider options for reassigning existing resources and/or obtaining additional resources to ensure a minimum standard of house functionality is achieved across all houses.

3.6 Closing a Gap in Housing Maintenance Standards

The UN/WHO describe housing as a basic right (40). Ensuring that housing in NSW (and Australia) is safe and supports the most basic healthy living practices should be a minimum requirement for rental housing. Implementing a minimum repair and maintenance standard for house functionality, in much the same way as a fleet of motor vehicles must meet a minimum standard of roadworthiness for registration, would provide benefits to the householders and assets. A comparable system has been trialled in New Zealand, and evaluations indicate that when properly enforced, it would mitigate the disease burden associated with poor housing, provide potential fiscal and economic benefits and positively impact well-being (41-43). The findings of this thesis indicate that periodic assessment of this minimum standard is an achievable target for a relatively modest financial investment in NSW. Audits and repairs to houses could be done periodically, on a cyclical basis and when tenancies change. Other, less critical health-related items in housing management (such as painting or fencing) may be subject to rental agreements and tenancy management. However, the flow-on benefits to residents living in houses that meet a minimum standard for health and safety indicate value in maintaining all housing at this level.

Implementing such a minimum standard approach could also consider options for allocating responsibilities for certain items. Costs for critical plumbing and electrical items, for example, should rest with Community Housing Providers (the landlords) and be repaired irrespective of other issues around tenancy or rent collection compliance, and should not be open to debate. Whilst prescribing minimum standards for house functionality would provide guidance to housing providers and some protection to tenants, it would also create a level of accountability for landlords. This could be seen as a liability risk by governments which are generally responsible for repairs and maintenance of most of the social housing sector nationally (44). However, that risk is already playing out in the courts with one community being awarded compensation by the High Court for the landlord, the Northern Territory government, failing to carry out basic repairs (45). A set of industry-agreed standards would also ensure input from communities and technical experts in defining the priorities, rather than the legal system.

Examples of minimum standards have previously existed in Australia, but often only as guidelines. The National Indigenous Housing Guide (NIHG), developed in 1999 and reviewed in 2003 (46) and again in 2007 (47), described guidelines for the design and specification, repair and maintenance, and quality assurance of Aboriginal housing with a specific focus on safety and health. Unfortunately, the guide was neither reviewed nor adopted by subsequent Australian governments. Any set of standards will require long-term commitment from governments and peak bodies. The NIHG was prepared for the Australian government by Healthabitat, the licensor of the HfH methodology applied in the NSW Health HfH Program. Whether these are exactly the right criteria or go far enough to incorporate all aspects of repair and maintenance management is open to debate, but the HfH methodology potentially provides a starting point to negotiate a widely agreed set of minimum standards for Aboriginal housing in Australia.

The findings of this thesis suggest that a considerable amount of effort will be required to bring all homes in the NSW Aboriginal community housing sector up to the minimum functionality

standard of the NSW Health HfH Program. The quantum of work required potentially represents a financial liability to the Aboriginal Housing Sector. The implementation of minimum standards may need to be staged over time, prioritising health hardware over less critical items to gradually address this backlog before or alongside other asset management.

3.7 Program Benefits for the Health System

Underpinning the NSW Health HfH Program is the acknowledgement of housing as a determinant of health and the evidence that improving housing can reduce environmentally-related diseases in populations (48, 49). Routinely collected health data indicate higher rates of environmentally related infectious diseases, such as skin and respiratory conditions, in the Aboriginal population of NSW. Exposure to these infectious diseases can also be a risk factor for serious and more complicated chronic conditions, such as acute rheumatic fever and rheumatic heart disease (ARF/RHD) (50). The NSW Health evaluation of the health benefits of the NSW HfH Program conducted in 2010 showed an association between the NSW HfH Program implementation and reduced hospital separations for environmentally attributable disease conditions (6). This finding supports claims in the substantive literature that investing in improving healthy living environments is an investment in the health system (30, 51-54).

Functional housing supports the preconditions for effective health messaging and health promotion activities provided by primary care workers (6). NSW Health describes how the relationships developed with communities through implementing HfH projects build a bridge between the health sector and the community to discuss other health issues that may be impacting the community. This engagement with the community has led to the co-design of other health-related projects to improve, for example, waste management, companion animal health, or indoor air quality (6, 55). The NSW Health HfH Program also provides opportunities to share information with householders on health-related issues in the household, such as food safety or protection from arboviruses. Another less tangible benefit of the program is the reduction in social burden on families from living in functional housing that supports healthy living. Taking away some of the immediate, micro issues impacting families, like a shortage of hot water, blocked drains or broken lights, can potentially allow space for greater control over other issues affecting families, potentially also supporting improved mental health (6, 33, 55, 56). An economic analysis, as described in Chapter 7, would help to quantify the value of these more indirect, but tangible benefits (57).

3.8 Valuing the HfH Program Through Economic Analysis

Ensuring equitable outcomes for Aboriginal community housing residents should alone be grounds for adequately resourcing the Aboriginal Community Housing Sector. However, the evidence presented in Chapters 4 and 5 of this thesis - showing very little improvement in the poor functionality of houses at first surveys over recent decades - indicates the resourcing and management of the Aboriginal community housing sector in NSW over that time has not been adequate to support safe and healthy living practices. However, for a relatively small investment in housing – around $6500 per house – there is the potential to make substantial improvements in housing and potentially health (6).

The Independent Hospital Pricing Authority reports an average cost of $5443 per episode in NSW for acute admitted care in 2022-23. With 1.66 million episodes in NSW in the financial year 2018/19 (58) this equates to over $9billion per year. Although not all acute admissions are related to the living environment, there is some evidence from the first 10 years of the NSW HfH

Program that hospital admissions for a subset of illnesses were reduced in Aboriginal houses that had received a HfH project versus a control group of houses that had not (6). When combined with the economic benefits described in Chapter 7, there is a compelling case for a rigorous health economic evaluation of the HfH Program to estimate its potential cost-benefit to the broader NSW public health system.

A principle of the NSW Health HfH Program is to include all houses owned or managed by the housing provider, irrespective of whether tenants pay rent, as the program is only bringing the houses up to a very basic standard of functionality. The costs of ensuring tenants live in a functional house may be outweighed by potential savings to the health sector through improved health outcomes and subsequent reduced hospitalisations and primary care (6, 54, 59). Other cost savings from extending the life of assets and other less tangible benefits, such as temporary employment, education opportunities and community safety, have been posited but not evaluated and may assist in determining the true cost-benefit of such programs (55).

The scoping literature review in Chapter 7 identified no economic analyses of similar programs aiming to improve health through physical infrastructure improvements with the scope of the NSW HfH Program. It also explored how the intangible impacts of the program could be evaluated. Undertaking an economic analysis of the NSW health HfH Program using the protocol described in Chapter 7 would capture the other health, social, economic and intangible benefits of the program and may provide useful insights for the HfH Program and social housing in NSW more broadly. A health economics assessment could also align with the recently released NSW Treasury First Nations Investment Framework that calls for systematic inclusion of Aboriginal communities in evaluating initiatives and to value First Nations culture in cost-benefit analyses (60).

3.9 Climate Adaptation and Housing

Novel analyses of climate modelling data and Aboriginal demographic data in this thesis demonstrate for the first time the NSW Aboriginal populations' exposure to a range of climate-related hazards compared to the non-Aboriginal population. The implications for culture, health and adaptation planning, including housing, now and into the future, as the reality of climate change transpires were also discussed.

The current disproportionate exposure of Aboriginal people in NSW to climate-related hazards, identified in this thesis, and the predicted exacerbation of related health effects in the near and far future, will inequitably impact the health and well-being of Aboriginal people in NSW. This will hinder measures to close the gap in health between Aboriginal and non-Aboriginal populations (21). As we spend much of our time in the home environment (61), Aboriginal housing will play a crucial role in adaptation, particularly since those most likely to be impacted by climate extremes are often those with the least adaptive capacity (62). For example, the historical location of many discrete Aboriginal communities (former missions and reserves) next to rivers (63) increases flooding vulnerability. This is often an issue that can only be addressed by major infrastructure investment (such as levee banks) or high-level planning options (such as relocation), both beyond the control of householders and communities. Furthermore, the relocation of Aboriginal people from the reserves where they were historically forced to settle potentially compounds the historical dispossession of communities and continues the legacy of colonisation. The cultural implications of climate events for Aboriginal people, discussed in Chapter 8, underscore the importance of incorporating cultural considerations into climate change adaptation strategies (64, 65) and the significance of understanding the often-

overlooked role that traditional knowledges may play in developing future adaptation strategies (64).

