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# Redefining energy vulnerability, considering the future

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Within the EU, energy poverty is believed to affect at least 9.8% of households. Energy poverty can be broadly defined as a households' inability to meet its energy needs. This is a problem that affects all European countries, but narrow interpretations of data based on notions of material deprivation may lead to energy poverty being overlooked or not considered an issue by policymakers. The EU Energy Poverty Advisory Hub makes a number of essential points when it comes to the measurement, definition, and potential policies and measures to deal with energy poverty. We build on this, using the term energy vulnerability in order to encompass the segment of population identified as living in energy poverty as well as those at risk of becoming energy poor in the future. We use a capabilities approach with a doughnut economics framework to expand on the concept of energy vulnerability as a form of capabilities deprivation, allowing for greater recognition of those that are affected in the present and intergenerationally. This framework is applied using mixed methods consisting of both a Swiss-wide survey of 1,486 people and 8 semi-structured interviews with energy stakeholders to investigate the knowledge gap on energy vulnerability in Switzerland. The framework may be applied and have wider repercussions for other parts of the world where energy poverty is not directly addressed, and where using the term of energy vulnerability may help direct policies in a more dynamic and responsive manner. Furthermore, this article identifies some limitations of basing energy vulnerability definitions on data which focuses on material deprivations as this may risk overlooking those that are vulnerable due to other reasons such as building energy efficiency. We find that levels of energy poverty/vulnerability are higher than estimated in official statistics, highlighting the need for tailored policies both in Switzerland and elsewhere. Levels of energy vulnerability in Switzerland may not be reflected elsewhere, but certainly draw attention to the potential misrecognition of energy vulnerability which may be more widespread than previously believed. We examine existing policies that may help to reduce energy vulnerability, as well as suggest other potential mitigation methods.

KEYWORDS

**energy vulnerability, energy poverty, energy governance, energy efficiency, capability approach, doughnut economics**

## Introduction

Energy poverty is an area of research that has grown significantly since Boardman (1991) first defined it as households that spend more than 10% of their income on basic energy needs. Energy poverty (sometimes referred to as fuel poverty; Charlier and Legendre, 2021) is a global issue (Churchill and Smyth, 2020; Teariki et al., 2020; Che et al., 2021), which is often connected to a lack of access to electricity in the Global South (Lee et al., 2020). In the Global North it is defined differently in different countries (Castaño-Rosa et al., 2019), but generally refers to a household's inability to meet its energy needs. It is multidimensional (Okushima, 2017; Castaño-Rosa et al., 2019; Charlier and Legendre, 2019; Sokołowski et al., 2020) and hard to capture with any single indicator (Siksnelyte-Butkiene et al., 2021). Energy poverty in Europe is believed to have worsened in recent years, due to the economic crisis and rising energy prices (Castaño-Rosa et al., 2019), as well as the global COVID-19 pandemic (Nagaj and Korpysa, 2020). Even for countries where fuel poverty is said to only affect a small minority, it seems likely that the situation is worsening (Mastropietro et al., 2020).

Furthermore, owing to the fact that energy poverty indicators are often only considered in isolation (Deller et al., 2021), some population segments are likely overlooked, and thus it is probable that energy poverty numbers are systematically underestimated (Robić, 2021). There is a risk of "non-recognition" of vulnerabilities to energy poverty that translates into deficient policy for addressing this issue (Simcock et al., 2021). In this paper, we extend the term *energy vulnerability* to consider both the segment of the population that is identified as energy poor as well as those that may be potentially vulnerable to energy poverty in the future.

The research questions we seek to answer are:

1. What are the drivers of energy vulnerability in the case of Switzerland?
2. What do Swiss stakeholders see as potential ways of mitigating energy vulnerability?

Bouzarovski and Petrova (2015), identify six main factors of energy vulnerability: access, affordability, flexibility, energy efficiency, needs, and practices. These are further expounded upon by Thomson et al. (2017) to include issues such as the inability to invest in new energy infrastructures. In this paper, we argue that identifying the energy vulnerable requires an expansive approach, based on the capability approach. Following Day et al. (2016) and Hearn et al. (2021), we stress the usefulness of a definition of energy vulnerability as being connected to capability deprivation, to help to better understand the potentials of energy vulnerability in the local context, particularly when applied in tandem with intergenerational considerations. In order to do so we apply a doughnut economics approach (Raworth, 2017) to the topic of energy. This enables us to bring in energy vulnerability as something which occurs both in the present when the social boundaries of a safe and just space are not attained, as well as in the future through the current use of energy from unsustainable sources. It also allows for the creation of enduring mitigation policies which consider future levels of energy vulnerability.

A first contribution of this paper is therefore to provide a clear conceptual distinction between energy poverty and energy vulnerability. Further, this distinction enables the creation of differentiated energy policies which specifically target different segments of the population that experience different forms of energy vulnerability. An additional original contribution of the paper is that it provides evidence of different forms of energy vulnerability and its drivers for the case of Switzerland. Finally, energy vulnerability data from national surveys is shown to provide a potentially significant contribution to debates on energy vulnerability which often rely on the European Survey on Income and Living Conditions (SILC) data, smaller-scale surveys, and interviews, adding clarity and revealing hitherto neglected patterns.

By applying a capabilities approach framework to energy vulnerability (Hearn et al., 2021), we are able to identify factors that could increase risk of energy vulnerability. The capabilities approach framework goes beyond measures of energy poverty collected by EU Energy Poverty Observatory (EU Energy Poverty Observatory, 2017; EPAH, 2021), to include factors that fall within physical, natural, human, social, and financial capital. In this way, we are fully able to capture the drivers of energy vulnerability.

We focus on Switzerland because it is one of the wealthiest European countries, with the highest levels of income in Europe (second highest GDP per capita in the world; FDEA, 2020). In addition, Switzerland has a pragmatic cantonal welfare system which has long been considered to focus on alleviating poverty and reducing unintended and counterproductive results (Segalman, 1986). Both high income and a dynamic welfare support system should thus result in the lowest levels of energy poverty/vulnerability.

Globally, Switzerland ranks high in energy security, energy equity (accessibility and affordability) and environmental sustainability (World Energy Councils Trilemma index tool[1]). Nevertheless, there are clear signs that a proportion of the population lives in or is vulnerable to energy poverty, particularly taking into account the recent fuel price rises. Data from SILC (EU SILC, 2021), indicates that in 2019, 0.3% of the Swiss population were unable to keep their home adequately warm, and 4.1% were in arrears on their utility bills in 2018. Thus, our study in part explores the dissonance between Switzerland's wealth status and presence of energy poverty,

1 https://trilemma.worldenergy.org/

which may in part be due to the misrecognition of those that are energy vulnerable (Simcock et al., 2021).

