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Public preferences for phasing-out fossil fuels in the german building and transport sectors

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Abstract

In most of Europe, the decarbonisation of the building and transport sectors lags behind emission targets. Achieving full decarbonisation requires not only the diffusion of net-zero emission technologies but also the phase-out of technologies that emit greenhouse gases (GHG). However, implementing policy changes in these sectors can have an immediate and significant impact on people's day-to-day life, leading to a higher risk of political backlash, as exemplified by the yellow vest movement in France. In this study, we investigate public preferences for phase-out policy packages in both sectors in Germany by conducting two conjoint experiments with 1,777 respondents in March 2022. Respondents collectively evaluated a total of 17,770 policy packages per sector, specifically targeting the phase-out of fossil fuel-based heating systems and internal combustion engine vehicles (ICEVs). We find that respondents favour earlier phase-out dates for both technologies, but the type of preferred instruments varies: while regulatory instruments like bans are preferred for heating systems, economic instruments like taxes are preferred for ICEVs. These preferences are even more pronounced in people most concerned about climate change. In addition, we find that people with higher knowledge about sector emissions tend to demonstrate higher acceptance of policy interventions and that supportive measures significantly enhance the attractiveness of policy packages. Our findings can inform the design of phase-out policy packages, potentially increasing their acceptability and political feasibility.

Introduction

To keep global temperature rise below 1.5 °C many countries, industries, and businesses have pledged to reduce net greenhouse gas (GHG) emissions to zero by mid-century. Strategies to achieve this are often still vague or incomplete. For example, emissions in the European Union's (EU) transport sector have continued to rise, and a policy report found that existing policies are not on track to meet future climate targets (European Environment Agency 2022). By comparison, emissions have fallen somewhat in the building sector over the past decade (European Environment Agency 2021) but the pace of investments in insulation and sustainable heating systems needs to double if 2030 and 2050 emission targets are to be met (European Environment Agency 2023).

In the EU and elsewhere, the pressure to decarbonise both the transport and building sectors has been increasing. Pressure has been coming from public movements such as Fridays for Future, the European Commission with its European Green Deal and the Fit for 55 package, and energy regulators in their response to the turmoil in oil and natural gas markets. These developments may have opened a window of opportunity to overcome previously insurmountable lock-in effects surrounding fossil fuels, with the associated infrastructures and institutions that had emerged and solidified over decades. For net-zero emissions targets, a complete phase-out of fossil fuels will be needed. This can take several forms, including decommissioning coal powerplants,

replacing oil and gas boilers in people's homes, and replacing internal combustion engine vehicles (ICEVs) with electric vehicles and other transportation modes. Doing these things often requires high initial investments, and in some cases behavioural changes, requiring an adequate policy framework (Geels *et al* 2017, Creutzig *et al* 2018, Markard 2018). Public support for these policies is crucial, if they are to be enacted and effective. While polls show that recognition for policy intervention is high (Wolf *et al* 2023), counter-movements arising from public opposition, such as the 'Gilets jaunes' in France or the 'Pro-Diesel' movement in Germany may slow down or halt urgently needed policy intervention (Guilluy 2018, Arning and Ziefle 2020, Douenne and Fabre 2022).

Understanding individual preferences for policy instruments and policy packages, as well as the underlying drivers for those preferences, is important. The existing literature shows that preferences are shifting, and typically context-specific. When it comes to climate policy in general, studies consistently find that concern about climate change, and perceived distributional fairness and effectiveness are among the most important determinants for public opinion (Bergquist *et al* 2022, Dechezleprêtre *et al* 2022). These determinants likely explain why packaging different sets of policy instruments also shows higher public support when packages include supportive measures (Bergquist *et al* 2020, Wicki *et al* 2020). While there has been a rising number of studies focussing on phase-outs, 'there is an additional need to further elucidate the conditions that enable or prevent the introduction and smooth implementation of phase-out policies' (Trencher *et al* 2022). Indeed, only a few studies have assessed public preferences for phase-out policies. Focusing on the power and transport sectors, these have consistently found a preference for earlier phase-outs and for packages that include supportive measures (Rinscheid and Wüstenhagen 2019, Rinscheid *et al* 2020, Wicki *et al* 2020). No study has assessed public preferences toward a phase-out of fossil fuels in the building sector.

