The German Longitudinal Environmental Study (GLEN)

Proposal as a DFG longterm project

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Project Description – Project Proposal

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Abstract
Climate change and the depletion of the Earth's natural resources are among the largest challenges humanity currently faces. In light of this, the planned German Longitudinal Environmental Study (GLEN) aims at investigating the incentives, restrictions, attitudes, and beliefs that underlie human-environment interactions. In doing so, the GLEN project aims to provide a foundation for evidence-based environmental policy assessments and guidance. The project will build up a large-scale panel study of the adult population in Germany in which the same individuals will be repeatedly observed over time using a standardized and stable online survey instrument. Due to its longitudinal design and the linkage of the collected survey data to geospatial information on respondents' social and ecological environments, the panel will be well suited to analyzing natural experiments such as regional policy measures (e.g., price changes, information campaigns) and exposure to local environmental conditions (e.g., extreme weather events). In addition, the panel will be used as a platform for survey experiments to investigate trade-offs in environmental preferences, consumption decisions, and the acceptance of environmental technologies and policies. With this design, GLEN will meet the urgent need for data suitable for causal research and simulations in the environmental social sciences. With occasionally refreshed samples, it will also allow for the monitoring of trends in environmental concern and behavior, focusing on diverse social, political, economic, and psychological aspects. Accordingly, GLEN is primarily understood as a data infrastructure for environmental research across all social science disciplines. Key questions that can be addressed with the data include: What influences environmental concern, behavior, and the acceptance of technologies and policies to protect the environment? What consequences do environmental policies and changing environments have for social inequalities, and how does that affect (perceived) environmental justice? As a long-term project, GLEN will cover the period between 2024 and 2035, and thus the period in which decisive policy measures to replace fossil fuels are set to be implemented in accordance with international agreements.
In sum, the project includes three work streams to pursue three closely related goals: (I) First and foremost, the project will generate a data infrastructure for the environmental social sciences, to be used not only in Germany, but also internationally. (II) The project team will utilize the data for substantive environmental social science research. (III) The project will provide evidence-based policy evaluations and guidance with regular policy reports and embedded experiments. The project team requests funding for the first 3-year period of the planned long-term project.

Project description

1 Starting point

Climate change and the overexploitation of the Earth's natural resources are among the largest challenges humanity currently faces. Environmental research indicates transgressions of planetary boundaries in several domains, including biodiversity, pollution, and climate (e.g., Persson et al., 2022; Rockström et al., 2009). Ambitious policies that affect technological innovation, human behavior, and their interplay with socio-economic conditions are needed to counteract the current trends. Energy transition and the decarbonization of society are a top priority of policy.

The social sciences are key to understanding how environmental behavior relates to structural parameters as well as individual knowledge and environmental concern, social norms, lifestyles, and quality of life. To empirically analyze these complex relationships, data from large, nationwide randomly drawn samples following the same individuals over time are needed. Only these allow for the investigation of causal relationships and changes that can be generalized to the larger population while detecting subgroup differences. Attempting to close this data gap by including small "eco-modules" to current panel surveys is not sufficient – only a stand-alone panel will enable collecting data on multiple facets of environmental concern and behavior needed for causal research and policy evaluations within one (sampling) framework. Currently, such data is lacking on an international scale (Prakash and Bernauer, 2020). This data gap may be the reason that the perspective of social sciences is absent in most interdisciplinary research initiatives (Victor, 2015) and underrepresented in the Intergovernmental Panel on Climate Change (IPCC).

The proposed project aims to fill this data gap with a large-scale, Germany-wide panel study to address key data needs covering a broad range of sociological, political, economic, and psychological facets of environmental behaviors and attitudes. The data will also cover core data requirements in additional social science disciplines, including communication sciences, public health, and social geography. The proposed data infrastructure will drive research among external data users and the project team and advance policy monitoring to promote more sustainable behavior.

1.1 State of the art and preliminary work

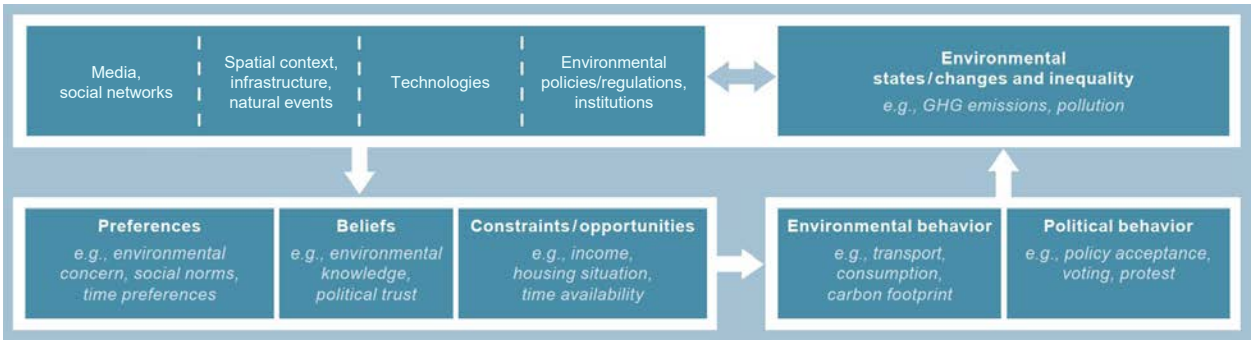
1.1.1 Theoretical framework

The project connects theoretical assumptions and empirical findings from a wide range of environmental social sciences, while remaining consistent to natural and geoscientific variables such as CO_2 emissions and characteristics of geospatial environments. It builds on the well-known macro-micro-macro framework (Coleman, 1990) and the assumption of micro level theories (e.g., Gintis, 2007; Hedström, 2005) that social actions depend on individual goals (preferences), subjective ideas about consequences (beliefs), and constraints and opportunities (resources).

This framework is compatible with a wide spectrum of action theories such as rational choice and framing theories (Coleman, 1990; Gintis, 2007; Tversky and Kahneman, 1981), theories on bounded rationality (Gigerenzer and Selten, 2001), the theory of planned behavior (Ajzen, 1991), and psychological theories on the activation of and compliance with social norms (Bicchieri, 2016; Cialdini et al., 1990). It allows for the integration of action patterns that are not yet well established in action theories, such as individual responses to "nudges" (Thaler and Sunstein, 2008). As the literature in all social science disciplines typically draws on at least one variant of an action theory, this framework allows to integrate a large body of research.

Figure 1 outlines the framework in an intentionally simplified illustration. The final explanandum of environmental social sciences is shown at the top right: Socially produced ecological problems, such as CO_2 emissions and climate change, and their distribution across different social groups. To achieve environmental policy targets, it is important to understand how macro variables such as policies and technologies (top left) influence individual preferences and desires, beliefs, constraints (bottom left), and resulting behaviors (bottom right) at the micro level. When aggregated at the macro level, these variables yield the outcomes targeted by policies.

Figure 1: Interrelationship between macro and micro variables and key focus areas of the planned project



Source: Own elaboration.

The following includes a review of the state of research in the four key focus areas of the planned panel study and research. First, individual actions are embedded in a socio-economic, environmental, spatial, and temporal context that affects their preferences, beliefs, and constraints. Factors on the macro level include social media, infrastructure, markets and available technologies, as well as environmental policies, regulations, and institutions that structure these contexts. Core variables on the micro level will include individual preferences (e.g., environmental concern, internalized social norms), beliefs (e.g., environmental knowledge, trust), and constraints and opportunities (e.g., income, time restrictions). Second, these variables are thought to be key predictors of individual environmental behaviors (e.g., transport, consumption) and the resulting carbon footprint. Third, individual preferences, beliefs, and constraints are also thought to structure individual acceptance of policies and political behavior such as voting and protests. Finally, these individual actions lead to ecological and social outcomes on the macro level that affect the need for policy action and technological developments and cause feedback loops to individual beliefs and preferences. We acknowledge the argument (e.g., Folke et al., 2019) that a handful of multinational corporations are ultimately responsible for the fate of the biosphere (e.g., 84% of all pesticides are produced by 4 corporations and 70% of greenhouse gas (GHG) emissions are attributable to 100 companies; Folke et al., 2019). However, the actions of these corporations are linked to the focal points of this project by changes in demand (Claydon, 2011), legitimacy (Börzel and Risse, 2010), and governance (Sullivan and Gouldson, 2020), all of which are – at least partly – driven by individual actions, political protest, and the public opinion.

As the associations discussed above include processes that develop over time, with actors anticipating but not totally foreseeing the consequences of their actions, complex dynamics arise that include path dependencies, unintended consequences, and rebound effects (Azevedo, 2014). Social science research is crucial to quantifying such unintended side effects and acknowledging them in the planning of policy measures.

One task of the proposed project will be to formulate more detailed hypotheses for all the outlined relationships: effects of macro on micro level variables, explanations of consumption, policy acceptance, and protest behavior (micro propositions), and the impact of micro on macro level changes. Exploring these questions in a longitudinal study is a particular desideratum. The review in the next section indicates which questions require particular attention.

