Journal of Cleaner Production 491 (2025) 144534

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Choosing photovoltaics installation as a job emerges as a pro-environmental behaviour in the context of low-carbon transitions' skill shortages in Germany

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ARTICLE INFO

Handling editor: Stefan Kaufman

ABSTRACT

Shortages of skilled workers in vocational jobs constitute critical obstacles to achieving low-carbon transitions in many countries worldwide. Despite its significance, academic research on the role of work in implementing low-carbon transitions remains limited. This study aims to advance the scientific understanding of work and occupational choice from a transition perspective and to provide insights for practice and policymaking into designing effective strategies to address skill shortages. Specifically, we explore factors influencing the decision to enter or not to enter vocational occupations in photovoltaic installation in Germany. For that, we follow a mixed-methods design combining case studies of bottom-up initiatives tackling skill shortages in installation jobs with an online survey among German adolescents. Our findings reveal that photovoltaic installation is particularly appealing to pro-environmental groups, fostering strong efficacy beliefs. They further indicate potential spill-over effects from work to other behavioural roles suggesting a unique intersection between occupational and environmental identities. We also find heightened interest in part-time work in the installation trades, particularly among women and high educated groups. However, a lack of low-threshold entry points, limited part-time opportunities, and a male-dominated industry deter broader engagement in the skilled trades, particularly among women. Since attracting currently non-engaged population segments in vocational occupations is key to growing a sufficiently large installation workforce, policymaking and practice need to act on these barriers, providing more points of contact with the skilled trades, promoting safe spaces and low-threshold opportunities to try out practical craftwork, particularly for women, and developing more flexible labour conditions. Our results further indicate opportunities to broaden popular support for low-carbon transitions by increasing the social recognition of the skilled trades' crucial role in implementing low-carbon transitions. Work and occupational choice emerge as key components of low-carbon transitions and environmental behaviour highlighting the need for further research across academic communities.

1. Introduction

Across the world, shortages of skilled workers increasingly constitute barriers to low-carbon transitions (Czako, 2022; IEA, 2023; IRENA & ILO, 2022; OECD, 2023). In the photovoltaic (PV) sector as the main job source in low-carbon transitions, jobs are projected to triple from 4.3 million in 2021 to almost 14 million jobs in 2030 globally (IRENA & ILO, 2022). In the EU, PV expansion could create 1.2 million jobs by 2027

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https://doi.org/10.1016/j.jclepro.2024.144534
Received 29 February 2024; Received in revised form 18 November 2024; Accepted 17 December 2024
Available online 28 December 2024

thereby doubling the PV workforce within 5 years (SolarPower Europe, 2023). Most of the jobs created in low-carbon transitions are installation or 'implementation jobs'[1] requiring vocational education and training (VET). Yet, already with today's installation rates, vocational jobs such as electricians or heating installers exhibit severe shortages in countries such China, the U.S., or EU, threatening the feasibility of accelerating low-carbon transitions (IEA, 2023).

Many countries adopted policies to address skill shortages and develop a sufficiently large and skilled workforce for implementing low-carbon transitions. For example, the United States' Inflation Reduction Act of 2022 grants financial incentives for apprenticeships in renewable energy jobs (Office of Apprenticeship, 2024). The European Commission adopted the European Skills Agenda in 2020 as part of the European Green Deal, mainly focussing on re- and upskilling the existing workforce, often in fossil-based occupations. It comprises the anticipation of skill needs, updating training curricula, establishing and refurbishing training centres, and funding training programmes (Czako, 2022). For PV, the Commission launched the European Solar Academy in June 2024 (European Commission, 2024). Similar endeavours are pursued in the Net Zero Strategy in the United Kingdom (HM Government, 2021). However, the inability to attract and retain workers in implementation jobs is considered a larger challenge than (re)training (Kuokkanen, 2023). This reveals potential weaknesses in existing policy frameworks because their attendance to attracting and retaining workers is limited which has also been criticised by European industry associations (EuropeOn, 2022; SolarPower Europe, 2023). In reaction, the Commission, member states such as Germany, and industry associations launched image campaigns and a Year of Skills in 2023 to increase the reputation of vocational jobs (Czako, 2022; IEA, 2023). Yet, beyond image campaigns and endeavours to attract foreign skilled workers, policy action on attracting and retaining workers remains limited. This becomes particularly problematic when taking a gender perspective on implementation jobs. Women are strongly underrepresented in implementation jobs, constituting only 12 % of the global PV installation workforce (IRENA, 2022). Accordingly, attracting, retaining, and promoting women and other underrepresented groups in the implementation workforce constitutes a key pillar of skill strategies for low-carbon transitions and a priority area of timely action (Czako, 2022; IEA, 2023; IRENA, 2022; IRENA & ILO, 2022; Koneberg et al., 2022; Kuokkanen, 2023; OECD, 2023).

Despite the pivotal importance of the shortage of skilled workers in implementation jobs, academic research on this topic is limited in many climate-related discourses including sustainability transition and environmental behavioural research, the nexus of which is addressed in this special issue. However, we argue that given the skill shortage, the choice of occupation becomes an environmentally significant behaviour. As such, it is a relevant and topical research area for both discourses because it responds to recent calls to sustainability transition research (STR) to attend more to behaviour and the internal states of individuals (Bögel and Upham, 2018; Kaufman et al., 2021) and simultaneously addresses gaps in environmental behavioural research regarding systemic and transformation-oriented perspectives (Kaufman et al., 2021). Therefore, this study aims to advance the understanding of work and occupational choice in sustainability transitions and inform policymaking and practice on strategies to effectively augment the implementation workforce. Based on case studies of innovative initiatives in Germany striving to attract people in implementation jobs as well as an online survey of a general youth population in Germany, we explore the following research questions:

1. How do the actors involved in the initiatives understand the role of occupation in the context of sustainability transitions?
2. How do the involved actors and other youth groups perceive an occupation in PV installation?

Focussing our research on Germany promises relevant insights for the wider international context because Germany has implemented ambitious policies in 2022 stipulating the expansion of renewable energies such as PV and wind power: inter alia, Germany tripled the annual installation targets for PV from 7.2 GW in 2022 to 22 GW from 2026 onwards (BMWK, 2022), a goal that appears to be in reach. Germany thereby resembles other countries such as the United States that underpinned raised climate ambition with concrete stipulating policies. Having thus entered "later transition stages" (Markard et al., 2020, p. 1) these countries now face skill shortages as transition challenges and feasibility constraints (IEA, 2023; OECD, 2023). As a result of its increased policy ambition, Germany is projected to grow the largest PV workforce in the EU by 2027 (SolarPower Europe, 2023). Yet, already in 2022, it faced shortages of 216,000 skilled workers in PV and wind expansion (Koneberg et al., 2022). In the two professions facing the highest shortages, electricians and heating installers, 80 % of vacant positions could statistically not be filled in 2022. As in most other countries, female shares in these professions are below 0.5 % and 1.5 %, respectively, and eight of fifteen bottleneck professions in PV and wind expansion in Germany are vocational jobs requiring dual training[2] (Koneberg et al., 2022). The German case also provides insights for countries in earlier transition stages which will likely face similar skill shortages once adopting more ambitious policies for renewable energy stipulation.

The paper is structured as follows. Section 2 reviews the literature on skilled worker shortages and environmental behaviour. Section 3 presents the employed methods and research approach. Results are presented in section 4 and discussed in section 5.

2. Literature review

2.1. Skills shortages as bottlenecks in sustainability transitions

The shortage of skilled workers for installing low-carbon technologies is well-recognised as a barrier to climate action in policy and industry reports (e.g. Czako, 2022; IEA, 2023; IRENA, 2022; IRENA & ILO, 2022; Koneberg et al., 2022; OECD, 2023). Yet, despite a few notable exemptions (Briggs et al., 2022; García-García et al., 2020; Jagger et al., 2013; Wachsmuth et al., 2023), peer-reviewed climate and transition research remain largely inattentive to skill shortages as potential barriers to climate action. This inattention is problematic because it creates path-dependencies in policymaking and further research. For example, specialists concerned with climate policies might be unaware of problems in labour realms, risking incomplete analyses. Emblematic is the Sixth Assessment Report of the IPCC which compiles the most relevant peer-reviewed scientific knowledge about mitigating climate change and serves as agenda setting 'beacon' both for policymaking and research (2022). The report highlighted technology installers as influential middle actors in climate action but referred to potential shortages

[1] We use 'implementation jobs' or 'implementation work' for gainful occupations which are practically involved in installing low-carbon technologies such as PV or heat-pumps. The term is narrower than 'green jobs' describing more broadly "decent jobs" that "contribute substantially to preserving or restoring environmental quality" (UNEP, ILO, IOE, and ITUC, 2018, p. 3) and which also comprise occupations such as research and administration. Acknowledging the importance of these, we chose to focus on implementation jobs because these face the largest shortages and require different educational pathways than the other occupations, namely VET.

[2] The dual training system is the VET system in Germany. It consists of three or three-and-a-half years of basic training to acquire a state-recognised professional qualification. In the skilled crafts and trades, the practical part is conveyed in enterprises and inter-enterprise-training centres and the theoretical background is taught in vocational schools under state responsibility.

as barriers to implementation only once in the building chapter. Indeed, the importance of installers and the associated demands for re- and upskilling are well-recognised in social science energy research which is closely related to STR (Gleeson, 2016; Janda and Parag, 2013; Moezzi and Janda, 2014; Parag and Janda, 2014; Simpson et al., 2020). Yet, this research largely focuses on the professional jurisdictions, activities, practices, and skills of the existing workforce as well as associated demands and strategies for upskilling. To our knowledge, however, it has not yet focussed on attracting and retaining the prospected numbers of workers.

Sustainability transition research increasingly acknowledges 'transition bottlenecks' challenging the uptake of mature and cost-effective technologies such as PV in advanced transition stages (Geels et al., 2020; Köhler et al., 2019; Markard et al., 2020; Wachsmuth et al., 2023). Yet, these articles refer to social acceptance (Geels et al., 2020), consumer practices (Markard et al., 2020), or raw material supply (Hyvönen et al., 2023) as feasibility constraints and bottlenecks. Only Wachsmuth et al. (2023) consider skill demands but conceptualise them as socio-economic impacts *of* transitions, not as feasibility constraints *to* transitions. Moreover, research in this discourse largely overlooks the installation step of low-carbon technology diffusion which connects the production and consumption or use of these technologies as highlighted in social science energy research (Janda and Parag, 2013; Parag and Janda, 2014).

Existing studies on skill shortages in low-carbon transitions forecast substantial increases in skilled labour demands in low-carbon transitions, document existing skill shortages, assess future skill demands, and warn against exacerbating shortages due to factors such as the overproportionally ageing workforce in the energy sector (Kuokkanen, 2023), underrepresentation of women (IRENA, 2022), image problems of vocational jobs (IEA, 2023; SolarPower Europe, 2023), and market structures in the construction sector (Jagger et al., 2013). The latter include delays in the formal training system, sector-typical economic oscillations, and appropriability of employees (Jagger et al., 2013). In this context, studies discuss various social implications for developing a low-carbon workforce and resume calls to safeguard inclusivity, social justice, and well-being (IRENA & ILO, 2022; OECD, 2023). For example, García-García et al. (2020) warn that low-carbon transitions risk a "dark side" (García-García et al. (2020), p. 13.) with adverse effects on the quality of jobs or female labour participation. Briggs et al. (2022) argue that despite being cost-optimal, boom-and-bust cycles of sharp activity peaks in local hotspots would pose severe challenges to regional labour markets, undermine the social license of the energy transition, and eventually prove infeasible. Consequently, they endorse Jagger et al.'s call to prioritise broad formal qualifications equipping workers with "portable" or "transferable" core skills over quick-training narrow untransferable skills through informal routes. Despite being time-saving and flexible, the latter leaves semi-skilled workers vulnerable to sector-typical economic oscillations (Briggs et al., 2022; Jagger et al., 2013; SolarPower Europe, 2023). Thus, an integration of informal and formal training routes allowing informally trained workers to acquire broader formal qualifications is essential to avoid precarious working relations in low-carbon transitions (Czako, 2022).