In this study, we fill this gap by comparing preferences for phase-out policy instruments in the building and transport sectors, based on data from the German public. By assessing both sectors using the same framework, we can study the effects of the different contextual factors that the two sectors offer. We chose Germany as a case study due to its current plans to phase-out fossil-fuel based heating systems and the role it plays as the largest economy in European phase-out ambitions in both the building (European Commission 2022) and transport sectors (European Parliament 2023). While Germany has been a frontrunner in the transition to sustainable electricity, and catching-up on sustainable heating, the ambitions in transforming the transport sector are more ambivalent due to the central role of the car industry (Haas 2021). The CO_2 emissions in the German transport and building sectors show similar trends to Europe as a whole: transport sector emissions have not notably declined since 1990, and while building sector emissions have, progress is not in line with the 2045 climate neutrality goal (Günther and Gniffke 2023).

For both sectors, we explore preferences with respect to phase-out date, the choice of economic and regulatory policy instruments including taxes and bans on technology purchase and use, and the supplementing of these with support instruments including loans and subsidies. Vis a vis distinct types of phase-out instruments as suggested for example by Trencher *et al* (2022), this selection covers management and planning, economic, command and control, as well as capacity building policy instruments. The selected policies are salient to current policy proposals at the EU and national levels and could be effective in achieving a full phase-out. We conducted conjoint survey experiments to be able to assess all these elements of policy packages consistently.

Method

Experimental design

The experiments were designed to shed light on respondents' preferences not only concerning individual policy instruments, but also concerning mixes of policy instruments. Conjoint experiments are well-suited for this task as they let respondents repeatedly assess options composed of a range of randomly chosen attributes. The options in our experiment comprise four attributes of policy packages: phase-out year, policy instrument targeting the purchase, policy instrument targeting the use phase, and support measures. For each attribute there were five levels of intensity or ambition. Our experiment contained separate choice options for each of the two sectors. All respondents participated in both experiments in a randomised order. As shown in supplementary figure S1, we found that the order of the two experiments did not introduce a bias.

The experimental design allowed us to exclude unintended, competing causes. In each experiment, there were five tasks, such that each respondent performed ten tasks in total—five in the building sector experiment and five in the transport sector experiment. Within each task, respondents saw two alternative policy packages next to each other. Neither the display arrangement of these two packages nor the number of tasks did introduce a bias (supplementary figures S2 and S3). The intensity or ambition levels for each attribute within the policy packages were chosen at random which is essential for our analysis method. We did not, however, randomise the order of the attributes as seen by the respondents, because the order of the attributes follows a logical structure we did not want to break. In each task, we asked respondents to first choose the policy package they prefer and

Table 1. Attributes and attribute levels for conjoint experiments in the heat and transport sectors.

Policy attribute	Building sector	Transport sector
Phase-out year	2030	2030
	2035	2035
	2040	2040
	2045	2045
	2050	2050
Purchase instrument	No instrument	No instrument
	Purchase tax on fossil fuel heating systems of 10% of the purchase price	Purchase tax on ICEVs of 10% of the purchase price
	Purchase tax on fossil fuel heating systems of 20% of the purchase price	Purchase tax on ICEVs of 20% of the purchase price
	Ban on the purchase of fossil fuel heating systems from 2025 on	Ban on the purchase of ICEVs from 2025 on
	Ban on the purchase of fossil fuel heating systems from 2030 on	Ban on the purchase of ICEVs from 2030 on
Use instrument	No instrument	No instrument
	Tax on fossil fuels (0.2 EUR/l)	Tax on fossil fuels (0.2 EUR/l)
	Tax on fossil fuels (0.5 EUR/l)	Tax on fossil fuels (0.5 EUR/l)
	Replacement of fossil fuel heating systems older than 15 years	Driving ban of ICEVs in city centres on workdays
	Replacement of fossil fuel heating systems older than 30 years	Complete driving ban of ICEVs in city centres on all days
Support instrument	No instrument	No instrument
	Subsidies for climate-friendly alternatives	Subsidies for climate-friendly alternatives
	Trade-in bonus	Trade-in bonus
	State-supported building renovation measures	State-supported infrastructure measures (charging infrastructure, public transport)
	Preferential loan	Preferential loan

then to rate both packages on a scale from one to five (see Supplementary Notes S1 and S2 for examples). Choices and ratings led to the same results (supplementary figure S4). The ratings allow us to measure attitudes towards phase-out policy intervention in general, which cannot be done with a forced choice between two options alone.

Choice of attributes

Given the urgency of eliminating GHG (IPCC 2022), both the timeline and the acceptance of phase-out strategies are crucial. Yet, behavioural sciences show that people struggle with making decisions for long-term challenges such as climate change. They frequently fail to correctly weight future benefits in comparison with immediate costs—a status quo bias (Weber and Johnson 2015), which is the case for most climate action, being characterised by high up-front costs and future or abstract benefits.