1.1.2 Research review and planned contributions of the proposed panel study

Environmental concern and beliefs

Understanding which factors affect environmental concern and beliefs is vital, as both are seen as predictors of environmental and, especially, political behavior. Environmental concern (for a review: Gifford and Nilsson, 2014) was found to be associated with sociodemographic characteristics (Sargisson et al., 2020), personality traits (Hopwood et al., 2022), general social values (Hirsh, 2010), environmental knowledge, and childhood experiences (e.g., Asah et al., 2018). Social context affects concern and beliefs through norms, social identity, and embeddedness in social networks (Fritsche et al., 2018). Moreover, environmental concern is influenced by environmental, political, and economic factors (Hartmann and Preisendörfer, 2021). For instance, economic crises trump environmental issues (Kenny, 2020), while disasters such as hazardous accidents bring environmental concern to the forefront (e.g., Böhmelt, 2020). In line with Downs' (1972) issue-attention cycle, topics may receive heightened public attention for a limited time,

with attention waning once policymakers have addressed the issues. Researching such developments requires observations before and after exposure to natural or social events (e.g., extreme weather events). Although some studies rely on longitudinal techniques, further research investigating the temporal and spatial reach of events and the role of the media will be valuable. Factors related to the life course and lifestyles, such as parenthood (Thomas et al., 2018) and intergenerational learning (Lawson et al., 2018), have also been examined rarely so far.

In addition, a better understanding of individual beliefs is imperative. For instance, despite the scientific consensus on human-caused climate change, in all countries a portion of the population denies climate change (Fischer and Van den Broek, 2021). Similarly, judgmental biases, such as misperceptions of costs and feasibility of behaviors, may impede individual choices of efficient, sustainable behaviors. Research on factors that influence individual "energy literacy" and the acceptability of technologies and other innovations is needed (Bleicher and Gross, 2016; Steg et al., 2021).

There are several main desiderata for longitudinal data in this focus area: The planned panel will include comprehensive measures of environmental concern and beliefs and their determinants. The longitudinal data will allow analyses accounting for time-constant unobserved confounders and allow testing whether assumed causes precede changes in environmental concern. For example, panel data will provide insights as to whether enhanced pro-environmental attitudes are a consequence of living near green spaces, or whether pro-environmental individuals move near green spaces. The panel data will also allow for the separation of effects caused by changes in spatial and social contexts from general time trends. Furthermore, it will help to disentangle age and cohort effects as well as research life-course effects on concern and beliefs (e.g., at the transition to parenthood or labor force entry).

Environmental behavior

Numerous studies have investigated individual environmental behavior and its determinants. One important conclusion is that environmental concern and behaviors are only moderately correlated, depending on the behavior in focus (e.g., Bamberg and Möser, 2007; Steg et al., 2021). Multiple explanations have been offered: First, empirical results indicate that the effect of environmental concern recedes in "high-cost" situations (Diekmann and Preisendörfer, 1998; 2003), although there is also contradictory evidence (Best, 2009). Second, alternative "soft" predictors of environmental behavior such as risk and time preferences, lifestyles, and internalized social norms may also play a role (e.g., Horne and Kennedy, 2017; Liebe et al., 2018). Third, as many studies focus on self-reported symbolic or "intent-oriented" behaviors (Stern, 2000) such as paper recycling or buying organic products, respondents likely overestimate their pro-environmental behavior due to a "better than average bias" (Leviston and Uren, 2020). Furthermore, explanations must bear in mind that protecting the global commons poses a social dilemma that motivates free-riding behaviors (e.g., Ostrom, 1990). In such situations, individuals assume that (most) others do not act pro-environmentally, rendering their own contribution ineffective, or that others should bear the costs of taking environmentally friendly actions (e.g., Fehr-Duda and Fehr, 2016). A better understanding of how free-riding can be limited by inducing other-regarding preferences, economic incentives, and institutional arrangements is therefore imperative.

Important predictors of environmental behavior are infrastructure, pricing, and taxation (e.g., Best and Kneip, 2019; Fullerton and Kinnaman, 1996), which can be addressed with environmental policies (see Appendix 3 for types of policies). One possible intervention for climate change mitigation is (emission) taxes combined with redistributive measures to reduce the social burden on households (e.g., de Graaf and Wiertz, 2019). To evaluate effectiveness, it is important to monitor how consumption and investment behavior respond to price changes, including possible side-effects and trade-offs (for the estimation of elasticities: Liddle and Huntington, 2021). Furthermore, emissions increase with disposable income (Nielsen et al., 2021; Oswald et al., 2020). Carbon footprint calculators have been used to approximate individual CO_2 or GHG emissions overall and in different life domains such as transport, housing, food, clothing, and other areas of consumption (Bruderer Enzler and Diekmann, 2019; Dietz et al., 2009). By focusing on core indicators, surveys can approximate the carbon footprint reasonably well (Belz et al., 2021; Bruderer Enzler and Diekmann, 2019).

Moreover, comprehensive research must consider negative spillovers. For instance, engagements in some pro-environmental actions provide a license for other less sustainable behaviors ("moral licensing"), or external incentives may "crowd out" intrinsically motivated behaviors. Under which conditions this is most likely to happen is not yet well understood (Steg et al., 2021). A relatively new strand of research focuses on lifestyles and consumption patterns (Gilg et al., 2005), peer effects (Graziano and Gillingham, 2015), and the preference for social status: "Status striving" may motivate individuals to consume carbon-intensive commodities such as large homes and vehicles, but also foster sustainable consumption if environmentally friendly lifestyles become status indicators (e.g., rooftop solar panels, vegan food). To date, the evidence for these effects is inconclusive (Berger, 2017; Griskevicius et al., 2010).

In addition, data are needed that allow age and cohort effects to be disentangled under certain assumptions. This will enable more reliable simulations of how GHG emissions will change as the population ages (Ottelin, 2022).

The planned panel will address these research gaps by capturing both symbolic environmental behaviors and CO_2 emissions. By enabling longitudinal analyses, the panel will improve the monitoring and understanding of how changes in individual environmental concern, social incentives, prices (including taxation and subsidies), infrastructure, and environmental policies affect individuals' sustainable behavior. The data will also allow to investigate the direct net effects of local infrastructure on behavior (beyond selection effects) and examine how lifestyles and life course transitions affect behavior and the gap between concern and behavior. By monitoring multiple dimensions of behavior, potential trade-offs and side-effects (as conjectured in the literature on moral licensing and rebound effects) can also be detected.

Acceptance of environmental policies, political action, and protest behavior

Public acceptance of environmental policies, voting, and protest behavior are important topics as they affect the feasibility of environmental reform (Schaffer et al., 2021). Determinants include environmental concern and trust in the government (e.g., Fairbrother et al., 2019), but also descriptive norms: Acceptance of policies is lower if public support is perceived as low (Ding et al., 2011; Falk et al., 2021). Another factor is knowledge and understanding, in particular in the case of complex measures such as tax regulations (Maestre-Andrés et al., 2019) or international climate policies (e.g., emissions trading). Some cross-sectional studies have attempted to explore individual knowledge by randomly treating respondents with different information (Carattini et al., 2018), but it remains unclear to what extent such information treatments might permanently change individual attitudes, including those with strong prior political preferences (Bernauer and McGrath, 2016). It has also been argued that (experience with) participatory decision-making processes (such as citizen initiatives or local plannings) may increase acceptance of environmental policies and foster their successful implementation (e.g., Bulkeley and Mol, 2003; Newig et al., 2018). Only panel data allow disentangling causal and selection effects (e.g., become citizens more concerned as a result of participation, or do only the more concerned citizens participate?). Other important aspects of the participatory process include power delegation and communication (Jager et al., 2019). Moreover, as longitudinal studies on individual preferences are scarce, there is little knowledge on habituation effects. Support also varies with the design of measures (Maestre-Andrés et al., 2019; Stadelmann-Steffen and Dermont, 2018). Research has consistently found that public support is reduced by perceived burdens, be it in form of lower purchasing power, higher risk of job loss, lower comfort levels, or tax loads (Carattini et al., 2018). In contrast, support increases with the perceived effectiveness and fairness of the distribution of burdens, although there is some dissent as to which fairness principles are preferred (Preisendörfer, 2014).

The specific policy measures discussed evolve over time, but some general dimensions can be distinguished (see Appendix 3 for details). First, market-based (e.g., CO_2 price) vs. regulatory measures (e.g., mandated energy efficiency standards) differ in terms of acceptance and perceived effectiveness (Edenhofer and Schmidt, 2018; Patt and Lilliestam, 2018). Second, "pull" measures such as purchase premiums for electric cars usually find more support than "push" measures such as higher fuel prices, although experts regard the latter as more cost efficient (Levi et al., 2021). Third, research is inconclusive with regard to framing effects: While some studies have suggested that re-framing policies from reducing climate change risks to achieving technological innovation, green jobs, and health benefits could enhance public support, others

did not find such results (Bernauer and McGrath, 2016). Fourth, the degree of innovation is deemed important: Individuals may be differently hopeful or skeptical about technological advances. Fifth, acceptance likely depends on whether measures are planned on the local, national, European, and/or global level (with the latter including the consideration of environmental policy in development policy). This is suggested by literature on dilemma situations and the “not in my backyard” syndrome, as well as studies on the relevance of trust in political institutions (Ostrom, 2010; Van Lange et al., 2013).

