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## Health Impacts and Economic Costs of Residential Fires (RESFIRES study): Protocol for a population-based cohort study using linked administrative data

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8 **Health Impacts and Economic Costs of Residential Fires (RESFIRES study): Protocol for a**  
9 **population-based cohort study using linked administrative data**  
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16 **BMJ Open**

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**ABSTRACT**

**Introduction:** Residential fires remain a significant global public health problem. It is recognised that the reported number of residential fires, fire-related injuries and deaths significantly underestimate the true number. Australian surveys show that around two-thirds of respondents who experience a residential fire are unwilling to call the fire service, and studies from the US and New Zealand highlight that many individuals who access medical treatment for fire-related injuries do not have an associated fire incident report. The objectives of this study are to quantify the incidence, health impacts, risk factors and economic costs of residential fires in New South Wales, Australia.

**Methods and analysis:** The RESFIRE cohort will include all persons living at a NSW residential address which experienced a fire over the period 2005-2014. Nine data sources will be linked to provide a comprehensive picture of individual trajectories from fire event to first responder use (fire and ambulance services), emergency department presentations, hospital admissions, burn outpatient clinic use and death. This data will be used to describe the circumstances and characteristics of residential fires, provide a profile of fire-related injuries (including burns, smoke inhalation, other injuries sustained during fire) examine trends over time, and explore the relationship between fire circumstance, emergency and health services utilisation, and health outcomes. Regression modeling, including multilevel modelling techniques, will be used to explore factors that impact on these relationships. Costing models will be constructed.

**Ethics and dissemination:** Ethical approval for this study has been obtained. The reference group overseeing this study comprises key stakeholders including NSW Fire and Rescue Service, policy agencies, health service providers and burns clinicians ensuring wide dissemination of results and that the information will inform practice and identify areas for targeted prevention. Summary reports in formats designed for policy audiences in parallel with scientific papers will be produced.

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3 Article summary:  
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5 Strengths and limitations of this study  
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- 8 • This large population-based retrospective cohort study will, for the first time, link nine  
9 administrative datasets to provide a comprehensive profile of residential fires, and provide  
10 the ability to track an individual's pathway through first responder and health care system and  
11 to map their subsequent health outcomes.  
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  - 13 • This study will provide much needed data on the incidence, risk factors, health outcomes and  
14 economic costs of residential fires.  
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  - 16 • Although more serious injuries requiring emergency department and/or hospital admission  
17 will be identified in this study, individuals who may only access general practitioners, medical  
18 centers or pharmacies to treat their injuries are not included. This may lead to an  
19 underestimation of the true burden of residential fires, although if people extinguish minor  
20 fires themselves and only sustain minor injuries that do not require medical treatment the  
21 health impact and economic cost is likely to be minimal.  
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## INTRODUCTION

Fire-related burns are the fourth most common cause of unintentional trauma worldwide and have been identified as a global priority for prevention.[1, 2] An estimated 265,000 people each year die as result of fires,[3] and in most industrialised countries the vast majority of fire-related deaths and injuries occur in the home.[4] Fire prevention programs that promote the use of smoke alarms are the leading strategies adopted to minimise this burden.[2, 5] Australia is among the countries that have implemented strategies and best practices in fire prevention programs including legislation that requires functioning smoke alarms in every home.[6, 7] Despite this, residential fires remain a significant public health problem in Australia. In New South Wales (NSW), Australia's most populous state, over a five year period between 2013-2017 there were 34,000 reported residential fires, resulting in 5,000 injuries and 144 deaths.[8-12] Estimates suggest that more than half of these may have been prevented if the homes had working smoke alarms and a practiced home escape plan in place.[13]

It is well recognised that the reported number of residential fires, fire-related injuries and deaths significantly underestimate the true number.[8] Australian population-based surveys show that around two-thirds of respondents who experience a residential fire are unwilling to call the fire service,[14] and studies from the US and New Zealand highlight that many individuals who access medical treatment for fire-related injuries do not have an associated fire incident report.[15] Although most residential fire-related injury and deaths result from smoke inhalation and toxic fumes rather than burns,[16-18] under the International Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10) classification system which is used in many administrative health data collections, smoke-inhalation (ICD-10 code T59) is not included with burns (ICD-10 codes T20-T31) and hence is commonly not captured in burn-related hospital and death statistics.[19] The urgent need for accurate data to inform the development and evaluation of targeted residential fire prevention strategies has been identified by the NSW Coroner [20] and Australian Senate.[21]

Similarly, the costs of residential fires extend significantly beyond damage to the property and are estimated to be about 10 times the reported cost [22]. Research into the total cost of fire is defined as the losses that fire causes, directly and indirectly, and the cost of provisions to prevent or mitigate the losses caused by the fire.[23] In Australia, the total cost of fire was estimated in 2009 to be approximately \$12 billion per annum or 1.3% of the country's gross domestic product.[24] In similar cost studies conducted overseas it has been observed that the estimates used have wide bands of uncertainty with a need for improved methods for calculating fire structure and material performance and costs.[25, 26]

