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Jurisdictional decision-making about building codes for resiliency and sustainability post-fire

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Abstract

The increasing frequency and size of wildfires across the U.S. motivates the growing need to identify how affected communities can rebuild sustainably and resiliently. This study examines the jurisdictional decision-making process surrounding one important class of sustainability and resiliency decisions, focusing on energy and wildfire building codes for housing reconstruction. Through 22 interviews with staff and elected officials in three jurisdictions impacted by Colorado's Marshall Fire, we identify factors influencing decisions. Code decisions varied across jurisdictions and, in some cases, building codes were relaxed, while in other cases, increased resiliency and sustainability standards were adopted after the fire. Jurisdictions with more experience had more certainty regarding code costs and effectiveness, leading to more stringent code adoption. Thus, findings encourage jurisdictions to create rebuilding plans pre-disaster to reduce the impact of uncertainty in post-disaster decision-making. The data also indicate that while local jurisdictions are well-suited to work cooperatively with homeowners impacted by disasters to return to the community, the state can play a role by informing or mandating disaster plans or establishing minimum code requirements.

1. Introduction

1.1. Background

Across the United States, wildfires have increased in frequency and consequences, with fires quadrupling in size and tripling in frequency since 1984 (Iglesias *et al* 2022). These effects are expected to continue with climate change (USGCRP 2017). Further, while fires have historically been confined to forested, mountainous areas, recent fires have affected urban and suburban areas, increasing the economic and community impact of these disasters. In many such fires, burning homes serve as both the fuel and the consequences of the fire. Consequently, existing fire suppression and mitigation tools are no longer enough to control and protect against the threat of fires (Alexandre *et al* 2015, Schoennagel *et al* 2017, Kramer *et al* 2018).

Post-fire, state and local governments make consequential decisions to guide rebuilding, particularly through building code adoption and enforcement that establish minimum requirements for building. Building codes set requirements for the design and construction of buildings encompassing structural, electrical, heating, etc requirements. While jurisdictions make these decisions regularly, the study of adoption of resilience and sustainability-oriented codes is particularly insightful post-fire when risk awareness is generally heightened (Martin *et al* 2007, Mockrin *et al* 2016, Meldrum *et al* 2019).

In most jurisdictions in the United States, a model code, often those published by the International Code Council (ICC), is the starting point, and state and local governments adopt and, in some cases, adapt the model code to tailor the code to their community ('Understanding Building Codes' 2022). Generally, state governments are responsible for adoption and enforcement across their state (The Building Codes Assistance

Project 2015). Local governments typically have the authority to amend the code adopted by the state to include more stringent regulations. Twelve states, including Colorado, have no statewide code; thus, code decisions are handled by local governments (known as 'home rule authority'). Within these 12 states, there are some counties with no building code (Vuković 2022). Codes and regulations intended to target wildfire risk in particular are handled at the local level, where guidelines can be tailored to individual communities, although California and Oregon have statewide legislation (Haines *et al* 2008).

Decisions about building codes that guide rebuilding are important because community rebuilding practices have implications for community resilience in the face of future fires. We work within Schoennagel *et al*'s (2017, p 4584) concept of adaptive resilience, whereby communities 'engage in ecological, psychological, social, and policy processes that set the community on a trajectory of change to reduce future vulnerability.' Under this broad umbrella of resilience, this paper focuses on one aspect, fire resilience. In this context, adaptive resilience practices include building codes for fire-resistant structures, vegetation management, land-use planning, and community climate action. Adaptive resilience practices are needed due to the changes in fire severity, management, and impacts. Building codes, our focus herein, are one significant means of managing community risk through proven protective building practices. For example, researchers found higher rates of home survival in the Paradise, California fires from more modern construction due to the adoption of fire-resistant practices in building codes (Knapp *et al* 2021), and building practices clearly played a role in the Marshall Fire as well (Fischer *et al* 2022).

Decisions about building codes for rebuilding also have important implications for community sustainability and climate goals. The characteristics of a building's construction directly influence the operational energy consumption of these buildings, which is a major contributor to a community's carbon footprint (Fischer and Varma 2016). Energy efficiency issues are the purview of energy codes. Material choices and embodied carbon are also critical, but are not our focus here because these concepts have not been fully incorporated into codes and standards. These issues are particularly poignant in a post-fire environment because the link between global greenhouse gas emissions, climate change, and wildfires is well understood (Western Fire Chiefs Association 2022).

This paper explores jurisdictional decision-making around these two key themes of resiliency and sustainability in the context of the Marshall Fire, which occurred on 30 December 2021. The Marshall Fire affected three Colorado jurisdictions, unincorporated Boulder County (UBC), Louisville, and Superior, destroying 1084 homes. Following the fire, elected officials faced decisions about what building codes to adopt and enforce for the rebuilding effort. This research addresses the questions: (1) How are resiliency and sustainability measures for the built environment considered in jurisdictional decision-making about building codes in a post-disaster environment? (2) What factors influence the adoption and enforcement of resiliency and sustainability-oriented building codes in a post-disaster environment? To address these questions, we analyze the decision-making process for three rebuilding code decisions: (1) the choice of required residential energy code (year, provisions, appendices), (2) the choice of whether and how to update the residential building code to include building code requirements for fire resistance, and (3) the choice of whether to maintain the requirement for indoor single-family residential fire sprinkler systems. Given the absence of state-mandated building codes in Colorado, each of the three jurisdictions made these considerations and decisions for their individual community considering their goals and the needs of their constituents, resulting in differing decisions to integrate resiliency and sustainability in the rebuilding effort.

1.2. Literature review

There is a window of opportunity to make changes to policy and practice in response to learning from a disaster (Kingdon 1984, Solecki and Michaels 1994, Birkland 2006, Mockrin *et al* 2018, Schumann *et al* 2020) and reduce loss in future disasters (Haas *et al* 1977, National Research Council 2006, Cutter *et al* 2008). Examples of changes include updating building codes to require fire-resistant materials and restricting vegetation surrounding homes (Link-Herrera 2019). Yet, this opportune moment is not always seized (Solecki and Michaels 1994, Birkland 2009). For instance, risk-reducing measures are often forgone due to place attachment, a desire to return to 'normal' through quickly rebuilding, and the perception that risk has decreased in the area, among other factors (Martin *et al* 2007, Alexandre *et al* 2015, Mockrin *et al* 2015, 2016, Link-Herrera 2019, Albright and Crow 2021, Kramer *et al* 2021).