If environmental problems worsen or the cost of energy or consumption rises, we can expect an ideological divide that could endanger social cohesion. Protests such as the “yellow vest movement” in France have led to carbon taxes being suspended, while at the same time pro-environmental movements such as "Fridays for Future" (FFF) are calling for more climate action. The fragmented state of research thus far limits our understanding of reasons and processes leading to protest movements (Opp, 2022). Although deprivation is one process of note, it does not suffice to explain protest behavior (e.g., for the "yellow vest protests" in France: Lüders et al., 2021). Also explanations based on a "new generation movement", as often cited for FFF, are too simple (Koos and Lauth, 2020; Rucht, 2019). As yet, research relies on macro data, selective samples of protesting individuals, and/or cross-sectional data (Koos and Lauth, 2020; for exceptions: Opp and Kittel, 2010; Rucht, 2016), which also limits our understanding how political and protest behavior reacts to period effects vs. changes over the life course.

Key desiderata addressed by the planned panel include monitoring the (dis)approval of implemented and planned policy measures at regular intervals and understanding which factors affect individual support for policies, including different methods of framing information and citizen involvement through participatory politics. The longitudinal data will enable the study of habituation effects as well as responsiveness to changes in individual or contextual factors. As a large-scale population survey, the panel will also allow to assess differences in policy acceptance across groups, which are important for identifying measures that a majority of actors with different interests, experiences, and knowledge might agree to. Finally, the panel will fill gaps in population-based micro data on different forms of participation in decision-making, environmental movements, and protests.

Environmental inequality and justice

Environmental inequality describes the unequal distribution of environmental goods and bads across different social groups. As part of the broader environmental justice debate (Bullard, 2018; Mohai et al., 2009), it is hypothesized that minorities or socio-economically disadvantaged individuals bear disproportionately high environmental burdens. Accordingly, previous studies have documented the unequal distribution of environmental hazards such as noise, air, water, and soil pollution across different social groups (e.g., categorized by income, social class, minority status: Banzhaf et al., 2019; Crowder and Downey, 2010; Diekmann and Meyer, 2010; Mohai and Saha, 2015; Rüttenauer and Best, 2021). More recently also access to environmental goods, e.g. green spaces, has gained attention (e.g., Jünger, 2022). Beyond obvious health effects (Currie et al., 2015), environmental pollution also affects other life domains; for example, effects of early exposure to air pollution on educational attainment and later income were found (Colmer and Voorheis, 2020; Manduca and Sampson, 2021).

However, results depend on the regional level of aggregation as well as the investigated goods and bads and their empirical measurement. There is a need for thorough, fine-grained methods to avoid misleading conclusions. To deflect ecological fallacies, individual-level survey data linked to environmental context data are needed (Meyer and Bruderer Enzler, 2013). To date, however, many studies have relied on aggregate data (Rüttenauer, 2019) or were restricted to a few exemplary cities (e.g., Diekmann et al., 2023; Padilla et al., 2014). Moreover, even if exposure to environmental bads for high-income groups is high, these groups are more able to invest in protection against such burdens. This "environmental shielding hypothesis" has rarely been studied to date (Diekmann et al., 2023). Large-scale, geocoded, individual-level panel data is required to disentangle the two proposed main explanations for environmental inequalities: selective siting vs. selective migration. Studies using spatially aggregated longitudinal data to analyze selective migration processes report mixed results (e.g., Banzhaf et al., 2019; Mohai and Saha, 2015). Household level studies tend to confirm the idea of selective migration based on income

and minority status, but the income effects are much smaller than the disadvantages of minorities (Best and Rüttenauer, 2018; Crowder and Downey, 2010). Explanations for this minority effect that go beyond lower socio-economic resources (Depro et al., 2015) include disadvantages in the housing market (e.g., Auspurg et al., 2019b; Ewens et al., 2014) and residential preferences in combination with trajectories in city structure (Rüttenauer, 2019).

Another aspect of environmental inequality is burdens resulting from environmental policies, such as rising costs of living. While high income groups cause particularly high shares of CO_2 emissions (Oswald et al., 2020), measures such as CO_2 prices and taxation place a heavier burden on low income groups unless redistributive measures are taken (Diekmann and Bruderer Enzler, 2019; Edenhofer and Schmidt, 2018). There are other, arguably more important determinants of inequality in income and wealth. However, it is an empirical question of how large the effect of energy transition policies on inequality is. Moreover, there is an intense public debate in Germany on the distributional aspects of energy transition polices that might trigger strong misperceptions. Therefore, it is important to compare the objective effects with public perceptions, not least because the acceptance of interventions depends on perceived fairness. However, there is a lack of empirical research in this area. With panel data, climate policy studies can analyze this aspect and thus also elucidate differences in policy support between social groups.

The planned panel will provide insights as to how environmental burdens relate to different dimensions of social stratification, and how this is moderated by definitions of regional context (e.g., by using different spatial resolutions; raster vs. administrative neighborhood definitions), type of burden, and objective measurements vs. subjective perceptions. The large-scale, spatially coded panel data will provide unique opportunities to identify causal mechanisms. The data will also cover consequences of environmental burdens on inequalities, such as effects on well-being, and perceived justice of pollution and the cost of CO_2 reduction. As data on emissions will be collected regularly, the panel data can also be used to measure the regional and social distribution of CO_2 emissions. These results can then be used, for example, in simulation models to provide information on the distributional effects of climate policies.

1.1.3 Data requirements and existing data sources

In recent years, the social sciences have benefited from the rise of *panel data* and the toolkit of econometric methods for causal analysis to account for unobserved heterogeneity that might otherwise bias estimates. A further boost in insights has been provided by *survey experiments* (e.g., information, choice, and factorial survey experiments), that are able to advance the understanding of justice principles, acceptance of measures, and judgmental biases. Finally, the increased possibility to link *geocoded regional data* provides researchers with better opportunities to measure the local environment and study spatially limited events or measures, including the possibility to use them as natural experiments. To leverage these advances in environmental social sciences, a better data infrastructure is needed:

- A *single-purpose survey* that provides space for comprehensive measurements of a broad range of concerns, beliefs, constraints, and political and environmental behaviors is needed to monitor and understand public support and actions central to fighting climate change and reducing individual ecological footprints, including rebound or other possible side-effects.
- A *panel study* that follows the same individuals over time is required for causal analyses based on within-variance (diff-in-diff or fixed-effects) to study effects of changes in context factors on environmental concern and behaviors, disentangle age and cohort effects, and monitor behaviors over time without bias due to shifts in sample composition or measurement instruments. Intervals between survey waves must be short to capture volatile changes and avoid recall errors.
- A *random sample* from a broad population allows for generalizations and mitigates selection bias. Sample refreshments reduce bias in later stages of the project.
- A sufficiently *large data base* is required for detecting differences across social groups (e.g., low- vs. high-income households, minorities) or regions (e.g., effects of different regional policies). Moreover, a large sample permits the observation of rare events and new phenomena, such as the social diffusion of emerging technologies.

- A data infrastructure of maximum benefit includes special features such as *experimental designs and context data*. Embedding population-based *survey experiments* (such as conjoint, choice, multifactorial survey, or information treatment experiments) or *randomized controlled trials* opens up additional possibilities to study causal mechanisms or to evaluate the acceptance of (planned) measures. *Spatial context* data (e.g., exposure to pollution, infrastructure) help to understand social influence and evaluate effects of local infrastructure.

To our knowledge, no micro data are available, neither in Germany nor internationally, that come close to meeting these criteria. In Germany, the largest database for the environmental social sciences is the Umweltbewusstseinsstudie (Belz et al., 2021), based on a large, random sample, but whose cross-sectional design precludes longitudinal analyses. The Green-SÖP (Frondel et al., 2020), with data collection from 2012-2016, has a strong focus on energy issues without data on environmental concerns, psychological factors, or protests, whereas the German Mobility Panel (Ecke et al., 2021) is limited to mobility research. The GESIS Panel (Bosnjak et al., 2017) includes a module on environmental concern and behavior; however, the number of behaviors surveyed is very limited (e.g., without a comprehensive carbon emissions module). The same is true for large-scale studies such as the ALLBUS and the SOEP that contain some items relevant to environmental research. Beyond Germany, limited data is available from multi-purpose studies such as Understanding Society, the European Social Survey, and the World Values Survey. These multi-purpose studies are necessarily limited in the number of environmental items and do not include comprehensive measures of behaviors and control variables necessary for thorough causal analyses or policy evaluations. The only existing environmental panel study of which we know is the Swiss Environmental Panel (Diekmann et al., 2018) with three waves, in which, however, only a limited number of questions is repeated across waves. As yet, the fragmented data structure consisting of many different items spread over different, often small-scale, cross-sectional studies without random samples have hampered causal analyses as well as trend reporting that focuses not only on attitudes, but also behaviors.