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3 The objectives of this study are to quantify the incidence, risk factors, health impacts and economic  
4 costs of residential fires in NSW. Using linked person-level data this study will provide, for the first  
5 time, a comprehensive picture of first responder use (fire and ambulance services), health service  
6 utilisation (Emergency Department, hospital in-patient and specialist burns outpatient clinics), health  
7 outcomes (length of stay, rehabilitation, re-admissions and death) and economic costs. Specifically, it  
8 will address the following research questions:  
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- 13 1. What is the incidence, risk factors, injury profile, emergency services and health service  
14 utilisation and health outcomes for people resident at an address which has experienced a  
15 fire;  
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- 18 2. Do first responder and health service utilisation and health outcomes differ by type of fire,  
19 smoke alarm use, nature of injury, demographic characteristics or geographic location?  
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- 22 3. Has fire incidence, circumstance and fire-related injuries changed over the last decade, and if  
23 so do these trends differ between geographical location?  
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- 26 4. To what extent is there underreporting of residential fires, and related injuries and deaths  
27 across the datasets?  
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- 30 5. What are the total economic costs, including future projected costs, associated with  
31 residential fires and residential fire-related injuries.  
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## 33 **METHODS AND ANALYSIS**

### 34 **Study population and cohort identification**

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36 Just under a third of Australia's population reside in NSW, and of the 8 million residents, two thirds  
37 live in the Sydney Metropolitan region.[27] NSW has an estimated 2.8 million private dwellings, over  
38 half (56.1%) of which are single or two person households, 32.5% are three or four person households,  
39 and 11.3% contain five or more people.[28] The study cohort will include all persons residing at a NSW  
40 residential address which experienced a fire in the period 1 January 2005 to 31 March 2015. In  
41 addition, any person identified as having a residential fire-related injury or death from any of the  
42 linked administrative health datasets during this period will be included in the cohort irrespective of  
43 whether there is record of residential fire.  
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### 50 **Data sources**

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53 Nine data sources will be linked to identify the complete study cohort, and to provide information on  
54 each individual's health trajectory and costs. Datasets included and the case selection criteria for each  
55 dataset are shown in Table 1.  
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3 The Australian Computer Aided Dispatch (CAD) system records all '000' calls to emergency services  
4 requiring Fire and Rescue NSW (FRNSW) or ambulance attendance. The CAD will be used to identify  
5 all NSW residential addresses that experience a fire event for which a first responder service is called.  
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7 The FRNSW Australian Incident Reporting System (FRNSW AIRS) contains detailed information on the  
8 circumstances, management, and consequences all fires attended by FRNSW recorded in the CAD.  
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10 This information includes ignition factors, area of fire, type of structure, presence or absence of  
11 functioning smoke alarm, and whether alcohol use was contributing factor, and will be used in  
12 descriptive analysis and as covariates in the models.  
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17 The NSW Ambulance datasets comprise data from the ambulance CAD system, the paper-based  
18 Patient Health Care Record (PHCR) and electronic medical record (eMR). The eMR includes clinical and  
19 treatment information on the patients. This includes case nature or diagnosis, vital signs, management  
20 and treatment type, and result or outcome of treatment – that is patient transportation or not and  
21 code. The PHCR contains information as per eMR and includes drug and fluid treatment, cardiac  
22 management and equipment, and medication used. The CAD records have been available from July  
23 2000, the PHCR data are available from April 2001 and the eMR data are available from 2011.  
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29 The NSW Emergency Department Data Collections (EDDC) contains information about ED  
30 presentations to NSW hospitals. The NSW EDDC covers 80 EDs, including all EDs in public hospitals in  
31 the Sydney metropolitan area and captures about 75% of all presentations to NSW EDs. The  
32 information reported includes patient demographics, mode of arrival, triage category, whether  
33 admitted to ward, and presenting diagnosis. Across EDs in NSW presenting diagnosis can be recorded  
34 using the Australian version of the International Statistical Classification of Diseases and Related  
35 Problems, 9<sup>th</sup> revision, Clinical Modification, (ICD-9-CM),[29] or the Australian Modification of the 10<sup>th</sup>  
36 revision, (ICD-10-AM),[30] or the Systematized Nomenclature of Medicine, Clinical Terms (SNOMED  
37 CT).[31]  
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45 The NSW Admitted Patient Data Collection (APDC) will be used to identify residential fire-related  
46 hospital admissions, and to provide information for risk-adjustment and hospitalisation costs. These  
47 data collections contain information on demographics, diagnosis related groupings, source of referral,  
48 and diagnosis and external causes coded to ICD-10-AM. Audits have shown good to excellent coding  
49 of diagnosis, procedures and external causes in Australian hospital data.[32, 33] Data is collected on  
50 all episodes of care in hospital with end with the discharge, transfer or death of the patient, or when  
51 the service category for the patient changes (for example a change from acute care to rehabilitation  
52 during a stay in the same hospital). Thus for a single burn an individual may have multiple episodes of  
53 care recorded. To avoid over-counting of the same injury, a continuous period of stay will be  
54 constructed by combing all contiguous episodes of care for the same patient. Where episodes of care  
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3 are non-contiguous, but the primary diagnoses are the same at the 3-character level (i.e. T20) for an  
4 individual, the hospitalisation will be considered as a readmission for the burn. Where the episodes of  
5 care are non-contiguous and the primary diagnosis and external causes indicate a different burn  
6 location and mechanism the hospitalisation will be considered as a separate burn event.  
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10 The Agency for Clinical Innovation NSW Statewide Burn Injury Service (SBIS) Registry contains  
11 admission records and case details for all patients admitted to the three designated Burn Units in NSW  
12 (two adult, one pediatric) and captures both hospitalisations and outpatient clinical visits. Detailed  
13 demographic, etiological and clinical data items are collected including a free text description of the  
14 circumstances resulting in the burn injury. Cases are classified according to mechanism of injury.  
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19 Mortality data will be obtained from the NSW Registry of Birth, Deaths and Marriages (RBDM) and the  
20 Australian Bureau of Statistics Cause of Death Unit Record File (COD-URF). The RBDM contains records  
21 of all deaths of NSW residents, either certified by a registered medical practitioner or by the state  
22 coroner and provides date of death. Most deaths are registered within 4 weeks. The COD-URF provides  
23 additional information recorded on the death certificate including underlying cause of death and up  
24 to 20 contributing causes of death coded to ICD-10.[34]  
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### 30 **Data Linkage**