While post-disaster changes may be undertaken by individuals or households, government plays an important role in regulating community-wide changes (Froman 2021). Regulations set by governments, including those associated with building codes, defensible space, or zoning requirements (May 1992, Brzuszek *et al* 2010, Buxton *et al* 2010, Muller and Schulte 2011, Syphard *et al* 2012), are important because builders and homeowners typically do not pursue construction designs that go beyond what is mandated (Froman 2021). Building codes across hazards and contexts have been shown to be effective at reducing disaster risk (Burby and May 1999, Burby *et al* 2000, Kodur *et al* 2019, Knapp *et al* 2021). However, the most

common actions taken by governments typically fall into the category of education, voluntary mitigation, and improving emergency response rather than regulation changes (Muller and Schulte 2011, Stidham *et al* 2014).

Existing studies primarily focus on whether adaptive policy change was made post-disaster (Muller and Schulte 2011, Albright and Crow 2015, Mockrin *et al* 2016); few studies have examined what led to these policy decisions (Duerksen *et al* 2011, O'Donovan 2017, Crow *et al* 2018). Of the studies done, some have identified that policy-setting bodies are necessary to ensure that the window for policy change post-disaster will shape redevelopment in a community (Solecki and Michaels 1994, Smith and Wenger 2007). Another by Ripberger *et al* (2018), identified factors supporting the adoption of tornado protection in building codes in Oklahoma, including objective risk data, homeowner risk perception, and level of damage, while factors undermining adoption included individualistic and conservative worldviews and skepticism of climate change (Ripberger *et al* 2018). To date, there is a dearth of studies that have focused on factors influencing building code policy decisions post-fire (Mockrin *et al* 2018).

Compared to policy change broadly, the decision-making process of post-disaster policy change is under-studied (Labossière and McGee 2017). The unique post-disaster environment requires significant collaboration between agencies and departments across multiple levels of government to coordinate rebuilding efforts (MacKenzie 2017). Additionally, local governments are often managing a variety of stakeholder needs and competing priorities under extreme time sensitivity for decision-making (Olsen and Shindler 2007, FEMA 2021).

Research that has been done outside of the disaster sphere into jurisdictional decision-making for policy change indicates the benefits of making decisions at the local level, including allowing for more public participation, which has been shown to increase government trust, and public support for policy (Beierle and Konisky 2000, Wang and Van Wart 2007). However, local decision-making can pose challenges, including resistance to change of housing-related policies (Einstein *et al* 2019). Further, local governments often lack the capacity (regarding resources, expertise, etc) needed for complex policy change (Schuetz 2022). Thus, studies have pointed to both the effectiveness of state mandates in ensuring effective implementation at the local level (Berke and French 1994, Berke *et al* 2014) and the necessity of local involvement to respond to the characteristics and needs of the community (Steelman and Kunkel 2004, Kocher and Butsic 2017). In particular, state policy and guidance can reduce the influence of local variables to produce better preparation and planning (Berke *et al* 1996, 2014, Burby and May 1997). With rising demand for local decision-making, paired with the need for objective information and technical assistance (Honadle 2001), additional research is needed on what decisions get made at the local level, what influences these decisions, and how this shapes community outcomes.

When looking specifically at decisions to adopt more sustainable and resilient building codes, challenges may prevent decision-makers from moving toward adoption. For instance, building codes have historically focused on safeguarding human life ('Understanding Building Codes' 2022), and have not fully considered sustainability and resiliency. In addition, studies have documented perceptions that updated codes are too expensive, in part due to the influence of the homebuilding industry, which has often been in opposition to updating building codes, particularly those that improve energy efficiency (Shapiro 2016).

To address these needs, this study focuses on post-fire building code decisions made by local jurisdictions and what factors were influential in the decision-making process.

2. Methods

To investigate building code decisions and what influenced the code decisions, we studied the three jurisdictions affected by the Marshall Fire in Boulder County—UBC, the Town of Superior, and the City of Louisville.

2.1. Context

In December 2021, the most destructive fire in Colorado history, the Marshall Fire, swept through the grasslands of Boulder County, destroying 156 homes in UBC, 378 homes in the Town of Superior, and 550 homes in the City of Louisville, as shown in figure 1.

Boulder County is a relatively affluent, well-educated community with a median household income of $92 466; 62.9% hold a bachelor's degree or higher ('U.S. Census Bureau QuickFacts' 2022). These jurisdictions are perceived to be environmentally conscious and have mission statements and community plans focused on the values of sustainability and resiliency. For example, Boulder County's mission statement states: '*We are committed to environmental, social, and economic sustainability…*' ('Vision & Guiding Values' n.d.). Louisville and Superior each have a Sustainability Action Plan, which outline the goals and needed actions in pursuit of sustainability and resiliency.

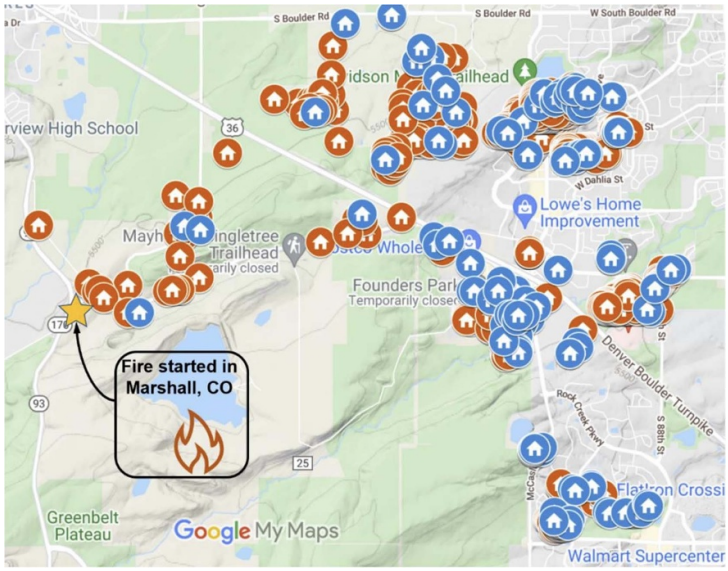

Figure 1. Map of the destroyed properties from the Marshall Fire. Red icons are destroyed homes and blue icons are damaged homes (Fischer *et al* 2022). Reproduced with permission from GEER.

