EUROPEAN TRANSPORT CONFERENCE
18 – 20 SEPTEMBER 2024

UNDERSTANDING THE ACCEPTANCE AND DESIGN OF PERSONAL CO2 BUDGETS FOR MOBILITY: INSIGHTS FROM AN INTERVENTION STUDY

Dr. Kerstin Stark

Institute of Transport Research, German Aerospace Center (DLR)

Dr. Heike Marquart

Institute of Transport Research, German Aerospace Center (DLR)

1. INTRODUCTION

As the world strives to meet ambitious climate goals, policy measures to restrict personal carbon dioxide (CO2) emissions especially in the area of transport become paramount. This study, which is part of the pan-European research MyFairShare funded under the JPI Urban Europe ERA-NET Cofund Urban Accessibility and Connectivity (ENUAC), investigates the concept of personal CO2 budgets for mobility and its potential to drive behavior change towards lower emissions transport modes. The idea behind the CO2 budget is to break down nationally agreed CO2 reduction targets into the individual share of each citizen and to assign corresponding personal allowances for the CO2 emissions of the means of transport used. In general, mobility carbon budgets could serve as an instrument in the transition to a sustainable transport system supporting individuals in meeting individual CO2-targets and indicating the need for improved transport services to decision-makers.

While there is widespread agreement that climate change must be mitigated and that politicians are called upon to introduce appropriate measures, it remains controversial whether consumer behavior must also change significantly and to what extent restrictions and cuts must be accepted. The most controversial, and in some cases already a reason for cultural conflicts, are measures relating to individual mobility - in particular, there is little acceptance of restrictions on private car use.

Current political debates regarding this topic are very controversial at the moment. They specifically deal with the question, how much behavior change among citizen is demanded by the political parties and to what extend technology and efficiency can help to achieve climate targets. Current debates amon srious climate experts, however, show that changes in behavior and lifestyle are needed. There is sufficient evidence that Germany and other industrialized countries will not be able to meet their climate targets without tough cuts and lifestyle changes (Rogelj, J., D. Shindell, K. Jiang, S. Fifita, P. Forster, V. Ginzburg, C. Handa, H. Kheshgi, S. Kobayashi, E. Kriegler, L. Mundaca, R. Séférian, and M.V. Vilariño 2022).

Climate politics are contested, yet there is a chance that people might be reached for arguments and develop acceptance of more profound lifestyle changes if they perceive climate measures not only as necessary but also as *fair*. Of course, acceptance is not just a question of perception or communication, but depends on the design and impact of political measures. In particular, following the IPCC climate policy measures has the capacity to promote social equity if they are designed to be designed in such a way that they have a redistributive effect (Lee et al. 2023).

The motivation for this study is to gain insights into how political measures, using the example of the personal carbon budget for mobility, must be designed so that they are perceived as fair. We do not provide a definition of fairness at this point, but will present requirements for fairness in the discussion based on empirical evidence and with reference to the literature.

In this article, we present the results of an intervention study as part of the MyFairShare research project. We look at three different design options for the personal mobility budget and show the acceptance conditions for the introduction of such a measure.

2. LITERATURE REVIEW

To reduce emissions in the transport sector, policies are needed to increase energy efficiency and reduce transport demand. That is, policies need to *avoid* traffic, *shift* it to less carbon intensive modes of transportation and *improve* fuel-efficiency. While it seems politically opportune to address the *efficiency* dimension, measures aimed at *shifting* and *avoidance* are less popular and account for only a small proportion. There is therefore an interest in innovative measures and instruments that address these neglected but extremely important dimensions of climate mitigation policy.

Climate research calculates what carbon budget remains globally to achieve the target of maximum global warming of 1.5 degrees. Following this, the approach of a *personal* carbon budget can help societies reach the globally set climate goals (Fuso Nerini et al. 2021). Only recently, the renowned German climate researcher Hans Joachim Schellnhuber introduced the idea of a personal carbon budget into the broader public debate. In an interview with public broadcasting (ARD magazine Panorama), Schellnhuber said that every person gets three tons of CO2 per year and if one needs more, they should have to buy it from others who consume less (Lambrecht und Baars 2023).