In summary, social science energy research highlights the importance of technology installation as a crucial transition step while industry and policy reports warn against exacerbating skill shortages as transition bottlenecks and risks of adverse social side-effects in building an implementation workforce. However, academic STR remains largely inattentive to these issues, and, to the best of our knowledge, skill shortages have not yet been explicated as feasibility constraints in scientific 'flagship' publications on climate action such as the IPCC Reports.

2.2. Work as environmental behaviour

Given the systemic shortage of skilled workers for climate action, the choice of occupation becomes an environmentally significant behaviour. These are behaviours that have a direct or indirect environmental impact and/or are performed with a pro-environmental intent (Stern, 2000). The importance of behaviour and lifestyle change is widely acknowledged in environmental research (IPBES, 2019; IPCC, 2022), recognising that behaviour occurs in different roles, including as consumers, citizens, investors, and members of communities and organisations (Nielsen et al., 2021; Stern, 2000). Yet, environmental behavioural research largely focuses on the consumer role and, less so, on the citizen role. Scholars recurrently criticised the strong consumer focus and called for broadening the scope for future research (Bögel and Upham, 2018; Köhler et al., 2019; Nielsen et al., 2021).

Research on the consumer role focuses on private household behaviour, consumption, technology acceptance at the end-use, lifestyle, and everyday life (Bögel and Upham, 2018; Creutzig et al., 2022; Steg and Vlek, 2009). Yet, the conceptualisation of lifestyle and everyday life stops once the person is at work (Moezzi and Janda, 2014). Most prominently, UNEP conceptualises the key domains of 'sustainable lifestyles' as food, housing, mobility, consumer goods, and leisure: "What food will I eat? What house will I live in? How will I get to work in the morning? What type of clothes will I wear? How will I spend my spare time?" (UNEP, 2016, p. vi). However, work and the question 'How will I spend my working time?' is neither regarded as a domain of 'sustainable lifestyles' nor as an environmentally significant decision. A smaller part of the literature studies environmental citizenship and activist behaviours including voting, petitioning, and demonstrating (e.g. Wallis and Loy, 2021) while also green investing and supporting environmental groups are conceptualised as environmental behaviour (Nielsen et al., 2021; Stern, 2000). If behaviour at work is studied at all, it is mostly addressed as 'greening the workplace' through energy- and resource-saving practices similar to domestic practices (e.g. Blok et al., 2015; Ruepert et al., 2016). Accordingly, prevailing concepts and scales of 'environmentalism' and environmental behaviour neglect occupational choice and work as domains for environmental action (Dunlap et al., 2000; Stern, 2000).

These previously studied environmental behaviours can be clustered into two *ideas of effect*: *be* the change and *claim* the change. *Being the change* places the onus of change inside a self, focuses on the environmental footprint, and is primarily associated with the consumer role. *Claiming the change* places the onus of change outside to more powerful others and is associated with citizenship and activist behaviours like protesting, petitioning, or voting. This prevalent dichotomy overlooks the third idea of *doing the change*, of implementing transitions as a service for third parties. All three *ideas of effect* and the associated behaviours such as switching diets, joining climate strikes, or becoming an electrician, can have very different contextual constraints and enablers and thus be differently appealing and accessible for individuals (Stern, 2000). Therefore, this study aims to advance the understanding of factors influencing *doing the change* behaviours.

Despite its absence in environmental behavioural studies, research in adjacent discourses suggests that *doing the change* at work might be a particularly relevant behavioural role, especially for young people, for at least three reasons.

First, choosing a career is a far-reaching decision for adolescents, potentially creating path-dependencies in practices but also *moments of change* and *windows of opportunity* for sustainable behaviour change (Schäfer et al., 2012). Career choices influence many life domains including residence, social relationships, and daily practices (Elder et al., 2003), and, consequently, also the associated environmental impact. These infrequent behaviours and decisions such as the life event of adolescent career entry are largely understudied in environmental behavioural research despite their higher environmental impact than the most studied frequent behaviours (Ivanova et al., 2020).

Second, occupational identity is particularly salient for young people and has a major influence on adolescent identity formation (Savickas et al., 2009; Skorikov and Vondracek, 2011). Identity is a key factor influencing behaviours and decisions, including environmental behaviour, and has been proposed as a priority research perspective for transition and behavioural research (Bögel and Upham, 2018). Evidence from career research suggests that adolescents are considering environmental impacts in their occupational decisions and strive for purpose- and meaningful occupations (Lent and Brown, 2013; Međugorac et al., 2020; Savickas et al., 2009). Yet, relationships between occupational and environmental identities and related career choices remain understudied in environmental behavioural research.

Third, practical installation work can foster efficacy experiences and mental well-being. Previous research demonstrated that beliefs about one's ability to accomplish a behaviour (self-efficacy) and about its effectiveness in mitigating environmental change (response efficacy) are critical determinants of taking action (Bostrom et al., 2019). Efficacy beliefs are also presumed to influence how individuals cope with climate anxiety, a feeling particularly common among adolescents (Whitmarsh et al., 2022): low efficacy beliefs lead to paralysis, hopelessness, and powerlessness while higher beliefs increase behavioural engagement and, ultimately, psychological well-being (Clayton, 2020). Various studies find that installation and craftwork particularly increase efficacy beliefs and well-being because, other than employees in offices, craftworkers can see the finished physical result of their work (Binder and Blankenberg, 2022). However, environmental behavioural research on efficacy beliefs has so far either focused on self-efficacy for frequent consumption behaviours (e.g. Tabernero and Hernández, 2011) or measured response efficacy beliefs by just inquiring about the blanket perceived efficacy of "my actions" without explicating specific actions and behaviours in question (Bradley et al., 2020). Thus, research gaps remain regarding which specific behaviours and roles are associated with higher efficacy beliefs, particularly the occupational role of practical installation.

3. Methods

3.1. Emergent mixed methods research design

This work explored cases (Yin, 2018) of an emergent not yet scientifically conceptualised, thus "surprising" (Timmermans and Tavory, 2012) empirical phenomenon: implementation work as environmentally significant behaviour. To accompany this emergent field 'in real time', we took an exploratory and abductive research approach (Mitchell, 2018; Timmermans and Tavory, 2012) with an emergent mixed-methods design which allowed us to flexibly adapt to emerging findings and external conditions shaping the study (Creswell and Plano Clark, 2018). Fig. 1 displays the research process.

Mixed methods research involves the collection and analysis both of qualitative and quantitative data and builds on philosophical pragmatism (Mitchell, 2018; Tashakkori and Teddlie, 2010). Pragmatism emphasises doing 'what works' and using pluralistic approaches and the available means to explore and understand phenomena (Creswell, 2014). We chose a mixed methods approach to "harness strengths that offset the weaknesses of both quantitative and qualitative research" (Creswell and Plano Clark, 2018, p. 12) and get a more comprehensive understanding of the novel phenomenon. Resulting of the emergent research process, our design and respective analysis constitute a mixture of convergent and exploratory sequential designs. We emphasised the qualitative exploration of niche cases (see next section) over quantitative analysis as is common practice in mixed methods research when studying novel phenomena (Creswell and Plano Clark, 2018; Steckler et al., 1992; Tashakkori and Teddlie, 1998). We used the quantitative results to illustrate and validate the qualitative findings for the Solarcamps and to test their transferability to a different youth population. In mixed methods notation, the final design can be written as: *'quan + QUAL → quan = explore and generalise findings to Solarcamp participants and transfer to youth sample'* (Creswell and Plano Clark, 2018). With this approach, we follow recent calls to STR to move from primarily relying on qualitative single-case studies towards mixed methods (Hansmeier et al., 2021) and combining "in-depth attentiveness to particularity with the development of generic insight" (Köhler et al., 2019, p. 19).

3.2. Empirical case studies and data collection

We deliberately focussed our case studies on bottom-up niche initiatives rather than top-down activities of incumbents. Indeed, German governments on multiple levels as well as skilled trades associations launched image campaigns highlighting the opportunity to contribute to climate action in vocational jobs (e.g. BMWK, 2023; Solarcity Berlin, 2024; ZDH, 2022a, 2022b). However, few apprentices report having entered apprenticeships with pro-environmental intent (Rehbold and Rasch, 2022). Accordingly, these campaigns may be insufficient to overcome deeply engrained barriers to apprenticeships, specifically in groups addressed by the environmental messaging of the campaigns – a phenomenon well-researched in studies of behavioural change (e.g. Prochaska and Diclemente, 1983). Therefore, we focused on case studies of innovative niche initiatives involving 'environmentalists' (environmentally motivated individuals) in implementation jobs. This allowed us to explore the internal states of a population segment already aware and inclined (but not yet committed) to engage in implementation work as environmental behaviour and, thus, to better understand factors influencing the occupational decision after becoming aware. Moreover,

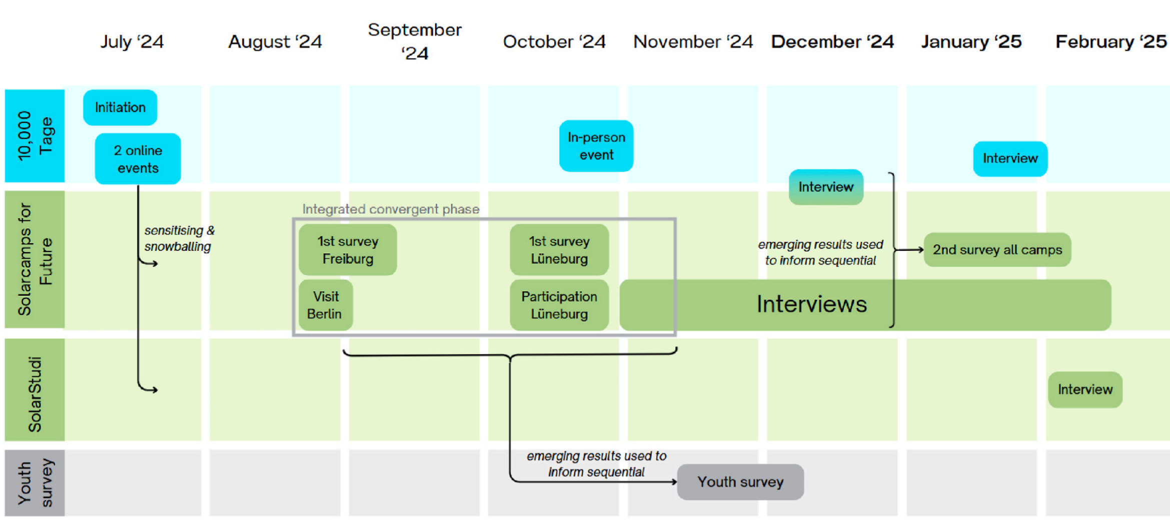

Fig. 1. This study's emergent research process and mixed methods design.

the focus on niche innovation is common in sustainability transitions research because these niches pioneer and showcase sustainable practices which may later be mainstreamed (Köhler et al., 2019).

We concentrated on PV installation as implementation job for several reasons. First, PV installation has the highest labour demand in energy transitions (IRENA & ILO, 2022). Second, the mounting of PV does not legally require formal qualifications – unlike, for example, the electrical connection of PV systems or heat pumps to the grid (Koneberg et al., 2022; Solar Energy UK, 2022; U.S. Bureau of Labor Statistics, 2024). Thus, the involvement of un- or semi-skilled helpers is common practice in the sector, also beyond Germany (Czako, 2022). This lowers formal entry barriers and allows the emergence of niche innovation. Thirdly and related, we only encountered PV-related bottom-up initiatives and none focussing, for example, on heat-pump installation or building insulation.

To complement the emergent findings of the niche cases with information beyond this 'particularity' and to explore their transferability to a different population, we also used data from an online survey among German adolescents which we conducted for a different research project.

The following subsections introduce the cases and elements of our mixed methods study. We collected this data between July 2023 and February 2024.