To answer our research questions, we employ a mixed methods approach. Specifically, we rely on quantitative data on energy poverty indicators collected in the Swiss Household Energy Demand Survey (SHEDS, see Section Methods), as well as qualitative data collected through semi-structured interviews conducted among experts in the renewable energy transition in Switzerland. Such an approach allows us to fortify typical measurements of energy poverty with contextual information provided in interviews. In order to build our definition of energy vulnerability we rely on home electricity and heating data, but exclude mobility related energy poverty as this was beyond the scope of this article.

This paper is structured as follows: we first examine definitions of energy poverty and energy vulnerability in Section Definitions of energy poverty and vulnerability, then outline our method (Section Methods) and our results (Section Results) from the SHEDs survey and from semi-structured interviews. This is followed by a discussion section and an outlook which includes policy suggestions on how energy vulnerability can be better addressed (Section Outlook).

## Definitions of energy poverty and vulnerability

Both scientific and gray literature offer multiple definitions and ways to measures energy poverty, highlighting the multidimensionality of energy vulnerability, and the way that this has developed since Boardman's (1991) initial definition. Although measures of energy poverty differ in their details, most recognize an inability to keep the home warm, energy bill debt, and high share of energy expenditure as indicators (often using Boardmans 10% of household disposable income on energy). EPOV defines households as energy poor if they are unable to achieve adequate levels of essential energy services due to a mixture of high energy expenditure, low household income, inefficient buildings, as well as inefficient appliances and varying household energy needs (EPOV, 2017). The EPOV definition is widely adopted and offers ways to compare statistics in countries across the EU, particularly as these are gathered in the SILC data.

There is a recognition in the literature that typical measurements of energy poverty may not be enough as they do not sufficiently capture the impact or scope of energy vulnerability. In fact, a household's capacity to meet and cope with energy challenges (related to both temperature and transport) may be the result of a variety of factors (Middlemiss and Gillard, 2015). Strict definitions of energy poverty may not assess whether households are able to achieve a decent standard of living (Middlemiss and Gillard, 2015) or meet essential capabilities that are energy-dependent (Thomson and Snell, 2013). These achievements are determined by more than material deprivation. Thus, we expand the definition in order to more fully capture the population that is energy vulnerable–those that are identified as energy poor as well as those at risk of falling into energy poverty both in the present, and in the future.

Following Day et al. (2016), who proposed the use of the capabilities approach and framed energy poverty as a form of capabilities deprivation, our conceptual framework builds on Hearn et al. (2021), who use a capabilities based energy justice framework that examines five different capitals where injustices may occur. Indeed, we apply elements of the Hearn et al. (2021) framework to the doughnut framework by Raworth (2017) to understand the drivers of energy vulnerability in a Swiss context. The doughnut economics framework (Raworth, 2017) sees a "safe and just space for humanity" which is positioned as the sweet spot between overshooting planetary ecological boundaries (such as biodiversity loss, climate change and unsustainable practices), and social parameters which are sufficient to enable a good and valued life (such as social equity, gender equality, and provision of sufficient healthcare and education; Stopper et al., 2016).

Through the use of the doughnut model (Raworth, 2017) we extend the definition of energy vulnerability, locating energy poverty and some forms of energy vulnerability as below the social boundary of what is considered necessary for a safe and just way of life. We also locate a form of energy vulnerability in the overshooting of the ecological boundary through the use of unsustainable sources of energy which may lead to energy vulnerability for future generations. However, we use only the slice of the doughnut framework relating to energy, rather than showing the whole doughnut (Raworth, 2017) (Figure 1).

The framework rests on five capitals (Figure 1): physical, natural, financial, and social capital. In the context of energy vulnerability, these are described as: (1) physical capital, referring to the energy efficiency of buildings, the heating and electric system, mobility-related issues and other technology aspects (such as smart meters); (2) natural capital, meaning environment and climate issues including altitude, weather patterns and vulnerability brought about through climate change; (3) financial capital, referring to the material means of residents, as well as the affordability of homes, energy and retrofitting; (4) human capital, referring to both the policy and regulatory framework as well as availability and suitability of energy advice; (5) social capital, referring to aspects such as levels of participation and awareness, norms and practices. We discuss our results using this framework in order to provide a clear and novel perspective on this topic.

## Methods

In this paper, we use quantitative data from the Swiss Household Energy Demand Survey (SHEDS) and qualitative data based on interviews with stakeholders in the Swiss energy

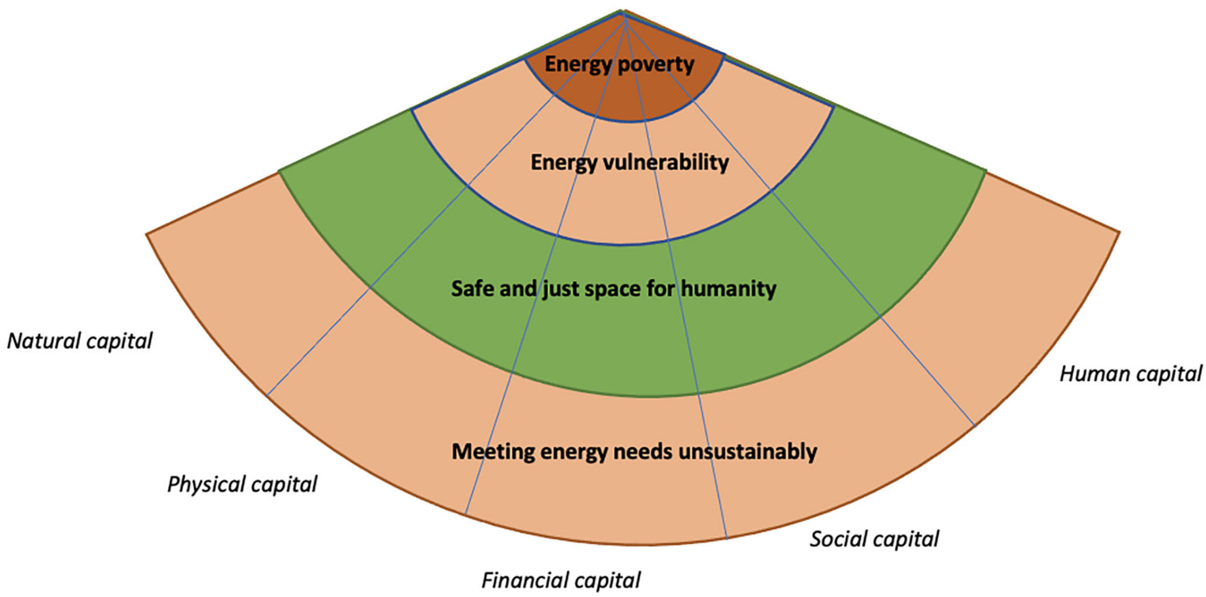


FIGURE 1
Situating energy poverty and vulnerability in the doughnut economic model, authors own elaboration.

sphere to answer our research questions, as can be seen in Figure 2.

