

Drivers and barriers to heatwave-resilient building retrofitting in the Australian context

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Abstract: Heatwaves have a mounted interest in the last decade due to their negative impacts on infrastructure, the ecosystem and public health. Population exposure to heat stress is substantially influenced by the resilience of the built environment as people spend the majority of their time indoors. Retrofitting the existing building stock could profoundly improve heatwave resilience, however, the current knowledge of the population’s heatwave-resilient retrofitting willingness is limited. An online survey about population perception of, adaptation to and retrofitting against heatwaves was conducted with a representative sample from the Adelaide metropolitan region in March 2015. The survey results about the retrofitting relevant questions presented in this paper suggest that the perceived financial limitations and missing tenant/landlord incentives represent the key barriers to domestic retrofitting. Beyond air-conditioning, the improvement of shadings was the most prevalent retrofitting measure. The number of known and applied retrofitting measures, nevertheless, were limited. Solutions, such as taking advantage of increased garden vegetation or changing the roof colour were underrepresented. Special attention should be paid to older population since they are not only more vulnerable to heatwaves but also less willing to retrofit their homes.

Keywords: Heatwave resilience; energy efficiency; building retrofitting.

1. Heatwave-resilient building retrofitting

Heatwaves are responsible for more deaths in Australia than all other natural hazards combined (Coates *et al.*, 2014). Beyond the excess death rates, heatwaves have miscellaneous negative impacts on infrastructure, the ecosystem and public health (Zuo *et al.*, 2014; Reeves *et al.*, 2010). Since one of three

heatwave-related deaths occurs indoors (Coates *et al.*, 2014), the role of the built environment in population resilience against heatwaves is fundamental.

Heatwaves negatively affect indoor thermal comfort, posing heat stress on building occupants. Although air-conditioning is the most prevalent adaptation technique to cope with heatwaves (Saman *et al.*, 2013), its use raises further concerns. Air-conditioning contributes significantly to the rise of urban air temperature and increases electricity demand (Santamouris, 2014). The increased electricity demand raises noticeably the yearly peak demand in cooling-focused regions, such as most of Australia, resulting in an inefficient electricity grid. The additional maintenance cost contributes to the soaring electricity prices, and increases the vulnerability of the less affluent population. Fuel poverty, referring to the condition when population cannot afford adequate heating or cooling, is rising in Australia and worldwide (VCOSS, 2005; Santamouris and Kolokotsa, 2014). Considering climate change, Australian projections show further increase in peak electricity demand (Saman *et al.*, 2013). Meanwhile, the increase in number of highly insulated buildings can foster overheating in summer, raising the cooling demand (Ren *et al.*, 2014). The differentiation between energy efficient and heatwave-resilient design and retrofitting, therefore, is necessary.

Australian households are responsible for the 25% of the total national net energy use (Australian Bureau of Statistics, 2015). To decrease the energy consumption, building retrofitting has to be addressed because of the relatively slow building stock turnover rate. Retrofitting, beyond reducing domestic energy consumption, extends the life-cycle of the existing building stock and saves embodied energy and carbon (Pullen, 2010). Even though a considerable body of scholarship concerns with the population uptake of energy efficient retrofitting (Achnicht and Madlener, 2014; Elsharkawy and Rutherford, 2015; Long *et al.*, 2014; Hall *et al.*, 2013), many fewer studies have been conducted about heatwave-resilient retrofitting (Saman *et al.*, 2013).

South Australia is especially exposed to heatwaves, with the highest number of heat-related deaths recorded nationwide (Coates *et al.*, 2014). Adelaide, South Australia, with a population of more than 1.2 million people, suffered from a series of subsequent, extreme heatwaves in January and February, 2009. During the 13 day-long heatwave period, the daily temperature reached 45.7 °C, with eight days exceeding 40 °C. This heatwave caused up to 16% excess ambulance call outs (Nitschke *et al.*, 2011) and an excess 68% electricity demand (Energy Supply Association of Australia, 2015), compared to usual summer days.

To enhance urban heatwave resilience, three aspects should be considered, including the built environment, population adaptation and vulnerability to heatwaves. Air temperatures of the urban microclimate can be decreased with mitigation techniques, such as the increased green space ratio (Adams and Smith, 2014) and the decreased waste heat generation (Santamouris *et al.*, 2014). Passive adaptations, such as adopting summer clothes or night time ventilation, furthermore, increase human thermal comfort without compromising the energy consumption. Nevertheless, thermal comfort and potential heat-induced health issues are also influenced by demographic characteristics, that increase vulnerability, such as age, level of isolation and pre-existing health conditions (Bi *et al.*, 2011; Li *et al.*, 2015). Although the impact on heatwave resilience of these factors are established in the literature, comprehensive survey about their interplay has not been conducted yet. To assess these aspects, a survey, with a representative sample in the Adelaide metropolitan region, South Australia, was conducted about the population heatwave perception, adaptation and heatwave-resilient building retrofitting. In this study, the analysis results concerning retrofitting are presented. The study aspires to define which demographic characteristics predict retrofitting activity and what drivers and barriers are to heatwave-resilient retrofitting.