Therefore, the first attribute in each policy package is the phase-out year of fossil-fuel based technology in each sector (table 1). From that year forward, the use of fossil-fuel based heating systems or internal combustion engine vehicles will not be permitted. We chose 2050 as the latest year in accordance with the European Green Deal (European Commission 2019) which requires net-zero greenhouse gas emissions by mid-century. 2030 is the earliest year within our policy packages as we deem earlier phase-outs to be unrealistic given the lifetime of these technologies and the fact that currently only a purchase ban in the transport sector is foreseen to be in place in 2035.

The second attribute in each policy package targets the purchase of fossil-fuel based technology in the sectors. Apart from no purchase policy instrument, we consider four policies targeting purchasing through economic and regulatory instruments (table 1). The two economic instruments are purchase taxes of different levels, and the two regulatory instruments are purchase bans in 2025 and 2030, respectively.

The third attribute in each policy package targets the use of fossil-fuel based technology in the sectors. Again, there are two economic and two regulatory instruments next to an absence of a use policy instrument (table 1). The economic instruments in both sectors are taxes on fossil fuels of 0.2 or 0.5 EUR per litre. The regulatory instrument in the building sector is an enforced replacement of fossil-fuel based heating systems that are older than 15 or 30 years. In the transport sector, the regulatory instruments are driving bans in city centres, either on workdays only, or every day.

The last attribute in the policy packages comprises supporting measures that seek to mitigate monetary and non-monetary disadvantages of the phase-out of fossil-based technology in both sectors (table 1). These are preferential loans or subsidies for climate-friendly alternatives, trade-in bonuses for abandoning fossil-fuel

based technology, and state-supported measures. In the building sector, state support measures are renovation measures and, in the transport sector, they are measures targeting the expansion of public transport and charging infrastructure for electric vehicles. Again, we add the option of having no supporting policy instrument.

We limited the number of attributes, attribute levels, and tasks in a way to not overwhelm respondents and to yield sufficient statistical power (Stefanelli and Lukac 2020). Our selection of attributes and attribute levels covers planning instruments (phase-out year), command-and-control instruments (bans), economic instruments (taxes, subsidies, trade-in bonuses, and loans), as well as capacity building instruments (state-supported infrastructure measures).

Sample

We sampled from the German population of voting age using the internet panel of the market research company Bilendi/respondi. We set quotas for age, gender, and municipality size leading to a sample that reflects the target population well (Supplementary table S1). We developed the survey in German and tested it on a group of approximately 15 people before launching it. We fielded the survey between 25 February and 10 March 2022. To filter speeders and low-quality results, we removed the 5% fastest respondents. The remaining respondents ($n = 1{,}777$) spent at least 4 min answering the survey (about 9 min median duration). Our results are robust against this data analysis decision (supplementary figure S5).

In addition to the two experiments conducted by all respondents, our survey also included questions about the socio-economic status of respondents, about their heating and driving behaviours, and about their attitudes towards climate change. The conjoint experiments also had two different framings to which we randomly assigned participants. Supplementary Note S3 shows a translated transcript of the survey.

Analysis

To analyse the causal effects of policy package attribute levels within our experiments, we use a standard method described by Hainmueller (Hainmueller *et al* 2014) based on linear regression. The central assumption of this method is a fully randomised design, which our experiments offer (supplementary figure S6). Using the method, we derive estimations of average marginal component effects and standard errors clustered by respondent for each attribute level using the R package cregg (Leeper 2020). As we have recorded both choice and rating of policy packages in each task, we can derive causal effects using either of the two as dependent variable. With ten tasks per respondent, our analysis includes 35,540 observations per sector (Annaheim *et al* 2023).

To examine heterogeneity of the preferences within the population, we further perform several subgroup analyses. We compare subgroups based on marginal means rather than average marginal component effects to avoid misinterpretation of the estimations (Leeper *et al* 2020).

Results

Respondents prefer an early phase-out in both sectors

In terms of timing, respondents prefer a phase-out in 2030 or 2035 over phase-outs in 2040 or later. This is the case in both sectors (figure 1), but especially so in the building sector: Phasing out fossil-fuel based heating systems by 2030 compared to 2050 increases support by 6.5 percentage points 95% CI [4.0, 9.0].

Preferences with regards to policy instruments targeting the purchase of fossil-fuel based technology are less clearly defined. In most cases, the effects are small, indicating that purchase instruments do not play an important role in population-wide averages (figure 1). An exception is a purchase ban of internal combustion engine vehicles from 2025, where the support of policy packages reduces on average by 8.1 percentage points 95% CI [5.5, 10.7] compared with no purchase instrument.