## Quantitative data collection

We collected data on four indicators of energy vulnerability in the Swiss Household Energy Demand Survey (SHEDS) (Weber et al., 2017) in 2020 where we were allocated 1,486 respondents. A comparison of SHEDS respondents and the general Swiss population on key characteristics can be seen in Table 1. Participants were surveyed in May and June 2020, following an extended quarantine due to the COVID-19 pandemic[2]. Data was analyzed using STATA.

To determine energy vulnerability levels in Switzerland, we collected similar data to that gathered by the EU Energy Poverty Observatory (EPOV, 2017). The questions used in EPOV and those included in SHEDS can be seen in Table 2. We did not collect data on hidden energy poverty (EPOV measure 4, Table 2), as a significant aspect of this is covered through the first self-reported question on inability to keep warm.

We deemed that a positive answer to any one of the three questions qualified a household as energy vulnerable. Positive answers are defined as:

- Respondents are not able to keep their home adequately warm.
- Respondents are in arrears on utility bills.
- Respondents spend more than 10% of income on heating in the winter after rent/mortgage.

2 The pandemic delayed data collection which had originally been scheduled for April 2020.

## Qualitative data collection

As part of our qualitative data collection, we carried out eight semi-structured interviews with Swiss energy stakeholders (Table 3). Our criteria for interview selection was that all interviewees had to be engaged directly in employment concerning the Swiss energy transition, able to speak English fluently enough to be interviewed in English, and be available for an interview. Each person contacted was sent an email requesting an interview, explaining that one of the main topics was the reduction of energy poverty and ensuring a fair energy transition. Interviewees were also asked if they could suggest further names to contact for an interview (snowball sampling). Eight interviews were conducted following Kuzel (1992) who recommends 6–8 interviews according to specific research objective. The semi-structured in-depth interviews lasted between 30 and 60 min and were conducted online using the Zoom platform, transcribed before coding and content analysis using MaxQDA2020. The interviewees represented a variety of sectors including consulting, energy-related start-ups, cantonal authorities, and energy cooperatives. We detail the

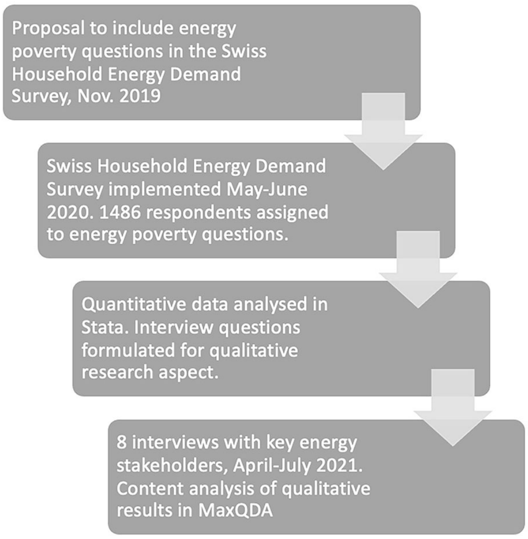


FIGURE 2
Quantitative and qualitative research calendar.

TABLE 1 Descriptive of key variables in SHEDS as compared to Swiss population.

| | SHEDS sample ($N = 1{,}486$) | Swiss population statistics |
|---|---|---|
| Gender ratio (% female) | 46.50% | 50.39%[b] |
| Average age | 48.82 | 42.6[c] |
| Average income | 6,000–8,999 CHF/month[a] | 6655 CHF/month[d] |
| Tenant or living in cooperative dwelling | 60.26 | 61%[e] |
| Live in urban area (city or agglomeration) | 71.09% | 75%[f] |

[a] *Responses to the income question in the SHEDS survey are based on categories: Less than 3,000; 3,000–4,500; 4,501–6,000; 6,001–9,000; 9,001–12,000; More than 12,000.*
[b] https://data.worldbank.org/indicator/SP.POP.TOTL.FE.ZS?locations=CH
[c] https://www.bfs.admin.ch/bfs/en/home/statistics/population/effectif-change/age-marital-status-nationality.assetdetail.18845603.html
[d] https://www.bfs.admin.ch/bfs/en/home/statistics/work-income/wages-income-employment-labour-costs/wage-levels-switzerland.assetdetail.21224921.html
[e] https://www.bfs.admin.ch/bfs/en/home/statistics/construction-housing/dwellings/rented-dwellings.html
[f] https://www.bfs.admin.ch/bfs/en/home/statistics/catalogues-databases/press-releases.assetdetail.16504127.html

results from SHEDS in the next section and then discuss these together with interview data in our discussion section.

# Results

## Quantitative results

Following the energy vulnerability questions shown in Table 2, our results showed that 177 respondents (11.9%) could be considered as energy vulnerable, having responded positively to at least one of the energy poverty measures in the survey. Out of this group, a small number of people (10.7% of energy vulnerable, 19 respondents) responded positively to more than one energy poverty measure and could be considered highly energy vulnerable. A detailed breakdown of responses to the three energy vulnerability questions is below (Table 4).

Among the three energy poverty questions, the question on percentage of income spent on heating had the most positive responses, with 8% of respondents stating they spend more than 10% of income on heating in the winter (Based on Boardman's, 1991; measure of energy poverty). The question regarding arrears on utility bills showed the lowest positive response, with only 1.3% of respondents stating they were in arrears on their utility bills.

Descriptive statistics show that the energy vulnerable are, on average, less wealthy and consist of a slightly higher population of tenants (Table 5). We explored the determinants of energy vulnerability in Switzerland using a logistic model with the energy vulnerability as the binary dependent variable. Table 6 shows the results of four models that included varying explanatory variables such as gender, age, income, household size, location e.g., whether the respondent lives in a city, and whether the respondent is a tenant. The coefficients in Table 6 are expressed in odds-ratios, that is the effect of the explanatory variable on the odds of being energy vulnerable. Results of logistic model with expected change in log odds can be found in Appendix Table A1.

Across three models, income and age were significant in increasing the odds of being energy vulnerable. Higher income was associated with lower odds of being energy vulnerable, while, holding all other variables constant, the odds of respondents in the lowest income category being energy vulnerable were 2.5 times higher relative to the base category (6,000–8,999 CHF/month). Increasing age was also associated with a lower probability of being energy vulnerable, while probability of adults ages 35–64 being energy vulnerable is affected by income (see Appendix Table A1 for interaction variable). Sex, living in a city, tenancy, and household size were not found to be significant, even though these are variables that are often considered to be significant in energy poverty literature (Bouzarovski and Petrova, 2015; Castaño-Rosa et al., 2019).

Given that the energy vulnerability measure combines three questions, two of which focus on income and one that focuses on perception of home temperature, we also explored the relationships of sociodemographic information with positive answers to individual energy poverty questions. The question asking whether respondents were in arrears on their utility bills was not included given the low number of positive responses and concerns over an unbalanced dataset. Results are shown in Table 7 (full results can be found in Appendix Table A2).

