Ambition and reality in the climate resilience of residential buildings: A case study on flood reconstruction in Austria

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Abstract

Climate resilient development pathways call for the integration of climate change adaptation and mitigation in policy strategies. However, implementing climate resilience in practice requires coordination between policy domains. Residential buildings may showcase climate resilience, as they can be vulnerable to climate-related natural hazards and contribute significantly to carbon emissions. The present paper analyses whether recovery and reconstruction in a peri-urban area after a severe flood in 2013 at the Danube in Austria opened a window of opportunity for making residential buildings not just flood-proof but also energy efficient. Five main policy instruments and their underlying governance process are described, and their outcomes are assessed using public statistics, interviews with 15 policy actors, streetside observation of 126 buildings and six ethnographic case stories of specific households. The policy instruments are uncoordinated and address only their own policy domain. Households hardly remodel their building after the flood. Transformation to climate resilience is mostly limited to new buildings when they are no longer exposed to flooding and have to comply with building regulations. Overall, the ambitions for climate resilience put forward in policy strategies do not manifest in the reality of the case study. Funding criteria for disaster aid and renovation subsidies should be adapted to incentivise both flood protection and energy efficiency. Local authorities could take an intermediary role in the rollout of policy instruments.

1. Introduction

The sixth IPCC report yet again highlights the need for rapid and comprehensive action on climate change (IPCC 2023). As climate impacts unfold at an alarming pace, policy strategies need to reorient in order to jointly address adaptation and mitigation, in other words, coping with current climate impacts while at the same time minimising future climate impacts. The term ‘climate resilient development pathways’ describes the integration of climate change adaptation and mitigation (Göpfert et al. 2019; IPCC 2022). Although climate change adaptation and mitigation are intrinsically linked, they are typically managed as separate policy domains. This may incur divergence or contradiction between institutional frameworks and implementation actions, and may initiate path dependencies that restrict other policy goals (Landauer et al. 2019; Kondo et al. 2021). Climate resilience, by contrast, could leverage synergies between adaptation and mitigation activities (Langlais 2009). Climate resilience may enable more efficient use of public and private resources and could, to some extent, avoid that system capacities are overwhelmed by the climate impacts which are already happening.

The present paper showcases residential buildings as an exemplary application of climate resilient development pathways. Residential buildings are allocated in space and therefore can be mapped to areas of significant risk from climate-related natural hazards (EU 2007). Buildings cause substantial carbon emissions from the production of construction materials and from space heating. Insulating and flood-proofing the building envelope is highly effective to buffer the impacts of heat waves and floods and to reduce carbon emissions. Once constructed, buildings persist over decades and therefore allow enduring transformation as well as crippling path dependency. Buildings are targeted by many established policy instruments, such as zoning regulations, construction standards, housing grants or retrofitting subsidies. Prominent examples for climate resilience in urban buildings are the communities of Valmeyer (USA; Knobloch 2006) or L’Aquila (Italy; Micangeli et al. 2013) where reconstruction and relocation after natural hazard events were leveraged to introduce sustainable energy systems. It thus comes as no surprise that the climate and energy strategies of many cities refer to co-benefits when integrating adaptation with mitigation in housing policy (ICLEI 2020, OECD 2021).

However, implementing climate resilience in mainstream policy meets practical challenges. Governance plays a critical role in ensuring political and societal acceptance and in promoting uptake on the housing market (Rutting et al. 2023). Governance may take an active approach by planning, issuing and enforcing legal frameworks and financing, or may instead rely on self-regulatory change and the free play of market forces (Patterson et al. 2017). Responsibility for adaptation and mitigation issues is typically scattered between administrative silos that are hardly coordinated and lack structures for social innovation (Candel & Biesbroek 2016; Peters 2018). However, problems cutting across policy domains require dedicated efforts at coordinating and integrating these domains (Biesbroek 2021).

In the light of these governance barriers, climate resilience might be more likely to emerge in the aftermath of natural hazard events than as the outcome of a planned policy process. Re-establishing systems after exogenous shocks opens a window of opportunity for disrupting deadlocked policy discourses (Friedman et al. 2019; Rose et al. 2020) and for introducing novel ideas (Brundiers & Eakin 2018). In the weeks and months after a natural hazard, multiple policy activities for assistance and recovery coincide with the reconstruction of damaged buildings. Successful post-disaster learning need not be limited to those affected, but should span organisational (Corbacioglu & Kapucu 2006), social (Pelling & High 2005) and policy domains (Birkland 2004). A natural hazard may help to abandon lock-in and path dependency by exposing the perpetuation of prevalent policy strategies as insufficient, and instead initiating a reorientation to new approaches (Vergne & Durand 2010). Natural hazards may therefore catalyse and accelerate transformative change to climate change adaptation and decarbonisation, that is, to climate resilience (Birkmann et al. 2010, Sword-Daniels et al. 2015).