Table 1. Population, number of elected officials and staff, and presence of disaster recovery department by jurisdiction.

	UBC	Louisville	Superior
Population	2400	20 975	13 271
Elected officials	3	7	7
Staff	2904	456	174
Existing disaster recovery department	Yes	No	No

Note: Total population of Boulder County including incorporated and unincorporated areas is roughly 330 000 (2022). Staff is not divided between incorporated and unincorporated areas, so the total reported staff is for all of Boulder County.

Although all three jurisdictions are within Boulder County, each is governed locally, with distinct characteristics. Table 1 shows some of these differences, including the number of elected officials making decisions, the presence or absence of an existing disaster recovery department, and prior exposure to disaster. We studied each jurisdiction affected by the Marshall Fire to explore similarities and differences in decision-making. Detailed case studies on each jurisdiction can be found in Supplementary Information SI-1.

2.2. Data collection

To track outcomes for building code decisions and the factors that influenced these decisions, we collected data through interviews with staff and elected officials within each jurisdiction. In advance of these interviews, the research team observed 78 public jurisdictional meetings from January 2022 to July 2022 and collected public documents to understand the issues, sentiments, and dialogue surrounding rebuilding decisions. The public meetings helped to identify three code decisions of focus.

2.2.1. Code decisions studied

We studied the following jurisdictional decisions that influenced housing rebuilding: the choice of required residential energy code (year, provisions, appendices) for sustainability, and, for resiliency, the choice of whether and how to update the residential building code to address fire resistance and whether to enforce the requirement for indoor single-family residential fire sprinkler systems. Table 2 outlines these decisions and examples by sustainability and resiliency themes.

Energy codes influence a building's life-cycle energy demands. The International Energy Conservation Code (IECC) is a model code released by the ICC every 3 years. The ICC reports that the 2021 IECC achieves a 9.4% improvement in energy efficiency and reduces greenhouse gasses by 87% compared to the 2018 IECC through the building envelope, mechanical system, electrical power, and lighting system requirements (International Code Council, Inc 2021b). The ICC also publishes a net zero appendix (appendix RC) that can be adopted alongside the residential energy code, which defines requirements for a residential building to

Table 2. Code decisions of focus for sustainability and resiliency.

Theme	Code decision
Sustainability	Energy Code (e.g. insulation, solar panel requirements, heating and cooling systems, electrification of appliances)
Resiliency	Wildfire Building Codes (e.g. defensible space, roofing, fire resistant siding and decking, window requirements, covered vents) Indoor Single Family Residential Fire Sprinklers

Table 3. Number of staff and elected official interviewees across jurisdictions.

	Staff	Elected official	Total
UBC	7	1	8
Louisville	3	4	7
Superior	4	3	7

achieve net zero energy consumption over 1 year (International Code Council, Inc 2021b). The BuildSmart code is specific to Boulder County (Boulder County 2016). It was based on the 2015 IECC and heavily amended in 2016 to achieve a higher energy efficiency standard, making BuildSmart more stringent than the 2021 IECC, particularly in its insulation requirements.

To explore resiliency, we analyze decisions for building codes and fire sprinkler requirements as these directly influence measures to harden homes to be more resistant to future fires. In the three jurisdictions of interest, all had adopted the International Residential Code (IRC) for single-family residential structures ('Boulder County Building Code Amendments'n.d.; 'Building Codes | City of Louisville, CO'n.d.; 'Building Codes | Town of Superior Colorado'n.d.). Jurisdictions considered adopting the 2021 International Wildland-Urban Interface Code (IWUIC), which includes regulations for defensible space, roof, decking and siding materials, windows, and covered vents (International Code Council, Inc 2021a). These measures are intended to guard life and properties from wildland fire (International Code Council, Inc 2021a). The requirement for indoor single-family residential fire sprinklers falls under the residential building code, but this decision was made separately from the building code decision about the wildland fire codes, and, therefore, we explore it separately. Fire sprinklers relate to resilience because they can lessen the destruction of fire within a home (Ahrens 2021).

Decisions were made by each jurisdiction separately. However, there was certainly information sharing and cross-pollination of ideas by elected officials, staff, and residents.

2.3. Interviews with staff and elected officials

Data collection involved interviews with staff (primarily those in planning and building departments) and elected officials in each jurisdiction. Interviewees were identified by their participation in public meetings and relevant positions listed on each jurisdiction's website. Additionally, interviewees were asked to identify contacts who could provide valuable perspectives to the research, which we used in a snowball sampling approach to identify additional interviewees. In total, we identified thirty relevant players across three jurisdictions.

Ultimately, 22 interviews were conducted with staff and elected officials during the summer and fall of 2022 (see table 3). When interviews were conducted, each jurisdiction had nearly completed debris removal and had started construction on multiple rebuilt homes. We selected this timing because most of the major decisions to guide rebuilding had been made, allowing interviewees to explain the decision-making process.

Interviews were semi-structured and lasted approximately 1 h in a setting of the interviewee's choice (online or in person). With permission, interviews were audio recorded and transcribed using the online transcription service, Trint (Trint Limited 2022). The data collection follows the methods outlined and approved in IRB Protocol 22-0074.

Interview questions centered around the three rebuilding decisions. Interview questions first asked interviewees to share priorities and goals that had been set for rebuilding in their community and moved to discussing hurdles in the process. We then asked specific questions about the three decisions of interest to uncover the factors and driving forces behind each decision. For example, we asked, '*What information did*

Table 4. Decisions related to energy code adoption by jurisdiction, pre- and post-fire.

	Pre-fire		Post-fire decisions	
Jurisdiction	Date adopted	Energy code adopted	Date adopted	Energy code adopted
UBC	Feb 2016	BuildSmart	No change	BuildSmart No opt-out for fire victims.
Louisville	Oct 2021	2021 IECC with net zero appendix.	March 2022	2021 IECC with net zero appendix for all new construction. Opt-out for fire victims to 2018 IECC, provided certification of underinsurance.
Superior	Aug 2020	2018 IECC	Feb 2022	2021 IECC with net zero appendix for all new construction. Opt-out for fire victims to 2018 IECC.

you need to consider in the decision about whether or not to enforce the newest energy code for fire victims?' and '*How were stakeholders' priorities and desires considered in [specific decision of interest] decision?*' Interviews concluded by discussing how resiliency and sustainability outcomes were being considered in the rebuilding process. The full interview guide used can be found in SI-2.