TABLE 2 EPOV energy poverty indicators and corresponding questions in SHEDS.

| Measure from EPOV | Associated survey question used in this study (from SHEDS, 2020), all answers are self-reported |
|---|---|
| 1. Inability to keep warm<br>*Self-reported* | 1. Are you able to keep your home adequately warm? |
| 2. Arrears on utility bills<br>*Self-reported* | 2. Are you in arrears (debt) on your utility bills? |
| 3. High share of energy expenditure, twice the national median<br>*Identified in data* | 3. Do you think you spend more than 10% of your income on heating in the winter after rent/mortgage? |
| 4. Low absolute energy expenditure, below national median<br>*Identified in data, termed as "hidden energy poverty"* | 4. Not included in SHEDS |

TABLE 3 Energy stakeholder interviews in Switzerland.

| Interview number and code | Gender | Main stakeholder positions |
|---|---|---|
| 1S | Male | Solarify[a]. Innovative PV panel company that allows individuals to participate in the Swiss energy transition without requiring a roof. |
| 2Z | Male | Energie Zukunft Schweiz[b], Swiss PV, energy efficiency and renewable energy company |
| 3M | Female | Mehr Als Wohnen (see text footnote[6]) Housing Cooperative, part of the 2000 Watts society[c], Zurich |
| 4V | Male | Energy Department, cantonal level, Basel-Land |
| 5T | Male | Sun2wheel[d] e-mobility vehicle to grid firm, and SustainTec energy advice and sustainability[e] |
| 6K | Male | Consultant in sustainable finance |
| 7C | Female | Cantonal Energy group, Energietal Toggenburg[f] |
| 8H | Female | Green party representative, Zurich |

[a] https://solarify.ch/so-funktionierts/
[b] https://energiezukunftschweiz.ch/
[c] https://www.2000watt.swiss/en/english.html
[d] https://sun2wheel.com/en/home/
[e] https://www.sustaintec.ch
[f] https://energietal-toggenburg.ch/home/

Results of the question breakdown indicate higher odds for younger people to be unable to keep their home warm. Being female reduces the odds of spending more than 10% of income on heating. The odds of those living in the countryside to pay more than 10% of income on heat is 1.7 more likely than those living in the city, though type of living area has no effect on ability to warm the home. Income has an inverse effect on probability of having a cold home and paying more than 10% of income on heat. Interestingly, the odds of being unable to keep the house warm are about 3 times more for respondents in the 4,500–5,999 CHF/month income category, while association between lower income categories and home warmth was not found to be significant. Household size and tenant status did not have a significant association with either inability to keep the house warm or paying more than 10% of income on heat.

## Qualitative results

Stakeholders were interviewed following initial data analysis of the questions asked in SHEDS. This enabled us to focus on major areas of interest in our research, namely the perceptions of energy poverty, and how to ensure that this is reduced through energy efficiency measures. Stakeholders interviewed were not provided with information prior to the interviews in order to avoid influencing responses.

In the interviews, we asked about energy poverty, energy efficiency, policy aspects and subsidies, drivers and barriers for equity, and motivation and social consequences for users and businesses.

Stakeholders were very clear in stating that energy poverty was not perceived as being of significance in Switzerland, and the term itself needed explanation in multiple interviews.

> *≪I do not think you could actually really figure out who lives in energy poverty. But we do have some situations that are really hard for people. We actually have two examples. One would be people living in really old buildings where there is the gas line going through. They pay a lot for their gas bills and they usually also pay a lot for electricity, because the housing is just so old. Sometimes housing is even protected. So*

TABLE 4 Results of energy poverty questions included in SHEDS ($N = 1,486^*$).

| **Are you able to keep your home adequately warm?** | | | |
|---|---|---|---|
| Yes | No | Prefer not to answer | |
| 93.9% | 3.9% | 2.2% | |
| **Are you in arrears on your utility bills?** | | | |
| Yes | No | Prefer not to answer | |
| 1.3% | 97.5% | 1.2% | |
| **Do you think you spend more than 10% of your income on heating in the winter after rent/mortgage?** | | | |
| Yes | No | Not sure | Prefer not to answer |
| 8.0% | 70.1% | 17.6% | 4.4% |

[*] 1,398 respondents provided a response other than "Prefer not to answer" for all three questions.

> *if you want to invest in the infrastructure itself, which usually is not even the person that lives in there, but who is the owner, you know.*≫ (7C)

In terms of energy efficiency and mitigating energy vulnerability, one stakeholder (7C) noted that renovation policies were having some effect, with some communities already consuming 20% less energy compared to 2013. Another stakeholder (3M) explained how although the district was constructed to Minergie standards, none of the buildings are Minergie certified as doing so would have entailed additional certification costs, as well as limited the use of recycled building material (e.g., recycled concrete).

Discussions on policy aspects and subsidies centered on the need for extra subsidies that make renewable heating systems more appealing than fossil fuel systems (7C) as well as on the fact that subsidies currently heavily favor fossil fuels globally (6K). At the moment, subsidies are perceived as very important in promoting the energy transition and stakeholders saw these as a major tool in financing energy efficient renovations which would have an effect on reducing energy vulnerability (2Z). Non-subsidy ways of incentivizing change toward greater energy efficiency may require more risk-taking and innovation: risk-taking on the part of real estate and construction companies in trying new ideas (3M), risk-taking on the part of banks as the business case for loans may not always be clear (4V), and more innovation and start-up projects that demonstrate the viability of different solutions (3M, 1S, 7C).

One respondent noted the importance of working with multinational companies in the oil and gas sector as they are the current dominant players in the energy market. Working hand-in-hand with these companies may be more effective in guiding where money flows and convincing them of an alternative green future (1S).

Stakeholder positions on the motivation and social consequences for users and businesses included the premise that innovation requires greater spending, with one stakeholder noting that the vision plan assigned 1% of total revenues for innovation (3M).

## Discussion

In this section we start by examining the discrepancies between SILC and SHEDs data. We then examine the results from SHEDs results together with interview data in the context of the five different capitals from the energy justice framework, we sketched in Section Definitions of energy poverty and vulnerability. We also bring in secondary material that provides context on Swiss climate, housing stock, and demographics. We start with the categories of Climate (Natural Capital), Financial and Social Capital (Socio-economic factors), and Physical Capital (facilities/housing). This is followed by a section on Social Capital (Participation/ awareness raising) and the policy and regulatory framework (emerging from Human Capital). From the results detailed above, as well as a series of targeted interviews with energy experts, we are able to provide answers to our two research questions.

We find that energy vulnerability in Switzerland appears to be related to age and income. However, we do not find a relationship between energy vulnerability and home ownership. This leads us to infer that income and costs will have some effect on energy vulnerability, but that targeted retrofitting of energy inefficient housing and a stronger policy and regulatory framework could significantly decrease energy vulnerability.