Similarly, economic restrictions in the use of fossil-fuel based technologies in the building and transport sectors receive lower support (figure 1). In both sectors, a tax on fossil fuels decreases policy support by up to 13.5 percentage points 95% CI [11.1, 15.8] compared with no use instrument. While both sectors show a similar trend, the effect is more pronounced in the building sector. In contrast, regulatory interventions are much less supported in the transport than in the building sector. A complete ban of driving ICEVs in city centres decreases support by 15 percentage points 95% CI [12.4, 17.6] compared with no use instrument.

Supporting policy instruments play a major role in policy package preferences (figure 1). In fact, we find the largest average marginal component effects within this category. Subsidies for climate-neutral alternatives, trade-in bonuses, and state-supported measures experience particularly high support of up to 20.8 percentage points 95% CI [18.4, 23.1] compared with no support instrument. Supporting policy instruments clearly are decisive measures for or against support of a policy package as they can partly or entirely compensate negative effects of purchase and use restrictions from other policy instruments.

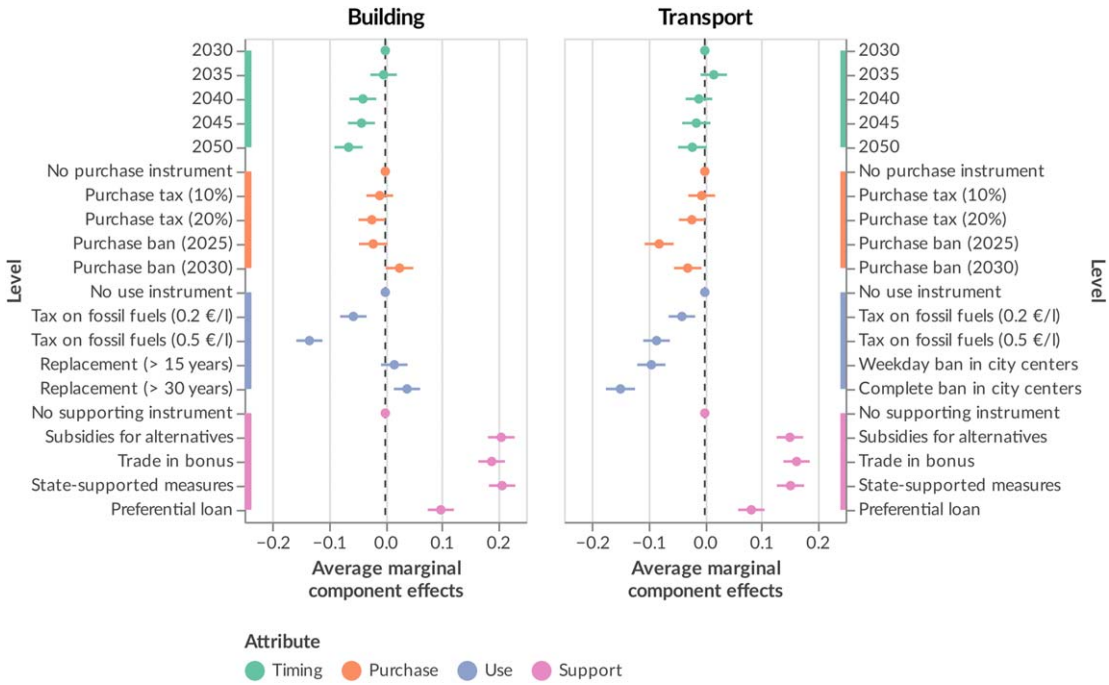

Figure 1. Population average preferences regarding attributes of policy packages. Points show the average marginal component effects of the forced choices of policy packages in the building (left) and transport (right) sectors. The points show the estimated decrease or increase in probability that a policy package is chosen, relative to the baseline level (first level of each attribute). Horizontal bars represent the 95% confidence interval. There were n = 1,777 respondents and 17,770 policy packages per sector. For data in table form, see Supplementary Tables S2 and S3.

Respondents who are concerned about climate change prefer earlier phase-outs in both sectors

Among different subgroups in the population, we find the largest differences across groups with different levels of concern about climate change (figure 2). We group respondents in three groups based on the responses on six Likert items about changing climate: people with high (n = 1306), medium (n = 403), and low climate change concern (n = 138) (see Supplementary Note S4). The largest discrepancies between the groups are within the phase-out timing and purchase instrument attributes. While phase-out date preferences of people with high climate change concern follow the same trend as the ones of the entire population, the effect is more pronounced. Here, support increases by 10.8 percentage points 95% CI [7.8, 13.8] when moving from a phase-out in 2050 to a phase-out in 2030. Respondents with low concern follow the opposite pattern and prefer later phase-out years over earlier ones.