2. Survey data collection and analyses methods

Quantitative data were collected via an online survey with closed questions. An online survey method was selected as the most time-efficient method to explore household behaviour and belief. To ensure the representative sample for age and gender, within the Adelaide metropolitan region, a survey panel provider was commissioned. A panel provider recruits participants for a representative sample of the whole population. Only people who lived and/or worked in the Adelaide metropolitan region and aged 18 or over were eligible for participation. In March 2015, 393 responses were received.

The survey addressed three topics, namely heatwave perception, adaptation to and retrofit against heatwaves. Research surveys about heatwave perception and adaptation (Nitschke *et al.*, 2013; Loughnan *et al.*, 2014a; Loughnan *et al.*, 2014b; Akompab *et al.*, 2013), retrofitting for heatwave resilience (Saman *et al.*, 2013) or energy efficiency (Australian Bureau of Statistics, 2013; National Centre for Social Research, 2010) were reviewed, since previous research with comprehensive survey about all these three aspects has not been undertaken yet. Questions with potential answers were adopted and further developed. Information about participants' demography and their built environments was also collected for in-depth analysis of different subgroups, based on the findings and limitations of earlier research. The survey was comprised of 59 single- and multiple-choice questions with rating, constant sum-scale and paired choice answers. Although closed-ended questions were used, when respondents were asked about their adaptation and retrofitting choices, an additional option to list not covered techniques was included. The survey was designed, distributed and coded using Qualtrics online survey software (2005). The questionnaire was piloted to ensure that all difficulties and ambiguities were resolved. Statistical analysis of answers about retrofitting, covered in this study were conducted using SPSS and Minitab (IBM Corp., 2013; Minitab Inc., 2010). The distribution of responses were significant, tested by Chi-square goodness of fit test, unless otherwise stated. Connections between variables were evaluated by using Chi-square and Spearman's rho tests.

3. Results of the survey analysis

The magnitude of heatwave-resilient domestic retrofitting was explored accounting for both past and possible future measures. Less than one third of the respondents stated that they had retrofitted their homes in the past 5 years (30%). Even less respondents (20%) intend to undertake retrofitting in the following two years ($\chi^2 = 9.79$, $df = 1$, $N = 392$, $p < 0.05$). The difference was due to the fact that only 29% of the past renovators planned to make further changes in the near future and only 16% of the respondents, who had not retrofitted, planned to take measures in the next two years ($\chi^2 = 7.118$, $df = 1$, $N = 392$, $p < 0.05$).

On average, 2.2 retrofitting measures were taken per renovators. More than two-thirds of the respondents undertook one or two measures and only 14% took four or more measures. A more efficient air-conditioning was installed and/or the shadings were improved by more than half of the past renovators (Figure 1). Solar panels were installed in a little more than one third of the cases. Roofs or walls were insulated and water-retaining vegetation was planted in about one-fourth of the cases. The rarest undertaken retrofitting techniques included changing external doors and windows, roof colours and applying reflective foil on windows. The responses were further analysed to explore whether the popularity of different techniques changed with the number of measures taken. Changes in air-conditioning and in the house shadings were the most popular techniques (44% and 41%, respectively) among participants taking only one measure. Techniques, considered only when more than one measures

were taken, included the insulation of the walls and/or roofs ($\chi^2 = 17.05$, $df = 1$, $N = 118$, $p < 0.05$), planting more water-retaining vegetation ($\chi^2 = 1311.96$, $df = 1$, $N = 118$, $p < 0.05$) and the installation of a solar panel ($\chi^2 = 23.75$, $df = 1$, $N = 118$, $p < 0.05$).