3.2.1. Case I: 10.000 Tage

10.000 Tage (English: 10,000 days) is an open social innovation project seeking to build multi-actor alliances for projects tackling the shortage of skilled workers in climate jobs (10.000 Tage, 2023). It was initiated in July 2023 by the NGO *Project Together* and supported by the German *Federal Ministry for Education and Research* (BMBF). During our research, we participated as non-participant observers with interaction (Bryman, 2012, p. 444) in one in-person and two online events organised between July and October 2023 for the involved initiatives to facilitate alliance-building. These observations together with information available from the project website sensitised us to the emergence of environmentally motivated bottom-up initiatives tackling the skill shortage in implementation jobs (*SolarStudi* and *Solarcamps for Future,* cases two and three). We further conducted semi-structured interviews with one of the initiators, a *Project Together* executive, and a leading activist from *Fridays For Future* who was involved in *10,000 Tage* and *Solarcamps for Future*.

3.2.2. Case II: SolarStudi

SolarStudi is a cooperation of the climate citizens' initiative *HalleZero* and a local installation enterprise in Halle initiated at the end of 2022 (HalleZero, 2023). *SolarStudi* organises employment opportunities, primarily for university students, to install PV as a side job. We gathered initial information about the initiative through the website and conducted one semi-structured interview with the initiator.

3.2.3. Case III: Solarcamps for future

Solarcamps for Future are summer camps organised by volunteers and promoted by the *Fridays for Future* movement in which participants learn basic skills of PV installation enabling them to work as installation helpers (Solarcamps For Future, 2023). The piloting camp in Braunschweig (2022) was followed by the camps in Kassel, Berlin, Freiburg, and Lüneburg between July and October 2023. For our analysis, we draw from participatory observation as non-participant observers with interaction of the camps in Lüneburg and Berlin, 14 semi-structured interviews with initiators, organisers, and participants, as well as two online surveys among participants (see Appendix B for an exemplary survey guideline). The observations informed the development of the interview guides and surveys. These surveys were co-developed and implemented with the organisers of the camps in Freiburg and Lüneburg and sent to participants by the local organisers. We followed this approach because the Freiburg camp had explicitly called for accompanying research on its website and all camps were to be evaluated via surveys regarding the quality of the instructions and participant satisfaction. Since the Kassel camp Kassel was finished when we became aware of the camps, the Freiburg camp was the first opportunity for us to add our questions to the survey developed by the organisers. The first survey is a full-population survey among all participants in Freiburg and Lüneburg and was conducted in September and October 2023 on the last day of the respective camp during a dedicated timeslot. The second survey was conducted between January and February 2024 among participants in Braunschweig, Berlin, Kassel, and Freiburg. Table 1 displays the samples of both surveys and the response rates in the second survey.

3.2.4. Online youth survey

Lastly, we conducted an online survey among German adolescents aged 16 to 25 between November and December 2023 (N = 1299) selected from the online panel of the provider *Bilendi* (Callegaro et al., 2014). *Bilendi* offered participants rewards for successful engagement and ensured approximate gender balance through several recruitment waves. We commissioned a sampling emphasis on students aspiring to or with university entrance qualifications because those can choose between academic education and the dual education required for implementation jobs. Additional information on the survey commission and the composition of the German youth population is provided in Table A2 in Appendix A. Table 2 displays the sample.

The sample is neither representative of the respective age cohort nor of the initial target population (young people between 16 and 23 years with or aspiring to university entrance qualification). Because the panel provider had difficulties recruiting enough men with the required educational background in the initial age range, they recruited male participants in the last wave from the age cohort up to 25 years without restrictions on educational backgrounds. Consequently, the sample has three main caveats: first, it comprises more women than men; second, female participants more often have or aspire to university entrance qualification than males; third, the share of male participants already in employment is higher and more men are over 23.

Table 1
Sample of first and second Solarcamp survey.

	1st Solarcamp survey (*N* = 68)		2nd Solarcamp survey (*N* = 41)	
variable	mean ± s.d.		mean ± s.d.	
Age	31 ± 9.9		29 ± 12	
	n	percentage	*n*	percentage
Location				
Lüneburg	23	34 %	–	–
Freiburg	45	66 %	22*	54 %
Braunschweig	–	–	4*	10 %
Kassel	–	–	11*	27 %
Berlin	–	–	4*	10 %
Gender				
male	33	49 %	25	61 %
female	27	40 %	14	34 %
diverse	6	9 %	2	5 %
not specified	2	3 %	–	–
Employment and education status				
high-school student	–	–	1	2 %
dual education	–	–	2	5 %
university student	26	38 %	21	51 %
employed	42	40 %	11	27 %
other	15	22 %	6	15 %

* response rates: Braunschweig 19 % (21 participants in total), Kassel 44 % (25 participants in total), Berlin 27 % (15 participants in total), Freiburg 49 % (45 participants in total).

Table 2
Sample composition of the online youth survey among German adolescents.

	youth survey ($N = 1299$)			
variable	male ($N = 516$)		female ($N = 783$)	
	mean ± s.d.		mean ± s.d.	
Age	22 ± 3.0		20 ± 2.6	
	n	percentage	*n*	percentage
Education*				
lower	187	36 %	135	17 %
higher	329	64 %	648	83 %
Employment and education status				
high-school student	109	21 %	262	33 %
dual education	41	8 %	64	8 %
university student	135	26 %	329	4 2%
employed	185	36 %	49	6 %
other	46	9 %	79	10 %

*participants with or aiming for university entrance qualification are coded as 1 (higher education) and others as 0 (lower education).

3.3. Data analysis

The results of the first Solarcamp surveys were concurrently integrated with our insights from interactions with camp organisers, participatory observations, and semi-structured interviews. The emerging findings of this first convergent phase then influenced the designs of the youth survey and the second Solarcamp survey (cf. Creswell and Plano Clark, 2018; Miles and Huberman, 1994, p. 41).

All interviews were conducted and recorded via *Zoom* and transcribed verbatim. The interview sample is summarised in Table A3 in Appendix A. We analysed interviews, answers to open-ended survey questions, and the websites of the three initiatives presented above through abductive thematic analysis (Thompson, 2022) using the software *Atlas.ti*.

For the surveys, we conducted statistical analyses in *RStudio*. According to the research aims and questions focussing on niche cases and empirical manifestations of the phenomenon 'implementation work as environmental behaviour', we restrict the analysis of the youth survey to follow the emerging leads from the niche cases. An in-depth analysis is beyond the scope of this paper.

3.4. Discussion of methods

Our results should be considered in light of several limitations resulting from the emergent research approach and the 'particularity' of the samples.

First, the samples bear inherent biases. Solarcamp surveys have a self-selection bias for participation in the camp. Consequently, Solarcamp participants are likely to be more settled in career plans, aware of the skill shortage as a transition bottleneck, environmentally minded, and inclined for craftwork than the general population. Furthermore, the samples between the two Solarcamp surveys vary: The first surveyed the full population of Freiburg and Lüneburg camp participants and the second surveyed four camps (excluding Lüneburg) with response rates of 20–50 %. Thus, the surveys address different camps at different times with different recruiting procedures which constitute confounding factors. Lastly, the sample of the youth survey is not representative, oversamples women with high education and employed men, and should not be considered a truly random sample due to the recruitment procedure. Accordingly, the results are not generalisable to the age cohort or target population and findings merely indicate potential effects which should be tested in future research with more representative samples.

Second, the exact formulation of questions and items partly differed across the surveys. Particularly in the youth survey the way possible barriers were elicited confounds the analysis: participants were first asked *"how well can you imagine working in any of the forms listed below in the trades of the future*[3]*?"* to elicit their willingness for part-time and full-time work before the succeeding question asked, *"what would be reasons for you personally why you would rather not work in the trades of the future"*. This formulation could undermine the independence of the subsequently reported barriers limiting the expressiveness of the analysis, particularly for those participants with high inclination (for example for full-time work).

Third, the depth of empirical material of the three case studies varies. *10,000 Tage* functioned as a 'door-opener' sensitising us to the emergence of initiatives involving environmentalists in PV installation and allowing us to 'snowball' to these initiatives. According to the emergent leads (cf. Charmaz, 2006), we did not conduct further data gathering for *10,000 Tage* beyond the two interviews and participatory observation. *Solarcamps for Future* then became the empirical emphasis, partly due to the offered support, for example by including our questions in their evaluation surveys, allowing participatory observation, and connecting us with participants for interviews. The third initiative, *SolarStudi*, was undergoing an internal change process within the initiative when we contacted them as the initiator and main organiser had gone abroad. Consequently, *SolarStudi* lacked the organisational support structure for a similarly in-depth data collection as with the *Solarcamps*. Therefore, we only conducted one interview with the initiator.

Overall, we believe that the versatility and richness of the data collected across these cases and the triangulation provide a thorough basis for our exploratory study and yield robust indications of possible effects. Ultimately, the strength of this paper lies in its abductive approach. It highlights relevant research gaps in STR and environmental behavioural research by concurrently drawing both from an extensive review of the respective literature streams and empirical manifestations of these overlooked aspects. Future research with representative samples and predetermined designs can now draw on our insights to develop and test informed hypotheses and thereby contribute to closing the research gaps.

4. Results

4.1. Integrated analysis of niche initiatives

4.1.1. Impact and recognition of implementation work as environmental behaviour

Our results reveal that the actors involved in the initiatives understand work in general and PV installation in particular as environmentally significant behaviour. Initiators, organisers, and participants motivate their involvement in the studied initiatives with their recognition that the shortage of skilled workers in implementation jobs impedes climate action, thereby highlighting both the environmental impact and intent of working in implementation jobs. Explaining their 'course of recognition', some interviewees refer to media coverage or own theoretical considerations others report having experienced the skills shortage themselves: "*And then I thought to myself: well, that means we really need to* anpacken[4] *practically and value this craft sector much*

[3] "Trades of the future" was used instead of 'solar trade' or 'climate crafts' in the youth survey as an umbrella term for roofers, electricians, and heating installers.

[4] Interview and survey participants, politicians, and campaigns all use the German verb "*anpacken*" relating to implementation work. However, word-to-word translation is difficult without loosing its nuancing connotations. *Anpacken* means proactively, energetically lending a hand to manually tackle and getting to grips with a problem. *Anpacken* is associated with physically arduous actions and implies getting one's hands dirty. It is often used to juxtapose and criticise standing aside while watching other people work. Due to these connotations, we keep the German word in the text. Prominently, the slogan of the Solarcamps is "*Anpacken for more climate action*".

more" (#SoSt).[5]

Besides this diagnosis, interviewees believe that "*jobs are influential because people spend as much time on nothing else in their lives as they do on their work, […] on average 10,000 days […]. If you use this time sensibly as a society […] to work against the climate crisis […] you can achieve a lot more"* (#SoCaOrg02). Solarcamp participants even believe that their occupational choice has a higher climate impact, *id est* response efficacy, than their consumption, lifestyle, or voting behaviour: 87 % believe they can contribute to solving environmental and climate problems through their occupational choice whereas only 53 % think this about their consumption (Fig. 2). As the initiator of *10,000 Tage* put it: *"I believe that what has so far been perceived as climate engagement is either personal consumption or political activism, but not work really."* (#10kd)

Consequently, particularly organisers and initiators report that a main goal of the initiatives and part of their motivation to get involved was "*to raise general awareness that these people are needed to implement [the energy transition] and also enhance the reputation of the trades themselves"* (#SoCaOrg03).

In summary, actors involved in our studied initiatives perceive gainful occupation and implementation work as particularly impactful yet under-recognised environmental behaviours.

4.1.2. Attractiveness of implementation work in niche cases

Our findings further reveal five main aspects which rendered PV installation a particularly appealing environmental behaviour, specifically for 'environmentalists' and groups not yet engaged in other environmental behaviours.