Respondents with varying climate change concern also show varying preferences towards policy instruments targeting the purchase of fossil-fuel based technologies (figure 2). While those with low or medium concern prefer the use of no policy instrument, those with high concern prefer purchasing bans, with support increasing up to 6.9 percentage points 95% CI [4, 9.8] compared with no instrument. The diverging preferences across these groups explain the unclear picture in population averages (figure 1) for purchase instruments and in parts for the phase-out year, as they cancel each other out in the population average.

Within use instruments, we find differences across groups only in the transport sector (figure 2). While preferences show the same trend across all groups, the group with low climate change concern shows a strong refusal of driving bans, with support decreasing sharply up to 30.4 percentage points 95% CI [21.4, 39.5] compared with no use instrument. Finally, we find only a negligible difference in preferences for support instruments across respondents with varying concern.

Support for policy intervention varies with knowledge and climate change concern

Knowledge about sector emissions is associated with support for policy interventions. We divide our sample in subgroups based on their sector emission share estimations and deem +− 3 percentage points correct, otherwise the estimation is classified as being too low or too high. We find that those underestimating sector emissions rate policy packages generally lower by approximately 10% in both sectors (figure 3) compared with those estimating correctly. Those that overestimate sector emissions show similar average ratings than those with correct estimations. As there is no relationship between emission estimations and choices (supplementary figure S7), knowledge about sector emissions is not associated with preferences about policy package designs but with preferences for policy intervention generally.

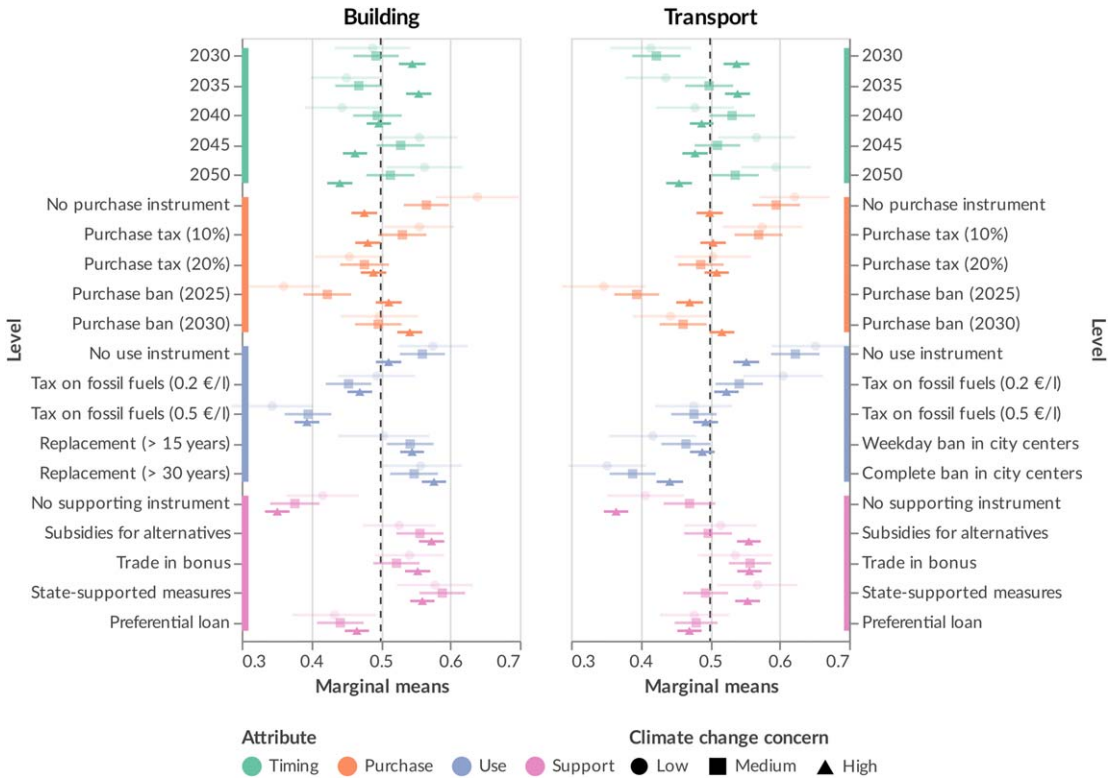

Figure 2. Relationship between climate change concern and policy preferences. Points show marginal means of the forced choices of policy packages within the building (left) and transport (right) sectors. Subgroups of our sample with varying climate change concern are shown using varying opacity (higher opacity represents higher concern) and using different shapes. Horizontal bars represent the 95% confidence interval. There were n = 1,777 respondents and 17,770 policy packages per sector. For a comparison of group sizes, see supplementary figures S9 and S10.