1.1.4 Preliminary work of the applicants

Our team combines expertise in environmental social science studies (e.g., Bruderer Enzler and Diekmann, 2019; Diekmann et al., 2023; Diekmann and Preisendörfer, 2003; Liebe et al., 2021; Mayerl and Best, 2018; Rüttenauer and Best, 2022) with rich experience in the design, implementation, and management of panel studies, including survey methods research (e.g., Bozoyan et al., 2021; Müller and Schmiedeberg, 2020; Steinkopf et al., 2010), as well as in the design and implementation of multifactorial survey experiments (e.g., Auspurg and Hinz, 2015; Auspurg and Jäckle, 2015), natural experiments (Auspurg et al., forthcoming; Best and Kneip, 2011), and the collection and analysis of spatial and geo-coded data (Rüttenauer and Best, 2021; Schmiedeberg and Schröder, 2014). All applicants have conducted research on core explananda in our schematic overview (Figure 1), such as research on (environmental) attitudes, justice perceptions, and cooperation problems in dilemma situations, and are thus familiar with the core theories discussed in the literature. Members of the team have extensive experience in the field of social inequalities (including social context and life course analysis) and panel data analyses (e.g., fixed-effects individual-slope regression analyses, growth curve analyses), which will stimulate such research in the environmental social science studies. At the same time, ample experience in analyses with both experimental and trend data (e.g., Auspurg et al., 2019a; Best and Kneip, 2019), as well as spatial data, such as models to identify spill-over effects or spatial autocorrelations (Diekmann et al., 2023; Rüttenauer and Best, 2021) is present among the team.

Two of the applicants, Claudia Schmiedeberg and Christiane Bozoyan, have been the coordinators of one of the largest panel studies in Germany (the German Family Panel pairfam), which was recently transferred into a large international study (with a push-to-web design) after 14 years of successful implementation. The coordination included responsibility for all tasks involved in successfully running a large panel study: instrument testing and questionnaire design, sampling (and refreshments), the coordination of fieldwork in cooperation with a survey institute, data preparation (including the construction of survey weights), the timely publication of Scientific Use Files (SUFs) along with extensive data documentation, and on-site data use management for external researchers through the establishment of a research data center. Moreover, they have successfully managed the transition of the face-to-face panel to the push-to-web mode. The GLEN project will benefit greatly from their extensive experience and associated networking. For example, the

team has coordinated with other panel studies from related fields (such as the German Cohesion Panel, Swiss Environmental Panel, Understanding Society) to address the desire for more coordinated panel studies that allow for better data harmonization and pooling for meta-data research (Leopoldina et al., 2015).

Moreover, we can build on preparatory work and experience regarding environmental survey instruments of Andreas Diekmann, Katrin Auspurg and Henning Best. Andreas Diekmann's team piloted survey instruments for the Schweizer Umweltpanel within a large-scale household survey focusing on GHG emissions in Switzerland. Further instrument development was achieved within the DFG- and SNF-funded project "Environmental Justice", where Andreas Diekmann was also one of the PIs. This project used spatial analyses including the geocoding of extensive contextual data (Diekmann et al., 2023; Preisendörfer et al., 2022) and developed novel measures of fairness principles. In addition, this project designed multifactorial survey experiments on individual willingness to accept various policies and developed a largely unobtrusive questionnaire to reduce the selection bias of "green" individuals. Katrin Auspurg conducted a population-based survey in Bavaria in 2018 with an experimental core module on the willingness to agree to different concepts of a city toll (Thiel, 2020). Henning Best is the co-author of the GESIS Panel core module on the environment for which he developed, translated, and tested environmental attitude scales that can serve as a starting point here. He is the PI of a current DFG-funded project on environmental inequalities in Germany and can contribute his experience with geocoding survey data and combining them with environmental information as well as in analyzing spatial data.

A large panel study requires extensive planning and pretesting before the main survey can be fielded. To achieve the main objective of creating an infrastructure that addresses the key data requirements of a broad spectrum of social science disciplines, we have conducted several preparatory workshops with potential data users on the planned panel design and survey modules. Internationally renowned experts in diverse (disciplinary) areas of environmental social science and survey methodology research, including online panel research, have been invited to share their expertise (see Appendix 4 for the list of experts involved). They have given important indications of research desiderata in their disciplines that require individual panel data and important measurement scales developed in, for example, psychology, political and communication science, economics, and lifestyle research that could be of optimal benefit for trans-disciplinary social science research. The meetings have also helped identify researchers' needs and existing sources of (geographic) context data that could enrich the panel data and solicit advice on recent methodological developments in online panel studies.[1]

Specific preparatory tasks concerning survey design and instruments are ongoing. Currently, we are analyzing an experiment implemented on different strategies of contacting respondents for a self-administered survey implemented in wave 14 of the German Family Panel pairfam, as well as various smaller pilot studies that we conducted in 2022 to test outstanding questions regarding, for example, the reliability of different subscales for measuring environmental concern. A LMUExcellent grant we successfully secured (~ €50,000) allowed us to implement a large pretest with a register-based population sample (net *N = 763*). We can use these data to develop questionnaire modules on, e.g., individual CO_2 emissions (see Appendix 5.1).

1.2 Project-related publications

1.2.1 Articles published by outlets with scientific quality assurance

1) **Auspurg, Katrin** & Jäckle, Annette (2015). First equals most important? Order effects in vignette-based measurement. Sociological Methods & Research, 46(3), 490-539.

2) **Auspurg, Katrin**, Brüderl, Josef & Wöhler, Thomas (2019). Does immigration reduce the support for welfare spending? A cautionary tale on spatial panel data analysis. American Sociological Review 84(4), 754-763.

3) **Bozoyan, Christiane**, & Vogt, Sonja (2016). The impact of third-party information on trust: Valence, source, and reliability. PLoS ONE, 11(2): e0149542.

4) Bruderer Enzler, Heidi & **Diekmann**, **Andreas** (2019). All talk and no action? Environmental impact and pro-environmental behavior: Correlations to income and environmental concern. Energy Research and Social Science 51, 12-19.

[1] Participants in these preparatory workshops and meetings also indicated their willingness to serve on the planned advisory board, which will be established after the funding decision.

5) Liebe, Ulf, Gewinner, Jennifer & **Diekmann, Andreas**. (2021). Green energy defaults have massive and persistent effects in the household and business sector. Nature Human Behaviour 5(5), 576-585.

6) **Diekmann, Andreas** & Przepiorka, Wojtek (2015). Punitive preferences, monetary incentives and tacit coordination in the punishment of defectors promote cooperation in humans. Scientific Reports (Nature Publishing Group), 5, Article number 10321.

7) Müller, Bettina & **Schmiedeberg, Claudia** (2021). Do respondents get used to answering sensitive questions? Public Opinion Quarterly 84(3), 654-674.

8) Rüttenauer, Tobias & **Best, Henning** (2022). Perceived pollution and selective out-migration: revisiting the role of income for environmental inequality. Journal of Ethnic and Migration Studies 48(15), 3505-3523.

9) Rüttenauer, Tobias & **Best, Henning** (2021). Environmental inequality and residential sorting in Germany: A spatial time-series analysis of the demographic consequences of industrial sites. Demography 58(6), 2243-2263.

10) **Best, Henning** & Rüttenauer, Tobias (2018). How selective migration shapes environmental inequality in Germany: Evidence from micro-level panel data. European Sociological Review 34(1), 52-63.

See also CVs and publications from each Principal Investigator in Appendix 2.

1.2.2 Patents (does not apply)

2 Objectives and work program

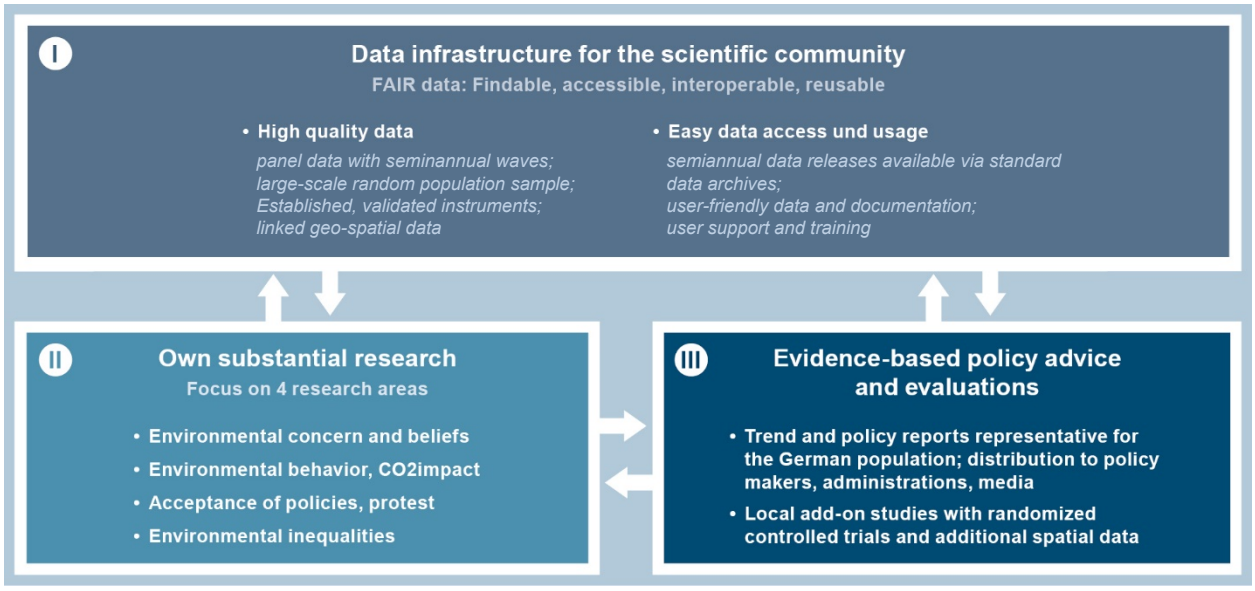
2.1 Anticipated total project duration

The long-term project is planned for 12 years. The present proposal refers to the first three years (2024/01-2026/12).