2.4. Data analysis

Interviews were inductively and deductively coded in QSR Nvivo software (QSR International Pty Ltd 2020) to identify influential factors for each of the three decisions. Initially, we coded factors deductively into three overarching parent codes—*decisions, tradeoffs* (used to identify anything considered in their decision), and information. Each of these parent codes was then coded inductively into specific sub-codes. For example, *incentives and aid, experience*, and *risk awareness* were sub-codes categorized under the parent code of *tradeoffs*. For example, decision-makers had to determine whether the risk perception of residents would guide their decision, leading to risk awareness being coded as a tradeoff. The full coding dictionary can be found in SI-3.

Many quotes were double-coded to account for the decision and influencing factors. For example, the following UBC interview excerpt—'*we did not face the issues about energy codes that Superior and Louisville did. Fortunately, we had a very rigorous energy code that was very proactive.*'—was coded to *energy code* as the *decision*, and *experience* as the *reason for the decision*. In addition, each interview quote was also associated with the jurisdiction (e.g. UBC).

3. Results

3.1. Residential energy code

The first decision made by jurisdictions was the selection of the governing residential energy code for rebuilt houses. Residents raised this as a major concern, and it was one of the most emotional and tense decision-making processes. Ultimately, UBC kept their current code in place, while Louisville and Superior gave their fire-impacted residents the option to build to the 2018 IECC[3], but required all other new construction to meet the 2021 IECC. Table 4 presents the pre- and post-fire energy codes adopted by each jurisdiction, including additional provisions, such as opt-outs, for fire victims.

At the time of the fire, UBC had an energy code that had been in place for several years, whereas Louisville had adopted the latest code only months earlier, and Superior was still considering the next code adoption. Louisville was among the first jurisdictions in the state to adopt the 2021 IECC, such that no homes in Louisville and few homes in the state had been built to this specific code at the time of the Marshall Fire.

Local jurisdictions desired to respond to residents' needs and enable them to return to the community post-fire. Uncertainty in cost, particularly with new code requirements and potential underinsurance, were

[3] By Louisville Ordinance No. 1825, residents impacted by the Marshall Fire can build to the 2018 IECC, the energy code in place in Louisville prior to October 2021, given that, at the time of submitting their permit application, they certify that inadequate insurance coverage prevents work to be performed in accordance with the 2021 IECC (Louisville 2022).By Superior Ordinance No. 0-2, residents impacted by the Marshall Fire can build to the 2018 IECC (Superior, CO 2022).

Table 5. Number of interviews mentioning costs and incentives with energy codes.

	UBC	Louisville	Superior
Costs	11	27	28
Incentives	8	13	14

driving factors for resident concerns. Thus, experience and timing with the code before the disaster were important factors influencing the jurisdictional decision making process.

3.1.1. Costs and incentives

By far, the most cited factor for the energy code decision-making process across the 22 interviews was the barrier—both perceived and real—of the additional costs associated with building to the 2021 IECC. Costs were mentioned 66 separate times across 17 interviewees as a major factor in the energy code decision, with a greater number of mentions among Louisville and Superior interviewees, as shown in table 5.

Following the fire, the first concern of impacted residents was code requirements that would increase rebuilding costs, particularly as 92% of people who lost their homes were underinsured (Plymell 2022). As one elected official in Louisville noted:

'*A week after the fire, someone was talking to me about the building code and that it is going to be [cost] 30% more to build their house [due to the 2021 energy code adoption]. And we had to do something.*'

The cost sensitivity resulted in residents in Superior and Louisville mobilizing to express their cost concerns regarding the 2021 IECC—sending emails pleading with elected officials not to enforce the 2021 IECC, attending public meetings to share their concerns, and even holding a protest (Cobb 2022).

In contrast, UBC policymakers had more certainty about costs for the BuildSmart code due to the code having been in place since 2016. Although interviewees mentioned challenges with costs in Boulder, these concerns were far less cited: 11 mentions, as compared to 27 and 28 in Louisville and Superior. When cost was mentioned by UBC interviewees, they always indicated that their experience with implementing the code overcame these challenges.

Incentives were offered by multiple entities to encourage the uptake of the 2021 IECC or higher. Although incentives were mentioned less frequently than costs, these two factors were always discussed in tandem. Uncertainty surrounds the incentives as it was unknown whether the incentives would be available and able to be used in the post-fire rebuilding. Thus, uncertainty regarding these incentives played a role in dissuading jurisdictions from requiring the new code for residents rebuilding after the fire, particularly in Louisville and Superior, as one Superior staff member indicated:

'*Some of the folks proposing grants and rebates did a disservice by saying, 'here's what's available.' And then, when people really started digging into it, 'Well, we are hoping the legislation approves it four months down the road. We are hoping Xcel approves this.' And people got very turned off very quickly when they think it is a given and [in reality] it is a definite, impending, maybe.*'

Across Louisville and Superior interviews, 19 mentions of uncertainty were linked with costs and 16 were linked with incentives, showcasing that the uncertainty underlying the costs and incentives was highly influential in the decision-making process. Facing uncertainty about the cost burden and the incentives available, Superior and Louisville responded to resident concerns by giving residents who were rebuilding the opportunity to opt-out of building to the 2021 IECC. In contrast, across all interviews with UBC staff and elected officials, uncertainty regarding the cost of implementing the energy code was only mentioned once.

Additionally, Louisville considered that a small number of homeowners with appropriate insurance coverage could rebuild to the 2021 IECC without it being a financial burden. However, insurance only covers costs for the minimum code required. Therefore, the Louisville ordinance enforces the 2021 IECC for those with sufficient insurance coverage, ensuring the insurance companies will pay for code costs, and gives the opt-out to the 2018 IECC given certification of underinsurance. Ultimately, jurisdictions tried to remove potential barriers to residents rebuilding.

