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Article

Can Citizen Science in the Humanities and Social Sciences deliver on the Sustainability Goals?

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Abstract: Both the sustainability discourse and the debate on citizen science are strongly focused on the natural and technical sciences. Yet, numerous participatory research activities can be identified in the social sciences and humanities that address sustainability issues of various kinds. These have hardly been studied so far, and their contribution to addressing sustainability challenges is poorly known. The study investigates which sustainability topics are taken up by citizen science in the humanities and social sciences, which factors influence the choice of topics, and its implications. For this purpose, the concept of Citizen Social Science (CSS) is taken up and sustainability is operationalized via the Sustainable Development Goals (SDG) and its specific Targets. Based on a collection of CSS activities in Germany, the addressed sustainability topics are identified accordingly. This is followed by an analysis of how these patterns depend on key characteristics of the CSS projects. The findings indicate a focus on three SDGs related to education, sustainable cities and partnerships for the Goals, while at the same time the project consortia are very heterogeneous. CSS shows particular strengths here through its multi-stakeholder approach. Going forward, the linking of Citizen Science with the SDGs requires further formalization so that its transformative effects can be incorporated into SDG monitoring and the scientific institutions need additional incentives to participate in CSS.

Keywords: citizen science; citizen social science; sustainability; SDG

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1. Introduction

The need for economic and societal transformation towards sustainability is imperative as global problems continue to grow. Sustainability refers both to challenges in physical environments, such as the preservation of biodiversity or the protection of natural livelihoods, and to socio-economic phenomena, such as poverty or inequalities [1]. As a common set of goals, reference is usually made to the Sustainable Development Goals (SDGs) of the United Nations.[1] The SDGs represent an operationalization of the sustainability requirements at the political level. They intend to make developments observable based on indicators and to make the need for political action visible.

Such solutions require scientific support, which cannot only be ordered – structurally and programmatically – top-down via political decisions. They also is a need to involve society via bottom-up processes. Citizen Science (CS), i.e. the participation of non-professional researchers in research activities, can play an important role here. On the one hand, research with citizen participation opens up additional epistemic access and knowledge bases that can generate new knowledge and stimulate knowledge and innovation and discussion processes; on the other hand, citizen participation can increase the acceptance of social transformation processes and already achieve concrete effects.

While much of CS takes place in the technical and natural sciences [3], CS that is situated in the humanities and social sciences – Citizen Social Science (CSS) - is increasingly receiving attention [4]. This also has epistemological reasons: "social sciences and humanities help understanding the human dimension and open a broad methodological spectrum for enriching scientific research with new approaches and for boosting public participation" [5]. Where calls for transformative science are being made, technical solutions will not do alone, for they require changes in the habits, attitudes, and behaviors of social groups. In this respect, citizen science projects that address humanities and social science topics and traditions can be an important building block for sustainability-related research and transformation.

The fact that CSaddresses relevant challenges in the context of sustainability has also been studied several times recently [6],[7],[8]. However, the sustainability is mostly discussed for CS in general, and thus looks predominantly at technical and scientific phenomena [9]. Studies that frame CS explicitly in the context of the SDGs have also been observed in recent years [10],[11],[2]. Yet, a specific focus on CSS and the SDGs is missing so far. This is desirable because the SDGs operationalize scientifically evident problems of great scope, for which the humanities and social sciences can make its specific as well as complementary contributions. A better understanding of the contributions of CSS would help at the policy level to develop appropriate support for CSS in the context of sustainability issues. An important factor in policy support for CSS is also that such bottom-up approaches are able to increase the acceptance and legitimacy of sustainable transformations in society [8]. This is because participatory research can create "socially robust" knowledge [12] and, in this respect, is a means of strengthening the acceptance and communication of sustainable (social) innovations. Current science policy agendas regarding Citizen Science do reflect this notion [13],[14]. This also brings to the fore the problem of who actually are or should be the driving actors or, put simply, who is responsible for CSS? After all, for participation, civil society must be involved, and for CS, scientific institutions do not always have to be the initiators of the projects [15]. The situation Germany is particularly interesting in this respect as participatory and amateur research in the humanities and social sciences form a diverse ecosystem in Germany with longstanding traditions [16]. Hence, CSS in Germany builds on existing communities with many relatable interests. Nevertheless, their link to sustainability still needs to be scrutinized. Moreover, CS has gained much attention in German policy making processes, most notably in federal research funding [17],[18] and the coalition agree of the current federal Government [19], also directly linking CS to sustainibility or the SDGs.