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32 The Centre for Health Record Linkage (CHeReL) will undertake the data linkage for this study, using  
33 probabilistic linkage techniques. Residential address from the FRNSW AIRS dataset will be used to  
34 identify cohort members across the health datasets held within the CHeReL Master Linkage Key (MLK),  
35 a system of continuously updated links between core health-related datasets in NSW.[35] Personal  
36 identifiers (full name, date of birth, sex and residential address) are used to identify individuals across  
37 and within the MLK datasets. The false positive and false negative rates for linkage between MLK  
38 datasets are 0.3% and 0.5% respectively.[36] The burns registry data (SIBS) which is not included in  
39 the MLK will be linked in a separate process using full name, date of birth, sex and address. The CHeReL  
40 applies a 'best practice protocol' for preserving individual privacy, which involves separating the  
41 process of linkage from the analysis of the health content.[37] Data custodians provide the personal  
42 identifiers to the CHeReL, and upload the health data extracts with the unique identifier for each  
43 individual in the cohort, provided by the CHeReL, into the Secure Unified Research Environment  
44 (SURE)[38] for analysis by researchers.  
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### 54 **Data Analysis plan**

#### 55 **Research Questions 1-2**

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3 Descriptive statistics will be used to quantify the incidence, demographic and socioeconomic  
4 characteristics, service utilisation, procedures and health outcomes of persons injured as a result of a  
5 residential fire and to describe the fire circumstance and characteristics. We will use multilevel  
6 modelling to identify individual-, fire characteristic-, and service utilisation factors associated with  
7 incidence of residential fire-related injury, and health outcomes. The main health outcomes of interest  
8 are total length of stay in days (LOS), length of stay for acute care, length of stay for rehabilitation,  
9 readmissions, 30-day mortality (fire-related and all-cause) and hospital costs.

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15 Variables of interest include:

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17 *Demographic and socioeconomic characteristics:* age, sex, country of birth, language spoken at home,  
18 pre-existing health status (measured using the Charlson Comorbidity Index (CCI) [39] with a 1 year  
19 lookback period [40]), health insurance status, and socioeconomic disadvantage (measured by the  
20 Australian Bureau of Statistics (ABS) Socioeconomic Indexes for Areas (SEIFA).[41]

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25 *Geographical measures:* Statistical area level 2 (SA2) which is a standard geographical area used by  
26 the ABS that broadly represents a community that interacts together socially and economically. SA2s  
27 have an average population of about 10,000 people (range 3,000-25,000).[42]

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32 *Injury characteristics:* type of injury will be classified into- burns, smoke inhalation and  
33 musculoskeletal injuries. Other characteristics of interest include total body surface area of burn  
34 (TBSA), depth of burn and procedures undertaken.

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39 *Service utilisation:* number of FRNSW and ambulance attendances, ED presentations, hospital  
admissions, and outpatient treatment.

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47 *Fire-related characteristics:* nature of fire (controlled, uncontrolled, electrical, chemical), day and time  
of fire, type of residential structure, action taken, areas of fire origin, presence of functioning smoke  
alarm and/or sprinkler system, evidence of alcohol consumption, geographical location of residence  
(mapped to postcode), and response agencies involved.

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### Research Question 3

To assess changes in trend in fire incidence, incidence of fire-related injuries over time, age-specific and age-standardised rates per 100,000 population with 95% confidence intervals will be calculated. Age-specific population estimates for NSW for 2005 to 2014 will be used to calculate age-standardised rates, using the Australian estimated resident population at June 2001 as the standard population. Depending on model fit Poisson or negative binomial regression will be used to examine the statistical significance of changes in trends over time.

#### Research Question 4

Capture-recapture modelling techniques will be used to determine to what extent residential fires, and related injuries and deaths are underreported across the datasets. Counting people captured by each system and the extent of overlap will provide the data required to run capture-recapture statistical models,[43-45] overall and by demographic and other variables. These models will estimate how many people attended hospital after injuries in fires but did not call the fire or ambulance service. They also will provide an estimate of injuries sustained after a residential fire but not captured in the hospital data (e.g., injuries treated in a primary care setting).

#### Research question 5

An injury cost model will be developed for all fires that are attended and not attended by FRNSW. Hospital admissions and number of days in hospital will be identified from the NSW APDC data. A dollar value for the cost of treatment for an individual will be calculated by multiplying the LOS (in days) for each episode of care by the daily AR-DRG cost per day provided in the National Hospital Cost Data Collection.[46] The Hospital Casemix Protocol will be used to assign costs to private inpatient episodes by AR-DRG. For emergency department attendances, costs will be assigned using the national average emergency department costs based on triage category. [47] The costs to individuals of the structural damage to the property will be estimated using the cost to insurance companies from the Insurance of Australia and out-of-pocket expenses. The costs of responding to the incident will be estimated based on the AIRS data on the services attended and material used. The cost of pain and suffering of individuals will be estimated using established values as per Tannous et al. (2017).[48]

A limitation of this study is that individuals who may access only general practitioners, medical centers or pharmacies to treat their injuries are not included. Primary care records will not be linked, as we are unable to detect from MBS records the reason for the GP visit, only that a GP visit occurred. However, it is worth noting that burns treated by GPs are likely to be minor in nature as there are rigorous guidelines in place for referral to a specialist outpatient burn clinic for more extensive burn injuries. Any outpatient burn clinic referral will be captured from the NSW Burn Injury Service Data, which includes outpatient visits. If people extinguish minor fires themselves and only sustain minor injuries that do not require medical treatment the health impact and economic cost is likely to be minimal.