Tenants in social housing do not own the property, are less likely to be able to afford measures to manage extreme heat in those properties, such as passive cooling modifications (insulation, sealing houses, shade verandas, etc) and active cooling measures (such as fans and air-conditioning), and are less likely to afford the ongoing running costs (65-68). The increasing availability of solar photovoltaic (PV) energy, which could reduce the ongoing economic burden on households, requires initial investments largely beyond the capacity of most tenants in social housing, as well as small Aboriginal Land Councils and Corporations that manage Aboriginal housing in NSW.

Making houses manageable and liveable in extreme conditions poses significant challenges (25, 67). Ensuring new housing is designed and existing housing retrofitted to support climate adaptation must be prioritised. Published and unpublished research around Australia on house temperature and retrofitting solutions indicates that housing is already becoming unliveable in some parts of Australia (69). Retrofitting passive cooling solutions alone is unlikely to provide thermal comfort, and active cooling solutions retrofits will also likely be required (69). However, in extreme temperatures, these retrofits still have temperature thresholds that limit their effectiveness. There is a tangible risk in some parts of NSW and Australia that environmental temperatures may increase to a point where people are displaced from their homes and traditional country for parts of the year, potentially creating a population of climate refugees (69). The social and cultural implications of people having to move 'off country' and relocate to cooler climates or regional centres need to be considered well in advance, and mitigation and adaptation strategies co-designed and implemented with Aboriginal people to minimise impacts.

Incorporating suitable housing retrofits to support climate adaptation may be something the NSW Health HfH housing program could consider as an addition to the repair and maintenance of the critical Healthy Living Priorities currently addressed by the program. However, given that Aboriginal community housing does not yet meet the minimum targets for safety and healthy living practices, this would be additional to, not in place of, the existing HfH priorities. The cost of climate adaptation measures is likely far greater than the relatively small per-house investment of HfH to date. Government funding grants would be required for climate adaptation and could provide an opportunity to trial (and measure and report) adaptation measures in collaboration with Aboriginal communities. However, experience from the NSW Health HfH Program has shown that any funded initiative will need to be implemented thoroughly and include quality control and householder education on energy management.

Food insecurity is already an issue in some Aboriginal communities and is predicted to worsen with climate change (70). Data from Chapter 4 of this thesis showed that the temperature of refrigerators and freezers is often a limiting factor for the critical HLP Indicator *Food safety: Prepare, Cook and Store Food*. Within the home, extreme heat reduces the efficiency of refrigeration, increasing running costs and reducing the capacity to store food safely.

3.10 Review of the Nine Healthy Living Practices Priorities

The nine Healthy Living Practices (9 HLPs) were first published in 1986 in the Uwankara Palyanyku, Kanyintjaku (UPK) Report (71), and in 1999, the National Indigenous Housing Guide (72) added safety as an overarching priority to the 9 HLPs. Safety and the 9 HLPs summarised in

Table 9.1 have since been widely referenced and used as an appropriate prioritisation for environmental health remediations, and used to evaluate and prioritise housing and health programs nationally (5, 7, 8, 52, 54, 73, 74).

Safety and the 9 HLPS form the basis for prioritising the work of HfH projects. While all the HLPs are considered important, funding limitations have restricted the focus of NSW HfH projects to safety and critical (being the first four) HLPs.

Table 9.1: Safety and the Nine Healthy Living Practice Priorities.

	Safety and the Nine Healthy Living Practices
critical	**Safety** and Life-threatening issues are the highest priority.
critical	**HLP 1** – Washing People
critical	**HLP 2** – Washing clothes and bedding
critical	**HLP 3** – Removing wastewater safely
critical	**HLP 4** – Improving nutrition, the ability to store, prepare and cook food
important	**HLP 5** – Reducing the negative impacts of crowding
important	**HLP 6** – Reducing the negative effects of animals, insects and vermin
important	**HLP 7** – Reducing the health impacts of dust
important	**HLP 8** – Controlling the temperature of the living environment
important	**HLP 9** - Reducing hazards that cause trauma

Source: Healthabitat (2020). "Safety & the 9 Healthy Living Practices." Available from *http://www.healthabitat.com/the-healthy-living-practices*

Controlling the temperature of the living environment is currently HLP priority 8. However, over the past 40 years, evidence has grown around the impact of climate (particularly heat) on human health, especially populations with chronic morbidities (75). The results of increasing fossil fuels and deforestation globally are changing our climate, with greater changes predicted. Temperatures in NSW are predicted to warm by 2.1 °C by 2070 (based on a medium CO2 emissions scenario), and the number of days greater than 35 °C is expected to increase by up to 40 extra days per year in parts of NSW (76, 77).

Given the threat now posed by a warming climate, it is timely to review the current health and climate literature and reassess whether HLP 8 - Controlling the temperature of the living environment - should be a higher priority for housing maintenance. Given how widely the nine HLPs have been referenced in policy and practice, changing the status quo should involve a collaboration of government, non-government, academic and Aboriginal stakeholders. In terms of maintaining consistent data reporting, any adjustment to the order of the HLP priorities and program priorities for HfH could potentially impact the reporting and the data collection. To ensure consistency with previously collected data, consideration would need to be given to ensure collection and recoding of future data can allow for retrospective comparison.

3.11 Housing Design for Safety and Health

The HfH Program and the evaluations conducted in this thesis focus on issues of repair and maintenance. While assessing housing design is outside the scope of this thesis, it should be acknowledged that robust and culturally appropriate housing design is an important consideration in constructing, upgrading and maintaining safe and healthy housing (30, 47, 52, 53, 78-80). Some items in the HfH survey data relate specifically to housing design, and future analyses of these data may provide insight into the capacity and flexibility of existing housing designs to address current and emerging issues, including temperature control.

Housing design solutions should reflect and respect the cultural and traditional aspects of Aboriginal communities, including incorporating appropriate design elements, such as space for cultural practices, community gathering areas, and ensuring privacy and safety for residents. Good design includes the flexibility for housing to adapt to changing needs, such as accessibility for an aging population or fluctuations in occupancy, including possible crowding during cultural or other activities (47, 69, 79-83).

Cultural considerations are not limited to design. Racism and discrimination have been identified in the literature as barriers to reporting maintenance (26, 32, 34). Ensuring culturally safe systems is crucial in the delivery of repair and maintenance services, both in the systems and the people working within them. Education of staff and the employment of Aboriginal community people in these services could be a starting point to reduce discrimination.

3.12 Shifting the Status Quo

The evidence presented in this thesis and in the broader literature describes a systematic failure over two decades by housing agencies to deliver safe and functional housing for Aboriginal communities. This suggests that, even with the greatest commitment of governments, other agencies, and communities, turning around the status quo will take much more than one political term of government. Long-term problems such as these require a long-term commitment to address. Whilst substantial improvements may be made within a four-year term of government, some changes will require longer-term commitment and resourcing to ensure housing meets defined minimum standards and addresses issues such as crowding and the looming impacts of climate change (84). Collaborative approaches involving Aboriginal communities, housing providers, and government and non-government agencies from both the housing and health sectors in the decision-making process would ensure housing solutions are tailored to the specific needs and aspirations of the Aboriginal community and incorporate health considerations in housing management (35, 85).

4.0 Strengths and Limitations

The strengths and limitations of the studies conducted in this thesis have been described in each of the chapters. This section describes the broader strengths and weaknesses of the overall thesis. Whilst this thesis is not evaluating the HfH methodology applied in the collection of data reported in three of the studies, there are some strengths and limitations of the method worthy of note, as they influence the quality of the overall HfH Program data that forms the basis of part of this thesis.

4.1 Strengths

The involvement of Aboriginal community members in the collection of project data is a strength of the program dataset analysed in this thesis and likely contributed to the very high participation rates by community housing providers and householders in the surveys and fix components of the HfH Program. Another strength of this thesis is the inclusion of Aboriginal researchers, policymakers and project managers in the research, who have provided cultural understanding to the interpretations and reporting of findings and implications of the analyses and the translation of results into action. Section 5.0 describes future opportunities that could further strengthen collaborations with Aboriginal researchers and stakeholders and enhance Aboriginal data governance and sovereignty of the NSW Health HfH Program data.