First, occupational choices become increasingly relevant for the youth environmentally 'ignited' in the *Fridays for Future* movement 2018/19. Many members of this cohort currently transition between high school, further education, and first job. This life event also confronts them with the question: "*either they say 'okay, my climate activism time is over now' or they make this life decision and say 'okay, my job should also contribute directly to reducing CO_2 emissions'."* (#10kd). At this 'moment of change', 'working for climate action' becomes particularly appealing for this cohort.

Second, interviewees regard PV installation as an attractive balance to and synergy with other occupations such as activism, office work, or studying. They highlight physical work as 'sport-like' balance to desk-based work, find that practical and *"climbing work"* (#SoSt) is fun, and believe that experiencing the practical side of the energy transition and knowing *"both sides"* (#SoCaPa04) helps them do better work as activists or energy engineers. Interviewees specifically highlight the attractiveness of installation work for students, particularly since the physically arduous and risky work is currently done by older employees: "*instead of going to the gym, they could install solar cells as a balance.'"* (#SoSt)

Third, these different benefits of PV installation as *doing the change* behaviour may make it appealing to groups less predisposed to engage in *being* or *claiming the change* behaviours such as changing diets or activism. For those, implementation work may be an attractive entry into environmental behaviours. Indeed, interview participants with less pro-environmental motivations report spill-over effects after the Solarcamps such as increased awareness and having changed diets: "*When I decided to go to the Solarcamp, [climate change] didn't play a primary role. […] Since Lüneburg […] I've become this CO_2 terrorist at home.* (#SoCaPa05).

Fourth and particularly important for 'environmentalists', practical installation work is associated with high self-efficacy and response efficacy in our case studies (even higher than in other behaviours, see Fig. 2). Many interviewees report powerlessness, paralysis, and anxiety in the face of climate change. Being frustrated with lacking success in demonstrating, particularly activist participants[6] experience practical installation work, the "*pragmatism of somehow just get into doing things*" (#SoCaPa01), as a "*moment of self-empowerment"* (SoSt) and effective coping mechanism. As posited in section 2.2, Solarcamp participants particularly ascribe these efficacy experiences to the fact that "*at the end of the day, I can see that I've built this"* (#SoCaPa03). Accordingly, 89 % of Solarcamp participants would recommend their friends to try out PV installation and 76 % believe "*that PV mounting is an effective strategy for feeling less powerless in the face of the climate crisis"* (see Table C2 in Appendix C).

Fifth and besides being an attractive complement, interviewees highlight the positive signalling effect of engaging in PV installation. Interviewees expressed worries that public support for the climate movement had recently decreased in Germany (More in Common, 2023). Particularly the emergence of the confrontational activist group *Letzte Generation* (English: Last Generation) engaging in civil disobedience had sparked a search in the German climate movement for forms of activism which could restore the public reputation of and support for the movement and climate policies. From interviewees' perspectives, showcasing their willingness to *anpacken* and *doing* boosts their legitimacy also to *claim the change*, augments the compatibility of their climate endeavours to a broader population, and potentially increases public support. "*We'll do something practical. We're not sticking ourselves on the street, we're doing crafts, we're going on the roofs, we're doing something with our hands.*"(#SoCaIn) *"Hey, we're not just claiming some utopian things all the time, we're also up for anpacken!"* (#SoCaOrg03). Accordingly, sending *"a political signal that activists are willing to actively help implement climate action"* was the second most frequently mentioned motivation to participate in the Solarcamps, reported by 61 % of the respondents[7] (see Table C3 in Appendix C).

4.1.3. Barriers to engaging in implementation work in the niche initiatives

Our results also reveal barriers to engaging in implementation work. Fig. 3 summarises these barriers reported in the Solarcamp surveys (see Tables C4 and C5 in Appendix C for additional information). Overall, perceiving *"working conditions in the skilled trades"* generally as unattractive is the first or second most frequently reported barrier in the first Solarcamp survey. Yet, the interviews and survey results provide more information on what specific *"working conditions"* might render implementation work unattractive for the studied groups.

First, 62 % of Solarcamp participants are inclined to work part-time (as auxiliaries) in the trades whereas only 22 % intend to start an apprenticeship and full-time employment in the trades. Additionally, 78 % of the Solarcamp participants believe "*that it would be attractive for many people to work one day a week as PV installation helpers"* (Table C2 in Appendix C). This preference for part-time work corresponds to the finding in section 4.1.2, that participants appreciate practical installation work as a balance and complement to other occupations such as office work rather than considering it as a means for occupational self-fulfilment. However, the current lack of part-time opportunities is a particularly relevant barrier for women, 79 % of whom report worries *"that it is not possible to work just a few days a week in the skilled crafts sector"*. Presumably, this is *"because of childcare […] and also because of the physical strain. I couldn't have imagined doing this manual labour five days a week"* (#SoCaOrg04). Moreover, having *"other interests that I want to pursue in my main job"* ranks among the most frequently reported barriers for Solarcamp participants, particularly for 86 % of women. This finding also corresponds to the overall predisposition of the Solarcamp participants whose primary motivation was *"to learn skills so*

[5] The following sections just include quotes in fragments to be concise and increase reasibility. Full quotes are provided in Appendix D.

[6] Most interviewees regarded *doing* as complement not alternative to *claiming* and *being* behaviours.

[7] This pertains for the entire sample. For FINTA participants, signalling that expliticly FINTA people are willing to *anpacken* and learn installation skills in a safe space was even more relevant.

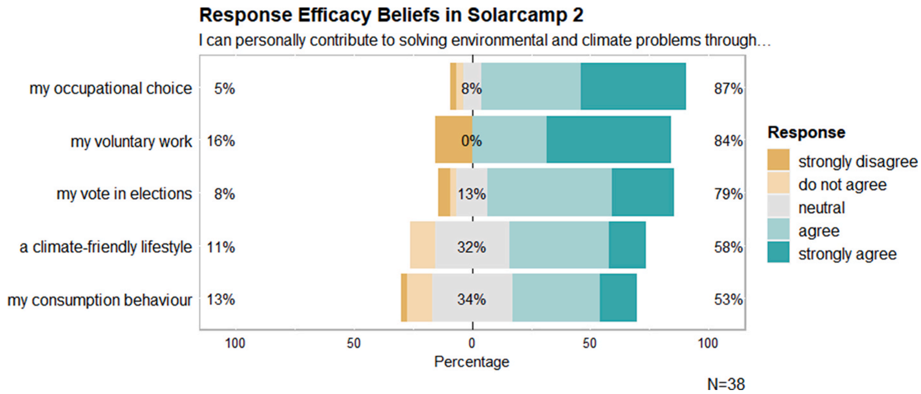

Fig. 2. Solarcamp participants consider their occupational choice as largest lever for climate impact.

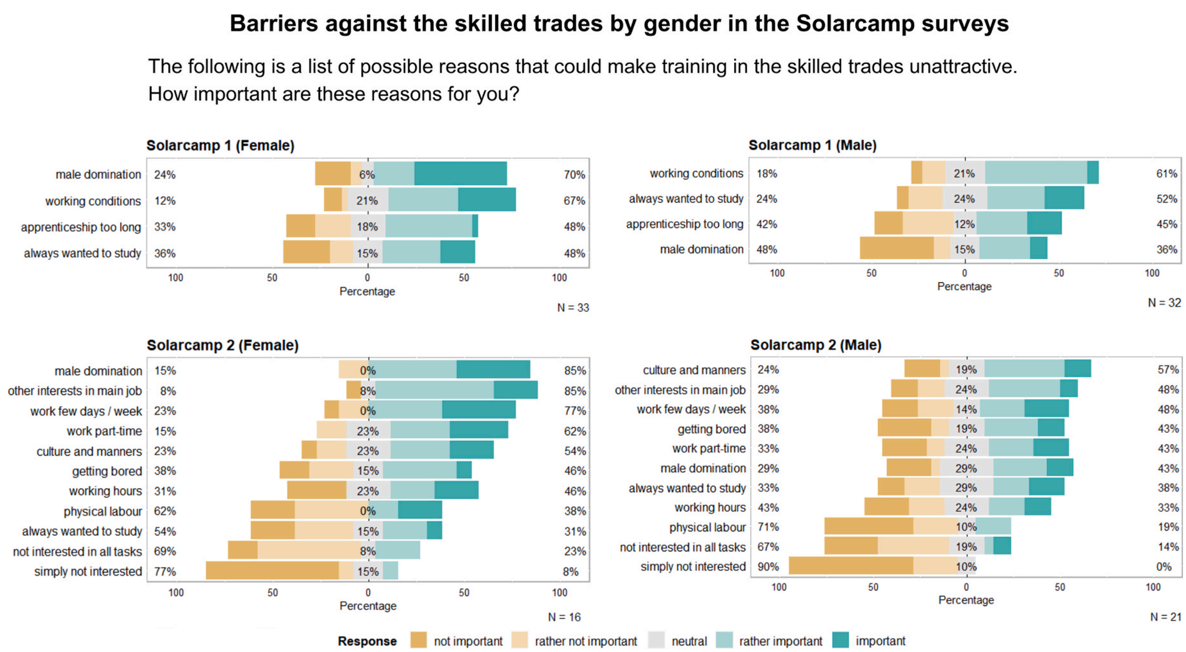

Fig. 3. Cultural aspects and preferences for working part-time in PV installation as a complement to other (academic) occupations constitute the main barriers among Solarcamp participants.

that I could work part-time in PV installation after the camp", reported by 76 % of the participants. This predisposition to pursue other interests as main jobs might also be the reason why the length of the apprenticeship was a frequently reported barrier in the first Solarcamp survey.

Second, the results confirm previous work discussed in sections 1 and 2 revealing that the male-dominated environment and communication culture in the skilled trades particularly deter women. Being *"worried about male-dominated, patriarchal and/or discriminatory structures in the skilled trades"* is the most frequently reported barrier among female Solarcamp participants with 70 % agreement in the first and 86 % in the second survey. Female survey and interview participants expressed feeling *"uncomfortable among male-only employees"* (participant second Solarcamp survey) both related to discrimination (*"the stupid chatter often annoyed"* (participant second Solarcamp survey)) and to personal insecurities with manual skills and technical knowledge. Female interviewees recurrently stressed the importance of the Solarcamp as a safe space and low-threshold entrance for women to try out craftwork and make mistakes. Accordingly, sending *"a political signal that FINTA people are also willing to actively help implement climate action if the framework conditions are right"* and *"deliberately [wanting] to learn PV installation skills in a safe space (safe and non-discriminatory setting) for FINTA people"* were reported by 71 % and 64 of FINTA people, respectively, as relevant motivation for participating in the Solarcamp (Table C3 in Appendix C).

Third, although female Solarcamp participants reported insecurities with practical craftwork before the camp they also described how the practical engagement boosted their self-efficacy to accomplish installation work and found that craftwork such as "cutting with an angle grinder just really was fun" (#SoCaPa02). Accordingly, Solarcamp participants predominantly report that the Solarcamps positively changed their confidence in their "general craft skills", their ability to "learn the activities of PV installation", their "understanding of the practice [and theory] of PV installation", and, ultimately, their "interest in working in the solar/climate trades" (Table 3). After accomplishing the Solarcamp, only 36 % of female participants reported worries of not being "cut out for physical labour". These findings suggest that missing low-threshold entrance opportunities and safe spaces to develop practical self-efficacy constitute severe barriers to attracting particularly women into these jobs.

Fourth and associated, the dearth of contact obstructs not only

Table 3
Reported changes after the Solarcamp in the second Solarcamp survey.