### Discrepancies between SHEDS data and data gathered for SILC in Switzerland

Although the EU SILC has provided a significant source of information for energy poverty indicators

TABLE 5 Descriptive statistics for energy vulnerable and total sample.

| | Energy vulnerable ($N = 177$) | Total sample of respondents with complete responses ($N = 1338$) |
|---|---|---|
| % of Females | 44.63% | 45.74% |
| Average age | 46.2 | 48.7 |
| Average income/month[a] | 7,125 CHF/month | 8352.21 CHF/month |
| Tenants | 66.10% | 59.27% |
| Live in city | 47.46% | 48.51% |

[a]For analysis purposes, income was converted into a continuous variable by assigning each respondent the midpoint of each category of income.

(Bouzarovski and Tirado Herrero, 2017), there may be gaps in the information collected. The focus on material deprivation may eclipse or underrepresent other potential causes of energy poverty and deprivation. Indeed, our results regarding the inability of achieving a preferred thermal comfort show energy vulnerability figures almost 20 times that of SILC 2020 for Switzerland (EU SILC, 2021)[3]. Conversely, SILC data for arrears on utility bills shows a figure almost 3 times that of SHEDS[4].

One further possible explanation for differences between SHEDS and SILC results may be the methodological differences by which data is obtained. SILC Data collection is predominantly based on phone survey with a small percentage of questionnaires complete face-to-face with a total sample size of 8,000 homes[5]. SHEDS data is collected using an online questionnaire which is completed at leisure by the respondent and remains anonymous. A long phone survey (the average completion time for the SILC survey is 62 min) may result in respondents suffering from an unwillingness to divulge information, particularly if this is perceived as portraying the respondent in a bad light. The stigma associated with poverty has been well documented (Day and Hitchings, 2011; Bartiaux et al., 2018; Middlemiss et al., 2019), and divulging an inability to keep the home adequately warm may go against social and cultural norms (Connon, 2017). Additionally, SHEDs data excludes the Tessin Italian speaking part of Switzerland, which may cause some minor variance in the data.

The discrepancy in results may also be due to question wording in SILC. The question "Is your home poorly heated?"

TABLE 6 Results of logistic mode.

| Dependent variable: Probability of being energy vulnerable | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Female | 0.753 | 0.721 | 0.713 | 0.713 |
| | (−1.53) | (−1.84) | (−1.90) | (−1.90) |
| Age | 0.982** | | | |
| | (−2.89) | | | |
| **Household income CHF/month (base = 6,000 – 8,999 CHF/month)** | | | | |
| 3,000 or less | 2.552** | | | |
| | (2.90) | | | |
| 3,000 – 4,499 | 1.349 | | | |
| | (0.89) | | | |
| 4,500 - 5,999 | 1.446 | | | |
| | (1.40) | | | |
| 9,000 – 11,999 | 0.628 | | | |
| | (−1.79) | | | |
| 12,000 or more | 0.365** | | | |
| | (−3.18) | | | |
| HH income (midpoints) | | 0.999*** | 0.999*** | 0.999* |
| | | (−5.12) | (−2.07) | (−2.07) |
| City dweller | 0.914 | 0.903 | 0.907 | 0.907 |
| | (−0.48) | (−0.56) | (−0.54) | (−0.54) |
| Household size | 1.041 | 1.071 | 1.094 | 1.094 |
| | (0.52) | (0.91) | (1.22) | (1.22) |
| Tenant | 0.958 | 1.073 | 1.081 | 1.081 |
| | (−0.20) | (0.34) | (0.38) | (0.38) |
| **Age (base = ages under 35)** | | | | |
| Ages 35–49 | | 0.591* | | |
| | | (−2.25) | | |
| Ages 50–64 | | 0.490** | | |
| | | (−2.92) | | |
| Ages 65+ | | 0.576* | | |
| | | (−2.07) | | |
| Ages under 35 | | | 1.566 | |
| | | | (1.67) | |
| Ages 35–64 | | | 2.569* | 1.640 |
| | | | (2.08) | (1.06) |
| Ages 65+ | | | | 0.638 |
| | | | | (−1.67) |
| Observations | 1,261 | 1,338 | 1,338 | 1,338 |

Coefficients show odds-ratios for main effects (t statistics in parentheses).
*Models 3 and 4 included interaction variables for Ages 35–64 X Income which can be found in Appendix Table A1.*
*Exponentiated coefficients; t statistics in parentheses.*
$^{*}$ $p < 0.05$, $^{**}$ $p < 0.01$, $^{***}$ $p < 0.001$.

3 Inability of achieving a preferred thermal comfort: Comparison of percentage of Swiss population in the SHEDS 2020 data (3.9%) vs. SILC 2020 (0.2%).

4 Arrears on utility bills: SHEDS 2020 (1.3%, utility bills) vs. SILC 2020 (3.2%).

5 The FSO details a number of potential errors attributed to such methods, including potential population coverage errors, measurement errors (such as those [43, 51–53] caused by the survey itself, the interviewer or the mode of collection), processing errors (incorrect input, editing or weighting of data), and non-response errors. The 8000 homes figure represents approximately 18,000 people.

TABLE 7 Results of logistic mode.

| Dependent variable: | (1) Inability to keep home warm | (2) Inability to keep home warm | (3) Paying more than 10% income on heat | (4) Paying more than 10% income on heat |
|---|---|---|---|---|
| Female | 0.955 | 1.006 | 0.674 | 0.626* |
| | (0.291) | (0.293) | (0.151) | (0.135) |
| Age | 0.964** | | 0.992 | |
| | (0.0109) | | (0.00728) | |
| **Household income CHF/month (base = 6,000 – 8,999 CHF/month)** | | | | |
| 3,000 or less | 1.416 | | 3.701*** | |
| | (0.842) | | (1.304) | |
| 3,000–4,499 | 1.306 | | 1.299 | |
| | (0.772) | | (0.528) | |
| 4,500–5,999 | 3.097** | | 1.064 | |
| | (1.180) | | (0.362) | |
| 9,000– | 0.243* | | 0.805 | |
| 11,999 | (0.156) | | (0.240) | |
| 12,000 or | 0.496 | | 0.337** | |
| more | (0.247) | | (0.137) | |
| HH income | | 0.999*** | | 0.999*** |
| (midpoints) | | (0.0000480) | | (0.0000357) |
| **Type of living area (base = city)** | | | | |
| Agglomeration | 0.518 | | 1.431 | |
| | (0.219) | | (0.373) | |
| Countryside | 1.030 | | 1.715* | |
| | (0.379) | | (0.467) | |
| Household | 1.158 | 1.178 | 1.032 | 1.075 |
| size | (0.127) | (0.129) | (0.0977) | (0.0954) |
| Tenant | 0.843 | 0.927 | 0.918 | 1.047 |
| | (0.303) | (0.319) | (0.233) | (0.251) |
| Ages <35 | | 2.016* | | 1.504 |
| | | (0.640) | | (0.379) |
| Ages 65+ | | 0.588 | | 1.297 |
| | | (0.281) | | (0.356) |
| Lives in city | | 1.397 | | 0.620* |
| | | (0.422) | | (0.136) |
| Observations | 1,261 | 13,38 | 1,261 | 1,338 |