The present paper demonstrates how a lack of policy coordination hinders climate resilience for the case of residential buildings in a periurban area after a severe flood in 2013 at the Danube in Austria. We analyse climate change adaptation regarding flood protection and climate change mitigation regarding energy efficiency of buildings as the reaction to the exogenous shock of the flood event and to the endogenous response of the governance system. A portfolio of five main policy instruments was implemented after the flood that directly affected the recovery and reconstruction of the building stock: disaster aid payments, a planned relocation programme, construction standards for new buildings, information on residential energy saving, and subsidies for renovating existing buildings. Residential buildings were repaired, adapted and erected within and outside the floodplain. We trace governance activities and their outcomes by means of semi-structured interviews with policy actors and households, and coding of building characteristics. Selected case stories illustrate how climate resilience played out in specific households. Overall, the policy portfolio hardly supported climate resilience and even lead to increased vulnerability and maladaptation (Juhola et al. 2016).

2. Climate resilience in Austrian regional planning

2.1 Austrian flood governance

The Austrian flood risk governance system is characterized by a broad range of different actors at different political levels. Because of Austria's federal state system, flood risk management is managed between the national, federal and local levels by separate organizations for lowland flooding, mountain torrents and the three large rivers Danube, Mach and Thaya (Rauter et al. 2019). The consequences are a broad number of actors, strategies, legislations and policy instruments, which can be contradictory for realizing climate resilient development pathways. For example, decisions on flood-proofing requirements for new buildings, land use management or emergency management are taken by the local authority; large-scale technical protection measures (such as dams or retention basins) are designed on the federal level, funded from national, federal and local sources, but maintenance costs for these measures are carried solely by the local authority (BML 2023).

Elected representatives and civil servants in Austrian flood risk management typically have an enduring mindset that considers public technical engineering measures to be the best and universal solution (Seebauer et al. 2023). Governance processes are mostly top-down, with hardly any consultation with or participation by concerned citizens (Seebauer & Winkler 2020; Thaler et al. 2020). Flood risk communication appeals to citizens to implement private preparedness measures (BMLFUW 2012; Rauter et al. 2020). However, these appeals are mostly limited to providing information leaflets, while the dominant strategy favours centralized and technical approaches. Small municipalities (of less than 5000 inhabitants, which is typical for Austria's countryside) usually lack qualified manpower and communal budgets to take substantial measures on their own, or to coordinate with neighbouring municipalities or with higher governance levels (Clar and Steurer 2019; Radinger-Peer et al. 2015).

2.2 Austrian housing governance

The Austrian governance system for housing provision is similarly characterized by a high level of federalism that needs political coordination (Niedertscheider et al. 2018; Brand and Pawloff 2014). The main national actor is the Ministry for Climate Action which is responsible for reaching internationally agreed climate targets. Most competencies for implementing housing policy lie with the federal states and their administrative departments for housing, environmental protection and spatial development (Steurer and Clar 2015). As in flood governance, the local authorities decide on spatial planning and land use.

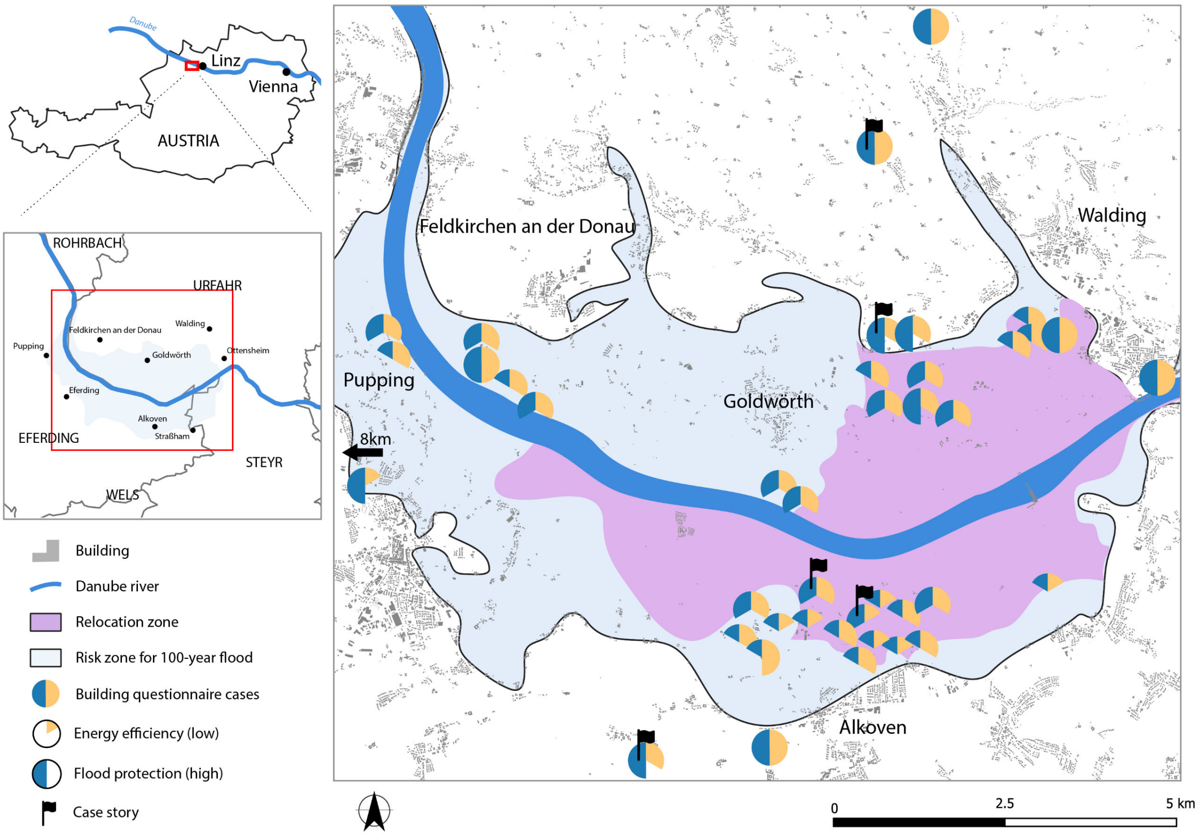
National policy strategies call for extended efforts in building renovation (Federal Chancellery 2020, BMK 2023). National schemes provide the bulk of funding for energy efficiency in buildings, which are partly in line with the goals and additional funding programs of the federal states. Austria has approximately 2,000 funding schemes at the national level for climate mitigation policies, of which more than 350 are directed at enterprises (Wieser 2024). Nevertheless, national and federal efforts do not comply with Austria's stated carbon emission reduction targets (Umweltbundesamt 2023). This is mainly due to shortcomings in implementation: The majority of measures are non-binding, uncoordinated, and follow a first-come-first-served funding approach that does not prioritize critical or vulnerable population segments (Seebauer et al. 2019; 2021). Federal actors tend to circumvent or delay national ambitions unless pressured by EU directives or national legislation (Steurer and Clar 2015).