The idea of a personal carbon budget (PCB) has been discussed for a while now (Fawcett 2012; Pitkänen et al. 2022). Usually, the PCB is associated with trading similar to the Emissions Trading. Emissions trading is a market-oriented approach to climate policy that is organized by the state or supranationally and works with incentive to reduce emissions, e.g. in production or operations. One example is the

EU Emissions Trading System (EU-ETS). It works according to the "cap and trade" principle, whereby an upper limit for greenhouse gas emissions is defined and corresponding certificates are issued to the companies obliged to participate. The certificates can be traded freely, with supply and demand determining the price – a sufficiently high price is intended to incentivize companies to reduce their greenhouse gas emissions.

Following Pitkänen, personal carbon trading provides the beneficial mechanisms for behavior change such as economic incentives, increased awareness, and changes in social norms related to acceptable levels of personal emissions (Pitkänen et al. 2022). While emissions trading schemes for the economy have been introduced in many countries, the approach of a personal carbon budget is still conceptual and novel and concrete design options of the instrument as well as real implementation paths are still under development (Pitkänen et al. 2022; Fuso Nerini et al. 2021).

In their study on the introduction of a personal carbon budget for mobility in Austria, Millonig et al. conclude that, in view of the discrepancy between stated environmental awareness and actual mobility behavior, a stronger focus should be placed on individual contributions through behavioral change. This could be achieved by helping people to understand their own contribution to overall emissions through approaches such as the personal carbon budget, which simplifies national climate targets (Millonig et al. 2022). They also discuss possible negative social consequences and therefore emphasize the relevance of a *fair* approach. Fairness could therefore be achieved, for example, by compensating for spatial location or other disadvantages that might increase the need for more personal emissions (Millonig et al. 2022).

Fairness is also important in terms of acceptance. In general, given the fact that climate policy measures aimed at changing behavior are controversial, it is considered important to investigate suitable design options that increase acceptance. There is empirical evidence that perceived fairness influences acceptance. The distribution of burdens and benefits in society is particularly relevant to perceptions of fairness. With regard to the acceptance of climate policy measures, it matters whether the burdens and benefits of a policy or a specific measure are distributed in such a way that weak groups are not affected more or that no group benefits more (Pitkänen et al. 2022; Bergquist et al. 2022). As a review article showed, especially negative impacts on people with low-income are rejected by the society (Maestre-Andrés et al. 2019). Similarly, in a qualitative study on the factors influencing the acceptance of a particular climate policy, namely the implementation of wind energy, it was found that issues of distributional justice – together with procedural justice – are crucial. In particular, envy and the feeling of not benefiting from a measure while others benefit from it were identified as factors

why a measure is perceived as unfair and is therefore not accepted (Langer et al. 2016).

Against this background, we want to gain insight into the conditions under which a personal carbon budget is perceived as fair and acceptable. We are not interested in the technical implementation or the possible effects of a carbon budget. Instead, we focus on specific distributional options and examine how acceptable and fair personal emissions trading is perceived.

3. METHODS

Figure 1: Map of Berlin, red: study area

The study was conducted in Berlin, Germany, as one of six so called living labs in the overall project exploring and testing the potential of mobility related CO2 budgets in different settings. In the study, we aimed to identify barriers to acceptance and potentials related to the 'personal carbon budget for mobility' as well as compared acceptance between different designs of the policy instrument. The general challenge in the investigation of hypothetical scenarios is the probands´ limited capacity to realistically imagine what they would do and feel. Therefore, in order to provide an experience for the probands that is as close as possible to a real-life situation, we designed an experimental study with information treatment and a fictive carbon budget, which they received over a period of time on a daily basis. The hypothesis was that probands would engage more seriously with their mobility behavior and might even change their travel behavior upon receiving daily information on their carbon budget consumption and transport emissions of each journey.