#### Statistical power

The study includes whole-of population data for a ten year period. According to Fire & Rescue NSW, the number of residential fires will be approximately 45,000, involving around 80,000 individuals of

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3 whom over 6,000 will have injuries that needed to be treated on the scene and the remainder required  
4 rescuing or evacuation. Percent annual change (PAC) in hospitalisation rates over time is our most  
5 sensitive outcome measure. Data from a previous study suggest there are approximately 70 hospital  
6 admissions per year in NSW for residential fire related injury, with the hospitalisation rate increasing  
7 by an estimated 4.9% per year prior to the introduction of smoke alarm legislation and by 36% per  
8 year following introduction of legislation.[7] Based the reported number of residential fires and  
9 hospital admissions in 2014, with an alpha of 0.05 and power of 80% the study is powered to detect  
10 a change of 2% per year, providing ample power.  
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### 20 **Significance of this study**

21 In addition to contributing to the theoretical domains of fire and health economics and quantitative  
22 modelling, this research will contribute by  
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- 24 – Providing an in-depth profile of individuals' journey following residential fires through  
25 health services and service providers
- 26 – Provide an in-depth profile of users of the different safety and health services
- 27 – Development of methodologies to collate health cost information for individuals and  
28 stakeholders impacted by fire;
- 29 – Developing an understanding of the duration of effect of fire incidents, at the individual,  
30 community service worker level as well as wider community  
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37 The research will provide a better understanding of the impact of residential fires injuries on service  
38 usage, (FRNSW, ambulance, emergency department, hospital) that can be used to identify priority areas  
39 for research as well as inform and influence policy and planning in this area in NSW and beyond.  
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### 45 **ETHICS AND DISSEMINATION**

46 Ethical approval for this study has been provided by the NSW Population and Health Service Research  
47 Ethics Committee (HREC/16/CIPHS/36) and Western Sydney University Human Ethics Committee  
48 (RH12399). To ensure the translation of the study findings into policy and practice, a reference group  
49 will be established comprising policy stakeholders including representation from Fire and Rescue  
50 Services, burns unit personnel, and policy bodies (Agency for Clinical Innovation). We will produce  
51 scientific papers and summary reports. The reports will be in formats designed for policy audiences in  
52 parallel with presentations collaborator meetings, relevant professional conferences and public  
53 forums.  
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Competing interests statement: None

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**Table 1: Data sources and case selection criteria for identifying cohort**

Data sources	Case selection criteria
<b>Residential fire event</b>	
1. Computer Aided Dispatch system (CAD)	All persons residing at a NSW residential address attended by FRNSW or ambulance for a fire event
2. FRNSW Australian Incident Reporting System (FRNSW AIRS)	As above
<b>Ambulance use</b>	
3. Computer Aided Dispatch system (CAD)	All NSW residents that used the service with: principle reason 'house fire'
4. Patient Health Care Record (PHCR)	All NSW residents that used the service with: main condition 'burns' or 'smoke inhalation'
5. Electronic medical record (eMR)	All NSW residents that used the service with: case nature of 'burns', 'smoke inhalation'.
<b>Emergency Department use</b>	
6. NSW Emergency Department Data Collection (EDDC)	All NSW residents with ED record with diagnosis codes denoting burns and smoke inhalation: ICD-9-CM (940-949 or 508.2) or ICD-10-AM codes (T20-T31 or T59) or SNOMED CT Codes (217574009, 217303001, 217301004, 217304007, 217305008, 217297008, 217307000, 217250007, 217245001, 217264007, 217289001, 125666000, 423123007, 424784002, 276466000, 288509005, 284196006, 72998004, 37645002, 84677008, 52405000, 6055000, 10132008, 403192003, 425656005, 219356008, 262582004, 447157009, 11868005, 80183002, 211879003, 426936004).
<b>In-patient hospital and specialist burns outpatient clinic use</b>	
7. NSW Admitted Patient Data Collection (APDC)	All NSW residents with hospital record with ICD-10-AM principal diagnosis code denoting burn (T20-T31) or smoke inhalation (T59) and an external cause code denoting exposure to uncontrolled/controlled fire in building or structure (X00 and X02).
8. NSW Burn Injury Service Registry	All NSW residents admitted to specialist Burns Unit or Burns Outpatient Clinic with mechanism category of 'flame', 'clothing/bedding/curtains caught alight' or 'house fire'.
<b>Deaths</b>	
9. NSW RBDM and COD-URF	All NSW residents that had a register of death with ICD-10 principal diagnosis code denoting burn (T20-T31) or smoke inhalation (T59) or an external cause code denoting exposure to uncontrolled/controlled fire in building or structure (X00 and X02).

# BMJ Open

## Health Impacts and Economic Costs of Residential Fires (RESFIRES study): Protocol for a population-based cohort study using linked administrative data

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**Health Impacts and Economic Costs of Residential Fires (RESFIRES study): Protocol for a  
population-based cohort study using linked administrative data**

**BMJ Open**

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**ABSTRACT**

**Introduction:** Residential fires remain a significant global public health problem. It is recognised that the reported number of residential fires, fire-related injuries and deaths significantly underestimate the true number. Australian surveys show that around two-thirds of respondents who experience a residential fire are unwilling to call the fire service, and international studies highlight that many individuals who access medical treatment for fire-related injuries do not have an associated fire incident report. The objectives of this study are to quantify the incidence, health impacts, risk factors and economic costs of residential fires in New South Wales, Australia.