2.3 Case study description

The Eferding Basin is a 60 km^2 natural basin and retention area at the Danube river in the federal state of Upper Austria, about 20 km upstream of the federal state capital of Linz (Figure 1). Historically an agricultural area, the Eferding Basin has developed into periurban sprawl of the nearby Linz urban region (Seebauer & Winkler 2020b). The area has a population density of ca. 100 residents/km^2 and is characterised by farm buildings and detached single-family houses with extensive gardens. The Eferding Basin has been affected by exceptional flood discharges in 1954, 1967, 2002 and 2013 which caused substantial damages to private properties and infrastructure (Habersack et al. 2002; Blöschl et al. 2013). The 2013 flood affected 706 households and incurred overall damages of €41 million (BMVIT 2015). The Eferding Basin comprises five municipalities with residential and agricultural areas at risk of flooding: Alkoven, Feldkirchen, Goldwörth, Pupping, and Walding.

The Upper Danube features high-level technical protection from flood risk, going back to the construction of hydropower plants along the river course in the 1970s (Seebauer & Winkler 2020a). However, hydrological and geomorphological circumstances do not allow the construction of flood alleviation schemes in the central segment of the Eferding Basin; therefore, this segment has been subjected to a voluntary relocation programme (Thaler et al. 2020; see Section 4.1). Planning for technical flood defence in the remainder of the Eferding Basin commenced in 2015 and is still ongoing.

Figure 1. Case study map.



3. Data and methods

We use a mixed-method approach for triangulation and cross-checking from different perspectives and to paint a ‘rich’ picture of the recovery and reconstruction dynamics in the Eferding Basin. To identify the main policy instruments and track their design and rollout, semi-structured interviews were conducted with nine stakeholders from governmental agencies and associations at the national, federal state and local level, and with six current or retired mayors from the Eferding Basin (see Table A.1 for a list of interviewees; interviewees are numbered as ix; all tables in the Appendix are indicated by the prefix A). Stakeholder interviewees were selected based on their roles in the climate adaptation or mitigation governance process.

To assess whether the flood event and the subsequent policy strategy improved building quality, we firstly compare the prevalence of carbon-neutral heating systems in the municipalities in the Eferding Basin to all other Upper Austrian municipalities using the Upper Austria carbon emission cadastre (EFA GmbH & Land OÖ 2021). However, these data refer to 2018 and no data from before the 2013 flood are available. Secondly, we observed buildings on the Eferding Basin floodplain from the streetside. A trained observer recorded external building features that could be detected despite fences, hedges, plot boundaries or surrounding buildings, using a structured coding sheet, and then approached the residents (by asking over the fence, ringing the doorbell, via neighbours) whether they would be willing to complete a more detailed building questionnaire that validated external building features, assessed internal features and also covered the building status before the 2013 flood. Streetside observation was conducted in July and August 2022. In all, 126 buildings were observed, of which 41 completed the building questionnaire (observed buildings are indicated on the case study map, see Figure 1). Each building was classified into a high, mid or low level of flood protection and energy efficiency, respectively (flood protection and energy efficiency levels of observed buildings are indicated in Figure 1; Tables A.2 and A.3 give the classification criteria). However, as for some buildings the classification to a specific level was not clear-cut or some building features could not be detected, we also provide as a robustness check the results for the subsample of buildings with unambiguous classification (see Table A.4). We compare the level of flood protection and energy efficiency between the municipalities in the Eferding Basin, and before and after the 2013 flood.

To show how affected households modified their buildings in reaction to the flood and the policy instruments, we report six ethnographic case stories that represent prototypical individual pathways to climate resilience (case stories are indicated in Figure 1). Case story information was obtained in semi-structured interviews. Household interviewees were recruited from the address lists of previous research activities in the case study region. All case story households completed the above building questionnaire and are included in the streetside observation data.

Stakeholder and household interviews took 1-2 hours each and were conducted face-to-face or online between February and March 2023. Interview transcripts were subjected to qualitative content analysis, first conducting deductive coding along the defined policy instruments and the elements of climate resilience, then extending the code system inductively to accommodate emergent aspects. All results refer to the level of single residential buildings on private properties.