Listed below are various things that the Solarcamp may have changed for you. Please indicate in which direction the Solarcamp has changed your perception. The Solarcamp has changed … *

	male ($N = 24$)		female/gender-diverse ($N = 14$)	
	positive change in %	mean ± s.d.	positive change in %	mean ± s.d.
my confidence in my general craft skills	68	3.9 ± 0.21	56	3.9 ± 0.21
my confidence that I could learn the activities of PV installation	72	4.3 ± 0.17	81	4.2 ± 0.16
my understanding of the theory of PV installation	80	4.3 ± 0.15	81	4.4 ± 0.17
my understanding of the practice of PV installation	88	4.5 ± 0.12	87	4.8 ± 0.11
my interest in working in the solar/climate trades	68	4.1 ± 0.17	81	4.3 ± 0.16

* measured on a 5-point Likert scale from 1 = "very negatively" to 5 = "very positively" with positive change coded as 4 and 5.

women but also other 'distanced groups', particularly academics. Interviewees reflect on the 'social silos' of academics and craftspeople and notice that "*the way our society is structured, the classic craftsman is very far removed from the young student*" (#SoSt). Moreover, they reveal that they "*would never have thought of [apprenticeship]*" leaving high school (#SoCaPa02). Accordingly, "*it was always clear to me that I would study*" is the second and third most frequently reported barrier among male and female Solarcamp participants in the first survey, respectively. Because of this distance, academics "*may also have prejudices [about the trades] and that's why our aim was to break down this distance and create a space for everyone to try themselves out. […] We just had the chance […] to appeal to people who aren't usually addressed […] since we were associated with the For Future movement*" (#SoCaOrg04). Many experienced the 'social mixing' during installation as fun, enriching, and a great opportunity "*to allow both sides to learn from each other*" (#SoCaPa03) and to develop a "*better mutual understanding*" (#SoCaPa01). However, some Solarcamp participants perceived the culture at the construction site as problematic and being "*worried that I won't feel comfortable with the culture and manners in the skilled trades*" was reported as relevant barrier by over 50 % of Solarcamp participants of both genders. Thus, increasing the diversity and 'social mixing' at the construction site was proposed by several participants as a promising strategy to make PV installation more appealing to currently deterred groups.

4.2. *Quantitative analysis of youth survey*

Based on our investigations of the niche initiatives, we employ the youth survey to explore the transferability of these results to a different population. As the sample is not fully representative, we urge caution in the interpretation of the following results. Our analyses reflect compositions and relationships within our sample and merely indicate potential effects beyond. These should be tested with more representative samples in future research.[8]

We expect results in section 4.2 to partly diverge and partly coincide with those of section 4.1 due to the particularity of the niche cases (including self-selection, environmental motivation, awareness of skill shortages, and practical experience with PV installation in the Solarcamps).

First, we expect that due to the lower public salience of work in climate action, response efficacy beliefs for occupational choice in the youth survey will be exactly the opposite, thus, lower than for the other environmental behaviours. We find this hypothesis confirmed in that two-thirds of participants believe in the environmental impact of their consumption behaviour, while only one-third believe in the environmental impact of their occupational choice (Figure E1 in Appendix E).

Second, we expect that also participants in the youth survey will be more inclined to work part-time than full-time due to the flexibility to pursue other interests in another occupation. We find also this hypothesis confirmed in that 27% are interested in working full-time in the trades but 45% are interested in working part-time. Coinciding with the previous findings, this part-time preference particularly pertains to 'unconventional target groups' for VET and the skilled trades such as women and highly educated (Tables E2, E3, and E6).

Third, we expect that barriers to working in the trades in the youth sample differ from the Solarcamp participants due to the particularity of the latter. For that, we investigate descriptive statistics and perform regression analyses on the most frequently reported barriers and the willingness to work in the trades (Figure E2 and Tables E2-E6 in Appendix E). Our findings suggest that, for our sample, first, physical labour is the main barrier to work in the trades for women; second, knowledge about the trades is the primary predictor for the willingness to work in the trades – hence, constitutes a severe barrier if low; third, focus on university careers make full-time engagement in the crafts unattractive but opens doors for part-time participation.

For full results and differences between different subgroups see Appendix E.

5. Implications and conclusion

5.1. *Contributions to transition studies and environmental behavioural research*

Our study makes four main scientific contributions.

First, based on a literature review we propose the question 'What do we do in our working time?' as an intersectional, relevant, and topical research area for different disciplines researching environmental challenges, including sustainability transition and environmental behavioural research.

Second, by exploring case studies of innovative initiatives in Germany, we demonstrate that the understanding of work as environmentally significant behaviour is empirically manifested. Yet, our findings transcend the established *environmental* lens on behaviour by establishing a *transformational* lens. This transformation lens acknowledges the temporality and procedural character of systemic sustainability transitions, occurring in stages where they face different challenges and require different actions (Markard et al., 2020). In contrast to *environmentally significant* behaviours, the impacts of *transformationally significant* behaviours are not determined by the time-independent direct CO_2 emissions but by the contribution to the acceleration of the transition. While the notion of rate-determining 'bottlenecks' is rather new in transition research and practically absent from behavioural research, it is long-established in other disciplines such as chemical kinetics: the speed of a process is determined by the slowest step. Acceleration, thus, requires intervention and additionality at this rate-determining step (Atkins et al., 2022, p. 814). *Transformationally significant* behaviours strategically target these rate-determining bottlenecks. In this study, implementation work (*anpacken*) emerges as *transformationally* significant behaviour tackling skilled workers shortage as transition bottleneck.

Third, our results underline previous findings highlighting barriers

[8] We further acknowledge debates on the expressiveness and appropriability of *p*-values, particularly when dealing with 'convenience samples' in social science research (e.g. Amrhein et al., 2019; Hirschauer et al., 2020; Wasserstein et al., 2019; Wasserstein and Lazar, 2016). This youth survey cannot reasonably be considered a truly random sample due to the panel recruitment procedure. Nevertheless, we provide *p*-values as well as standard errors in the Appendix owing to the different disciplinary conventions of our supposed readers but highlight the limitations.

and equity issues in the trades, particularly affecting women. Specifically, we find a high inclination to work part-time in PV installation complementing other occupations such as another job, volunteering, or care work. Yet, implementation work in the trades and (re-)training opportunities largely require full-time engagement. Similarly, the male-dominated environment appears to be particularly deterring for the female environmentalists in our observed niche cases. Crucially, the lack of knowledge and experience with the trades constitutes a major difficulty in attracting more people and 'unconventional' target groups into implementation jobs. Missing low-threshold entrances and safe spaces for women to try out installation as well as the dearth of points of contact between the social 'silos' of academics and craftspeople perpetuate this difficulty.

Fourth, *doing the change* at work, for example by installing PV, is marked by distinctive (non-environmental) characteristics differentiating it from *being* and *claiming the change* behaviours and constituting its distinctive appeal to different groups. Efficacy experiences during installation, physical aspects of *anpacken*, and financial rewards might render implementation work an attractive complementary role for environmentalists already engaging in *claiming* and *being the change* behaviours. Yet additionally, these non-environmental aspects could also appeal to groups currently not engaging in other environmental behaviours. For these groups, *doing the change* at work could foster active learning (Creutzig and Kapmeier, 2020) and constitute a 'foot-in-the--door' to forming an environmental identity, potentially leading to spill-over effects between roles as worker, consumer, and citizen (Nilsson et al., 2017). Ultimately, broader engagement in environmental behaviours could increase public support for climate action (Creutzig and Kapmeier, 2020).

5.2. Implications for further research, practice, and policymaking

Our study bears relevant implications for practice and policymaking and signposts an agenda for further interdisciplinary research. Policy implications primarily relate to facilitating entry and (re-) structuring labour conditions.

Image campaigns may be an effective first step to raise awareness and knowledge about implementation jobs and increase social recognition for the trades and their craftspeople who currently feel socially underappreciated (Wehden et al., 2025). Since one key reason for citizens turning to mostly right-extreme parties is a perceived lack of recognition by public discourses (Amlinger and Nachtwey, 2022; Honneth, 1995), increasing the social recognition of the crucial role of the trades in climate action could foster support for the transition among these groups and further stabilise democracy. Moreover, such campaigns may initially even attract more people into implementation jobs increasing the salience of the environmental attributes and knowledge about the trades in potential target groups. However, they likely are insufficient to overcome more engrained barriers to VET and to retain people in these jobs. Therefore, practice and policymaking should promote points of contact with the trades and provide safe spaces and low-threshold entrance opportunities to try out craftwork and acquire a realistic idea of these occupations, particularly for women. To increase knowledge and experience, educational policy should (re-)introduce craft and technical work into primary and high school curricula to create practical learning opportunities from early childhood on. Moreover, all social players are called upon to facilitate social mixing between the 'silos' of academics and craftspeople. In this regard, expanding Solarcamps together with civil society organisations reaching currently not engaged target groups appears a promising and practice-approved strategy to provide social mixing, low-threshold entrance, and safe safes for women.

As for labour conditions, this paper highlights high inclinations in our studied samples for *doing the change* as installation helpers as a complementary and attractive role for environmental behaviour. However, despite the common practice in the PV sector to deploy un- or semi-skilled helpers under the supervision of formally qualified tradespeople (Czako, 2022), the most severe shortages are at these higher skill levels of journeymen and master craftspeople (Koneberg et al., 2022). Additionally, these helpers mostly possess specialised and untransferable skills increasing their vulnerability to sector-typical economic oscillations. While this vulnerability might be less relevant for groups pursuing auxiliary work as a secondary occupation, promoting people from low-threshold try-outs like Solarcamps into formal VETs and retaining them in fully qualified occupations such as electricians is crucial to effectively tackle skill shortages at higher qualification levels. Accordingly, Solarcamps could prospectively prioritise younger target groups who are not as advanced in their education and career paths as the studied cohort and might thus be more open to apprenticeship and full-time jobs in vocational bottleneck professions.

Nevertheless, the high inclination for *doing the change* part-time reveals underutilised potentials both from a systemic perspective regarding the size of the installation workforce and from an individual perspective regarding the set of accessible options to participate in low-carbon transitions and, ultimately, to experience climate self-efficacy. Thus, enterprises, social partners, and policymaking are challenged to develop part-time schemes for working and (re-)training in installation jobs both as helpers and fully qualified tradespeople, particularly to attract and retain women. Crucially, if the deployment of un- or semi-skilled helpers increases, these schemes need to attend to the special demands placed on the construction site and process management and the supervising tradespeople to ensure installation quality and occupational safety. Issuing mandatory minimum certifications for occupational safety, developing work processes and quality management that account for requirements of auxiliaries, and training tradespeople for the increased importance of supervision and on-the-job-training are important pillars of such schemes.

Lastly, given the identified structural barriers to developing a low-carbon workforce, raising the low unionisation in the trades and promoting labour agreements are essential to guarantee secure jobs, good working conditions, fair wages, and upskilling opportunities in low-carbon transitions. Thereby "[r]enewing societal trust in a labour market [...] can turn the labour force from a bottleneck to a positive force in the transition" (Kuokkanen, 2023, p. 4).

This exploratory study provides promising starting points for future research which could test, differentiate, and substantiate our emergent results with more representative samples and predetermined designs. Environmental behavioural research could further examine efficacy experiences in practical installation, psychological and social differences between *being, claiming* and *doing* behaviours, and the life event of adolescent career entry. Sustainability transition research should attend more to the installation step of low-carbon technologies and the implementing workforce as potential transition bottlenecks and explore promising governance arrangements. Crucially, more research on other implementation jobs and geographies is needed. Due to Germany's increased policy ambition and advancement to "later transition stages" this study's focus provides relevant insights for the international audience. However, studies on other countries with different labour markets, education systems, and regulatory frameworks as well as on different technologies will contribute valuable facets to a more comprehensive understanding of implementation work. Lastly, more research on gender issues in implementation jobs is urgently needed to ensure gender-equitable transitions which enable the non-engaged half of the population to participate in climate action at work.