2.2 Objectives

The project has three closely related goals to be pursued in three integrated work streams (see Figure 2): (I) First and foremost, we will establish the panel study which will significantly expand the research data infrastructure for the environmental social sciences with micro level longitudinal data on individual attitudes and behaviors. (II) We will use this data infrastructure for research projects and scientific publications in the social sciences. (III) We will contribute to evidence-based policy evaluations and guidance with trend reporting and embedded experiments covering (regional) policy interventions.

Figure 2: Overview of the work streams



General objectives

I) Provide a unique data infrastructure for the scientific community: The proposed project aims at generating high-quality, FAIR (findable, accessible, interoperable, reusable) panel data for an interdisciplinary and international research community interested in environmental social sciences with micro data. To achieve data that benefit a large, worldwide scientific community, we strive to generate panel data with semiannual data collection and ad-hoc surveys between the regular waves over a total period of 12 years (in the long-term project). We aim at high data quality and connectivity to existing research and other data sources, easy data access und usage with

well-documented, user-friendly data published in timely releases, and openness to input from the scientific community (incorporated in the form of open modules and add-on studies).

II) Advance environmental social sciences with highly visible research: Our team of PIs and early career scientists will use the data infrastructure to advance substantive research and publication projects in all four key research areas described in Section 1.1, including methodological validations of the required tools. Our research focus will be on longitudinal analyses and (experimental) survey data linked to spatial context data, as such methods have thus far not been fully exploited and have a high potential for furthering environmental social sciences.

III) Contribute to social progress with evidence-based policy guidance and evaluations: We aim to contribute to evidence-based environmental policy guidance through continuous descriptive monitoring and causal analyses of the relationships between environmental concern, behaviors, and political support, as well as environmental and social inequalities resulting from environmental policies (Appendices 1, 3). We will complement existing efforts focused mainly on environmental attitudes by publishing regular policy reports on broader topics such as inequalities in CO_2 emissions or cost burdens. In addition, we plan cooperation projects with local governments for a more fine-grained evaluation of local interventions, for which the nationwide panel data will serve as a benchmark (see Section 2.3.3).

Interrelation between these three objectives: The data infrastructure will form the foundation for research and policy reporting, which will serve to further adapt data collection (e.g., identification of relevant topics in substantive research). Similarly, strong links in both directions are apparent between our research and policy guidance/evaluation symbolized by the double arrows in Figure 2. Key findings from our research will be regularly summarized in our policy reports; conversely, data collected for policy evaluations (e.g., through randomized controlled trials in add-on studies) serve as additional seminal data sources for substantive research.

Specific objectives as a long-term project

Establishing GLEN as a long-term project has several advantages. First, the envisioned *long-term data collection spanning 12 years* will provide the opportunity to cover the period in which particularly profound measures to replace fossil fuels will be implemented in accordance with international agreements. This survey period is crucial for a consistent monitoring of the period in which political planning and costly measures tackling climate change are taking place. For example, Germany aims for carbon neutrality in 2045; with the panel running from 2024-2035, it will support the scientific community during the central phase of transformation with data and research. Longitudinal data covering a longer period are also necessary to measure social change, analyze life course trajectories, and to disentangle age and cohort effects.

Second, although GLEN is intended primarily as a panel, it also allows for *long-term monitoring of environmental attitudes, behaviors, and policy evaluation*. The monitoring will complement existing social reports with the added dimension of environmental inequalities and the population's readiness for the transition to carbon neutrality. The planned design will allow for analyses (covering subgroup and regional variations) based on stable survey instruments. Long-term data that include individual environmental behavior will help evaluate the effectiveness of policies and provide more realistic, generalizable, and up-to-date priors that can feed and update simulations.

Third, as long-term project, we will *establish an internationally renowned research data infrastructure for the environmental social sciences* accredited as a research data center by the German Data Forum (RatSWD). The long-term program provides the time and resources to develop such an infrastructure and establish collaboration with the wider international research community.

Finally, another long-term contribution will be the *promotion of data usage for studying and research careers.* GLEN will contribute to the qualification of young researchers both within the project team and beyond. As a user-friendly data source for secondary research (including, e.g., tools to match individual and context data) suitable for all qualification levels (e.g., student use files), the data will promote the environmental social sciences among junior researchers. The long-term project will enable the development of introductory materials ("starter packs") and materials for (blended) learning. These will make the data attractive for teaching and facilitate usage for students as well as researchers at various career stages.

2.3 Work program including proposed research methods

We plan to implement an online panel with an initial sample of 15,000 respondents. We will prepare the main questionnaire and materials based on the 2022 pilot studies in close collaboration with the interdisciplinary scientific advisory board. Suggestions by the community are considered through regular calls for survey modules. The team will continuously be engaged in data collection and infrastructure (e.g., preparation of field work materials and instruments for upcoming panel waves and data processing and delivery from previous waves), scientific publications, and policy reports. Each project year, we will collect data from two panel waves and two ad-hoc surveys[2], publish two SUF releases, hold one meeting with the complete advisory board, and continuously engage in research, the results of which will be summarized in at least one policy report per year.

The core data infrastructure team will be located in Munich, supervised by panel data experts Christiane Bozoyan and Claudia Schmiedeberg. The other work streams (scientific research, reporting) are to be managed with the expertise of the PIs who will also supervise the substantive topics of the panel. These PIs will each be supported by one post-doc researcher and supervise the PhD theses of the doctoral staff.

The following gives an overview of the planned tasks for each of the three work streams (i.e., research data infrastructure, own substantial research, and policy reporting) during the first funding period (2024-2026) and an outlook on further survey waves and the envisioned long-term organization of the project. Before presenting the project organization and timeline in Sections 2.3.4 and 7.1.1, we first review the core methodological decisions as these determine the course of action and requested budget.

2.3.1 Planned data infrastructure

Basic survey design

Reference population, sample, and refreshments: The planned reference population for the panel study is German-speaking[3] individuals aged 18 and older with residence in Germany. The sample will be randomly drawn from municipal population registers. Data collection will focus on sampled individuals rather than households, mainly for financial reasons.[4] Central characteristics of the household or other household members will be collected via proxy information from the sampled respondent. To facilitate this, the questionnaire will be split into questions about the individual respondent and questions concerning the household. Mechanisms that will allow for the valid measurement of complex but integral household characteristics (e.g., household income, investments in energy efficiency, etc.) will be implemented. With respondents aged 18 and older, the panel will be able to follow individuals that leave the parental home or experience other important transitions in young adulthood (such as entering the labor market). Including respondents under 18 would largely increase practical and financial effort due to requirements of parental consent and data protection; the effort and costs involved is not warranted, given that most research desiderata can be solved with adult respondents or proxy interviews.

An initial sample size of 15,000 respondents registered to the online panel is targeted to enable regionally and socially stratified analyses, detect rare events and phenomena, and retain a sufficient number of respondents for longitudinal analyses of regional and social differences. Only with sufficiently large numbers of respondents from different federal states and metropolitan areas can effects of local policy measures be detected (with the other regions serving as control groups).[5] Experience from other studies (e.g., Brüderl et al., 2021; GIP, 2022; Satherley et al., 2015) shows that panel attrition reduces sample size considerably over time (see Figure 3 for a forecast of sample size across the 12-year time span of the long-term project).

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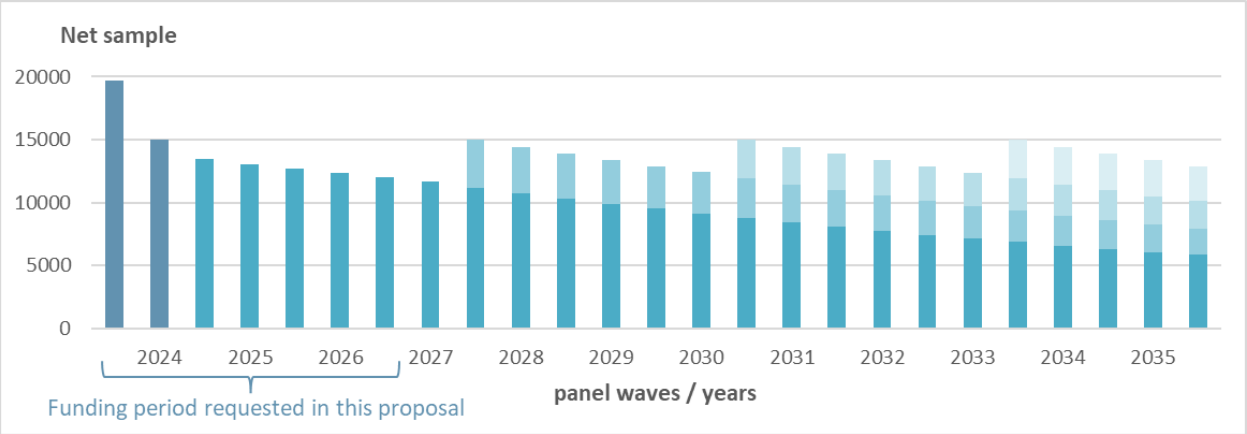
[2] We term the additional surveys “ad hoc" because the questionnaire program for these shorter surveys is defined on shorter notice, in contrast to the "regular" waves, which involve repeated querying of core panel modules.