4. Results

4.1 Governance process and policy instruments in flood recovery

During the recovery and reconstruction after the 2013 flood in Eferding Basin, the public administration used five main policy instruments for climate change adaptation or mitigation in the building stock: Regarding flood risk management, disaster aid payments and a planned relocation programme; regarding energy efficiency, construction standards for new buildings, information on residential energy saving, and subsidies for renovating existing buildings. This portfolio includes regulatory, information and economic instruments; however, adaptation instruments did at best implicitly address mitigation aspects and vice versa. Therefore, neither instrument was explicitly designed to enhance climate resilience.

Disaster aid payments are provided by the national administration, based on taxpayer money, and are distributed by federal authorities (i1, i2). In the federal state of Upper Austria, detailed rules specify the level of compensation which may range from 20% to 100% of incurred losses depending on the total amount of damage, whether households received other payments from insurance or private donations, as well as individual vulnerability such as low income or people with special needs living within the household (i2). Households receive the payments as a refund for submitted bills and workhour records. In principle, disaster aid payments are neutral towards climate resilience, as they neither encourage nor prohibit building-level measures for flood preparedness or energy efficiency (i2). However, as bills are required to claim the payment which must correspond to specific damaged assets, disaster aid is mostly used to restore the housing situation as it was before the flood. The administrative officers focus on managing and accounting the payments and do not inform or encourage households to consider using the money for climate resilience (i2).

The planned relocation programme offered financial compensation to homeowners who were willing to permanently leave and resettle outside the area at risk (Weingraber & Schindelegger 2018). The federal authorities informed the residents about this instrument (i2). Households who accepted the relocation offer were compensated for 80% of their building's market value and 80% of the costs for demolishing the building. Building plots were not compensated; the plots remained with their owners and were rededicated from building land to grassland, precluding any future construction on these plots (Land Oberösterreich 2024). The compensation money could be spent as the recipients saw fit and was not earmarked for any housing or energy efficiency purposes. Homeowners who rejected the relocation offer stay in their homes on the floodplain, but are banned from any changes in building cubature and façade openings, and may not erect additional buildings on their land. By January 2021, 74 out of 152 households living in the relocation zone had accepted the relocation offer; 63 buildings had already been fully demolished (Land OÖ 2021). The policy strategy for enhancing climate resilience of the buildings that remain on the floodplain could be described as a laissez-faire approach: as long as they comply with the building ban, they may renovate their houses for better energy efficiency. They do not receive technical flood protection or any support for flood-proofing their homes.

By contrast, national construction standards for new buildings mandated that the new homes built by households who accepted the relocation offer are highly energy efficient and use renewable energy for heating (OIB 2023) (i3, i4). Only buildings outside the Eferding Basin floodplain receive building permits. The adaptation and mitigation agendas converge here, as these new buildings are no longer exposed to floods and operate with minimal carbon emissions. However, the new constructions require carbon-intensive materials such as cement and consume additional land, given that most relocators' new homes have larger floor areas than their former homes.

Regarding information instruments, the Upper Austrian association for promoting energy saving 'OÖ Energiesparverband' plays a central role. The Energiesparverband provides energy counselling in a variety of formats, ranging from face-to-face interactions to online information (i5). Access to this information is voluntary. However, applicants for building renovation subsidies by the federal state are obliged to complete a personal counselling session (i5). Residents do not receive flood-related information from the Energiesparverband, so it does not contribute to climate resilience.

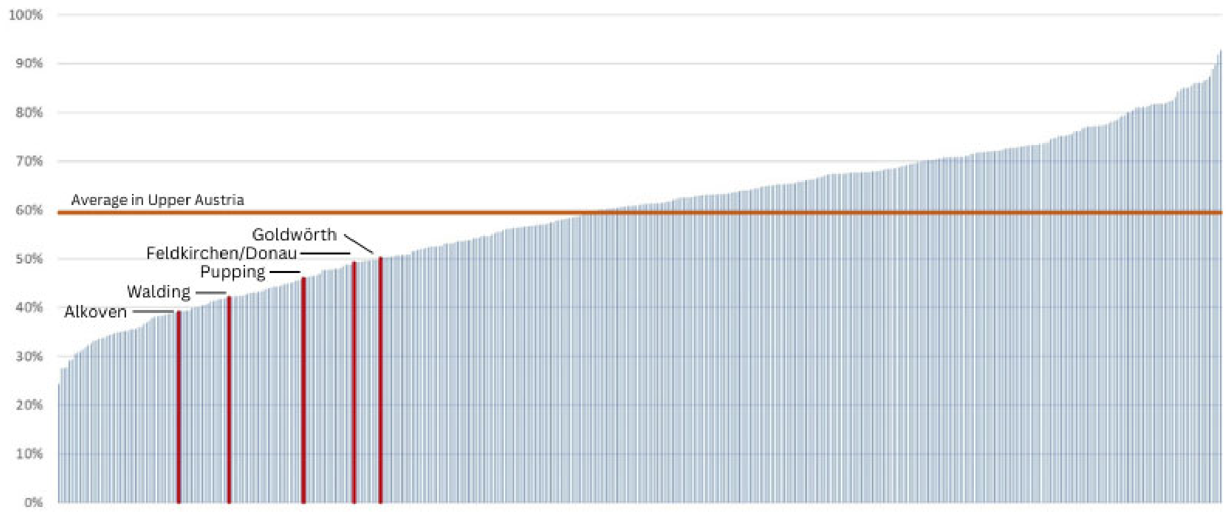
Subsidies for renovating existing buildings for higher energy efficiency are offered by national ("Sanierungsscheck", renovation check; "Raus aus Öl und Gas", exit oil and gas) and federal ("Wohnbauförderung", housing support) administrations (Umweltbundesamt 2023) (i3, i5). These subsidies fund remodelling activities such as thermally insulating outer walls, roofs or basement ceilings, installing triple-glazed windows and changing fossil-fuel heating systems. National and federal funding complement each other and retrofitting activities are allowed to receive funding from both levels; federal funding mainly focuses on realizing additional housing space, though. Subsidies play a central role in the implementation of national climate targets in the housing sector (i3, i4, i5, i6). However, the adoption of this policy instrument depends on the voluntary participation of homeowners who must be affluent enough to afford upfront investment costs (Schleich 2019) (i3, i4). Neither on the national level nor in the federal state of Upper Austria exist any subsidies for flood-proofing existing buildings (only a single other federal state in Austria offers flood-proofing subsidies; Land NÖ 2024). Current energy efficiency subsidies do not leverage apparent co-benefits for flood adaptation; for instance, switching from oil to renewable heating also avoids oil spills when tanks are floated by floodwater; or heat pumps can be set up for quick removal above water level when a flood comes.