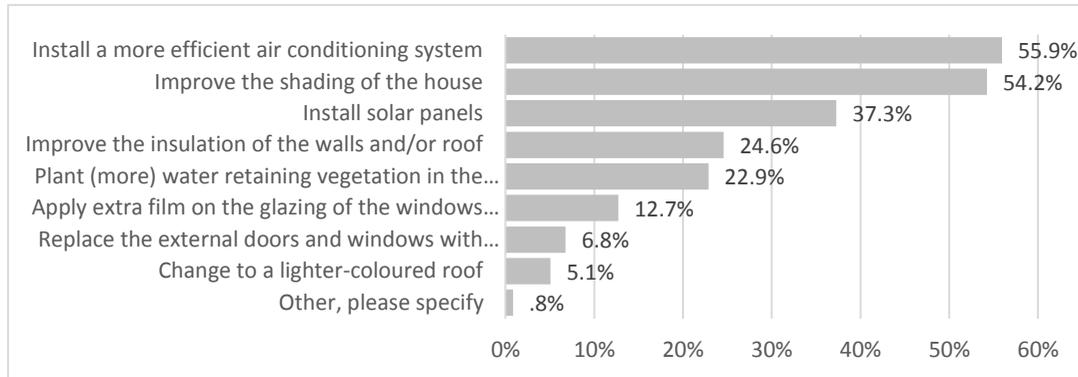


Figure 1 Percentage and frequency of past retrofitting types per overall number of measures taken

Participants planning to retrofit in the next two years were the most likely to invest in the shading of their homes, followed by installing a more efficient air-conditioning system and planting more water-retaining vegetation (Figure 2). The same amount of people were likely to install solar panel as those who were not. Note, however, that the distribution of the received responses on the likelihood scale, regarding to air-conditioning and solar panel installations were not significant. Changing the roof colour, replacing the external windows and doors, following to the insulation of the walls and roofs were the least likely to occur. On average, the respondents were planning to take 2.6 measures ($\chi^2 = 71$, $df = 9$, $N = 79$, $p < 0.05$). Almost half of the participants who were planning to retrofit (44%) were undecided about asking for professional advice, while only one quarter were willing to seek advice. One third (29%) of the respondents who were willing to retrofit were inclined to spend money up to \$2000 and another 29% up to \$5000. The maximum retrofitting budget peaks at \$10,000 for almost one-fifth of the respondents (19%), and another 10% of the future renovators were willing spend even more.

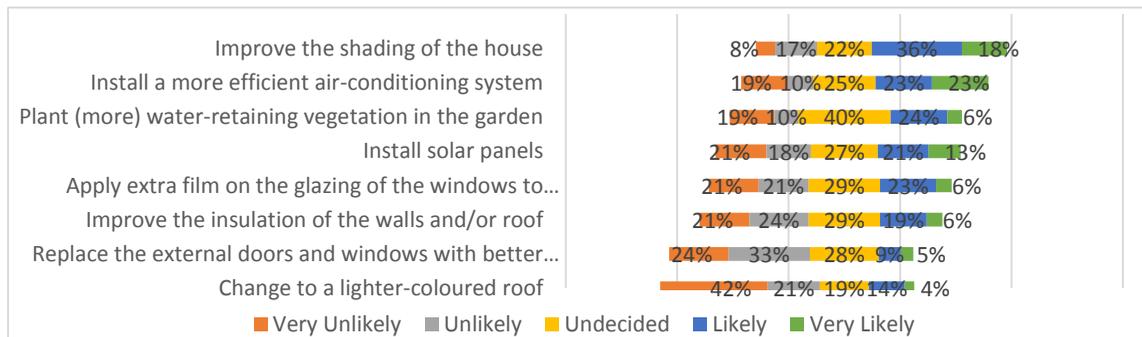


Figure 2 Likelihood of different retrofitting measures in the future (%)

When people were asked about specific retrofitting, the energy efficiency of their roofs was more important for them than the appearance (84%/62%). Meanwhile, the lesser time and money spent on garden maintenance were preferred to having a garden with lush vegetation. Amongst people who selected insulations, the roof or ceiling insulations were more popular than the wall insulations. Note that the size of the sub sample was very small (n=20).

In general, all listed drivers to heatwave-resilient retrofitting were rated as important (Figure 3). Financial saving and minimising heat stress were rated as the most important drivers. More than half of the respondents found the utilisation of government subsidies, carbon emissions and the increase of market value important.