[3] Migrants will be included in the survey and addressed with short introductory texts in several languages in the invitation letter and on the website. Translated questionnaires targeted toward an additional migrant sample may be implemented as an add-on study in later panel waves.

[4] To keep costs within the planned budget, including additional household members would require strongly reducing the number of sampled households.

[5] For state-level measures, stratified samples might increase statistical power, but many measures or events (e.g., improved public transport, environmental hazards) might occur in other regional units that cannot be foreseen when planning the sample. Evaluations of nationwide policies will rely on time-series designs or on specific control groups with outside options (e.g., respondents living in border regions).

Figure 3: Forecast of sample size development over the funding period and long-term project



In addition to shrinking sample size, selective attrition must be considered, as respondents' attitudes, interests, and capabilities influence their decision to take a survey (Lynn, 2018). Panel maintenance strategies such as frequent contacts to respondents and different kinds of incentives will be used to minimize attrition, following best-practice recommendations from other large panel studies (Blom et al., 2015; McGonagle et al., 2011; Watson et al., 2018). Efforts to mitigate selectivity will include an unobtrusive survey title for respondent communication (e.g., "Everyday Life in Germany"), frequent contact to respondents, ad-hoc surveys on different topics, and designing an enjoyable questionnaire (see Appendix 6). Nevertheless, selective participation is of concern for an environmental panel as, compared to a multi-purpose study, environmental topics are normatively loaded. To maintain a sufficient sample size, occasional sample refreshments are required, planned for every third year (hence, not in the period covered by this proposal).

Survey mode and recruitment: Data collection is planned as an online survey with two regular panel waves and two additional "ad-hoc" surveys per year. This design allows to react quickly to external shocks such as natural disasters or disruptive policies and also to prospectively evaluate policy measures that are only valid within short time intervals (such as the ~~9€~~ ticket). Flexible online panel infrastructures have acted as an important tool also in other domains (e.g., Blom et al., 2020; Haas et al., 2021). Moreover, panel data are relatively inexpensive when collected online as e-mail invitations reduce the cost and effort required for contacting respondents, and wave-on-wave retention is comparatively high in this mode (e.g., GIP, 2022). This is advantageous for the planned longitudinal analyses. Compared to interviewer-administered surveys, self-administered surveys are also less prone to social desirability bias (Krumpal, 2013). In addition, it has been shown that recruitment to self-administered online surveys via postal mail is feasible with field results comparable to face-to-face surveys (Cornesse et al., 2022). To address concerns about the representativeness of an online-only panel (Blom et al., 2017; Cornesse and Schaurer, 2021; Scherpenzeel, 2010), we supplement it with a separate, annual postal "catch all" survey of the online-reluctant. This offline supplement will focus on core questions and constructs that can then be used for weighting and imputation of the online data. As a considerable share of respondents are expected to complete the survey on mobile devices, an adaptive design will be implemented that is optimized for the device being used. Question formats that are difficult to display on small screens will be avoided (de Leeuw and Toepoel, 2018; Felderer, 2021; Toepoel, 2017).

After a short recruitment and registration survey, we plan a structure with semiannual regular panel waves and two short ad-hoc surveys between the waves (see Appendix 6 for a detailed explanation of the planned panel structure). In the case of major environmental or political events, the ad-hoc surveys will be used to cover these shocks. Otherwise, the ad-hoc surveys will cover non-environmental topics to reduce panel tiredness and panel conditioning. This structure with several surveys per year has notable advantages: It decreases interview duration per survey wave, may increase participant loyalty (due to frequent contact), and facilitates recall as respondents answer questions referring to the past few months or weeks. Moreover, a higher frequency of waves enables researchers to observe volatile changes over time, investigate seasonal variations, and allows first longitudinal analyses after a short period of time. In particular, the ad-hoc surveys allow flexibly reacting to external shocks (e.g., natural or political events).

As interview duration decreases willingness to participate and increases break-off rates, interviews will be limited to 25-35 minutes for the online survey to reduce non-response. Only part of the regular question program will be asked semiannually, leading to a stable core of basic modules complemented by regularly rotating in-depth modules (see Figure 4).

Incentives: Participation to the *recruitment survey* is planned to be incentivized with an unconditional cash incentive of €5. Prepaid cash incentives are frequently used and accepted in Germany today. Although they entail large initial costs, their cost-efficiency is equal to or even higher than conditional incentives as higher response rates compensate the larger number of incentivized recipients (for recent experiments in Germany see Witte et al., in press; Wolf et al., 2021). Once respondents are online, all incentives are conditional. Accordingly, participation in the registration survey is planned to be incentivized conditionally with €5 (respondents who participated offline in the recruitment survey or did not provide a valid e-mail address will receive €5 with a postal invitation as a special tailored incentive to push them to the online registration). In the *running panel* we use conditional incentives to avoid sending postal letters. Respondents will be announced a conditional incentive of €5 per wave in the e-mail invitation, and €3 for the ad-hoc surveys. These are paid electronically, using a flexible, adaptive payment scheme. To counteract temporary dropout, we offer an additional bonus of €5 to respondents who participated in all four surveys per year (similar to the GIP design, see Blom et al., 2016). Respondents who did not participate in two consecutive waves are invited to the next survey with a targeted invitation and incentive as such measures have proven successful (e.g., Carpenter, 2021; Lynn, 2016). The incentive scheme will be subject to experimental scrutiny and refinement.

Quality measures, pretest, and validation study: Several measures will be implemented to enhance participation and ensure high data quality: A telephone hotline, a project website, regular social media activities, personal online accounts for all panelists (where they can see and modify, e.g., their personal data and the incentive payout mode), and short project reports directed toward respondents between waves (see Appendix 6).

All elements of the survey will be – and partly have already been – extensively pretested. While this is true for all waves, it is particularly important for the first wave. A pilot study, funded by the "LMUexcellent Investment Fonds", has run in 2022 to test incentives and core parts of the questionnaire. The pretest was fielded in two German federal states (N = 763) as a push-to-web survey mirroring parts of the planned data collection design (see Appendix 5 for details). Moreover, it is planned to validate self-reported data in a subsample of randomly selected respondents from wave 1 by surveying them face-to-face shortly after the self-administered interview. Over time, the survey design will be continuously improved by taking into account research results from other online panels, but also by conducting our own methodological research. We will contribute to the ongoing debate concerning survey non-response (e.g., Peytchev et al., 2020) by implementing and experimentally varying adaptive survey design elements such as targeted invitation letters and inter-wave mailings. Moreover, we will investigate social desirability and panel conditioning effects (Müller and Schmiedeberg, 2020) as these aspects are particularly relevant for an environmental panel study. The goal of this research is to reduce bias and attrition, but also to make substantive contributions to environmental social sciences (see Section 2.3.2).

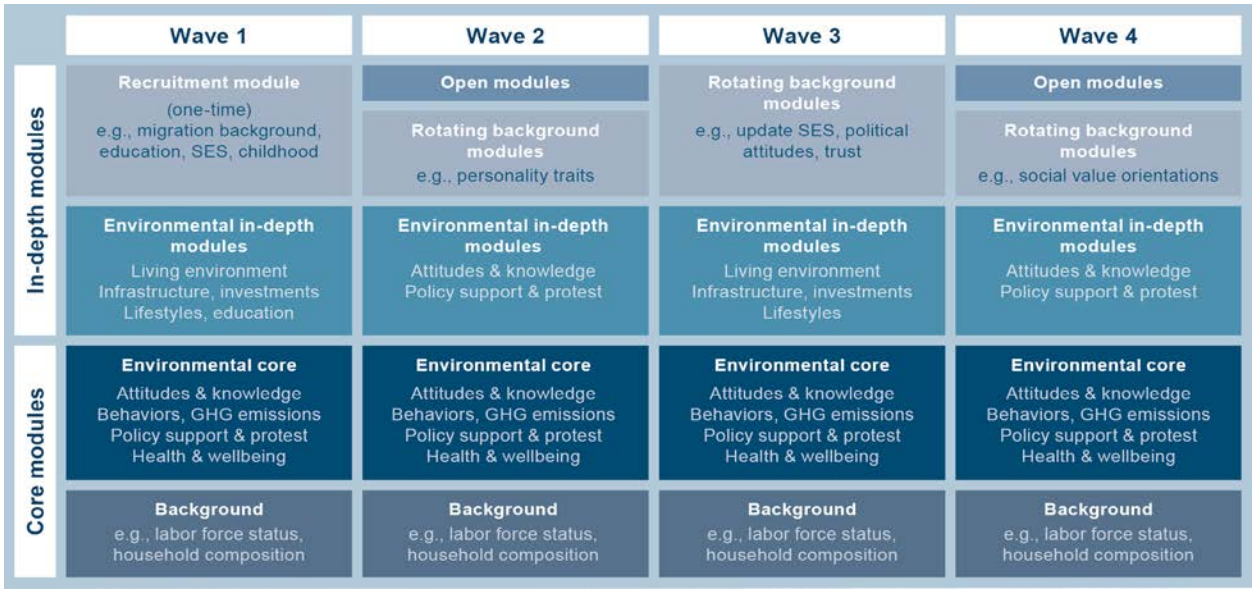
Topics covered in the survey

Thematic modules: When designing the contents of the panel study, stability and change in the question program must be balanced. To allow longitudinal analyses, instruments must remain constant throughout the panel. At the same time, the panel will steadily evolve to take into account environmental, societal, and political changes, as well as advances in research. We will rely on established scales as far as possible to ensure international connectivity, for instance for measuring environmental concern (e.g., Dunlap et al., 2000; Kaiser and Lange, 2021), time and risk preferences, motivation to engage in political action (see e.g. Koos and Lauth, 2020; Opp and Kittel, 2010), and established concepts such as social identity and generalized and political trust. The question program will be discussed regularly with the advisory board to ensure that the panel covers diverse national and disciplinary perspectives and meets the requirements of a broad scientific community (see Appendix 7 for the planned constitution of the advisory board).