3.1.2. Experience and timing

Experience can reduce cost uncertainty. As shown in table 4, each jurisdiction had a different energy code pre-fire. Boulder County had been enforcing its BuildSmart code since 2016, Louisville had adopted the 2021 IECC 2 months before the fire, and Superior was considering adopting the 2021 IECC prior to the fire but had not yet done so. These starting points influenced the decision-making process post-fire.

Boulder County had enforced the BuildSmart code for many years, including for post-disaster rebuilding, giving them the confidence to continue to enforce the current code. In fact, interviewees from

Boulder County were the only participants to mention experience as critical to their energy code decision. As one Boulder County elected official noted:

'*Well, we did not face the issues about energy codes, that Superior and Louisville did. So, fortunately, we had a very rigorous energy code that was very proactive. I forget when it was enacted—sometime in 2016 or 17.*'

This experience included more certainty regarding costs and the process of building to the code, precedence of keeping the code in place through previous disasters, and a network of builders with experience building to the code. A UBC interviewee explained, '*That made it easier for us because architects and builders were familiar with it*'. Each of these aspects of experience was considered crucial in allowing Boulder County to keep its BuildSmart code in place with little internal discussion or upheaval from residents.

Louisville and Superior both cited poor timing, rather than experience as a driving factor. With both jurisdictions having either recently adopted or about to adopt new energy codes, the first homes to be built to these codes would have been the fire rebuilds, as pointed out in multiple interviews. For example, one Louisville elected official stated:

The guinea pigs were the fire-destroyed, trauma-ridden, non-voluntary builders. And that's a really rough group to start a complicated process like this. We would never envision that these would be the people we'd want to do this with. And the way we wrote it was to say, 'Hey, rich person moving and building a new house, you are going to have to do it this way. And, if you do not like it, do not build a new house. And we are okay with that too'. So, that was who it [the new codes] *was aimed at. We are not going to grow without growing green. This* [the fire rebuilding] *was not growth, this was a replacement of people.*

Rather than categorizing the fire rebuilds as new construction, staff and elected officials referred to the rebuilds as replacement construction, which they considered separate from the new construction. In fact, they saw it as progress toward sustainability goals that even by building to the 2018 code, the 'replacement homes' would be significantly more energy efficient than the homes lost in the fire, which had been built to the codes of the 1980s and 1990s.

3.1.3. Information

Without direct experience like Boulder County, Superior and Louisville sought information to determine the costs associated with different energy codes. The information they received regarding the cost difference between the 2021 IECC and the 2018 IECC was overwhelming and conflicting. In particular, costs reported by builders differed greatly from a widely shared cost analysis conducted by the Pacific Northwest National Laboratory (Mendon *et al* 2015). For example, in February of 2022, the Home Builders Association of Metro Denver sent an open letter to fire victims and affected communities presenting estimates that the 2021 IECC code would add $35 per square foot to residential rebuilding costs compared to the 2018 IECC, or about $84 000 for a 2400 square foot home, while comparable estimates from the City of Louisville's Residential Construction Cost Analysis presented to council on 1 March was $12 000–$38 000 (Home Builders Associations of Metro Denver 2002, City of Louisville 2022). These discrepancies led homeowners, staff, and elected officials alike to be highly uncertain as to what cost estimates to trust. As one Louisville elected official indicated:

'*Who do we trust to give us a fair number? And then you get this final number from a company [research organization] that says, 'Here it is like this. Point by point, this is how much it would cost, and this is the differential.' And they are [builder] like, 'Thank you so much for your report [referring to the researchers' reports]. Woah, woah, woah, hold on, but you cannot build that. Like those are the numbers, but I cannot get those materials. I certainly cannot get 500 of them.' So that's theoretically how much it should cost.*'

Arguments about why these discrepancies existed included some interviewees attributing the relatively high costs from builders as an attempt to discourage adoption of the new 2021 IECC, while others believed it was due to other contextual factors, such as supply chain disruptions, high housing demand in Colorado at that time, and a lack of experience building to the new code and thus uncertainty from the builders as to the requirements. As a Louisville elected official explained:

'*I think the biggest thing was uncertainty in cost in general, no matter what those pieces were. And then uncertainty about access to materials and the supply chain issues that we are having and the uncertainty about the builders' ability to build something they have not really built before.*'

Other important information for some decision-makers was looking at the outcomes in other communities, like Colorado Springs. Colorado Springs had rebuilt after the 2012 Waldo Canyon Fire without enforcing the strictest energy code for the rebuilds. One Superior elected official contacted those involved in the rebuilding effort after the Waldo Canyon Fire to learn about the successes and failures in their recovery effort. Decision-makers noted that the rebuilds in Colorado Springs were often built to a higher energy code than required. After an in-person visit to the area impacted by the Waldo Canyon Fire, this elected official reflected, '*I came back [from Colorado Springs visit], like, why are we doing this? let us get out of the way and look what happened in Colorado Springs.*'

Table 6. Residential wildfire building code decisions pre- and post-fire by jurisdiction.

	Pre-fire		Post-fire	
	Date adopted	Building code adopted	Date adopted	Building code adopted
UBC	January 2016	2015 IRC with amendments (ignition-resistant requirements for Wildfire Zone 1)	May 2022	2015 IRC with amendments (ignition-resistant requirements for Wildfire Zone 1 & 2)
Louisville	September 2018	2018 IRC with amendments (no ignition-resistant requirements)	No change.	2018 IRC with amendments (no ignition-resistant requirements)
Superior	August 2020	2018 IRC with amendments (no ignition-resistant requirements)	No change. July 2022	2018 IRC with amendments 2021 IWUIC for Sagamore neighborhood with opt-out

Table 7. Frequency of costs and incentives mentioned regarding building codes across interviews.

	UBC	Louisville	Superior
Costs	16	7	10
Incentives	0	7	2

3.2. Residential building code

After the energy code discussion and decision, jurisdictions moved to consider the residential building code, particularly to include requirements from, or the entirety of, the 2021 IWUIC. Building code discussions were particularly relevant post-fire due to their role in minimizing destruction during fires. Before the fire, the only fire-resilient building code requirement was the ignition-resistant requirements for Wildfire Zone 1[4] in Boulder County. While Louisville made no changes to their residential fire-related building code, UBC added ignition-resistant requirements to their code for all new construction in Wildfire Zone 2 (where the Marshall Fire occurred), and Superior adopted the 2021 IWUIC for one impacted neighborhood (Sagamore) but gave residents the option to opt-out of the IWUIC (see table 6 for ignition-resistant requirements before and after the fire by jurisdiction). Common factors influencing these decisions included costs and incentives, risk awareness, and public opinion.