In terms of climate resilient development pathways, the climate change mitigation policy in the Eferding Basin is entirely disconnected from adaptation goals and vice versa. Both policy domains act within their silos with no or limited exchange (i1, i3). The only exception is a subsidy for windows to increase energy efficiency, like triple-glazed windows, which also can be used for watertight basement windows (i1, i3). Disaster aid payments could be used for improving energy efficiency of buildings after a shock (i2). However, these two positive examples of policy instruments for climate resilience are rarely used by households because they are hardly supported by the public administration at different governance levels. One key reason is that there is no formal communication from the public administration to affected households to encourage climate resilient development. The lack of communication is mainly based on the lack of policy coordination between climate mitigation and adaptation policies at national and federal level (i1, i2, i3).

4.2 Realised level of flood protection und energy efficiency

In all five municipalities of the Eferding Basin, the share of buildings with a carbon-neutral heating system in 2018 is lower than the average of all municipalities in the federal state of Upper Austria (Figure 2). However, a higher share could be expected as the post-flood recovery period provided a window of opportunity towards climate resilience where households might undertake extensive building remodelling they would otherwise consider too troublesome or expensive. It seems that the repair of damaged heating systems after the 2013 flood was not used to abandon fossil fuels and to switch to carbon-neutral heating systems. However, the municipal areas only partially overlap with the floodplain; in particular in Pupping and Walding, only a fraction of all buildings of the municipality were affected by the 2013 flood. Thus, an eventual effect of the flood on the adoption of carbon-neutral heating systems might be levelled out by the large number of buildings in the same municipalities where the owners had no incentive for remodelling their home.

Figure 2. Shares of buildings with carbon-neutral heating systems in all Upper Austrian municipalities.



Carbon-neutral heating systems for space heating and domestic hot water using alternative energy sources (heat pump, solar, photovoltaics), district heating or firewood. Figure gives the relative frequency in all 438 municipalities of Upper Austria. Data source: Upper Austria Carbon Emission Cadastre 2018 (EFA Gmbh & Land OÖ 2021). The Upper Austria Carbon Emission Cadastre 2018 also provides data on carbon emissions from space heating and domestic hot water per resident; these data show the same picture as Figure 2 and are therefore not reported here.

Data from the streetside observation allow to describe the climate resilience of the current building stock on the floodplain both regarding the flood protection and energy efficiency of single buildings (Table 1). The current level of flood protection seems fairly low considering that all observed buildings are located on the floodplain, that most of them had been damaged by the 2013 flood, and that implementing flood protection would substantially reduce their vulnerability. Across all five municipalities, about two thirds of the buildings even have low flood protection, which means that they are basically unprepared for a future flood. The municipality of Goldwörth stands out because among the few buildings that remained after the planned relocation programme, three are built on stilts or on an artificial hill and therefore feature a high level of flood protection. The current level of energy efficiency reflects the municipal averages from Figure 2: The majority of observed buildings have a mid- to low energy efficiency level. This supports the conclusion that the post-flood repairs were not used as an opportunity to improve the overall building quality. The robustness check of buildings with unambiguous classification shows a consistent picture, with the only exception that a low level of energy efficiency is even more prevalent in Feldkirchen (Table A.4).

Table 1. Current level of flood protection and energy efficiency in the municipalities in the Eferding Basin.

Municipality	Flood protection			Energy efficiency		
	High	Mid	Low	High	Mid	Low
Alkoven	4%	27%	69%	4%	49%	47%
Feldkirchen	9%	26%	65%	13%	57%	30%
Goldwörth	20%	47%	33%	7%	47%	47%
Pupping	0%	40%	60%	0%	60%	40%
Walding	15%	26%	59%	3%	65%	32%

Table gives relative frequencies. N=126 based on streetside observation (Alkoven n=49, Feldkirchen n=23, Goldwörth n=15, Pupping n=5, Walding n=34). Table does not include households who accepted the relocation offer, as these households moved away from these municipalities.