Coefficients show odds-ratios for main effects (t statistics in parentheses).
Exponentiated coefficients; t statistics in parentheses.
$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

(DE: ≪*Ist ihre Wohnung/Ihr Haus ungenügend geheizt?* ≫) has been reworded as "Are you able to keep your home an agreeable temperature?" (DE: *Ist es für Ihren Haushalt möglich, dafür zu sorgen, dass es in der gesamten Wohnung/im gesamten Haus eine angenehme Temperatur hat?)* with multiple options for responses: (1) Yes, I am, (2) No, for financial reasons (DE: ≪*nein, aus finanziellen Gründen*≫ or (3) No, for technical reasons (DE: ≪*nein, aus technischen Gründen*≫). Only responses that gave the reason as financial were used in the reported statistics for energy poverty. Indeed, the figures dropped from 7.5% in 2010 to 0.8% in 2011, when the new question wording was introduced (FOS, 2021). This lends further credence to the fact that the causes for energy poverty in Switzerland are largely unconnected to financial status and more closely connected to highly inefficient building stock.

## Natural capital: Climate

While changes in climate are not captured by current measurements of energy vulnerability, there is indication that they would be a useful indicator. The Federal Office of Meteorology for Switzerland (MeteoSwiss, 2020) notes that the climate in Switzerland has significant natural seasonal fluctuations which, when combined with the mountainous landscape, helps to explain the need for well-insulated buildings that are able to withstand temperature and cold weather extremes. However, heat waves, such as the ones experienced in the summers of 2003 and 2015, in which mortality increased by 5.4 and 7%, respectively (Ragettli et al., 2017), are likely to become more frequent. As a result of climate change, it is expected that cooling demand will increase over time, both for residential and office building stock (Li et al., 2012; Moazami et al., 2019; Silva et al., 2022). Summer heating may become an increasing threat that needs to be mitigated through targeted policies (SCNAT netzwerk, 2005). The impact of climate change may increase vulnerability to energy poverty exacerbated through summer heat (Bienvenido-Huertas et al., 2021), increasing intergenerational vulnerability.

This was corroborated in an interview with a board member of the Mehr Als Wohnen housing cooperative in Zurich who noted that all the buildings within the district are built to Minergie standards, and are heated using district heating which is controlled centrally, thus mitigating the impact of colder weather.

> "I do not actually see the winter as a problem. I see the summers as a problem." (3M)

However, in warmer weather, buildings that are designed to insulate against the cold may also struggle to cool down, and in the Hunziker Areal (Mehr Als Wohnen)[6] different solutions are being explored such as *via* water management, using ice batteries, and urban greening (including roof and façades).

On the self-reported question regarding heating costs, a total of 8% (119 respondents) believed that they did spend more

6 https://www.mehralswohnen.ch/

than 10% of their income on heating in the winter. This may have been skewed owing to the timing of the survey, which was initially planned for early Spring, but which was delayed until May/June owing to the COVID-19 pandemic. This delay meant that those surveyed were asked about the winter period at a time when it was getting increasingly warm and sunny, and a period of lockdown was ending. Furthermore, winter 2019/2020 was particularly mild in Switzerland, with average temperatures of 3 degrees C over the 1981–2010 norm, and was followed by the third mildest spring (MeteoSwiss, 2021). This could have had an effect on increasing the number of people able to keep their homes warm.

Policies which may help to mitigate the effect of climate on energy vulnerability for Switzerland have been identified as those associated with improving building stock to ensure that this is better able to withstand the effects of climate change which may involve extreme weather. Examples include improved solar protection and night ventilation strategies (Frank, 2005). It is further important to note that precipitation levels and temperatures vary across Switzerland, depending on whether one is within the Alpine regions, at the foothills, or the northern plateau (MeteoSwiss, 2018). The effects of climate change on temperature and precipitation will also have a regional variation (Henne et al., 2018) and will require a geospatial approach to identify the different risks to energy vulnerability across Switzerland.

## Financial and social capital: Socio-economic factors

As discussed in Section Discrepancies between SHEDS data and data gathered for SILC in Switzerland, socio-economic factors may not be enough to explain energy vulnerability in Switzerland. Although income plays a role in determining energy vulnerability, it is not always the lowest income categories that face these risks. As our analysis in Section Quantitative results showed, respondents from middle income categories were more prone to feeling cold at home. Although income is a factor in Swiss energy vulnerability, it is likely not the sole driver.

Our analysis of data from SHEDS also revealed that younger people are more likely to be afflicted by energy poverty, contrary to other studies which put pensioners and the elderly at risk (Mashhoodi et al., 2018). This may be owing to the types of buildings younger people occupy. Energy vulnerability among the younger population may be a result of tenancy in non-renovated homes.

Given the information that we received from the FSO on SILC data, a much larger group of people fall into the category of being unable to keep their home adequately warm owing to technical reasons rather than financial. One reason may be the low rates of home ownership in Switzerland, which make implementation of energy efficiency measures difficult (at least not without consent of the landlord). In fact, Swiss home ownership is low compared to many other countries with an average 36% recorded in 2021, dropping as low as 12% in more populated municipalities (Le News, 2021). For those that do own property, socio-economic factors may prevail as lack of affordability may be a barrier to energy efficiency retrofitting.

There is some indication from a stakeholder interview that the current financial situation may encourage those who are able (namely home owners) to afford home energy efficiency improvements to do so:

> *"I think one of the most important factors currently is that interest rates on banks are low to zero or even negative. So, the more money people have the more they are under pressure to find a good investment opportunity, which is at the same time safe but also has slightly bigger profits than a bank account."* (1S)

Low interest rates may also encourage landlords to commit to energy efficiency measures as they may be able to borrow money at better rates (against the value of the property for example), and receive a limited return albeit over a long period of time. In terms of strategies and policies which may help to reduce energy vulnerability, targeted financial benefits may provide short term relief rather than reliance on broader social assistance which may not be sufficient to mitigate conditions for those who are most vulnerable.

## Physical capital: Facilities/housing

An analysis of physical capital offers another dimension by which to assess energy vulnerability. There is a need to improve housing quality in Switzerland (Pagani et al., 2021), recognized in the national Energy Strategy 2050 which now provides tax incentives for building renovation (SFOE, 2021a) with a targeted reduction of 43% in energy consumption by 2,035 compared to 2000 levels (SFOE, 2021b). In all, of the approximately 1.5 million buildings in Switzerland, over 75% were built before 1980 and renovation is required for many of these (Frank, 2005). So far, there have been a number of voluntary energy efficiency programmes such as the éco21 in the Canton of Geneva (Cho et al., 2019), as well as ProKilowatt[7], a national tender-based energy efficiency scheme which provides up to 30% of the investment costs necessary for energy efficiency measures. Schemes such as the Gebäudeprogramm are financed from the $CO_2$ levy (Patel et al., 2021), which may help to overcome the normally high upfront costs of retrofitting.