The consistent collection of house functionality data with Aboriginal communities using a standardised and repeatable survey instrument continuously over more than 20 years has led to the development of a rich and informative dataset. This consistency is largely founded in the use of a non-commercial licensed methodology by NSW Health from a not-for-profit organisation, Healthabitat. NSW Health purchased a license to use the Housing for Health methodology and associated resources for each project for a nominal fee. License conditions include the requirement for community involvement in data collection and fix work, a minimum budget allocation to ensure the immediate fix-work component of the process, and an on-site audit of each project to ensure consistency of implementation and quality assurance. The license conditions prevent alteration to the methodology or resources. This independent oversight ensured consistency of implementation, including data collection, fix work and reporting across all projects.

The use of a single longitudinal dataset from the first 20 years of the NSW HfH program, detailing the condition of houses and the cost of repairs across NSW, is a unique strength of this data. The use of linked house functionality and fix-work cost data at the house level, not previously reported, was also a strength of this dataset. Whilst the data are primarily administrative and not drawn from a random sample of communities throughout NSW, the very high participation rates among householders and the high proportion of the NSW Aboriginal community housing sector represented in the data over two decades strengthen the generalisability of the thesis findings across the NSW sector.

Rigorous statistical techniques were applied to the analysis of the substantial 20-year housing dataset to produce robust results and add confidence in the findings of the specific studies and of the overall thesis. The application of specific analysis approaches, including the use of inferential statistics for analysing house functionality data, is a unique strength of the analysis. Using the linked house functionality and fix-work costs data, the analysis describes the cost of moving houses from one category of house functionality to another, providing a deeper insight into what drives improvements in house functionality associated with the HfH Program. The methods applied to analyse the data, and the results presented in this thesis, provide examples of how the dataset may potentially be used for further analyses to answer important research and evaluation questions.

The housing studies also identified the need to quantify other costs and indirect impacts of the program for individuals and communities, such as health and social benefits. The application of a systematic review methodology to identify an appropriate health economics evaluation framework for evaluating the NSW HfH Program will inform future work. Another strength of this thesis is the unique approach of combining census data, environmental data, and climate

modelling to investigate the impact of climate change on NSW Aboriginal communities now and into the future. This novel use of existing, publicly available data described for the first time the emerging impacts of climate change on environmental exposures for Aboriginal populations in NSW. It highlighted current and future inequities in these exposures and their associated implications for adaptation, including implications for the housing sector, and future considerations for the HfH Program. It also acknowledges the potential for traditional knowledges to inform future adaptation strategies.

4.2 Limitations

There are some limitations of the HfH methodology and NSW HfH Program data collection that, whilst not limitations of the analyses, do directly affect analyses undertaken in this thesis. The HfH data are administrative data collected to implement the program efficiently and inform future policy. It is not specifically collected for research purposes; however, it is a large and informative repository of information unique to the Aboriginal housing sector in NSW. While the involvement of community members in data collection is a strength of the data, it may also be a limitation. The use of community workers who may not be familiar with data collection processes may increase data collection errors. This risk is minimised through training community members, accrediting team leaders, using clear and simple standardised tests for each survey question, and having in-built validity checks in the survey database during data input. In addition, the second Survey-Fix identifies any data (and therefore repairs) that may have been incorrectly recorded at the first survey, reducing the impact of incorrect data across the project. However, this doesn't eliminate the potential for data errors within each survey. However, community engagement is a priority for the program and a crucial aspect of its interaction with local communities.

This thesis presents the first comprehensive analysis of the 20-year consolidated NSW HfH dataset, incorporating some assumptions made during the analysis that could be tested in future studies. The categorisations of house functionality scores in Chapters 5 and 6 are insensitive to changes within categories. The potential to model the data as continuously distributed scores could provide a more sensitive analysis, and this is discussed further in Section 5.0 - Future Research. The analysis of the HfH data assumes that the items comprising an indicator score are weighted evenly. However, this is not the case as some items are more important, complex and/or expensive to address than others. Therefore, two houses with the same score may require substantially different effort and expense to improve the scores. There has not yet been an assessment to determine the appropriate weighting of the indicators in the calculation of house scores, but this could be considered for future research. The analysis also assumes that the HfH indicator scores are ratio-scaled, although this may not be the case. A one-unit increase in the measurement of house functionality from 1 to 2 may not be the same as an increase from 8 to 9. Reviewing the measurement scale of HfH indicator scores was also beyond the scope of this thesis but is an important opportunity for future research.

The financial data analysed in this thesis provides novel insight into the fix-work costs of improvements to Aboriginal housing included in this data. However, a notable limitation is that it only reflects the fix-work costs and not the true cost of implementing the NSW HfH Program, including the in-kind contributions of project and program management by NSW Health. Estimating this would be an important consideration for any future economic analysis, such as that suggested in Chapter 7, which provides a high-level protocol defining the essential components for a comprehensive economic evaluation of the NSW HfH program.

The dataset provided by NSW Health analysed in this thesis includes quantitative data on house condition and expenditure costs for fix-work. Although a substantial dataset was provided, no qualitative data were collected on the acceptability of the program to Community Housing Providers or households. The inferences made about the acceptability of the HfH Program, given the very high participation rates by both community housing providers and households, could be validated using qualitative methods.

The selection of communities to participate in the NSW Health HfH Program was not random, as its intention was to prioritise community projects based on need. However, as little or no objective information on house functionality was available (prior to SF1), community selection was also influenced by other factors, including funding provider priorities; community advocacy; coordination with other housing or infrastructure works in communities at the time; project resources, and other political or media issues. Nearly two-thirds of communities covered by the Aboriginal community housing sector participated in the NSW Health HfH Program over the 20-year period. This relatively high participation rate in the program by communities in the Aboriginal community housing sector suggests the results presented in this thesis are broadly generalisable to the wider NSW Aboriginal community housing sector. However, the extent of any potential bias in the results presented in this thesis is unknown, and this is a limitation of the research.

Martin & Mirraboopa (2003) discuss how the researcher's worldview influences the assumptions upon which research is based, and that the analysis and interpretation of the data further entrench that worldview (86). My engagement with Aboriginal communities and colleagues over the past 35 years has strongly influenced my worldview. However, as a non-Aboriginal male, my research may be biased by my worldview and unintentional misunderstandings or naivety of Aboriginal culture. Furthermore, while my role as Manager of the NSW Health HfH Program for nearly 25 years provides an in-depth understanding of the intricacies of the HfH methodology and the program, it also creates the potential to bias the research I led in this PhD thesis. As acknowledged earlier in this thesis, I have sought formal and informal input from Aboriginal community members, health and building practitioners, policymakers, and researchers, including my Aboriginal co-supervisor and co-authors, to guide and improve the direction and cultural safety of my research and minimise any potential for researcher bias.

Given the breadth of Aboriginal people affected by the poor housing conditions and the disproportionate impact of climate change on Aboriginal populations across NSW, both of which are identified in this thesis, the limited engagement and involvement of Aboriginal communities in determining future recommendations is recognised. The recommendations in section 6.0 of this Chapter acknowledge the need for extensive Aboriginal community engagement in their development and implementation.

5.0 Future Directions

5.1 Evolving the NSW Health HfH Dataset

This section outlines future work that could be undertaken by NSW Health to build on the findings of this research and add value to the consolidated dataset and the broader NSW Health HfH Program.

The NSW Health HfH Program "*aims to improve the health of Aboriginal people and communities in NSW by improving their living environment*" (29). There are various components of the program (described in Chapter 3) that contribute to achieving this aim, including community consent, participation and employment in data collection. The purpose of data collection is two-fold - initially to prioritise immediate housing repairs, and secondly to strengthen the evidence for improved housing policy and guidelines. Since the first pilot project in 1997, more than 53,000 items related to safety and health have been fixed by the NSW HfH Program. This persistent and methodical surveying, recording and fixing of houses with Aboriginal communities for more than 20 years has made possible the creation of a new, aggregated dataset with the potential to evaluate and guide HfH Program development, and inform Aboriginal housing management policy in NSW.