In particular, the study design consisted of an app-based GPS tracking of all journeys on seven consecutive days combined with a qualitative approach applying interviews. We used the inhouse research app "MovingLab", where probands tracked their daily routes and vehicle type and were sent figures on their remaining carbon budget.

The GPS tracking data was never intended to be used to spatially analyze the movements of the probands. Rather, we used the tracking and the information as a treatment: Through the tracking task the probands could see how much CO2 their individual mobility choices entailed, hence, they could engage more deeply with their actual mobility behavior. The tracking could encourage them to think about their daily journeys, their mode choices and the resulting emissions. Furthermore, they were

supposed to experience the consequences of receiving a real personal carbon budget.

As sampling criteria, we specified that the subjects 1) work in the study area in Berlin (see figure 1 and 2) have to use a car at least occasionally for their commute. For the sampling, we used a short online questionnaire that essentially asked about these criteria. For the sampling, we did not ask about sociodemographics such as income or education. In this context, it should be noted that the typical people who work or study in the study area (the Adlershof Science and Technology Park) are employees of research institutes, (high-)tech companies or students. We therefore expected to obtain a sample of well-educated and informed younger and middle-aged people, rather than senior citizens or workers. For this exploratory study, we found an unbalanced sample acceptable in this respect.

We used several communication channels and multipliers: We contacted dozens of local companies and research institutes by email, posted the link on LinkedIn, X and our institute's website. We distributed flyers with a link and QR code to the questionnaire at points-of-interests such as popular lunch spots, supermarkets and the local university. Despite intensive recruitment efforts, it was difficult to acquire enough people. 52 people opened the link to the questionnaire, 21 people completed it in full, 18 people completed the tracking and nine people were willing to take part in an interview (table 1 and 2).

Table 1: Interviewees by gender

completed	21
not completed	27
Total response	48
Participants tracking	16
Participants interviews	9

Table 2: Response to screening questionnaire

Male	Female
7	2

After successfully completing the questionnaire, participants received a written briefing by email in which they were introduced to the "Moving Lab" tracking app and given instructions on how to participate in the study. The concept of the personal carbon budget was described as follows: Each citizen has a personal carbon budget for mobility based on national carbon reduction targets, which is understood as an upper limit for their own mobility behavior.

The participants were instructed to undertake all their typical journeys within a week with a fictitious carbon budget of 12 kg and to change their mobility behavior if they

were in danger of exceeding their budget limits. Specifically, the instruction was (translated from German):

> *For seven consecutive days, use the "MovingLab" research app to record all your journeys and means of transport used and organize your mobility in such a way that you do not exceed the CO2 budget. You will be allocated a CO2 budget for the study:*
>
> *Your personal CO2 budget for the next 7 days is 12 kg CO2.*
>
> *If your personal CO2 budget for mobility becomes tight, we ask you to switch to low-CO2 means of transportation. Cycling and walking are the most suitable options as they are considered CO2-neutral. Public transportation (buses and trains) are also low-emission. Alternatively, you can avoid unnecessary journeys. You will receive an overview of your used and available CO2 budget*

To calculate a plausible, i.e. ambitious but not unattainable weekly carbon budget, we relied on the actual traffic behavior of a car-using sampling person on the one hand, and on the calculations of the NGO *Atmosfair*[1] on the other. The colleague has a rather short commute to work of around eight kilometers and drives it every day in a fuel-efficient combustion engine. He did not use the car outside of his commute. In one week, his CO2 emissions amounted to approx. 9 kg. *Atmosfair* calculates, broken down for one week, 30.25 kg of CO2 emissions as the upper limit for all activities and areas of consumption (not just mobility). We have assumed the share for mobility to be one third, i.e. approx. 10 kg. We have added another 2 kg to this value in order to have a realistic limit value for longer distances.