CRediT authorship contribution statement

Simon Wehden: Writing – original draft, Visualization, Supervision, Software, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Helen Garber:** Writing – review & editing, Software, Formal analysis, Conceptualization. **Myriam Aichinger:** Writing - review & editing, Software, Investigation, Formal analysis. **Eva Hempel:** Investigation. **Felix Creutzig:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Kathryn B. Janda:** Supervision, Conceptualization.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used *NoScribe* to create first versions of interview transcripts and *DeepL* in order to translate the German texts into English. After using these, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Simon Wehden reports financial support was provided as PhD scholarship by Heinrich Boll Foundation. Myriam Aichinger reports financial support was provided as student scholarship by Heinrich Boll Foundation. Simon Wehden reports administrative support was provided by Solarcamps for Future. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank Larissa Ziegler, Philipp George, and Johanna Hauke for their support in developing and implementing the Solarcamp surveys as well as all other local organisers and the federal organisation board of the Solarcamps for diffusing the surveys. We thank Linda Ghirardello, Jonas Ludwig, and Aneeque Javaid for their methodological advice. We acknowledge PhD and student scholarships for Simon Wehden and Myriam Aichinger funded by the Heinrich Böll Foundation and further funding for the youth survey from Einstein Center Climate Change.

Appendix A. Tables on data collection and samples

Table A1
Commissioning of the youth survey among German adolescents

Sample	Number of cases	$N = 1.300$
	Country	Germany
	Questionnaire length	12 min Assumption that the study can be conducted with mobile devices.
	Target group	Men and women aged 16–23 who live in Germany and 1.1 who are aiming for a university entrance qualification (i.e. who are in a school that aims for university entrance qualification) 1.2 already have a university entrance qualification and are currently in a transition phase (e.g. gap year) between school and university/training 1.3 have discontinued their studies/training and are in the process of reorientation 1.4 are currently studying for a Bachelor's/Master's degree/are in training 1.5 are still pupils (school does not have to aim for the university entrance qualification) 2. Please complete the sample with men and women aged 16 to 23 who live in Germany. Note: Participants from groups 1.5. and 2 will only be invited if there are no participants from categories 1.1–1.4 can no longer be recruited. If necessary, the age can be extended to 25.
	Quotas	Good distribution by gender and age (2 classes)
	Incidence rate	90–100% within the pre-selected men and women aged 16–23 years
Bilendi services	• Invitation of survey participants • Incentivisation of the participants • Free over-recruitment of up to 10% of the sample for data cleansing	

Table A2
Composition of age cohort of 15–24 year-old inhabitants in Germany in 2023, provided on request by the German Federal Office of Statistics based on the Micro-Census 2023.

	German inhabitants between 15 and 24 in 2023				
	total	male		female	
variable		n/1000	percentage (within gender group)	n/1000	percentage (within gender group)
total	8474	4387	52 %	4087	48 %
Education*					
lower	4332	2486	57 %	1846	45 %
higher	4142	1900	43 %	2241	55 %
Employment and education status†					
high-school student	2550	1296	30 %	1255	31 %
dual education	1772	960	22 %	812	20 %
university student	1555	717	16 %	838	21 %
employed	4270	2284	52 %	1985	49 %

*lower education is coded as the sum of people without university or university of applied science entrance qualifications minus those going to a Gymnasium (German high-school for acquiring university entrance qualification); higher education is coded as the sum of people with university or university of applied science entrance qualification plus those going to a Gymnasium.
†The sum of employment and education status exceeds the total number in the age cohort. This presumably is due to double counting employed people in education.

Table A3
Composition of the final interview sample.

Study	Role	ID
10.000 Tage	executive	#10kd
SolarStudi	initiator	#SoSt
Solarcamps	initiator of the first Solarcamp	#SoCaIn
Solarcamps	co-organiser of the first Solarcamp	#SoCaOrg01
Solarcamps, 10,000 Tage	co-organiser of a Solarcamp, leading member of FFF Germany, participant in 10,000 Tage	#SoCaOrg02
Solarcamps	co-organiser of a Solarcamp	#SoCaOrg03
Solarcamps	co-organiser of a Solarcamp	#SoCaOrg04
Solarcamps	participant	#SoCaPa01
Solarcamps	participant	#SoCaPa02
Solarcamps	participant	#SoCaPa03
Solarcamps	participant	#SoCaPa04
Solarcamps	participant	#SoCaPa05
Solarcamps	participant	#SoCaPa06
Solarcamps	participant	#SoCaPa07
Solarcamps	participant	#SoCaPa08
Solarcamps	participant	#SoCaPa09

Appendix B. Exemplary interview guide

In the following, we provide an exemplary interview guide for the semi-structured interviews among Solarcamp participants which we adapted to initiators, organisers (see exemplary questions in parantheses), and for the *Solarstudi* and *10,000 Tage* interviews.

Questions on the Solarcamp.

- What is the Solarcamp in your words?
- How would you describe the aims of the Solarcamp?
- What problems is the Solarcamp trying to tackle?
- (How did the idea of the solar camp come about?)
- (Where should the solar camps develop from your perspective?)

Questions on personal motivation.

- Why did you take part in the Solarcamp?
- How did you hear about the Solarcamp?
- What did you learn/take away?
- Has the Solarcamp changed anything for you?
- What purpose does the Solarcamp fulfil for you personally?

Questions on activism/climate protection:

- What does climate protection mean to you?
- Are you an activist/volunteer? And if so, in what form?
- Do you have a connection to Fridays for Future, who are co-organisers of the camp, or another social movement?

Questions on craft and jobs:

- What job do you currently do?
- Do you have experience with crafts?
- Can you imagine going into the trades?
- What is your personal goal for your future work?

Concluding question.

- Is there anything else you would like to talk about? Or would you like to emphasise something in particular?

Appendix C. Tables for Solarcamp surveys

Table C1
Response efficacy beliefs among Solarcamp participants.

This question is about how you assess your own opportunities for climate action. I can personally contribute to solving environmental and climate problems through … *		
2nd Solarcamp survey ($N = 38$)	agreement in %	mean ± s.d.
my consumption behaviour.	53	3.5 ± 0.97
a climate-friendly lifestyle.	58	3.6 ± 0.87
my vote in elections.	79	3.9 ± 0.98
my occupational choice.	87	4.2 ± 0.90
my voluntary work.	84	4.3 ± 0.89

* measured on a 5-point Likert scale from 1 = "strongly disagree" to 5 = "strongly agree" with agreement coded as 4 and 5.

Table C2
Attractiveness of PV installation reported in the second Solarcamp survey.

How much do you agree to the following statements?*		
2nd Solarcamp survey ($N = 37$)	agreement in %	mean ± s.d.
I would recommend my friends to try out PV installation.	89	4.5 ± 0.76
I think that PV mounting is an effective strategy for feeling less powerless in the face of the climate crisis.	76	4.0 ± 1.1
I think that it would be attractive for many people to work one day a week as PV installation helpers.	78	4.1 ± 1.0

* measured on a 5-point Likert scale from 1 = "strongly disagree" to 5 = "strongly agree" with agreement coded as 4 and 5.

Table C3
Main reasons for participating in the Solarcamp reported in the second survey.

The following are possible reasons that could have motivated you personally to take part in the Solarcamp. Please indicate how important these motivations were for you personally:*		
2nd Solarcamp survey ($N = 38$)	Importance in %	mean ± s.d.
I wanted to learn skills so that I could work part-time in PV installation after the camp.	76	3.8 ± 1.1
I wanted to send a political signal that activists are willing to actively help implement climate action.	61	3.5 ± 1.4
I deliberately wanted to learn PV installation skills in a safe space (safe and non-discriminatory setting) for FINTA people.	64⚧	3.7⚧ ± 1.3⚧
I wanted to send a political signal that FINTA people are also willing to actively help implement climate action if the framework conditions are right.	71⚧	3.8⚧ ± 1.1⚧

* measured on a 5-point Likert scale from 1 = "not important" to 5 = "important" with importance coded as 4 and 5.
⚧just female and gender-diverse participants ($N = 14$).

Table C4
Barriers to working in the trades reported in the first Solarcamp survey.

The following is a list of possible reasons that could make training in the skilled trades unattractive. How important are these reasons for you?*				
	male ($N = 33$)		female/gender-diverse ($N = 33$)	
	importance in %	mean ± s.d.	importance in %	mean ± s.d.
The working conditions in the skilled trades don't seem attractive to me.	61	3.4 ± 1.0	67	3.8 ± 1.2
It was always clear that I would study.	52	3.4 ± 1.2	48	3.1 ± 1.5
I am worried about male-dominated, patriarchal and/or discriminatory structures in the skilled crafts.	36	2.6 ± 1.5	70	3.8 ± 1.6
The apprenticeship is too long for me.	45	3.1 ± 1.4	48	3.0 ± 1.2

* measured on a 5-point Likert scale from 1 = "not important" to 5 = "important" with importance coded as 4 and 5.

Table C5
Barriers to working in the trades reported in the second Solarcamp survey.

The following is a list of possible reasons that could make training in the skilled trades unattractive. How important are these reasons for you?*				
	male ($N = 22$)		female/gender-diverse ($N = 14$)	
	importance in %	mean ± s.d.	importance in %	mean ± s.d.
I'm worried that I won't feel comfortable with the culture and manners in the skilled trades.	55	3.3 ± 1.5	57	3.6 ± 1.4
I have other interests that I want to pursue in my main job.	45	3.1 ± 1.5	86	4.0 ± 1.0
I'm worried about male-dominated, patriarchal, and/or discriminatory structures in the trades.	41	3.0 ± 1.6	86	4.1 ± 1.0
I'm worried that it is not possible to work in the skilled crafts sector just a few days a week.	45	3.2 ± 1.6	79	3.9 ± 1.3
I'm worried that it is not possible to work part-time in the skilled crafts sector.	41	3.1 ± 1.7	64	4.0 ± 1.1
I'm worried that I would get bored working in the trades in the long term.	41	2.8 ± 1.6	43	2.9 ± 1.4
The working hours in the skilled crafts don't suit me.	32	2.7 ± 1.6	50	3.2 ± 1.9
It was always clear to me that I would study.	38	3.1 ± 1.6	31	2.5 ± 1.4
I'm worried that I'm not cut out for physical labour.	18	1.9 ± 1.2	36	2.7 ± 1.5
I'm worried that I wouln't be interested in all the tasks in the skilled trades of the future.	14	2.1 ± 1.3	21	2.3 ± 1.1
I'm simply not interested in working in the solar/climate trades.	0	1.3 ± 0.4	7.1	1.7 ± 0.9

* measured on a 5-point Likert scale from 1 = "not important" to 5 = "important" with importance coded as 4 and 5.

Appendix D. Exemplary full-length interviews quotes

For section 4.1.1: Impact and recognition of implementation work as environmental behaviour.

Realising work skilled worker shortages as bottleneck

"How do we actually get the climate transition done? […] You can somehow break it down to regulation, capital and personnel. […] Okay, let's assume that the things that the Habeck Ministry[9] *is now pushing for all go through and we also see that this regulatory pressure leads to the capital side being pulled along. Then there is a bottleneck that can still lead to the fact that none of this will be of any use, namely securing personnel and skilled labour. […] Policies not only fail when they are adopted, but also when they are implemented [on-the-ground]."* (#10kd)

"During this planning [for a big solar day on the market square in Halle] we realised: the companies are not responding [to our mails], even though it should be great for them to get lots of customers. And then we realised that they weren't responding because customers currently aren't their problem. Actually, they have far too many enquiries and can't keep up because they don't have enough workers […]. And then I thought to myself: well, that means we really need to anpacken[10] *practically and value this craft sector much more."* (#SoSt)

Raising awareness for the importance of implementation work(ers)

"The political signal was: more recognition [for the trades], especially among academics, […] and towards politicians who simply don't support the trades as much as we would like them to. In all the discussions about climate action, there is not much said about the trades." (#SoCaOrg04)

For section 4.1.2: Attractiveness of implementation work in the niche cases.