3.2.1. Costs and incentives

While UBC was concerned about the cost burden of rebuilding for their residents, they knew the costs associated with adding ignition-resistant requirements to the 2015 IRC from their experience implementing fire-resistant building code mandates. Thus, those interviewed did not feel that the additional requirements would burden the residents rebuilding. While costs were cited many times, as presented in table 7, these 16 citations primarily focused on the necessity of providing cost information to residents versus concerns that costs would be an insurmountable financial barrier for residents.

In Louisville and Superior, costs were a major concern and were discussed by 12 interviewees. Following the upheaval surrounding the energy code decision, staff and elected officials remained wary of adding requirements that might increase costs for their residents. In both Superior and Louisville, interviewees were direct in pointing to costs as the primary factor influencing their decision. For instance, one elected official in Louisville indicated the common feeling of their residents: '*Oh, you are kidding me. So not only do I build 2021, but you are also going make me build to some crazy high WUI standard, like, are you paying for that?*'.

Louisville, in particular, was adamant that they would not be ready to have conversations about changing the building code to include fire-resistant measures unless there were incentives to support implementing them. After the energy code conversations, they wanted to be certain that any additional codes adopted would not be a financial obstacle to residents rebuilding in the community. This mindset led Louisville to table all conversations about changes to the building code for ignition-resistant materials very quickly.

[4] Boulder County is divided into two wildfire zones. Wildfire Zone 1 encompasses the mountainous region of the County, where there has generally been more risk of wildfire. Wildfire Zone 2 covers the plains region, including the area where the Marshall Fire took place. See SI-1A for a map of the Wildfire Zones.

Superior was also focused on concerns about the cost burden to their residents, but because of demand from residents in Superior's Sagamore neighborhood, they decided to consider specific neighborhood code measures, explored in the next section.

3.2.2. Risk awareness and public opinion

While a disaster tends to heighten risk awareness, interestingly, some community members perceived a decreased fire risk after the Marshall Fire. Both risk perceptions impacted the decisions surrounding building codes.

For UBC, all interviewees who worked in the building department and elected positions cited increased risk awareness as a driving factor for modifying the building code in the plains region (i.e. Wildfire Zone 2). After the fire, residents had new experiential knowledge of how certain practices in the code related to how the fire had spread. For example, one of the modes of spread in the Marshall Fire was embers from the fire entering homes from uncovered vents on the outside of the house, which is directly addressed by code regulations for covered vents. From this lived experience, Boulder County received public support for broadening the geographic scope of the wildfire building code. As one staff member from Boulder County indicated:

'*I think it is experiential. People had just had this happen to them and when things happen like this, people get it. It is fresh. They understand why we are moving forward with certain things. They sometimes wish we would have had it previously, so maybe they would not be in the situation they are in. And so you have the ability to really have these thoughtful discussions around how to best move forward.*'

On the other hand, interviewees noted perceptions of decreasing risk in their community, believing that a disaster would be unlikely to strike the same place multiple times. Over half of the interviewees across Louisville and Superior mentioned hearing sentiments of decreased perceptions of fire risk from their residents and cited this factor as influential in the decision-making process. An elected official in Superior noted:

'*This was a rare event and probably is not going to happen again or happen in this exact form or in this exact location. And, you know, why should I have to change? I'm speaking in terms of the voices…I want to live my life without being in fear that that same thing is going to happen again. I want to have vegetation outside. I want to have my deck or my whatever…So there were some, you know, some that just denied that it would happen in that form again.*'

However, staff and elected officials noted that some residents in the Sagamore neighborhood differed in their risk awareness from those in the rest of the community. Sagamore lost 370 homes (100%) (Brennan 2022). Due to the small lots and proximity of homes, these residents became extremely aware that their neighbors' homes were ignition for their own homes, causing them to push for the addition of fire-resistant measures in the building code. One elected official in Superior noted:

'*We are at a point today that I think a lot of people perceive safety as what their neighbors do. And, you know, you can control yourself. You can wear your seatbelt, but your neighbor may not. And I want you, the government, to tell them what to do to make me feel safer…And again, with Sagamore being actually five-foot setbacks, there's ten feet between homes, that's a more manifestly felt feeling and that if my neighbors do not do this then my home will be at greater risk.*'

However, not all Superior or Sagamore residents wanted to build back with additional fire-resistant measures. Driven primarily by public demand, the Superior Town Board passed the IWUIC building code for the Sagamore neighborhood so that insurance might cover the costs of implementing this code, but created an opt-out for those in the neighborhood that did not want to build back with fire-resistant practices in place. Although the full effectiveness of the IWUIC code is dependent on all homes within a neighborhood being hardened (International Code Council, Inc 2016), some homes in the Sagamore neighborhood will be hardened according to the IWUIC code, and some will not.

3.3. Residential fire sprinkler requirement

In UBC, where fire sprinklers had been required for single-family residences since January 1995, the requirement was kept in place. Given the experience and length of time with the requirement, residents did not discuss or advocate for changes to this code. Therefore, the factors considered below as being significant in the residential fire sprinkler decision are those that were significant in Louisville and Superior only, where the requirement was either completely removed or waived for fire rebuilds (table 8).

3.3.1. Risk awareness

Removing the requirement for fire sprinklers post-fire may seem illogical; however, interviewees emphasized that the primary purpose of indoor fire sprinklers is to contain fires that start inside the home. While this sentiment is backed by science, indoor fire sprinklers can also help to protect homes during wildfire when the

Table 8. Decision to require single-family residential fire sprinklers pre-and post-fire by jurisdiction.