Support for policy intervention also increases with climate change concern of respondents. Here, respondents with high climate change concern rate policy packages on average 55% (building) and 67% (transport) higher than those with low concern (supplementary figure S8).

The support for policy intervention varies not only with climate change concern and emission attribution but also with the interaction of the two. Respondents with low climate change concern show the largest differences across emission attributions (figure 4). Within this group, average ratings of all transport policy packages are 20% lower for those that underestimate emissions compared with those with correct estimations. This effect is smaller in the building sector (13%). Respondents with medium climate change concern show a similar, albeit slightly smaller effect, while the effect is almost non-existent in the most concerned group: respondents with high concern all rate policy packages similar (figure 4).

Apart from concern about climate change and knowledge about sector emissions, other subgroups have only minor differences in choices or ratings. Socio-demographics like age, gender, and education of respondents have almost no association with choices and ratings (supplementary figure S11). Being personally affected has some effect on choices, with homeowners and car users preferring later and less stringent phase-outs (supplementary Figures S12 and S13). Respondents with low trust in the government have similar choices but different ratings (supplementary figure S14), suggesting that their preference for any kind of policy intervention is lower. This effect may in parts be explained by low climate change concern of respondents with low trust, as there is a strong association between trust and concern. In addition, we did not find an effect of framing the experiments in the context of fostering renewables uptake or phasing-out fossil fuels (supplementary figure S15).

Discussion and conclusion

In our experimental study, we observe a clear preference among German citizens for earlier phase-outs of fossil fuel-based technologies in both the buildings and transport sectors. Regulatory instruments, such as bans, are preferred in the buildings sector, while economic instruments, such as taxes, are preferred in the transport sector. Supportive instruments, including subsidies, are evaluated positively and proved effective in mitigating negative attitudes towards other policy instruments within the package. High levels of concern about climate