Cohort effect

"What if I went out on the streets as a climate-conscious young person and dedicated my entire life to the climate transition? What can I do if I want to keep involved? Those who were 14/15 when Fridays for Future started are now leaving school […]. They have two options: either they say 'okay, my climate activism time is over now' or they make this life decision and say 'okay, my job should also contribute directly to reducing CO_2 emissions'." (#10kd)

Balance to and synergy with other occupations such as activism, office work, or studying

"I've seen in my Solarcamp internship that [an idea] is nonsense because it's very difficult to implement practically. I now know both sides and can imagine using the knowledge again for a bachelor's thesis." (#SoCaPa04)

"These are the people who will be developing the solar cells for tomorrow but they don't know how to screw something like this onto the roof." (#SoSt)

"Many students need to work beside their studies, […] there are overlaps between this trade and many degree programmes, […] and the work assignments for installing PV are super flexible […] which also fits well with the everyday working life of students […]. Then I thought to myself: 'why do the old men go up on the roof to install the heavy solar cells, who already have back pain while […] many students are frustrated with sitting in the library […] and having to do cognitive work all the time without any external structure. Instead of going to the gym, they could install solar cells as a balance.'" (#SoSt)

Foot-in-the-door and spill-over effect

"That's why I found this transformation after Lüneburg so encouraging. […] My wife always said 'let's eat vegan or vegetarian, let's eat less meat', I always smiled at her. After Lüneburg, I was the one who changed my diet. […] When I decided to go to the Solarcamp, [climate change] didn't play a primary role. It was clearly about finding a new professional focus, getting into the solar trade and getting training on the roof […] Since Lüneburg […] I've become this CO_2 terrorist at home. […] I'm thinking a lot more about it, awareness has definitely increased." (#SoCaPa05).

Climate self-efficacy and response efficacy

"Before [the Solarcamp] I felt this sense of despair, I thought everything was somehow lost. And now I think I can do my bit. […] I can get involved in projects like this one that we are now planning [installing PV in socially disadvantaged districts]." (#SoCaPa03)

"It felt great to realise 'hey, I can get involved myself. I'll just screw this shit on myself, even if politics is somehow lagging. […] It was a moment of self-empowerment, […] of 'cool, we're doing something here right now'. […] The big problem we have is […] a total lack of hope. […] [SolarStudi] is a

[9] Note: Robert Habeck is German Minister for Economics and Climate Action.

[10] Interview and survey participants, politicians, and campaigns all use the German verb "*anpacken*" relating to implementation work. However, word-to-word translation is difficult without loosing its nuancing connotations. *Anpacken* means proactively, energetically lending a hand to manually tackle and getting to grips with a problem. *Anpacken* is associated with physically arduous actions and implies getting one's hands dirty. It is often used to juxtapose and criticise standing aside while watching other people work. Due to these connotations, we keep the German word in the text. Prominently, the slogan of the Solarcamps is "*Anpacken for more climate action*".

small project of self-empowerment, an experience of self-efficacy. Which of course also gave me this feeling during the assignments: 'We can actually do it. And what do we have to do next? '[…] And that gives me hope. […] And I think it's great when students go out and say 'hey, I feel really good right now, I've just done something cool, it's a great feeling, I want to do more of it'." (#SoSt)

"It's not just this 'okay, I spend the whole day working on sustainability, but then I don't know how this contributes to it in any way'. It's more outcome-focused. In the end, you can see or know how something comes out of it." (#SoCaPa01)

Positive signalling effect of engaging in PV installation

"Under this original Tweet from Fridays for Future about the Solarcamps, you read comments like 'Normally I don't identify with the climate movement at all, but this is a good thing.' […] And you suddenly realised 'We've come across an idea that isn't generating resistance anywhere.' […] [In Berlin] they've established themselves as a contrast to the Last Generation and said 'We'll do something practical. We're not sticking ourselves on the street, we're doing crafts, we're going on the roofs, we're doing something with our hands.'"(#SoCaIn)

For section 4.1.3: Barriers to engaging in implementation work in the niche initiatives.

Part-time

"If it were possible to work 1–2 days a week in the trades, I would be up for it and think that [climate activism and solar trade] would also fit together ideally and make a good mix of office and practical work. I can also think of many people who would have the need for something like this and would then like to work part-time in this area." (participant 1st Solarcamp survey)

"I think the most important thing for me would be to be able to work in several jobs […] That [implementation work] is spread over several shoulders [and that] not just a few people are completely in the trades and then often bear physical consequences and others not at all and then also have psychological problems. […] That craft businesses become more flexible with working hours and that there is not just this five-day week. […] When people sit at a desk for 30 years … […] I could imagine that it would also be better for their mental health if there was more physical work involved. […] So for me, the trades were always great, it was really good for my psyche." (#SoCaOrg04)

Male-dominated environment and communication culture

"I've often had the experience […] as a woman, when it comes to technical things … So I definitely feel that if you don't get it right straight away, then you're ridiculed, then you're just the stupid student who can't do it anyway. […] But I think [the Solarcamp] had a safe space character. Because you just thought 'yes, it's okay if I do it wrong here now. I can try it out in this environment, where it's not so bad if it doesn't work straight away'." (#SoCaPa02)

Appendix E. Results of quantitative analysis of the youth survey

E.1. Impact and recognition of implementation work as environmental behaviour

Occupational choice is perceived as the behaviour with the lowest environmental impact in the youth sample: only 36 % of participants believe that their occupation matters for the environment but 65% believe in their consumption impact[11] (Figure E1 and Table E1), reflecting the abundant media framing of sustainable lifestyles as consumption choices (c.f. section 2.2). The consumption framing increases the salience of the corresponding behaviours' sustainable attributes and, ultimately, respective response efficacy beliefs in the population. Conversely, the lack of public awareness of the environmental impact of occupational choice results in potential underestimation.

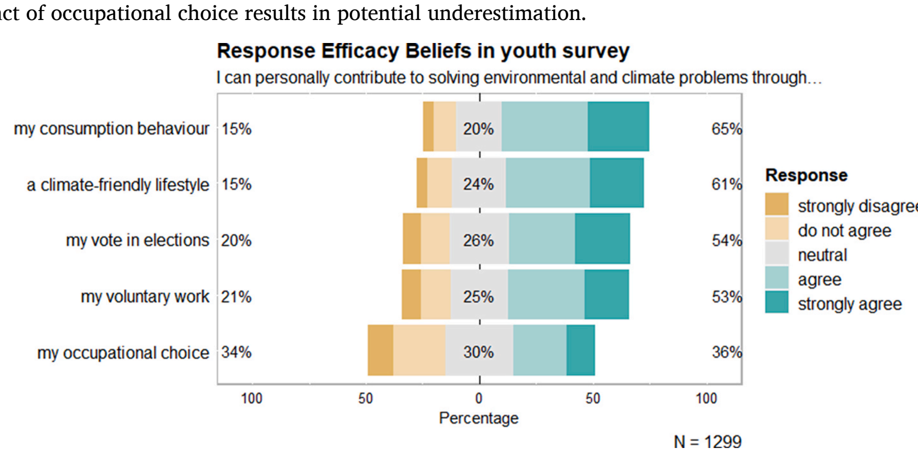

Fig. E1. Participants in the youth survey regard occupational choice as their smallest lever for climate impact.

[11] Also the very low p-value of the Wilcoxon Signed Rank Test for paired data ($p = 2.2\cdot 10^{-16}$) indicates a substantial difference in the distribution between occupational and consumption impact.

Table E1
Response efficacy beliefs in the youth sample.

This question is about how you assess your own opportunities for climate action. I can personally contribute to solving environmental and climate problems through … *		
$N = 1299$	agreement in %	mean ± s.d.
my consumption behaviour.†	65	3.7 ± 1.1
a climate-friendly lifestyle.	61	3.6 ± 1.1
my vote in elections.	54	3.5 ± 1.2
my voluntary work.	53	3.4 ± 1.1
my occupational choice.†	36	3.0 ± 1.2

* measured on a 5-point Likert scale from 1 = "strongly disagree" to 5 = "strongly agree" with agreement coded as 4 and 5.
† Wilcoxon Signed Rank Test for paired data: $p = 2.2 \cdot 10^{-16}$.

E.2. Attractiveness of and barriers to implementation work

Descriptive analysis

Confirming our previous findings, more participants are willing to work part-time as an auxiliary in the 'trades of the future' rather than full-time: 45 % compared to 27 %, respectively (Table E2).

Table E2
Inclination to work in the 'skilled trades of the future' in the general youth survey.

How well can you imagine working in any of the forms listed below in the trades of the future?*	
$N = 1299$	inclination in %
To work part-time as an auxiliary in the trades of the future (e.g. during studies, during the school holidays, or alongside another job)	45
To first complete a full apprenticeship in the trades of the future and then work there full-time	27
* measured on a 5-point Likert scale from 1 = "I can't imagine that at all" to 5 = "I can imagine that very well" with inclination coded as 4 and 5	

Based on their inclination elicited on 5-point Likert scales, we split the sample into three groups:

1) *not interested* ($N = 610$): participants indicating an inclination of 1–3 both for part-time and full-time work.
2) *part-time* ($N = 413$): participants indicating an inclination of 4 or 5 for part-time work but of 1–3 for full-time.
3) *full-time* ($N = 276$): participants indicating an inclination of 4 or 5 for full-time work.

We operationalise being inclined for *part-time* work as being only partially interested but deterred by various barriers to work *full-time*. Table E3 summarises the composition of these groups.

Table E3
Distribution of education, employment, gender, and knowledge in the three subgroups *not interested, part-time,* and *full-time*.

	total ($N = 1299$)		*no interest* ($N = 610$)		*part-time* ($N = 413$)		*full-time* ($N = 276$)	
	percentage		percentage		percentage		percentage	
education (higher)	75 %		77 %		81 %		62 %	
employment	18 %		14 %		11 %		38 %	
gender (female)	60 %		69 %		65 %		32 %	
	good know.*	mean ± s.d.	good know.*	mean ± s.d.	good know.*	mean ± s.d.	good know.*	mean ± s.d.
knowledge	57 %	3.6 ± 1.0	48 %	3.4 ± 0.98	59 %	3.6 ± 0.97	74 %	4.1 ± 0.93

*measured on a 5-point Likert scale from 1 = "applies not at all" to 5 = "fully applies" with 'good know.' coded as 4 and 5.

As Table E3 shows, the *not interested* and *part-time* groups have a higher proportion of female and higher educated participants and a lower proportion of employed participants relative to the *full-time* group. Hence, also this sample shows previously observed tendency that *part-time* work might be more appealing than *full-time* to women and highly educated groups. Moreover, knowledge about the skilled trades increases on average among participants in this sample from *no* to *part-time* to *full-time interest.* This trend also corresponds to previous findings suggesting that the lack of knowledge deters distanced groups (see next subsection for regression results).

Figure E2 and Table E4 display the reported importance of the elicited barriers. Being '*simply not interested'* is the most frequently reported barrier among the *not interested* group reported by 60 %. Similarly as perceiving *'working conditions'* as unattractive, this finding is trivial and adds little valuable information. More importantly, worries about *'not being interested in all tasks'* and '*not being cut out for physical labour'* are the two most frequently reported reasons in the *part-time* group reported by 56 % and 53 % of participants, rank second and third in the *not interested* group (57 % and 58%, respectively), and first and third in the *full-time* group (51 % and 49 %, respectively). While particularly results of the *full-time* group need to be interpreted cautiously, these percentages suggest that both reasons are also relevant to a group most clearly inclined to craftwork in our operationalisation. *'Not being interested in all tasks'* is much more prominent in the youth sample than in the Solarcamps which could be due to the different trades the questions referred to: Solarcamp participants were asked about the *'solar/climate trades'* which they experienced practically before. Hence, they had a clear idea of the tasks in these trades while the youth sample was asked about the *'trades of the future'* without having experienced these trades before. Additionally, 50 % of the members in the *part-time* group report *'It was always clear that I would study'* as the third most frequently reported reason, indicating that particularly (aspiring) students would be open for a subordinate involvement in the trades but not instead of going to university. Worries about '*male domination*' were not as pronounced in the youth sample as in the Solarcamps and only rank as the sixth most reported reason among women (reported by 49% of women). Yet, this is in line with our expectations based on our observations during the Solarcamps and the interviews which suggested a particular prominence of these aspects in the Solarcamps.

Overall, these descriptive findings correspond to our expectations derived from the case studies in section 4.1 and suggest an informed transferability to other groups beyond the 'particularity' of the Solarcamps.