1. The 17 SDGs are sustainability goals ratified by the United Nations in 2015 and signed by all member states, which are intended to serve as guiding principles for sustainable development in all areas of life worldwide [2].

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This leads to the following research question: **Which SDGs are addressed by CSS and how are these related to specific factors – in particular actor compositions and participation intensity?** This study takes a look at a sample of CSS activities in Germany and shows which of the SDGs are addressed. It also takes a look at structural characteristics and implementation conditions in order to classify the results. Finally, conclusions are drawn with regard to the contribution of CSS and related research policy.

2. Literature Review

2.1 Growing importance of Citizen Social Science

As mentioned earlier, Citizen Science is increasingly being discussed in terms of the humanities and social sciences, i.e. CSS. In this respect, CSS is now recognized as an important field within CS [20],[21]. The debate around CS is yet still dominated by technical and natural science perspectives, and CSS is generally less well known [22],[23],[3]. One reason for this is that CSS builds on distinct traditions and practices of participatory research, such as participatory action research or living labs, that often forgo self-attribution as CS. In scholarly discourse these connections are certainly drawn [24],[6],[5]. At least three streams are discernible in the scientific consideration of CSS: questions of the goals and purposes of CSS, questions of scientific quality and implementation hurdles, and questions of relevance to science policy.

The first stream includes works that contrast CSS primarily as a method for knowledge generation with CSS as an approach for additional objectives, such as the democratization of science, scientific quality assurance, or real experiments [4],[25]. The characteristic of social science research, namely to make complex social phenomena explicable, represents a particular contribution of interdisciplinary CS or CSS [5]. Especially in CSS projects with intensive citizen participation, methodological reflection, theoretical reflection, as well as contextualization are a potential worth emphasizing [26]. In addition, CSS as a bottom-up approach facilitates the integration of the perspectives of vulnerable groups and thus opens up additional areas of knowledge [27],[28].

In addition to such debates, the special challenges associated with CSS have come into foucs. Heiss and Matthes [29], for example, describe hurdles in mobilizing target groups, ensuring data quality, and ethical issues. This also involves even more active citizen participation in CSS, via different and project-specific formats, and critical engagement of science with the contemporary society [30]. In general, qualitative research methodology, which is important in CSS, is under the constraint of limited resources because these methods are often accompanied by large time commitments. Here, an appropriate combination of scaling research design, outreach to the public, and civic self-organization can help CSS projects succeed [31].

A third stream would be science policy discourses around CS that implicitly or explicitly co-address CSS. These might include the Ten Principles of Citizen Science [32], the overlap with science policy programs such as Responsible Research and Innovation [33], and the general potential of CS to influence policy agendas through science-based evidence and appropriate governance of activities [34]. An overview of the European CS landscape, the representation of CSS in it, and its institutional anchoring in individual states can be found in Vohland et al. [35], for example. In Germany, for example, there are science policy agendas[13],[36], but also positions of communities of practice [37],[22],[29],[38] that also draw attention to the importance of social sciences and humanities for CS.

1.2 Impact of CS with regard to sustainability

CS and CSS have been, moreover, the subject of studies on their societal or sustainability-related impact. Although concrete impacts are reported in many case studies, the debate very often emphasizes obstacles and preconditions for broader impacts. Bonney [39] points to what he sees as some important conditions for broader CS participation and impact. These include (i) that data quality could be improved through increased use of triangulation of multiple data sources; (ii) that greater participation could be achieved

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through better recognition of individual practice benefits; (iii) that digital platforms need to be more responsive to the needs of bottom-up projects; (iv) that all key stakeholders in community projects need to be involved; and (v) that cross-project structures for CS need to support the development and implementation of CS projects.

Despite the widely expressed ambitions of CS projects in terms of its educational impacts, it should be noted that knowledge acquisition by co-researchers does not necessarily go beyond project-related expertise, i.e., participants' attitudes toward science or the environment or their understanding of the scientific process do not change significantly as a result of participation in CS [40].