Over the life of the NSW HfH Program, only limited high-level aggregated program data have been reported. Safety and Healthy Living Practice Indicator results for HfH projects have been aggregated at 2-yearly intervals to maintain community anonymity and are reported through Healthstats NSW – a public health reporting platform for NSW Health (73). Previous analysis had only been undertaken in-house by the Health Protection NSW, Aboriginal Environmental Health Unit. Prior to the establishment of this collaborative PhD proposal between Health Protection NSW and the University of Sydney, and the consolidation of the 20-year dataset, the HfH data had not been shared externally. One outcome of the PhD project has been the demonstration of the potential the data has to inform policy and further research. Making the existing, or any updated dataset, more available to groups external to NSW Health would enable further analysis by researchers and others, thus utilising the value of the data and increasing potential for influencing improvement in Aboriginal housing policy. It would also satisfy the NSW Government's Open Data Policy, which aims to make data more accessible for community, research, business and industry to help deliver better outcomes to the people of NSW. However, the Open Data Policy also acknowledges that such access still requires certain protections consistent with legislation and best-practice research guidelines (87).

In the case of this PhD, a de-identified version of the dataset was released for the University of Sydney PhD thesis by the Data Custodian, Health Protection NSW, under the legal authority of the Health Administration Regulation and NSW Health Combined Delegations Manual and subject to conditions (see Appendix II). The Data Custodian did not require ethical approval for the release of the dataset, as the housing repair and maintenance data are de-identified, relate only to housing, and do not include personal health information about individuals. As this was the first time the data had been released, processes and protocols established for the Disclosure of Unit Record Data for Research or Management of Health Services were followed, although not all were relevant to the release of the de-identified housing data. The data management and ethics environment has evolved over the life of the NSW Health HfH Program and since the commencement of this PhD in 2017. Recent work by NSW Health on the application of the NSW Government's Open Data Policy for the release of the HfH data for external use has identified the need for further development of specific protocols for this evolving NSW HfH Program dataset. This is included as a recommendation below, and NSW Health has commenced this work.

Whilst the HfH methodology can be applied to any house, in the case of the NSW Health HfH Program, it has almost solely been applied to Aboriginal community housing. The NSW HfH Program dataset includes "*information or knowledge, in any format or medium, which is about and may affect Indigenous peoples both collectively and individually",* thus falls under the

definition of Indigenous.Data agreed at the Indigenous Data Sovereignty Summit in June 2018 (88).

Included in the development of protocols for the release of the HfH dataset is the need to strengthen Aboriginal data sovereignty and governance of the dataset. The Indigenous Data Sovereignty Summit defined these principles:

- ›Indigenous.Data.Sovereignty" *refers to the right of Indigenous people to exercise ownership over Indigenous Data. Ownership of data can be expressed through the creation, collection, access, analysis, interpretation, management, dissemination and reuse of Indigenous Data*.
- ›Indigenous.Data.Governance" *refers to the right of Indigenous peoples to autonomously decide what, how and why Indigenous Data are collected, accessed and used. It ensures that data on or about Indigenous peoples reflects our priorities, values, cultures, worldviews and diversity.* (88).

Strengthening data sovereignty and data governance are also recognised as key principles of self-determination underpinning the National Agreement on Closing the Gap (CtG), agreed to by all Australian governments and First Nations communities in 2020. It aligns with the objective of Priority Reform 4 for *"Aboriginal and Torres Strait Islander people have access to, and the capability to use, locally-relevant data and information to set and monitor the implementation of efforts to close the gap, their priorities and drive their own development"*. (89).

Strengthening data sovereignty and data governance empowers First Nations people to ensure their stories are accurately reflected, to identify what works, what doesn't and why, and to make the best decisions to support communities in line with needs and aspirations (88). Its inclusion in the development of a protocol for the release of the HfH Program data by NSW Health is a recommendation of this thesis.

Throughout my PhD, I have sought to develop Aboriginal involvement in the research, engaging an Aboriginal academic Co-supervisor and collaborating with Aboriginal colleagues and peers on the development of research questions, analysis, interpretation and write-up of results; developing recommendations for translating this research into action to improve housing in Aboriginal communities; and feeding back results to NSW Health, who can in turn provide feedback to communities. I have acknowledged these contributions via co-authorship.

5.2 Future Research

The analysis of the NSW HfH Program data in this thesis has uncovered further research opportunities that would be strengthened through the inclusion of more recent data collected by the NSW Health HfH Program after the study period of 1997 to 2017 reported in this thesis. These opportunities are discussed below.

To overcome the limitations of a binary pass/ fail measure of house functionality being insensitive to the extent of variation from an "acceptable/minimum" standard, it may be possible to analyse a continuous house score using a statistical model that assesses the expenditure needed on each house to improve the house functionality score (not just by category), while accounting for a range of potential factors including rurality, age of house, occupancy ratio, etc. If a robust predictive model could be developed based on the historical HfH survey data, it may be possible to apply this predictive model to prospective projects after

Survey-Fix 1 to better estimate the expenditure required to bring the house up to at least an "acceptable/ minimum" standard to support healthy living practices.

NSW Health HfH survey data includes variables such as inside and outside air temperatures, weather conditions at the time of the survey, house construction, house shading, presence of insulation, and heating and cooling systems. These data could be used to investigate the thermal performance of the house infrastructure and the ability to maintain liveable temperatures inside homes. The results of such an analysis could provide useful intelligence for future design and upgrades to existing houses, given the disproportionate risks of climate change to the Aboriginal population of NSW identified in Chapter 8 of this thesis.

Further analysis could be undertaken of selected individual items that make up the HLP indicators to identify those that may be more likely to fail. This could inform future specification of materials and maintenance regimes. For example, if stoves or hot water tempering valves are subject to high rates of failure, future housing upgrades, new construction and repair and maintenance programs may specify a higher standard of those materials or more frequent condition assessments.

Changes in results over time of selected survey items could identify emerging trends that may have implications for ongoing Aboriginal housing management. For example, the presence of frail or aged householders and house accessibility is recorded at survey. Analysis of these records over time may identify whether this is an emerging issue for consideration in Aboriginal community housing (along with the general aging population across Australia) (90).

Extending the time period of NSW Health HfH survey data beyond the 2017 end date in the data assessed in this thesis would likely include additional communities where a HfH project has been conducted on more than one occasion. Analysis of HfH survey data from these communities with repeat projects could provide valuable insights into the sustainability of HfH project improvements over time. Such analysis may indicate an optimal time between HfH project visits to communities to maintain health hardware and housing infrastructure at an "acceptable/minimum" standard of house functionality.

Aside from anecdotal feedback from community housing providers, householders, and project managers, the NSW HfH Program has not undergone a comprehensive qualitative evaluation. Results presented in this thesis, demonstrating very high participation rates among community housing providers and householders, infer that the program is well accepted. However, a qualitative review of the NSW HfH Program would strengthen the understanding of the program's acceptability and provide insight and context to the substantial quantitative data from the HfH Program. A qualitative review could also provide an opportunity to canvas community insights on the future of the HfH Program and considerations for strengthening community control. In addition to including end-users of the program, such as community housing providers and householders, to confirm acceptability, including policymakers from other organisations may provide insight into pathways and barriers to scaling up the benefits of the HfH Program.

The scoping literature review in Chapter 7 demonstrated that the few economic analyses of health-focused housing programs conducted have implemented a wide range of methods to identify a disparate and partial mix of costs and benefits (91, 92). Undertaking an economic analysis of the HfH Program using the protocol described in Chapter 7 would capture the more intangible benefits of the program and could provide powerful supporting evidence of the value

and importance of the HfH Program, as well as useful insights for social housing in NSW more broadly.

The word "health" in the program title *Housing for Health* affirms the priority of this targeted housing maintenance program and the importance of housing as a determinant of health. However, over the life of the NSW HfH Program, it has also attracted a level of scrutiny from politicians and bureaucrats requesting evidence of health outcomes, despite the complexity of identifying a link between health and housing survey data on projects conducted in communities with relatively small populations. This level of scrutiny is not required of other housing and infrastructure programs with funding commitments far greater than the NSW Health HfH Program. Between 1998 and 2009, the NSW HfH Program received 5% of the $200 million budget allocation of the NSW Aboriginal Communities Development Program, with the remainder allocated to new infrastructure, new housing, and major housing renovations, none of which were expected to demonstrate health outcomes (20). The inability to identify the precise impact of housing conditions on health should not impede efforts to improve those conditions (93). Improving housing conditions for Aboriginal people to a basic level, equivalent to and commensurate with the expectations of the rest of the NSW population, is an equity issue (64, 94). Such requests to demonstrate a health evaluation of small projects focused on Aboriginal housing, not requested of non-Aboriginal housing and infrastructure programs, apply a disproportionate level of scrutiny and highlight the systemic racism and discrimination in housing that continues to disadvantage Aboriginal people (95).