**Methods and analysis:** The RESFIRE cohort will include all persons living at a NSW residential address which experienced a fire over the period 2005-2014. Nine data sources will be linked to provide a comprehensive picture of individual trajectories from fire event to first responder use (fire and ambulance services), emergency department presentations, hospital admissions, burn outpatient clinic use and death. This data will be used to describe the circumstances and characteristics of residential fires, provide a profile of fire-related injuries examine trends over time, and explore the relationship between fire circumstance, emergency and health services utilisation, and health outcomes. Regression modeling, including multilevel modelling techniques, will be used to explore factors that impact on these relationships. Costing models will be constructed.

**Ethics and dissemination:** Ethical approval for this study has been obtained from the NSW Population and Health Service Research Ethics Committee and Western Sydney University Human Research Ethics Committee. The study reference group comprises key stakeholders including Fire and Rescue NSW policy agencies, health service providers and burns clinicians ensuring wide dissemination of results and translation of data to inform practice and identify areas for targeted prevention. Summary reports in formats designed for policy audiences in parallel with scientific papers will be produced.

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2  
3 Strengths and limitations of this study:  
4

- 5 • This large population-based retrospective cohort study will use nine administrative datasets  
6 to provide a comprehensive profile of residential fires in NSW over a 10-year period.  
7
- 8 • By linking fire data to health service data we will be able to track an individual's pathway  
9 through the fire event, first responder and health care use and map their health outcomes.  
10
- 11 • Results of this study will have the potential to identify high risk populations and to inform  
12 service planning and policy development.  
13
- 14 • Limitations to the study design include quality of the linkage between datasets, completeness  
15 of the data and accuracy of coding.  
16
- 17 • Individuals who only access GPs, medical centers or pharmacies to treat their injuries will not  
18 be included in health care use, potentially leading to an underestimation of the true burden  
19 of residential fires.  
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## INTRODUCTION

Fire-related burns are the fourth most common cause of unintentional trauma worldwide and have been identified as a global priority for prevention.[1, 2] An estimated 265,000 people each year die as result of fires,[3] and in most industrialised countries the vast majority of fire-related deaths and injuries occur in the home.[4] Fire prevention programs that promote the use of smoke alarms are the leading strategies adopted to minimise this burden.[2, 5] Australia is among the countries that have implemented strategies and best practices in fire prevention programs including legislation that requires functioning smoke alarms in every home.[6, 7] Despite this, residential fires remain a significant public health problem in Australia. In New South Wales (NSW), Australia's most populous state, over a five year period between 2013-2017 there were 34,000 reported residential fires, resulting in 5,000 injuries and 144 deaths.[8-12] Estimates suggest that more than half of these may have been prevented if the homes had working smoke alarms and a practiced home escape plan in place.[13]

It is well recognised that the reported number of residential fires, fire-related injuries and deaths significantly underestimate the true number.[8] Australian population-based surveys show that around two-thirds of respondents who experience a residential fire are unwilling to call the fire service,[14] and studies from the US and New Zealand highlight that many individuals who access medical treatment for fire-related injuries do not have an associated fire incident report.[15] Although most residential fire-related injury and deaths result from smoke inhalation and toxic fumes rather than burns,[16-18] under the International Classification of Diseases and Related Health Problems, Tenth Revision (ICD-10) classification system which is used in many administrative health data collections, smoke-inhalation (ICD-10 code T59) is not included with burns (ICD-10 codes T20-T31) and hence is commonly not captured in burn-related hospital and death statistics.[19] The urgent need for accurate data to inform the development and evaluation of targeted residential fire prevention strategies has been identified by the NSW Coroner [20] and Australian Senate.[21]

Similarly, the costs of residential fires extend significantly beyond damage to the property and are estimated to be about 10 times the reported cost [22]. Research into the total cost of fire is defined as the losses that fire causes, directly and indirectly, and the cost of provisions to prevent or mitigate the losses caused by the fire.[23] In Australia, the total cost of fire was estimated in 2009 to be approximately \$12 billion per annum or 1.3% of the country's gross domestic product.[24] In similar cost studies conducted overseas it has been observed that the estimates used have wide bands of uncertainty with a need for improved methods for calculating fire structure and material performance and costs.[25, 26]

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3 The objectives of this study are to quantify the incidence, risk factors, health impacts and economic  
4 costs of residential fires in NSW. Using linked person-level data this study will provide, for the first  
5 time, a comprehensive picture of first responder use (fire and ambulance services), health service  
6 utilisation (Emergency Department, hospital in-patient and specialist burns outpatient clinics), health  
7 outcomes (length of stay, rehabilitation, re-admissions and death) and economic costs. Specifically, it  
8 will address the following research questions:  
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- 13 1. What is the incidence, risk factors, injury profile, emergency services and health service  
14 utilisation and health outcomes for people resident at an address which has experienced a  
15 fire;  
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- 18 2. Do first responder and health service utilisation and health outcomes differ by type of fire,  
19 smoke alarm use, nature of injury, demographic characteristics or geographic location?  
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- 22 3. Has fire incidence, circumstance and fire-related injuries changed over the last decade, and if  
23 so do these trends differ between geographical location?  
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- 26 4. To what extent is there underreporting of residential fires, and related injuries and deaths  
27 across the datasets?  
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- 30 5. What are the total economic costs, including future projected costs, associated with  
31 residential fires and residential fire-related injuries.  
32