	Pre-fire		Post-fire decisions	
Jurisdiction	Date	Fire sprinkler requirement adopted	Date	Fire sprinkler requirement adopted
UBC	January 1995	Adoption of single-family residential fire sprinkler requirement	No change.	Single-family residential fire sprinkler requirement in place
Louisville	January 2015	Adoption of single-family residential fire sprinkler requirement	April 2022	Removal of single-family residential fire sprinkler requirement for all construction
Superior	January 2012	Adoption of single-family residential fire sprinkler requirement	May 2022	Single-family residential fire sprinkler requirement in place. Requirement waived for fire rebuilds

fire might enter the home through embers or convective heat (Office of Energy Efficiency and Renewable Energy 2022). Yet, people cited that fire sprinklers are not necessarily meant to save the structure with the fire approaching from the outside. One elected official in Superior expressed this idea:

'*It is kind of ironic that a disaster, created by fire, people would be wanting to opt out of a fire sprinkler system. But the reality is interior fire sprinkler systems do nothing when the fire approaches from outside and not inside.*'

Both Louisville and Superior had members of the local fire department affirm that fire sprinkler systems would have been useless in the Marshall Fire in reducing the number of structures lost but that it was crucial to keep the requirement in place to help save the lives of residents and firefighters. This catalyzed a discussion about how much should be done to save lives. Nearly half of the interviewees across Louisville and Superior indicated that they were unclear and uncertain as to which benefits they should be prioritizing in the decision. As one interviewee, an elected official from Louisville, summarized, there was a limit to this logic:

'*But I did have a firefighter friend that was like, 'The thing we are walking into—saving lives, saving animals, saving whatever we can—if anything you can do for us could save a life, could protect a firefighter, you should do anything possible'. And while I agree with that sentiment, at some point, it loses validity. I mean, you could put a fire hydrant in front of every single home, and that would speed up the firefighters because they do not have to attach 100 yards down the street. So, are you telling me we do not care about firefighters because we do not have a fire hydrant in front of every home?*'

This became a topic of contention between decision-makers who disagreed on how much should be done to protect lives. We note that two lives were lost in this fire and that different decisions may be made if additional lives had been lost.

3.3.2. Costs

Costs were likewise a major factor for what should be required for residential fire sprinkler systems. Nine out of fourteen interviewees from Louisville and Superior discussed costs as a prominent factor for this decision. Costs for a fire sprinkler system were identified to be between $10–20 000, and required additional costs for many homes that did not have sufficient existing water line sizes and would therefore require a large basement water tank. Many of these homes did not have a sprinkler system in the house before the fire due to being built prior to the sprinkler system requirement.

For both Superior and Louisville, the fire sprinkler issue was one of the last decisions and was made much faster than all other previous decisions. Very few tradeoffs were brought up in the discussion surrounding fire sprinklers because, at this point in the recovery process, staff and decision-makers were largely subscribing to the philosophy that if a requirement or code was a cost barrier, then it should be removed. An elected official from Superior noted:

'*We also tried to remove regulatory requirements that increased cost. So efficiency codes or indoor sprinklers, both of which are net positives for the homeowner as well as the environment. None of us could sit on the board and mandate something that was going to increase costs. Our board has been pretty unified in terms of identifying areas that can cut costs for homeowners and identifying areas we can help speed things up*'.

Ultimately, the priority was placed on enabling residents to rebuild their homes, and anything that was a real or perceived cost barrier threatened this priority, especially because of the widespread underinsurance among homeowners.

4. Discussion

The three jurisdictions impacted by the Marshall Fire each faced various challenges in the decision-making process surrounding what codes to adopt and enforce for the homes rebuilt after the fire. We found that jurisdictions prioritized responding to residents' needs and enabling them to return to the community. Uncertainty and concerns regarding the cost of adopting higher requirements for building codes influenced this local decision-making process. We discuss the central influence of uncertainty and localized decision-making and suggest that pre-disaster planning, state involvement or guidance in building code decisions, and setting standards before a crisis may influence the adoption of newer codes for fire risk reduction and energy goals.

4.1. The central influence of uncertainty

While each of the factors explored above influenced the decision-making process, uncertainty, particularly regarding costs and what would be covered by insurance or incentives, as well as the effectiveness of some of the code provisions, drove many of the decisions to create opt-outs or roll back code requirements for those affected by the fire. Interviewees identified many areas of uncertainty, particularly when they had conflicting information. Cost uncertainty has been acknowledged as a challenge to more sustainable and resilient code adoption even outside the pressured post-disaster context, driven partly by opposition from the residential building industry (Shapiro 2016). Post-disaster is an innately emotional time, particularly for those who lost homes during the disaster (Mockrin *et al* 2016). In the post-disaster context, when residents faced obstacles to rebuild and return to the community, this uncertainty heightened emotions, influencing residents to request that jurisdictions adopt more lenient code requirements. Jurisdictions aimed to lessen the trauma and uncertainty by rolling back requirements perceived to have additional costs for residents.

When there was less uncertainty, for instance, in UBC when costs for ignition-resistant requirements or the BuildSmart code were already in place and known, jurisdictions kept codes in place or even added code requirements. Thus, uncertainty was closely tied to experience and timing with respect to code adoption; if jurisdictions and builders had experience with a particular requirement or building practice, there was less uncertainty. UBC's experience enforcing code requirements gave them more certainty on the costs associated with the decisions. While other jurisdictions were provided with cost information, this information conflicted with costs builders were reporting to homeowners. This observation supports that information gained from direct experience better reduces uncertainty, particularly regarding the efficacy of the policy in practice (Taylor *et al* 2021). Ultimately, jurisdictions defaulted to making decisions aligned with their experience before the disaster. Further, while incentives were often offered to counteract uncertainty in cost and to provide constituents with the ability to recover gaps between their insurance and rebuilding costs, uncertainty about the incentive amounts, eligibility, and process also supported loosening the code requirements.

4.2. Impacts of localized decision-making

Organizational structure and strategy play a major role in mediating behavioral factors in decision-making (Ballesteros and Kunreuther 2018). In other words, the level of government at which decisions are made and how collaboration occurs across different levels of government impacts decision-makers' responses.

At the local level, it is particularly difficult to reconcile the upfront costs of mitigation, both in terms of political and economic costs, against future benefits that are uncertain in their time, magnitude, and beneficiaries (May and Williams 1986, Wyner and Mann 1986). Post-disaster, when decisions are made, short-term costs are at the forefront of residents' minds and prioritized over longer-term benefits. This was evident in the discussions surrounding code adoption and enforcement, where the central point of discussion was the costs associated with code implementation, with much less discussion of long-term benefits.