For CS to be more effective in contributing to sustainability transformations, there is a need for even broader participation in research in three respects [1]: (1) the diversity of participants, e.g., in terms of socioeconomic status, gender, and scientific literacy; (2) the number of participants; and (3) the intensity of participation in terms of depth and timeframe. Only in this way could the necessary critical mass of engaged people, generated data, and diversity in the knowledge base for research, innovation, and learning be achieved to bring about the changes necessary for greater sustainability. Moreover, it is often pragmatic realities and cumbersome process flows in the collaboration of different actors that impose major hurdles to far-reaching ambitions of CSS projects [7]. In this context, Bonney et al. [41] emphasize the effects of community-based projects that can bring together very different population groups. This requires a targeted recruitment strategy that appeals to diverse groups of volunteers [42].

Another important aspect is monitoring the impact of CS projects. Sprinks et al. [43] note that impact measurement in CS projects often includes both, thematically focused, isolated indicators and broader, integrated assessments. However, general principles and frameworks of impact measurement have been lacking and are very difficult to standardize due to the diversity of CS topics, intervention designs, and complexity of outcomes. Here, Wehn et al. [44] propose a pragmatic approach to impact measurement via a storytelling scheme that evaluates and communicates their policy impacts to a broader audience. The measurement issues are also relevant with regard to the Sustainable Development Goals, including very specifically in relation to the SDGs. Fritz et al. [2], for example, develop a concept outlining how CS could be integrated into official reporting tools for the SDGs. Data from participatory research projects should also be collected, documented, and reported to national monitoring bodies. But until today, suitable data are still lacking for many of the 244 indicators, partly because very large data sets are needed for monitoring [10],[1]. Furthermore, data should be made freely available within the framework of open data policies so that they can be used for further sustainability research [45].

1.3 Findings on CS and the SDGs

Conceptually, the link between CS and sustainability has already been established extensively and complemented by empirical findings. For example, Fraisl et al. [10] provide an overview of the areas in which CS already contributes and could contribute data to the SDG indicator framework. For this purpose, they investigated CS projects listed in various internet portals and through a citation analysis. Their result: CS could contribute to 76 of the 244 indicators assigned to the SDGs. In particular, for SDG 15 “Life on Land”, many indicators were found that are already being actively incorporated into SDG reporting. Actions to integrate CS data into SDG reporting have also been ongoing for some time [46],[47].

Moczek et al. [9] asked 125 European CS actors which SDGs their projects contribute to. Here, three SDGs were mentioned particularly often: SDG 3 “Good Health and Well-Being”, SDG 4 “Quality Education”, and SDG 15 “Life on Land”. Respondents considered it potentially possible that all SDGs could be supported with CS. Using a similar methodological approach, Shulla et al. [48] interviewed a total of 82 practitioners from various disciplines, citizen scientists, policy makers, and researchers. Goals 4 “Quality Educa-

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tion", 11 "Sustainable Cities and Communities", and 13 "Climate Action" were most frequently named by the surveyed practitioners as relevant to their work. This is similar to the trend observed by Salvia et al. [49] for scientific research in general.

However, qualitative interviews among CS coordinators, such as that of Sprinks et al. [43], show that aspirations for closer coupling of CS and the SDGs in a CS context are complex to implement. The main obstacles are the very generalized character of some of the SDGs, which offers few linkages for concrete CS projects, and the low level of formalization of the link to the SDGs. Conversely, the linkage is successful if the project can be more easily associated with the SDGs and the project methodology can objectively measure indicators.

In a case study evaluation of 30 CS projects, Ballerini and Bergh [11] find that the projects do have concrete local impacts in terms of sustainability, such as educating and engaging communities and influencing local policy-making. As such, they could provide much-needed local and contextual data for the SDGs. What hinders them, though, is that projects are currently rarely aligned with the SDGs or their reporting systems. This, they argue, is related to a widely perceived lack of knowledge about the goals as well as low levels of collaboration with the United Nations bodies, which discourages projects from delivering data. In this context, Shulla et al. [48] also emphasize the need for institutionalization of CS representation in national and international SDG processes.