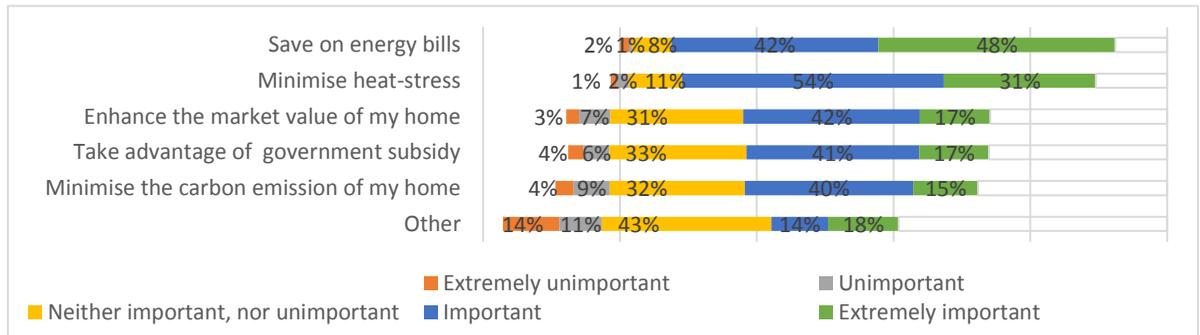


Figure 3 Drivers to retrofitting (%)

In response to the question about the factors to retrofitting selection, the efficiency (32%), the fact that other retrofitting techniques were not necessary (19%) and the expenses of retrofitting (17%) were mentioned the most frequently. The limited opportunities as a tenant was cited only by the 6% of the renovators (Figure 4), showing a low retrofitting activity among tenants. The compliance with Housing South Australia and the durability of building materials were also included under the other category.

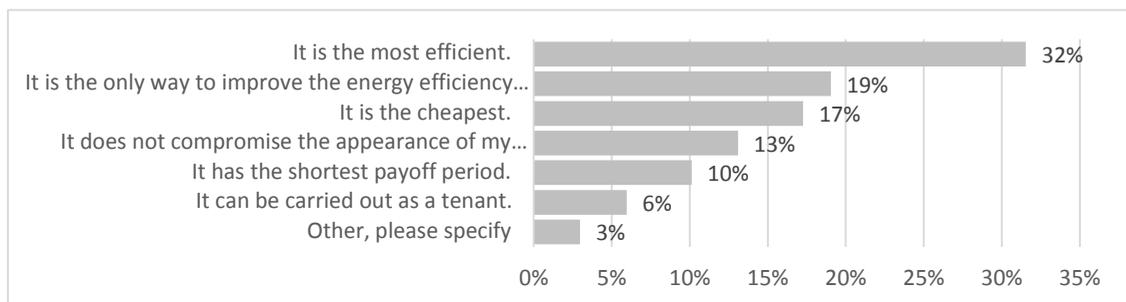


Figure 4 Factors of retrofitting selection

Exploring the barriers to retrofitting, only less than half of the non-renovators (29%) stated that their homes cope well with summer heat. The main barriers included being a tenant and the expenses of

retrofitting for 21% and 20% of the non-renovators, respectively. More than a tenth stated they did not know enough about the topic and 7% argued that they planned to move in the next two years. The number of respondents was only marginal who stated that it would not save money for them or would spoil the appearance of their homes (Figure 5). The low number of concerns about the home appearance is low compared to the significant number of heritage-like buildings in Adelaide.

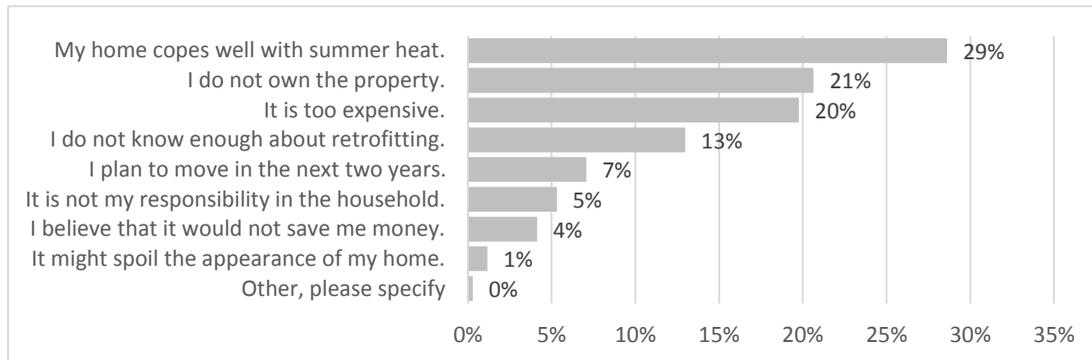


Figure 5 Barriers to retrofitting

In general, no statistically significant differences were found in past retrofitting between groups with different age, income, gender and qualification. Regarding future retrofitting, people over the age of 65 and/or people out of the labour force were less willing to retrofit ($\chi^2 = 8.087, df = 1, N = 392, p < 0.05$), ($\chi^2 = 6.46, df = 1, N = 392, p < 0.05$). Respondents with higher household incomes were inclined to spend more money on retrofitting (Spearman's rho $r = 0.507, n = 69, p < 0.00$). Also respondents with lower income, who did not retrofit, were more inclined to cite cost as an obstacle ($\chi^2 = 10.86, df = 3, N = 194, p < 0.05$). The lack of knowledge about retrofitting was mentioned the most frequently by middle-income earners, with household income of \$1500-3000 per week ($\chi^2 = 9.49, df = 3, N = 194, p < 0.05$).