In an environment where such requests for a demonstrable health benefit continued, in 2010, NSW Health undertook a health outcomes evaluation of the first 10 years of the HfH Program. The study linked routinely collected health data on hospitalisations for specific environmentally-related diseases (mostly skin, respiratory and gastrointestinal infections) by admission address to houses that had received the HfH Program. Rates of hospital admission before and after project implementation were assessed and compared to a control population. The NSW Health study demonstrated a significant 40% reduction in disease conditions related to the living environment (6). Whilst this analysis does not establish a causal link between the HfH intervention and disease reduction, the NSW Health study is particularly robust compared with other similar studies relying on either self-reported health and/or housing condition data or smaller study populations (11, 32, 59, 78, 96-102). The NSW Health study used objective health and house function data from a substantial sample size of 2230 houses to demonstrate a strong association. In addition, hospital admissions for those conditions may only represent the 'tip of the iceberg' for the true burden of disease in the community, as these disease conditions generally present to the health system through a primary care provider, such as an Aboriginal Medical Service or general practitioner (103), and may lead to longer-term impacts on health, such as kidney and rheumatic heart diseases (104).

The increased improvement in living conditions resulting from implementing the HfH Program in the second decade of the program (as demonstrated in Chapters 4 and 5 of this thesis) may be associated with larger improvements in health. A more comprehensive health evaluation linking routinely collected health data, including primary health care data (where available), to house address could investigate this hypothesis. Since the 2010 NSW Health evaluation was conducted, the NSW Health HfH Program has continued for another 15 years. A more comprehensive health analysis would be possible, and the outcomes of a contemporary re-evaluation of the program could also support a future economic evaluation, such as that described in Chapter 7. However, the logistical and ethical requirements for accessing primary

care data would increase the complexity of such a study. Additionally, with several NSW communities receiving a repeat HfH project since the 2010 analysis, the impact of the first HfH project in a community would need to be considered as a potential confounder in any health-related analysis. A different study design from that used in 2010 would be required to control for any confounding by the implementation and previous success of the program itself. Another option could be to undertake a large cohort study that followed people over time. However, this would be expensive and onerous for the subjects, and the use of routinely collected health data is recommended before exploring more detailed and costly research methods.

Any study re-evaluating the health outcomes of the relatively small HfH program is unlikely to establish causal links. It may add to the already prodigious literature identifying housing as a determinant of health, but given the diminutive resources in the sector and the overwhelming need identified in this thesis and other reports (35) to bring housing to a basic minimum standard, the resources required to undertake any health study should be carefully balanced against the resources needed to equitably raise and maintain houses to a basic minimum standard. Research should also be directed toward understanding how to sustain and scale the benefits of the HfH program and similar initiatives across a diverse and complex geographic and social landscape, ensuring a minimum standard of house function for all Australians.

Chapter 8 of this thesis acknowledges that First Nations people in Australia hold important local and historical knowledge on responding to environmental changes and extreme environmental conditions (64). Further research with Aboriginal communities to explore the use of traditional knowledges would help to understand and inform appropriate climate adaptation strategies. This is an active area of research with further research underway (105).

6.0 Final Conclusions and Recommendations

The NSW Health HfH Program has made significant improvements to Aboriginal community housing over the 20-year study period. Program implementation has improved over time, and the cost per house has reduced. For a relatively modest cost, it is possible to achieve substantial improvements towards a minimum standard of house functionality that supports safe and healthy living.

The NSW Aboriginal community housing sector overall is not adequately resourced to support safe and healthy living. A lack of maintenance and quality assurance systems was identified as the primary reason for this failure to provide suitable housing for tenants. Greater investment in housing repair and maintenance is required within the Aboriginal community housing sector, along with future consultation on aligning the governance of the HfH Program and dataset with the Close the Gap priority reforms. Such investment in housing is an investment in assets and people, the benefits of which will likely be reflected in the health system over the long term.

The Aboriginal population in NSW is disproportionately exposed to the impacts of climate, including extreme heat, fire intensity, flooding and rainfall variability. This is predicted to increase in the coming decades, with climate change having a risk multiplier effect, impacting pre-existing health disparities and having implications for health and adaptation planning.

6.1 Recommendations

These recommendations are made in the absence of extensive consultation with Aboriginal communities and Aboriginal housing providers, which should underpin their development and implementation.

The following recommendations apply to the NSW Health Housing for Health program:

- Continue to deliver the NSW Health Housing for Health program and update and maintain the consolidated NSW Housing for Health dataset to include all projects as they are completed.
- Work closely with community housing providers to embed the principles of the HfH Program into routine maintenance programs.
- Investigate options to increase Aboriginal governance of the HfH Program.
- Establish protocols for broader public access to the HfH Program data, including continuing to strengthen Aboriginal governance and sovereignty of the data and formalising processes in line with evolving ethics requirements.
- Undertake further analyses that include the most recent HfH Program data (since 2017) to assist in strengthening the evidence for improving Aboriginal community housing in NSW.
- Undertake a comprehensive cost-benefit economic analysis of the NSW HfH Program.
- Include qualitative and participatory research methods in future evaluations of the NSW Health Housing for Health Program to ensure the views, preferences, expertise and knowledges of key Aboriginal stakeholders are embedded in the evaluation outcomes and recommendations.
- Undertake an updated health outcomes evaluation linking the updated HfH Program survey data to available health data.

The data described in this thesis relate to the NSW Aboriginal community housing sector, and care should be taken when generalising the results presented in this thesis to the sector throughout Australia. The following recommendations apply to the NSW Aboriginal community housing sector but may also have relevance for the wider Australian Aboriginal housing sector and the social housing sector more broadly:

- NSW and Australian governments secure long-term policy and governance commitment to improve Aboriginal housing in NSW and adequately resource the Aboriginal community housing sector to ensure all housing meets a minimum standard that supports safety and healthy living.
- Clearly articulate and adopt minimum design, maintenance and quality assurance standards for Aboriginal community (and other social) housing to promote safe and healthy living in a manner that acknowledges appropriate cultural mores,
- Audit Aboriginal community housing cyclically and when tenancies change to ensure all Aboriginal community housing meets the minimum standard criteria for safety and healthy living.

- Improve and prioritise repair and maintenance systems in the NSW Aboriginal community housing sector, incorporating cyclical maintenance programs to ensure all existing housing stock meets minimum standards for safety and health to protect both assets and householders.
- Community-wide maintenance audits and repairs should accompany any initiative for new house construction or upgrades in a community.
- Upgrades to existing housing stock should consider culturally appropriate solutions to minimise crowding and manage temperature control,
- Prioritise regional and remote area housing in any programs or initiatives to improve the condition of Aboriginal community housing in NSW,
- Continue to address crowding as a priority issue in Aboriginal community housing to improve the effectiveness of repair and maintenance.

The following recommendations focus on climate-related issues more broadly :

- Undertake a review of the nine Healthy Living Practice priorities (9 HLPs), considering current health and climate evidence, including the increasing impact of climate on health,
- Examine and invest in culturally appropriate climate adaptation strategies to manage housing, including temperature control, that do not financially burden households.
- Engage with Aboriginal communities to explore the use of traditional knowledges to inform climate adaptation strategies,
- Implement a Climate Health and Equity Impact Statement for all new government policies and programs to ensure any long-term implications for climate, health and equity are adequately considered.

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"Knowing is not enough; we must apply.
Willing is not enough; we must do."

- Johann Wolfgang von Goethe (1749-1832)

Appendices

Appendix I
Survey Items by Critical Healthy Living Practice Indicator

Below is a list of the 11 Critical Healthy Living Practice Indicators used by Healthabitat and the NSW Housing for Health (HfH) Program to assess whether a house functions to support safe and healthy living. Each CHLP Indicator comprises between 1 and 17 items from the HfH surveys.