The participants could decide when they wanted to start tracking and were reminded after a few days. The probands then tracked their journeys with the app for seven days and received daily emails with information about their budget consumption, the means of transportation used and the amount of emissions (see Figure 2). At the end of the seven days of tracking, they received a debriefing email and an invitation to an online interview.

[1] https://www.atmosfair.de/de/

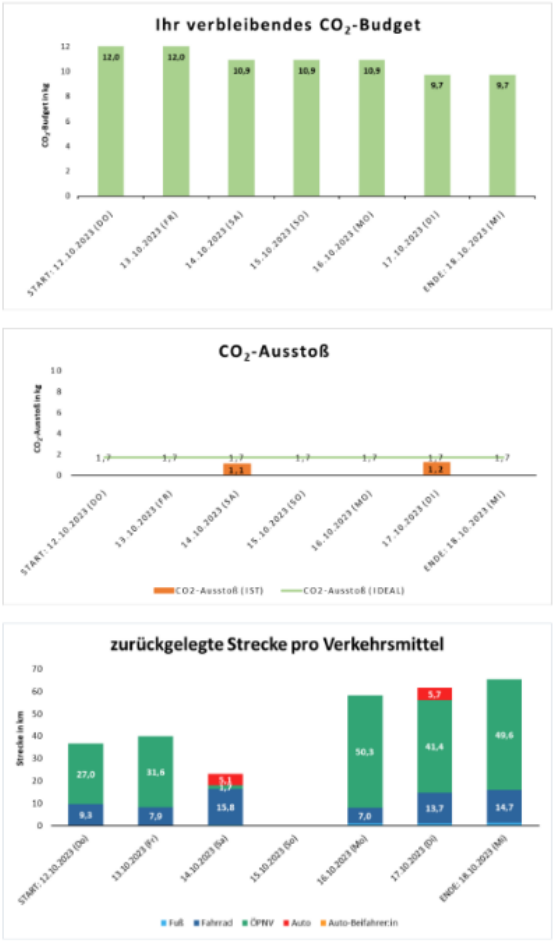

Figure 2: Example of the daily information probands received; here: after one week of tracking

The interviews were semi-structured and contained guiding questions about the probands' experiences with the experiment, their assessment of the carbon budget as a climate policy instrument and their perception of the fairness of three possible designs of the instrument (more on this in the results). The interviews are the core of the study. We opted for this method rather than a group discussion or a standardized survey because we were able to give the subjects the space to describe their perceptions and assessments in their own words on this rather complicated and unfamiliar topic, as well as to give us the opportunity to ask questions.

The interviews were conducted and recorded via video call, then fully transcribed and analyzed. The interviews were analyzed according to the principles of content analysis (Kuckartz und Rädiker 2022). A comprehensive code system was created, which was developed intersubjectively by two researchers (the authors) both deductively and inductively. The deductive part consisted of the categories (or codes) specified by the interview guide.

4. RESULTS

The results section consists of two parts. First, we present the results of the analysis of the perceived acceptability and fairness of the carbon budget, taking into account different instrument designs with regard to the distribution of the carbon budget in the population. We distinguish three options. Second, we present possible features of the personal carbon budget that could support the acceptance of this policy instrument.

4.1. Fair design of the personal carbon budget

In the interviews, we asked the participants the following question about the design of the carbon budget for mobility (translated from German):

> *Various options are being discussed as to how such a mobility CO2 budget could be designed:*
>
> - *Option 1 would be for everyone to receive the same budget, regardless of their personal circumstances.*
> - *Option 2 would be that those who have a higher mobility requirement due to personal characteristics, e.g. because they have children, are dependent on a car due to physical limitations or live in the countryside, would receive more. In other words, a social differentiation.*
> - *Option 3 is that everyone receives the same, but the budget can also be traded, similar to emissions trading between companies. This means that those who don't need all of their budget can sell parts of it to households that need more.*
>
> *What do you think about the different options? Which would you find fairer?*

The probands did not need to comment on each option, but rather select their favorite, some of them shared their opinion on each option.