7 https://www.prokw.ch/

Switzerland benefits from a longstanding sustainable building certification, Minergie[8] which dates back to 1998, accounting for the certification of 50,000+ buildings. This can be partially financed through the Gebäudeprogramm[9], and Minergie buildings are required to be a minimum of 20% greater energy efficiency than MOPEC (Modele de Prescriptions Energetiques des Cantons) buildings (EnDK, 2021). One of the significant advantages of improving home energy efficiency is that this will have an impact on reducing carbon emissions but will also have a potentially significant effect on reducing vulnerability to energy poverty, including health improvements (Baniassadi et al., 2022). At the same time, one of the shortfalls of the Swiss system is that although the Federal Government is in charge of creating legislation, each canton is free to implement these according to their own interpretation, leading to potential confusion and uncertainty for the consumer.

A significant problem which is discussed frequently in the literature is the split incentive whereby landlords and tenants have no incentive to improve housing efficiency (Melvin, 2018). However, a recent study in Switzerland indicates that 70% of tenants would be willing to accept rental increases that are greater than the potential savings from energy efficiency retrofittings (Lang and Lanz, 2021). One of our interviewees noted the difficulties of retrofitting rented buildings that they have encountered:

> *"But on the other hand, people who rent, who are not owners, they are also very interesting. I mean first of all they can jeopardize a project of the building owner to make the building more efficient. We see this in practice because of many reasons, because then the owner can increase the rent. Sometimes they really do as much as possible, sometimes you can get kicked out." (4V)*

Furthermore, although the efficiency rating of buildings is important, and there is clearly much work still needed in order to improve this in Switzerland, the actual efficiency of a building is determined through its use, and not just its rating:

> *"You can also operate a very energy efficient building very inefficiently." (4V)*

For example, opening windows and airing for extended periods or sleeping with the windows open, which are often seen as culturally-related habits, has a significant effect on the efficiency of Minergie rated buildings. This connects to the next section on the importance of participation and raising awareness.

8 https://www.minergie.ch/fr/

9 https://www.dasgebaeudeprogramm.ch/de/

Tenants do not all have the same experience and the quality of homes varies dramatically. Of note are the multiple housing cooperatives in Switzerland which tend to be characterized by high quality energy efficient housing, which may partially account for their popularity (Balmer and Gerber, 2018; Hearn et al., 2021). Despite these initiatives, Switzerland suffers from a housing shortage, worsened by both escalating prices and a surge in the demand for second homes in 2020 (Swissinfo, 2021).

Furthermore, the housing cooperative stakeholder explained that indoor spaces are deliberately streamlined and smaller than in other districts, leading to reduced energy consumption and enhanced efficiency, which reduces energy costs for residents. Providing multiple shared spaces (including a shared freezer room, sauna, guest rooms) allowed residents to maintain a high quality of life despite these much smaller private spaces.

Clear policies that would help to mitigate energy vulnerability related to buildings involve not only increasing the speed and degree of renovations, but also comprehensive energy efficient building programmes to alleviate the current housing shortage and reduce market pressure. Furthermore, examining the uptake of energy efficiency measures by vulnerable households could provide an interesting additional indicator for energy vulnerability.

Within physical capital it is important to consider that in the case of Switzerland, electricity has been largely decarbonised. However, when it comes to heating systems, 56% of homes continue to use either oil or gas, thus contributing to potential energy vulnerability issues in the future (Burger et al., 2018).

## Social capital: Participation/awareness raising

> *"In some municipalities the most important argument is that they include the local residents in the local energy transition." (1S)*

Switzerland is often held up as an example of participative or direct democracy, where participation is de rigeur (Ladner and Fiechter, 2012), which is reflected in the quote above. The requirement for citizen participation is held to be vital, and perhaps this helps to account for lower levels of energy poverty when compared to neighboring countries. However, as noted above regarding the differences between SILC and SHEDs data, misrecognition of groups that are energy vulnerable does occur:

> *"But we have about twenty five percent of the population who are foreigners. They cannot vote, as you're probably aware of. That's a problem because they're excluded from many things. And I think we need to find ways of rethinking democracy in the modern day, these representative*

> *parliaments are very valuable, but we should probably enrich them with new techniques, like this "Bürger panel" (German trans. as citizens)."* (8H)

This stakeholder considered the use of citizen or "Bürger panels," consisting of randomly chosen members of the public, as a method of ensuring that participation is best harnessed. These have been trialed in Urstalden and Winthertur (Bürgerpanel, 2022; RadioCentral, 2022) and use a lottery system to select residents who make recommendations and decide on concrete measures to tackle multiple issues. These citizen panels are open to all residents and not just to Swiss nationals so as to bring in a greater level of inclusiveness than other methods. This may in turn have an effect in ensuring that those who are energy vulnerable, including those who are non-Swiss, become better represented and that issues such as energy vulnerability become better known.

Awareness raising is very important when it comes to energy vulnerability in Switzerland, because the topic is not widely accepted as significant, and in some cases is deemed irrelevant. In some cases, characteristics of energy vulnerability are ascribed to quality of life. This may be the case in rural areas, among low-income farmers:

> *"Talking about farmers again, low-income farmers. They would never say they are living in energy poverty… for example if their heating system is with wood, they collect the wood themselves, they put the wood in their stove themselves. We still have houses, you know, where the… the windows are frozen in the winter, where you can see your own breath in the only part that is heated… But the question is always is it energy poverty or is it something (...) or is it sometimes also a quality of living, I do not know… So I guess, compared to other countries, there is no energy poverty, but I would say because we are in a rural region we still do have."* (7C)

Energy vulnerability reduction is often framed as part of climate mitigation policies through the use of energy efficiency retrofitting programmes. Awareness of energy efficiency schemes does seem to be permeating Swiss society and multiple stakeholders discussed the use of media campaigns to reach citizens:

> *"If we do the communication together (with the municipal authorities), usually newspapers are also interested in it. So, it is one way for municipalities to actually show to their citizens we are doing actually, you can even join this initiative, you can be part of it and let's do the energy transition together."* (S1)
>
> *"The most important part is communication. So, we are just very active. Every month we put something in the newspapers, we use social media, we use online marketing, we have different channels from the communities themselves."* (7C)

As a cantonal energy association, the Energietal Toggenburg offered over 100 different energy-related events within the canton during 2019. Although this was reduced and largely moved online temporarily during the COVID-19 pandemic, the idea of citizen participation is seen as crucial in order for people to fully engage with measures that may reduce energy vulnerability.

Taken nationally, increasing participation and spreading awareness of both energy efficiency schemes and energy vulnerability may result in greater uptake in efficiency programmes as well as more targeted treatment of those who are energy vulnerable on a cantonal level.