4. Discussion

This study shed light on the population's drivers and barriers to heatwave-resilient retrofitting and the influencing demographic factors, in Adelaide. Although only one-fourth of the survey participants stated that their homes cope well with heatwaves, more than half of those living in homes without sufficient coping capacity did not engage in retrofitting activities. These results indicate that the majority of the existing residential building stock was not heatwave-resilient and the occupants were not willing to retrofit. The key barriers to heatwave-resilient retrofitting included being a tenant, the expenses of retrofitting and the lack of knowledge. These results are consistent with the main barriers of energy efficient building retrofitting according to the latest national Household Energy Consumption Survey, listing property renting, financial constraints and not seeing the need and motivation (Australian Bureau of Statistics, 2013). Increasing household income, however, did not increase retrofitting activity. This finding challenges if financial constraints are only perceived barriers to retrofitting for middle- and high-income earners, and only influence the volume and type of retrofitting. Future research should investigate this issue in the context of the level of heatwave resilience of the existing built environment.

The number of retrofitting measures considered by the survey respondents is limited with two most popular interventions, including the improvement of air-conditioning and shadings. The utilisation of greenery around the house was an unpopular solution, since the majority of people preferred limited time and costs spent on garden maintenance. Unfortunately, the changing of roof colour was an unpopular measure, even though potential energy savings and reduced electricity infrastructure costs would be significant (Saman *et al.*, 2013). As respondents reported that the energy efficiency of the roof was more important than the colour, a missing knowledge about this retrofitting measure appears. Nevertheless, an increased willingness to change roof colour and external windows, doors was found in regard to the future compared to the past retrofitting measures. Future retrofit programs should concentrate more on advocating these less popular, still highly efficient retrofitting interventions.

Future heatwave-resilient retrofitting was less likely to be undertaken by respondents above the age of 65 and/or out of the labour force. While Long *et al.* (2014) in the United Kingdom found that recently retired people were more likely to retrofit, Achtnicht and Madlener (2014) in Germany discovered that older people were less inclined to retrofit their homes. Note that in the study of Long *et al.*, the retrofitting expenses were subsidised by the local council. Considering the higher vulnerability to heatwaves of the older population (Bi *et al.*, 2011) compounded by an increasing risk due to the ageing population, the issue of retrofitting by older household owners should be addressed (Loughnan *et al.*, 2014b). Further research should be conducted about the underlying reasons of the missing willingness to retrofit among older people.

The findings of this study show that financial constraints were revealed as a perceived barrier to retrofitting and as a limitation in the retrofitting measure selection, especially for people with lower income. Both the perceived lack of financial sources and the unwanted professional advice lead people to purchasing a new air-conditioner instead of considering other passive retrofitting. The problem is also highlighted by the 13% of the participants who did not consider retrofitting, due to the lack of knowledge about the topic. The concept of building energy performance certificate (EPC) (Szalay, 2008; EC, 2003), adopted by the European Union (EU) since the early 2000s' could address this issue. The certification must be issued after the construction and in case of acquisition or tenure, longer than one year. The EPC evaluates the building overall energy performance and includes a list of recommended retrofitting techniques. Based on the learnings from the EU, EPC could be completed with the financial implications of retrofitting (Amecke, 2012). The introduction of the EPC would enhance the population's knowledge of the built environment and present energy-saving opportunities that was cited as primary driver to retrofitting. Furthermore, EPC could increase the importance of energy efficiency in property market value and raise the population awareness about carbon emission. Both issues, ranked as only secondary drivers to retrofitting by the survey respondents.

5. Conclusions and implications for policy makers

This paper provides insights into the key drivers and barriers to heatwave-resilient domestic retrofitting in Australian context. The key aspects that should be addressed, include the population's limited financial opportunity perceived, the deterrent impact of property renting and the lack of knowledge about heatwave-resilient retrofitting. Government retrofitting schemes should target population with lower income, over the age of 65 and ones being out of the labour force, particularly as these people are more vulnerable to heatwaves. Further education programs, especially on unpopular solutions such as cool roofs and increased garden vegetation should be promoted. The proposed building EPC would, furthermore, encourage the uptake of future retrofitting. Future research should address the reasons for

lower retrofit activity among older respondents and the perceived financial constraints related to retrofitting among middle and high income earners.

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