Data from the building questionnaire allow to track how buildings were adapted: either from before the 2013 flood to today among households who rejected the relocation offer, or from the former (now demolished) to the current home among households who accepted the relocation offer (Table 2). Households who rejected the relocation offer and stayed on the floodplain show minimal changes in the level of flood protection and energy efficiency. If they made any changes, they improved by just one level. Typical changes in flood protection are moving their living area from the ground floor to the first floor, or implementing a personal emergency plan and materials for reacting to a flood warning. Typical changes in energy efficiency are installing a heat pump in addition to firewood heating, changing windows or insulating selected walls. By contrast, households who accepted the relocation offer and left the floodplain show substantial changes towards climate resilience. They are no longer exposed to flooding and are therefore classified with a high flood protection level. Strict construction standards mandate that their new home has a high energy efficiency level. However, as illustrated in the case stories below, many of these households undermine the energy efficiency gain by an extension of floor area.

Table 2. Level of flood protection and energy efficiency before/after the 2013 flood and relocation.

Relocation offer	Status	Flood protection			Energy efficiency		
		High	Mid	Low	High	Mid	Low
Rejected	Before the 2013 flood	2	13	18	2	19	12
	Current home	3	13	17	3	23	7
Accepted	Former home	0	5	3	0	5	3
	Current home	8	0	0	4	3	1

Table gives absolute frequencies. N=41 based on building questionnaire (households who rejected the relocation offer n=33, households who accepted the relocation offer n=8).

4.3 Household pathways to climate resilience

Households show high variety in their reactions to the above policy instruments in order to realise flood protection and energy efficiency at their homes. To characterize the scope of reactions, we describe the case stories of six households to illustrate prototypical pathways to climate resilience, ranging from inaction to transformation.

Inaction for financial reasons

The single mother with two adolescent children had purchased the building in 2006. Following the purchase, the building was partially refurbished and extended with the help of federal housing support. However, part of this extension was not completed and is still bare brickwork. After the 2013 flood, the household received substantial payments from disaster aid, insurance and private donations, and used this money to restore the pre-flood housing situation. As the only flood-preventive measure, the kitchen and living quarters were moved from the ground floor to the upper floor. In a future flood emergency, the household intends to evacuate the ground floor and to again cover eventual damages from disaster aid and insurance. The homeowner acknowledges the persistent flood risk but considers herself sufficiently prepared for future flooding and highly values her residential surroundings; therefore, she rejected the relocation offer. Energy efficiency improvements of the building were and still are an issue, such as replacing windows, insulating the roof or installing photovoltaic panels, but are postponed because of immediate family needs and limited financial capabilities. The funding rates of current renovation subsidies are too low to consider further building refurbishments; in addition, since the household has free access to wood fuel from their own forest, there is no incentive to adopt more efficient heating. The homeowner receives informal advice on flood protection and energy efficiency from her family and friends and never considered contacting any formal energy counselling organisation. This example illustrates how low financial capabilities limit access to policy instruments.

Inaction for biographical reasons

The retired couple has been living in the large farmhouse from childhood on. Since then, the building has been repeatedly remodelled to meet the domestic needs of changing family constellations. Part of the building is not inhabited because their children have long left the parental home. The associated farmland is leased to other farmers. Payments from disaster aid, insurance and private donations after the 2013 flood were used to return to the previous living situation. Immediately after, but not necessarily because of the flood, the firewood boiler broke down and was substituted by a similar model for which they received national funding. The household has an unlimited supply of wood fuel from their own forest. Hot water is heated using an air-to-water heat pump. As the only flood preparedness measure, a new broader staircase was built to the upper floor so that furniture and machinery can be moved from the ground floor workshop and storage rooms quickly in case of an impending flood. The roof was insulated when the overall roof tiling had to be renovated. Generally, building adaptation for flood or energy purposes is only done as an add-on to urgent, extensive repair works. The household did not apply for subsidies for any of these renovation works, and did not retrieve any information on flood protection or residential energy saving besides informal advice from friends and neighbours. The couple rejected the relocation offer because they want to spend their remaining years in peace and because they believe that early warning systems and river water level management (by managing the reservoirs of hydropower plants) have improved since the 2002 and 2013 floods. Moreover, their children are still uncommitted whether they intend to keep and live in the property in the future, so the couple focuses on their own short-term housing needs. This example illustrates that the uptake of policy instruments depends on favourable biographical conditions.

Self-reliance and circumventing policy restrictions

The farmstead comprises a main and a side residential building where in total four generations and an elderly care nurse live in separate households. A couple in their 30s act as family heads. The entire family draws on intergenerational flood experience since the 1954 flood, and has a strong do-it-yourself mindset when it comes to breaking down and moving electrical appliances and machines to a dry place during a flood emergency, cleaning up and repairing damages when the floodwaters recede, and generally for remodelling their home. Payments from disaster aid and insurance fully covered the 2013 flood damages. Because of their mindset of self-reliance and independence from the authorities, they feel well prepared for a future flood and saw no reason to accept the relocation offer. After the 2013 flood, when they heard rumours that a planned relocation programme was to be announced, they acted quickly and obtained a permit for a building extension before the programme's building ban went into force, thereby circumventing the policy restrictions. The main motivation for the extension was the anticipation of starting a family and the expected need for additional living space. They applied for housing subsidies and therefore had to construct the extension in line with energy efficiency standards; however, increasing the living space also means increased flood vulnerability. For information on residential energy saving, they rely on their personal circle of friends among which is an energy professional. This example illustrates that policy instruments may fall short of achieving real impacts if they presuppose voluntary acceptance by citizens.