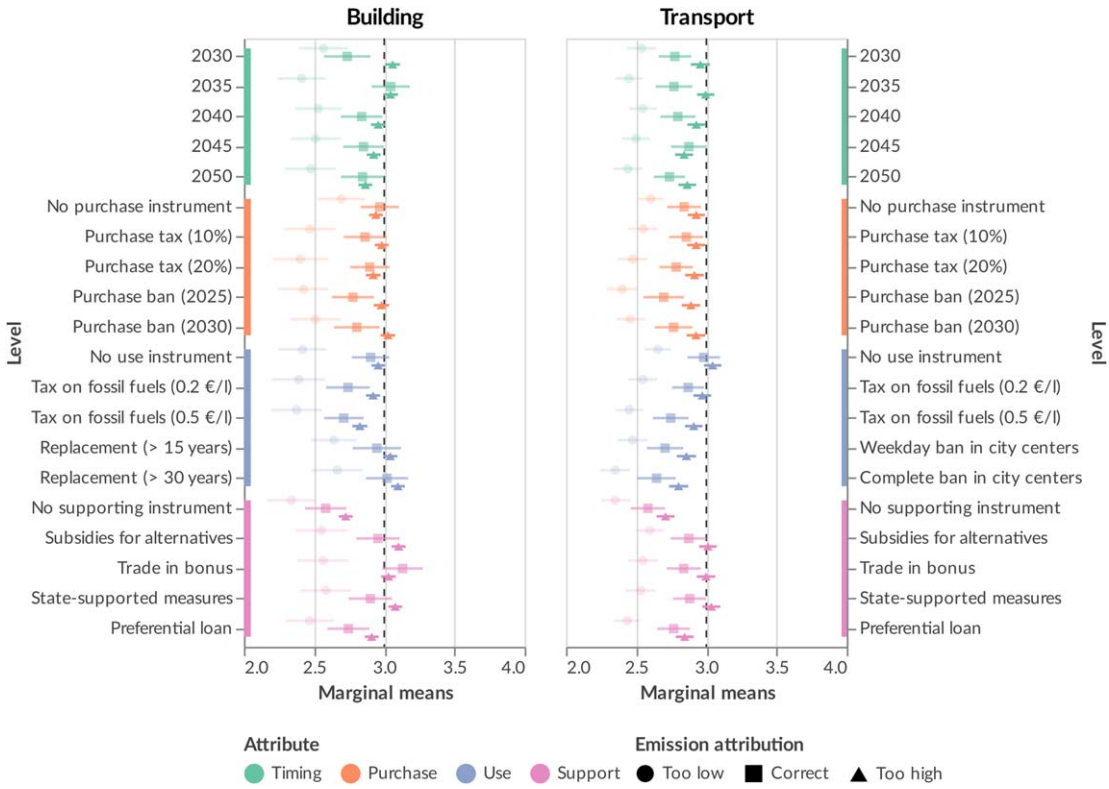

Figure 3. Relationship between emission attribution and policy preferences. Points show marginal means of the ratings of policy packages in the building (left) and transport (right) sectors. Subgroups of our sample with varying sector emission attributions are shown using varying opacity (higher opacity represents higher sector emission share estimation) and using different shapes. We define an attribution as correct if it is within a +−3 percentage points range of the true value, otherwise the attribution is too low or too high. Horizontal bars represent the 95% confidence interval. There were n = 1,777 respondents and 17,770 policy packages per sector. For a comparison of group sizes, see supplementary figures S9 and S10.

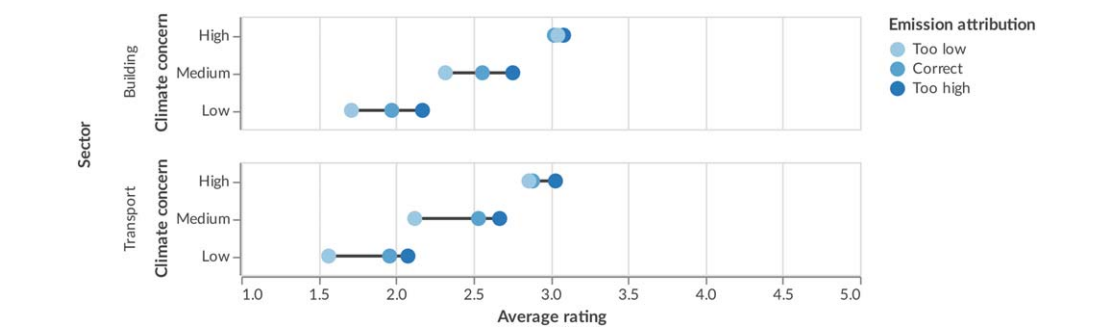

Figure 4. Average rating for subgroups with varying climate change concern and emission attribution. We deem emission attributions correct if they are within a +−3 percentage points range of the true value, otherwise the attribution is too low or too high. There were n = 1,777 respondents and 17,770 policy packages per sector. For a comparison of group sizes, see supplementary figures S9 and S10.

change and high knowledge about sectoral emissions increase support for policy interventions. Overall, our results indicate that public support for proposed phase-out policies in both sectors is higher than the heated public debate, dominated by several vocal media outlets and political figures, would suggest.

Two potential issues in our experimental design might have biased results, limiting its external validity: our opt-in sample and social desirability. To mitigate the former, we have performed quota-based sampling and several subgroup analyses. The subgroup analyses revealed relevant differences in choices only among subgroups with varying concern about climate change for which our sample corresponds to estimations from random samples in other studies (European Social Survey ERIC 2017, Wolf *et al* 2023). Therefore, we conclude that our opt-in sample is representative in this regard and did not introduce a significant bias. While it is possible that participants in our study have responded in a socially desired way, the conjoint design can mitigate this bias.

Because several attributes are varied randomly and in parallel, conjoint designs likely introduce smaller biases than other survey methods (Horiuchi *et al* 2022).

The finding that people prefer to phase out fossil fuel-based technologies sooner rather than later is very much in line with previous research (Rinscheid and Wüstenhagen 2019, Wicki *et al* 2020). It is also consistent with repeated polls, which have consistently ranked climate protection as one of the two most important political issues of 2022 and which have shown that the majority of Germans support the energy transition (Wolf *et al* 2023).

When it comes to explaining the variation in preferences for specific policy instruments, the picture becomes more complex. The first surprising finding is that while people strongly oppose purchase bans of ICEVs, they are rather in favour of purchase bans for oil and gas boilers—at least from 2030. One potential explanation is that the ownership of cars goes beyond their immediate function of transport, and is also associated with status, emotion, and even cultural heritage (Haas 2020, Mögele and Rau 2020). Heating systems, on the other hand, primarily serve the function of heating a home. Replacing old oil and gas boilers with heat pumps involves only minimal technological changes and differs slightly in terms of investment and operating costs. Another potential explanation is that the public discussion of phasing out ICEVs via purchase bans preceded that of phasing out fossil fuel-based boilers, which is why people may not have given the implications of phasing out the latter much thought when this experiment was conducted. A final possible explanation is that alternatives to fossil fuel-based boilers—such as heat pumps—are viewed as perfectly adequate for all users, whereas some people may question whether electric vehicles and modal shifts are a perfect substitute for ICEVs.