Understanding how those that are energy vulnerable are included in decision-making processes and the engagement level of vulnerable households within such procedural justice issues would provide an interesting novel indicator for energy vulnerability. This could be self-reported and assist in bringing procedural energy justice further into potential indicators for energy vulnerability and poverty.

## Human capital: Policy and regulatory framework on energy vulnerability reduction

There is no national strategy to tackle energy poverty or vulnerability in Switzerland. Part of the reason for this may be that the topic is not considered to affect enough people. However, based on the results from SHEDS, it would seem that vulnerability to energy poverty is not well-represented through current forms of data collection which focus on material deprivation and do not allow for other potential causes of vulnerability. As mentioned earlier, Switzerland is a nation where most homes are not owned by the residents, and this brings about a different type of energy vulnerability which is far more closely connected to lack of building renovation and poor energy efficiency of buildings.

For those that rent, there may be reluctance on the part of landlords to engage with energy efficiency improvements as, although the cost can be recouped through rent, long payback times may make this undesirable. This may be connected to the rent regulations in Switzerland which protect sitting tenants from certain increases in market rents, setting limits on the percentage increase in rent per year which is permitted (Lind, 2001). There are also regulations already in place within Switzerland that ensure that landlords are not able to increase the rent based on the total cost of energy improvements made on tenants' homes, but may only increase rent based on their actual costs. This was corroborated by the stakeholders that we interviewed:

> "In the relationship between owners and the people living in a house, subsidies will also lead to positive drawbacks. First of all, if you invest in renewables, you

> have less costs for your energy consumption. But also, the owner has to minus the subsidies from the investment in renewables, which means also in order to increase the rent, he is not allowed to take this part. This is also settled by the law, which is good in that sense." (S1)

This may have some effect on protecting tenants from unscrupulous landlords that would overly increase rent. However, it does little to increase the uptake of energy efficiency retrofitting which needs to be addressed. Additionally, tenants, themselves, are unlikely to pay for renovations as they do not own their home, nor do they necessarily see an increase in prices that would motivate such improvements:

> *"...The tenant. Why would he invest if he does not have to pay for the costs of living in there? That is sometimes, you know, the gap that we have. They do not invest because they are not paying for the gas or for the electricity" (4V)*

From our data, it seems clear that energy vulnerability in Switzerland is less connected to energy prices than in other countries. Energy prices vary from canton to canton, but these costs remain minor compared to the costs of upgrading and improving buildings and heating systems. National and cantonal schemes could offer greater incentives and tax breaks in order to increase uptake of energy improvement schemes as well as setting dates for higher minimal standards to ensure that poorly insulated properties no longer cause energy vulnerability.

## Limitations

Our quantitative study of energy poverty in Switzerland was limited by data availability. While the inclusion of variables related to spatial factors, certain personal factors, age of housing, and energy efficiency characteristics would have fortified the study, the limited sample size and low number of positive responses to energy poverty questions would have resulted in an unbalanced dataset. Nevertheless, the inclusion of explanatory variables related to sociodemographic characteristics coincides with those found to be significant in explaining energy poverty (e.g., Mashhoodi et al., 2018; Jessel et al., 2019; Longa et al., 2021; van Hove et al., 2022). Furthermore, the pandemic may have changed perceptions on energy vulnerability as SHEDs respondents had endured an initial lockdown, which also delayed the start of the survey until May 2020, when the weather was already improving.

Further, the SHEDs data on energy vulnerability is at the household level, and thus measuring energy vulnerability may perhaps be better achieved through examining individual responses rather than responses as a family. This may also help to reveal gender differences in energy vulnerability, which have been researched and which emphasize the risk of seeing households as homogenous units when it comes to the lived experience of energy poverty (Petrova and Simcock, 2021). We attempted to counter some of these limitations through including expert interviews in addition to quantitative data, which brought in more detailed aspects together with expert perceptions of energy vulnerability within Switzerland.

## Outlook

A capabilities approach framework for energy vulnerability puts heavier emphasis on self-reported indicators of energy poverty, but allows for a greater understanding of local regional and national differences in main drivers. Our research shows that despite its reputation as a wealthy nation, energy vulnerability is an under-studied aspect of Swiss society which affects a significant swathe of the population. Although energy vulnerability is not at the forefront of current policies in Switzerland, this issue as revealed by our framework may be much more serious than previously considered, particularly owing to poor housing stock. There is a need for adaptive strategies to ensure that the population is robustly protected when it comes to energy vulnerability, including in terms of future cooling demand, as this may well increase owing to the effects of climate change (Bienvenido-Huertas et al., 2021). Further, it is important to understand how heterogeneity in impacts of climate change can lead to regional differences in risk of energy poverty. Understanding how socioeconomic characteristics differ geospatially may also lead to better understanding of the different policy approaches required to address the variability in risk to energy poverty (Bouzarovski and Simcock, 2017). An approach exploring spatial heterogeneity and homogeneity in energy poverty has previously been applied in the Netherlands (Mashhoodi et al., 2018) and may be used to study regional vulnerabilities to energy poverty in Switzerland.

One of the big challenges of the energy transition in Europe is to find ways of decarbonising the energy system without increasing energy vulnerability. In the case of Switzerland, the situation is slightly different as most of the energy system is already carbon free, but the phasing out of nuclear power brings with it further challenges (Díaz Redondo and van Vliet, 2015), such as rapidly replacing this with renewable energy that is able to meet national needs (Rüdisüli et al., 2022). It is clear that energy vulnerability is a problem in Switzerland, which may be closer connected to building efficiency than to income or cost. This may have international repercussions as other nations may wish to reconsider how energy vulnerability is evaluated and measured and add new policy tools to existing policies.

Further research on the topic of energy vulnerability, as a term which is more widely encompassing and perhaps less associated with stigma than energy poverty, is warranted both for the case of Switzerland and for further afield. A case could be made for all non-renewable energy as being a potential source of energy vulnerability due to the potential amplification of vulnerability through climate change caused by the use of fossil fuels. Reframing energy poverty in this way may allow for more joined-up policymaking that brings into account both climate change mitigation and energy vulnerability mitigation, such as Positive Energy Districts (Hearn et al., 2021) which bring together renewable energy with principles of sustainability, inclusiveness and quality of life.

## Data availability statement

The datasets used in the study are available from the corresponding author on reasonable request.

## Ethics statement

The studies involving human participants were reviewed and approved by Application No. 2021/109, Schools of Business, Law and Social Sciences Research Ethics Committee (BLSS REC), Nottingham Trent University. The patients/participants provided their written informed consent to participate in this study.

## Author contributions

AH, DM, IS, and AS: conceptualization, methodology, writing–review and editing, and visualization. DM and AH: qualitative data collection. AH: writing–first draft. DM and IS: qualitative data analysis. AS and IS: supervision. All authors have read and agreed to the published version of the manuscript.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsc.2022.952034/full#supplementary-material

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