Figure 4 illustrates an overview of topics covered in the panel study. While a stable core questionnaire (~50%) will be part of each panel wave, further modules will rotate: Semiannual, annual,

less frequent (bi-/triennial), and one-time modules will be implemented. For instance, environmental attitudes that may be influenced by events or exposure to protest movements or local planning initiatives will be asked at least once a year, whereas more stable characteristics will be included in less frequent intervals. The survey will regularly include questions to approximate respondent GHG emissions based on behaviors in domains such as housing, mobility, and consumption, building upon previous work (Bruderer Enzler and Diekmann, 2019). In addition, further measures will be covered, such as investments for climate adaptation and approval of environmental policies. In the medium term, additional data may be collected by linking external data such as mobile app data for mobility analyses in add-on studies (see Section 2.3.3). Other topics will be limited to a regular core of central questions; for instance, in the case of health and well-being, this will be a set of basic indicators that have proven valuable for research, such as weight (BMI), sleep, and subjective health status, as well as established measures of mental health and well-being. Questions concerning living environment and infrastructure will be limited as the bulk of information will be derived from geospatial context data. Finally, a comprehensive body of questions will supply (socio-demographic) background information, including indicators for education, migration background, income, labor force status, and psychological factors (e.g., Big Five, Dark Triad).

Figure 4: Overview of survey topics



Open modules: To afford flexible possibilities to collect specific data for researchers, we will include open modules (as well as add-on studies, "GLEN+", described later). These modules will be included annually, with a Call for Contributions to invite proposals from the international scientific community and a transparent selection process. We will invite contributions from all social sciences, ranging from single questions and item batteries to survey experiments and longitudinal modules to be implemented in consecutive waves. After acceptance, proposed questions will be checked for methodological quality and must be pre-tested by the proposing researchers. Resulting data will be documented by the GLEN project team in collaboration with the proposing researchers and published with the SUF after a predetermined period (typically one year). Implementing open modules in the main survey will be free of charge.

Special features of the data

Experimental designs: To study causal mechanisms, we will implement multifactorial survey experiments (conjoint, choice, and factorial survey experiments) to evaluate the policy acceptance of different planned measures and possible trade-offs and compromises, respondents' (mis-)beliefs about the effectiveness and cost burdens of different measures, or their willingness to pay for measures such as new heating systems or other technological innovations. In these designs, the net effects (i.e., effects net of possible confounders), relative importance, as well as possible interactions of the experimentally varied dimensions can be determined. Multi-factorial survey experiments also have the potential to reduce social desirability bias, as respondents have multiple reasons to justify a particular choice or evaluation (Auspurg and Hinz, 2015; Hainmueller

et al., 2014). They will help to identify policies that represent the most acceptable trade-off between various benefits and costs. One innovation will be to create experimental designs that allow for causal mediation analyses through designs in which the amount of information about mediator variables is also experimentally varied (Acharya et al., 2018; Auspurg et al., 2017). In addition, standard information treatment or dilemma-experiments can be implemented. Data from these experiments (e.g., on individuals' stated willingness to pay) can then also be validated by behavioral data once policy measures are implemented.

Geospatial context data: These data are necessary to measure environmental burdens such as residential noise not only with subjective, but also objective data. These two measurements can differ, be it due to biased perceptions (Preisendörfer et al., 2020) or due to protection measures such as sound proof windows. Spatial data is available in the form of various data types and at different aggregation levels. For example, community-level population density will be linked to the survey data using community codes, whereas transport infrastructure may include, for instance, the distance from the respondent's home to the nearest train station, calculated using geographic coordinates. Regarding imperviousness, grid data is available. To facilitate the use of a broad range of spatial data drawn from public data bases, the survey data will be enriched with geocodes of respondents' place of residence in various formats, such as lat-long geocodes in WGS84 format (GPS), an interface to the European INSPIRE grid via the ETRS89-LAEA projection, and codes and shapefiles for NUTS3 areas. Using this geodata infrastructure, data from several databases such as Copernicus (e.g., weather, land use, green spaces), the IOR data infrastructure, E-PRTR (noise, air pollution), and basic indicators such as population density, unemployment rate, and demographic structures from the Census can be integrated. In addition, guest researchers' own georeferenced data can be merged with survey data via the geodata infrastructure described above. Data will be provided as ready-to-use datasets. We will strive to provide data at various aggregation levels and with various data types, taking into account the modifiable areal unit problem as well as arbitrary boundary setting (Buzzelli, 2020; Morenoff et al., 2001).

Data management and data service

All data will be made available in the form of scientific use files (SUFs) in semiannual data releases. Comprehensive data processing will encompass basic data management measures such as consistency checks, missing data coding, labelling, and the preparation of generated variables for core constructs (e.g., GHG emissions) and frequently used control variables (e.g., level of education), thereby relying on internationally established concepts and classifications (e.g., CASMIN, ISCO) as far as possible. These steps will increase user-friendliness and enhance the quality and replicability of analyses. Post-stratification and design weights will be provided with each data release. According to our principle of transparency, all syntax files will be made available in the SUF unless they include confidential content (in terms of respondent data privacy). To ensure transparency and user-friendliness, complete and transparent documentation materials (in English and German) on the entire data collection and preparation process will be provided.

To make the data visible and available to a large number of users in the scientific community, data will be referenced (e.g., in the da|ra meta-data portal) and downloadable via the Internet. The SUF will be distributed via the GESIS data archive.

An important issue with spatial data is data protection. Geospatial data bear the risk of respondent identification despite anonymization, as addresses can be reconstructed via characteristic combinations of factors. Therefore, access to sensitive data, such as small-scale context data, will be restricted to guest workstations at our safe data center in Kaiserslautern. As working at the project locations may prevent some researchers from using the protected data, easier access will be provided in the medium run to balance user-friendliness and data protection. We aim to participate in the RDCnet that connects safe data rooms from different data centers in the KonsortSWD.

To facilitate usage and advertise the data, tutorials will be provided describing first steps in data handling. User support will be available to current and prospective users via telephone and e-mail. In addition, introductory courses at the GLEN project locations and tailored in-house workshops at interested universities and research centers will be held regularly online and offline.

2.3.2 Substantive research of the project team

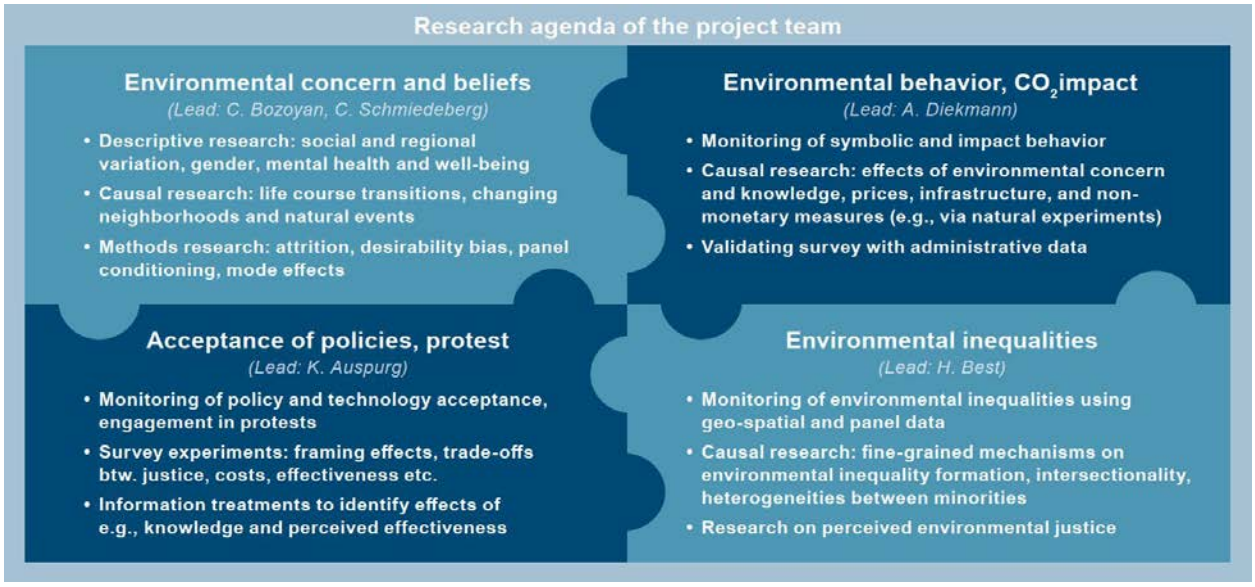
The second work stream of the project is own substantive research (see Appendix 1 for details). We will cover all main substantive topics discussed in the research review (Section 1.1.2), starting

with descriptive analyses, then striving for longitudinal and causal analyses. Moreover, our focus will be on the usage of novel experimental designs and methodological research to develop and validate measurements of constructs such as carbon footprints or relevant spatial contexts. Figure 5 shows the planned research agenda within the project team. The four focus areas are linked by several interdependencies for which we envisage collaborations.