## 33 **METHODS AND ANALYSIS**

### 34 **Study population and cohort identification**

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37 Just under a third of Australia's population reside in NSW, and of the 8 million residents, two thirds  
38 live in the Sydney Metropolitan region.[27] NSW has an estimated 2.8 million private dwellings, over  
39 half (56.1%) of which are single or two person households, 32.5% are three or four person households,  
40 and 11.3% contain five or more people.[28] The study cohort will include all persons residing at a NSW  
41 residential address which experienced a fire in the period 1 January 2005 to 31 March 2015. In  
42 addition, any person identified as having a residential fire-related injury or death from any of the  
43 linked administrative health datasets during this period will be included in the cohort irrespective of  
44 whether there is record of residential fire.  
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### 50 **Data sources**

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53 Nine data sources will be linked to identify the complete study cohort, and to provide information on  
54 each individual's health trajectory and costs. Datasets included and the case selection criteria for each  
55 dataset are shown in Table 1.  
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3 The Australian Computer Aided Dispatch (CAD) system records all '000' calls to emergency services  
4 requiring Fire and Rescue NSW (FRNSW) or ambulance attendance. The CAD will be used to identify  
5 all NSW residential addresses that experience a fire event for which a first responder service is called.  
6  
7 The FRNSW Australian Incident Reporting System (FRNSW AIRS) contains detailed information on the  
8 circumstances, management, and consequences all fires attended by FRNSW recorded in the CAD.  
9  
10 This information includes ignition factors, area of fire, type of structure, presence or absence of  
11 functioning smoke alarm, and whether alcohol use was contributing factor, and will be used in  
12 descriptive analysis and as covariates in the models.  
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17 The NSW Ambulance datasets comprise data from the ambulance CAD system, the paper-based  
18 Patient Health Care Record (PHCR) and electronic medical record (eMR). The eMR includes clinical and  
19 treatment information on the patients. This includes case nature or diagnosis, vital signs, management  
20 and treatment type, and result or outcome of treatment – that is patient transportation or not and  
21 code. The PHCR contains information as per eMR and includes drug and fluid treatment, cardiac  
22 management and equipment, and medication used. The CAD records have been available from July  
23 2000, the PHCR data are available from April 2001 and the eMR data are available from 2011.  
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29 The NSW Emergency Department Data Collections (EDDC) contains information about ED  
30 presentations to NSW hospitals. The NSW EDDC covers 80 EDs, including all EDs in public hospitals in  
31 the Sydney metropolitan area and captures about 75% of all presentations to NSW EDs. The  
32 information reported includes patient demographics, mode of arrival, triage category, whether  
33 admitted to ward, and presenting diagnosis. Across EDs in NSW presenting diagnosis can be recorded  
34 using the Australian version of the International Statistical Classification of Diseases and Related  
35 Problems, 9<sup>th</sup> revision, Clinical Modification, (ICD-9-CM),[29] or the Australian Modification of the 10<sup>th</sup>  
36 revision, (ICD-10-AM),[30] or the Systematized Nomenclature of Medicine, Clinical Terms (SNOMED  
37 CT).[31]  
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45 The NSW Admitted Patient Data Collection (APDC) will be used to identify residential fire-related  
46 hospital admissions, and to provide information for risk-adjustment and hospitalisation costs. These  
47 data collections contain information on demographics, diagnosis related groupings, source of referral,  
48 and diagnosis and external causes coded to ICD-10-AM. Audits have shown good to excellent coding  
49 of diagnosis, procedures and external causes in Australian hospital data.[32, 33] Data is collected on  
50 all episodes of care in hospital with end with the discharge, transfer or death of the patient, or when  
51 the service category for the patient changes (for example a change from acute care to rehabilitation  
52 during a stay in the same hospital). Thus for a single burn an individual may have multiple episodes of  
53 care recorded. To avoid over-counting of the same injury, a continuous period of stay will be  
54 constructed by combing all contiguous episodes of care for the same patient. Where episodes of care  
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3 are non-contiguous, but the primary diagnoses are the same at the 3-character level (i.e. T20) for an  
4 individual, the hospitalisation will be considered as a readmission for the burn. Where the episodes of  
5 care are non-contiguous and the primary diagnosis and external causes indicate a different burn  
6 location and mechanism the hospitalisation will be considered as a separate burn event.  
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10 The Agency for Clinical Innovation NSW Statewide Burn Injury Service (SBIS) Registry contains  
11 admission records and case details for all patients admitted to the three designated Burn Units in NSW  
12 (two adult, one pediatric) and captures both hospitalisations and outpatient clinical visits. Detailed  
13 demographic, etiological and clinical data items are collected including a free text description of the  
14 circumstances resulting in the burn injury. Cases are classified according to mechanism of injury.  
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19 Mortality data will be obtained from the NSW Registry of Birth, Deaths and Marriages (RBDM) and the  
20 Australian Bureau of Statistics Cause of Death Unit Record File (COD-URF). The RBDM contains records  
21 of all deaths of NSW residents, either certified by a registered medical practitioner or by the state  
22 coroner and provides date of death. Most deaths are registered within 4 weeks. The COD-URF provides  
23 additional information recorded on the death certificate including underlying cause of death and up  
24 to 20 contributing causes of death coded to ICD-10.[34]  
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### 30 **Data Linkage**

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32 The Centre for Health Record Linkage (CHeReL) will undertake the data linkage for this study, using  
33 probabilistic linkage techniques. Residential address from the FRNSW AIRS dataset will be used to  
34 identify cohort members across the health datasets held within the CHeReL Master Linkage Key (MLK),  
35 a system of continuously updated links between core health-related datasets in NSW.[35] Personal  
36 identifiers (full name, date of birth, sex and residential address) are used to identify individuals across  
37 and within the MLK datasets. The false positive and false negative rates for linkage between MLK  
38 datasets are 0.3% and 0.5% respectively.[36] The burns registry data (SIBS) which is not included in  
39 the MLK will be linked in a separate process using full name, date of birth, sex and address. The CHeReL  
40 applies a 'best practice protocol' for preserving individual privacy, which involves separating the  
41 process of linkage from the analysis of the health content.[37] Data custodians provide the personal  
42 identifiers to the CHeReL, and upload the health data extracts with the unique identifier for each  
43 individual in the cohort, provided by the CHeReL, into the Secure Unified Research Environment  
44 (SURE)[38] for analysis by researchers.  
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### 54 **Data analysis plan**