In the following, we present the categorized responses to the options one after the other.

Option 1: Equal distribution

The option in which everyone is allocated the same budget was judged ambivalently, as it neither favors nor disadvantages anyone, but there is no compensation for disadvantages either. In other words, no special requirements could be claimed and no special needs considered. It was argued that people have unequal preconditions and opportunities to adapt their mobility behavior, e.g. to change their place of residence or buy an electric car, and therefore need more carbon credits. The following quote illustrates this aspect including the ambivalence:

> *"Fair in the sense that everyone somehow has the same. But you can also be unfair in principle, because some people and some people in rural areas simply need more. (...) Yes, difficult, difficult to say, I don't know exactly." (Interview 4)*

In general, option 1 was considered acceptable rather than fair, depending on the conditions such as the amount of carbon budget. To illustrate this aspect here one quote:

"With option 1, I would say it really depends on what the exact conditions are. So if everything is well and realistically calculated, then I would say you could also do option 1." (Interview 9)

Similar to option 3, it was also recognized that an equal carbon budget would hit high earners harder, as they tend to lead a more lavish lifestyle with more vacations and long-distance trips. The following quote illustrates this aspect:

"If all-year mobility were considered, not just everyday travel, then an equally distributed budget would be a completely different discussion, because of course people who earn better tend to take longer vacations or whatever, which would then of course be very strongly reflected in such a budget, especially when it comes to air travel." (Interview 1)

Option 2: Social differentiation

The clear favorite among the probands was a carbon budget calculated on the basis of social criteria. It is assumed that different living conditions and capabilities lead to different needs in terms of transportation and mobility and that social hardship or injustice can only be prevented if people who are more vulnerable in this sense receive more emissions credits:

„I would definitely prefer the second option because […] there are simply people who have a greater need for mobility." (Interview 3)

It was reflected that people who live in the countryside and do not have sufficient public transport could be dependent on their (fossil) car, or that it is often socially or financially less well-off groups of people who have a low coping capacity - for example in that they have less money for low-emission cars or do not have the option of working from home. These people could then either be forced to buy additional budget for their commute or give up their job. Such effects could be avoided through socially differentiated distribution. Against this background, option 2 is considered fair, as it does not result in further discrimination against those who are already socio-economically disadvantaged.

However, a major challenge is seen in the fact that it will be difficult to determine exactly which social criteria should lead to a higher carbon budget and to what extent. In addition to socio-economic criteria such as income, household size or the ability to work remotely, spatial criteria were also suggested in a sense that people who live in the countryside need more budget.

Option 3: Equal distribution with trading option

The trading option was rated the least fair. Above all, the probands were concerned that the wealthy could buy their way out of emission savings and would have no incentive to change their carbon-intensive mobility behavior. This could also lead to social tensions and envy. To illustrate this aspect:

> *"Yes, well, with the third option, people who have a lot of money could theoretically drive as many cars as they want. That would probably be a bit less fair in that sense. […] If anything, it would cause even more social unrest if someone who can already afford the big SUV has a lot of money and can then somehow buy their CO2 in order to be able to drive the car." (Interview 4)*

In addition, probands mentioned that option 3 could encourage criminal behavior, be abused and create a black market. In this context, one proband alluded to the Covid-19 pandemic and the abuse of the trust of state authorities by numerous fraudulent operators of Covid test stations. Other voices referred to the impossibility of effectively checking that personal carbon trading is carried out properly. This expresses a mistrust of society and the state's ability to control when people are granted too many economically exploitable degrees of freedom.

And even without criminal intentions, the possibility of earning money with emissions trading was viewed critically by some, as this would set the wrong incentives. This was also linked to the concern that such a system, in which it would be relatively easy to acquire additional budget, would not be accompanied by a sufficient change in behavior among those who had enough money and therefore the climate targets could not be achieved.