Table I: Survey Items by Critical Healthy Living Practice Indicator.

Critical HLP Indicator	Survey item
1. Power, water, and waste connected	Electricity available
	Waste water system type
	Water available
	All waste water OK
2. Electrical safety	Aerial power connection to house is OK
	Power points: all tested OK
	Lights switch: all tested OK
	Light fittings: all tested OK
	W/machine power point test OK
	Location/position of laundry power point OK
	Safety switch OK
	Meter box OK?
	Electrical earth connection
	Electrical switch board OK?
3. Gas safety	Gas installation OK
4. Structure and access	Walls: outside condition
	Floor: finish and condition
	Lights: % tested OK
	Septic tank lid/s OK
	Termites NOT present
	Disabled/frail aged access OK
	Stairs and handrails OK
5. Fire safety	Fire escape is possible via all doors AND either all OR some windows
	Smoke detectors fitted: number
	Smoke detectors: number not testing OK
6. Shower working adequately	Shower hot water available

Critical HLP Indicator	Survey item
	Shower cold water available
	Shower: hot water temperature
	Shower taps: hot OK
	Shower taps: cold OK
	Shower rose OK
	Shower drainage OK
7. Facilities to wash children*	Bath/ basin/ tub available
(bath, large basin, or laundry tub)	Bath/ basin/ tub: hot water available
	Bath/ basin/ tub: cold water available
	Bath/ basin/ tub taps: Hot OK
	Bath/ basin/ tub taps: Cold OK
	Bath/ basin/ tub spout check OK
	Bath/ basin/ tub plug
	Bath/ basin/ tub drainage OK
	Bath/ basin/ tub secure OK
	If basin: is basin large enough to wash a young child
	If laundry tub: is independent drainage for washing machine available
8. Laundry services	W/machine space available
	WM taps: Hot OK
	WM taps: Cold OK
	W/ machine drainage OK
	Laundry Floor waste OK?
	W/machine power point test OK
	Location/position of laundry power point OK
	Laundry tub available
	Laundry tub secure
	Laundry tub taps: Hot OK
	Laundry tub taps: Cold OK
	Laundry tub drainage OK
	Laundry tub spout OK
9. Flush toilet working	Full flush test OK
	Refill time OK
	Cistern OK
	Pan is OK
10. All drains working	W/ machine drainage OK
	Shower drainage OK
	Bath drainage OK
	Toilet: floor waste OK
	Laundry Floor waste OK?
	Basin drainage OK

Critical HLP Indicator	Survey item
	Shower: floor waste OK?
	Sink Drainage OK
	Bath area: floor waste OK
	Basin area: floor waste OK
	Drainage from HWS OK
	Laundry tub drainage OK
	All waste water OK
11. Facilities to store, prepare and cook food	Bench material OK
	Splash back OK
	Kitchen cold water available
	Kitchen hot water available
	Kitchen: cold water tap OK
	Kitchen: hot water tap OK
	Storage area: above bench height and bench area
	Sink available?
	Kitchen sink spout check OK
	Sink Drainage OK
	Cooktop provided (stove type)
	All hotplates and knobs working OK (stove)
	Oven working OK
	Fridge/Freezer available?
	Freezer temp.
	Fridge temp.
	How many kitchens are available?

Notes:

* For washing a young child, the number of key items will vary depending on whether the house relies on a bath, basin or laundry tub.

Appendix II
NSW Health Approvals for the Use and Publication of Housing for Health Program Data

The development of this PhD proposal was a collaboration between NSW Health and the University of Sydney. The de-identified data used in the analyses in Chapters 4, 5 and 6 of this thesis were collected by NSW Health as part of implementing the NSW Housing for Health (HfH) program. Health Protection NSW, a section of the NSW Ministry of Health, was responsible for collecting the data and is the data custodian for the NSW Health Housing for Health Program data.

An application was made to formally release the NSW Housing for Health program data to the University of Sydney for use and publication as part of this PhD. The application covered: the Project Feasibility Assessment data; the House Survey and Fix data, and Project Expenditure Data. Approval was received from the data custodian, Health Protection NSW, for the release of the data for analysis and publication under Health Administration Regulation 2020, Clause 16(2) – Disclosure of Information (Approval H23/56859; dated 8 August 2023). The Data Custodian advised that specific ethics approval was not required prior to the release of the dataset by Health Protection NSW, as the Housing for Health data relates to housing and does not include any personal or health information about people or individuals, nor identify specific houses or communities. A copy of the Approval for Disclosure of Information and the Confidentiality Undertaking is included in this Appendix.

NSW Health also provided separate approvals to publish and cover costs of open-source publication for the published articles in Chapters 4, 7 and 8, and the prepared manuscript presented in Chapter 5. These were approved through internal briefing documents, the details of which are listed below:

Table II: Details of NSW Health approvals for manuscript publication

Chapter	Manuscript Title	NSW Health approval number	Approval Date
4	Prioritising Housing Maintenance to Improve Health in Indigenous Communities in NSW over 20 years	H20/59674	7 Jul 2020
5	Towards minimum standards for healthy housing in Aboriginal communities in New South Wales, Australia - are we there yet?	H24/110982 HA-2024-0003093	5 Jul 2024 19 Jul 2024
7	The economic evaluation of a housing maintenance project to improve the health of Aboriginal housing tenants in NSW: A scoping literature review and protocol for an economic analysis.	H22/89605	10 Oct 2022
8	Aboriginal Population and Climate Change in Australia: Implications for Health and Adaptation Planning	H22/35214	11 May 2022

HEALTH ADMINISTRATION REGULATION 2020

APPROVAL UNDER CLAUSE 16(2) - DISCLOSURE OF INFORMATION

I, **Dr Jeremy McAnulty**, Executive Director of Health Protection NSW, pursuant to clause 16(2) of the Health Administration Regulation 2020, hereby approve the release of information described in Schedule 1 below, to Jeffrey Standen, PhD Candidate at the School of Public Health, Faculty of Medicine and Health, University of Sydney. The Information in Schedule 1 is released subject to the following conditions:

1. the conditions listed in Schedule 2;
2. data will be stored on a password-protected local area network, and not on any portable devices including external drives, laptops or desktop computers; and
3. The NSW Ministry of Health or their representative will be permitted access to the relevant project materials for the purpose of audit as soon as it is reasonably possible upon request by the NSW Ministry of Health. Any such access is to take place at times mutually agreed, during business hours and subject to such reasonable conditions relating to occupational health and safety, security, and confidentiality as the Institution may require.

Signed this .....8th..... day of .....August..... 2023

.....

Dr Jeremy McAnulty PSM
Executive Director
Health Protection NSW

SCHEDULE 1

De-identified unit record data as follows:

1. A dataset of the NSW Health Housing for Health program Data Collection comprising records relating to NSW Health Housing for Health program data held by the Environmental Health Branch of the New South Wales Ministry of Health]/Health Protection NSW for the period 1998 to most recent available, including the following domains:

    - Project feasibility assessment data including community characteristics (e.g. remoteness classification, evidence of repair and maintenance programs)
    - House Survey and Fix data including house characteristics (e.g. date of surveys, size and age of house, population, number of bedrooms, electrical safety, hot water temperature, taps working etc)
    - Project expenditure data (costs by house, by trade and by stage)

SCHEDULE 2

CONDITIONS FOR DISCLOSURE OF INFORMATION

1. The data are to be used only for the PhD project entitled 'An analysis of a housing infrastructure initiative and its implications for public policy ';
2. the data are to be kept in a secure physical and electronic environment that is accessible only by persons directly involved in the above project;
3. a confidentiality undertaking will be completed prior to the information being released;
4. the NSW Ministry of Health, Health Protection NSW is to be acknowledged in any publication or report that arises from the use of the data;
5. the data will not be matched with information on individuals from another source other than the datasets specified in the Schedule/s;
6. a copy of any publication or report is to be provided to the NSW Ministry of Health at least two weeks prior to public release, emailed to MOH-HealthProtection@health.nsw.gov.au;
7. the data are to be destroyed after seven years after the approval of the PhD;
8. no information will be released with which it may be possible to identify an individual house;
9. individual houses identified in the data are not to be specifically identified in any publication or report;
10. this authority continues until and unless it has been revoked in writing;

Additional conditions for use of linked data

11. where record linkage was carried out by the Centre for Health Record Linkage, the Centre for Health Record Linkage is to be acknowledged in any publication, report or presentation that arises from the use of the data;

Additional conditions for use of information about Aboriginal people

12. the use of Aboriginal and Torres Strait Islander status is subject to the approval of the Aboriginal Health and Medical Research Council (AH&MRC) and AH&MRC Ethics Committee if one or more of the following apply:
    - Aboriginality is a key determinant
    - data collection is explicitly directed at Aboriginal peoples
    - Aboriginal peoples, as a group, are to be examined in the results
    - the information may have an impact on one or more Aboriginal communities
    - Aboriginal health funds are a source of funding.