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56 As this study involves linkage of disparate administrative datasets, we will assess and report on the  
57 quality of the data using the Australian Bureau of Statistics Data Quality Framework.[39] The  
58 dimensions of quality that will be assessed are: institutional environment, relevance, timeliness,  
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3 accuracy, coherence, interpretability and accessibility. In particular, it is anticipated that FRNSW AIRS  
4 data may have high degree of missing values. We will assess missingness, to determine whether data  
5 is missing completely at random (MCAR), missing at random (MAR) or missing not at random (NMAR)  
6 to ascertain whether principled methods, such as multiple imputation or inverse probability weighting  
7 are appropriate for use in our models.[40] Sensitivity analysis will be conducted around our results.  
8 Linkage rates between datasets not previously linked will be reported.  
9

### 14 **Research Questions 1-2**

15  
16 Descriptive statistics will be used to quantify the incidence, demographic and socioeconomic  
17 characteristics, service utilisation, procedures and health outcomes of persons injured as a result of a  
18 residential fire and to describe the fire circumstance and characteristics. We will use multilevel  
19 modelling to identify individual-, fire characteristic-, and service utilisation factors associated with  
20 incidence of residential fire-related injury, and health outcomes. The main health outcomes of interest  
21 are total length of stay in days (LOS), length of stay for acute care, length of stay for rehabilitation,  
22 readmissions, 30-day mortality (fire-related and all-cause) and hospital costs.  
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28 Variables of interest include:

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30 *Demographic and socioeconomic characteristics:* age, sex, country of birth, language spoken at home,  
31 pre-existing health status (measured using the Charlson Comorbidity Index (CCI) [41] with a 1 year  
32 lookback period [42]), health insurance status, and socioeconomic disadvantage (measured by the  
33 Australian Bureau of Statistics (ABS) Socioeconomic Indexes for Areas (SEIFA).[43]  
34

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37 *Geographical measures:* Statistical area level 2 (SA2) which is a standard geographical area used by  
38 the ABS that broadly represents a community that interacts together socially and economically. SA2s  
39 have an average population of about 10,000 people (range 3,000-25,000).[44]  
40

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43 *Injury characteristics:* type of injury will be classified into- burns, smoke inhalation and  
44 musculoskeletal injuries. Other characteristics of interest include total body surface area of burn  
45 (TBSA), depth of burn and procedures undertaken.  
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49 *Service utilisation:* number of FRNSW and ambulance attendances, ED presentations, hospital  
50 admissions, and outpatient treatment.  
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53 *Fire-related characteristics:* nature of fire (controlled, uncontrolled, electrical, chemical), day and time  
54 of fire, type of residential structure, action taken, areas of fire origin, presence of functioning smoke  
55 alarm and/or sprinkler system, type of smoke detector, evidence of alcohol consumption,  
56 geographical location of residence (mapped to postcode), and response agencies involved.  
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### 59 **Research Question 3**

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3 To assess changes in trend in fire incidence, incidence of fire-related injuries over time, age-specific  
4 and age-standardised rates per 100,000 population with 95% confidence intervals will be calculated.  
5 Age-specific population estimates for NSW for 2005 to 2014 will be used to calculate age-standardised  
6 rates, using the Australian estimated resident population at June 2001 as the standard population.  
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8 Depending on model fit Poisson or negative binomial regression will be used to examine the statistical  
9 significance of changes in trends over time.  
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#### 13 **Research Question 4**

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15 Capture-recapture modelling techniques will be used to determine to what extent residential fires,  
16 and related injuries and deaths are underreported across the datasets. Counting people captured by  
17 each system and the extent of overlap will provide the data required to run capture-recapture  
18 statistical models,[45-47] overall and by demographic and other variables. These models will estimate  
19 how many people attended hospital after injuries in fires but did not call the fire or ambulance  
20 service. They also will provide an estimate of injuries sustained after a residential fire but not captured  
21 in the hospital data (e.g., injuries treated in a primary care setting).  
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#### 28 **Research question 5**

29 An injury cost model will be developed for all fires that are attended and not attended by FRNSW.  
30 Hospital admissions and number of days in hospital will be identified from the NSW APDC data. A  
31 dollar value for the cost of treatment for an individual will be calculated by multiplying the LOS (in  
32 days) for each episode of care by the daily AR-DRG cost per day provided in the National Hospital  
33 Cost Data Collection.[48] The Hospital Casemix Protocol will be used to assign costs to private  
34 inpatient episodes by AR-DRG. For emergency department attendances, costs will be assigned  
35 using the national average emergency department costs based on triage category. [49] The costs to  
36 individuals of the structural damage to the property will be estimated using the cost to insurance  
37 companies from the Insurance of Australia and out-of-pocket expenses. The costs of responding to  
38 the incident will be estimated based on the AIRS data on the services attended and material used. The  
39 cost of pain and suffering of individuals will be estimated using established values as per Tannous et  
40 al. (2017).[50]  
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50 A limitation of this study is that individuals who may access only general practitioners, medical centers  
51 or pharmacies to treat their injuries are not included. Primary care records will not be linked, as we  
52 are unable to detect from MBS records the reason for the GP visit, only that a GP visit occurred.  
53 However, it is worth noting that burns treated by GPs are likely to be minor in nature as there are  
54 rigorous guidelines in place for referral to a specialist outpatient burn clinic for more extensive burn  
55 injuries. Any outpatient burn clinic referral will be captured from the NSW Burn Injury Service Data,  
56 which includes outpatient visits. If people extinguish minor fires themselves and only sustain minor  
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3 injuries that do not require medical treatment the health impact and economic cost is likely to be  
4 minimal.  
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### 6 7 **Statistical power**