We, the interviewers, did not go into more detail about the background and possible mechanisms of a cap-and-trade system in order to obtain an immediate reaction from the perception of fairness. Yet, it can be assumed that a more detailed explanation of how it works and how it is connected would have led to a more positive attitude. The reaction of one interviewee suggests this. He said:

> *„Option 3 is so new to me now that I would probably exclude it, because I just don't have an opinion on it off the top of my head, I'll have to think about it for a long time. But it's definitely exciting. Because I think you can take a more holistic approach. So you can simply set a mobility budget for the whole country and then divide it by the 82 million. And let people do as they please". (Interview 3)*

However, there was also the opinion that the trading mechanism could be fair if it considered that statistically people with lower incomes have less carbon-intensive consumer behavior anyway, especially in the area of mobility, and would therefore have unused CO2 entitlements to be sold to others – their CO2-saving behavior would then have a profitable effect. The extent to which the additional income generated in this way would then be reinvested in CO2-emitting behavior elsewhere would be another question.

4.2. Recommendations for the design of the personal carbon budget

In the interviews, we also asked the probands for an assessment of the effectiveness of the policy measure and for recommendations to policy makers, in case the personal carbon budget would be introduced as a measure (translated from German):

> *Imagine that in future every person is given a carbon budget for their own mobility, within the framework of which they have to organize their everyday life so that Germany reduces its carbon emissions.*
>
> *How effective and useful would you find such a measure?*

> *Suppose such a carbon budget for mobility were to be introduced. If you were to advise the federal government, what suggestions would you have for the design, what should definitely be taken into account?*

Overall, the effectiveness of the measure was rather doubtful. The main potential was seen in the fact that the instrument could be used as an orientation measure for individual citizens, to make it comprehensible and measurable what their personal carbon footprint actually is. On this basis, changes in behavior could then also take place if it is recognized where the greatest levers for CO2 savings lie. In short, the potential was seen in raising awareness of the need for CO2 savings and in a transparent database for individual behavioral adjustments.

In contrast, more challenges and counter-arguments were stated. It was doubted that bans or personal restrictions are effective, that mobility needs are too individual for a standardized budget broken down to the individual or that motorized private transport is not an important lever for reducing CO2 emissions. Very practical questions were also seen as a major problem: How should budget consumption be reliably tracked and monitored? How would misconduct be sanctioned?

Based on the answers to both questions, we have derived a number of factors that should be taken into account when designing the carbon budget for mobility as a policy instrument in order to improve its acceptance:

- To secure social balance, mobility should continue to be possible regardless of income. The wealthy should not be able to buy their way out of the restrictions, while people who do not have extra funds for additional budgets are denied mobility.
- The carbon budget amount needs to be adapted to the realities of life situations so that adherence to budget limits is feasible.
- Instead of enforcement the measure should work with voluntary participation and incentives. In this context, the measure could be presented as a voluntary guideline rather than a restrictive measure.
- In order to increase acceptance, the provision of clearly understandable information about the effects of the measure is recommended. At the same time, individual responsibility should not be overemphasized, but it should be made clear that the individual contribution is not irrelevant.

5. DISCUSSION AND CONCLUSION

For the study, we examined different designs of the personal carbon budget for mobility. The carbon budget can be used as an example for political instruments in the field of climate protection that address behavior change, so that the results are transferable to a certain extent. In particular, this is true with regard to the question of social differentiation versus equal distribution or the question of whether individuals accept personal restrictions that affect their usual consumer behavior.

According to our findings, there is a clear preference for option 2, the socially differentiated design, and more of a rejection of trading option 3, particularly as this would lead to more social imbalance and potential abuse.