Our findings also reveal an apparent discrepancy between preferences for earlier phase-outs on the one hand and opposing many of the economic or regulatory policy instruments on the other. This seeming contradiction aligns with previous research: According to (Van Lange *et al* 2013) there is a social dilemma inherent in the conflict between societal benefits that materialize in the long term and the short-term personal implications. This phenomenon is particularly relevant in the context of climate protection efforts characterized by high behavioural costs (Steg and Schuitema 2007, Hoppe *et al* 2023). Importantly, these instruments alone will likely not guarantee a complete end to the burning of fossil fuels, but planning and regulatory methods will be more effective to that end (Plötz *et al* 2023) and extensive subsidy programs put an additional burden on already strained state budgets. Nonetheless, support instruments play a crucial role: We demonstrate that the existence of a support instrument increases preferences for policy packages and compensates some of the negative attitudes towards more restrictive measures. Additionally, subsidies play an important role in the early phases of a socio-technical transition as they stimulate demand, create economies of scale and thus bring down the cost of the new zero-carbon technology (Patt 2015). They are also a means of making a transition more socially just, for example if the degree of financial support is determined by household income or wealth. Distributional fairness has been shown to be one of the most important determinants of public opinion about climate policy (Bergquist *et al* 2022). So our results suggest that there may be room for support instruments in the context of phase-outs, as a means of increasing the perceived equity, and with that the social and political acceptance, of policies that restrict or economically penalise choice.

Overall, our results confirm the importance of a balanced policy mix. Given that the support for pricing instruments, such as taxes, is relatively low, any political strategy for phasing out carbon-intensive technologies should not consist of pricing alone. Likewise, the fact that emissions in the transport and buildings sector in Germany have not fallen at all or not sufficiently over the last 20 years demonstrates that subsidies, information campaigns, and light regulation alone are insufficient for reducing GHG emissions at the required rate for climate neutrality by 2045.

Personal attitudes and characteristics, in particular concern about climate change and knowledge about the contribution of studied technologies to climate change, explain some variation in the results, as they are both positively associated with support for policy interventions. This supports previous findings (Bergquist *et al* 2022) and has further implications for policy design. Besides the timing, type, stringency, and combination of policy instruments, it is important that any policy implementation is accompanied by information about the problem that the policy is attempting to solve as well as the implications of the proposed solution. This raises awareness and knowledge, which in turn increases support and thus political feasibility.

The data collection and writing of this paper coincides with significant policy initiatives at the German and EU level, as well as an accompanying and intense public discussion. After the European Commission proposed to ban the sale of new ICEVs from 2035 (European Commission 2021), the regulation was weakened in response to opposition from Germany, and now entails provisions for ICEVs that operate on e-fuels (European Parliament 2023). The Commission also proposed a revision of the Ecodesign Directive that would set a 115% efficiency requirement for new boilers from 2029 (European Commission 2022), which is a de facto ban of stand-alone oil or gas boilers. While the consultation process is still ongoing, developments in Germany cast doubt on Germany's previously supportive stance on the Ecodesign revision. After the coalition parties agreed to implement a 65%-renewables requirement for new heating systems from 2024 on multiple occasions, the initial

proposal was recently significantly weakened to only apply to new buildings in certain areas and to existing buildings once municipal heat planning is in place.

These developments were partly due to claims that phasing out fossil-fuel based boilers and ICEVs via ambitious policy measures at both the national and EU level had insufficient public support. In this paper, we demonstrate that the majority of citizens in fact prefer earlier phase-out dates and are likely to support corresponding policy interventions. However, in order to gain and maintain support, deliberate policy design and communication are key.

Data availability statement

The data that support the findings of this study are openly available at the following URL/DOI: https://doi.org/10.5281/zenodo.7803031.

Code availability

The workflow code used to generate results of this study is openly available on Zenodo: https://doi.org/10.5281/zenodo.8171706.

Competing interests

The authors have declared that no competing interests exist.

Ethics statement

The design of this study has been proposed to the ETH Zurich Ethics Commission in Q4 2021 and has been approved and given the following ID: 2022-N-26. All participants were at least 18 years old and gave their written informed consent to participate in the study.

CRediT author statement

Tim Tröndle: Data curation, Formal analysis, Software, Visualisation, Writing—Original draft. **Jasmin Annaheim**: Conceptualisation, Investigation, Data curation, Formal analysis, Writing—review & editing. **Janna Hoppe**: Conceptualisation, Investigation, Supervision, Writing—review & editing. **Susanne Hanger-Kopp**: Writing—Original draft. **Anthony Patt**: Conceptualisation, Funding acquisition, Supervision, Writing—review & editing.

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