Transformation but backfire from short-term indulgence

The couple with two teenage children had accepted the relocation offer and has been living in a newly built low-energy house in a flood-safe location since 2016. The house had to comply with construction standards for wall insulation and features an air-source heat pump as heating system; the household further plans to add photovoltaic panels. After the 2013 flood, the household utilised disaster aid payments for makeshift repairs of their old home on the floodplain, serving as a temporary residence until the new home was completed. The floor area of the new house is substantially larger than in the former house. Thus, the household incurred a major backfire effect, because part of the efficiency gain of the low-energy building standard was offset by increased energy demand from the larger floor area. When planning the new house, the homeowners compensated the emotional loss of their former house by aiming for a 'perfect home'. They had a short planning horizon when anticipating the residential needs of their family and indulged in spacious rooms for each child and an extra apartment for the elderly grandparent, disregarding that within a few years their children would move out of the parental home, the grandparent would pass away, and these parts of the oversized building would then stand empty. An architect was the only information source regarding energy efficiency aspects of the new house. Moreover, based on their experiences during the approval process of their new house, the homeowners voice deep mistrust towards public authorities, which precludes accepting any advice from publicly funded organisations. This example illustrates the limits of policy instruments that do not include an absolute cap on demand for energy or land.

Transformation but backfire from policy restrictions

After the 2013 flood, the retired couple and their adult son started to repair their house on the floodplain, drawing on disaster aid and personal savings. However, when the renovation revealed that moisture and mould had caused greater damage than expected, they decided in 2015 to accept the relocation offer. They acquired a suitable piece of land well outside the flood risk zone and planned a low-energy twin house with a heat pump. As farmers, they were entitled by Austrian law to erect their farm buildings anywhere on their cropland regardless of zoning designations that are otherwise binding for all real estate development. However, local authorities must approve whether new farm buildings indeed have a predominantly agricultural and not just residential function. Lengthy revisions of the construction plan resulted in a new house with oversized garages and storage rooms and specific façade aesthetics that partially undermined the household's original ambitions for downsizing and building to a high energy efficiency standard, in a barrier-free manner and with minimal surface sealing. In financing the new house, the household forewent a federal housing loan, as this loan would have posed additional energy efficiency requirements but did not offer more attractive credit interest rates than the private banking market. This example illustrates the lack of coordination between different housing policy instruments.

Foresighted transformation

The household consists of a parent couple, two adolescent children, and a grandparent couple. They had invested substantial efforts in renovating their historical farmhouse on the floodplain in an energy efficient manner, but when the house was badly damaged by the 2013 flood, they restored only the bare essentials using disaster aid and decided to resettle with the support of the relocation programme on a flood-safe piece of land they had fortunately acquired a few years earlier. Being farmers, they exercised their right to build anywhere on their cropland. Driven by a strong value orientation for sustainability and energy autarky, they downsized the floor area as compared to their former house, built to almost zero-energy standards, installed a geothermal heat pump, electric vehicle charging stations and a photovoltaic system that produces more electricity over the year than is consumed on site, but now also have energy-intensive air conditioning. A shift from full-time to sideline farming also motivated their downsizing. They received national and federal subsidies for the photovoltaic system and for the heat pump. Approval as an agricultural building by the local authorities proved challenging and required the household to cut back on some energy ambitions. Information and expertise on energy efficient construction was mainly provided by craftspeople and contractors. This example illustrates an almost optimal outcome towards climate resilience.

5. Discussion and conclusions

The present paper analyses whether recovery and reconstruction after a severe flood initiated pathways to climate resilient buildings, that are, buildings that are both flood-proofed and energy efficient. Flood recovery might have provided a window of opportunity for extensive building remodelling, because money from disaster aid, insurance and private donations was available and households had to undertake extensive repair works anyway. We describe the governance process and the implementation of five main policy instruments, and then track the effects of these instruments on the level of municipalities, individual buildings and individual households, using public statistics, streetside observation and interviews with stakeholders and households. Overall, the ambitions for climate resilience put forward in climate policy strategies do not manifest in the reality of our case study.

Governance actors show practically no awareness for the integration of climate change adaptation and mitigation. In consequence, policy instruments are uncoordinated, neither vertically between governance levels nor horizontally between water, housing and energy authorities. Presumably, this diminishes the effect of the policy instruments. The local authorities at the municipal level play a marginal role in policy implementation. The economic instruments (disaster aid, planned relocation programme, renovation subsidies) pose funding requirements only within their own policy domain and do not provide incentives for improving building quality regarding other domains. Lack of policy coordination also appears in the staging of instruments: Disaster aid is earmarked to restore flood-damaged homes, not least because households need an (interim) place to live. However, this investment is sunk if the home is later demolished as part of the relocation programme. Thus, the state may pay twice for the same building: first when distributing disaster aid, and second when the relocation compensation is set accordingly to the now higher market value of the restored home.