There was also an ambivalence towards option 1, the equal distribution of carbon credits. As the literature supports, fairness of policies does not seem to be perceived in terms of everyone getting the same, but in terms of the distribution of burdens and benefits. Following this, it is perceived as fair if vulnerable groups are not burdened to a greater extent than others, even if this means that those groups receive more credits in order to cushion the negative effects of mobility restrictions or higher mobility costs. With respect to the trade option, given the findings from the literature on social envy as an obstacle to acceptance, the negative reaction to the trade option can be plausibilized in such a way that a certain idea of how the distribution of public goods should work dominates. According to this, people in need should receive the necessary support to ensure their mobility needs, so that inequalities are evened out, but the distribution system should not give anyone, including the vulnerable, the opportunity to profit from it.

In addition to the three options investigated, further options and combinations of options are worthy of investigation in future research. One such combination is the integration of social differentiation with the trading option. This approach would entail providing individuals who are particularly vulnerable to carbon cuts with a larger carbon budget, while also allowing them to engage in carbon trading. This proposal was put forth by one of our probands. It seems reasonable to posit that this could potentially give rise to even greater levels of opposition, driven by social envy and concerns about the potential for abuse of the principle of solidarity, should those perceived to be disadvantaged be able to benefit financially from receiving more emission rights than they require.

Considering the rejection of the trading option, in our study we wanted an immediate assessment by the probands, so we refrained from further explanations. However, in most approaches of a personal carbon budget that have been discussed so far, trading is a key element. And there is evidence that personal carbon trading would help economical vulnerable people given the positive correlation between income and personal emissions (Pitkänen et al. 2022). This was reflected only by some of the probands. It needs to be further investigated what shapes the preferences for social differentiation in policies, and whether the rejection of trading is a matter of communication in the sense that the potential benefits for vulnerable groups simply need to be emphasized and explained more in detail.

While we found fairness perceptions to be important for acceptance, the actual effects of a policy as well as its practical requirements and costs for the general public must not be forgotten. While option 1 (equal distribution) would be the easiest way to implement a policy instrument such as the carbon budget, a socially differentiated design (option 2) is more challenging in terms of practical issues. The advantages of social differentiation must be weighed against the practical disadvantages such as more bureaucracy, data protection restrictions or complicated verification and application procedures, which can drive up costs and even reduce the benefits for vulnerable groups. In terms of impact and costs, option 3 (equal distribution with trading options) could be a promising approach that combines both sensitivity to social differences and efficiency. However, a transparent system and fair regulations for trading need to be developed and monitored.

In order to be perceived as fair, political measures such as the personal carbon budget for mobility should therefore be designed in such a way that they take into account the different realities and preconditions of vulnerable people. Measures should not be overburdening and it should be realistically feasible to comply with the regulations. It should be noted that, according to our findings, vulnerable groups in this respect include not only people at risk of poverty, but also people with special needs in general, e.g. because they live in rural or suburban areas and/or have

certain care or employment responsibilities and cannot completely change their lives and mobility behavior from one day to the next.

With regard to the perceived usefulness of the personal carbon budget, it can be concluded that the carbon budget can serve as one element in the toolbox of climate protection, but if it were to be introduced and made mandatory at a national level, a great many practical issues would still need to be clarified. Some reflections on the practical issues and how to solve them are shown by Fuso Nerini et al. (2021). Even in our intervention study with a limited number of probands, it was not possible to track all trips and their carbon budget consumption with absolute reliability due to technical reasons and data protection rules. A more feasible way would be voluntary participation instead of a mandatory system, where the personal carbon budget serves as a guide for climate-friendly behavior. Alternatively, communities or workplaces could allocate a carbon budget based on the number of inhabitants or employees. These could then introduce appropriate measures and monitoring on a much smaller scale and reduce the complexity of implementation.

Our results underline that perceptions of fairness play a role in the acceptance of policies and that people's preference for social balance should be kept in mind when designing policies. Equally important is that policies must be effective in terms of carbon reduction as well as affordable for the national budget.

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