Additional conditions for use of Cause of Death Unit Record File (COD URF)

13. a copy of any publication or report is to be provided to the Australian Coordinating Registry (ACR) for the COD URF at least two weeks prior to public release, emailed to BDM.CODURF@justice.qld.gov.au;
14. any publication, report or data output will include:

a) the following source: “Source: Cause of Death Unit Record File held by the NSW Ministry of Health Secure Analytics for Population Health Research and Intelligence”; and

b) the following acknowledgement: “The Cause of Death Unit Record File (COD URF) is provided by the Australian Coordinating Registry for the COD URF on behalf of the NSW Registry of Births, Deaths and Marriages, NSW Coroner and the National Coronial Information System.”

c) any statistical tables, or figures derived from statistical tables, using records from the COD URF must not show cell counts less than five.

15. securely destroy the data and notify the ACR within the timeframe specified in the ethics application or earlier as to the destruction (unless approval for extension or indefinite retention has been provided by the ACR/data custodians). Notification should be to the ACR, emailed to BDM.CODURF@justice.qld.gov.au, and to the NSW Ministry of Health, emailed to moh-cee@health.nsw.gov.au;

16. acknowledge that these conditions continue to apply after projects end and/or approvals expire and Investigators will comply with any audit processes required to check the compliance of these and any additional conditions of approval; and

17. acknowledge that a breach of any of these conditions may result in further data access being restricted or current access being revoked.

CM: H23/56859-3

CONFIDENTIALITY UNDERTAKING

I, Jeffrey Standen, PhD Candidate at the School of Public Health, Faculty of Medicine and Health, University of Sydney understand that, in receiving unit record data of the NSW Health Housing for Health program from 1998 to most recent available for the project entitled 'An analysis of a housing infrastructure initiative and its implications for public policy', I will have access to confidential data, which includes project feasibility assessment, survey and fix, and financial information in respect of individual projects and houses.

I undertake strictly to preserve the confidentiality of these data, and understand that the disclosure of information may constitute an offence under Section 22 of the Health Administration Act 1982 (attached). I understand that I must comply with the conditions described in the Approval Under Clause 16(2) - Disclosure Of Information.

I agree to ensure that any staff of University of Sydney working on the above project are aware of the provisions of this Undertaking and the need to comply with them. I further agree that any report that is derived from the data will present information in an aggregate form only and that no personal information, or identifiable housing information, will be included in any report.

Signed: [redacted]
in the presence of

(name): IAN MYERS

(signature): [redacted]

(position): Staff Specialist - Childrens Hosp. at Westmead.

Date: 13/9/2023

Appendix III
Correction to Published Article

Appendix C of this thesis is a published Correction in the *International Journal of Environmental Research and Public Health (IJERPH)* to the original publication of "Aboriginal Population and Climate Change in Australia: Implications for Health and Adaptation Planning".

Formatting changes made to the accepted manuscript during copy editing resulted in errors in some of the figures and tables in the initial publication. A correction was subsequently published, and the online publication was updated to correct these errors. As lead and corresponding author for the original publication, I supervised the corrections to the original manuscript with the co-authors and communicated with the journal to ensure the corrections were published and the original electronic version was corrected. The publication presented in Chapter 8 comprises the corrected publication currently available online.

The Correction to the original published article is published as:

> Standen JC[1,2,*], Spencer J[1,†], Lee GW[1,2], Van Buskirk J[2], Matthews V[3,†], Hanigan I[2], Boylan S[2], Jegasothy E[2,3], Breth-Petersen M[2], Morgan GG[2,3]. "Correction: Standen et al. Aboriginal Population and Climate Change in Australia: Implications for Health and Adaptation Planning. *Int. J. Environ. Res. Public Health* 2022*, 19,* 7502*". Int. J. Environ. Res. Public Health* 8688*, 19, 16378*.

1 Health Protection NSW, St Leonards, NSW 2065, Australia

2 School of Public Health, Faculty of Medicine and Health, University of Sydney, Camperdown, NSW 2006, Australia

3 University Centre for Rural Health, Faculty of Medicine and Health, University of Sydney, Lismore, NSW 2480, Australia

***** Correspondence: jeff.standen@health.nsw.gov.au; Tel.: +61-2-9391-9627

† Affiliation to Aboriginal country: Jessica Spencer Wiradjuri; Veronica Matthews Quandamooka.

It is available as an open-source publication at: https://doi.org/10.3390/ijerph192416378

International Journal of
Environmental Research and Public Health

MDPI

Correction

Correction: Standen et al. Aboriginal Population and Climate Change in Australia: Implications for Health and Adaptation Planning. *Int. J. Environ. Res. Public Health* 2022, *19*, 7502

Jeffrey C. Standen [1,2,*], Jessica Spencer [1,†], Grace W. Lee [1,2], Joe Van Buskirk [2], Veronica Matthews [3,†], Ivan Hanigan [2], Sinead Boylan [2], Edward Jegasothy [2,3], Matilde Breth-Petersen [2] and Geoffrey G. Morgan [2,3]

1 Health Protection NSW, St Leonards, NSW 2065, Australia
2 School of Public Health, Faculty of Medicine and Health, University of Sydney, Camperdown, NSW 2006, Australia
3 University Centre for Rural Health, Faculty of Medicine and Health, University of Sydney, Lismore, NSW 2480, Australia
* Correspondence: jeff.standen@health.nsw.gov.au; Tel.: +61-2-9391-9627
† Affiliation to Aboriginal country: Jessica Spencer Wiradjuri; Veronica Matthews Quandamooka.

Error in Figures 2c and 3a

In the original publication [1], there was an error in Figure 2c containing a map of climate exposures with bar charts indicating relative exposure by category across Aboriginal and non-Aboriginal populations. The exposures in Figure 2c were projected additional days exceeding 35 °C annually, 2020–2039. There was also an error in Figure 3a containing a map of annual days with Macarthur Forest Fire Danger Index exceeding 50 (i.e., "severe" fire danger), with bar charts indicating relative exposure by category across Aboriginal and non-Aboriginal populations for historical data between 1990 and 2009. During publication, formatting changes of the accepted manuscript occurred.

The categories in the bar charts in Figures 2c and 3a were incorrect. The corrected Figures 2 and 3 appear below. There are no changes to the text in the manuscript.

check for updates

Citation: Standen, J.C.; Spencer, J.; Lee, G.W.; Van Buskirk, J.; Matthews, V.; Hanigan, I.; Boylan, S.; Jegasothy, E.; Breth-Petersen, M.; Morgan, G.G. Correction: Standen et al. Aboriginal Population and Climate Change in Australia: Implications for Health and Adaptation Planning. *Int. J. Environ. Res. Public Health* 2022, *19*, 7502. *Int. J. Environ. Res. Public Health* **2022**, *19*, 16378. https://doi.org/10.3390/ijerph192416378