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9 The study includes whole-of population data for a ten-year period. According to Fire & Rescue NSW,  
10 the number of residential fires will be approximately 45,000, involving around 80,000 individuals of  
11 whom over 6,000 will have injuries that needed to be treated on the scene and the remainder required  
12 rescuing or evacuation. Percent annual change (PAC) in hospitalisation rates over time is our most  
13 sensitive outcome measure. Data from a previous study suggest there are approximately 70 hospital  
14 admissions per year in NSW for residential fire related injury, with the hospitalisation rate increasing  
15 by an estimated 4.9% per year prior to the introduction of smoke alarm legislation and by 36% per  
16 year following introduction of legislation.[7] Based the reported number of residential fires and  
17 hospital admissions in 2014, with an alpha of 0.05 and power of 80% the study is powered to detect  
18 a change of 2% per year, providing ample power.  
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### 29 **Significance of this study**

30 In addition to contributing to the theoretical domains of fire and health economics and quantitative  
31 modelling, this research will contribute by  
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- 34 – Providing an in-depth profile of individuals' journey following residential fires through  
35 health services and service providers
- 36 – Provide an in-depth profile of users of the different safety and health services
- 37 – Development of methodologies to collate health cost information for individuals and  
38 stakeholders impacted by fire;
- 39 – Developing an understanding of the duration of effect of fire incidents, at the individual,  
40 community service worker level as well as wider community  
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47 The research will provide a better understanding of the impact of residential fires injuries on service  
48 usage, (FRNSW, ambulance, emergency department, hospital) that can be used to identify priority areas  
49 for research as well as inform and influence policy and planning in this area in NSW and beyond.  
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### 54 **ETHICS AND DISSEMINATION**

55 Ethical approval for this study has been provided by the NSW Population and Health Service Research  
56 Ethics Committee (HREC/16/CIPHS/36) and Western Sydney University Human Research Ethics  
57 Committee (RH12399). To ensure the translation of the study findings into policy and practice, a  
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3 reference group will be established comprising policy stakeholders including representation from Fire  
4 and Rescue Services, burns unit personnel, and policy bodies (Agency for Clinical Innovation). We will  
5 produce a suite of peer-reviewed manuscripts and summary reports. The reports will be in formats  
6 designed for policy audiences in parallel with presentations collaborator meetings, relevant  
7 professional conferences and public forums.  
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## 10 11 12 **PATIENT AND PUBLIC INVOLVEMENT**

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14 No patient involved.  
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24  
25 Author contribution: WKT, LH, and MW conceived and designed the study. LH, WKT and NG wrote and  
26 edited the manuscript. WKT, LH and NG provide data analytics. All authors reviewed and approved  
27 final version of manuscript.  
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30  
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37 Competing interests statement: None  
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**Table 1: Data sources and case selection criteria for identifying cohort**

Data sources	Case selection criteria
<b>Residential fire event</b>	
1. Computer Aided Dispatch system (CAD)	All persons residing at a NSW residential address attended by FRNSW or ambulance for a fire event
2. FRNSW Australian Incident Reporting System (FRNSW AIRS)	As above
<b>Ambulance use</b>	
3. Computer Aided Dispatch system (CAD)	All NSW residents that used the service with: principle reason 'house fire'
4. Patient Health Care Record (PHCR)	All NSW residents that used the service with: main condition 'burns' or 'smoke inhalation'
5. Electronic medical record (eMR)	All NSW residents that used the service with: case nature of 'burns', 'smoke inhalation'.
<b>Emergency Department use</b>	
6. NSW Emergency Department Data Collection (EDDC)	All NSW residents with ED record with diagnosis codes denoting burns and smoke inhalation: ICD-9-CM (940-949 or 508.2) or ICD-10-AM codes (T20-T31 or T59) or SNOMED CT Codes (217574009, 217303001, 217301004, 217304007, 217305008, 217297008, 217307000, 217250007, 217245001, 217264007, 217289001, 125666000, 423123007, 424784002, 276466000, 288509005, 284196006, 72998004, 37645002, 84677008, 52405000, 6055000, 10132008, 403192003, 425656005, 219356008, 262582004, 447157009, 11868005, 80183002, 211879003, 426936004).
<b>In-patient hospital and specialist burns outpatient clinic use</b>	
7. NSW Admitted Patient Data Collection (APDC)	All NSW residents with hospital record with ICD-10-AM principal diagnosis code denoting burn (T20-T31) or smoke inhalation (T59) and an external cause code denoting exposure to uncontrolled/controlled fire in building or structure (X00 and X02).
8. NSW Burn Injury Service Registry	All NSW residents admitted to specialist Burns Unit or Burns Outpatient Clinic with mechanism category of 'flame', 'clothing/bedding/curtains caught alight' or 'house fire'.
<b>Deaths</b>	
9. NSW RBDM and COD-URF	All NSW residents that had a register of death with ICD-10 principal diagnosis code denoting burn (T20-T31) or smoke inhalation (T59) or an external cause code denoting exposure to uncontrolled/controlled fire in building or structure (X00 and X02).