Each of the four key research areas will make use of the special expertise of the PIs in survey research, experimental designs, impact measures, and spatial analyses. Each of the substantive areas outlined in Section 1.1.2 will be the area of responsibility of one PI together with a pre- and a postdoc, who will also ensure (in consultation with the advisory board) that the data is suited for addressing the identified broader research gaps and that the panel meets the research interests of the wider research community. With this combination of infrastructure and research work, we follow the well-proven organization structure of other large-scale panel studies.

Publication outlets will be leading international journals, which will further increase the international awareness of the data. Research will be used for master theses, dissertations, and habilitation projects, thus serving the further qualification of (early career) scientists in the project.

Figure 5: Research agenda of the project team



2.3.3 Evidence-based policy reports and evaluations

As a third and last work stream, we will use GLEN to offer evidence-based policy guidance through continuous monitoring and causal analyses of environmental attitudes, behaviors, acceptance of measures, and inequalities resulting from environmental policies.

This includes two main elements: First, we will publish yearly policy reports with different focus themes (summarizing especially own research) and trend reports based on weighed data and a refreshment sample every three years. We will cooperate with the Munich Science Communication Lab (funded by the Volkswagenstiftung), a large project for boosting the dissemination of scientific findings.

Second, to evaluate policies using controlled designs, add-on studies (“GLEN+ studies”) will be developed using the same core questionnaire as the main study but including additional data collection efforts by other researchers or political entities (e.g., city or state governments). For instance, additional data collection may concern consumption or mobility data collected via a shopping diary, linked mobile app data, or interviews with respondents’ partners or their adolescent children to capture attitudes and protest behavior as a source of influences and conflicts in the family. For regional in-depth analyses of local policies or dynamics, GLEN+ studies can use additional regional samples that may be combined with randomized controlled trials, for example in the form of information-treatment or nudging-default experiments (Liebe et al., 2021). Interventions such as infrastructure projects, information campaigns or initiatives to involve citizens in local decision-making that are designed and planned together with local authorities provide the opportunity to evaluate measures using the design of natural experiments.

For such studies, local partners (e.g., cities, counties, metropolitan regions) will provide a local booster sample and carry all additional survey costs for that sample. After recruitment and registration, respondents of GLEN+ projects will be treated as regular panel members but may receive special ad-hoc surveys for a targeted evaluation of local measures. The additional samples will be surveyed simultaneously with the core sample, which then serves as a benchmark. In some of these studies, the data may also be linked (with respondents' informed consent) with administrative data (e.g., energy consumption or heating systems available in different districts). A first city (Munich, see Appendix 8) has already signaled strong interest in cooperating in such a project to target the evaluation of diverse measures to achieve climate-neutral neighborhoods.

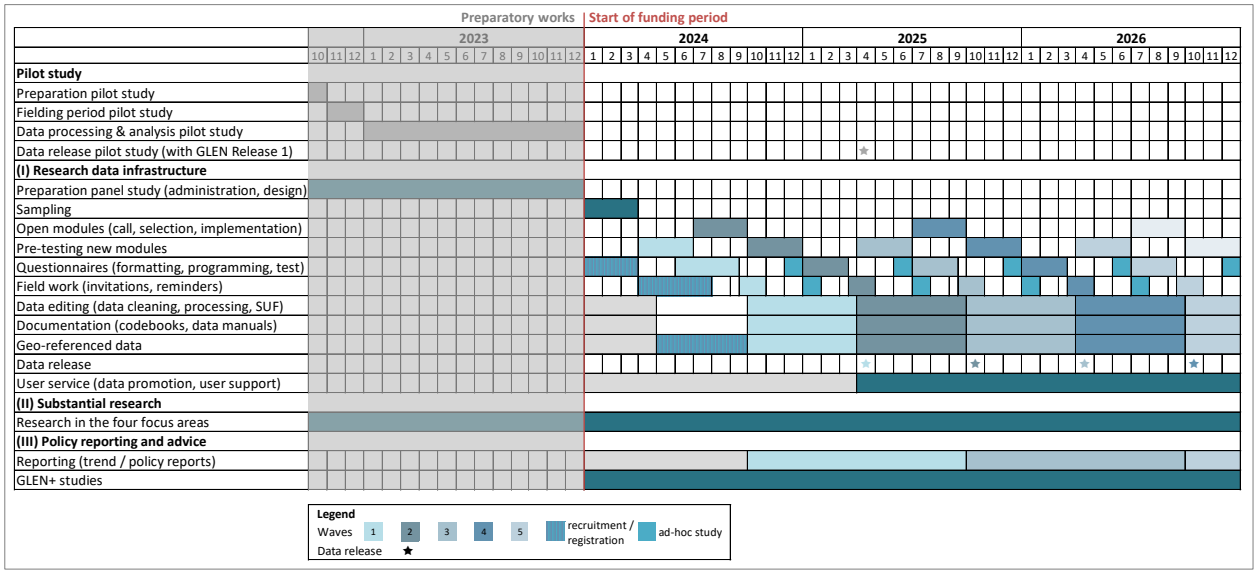
2.3.4 Work program and project organization

Timing and handling of our work program

As can be seen in Figure 6, the project is structured in three integrated work streams (i.e., data infrastructure, substantive research, policy reporting) to which all team members will contribute. Several steps will be performed simultaneously throughout: For instance, while the wave 1 data is being processed and documented, we will prepare wave 2 and an ad-hoc survey and undertake first steps concerning the question program of further surveys. At the same time, wave 1 data will be analyzed for the policy report and own research, and materials for user service and data promotion will be prepared.

Particular efforts will be required for initiating the panel survey in the first months after the project start, as we will have to finalize the recruitment and registration stages and the questionnaire program and establish routines for all further steps (e.g., layout of documentation materials, data editing routines, user contracts). Data collection of the first wave is scheduled for fall 2024. In these stages, this work stream will have priority for the entire team while substantive research and reporting tasks will gain importance once wave 1 data are available.

Figure 6: Project schedule



Central milestones are the semiannual publication of the SUF, preceded by clearly defined steps such as delivering the questionnaire for the two waves and two ad-hoc surveys of annual fieldwork, data collection, and data editing and documentation. Further milestones will include publishing the trend report based on data from waves 1 and 2 and subsequent annual policy reports, as well as regular scientific publications of all team members.

Work organization and team collaboration

The team of pre- and postdocs primarily responsible for the survey infrastructure will be concentrated at one project site (Munich), at least in the first funding phase, to facilitate the coordination of the complex and highly interconnected tasks of survey and data management. To coordinate cooperation across the three project locations, monthly informal team meetings to discuss operative issues and semiannual meetings for finalizing the question program of the upcoming survey

wave and ad-hoc surveys are planned online alongside annual in-person meetings with the scientific advisory board. Questionnaire modules, survey experiments and GLEN+ projects will be planned in online workshops, to which primarily advisory board members and cooperation partners with distinctive expertise in this area will be invited. Opportunities for discussion of our scientific research will take place at regular research colloquia and the two planned conferences in Leipzig and Munich. Further details of the planned general work organization are described in Section 7.1.

Scientific advisory board

GLEN shall be a data infrastructure for a broad international community of researchers from all social sciences. To ensure that these diverse perspectives are represented, the scientific advisory board will play an important role in the project. It will be involved in decisions about the question program and survey methodology, the selection of open modules and GLEN+ studies, research in the four core areas, and the long-term development of the project. For these tasks, we will organize annual advisory board meetings (in person at one of the project locations) and additionally invite individual board members to online meetings to discuss specific topics. In particular, regular consultations with methodological experts are planned to refine and advance data collection methods and processes.

The 15-member advisory board will include experienced/renowned researchers from disciplines such as psychology, economics, political science, geography, communication science, law, and climate research in the natural sciences and engineering. International perspectives are integrated through board members from various countries from Europe, the USA, and China. As environmental crises like climate change are global and require global answers, we will involve colleagues from the Global South to incorporate this perspective in our project. For more details on the constitution and organization of the advisory board, see Appendix 7.

Long-term organizational structure

In 2025, the regular scientific advisory board meeting will be utilized for an evaluation of the project and planning of the next funding phase (2027-2029). At this point, we plan to continue the illustrated work program for the entire project period: conducting semiannual online surveys (supplemented by two ad-hoc surveys and, yearly, by short paper-and-pencil questionnaires for online-reluctant respondents) with a longitudinal core and varying modules including survey experiments, which will be either proposed by external researchers or the project team. Project costs will decrease after the first funding phase, which is characterized by high investments in the recruitment of the online panel and infrastructure establishment. In particular, the refreshment samples will be considerably smaller than the initial sample.

To secure the stability of the organizational structure over the time span of the long-term project (12 years), steps on how to deal with possible changes in the composition of the PI team have been defined: If one of the PIs leaves the project, potential successors will be discussed with the advisory board with regard to their project fit. As of today, at least two of the PIs (Auspurg and Best) have full professorships that cover the entire duration of the long-term project.

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