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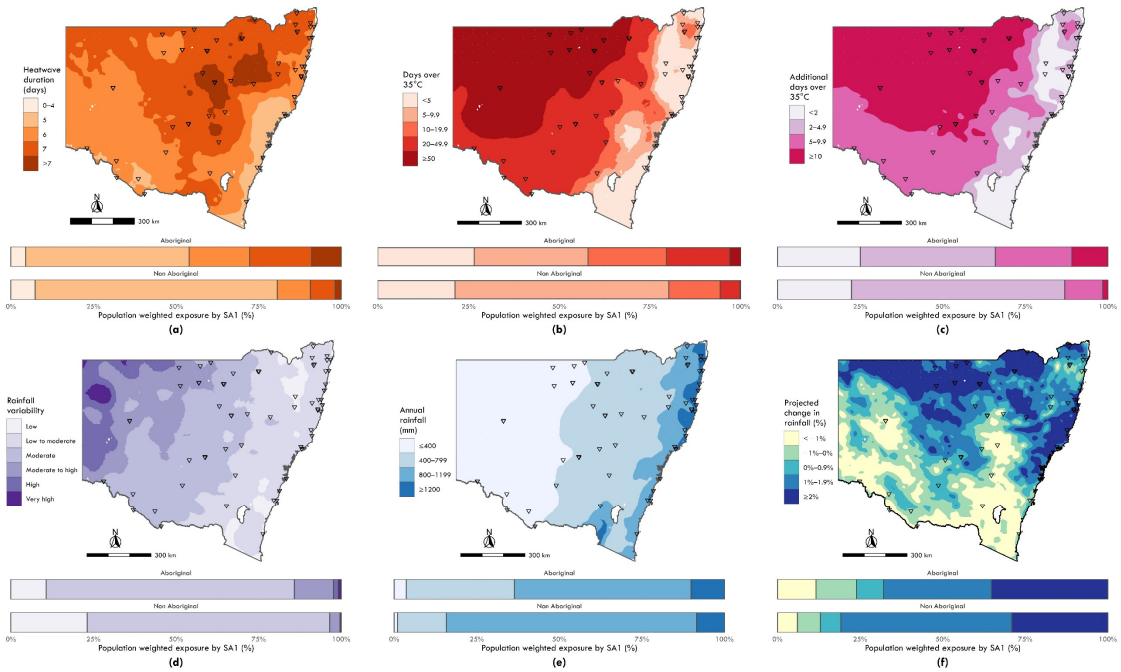

Figure 2. Maps of climate exposures with bar charts indicating relative exposure by category across Aboriginal and non-Aboriginal populations. Exposures include: (**a**) Historical annual average maximum heatwave duration (days), 1990–2019; (**b**) Historical annual days exceeding 35 °C, 1990–2019; (**c**) Projected additional days exceeding 35 °C annually, 2020–2039; (**d**) Historical annual rainfall variability, 1990–2019; (**e**) Historical annual rainfall in millimetres (mm), 1990–2019; (**f**) Projected relative change in annual rainfall, 2020–2039. Triangle markers denote identified discrete Aboriginal communities. See Appendix A for a summary of descriptive statistics for selected climate exposure estimates on a continuous scale.

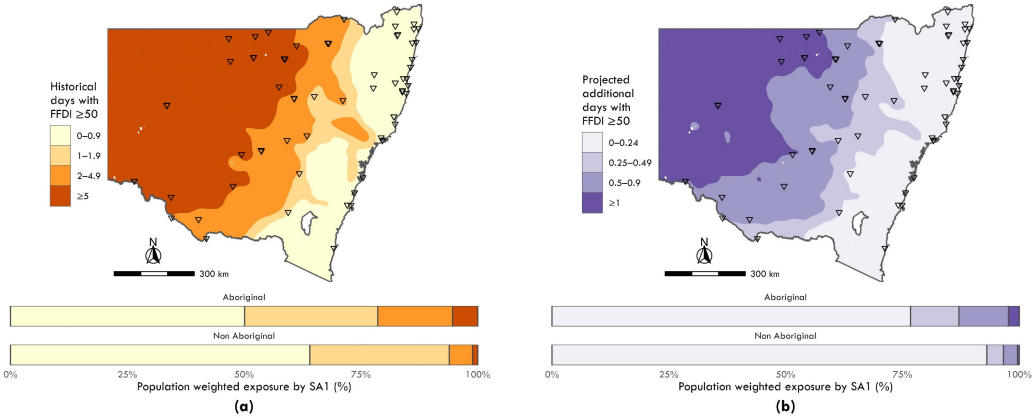

Figure 3. Maps of annual days with Macarthur Forest Fire Danger Index exceeding 50 (i.e., "severe" fire danger), with bar charts indicating relative exposure by category across Aboriginal and non-Aboriginal populations: (**a**) historical between 1990 and 2009; and (**b**) projected for 2020–2039. See Appendix A for a summary of descriptive statistics.

Error in Table A2

In the original publication, there was a formatting error in Table A2 containing climate exposure estimates by Aboriginal versus non-Aboriginal usual resident populations stratified by the Index of Relative Socioeconomic Disadvantage (IRSD). The IRSD quintile 5 for the relative change in drought-affected months (1990–2006 vs. 2007–2020) was included in the online version but omitted from the pdf version of the published manuscript.

The relevant section of the corrected Table A2 appears below.

Table A2. Climate exposure estimates by Aboriginal versus non-Aboriginal usual resident populations stratified by the Index of Relative Socioeconomic Disadvantage (IRSD). Small cell counts for either population have been aggregated.

Climate Exposure	IRSD Quintile	Exposure Category	Aboriginal URP		Non-Aboriginal URP		Binary Risk Category	High-Risk Exposure Population (%)		Odds Ratio
			n	%	n	%		Aboriginal	Non-Aboriginal	
Relative change in drought-affected months (1990–2006 vs. 2007–2020)	1	≤−10%	13,856	15.3%	344,184	23.3%	Lower			2.12 [2.09–2.15]
		−9.9–−5%	25,938	28.6%	609,131	41.2%	Lower			
		−4.9–−2.5%	9507	10.5%	135,713	9.2%	Lower			
		−2.4–0%	8878	9.8%	80,167	5.4%	Lower			
		0.01–5%	17,490	19.3%	178,228	12.1%	Higher	35.9%	20.9%	
		>5%	15,134	16.7%	130,805	8.8%	Higher			
	2	≤10%	8460	18.5%	418,629	30.7%	Lower			1.76 [1.72–1.79]
		−9.9–−5%	13,802	30.2%	452,136	33.1%	Lower			
		−4.9–−2.5%	4331	9.5%	109,654	8.0%	Lower			
		−2.4–0%	3622	7.9%	77,300	5.7%	Lower			
		0.01–5%	10,035	22.0%	202,484	14.8%	Higher	33.9%	22.5%	
		>5%	5427	11.9%	105,395	7.7%	Higher			
	3	≤−10%	6724	23.1%	459,306	38.2%	Lower			1.70 [1.66–1.75]
		−9.9–−5%	8323	28.6%	365,938	30.4%	Lower			
		−4.9–−2.5%	3383	11.6%	87,006	7.2%	Lower			
		−2.4–0%	2549	8.8%	68,078	5.7%	Lower			
		0.01–5%	5718	19.7%	153,570	12.8%	Higher	27.9%	18.5%	
		>5%	2401	8.3%	69,538	5.8%	Higher			
	4	≤−10%	6010	29.9%	526,829	45.0%	Lower			1.89 [1.83–1.96]
		−9.9–−5%	5613	27.9%	335,048	28.6%	Lower			
		−4.9–−2.5%	1503	7.5%	61,476	5.3%	Lower			
		−2.4–0%	1847	9.2%	66,667	5.7%	Lower			
		0.01–5%	3834	19.0%	134,397	11.5%	Higher	25.6%	15.4%	
		>5%	1324	6.6%	45,693	3.9%	Higher			
	5	≤−10%	4192	34.4%	645,501	43.2%	Lower			2.65 [2.53–2.79]
		−9.9–−5%	4677	38.4%	669,733	44.8%	Lower			
		−4.9–−2.5%	697	5.7%	39,584	2.6%	Lower			
		−2.4–0%	693	5.7%	40,711	2.7%	Lower			
		0.01–5%	1528	12.5%	81,108	5.4%	Higher	15.9%	6.6%	
		>5%	405	3.3%	17,986	1.2%	Higher			

The authors apologize for any inconvenience caused and state that the scientific conclusions are unaffected. This correction was approved by the Academic Editor. The original publication has also been updated.

Reference

1. Standen, J.C.; Spencer, J.; Lee, G.W.; Van Buskirk, J.; Matthews, V.; Hanigan, I.; Boylan, S.; Jegasothy, E.; Breth-Petersen, M.; Morgan, G.G. Aboriginal Population and Climate Change in Australia: Implications for Health and Adaptation Planning. *Int. J. Environ. Res. Public Health* **2022**, *19*, 7502. [CrossRef] [PubMed]

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