The level of government may contribute to the differences in UBC's outcomes compared to the other jurisdictions. While Louisville and Superior are city and town governments, UBC is governed at the County level with all of Boulder County. Boulder County has both a larger total number of residents and a much smaller percentage of residents who lost a home. While data from this study does not concretely illicit findings on the impact of levels of government on decision-making, past research has indicated that decisions being made at differing levels of government, and therefore proximity to residents, may impact how influential the identified factors were; in particular, governments with more distance between decision-makers and their constituents see a decrease in the influence of local factors (Berke *et al* 1996, 2014, Burby and May 1997). Certainly, meetings were less contentious, and residents less vocal in their concerns to UBC. The sheer number of impacted residents from Louisville and Superior, who were also closely situated to jurisdictional staff and elected officials with whom they could air their needs, may have swayed decision-makers. Further, while local jurisdictions are well positioned to work cooperatively with their

constituents, build trust, and make things better for community members, this work suggests that state guidance and involvement, as discussed below, may be needed if codes are to be imposed to reduce energy use or improve fire resilience.

4.3. A role for pre-disaster planning

Disaster preparedness, encompassing comprehensive preparedness that moves toward resilient communities that can coexist with the risk of disasters (Godschalk *et al* 1999, Raikes *et al* 2019), can influence rebuilding decisions and resilience. Post-disaster reconstruction plans allow communities to set their priorities prior to a disaster to lessen uncertainty and wavering in the emotion-ridden post-disaster phase (Schwab *et al* 2014). Research has shown that the more recovery topics that are addressed in the pre-disaster environment, the better the efficiency and quality of post-disaster decision-making (Wu and Lindell 2004). The data here suggests that robust processes for considering building code changes and adoptions, including the cultivation of trusted relationships and information sources, can be important. The effect of this planning is—in part—to reduce the uncertainty that so strongly influenced the outcomes in the case of the Marshall Fire.

Mandating plans at the state level but leaving plan creation to local jurisdictions can help leverage the effectiveness of state mandates (Berke and French 1994, Berke *et al* 1996, 2014, Burby and May 1997) while providing space for jurisdictions to tailor plans to their communities (Godschalk *et al* 1999). For instance, local engagement of residents has been shown to garner more support for policies and plans when a disaster occurs (Berke and Campanella 2006).

Florida has mandated post-disaster reconstruction plans for coastal communities at risk for hurricanes. These include plans for rebuilding and code enforcement, among other topics (Florida Department of Community Affairs, and Florida Division of Emergency Management 2010). Other states, such as Hawaii, have begun creating their own disaster recovery plans, emulating Florida (Courtney *et al* 2019).

4.4. Limitations

This paper has focused on one aspect of jurisdictional decision making, namely adoption and enforcement of building codes for single-family homes. We focused on these decisions because they are impactful for residents who are rebuilding, and for community risk reduction and climate goals. However, jurisdictions make other important decisions. In these communities, decisions about vegetation management, particularly in public 'Open Space' areas, were and continue to be fraught and significant. Other decisions are primarily made by homeowners and homeowners associations, e.g. adoption of above-code minimum requirements, parcel-level vegetation management, and type of fencing. These decisions are fruitful areas for future study. Further, we have noted uncertainty in the cost of implementing new codes, and a lack of alignment between builder-reported costs to homeowners and costs noted in reports. Future work can study the costs incurred in rebuilding to lessen this uncertainty and update costs. Finally, it is worth noting that the impacted jurisdictions are relatively affluent, well educated, and have substantial government capacity to handle the challenges of post-disaster recovery. Additional work is needed to determine how these factors influence decisions in jurisdictions with varying characteristics, as we expect they may be even more influential in under-resourced communities.

5. Conclusion

Destructive wildfires will continue to increase in frequency and size due to the impacts of climate change and the further encroachment of the built environment with wildland boundaries. Traditional fire suppression and firefighting methods are no longer sufficient. Therefore, it is important that we understand how to promote and guide better rebuilding outcomes.

In this study, we explored rebuilding outcomes tied to resiliency and sustainability through the perspective of jurisdictional decision-making after the Marshall Fire, focusing on building code adoption as an important and impactful form of local government decision-making. We identified influential factors that drove three building code decisions that govern construction for rebuilt homes: residential energy code, fire-resistant building code requirements, and the requirement for indoor single-family residential fire sprinkler systems. In some cases, the jurisdiction maintained or strengthened code requirements related to sustainability or resilience, while in other cases, they reduced requirements.

Factors driving the decisions differed across jurisdictions and decisions; however, jurisdictions prioritized reducing uncertainty to enable more residents to rebuild and return to the community. Uncertainties, particularly in code-associated costs, incentives, and future fire risk, were barriers to rebuilding with newly adopted codes. This uncertainty motivated jurisdictional decisions, with the goal of enabling residents to return to the community.

Jurisdictional preparation and planning before a fire can help align goals and priorities that would enable desired community outcomes. These plans can directly address some of the key challenges that influenced jurisdictions to waver from their stated pre-disaster priorities. This study demonstrates that one of the most important facets of preparing for rebuilding decisions is to preemptively seek information that jurisdictions and residents will need in a post-disaster environment, such as the cost implications of, and training contractors for, various code requirements. A better understanding of these factors—as well as related issues of incentives and insurance coverage—can substantially reduce uncertainty.

The Marshall Fire's occurrence in a state without state-wide building codes is significant. That these decisions happen at the local government level has implications for rebuilding outcomes, as elected officials at the local level are more closely situated to their constituents and, therefore, more disposed to making decisions in line with the shorter-term needs of their community and preservation of the status quo (Wang and Van Wart 2007).

For states that do not have statewide building codes, particularly those in which promoting sustainability and resiliency in the communities is a major priority, state leaders must consider their statewide priorities for rebuilding and if leaving the guidance of rebuilding up to individual jurisdictions will result in outcomes that meet these priorities. Colorado has moved toward more statewide guidance for wildfire resilience since the Marshall Fire, passing a bill to establish a wildfire resilience code board, whose purview includes the definition of minimum codes and standards to reduce wildfire damage (Velasco *et al* n.d.). Mandating post-disaster recovery plans would likely reduce the uncertainty and changes that occur when these decisions are left to local officials who are more closely connected to the residents.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary information files).

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Ethical statement

All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Institutional Review Board under Protocol 22-0074.

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