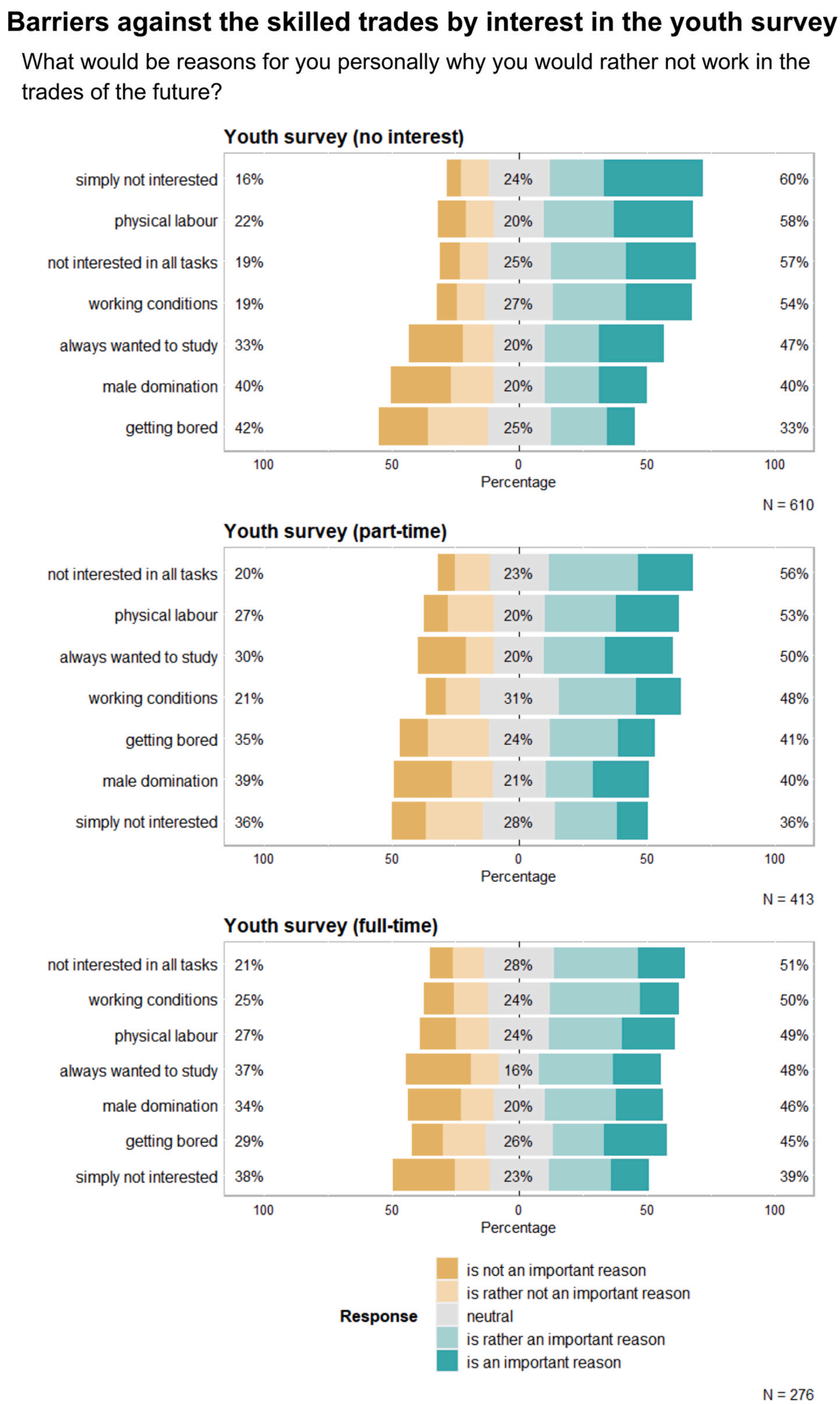

Fig. E2. Worries about *physical labour* and being *not interested in all tasks* constitute the main barriers against the skilled trades in the youth sample.

Table E4
Barriers to working in the trades reported in the youth survey for the three groups *no interest*, *part-time*, and *full-time*.

What would be reasons for you personally why you would rather not work in the trades of the future?*	youth survey ($N = 1299$)					
	no interest ($N = 610$)		*part-time* ($N = 413$)		*full-time* ($N = 276$)	
	importance in %	mean ± s. d.	importance in %	mean ± s. d.	importance in %	mean ± s. d.
I'm worried that I would get bored working in the trades in the long term.	33	2.8 ± 1.3	41	3.1 ± 1.2	45	3.3 ± 1.3
I'm worried that I'm not cut out for physical labour.	58	3.6 ± 1.3	53	3.4 ± 1.3	49	3.3 ± 1.3
I'm worried that I wouldn't be interested in all the tasks in the skilled trades of the future.	57	3.6 ± 1.2	56	3.5 ± 1.2	51	3.4 ± 1.2
The working conditions in the skilled crafts sector don't seem attractive to me.	54	3.5 ± 1.2	48	3.4 ± 1.2	50	3.3 ± 1.2
I'm worried about male-dominated, patriarchal, and/or discriminatory structures in the trades.	40	3.0 ± 1.4	40	3.0 ± 1.5	46	3.1 ± 1.4
It was always clear to me that I would study.	47	3.2 ± 1.5	50	3.3 ± 1.4	48	3.0 ± 1.5
I'm simply not interested in working in the skilled trades of the future.	60	3.8 ± 1.2	36	3.0 ± 1.2	39	2.9 ± 1.4

* measured on a 5-point Likert scale from 1 = "is not an important reason" to 5 = "is an important reason" with importance coded as 4 and 5.

Binary logistic regressions

To further explore in how far the associations between reported barriers and background variables in this sample substantiate the findings of the niche cases, we consider the most relevant barriers as dependent variables which we binarised by coding Likert values of 4 and 5 as 1 and regressed using binary logistic regressions. According to the findings in section 4.1 and the descriptive analysis in the previous paragraph, we focus these regressions on the two most frequently reported *barriers physical labour* and *not interested in all tasks* as dependent variables following formula (1)

$$\text{Logit}(P(barrier = 1)) = \beta_0 + \beta_1\text{knowledge} + \beta_2\text{gender} + \beta_3\text{education} + \beta_4\text{employment} \tag{1}$$

where *knowledge* is an ordinal variable (elicited on a 5-point Likert scale *"I have a good idea of what tasks are involved in a job in the trades of the future (*e. g. *as an electrician, plumber, heating engineer or roofer"* from 1 = "*applies not at* all" to 5 = "*fully applies*"*)*, and *gender, education*, and *employment* are binary variables coding female, lower education, and being employed as 1, respectively (see section 3 for explanation of educational backgrounds). β_0 represents the intercept and β_1 to β_4 represent the regression coefficients for the different explanatory variables.

For these regressions, we restrict the sample to the two groups *no interest* and *part-time* because participants in the *full-time* group most clearly indicate an interest in craftwork and their answers to questions on barriers likely confound the analysis.

Table E5
Regression results for the barriers *physical labour* and *not all tasks* suggest that these barriers are particularly relevant for women.

	sub-sample *no interest* & *part-time* ($N = 1023$)			
	physical labour		not interested in all tasks	
	estimate (std. error)	*p*-value	estimate (std. error)	*p*-value
(intercept)	0.57 (0.24)	0.02	0.71 (0.24)	0.003
knowledge	−0.02 (0.07)	0.74	−0.05 (0.07)	0.46
gender (female)	0.79 (0.15)	$5.4 \cdot 10^{-8}$	0.44 (0.14)	0.002
education (lower)	−0.08 (0.16)	0.60	−0.33 (0.16)	0.04
employment	0.25 (0.20)	0.23	−0.47 (0.20)	0.02

The regression results displayed in Table E5 substantiate our findings in section 4.1. For *physical labour,* the coefficient for *gender* (estimate = 0.79, $p = 5.4 \cdot 10^{-8}$) suggests that women in our sample are more likely to report worries of *'not being cut out for physical labour'* as a relevant barrier to entering the 'trades of the future', keeping the other variables constant. For *not interested in all tasks,* the coefficients for *gender* (Estimate = 0.44, $p = 0.002$) and *employment* (estimate = −0.47, $p = 0.02$) indicate that female and not (yet) employed participants are more likely to report this concern compared to male and employed participants, respectively (at a Bonferroni-adjusted α-level of 0.025).

Lastly, we explore the effects of the most important barriers and background variables on the willingness to work in the skilled trades as hypothesised based on the findings of section 4.1. We binarise *willingness* by coding it as 1 if participants indicate an interest of 4 or 5 in part-time and/or full-time work and regress it in a binary logistic regression model following equation (2)

$$\text{Logit}(P(willingness = 1)) = \beta_0 + \beta_1\text{physical\_labour} + \beta_2\text{not\_interested\_in\_all\_tasks} + \beta_3\text{knowledge} + \beta_4\text{gender} + \beta_5\text{education} + \beta_6\text{employment} \tag{2}$$

where *physical_labour* and *not_interested_in_all_task* are the ordinal forms of the two previously regressed barriers and *knowledge, gender, education*, and *employment* represent the background variables as described above.

Table E6
Regression results suggest that the willingness to work in the 'trades of the future' is primarily influenced by gender and knowledge about the trades.

	full sample ($N = 1299$)		sub-sample *no interest &part-time* ($N = 1023$)		full sample ($N = 1299$)	
	Willingness (part- and/or full-time)		Willingness part-time		Willingness full-time	
	estimate (std. error)	*p*-values	estimate (std. error)	*p*-values	estimate (std. error)	*p*-values
(intercept)	−1.06 (0.31)	0.001	−0.75 (0.36)	0.03	−4.1 (0.44)	$<2\cdot10^{-16}$
physical_labour	−0.08 (0.05)	0.08	−0.07 (0.05)	0.19	−0.07 (0.06)	0.26
not_ all_tasks	−0.01 (0.05)	0.78	−0.03 (0.05)	0.61	−0.002 (0.06)	0.98
knowledge	0.36 (0.06)	$2.8\cdot10^{-9}$	0.21 (0.07)	0.002	0.58 (0.09)	$7.6\cdot10^{-12}$
gender (female)	−0.52 (0.13)	$6.5\cdot10^{-5}$	−0.21 (0.15)	0.15	−0.96 (0.16)	$4.4\cdot10^{-9}$
education (lower)	0.004 (0.14)	0.98	−0.26 (0.17)	0.12	0.50 (0.16)	0.002
employment	0.14 (0.17)	0.40	−0.31 (0.21)	0.14	0.73 (0.18)	$5.0\cdot10^{-5}$

As summarised in Table E6, the regression results for the entire sample suggest that controlling for reported barriers and background variables, primarily *knowledge* and *gender* are associated with *willingness* at an α-level of $\alpha = 0.017$ (after Bonferroni adjustment). The coefficient for *gender* (estimate $= -0.52, p = 6.5\cdot 10^{-5}$) suggests that women are less likely than men to report willingness for craftwork in our sample. Moreover, increasing *knowledge* about the '*trades of the future*' is associated with an increasing likelihood of indicating such willingness as also suggested by the descriptive findings in the previous subsection and section 4.1. *Barriers, education,* and *employment* were not found to clearly affect *willingness* at $\alpha = 0.017$ in this model.

Yet, the elicitation of the questions limits the expressiveness of the regression results, particularly for the *full-time* group. Owing to these constraints and the observed similarity of the *no interest* and *part-time* groups, we regressed *willingness* again for the sub-sample without the *full-time* group. Again, the coefficient for *knowledge* (estimate $= 0.21, p = 0.002$) confirms the previous analyses suggesting a robust relationship in our sample: knowing more about the trades increases the likelihood of being willing to work there.

Lastly, to test the relationships observed in the descriptive analysis (see Table E3), we similarly modelled the *willingness for full-time* work in the full sample. The coefficients confirm that *willingness for full-time work* in our sample is associated with higher *knowledge*, male *gender*, lower *education,* and being *employed*.

Data availability

Data will be made available on request.

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