Affected households show widespread inertia in their reactions to the shock of the flood. Changes of existing buildings are minimal. By contrast, all new homes of relocating households are climate resilient. However, the policy instruments are not designed to preclude backfire from increased floor areas in new homes. Households tend to focus on a quick return to normal life instead of taking a long-term perspective on their future housing needs, energy costs and flood risk.

In our case study, transformation to climate resilience is limited to new construction. Thus, as the rate of new construction in the entire building stock is generally low (in 2021, 1.8% of all Austrian dwellings were newly constructed in this year; Statistik Austria 2024), the current policy portfolio seems to fall short of accelerating the societal transformation to lower carbon emissions and better preparation for future climate impacts.

However, our results also indicate how policy instruments could be revised to achieve more climate resilience. Regulatory restrictions, such as the construction standards for new buildings and the building ban seem more effective than economic instruments, such as the relocation compensation or renovation subsidies, which depend on voluntary acceptance by citizens. Funding requirements could be adapted across policy domains; for instance, households could be offered higher disaster aid if they restore the damaged building with better flood protection and in a more energy efficient manner. Local authorities, who are closest to affected households, in particular during flood recovery, could function as intermediaries in the rollout of policy instruments. They could provide counselling on flood protection and energy efficiency; facilitate application to funding schemes; and direct households to construction professionals who check damaged buildings for flood damages, mould or renovation needs. In the public administration, departments could involve and consult their respective counterparts in the design of policy instruments, for instance by coordinating funding criteria to address flood protection as well as energy efficiency.

Methodologically, the present paper applies streetside observation of building features to compensate for the lack of a continuously updated building register. Such a register would allow tracking how buildings are remodelled and constructed over time and could be used to evaluate the impacts of shocks and policy instruments. In Austria, households must notify the authorities for minor or obtain a permit for major building modifications, but this information is not entered in a central building register. Streetside observation is an empirical option to close this data gap for a defined area. However, even in the open landscape and settlement structure of the Eferding Basin, the streetside observer did not have an unrestricted view of all external building features; in urban settings, it might be even more difficult to discern all relevant features. Nevertheless, as main advantage in representativeness, streetside observation allows building classification even when the building inhabitants cannot be reached and therefore collects data that are unbiased by self-selection of those inhabitants who are willing to provide information.

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Appendix

Table A.1. List of stakeholder interviewees.

No.	Interviewee
i1	National ministry for water management
i2	Federal authority for rural issues
i3	National ministry for climate action
i4	Federal authority for climate coordination
i5	Upper Austrian association for promoting energy saving
i6	Federal authority for spatial planning

Table A.2. Classification criteria for building flood protection.

Criteria	High	Mid	Low
Doorstep and first floor elevation	More than 2 m above street level	0.8 to 2 m	Less than 0.8 m
Building elevation (e.g. stilts, hill)	Yes	No	No
Presence of a basement	No	Yes, with watertight walls, pressure flap on sewer pipe	Yes, without structural measures
Use of ground floor or basement	No or marginal use	Reduced use	Integrated into daily life
Preventive measures (e.g. sandbags, flood barriers for doors/windows, portable pumps)	Well equipped	Partial	None
Wall construction material	Waterproof (e.g. concrete, granite)	Partially waterproof and easy to dry (e.g. brick)	Not waterproof (e.g. wood, plaster)

Criteria based on the flood preparedness guidebook “Die Kraft des Wassers – Richtiger Gebäudeschutz vor Hoch- und Grundwasser“ (Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management 1999).

Table A.3. Classification criteria for building energy efficiency.

Criteria	High	Mid	Low
Building size relative to use and number of residents	Small building; building with multiple households/generations living together	Average building (e.g. single family house))	Large building (e.g. farmhouse, villa)
Floor area of main building	Less than 150 m²	150 to 300 m²	More than 300 m²
Year of construction	After 2000	Between 1945 and 2000	Before 1945
Windows	Triple-glazed	Double-glazed	Single-glazed
Wall insulation	Well insulated	Insulated	Not insulated
Energy source for space heating and domestic hot water	Renewable	Partly renewable	Fossil

Criteria based on the building renovation guidebooks "klimaaktiv Kriterienkatalog für Wohnbauten Neubau und Sanierung 2020" (Austrian Federal Ministry for Climate Protection, Environment, Energy, Mobility, Innovation and Technology 2020) and „klimaaktiv Heizungsmatrix" (in „Die richtige Heizung für mein Haus – Eine Entscheidungshilfe", Austrian Federal Ministry for Climate Protection, Environment, Energy, Mobility, Innovation and Technology 2020).

Table A.4. Current level of flood protection and energy efficiency in the municipalities in the Eferding Basin (all buildings with unambiguous classification).

Municipality	Flood protection			Energy efficiency		
	High	Mid	Low	High	Mid	Low
Alkoven	6%	21%	73%	6%	50%	44%
Feldkirchen	10%	25%	65%	9%	26%	65%
Goldwörth	18%	45%	36%	8%	42%	50%
Pupping	0%	50%	50%	0%	50%	50%
Walding	7%	36%	57%	4%	61%	35%

Table gives relative frequencies. N=96 in flood protection, n=94 in energy efficiency, based on streetside observation (Alkoven n=33 flood protection / n=32 energy efficiency, Feldkirchen n=20/23, Goldwörth n=11/12, Pupping n=4/4, Walding n=28/23).