Table 1. Comparison of selected SDG related CS studies

Author(s)	Unit(s) of Analysis	Methodological Appoach	Key Results	Limitations
This study	CSS projects contribution to SDG Goals & Targets	Broad search of projects and related documents; mapping CS contributions to SDG Goals & Targets	See chapter 3 & 4	Explorative identification of projects; assessments via publicly available data
Ballerini and Bergh 2021 [11]	CS projects and CS produced data	30 case studies, explorative desk research; questionnaire; interviews	CS projects are largely focus on local impacts & generate disaggregated data; only few projects directly aim at SDG monitoring	Small sample for global scope, regional bias
Sprinks et al. 2021 [43]	CS impacts and link to SDGs	11 semi-structured interviews with citizen science project coordinators	Complex impact assessment in CS hampers measuring SDG contributions	Small sample, subjective judgments
Moczek et al. 2021 [9]	CS contribution to SDGs	Survey among projects and stakeholders	CS could support all SDGs; but lack of infracture & support	EU focus
Fraisl et al. 2020 [10]	SDG indicators and linked CS projects	Broad search of projects; mapping CS contribution to SDG indicators, peer-reviewed by UN statisticians	CS already contributes to 5 indicators, and "could" to 76 more	Explorative identification of CS projects
Shulla et al. 2020 [48]	CS contribution to SDGs	Online survey among CS practitioners, policy makers and researchers	CS mainly involves SDG 4, 11, 13 and 15; CS data infrastructure for the SDGs monitoring framework important	Heterogenous sample
Fritz et al. 2019 [2]	CS an SDG reporting systems	Concept paper; SDG indicator classification	More efforts by United Nations and National Statistics Office to include CS necessary	Not an empirical study

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3. Materials and Methods

This section describes the methods used to identify CSS in Germany. This includes a definition of CSS, which forms the basis for the construction of the CSS project database and central characteristics of the projects.

3.1 Working definition of CSS

In this study, CSS is understood following the approach of Göbel et al. [50] as scientific research in the humanities and social sciences conducted in collaboration between professional and non-professional researchers (or co-researchers). CSS is characterized by three central dimensions: (1) Scientific research in this context means the method-guided generation of theory- and application-oriented knowledge. CS here is to be understood in terms of participatory research as one of the multiple ways in which the public participates in the production of scientific knowledge [51]. Different practices of participatory knowledge generation are considered, such as data collection and analysis or experimental production of physical prototypes. (2) CSS refers to CS activities in the humanities and social sciences that address phenomena of social interaction, culture, and intellectual life using a wide range of quantitative and qualitative methods. This approach takes into account approaches that are primarily disciplinary in nature, such as history, sociology, political science, or linguistics, as well as those that bring humanities or sociological perspectives to interdisciplinary collaboration. (3) Collaboration takes place between professional and non-professional researchers. Non-professional researchers are persons who voluntarily participate in research activities but do not work professionally in the respective scientific field [52]. Accordingly, co-researchers can also be professional scientists in another field. The main purpose of this definition is to identify projects that are CSS in nature and to be able to assign central characteristics to them through our own research.

2.2 Data basis and methods of analysis

As mentioned above, the study is exploratory in nature, i.e., it provides a picture of the current CSS landscape without claiming to conclusively determine the absolute number of projects. For this purpose, a database of CSS projects active in Germany was established. In order to identify suitable CSS activities, a term thesaurus first had to be formed, on the basis of which a broadly based document and Internet search could be carried out. For this purpose, the terms used in relevant publications were consulted (including Citizen Science, Participatory Research, Action Research, Living Lab, Science Shop, Crowdsourcing, Science Café, as well as its German translations). Furthermore, the projects listed on what is probably the most comprehensive portal for CS projects in Germany (www.buergerschaffenwissen.de) were analyzed according to the criteria that fit the definition of CSS. In addition, funding programs and databases of the federal government and some federal states were evaluated as further registers for potentially relevant CSS activities. The searches took place between March 2019 and March 2021, with new hits added incrementally to the database after an initial major search.

The relevant CSS activities were compiled into a database. For each activity, a number of characteristics were researched: Name of the project, website, subject area, focus, funding source, funding agency, funding program, annual funding volume, duration, federal state, degree of lay participation, academic location, leading institution, other institutions/groups involved, number of institutions involved, address and contact information. The classification of the subject area was first done using inductive coding [53],[54]. In a second step, the classifications were consolidated and summarized as far as possible to avoid redundancies and overlaps. For the degree of lay participation, a case-by-case assessment was made based on the available information, following Bonney et al. [55], along three characteristics: contributive (weakest form), collaborative, and co-creative (strongest

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participation). Projects were distinguished between intra-academic and extra-academic, depending on whether or not the lead institution was an academic institution.

As SDGs were only rarely directly mentioned in the project descriptions nor there was a public database that would specify the SDG components of those projects, the only viable approach to identify the addressed SDGs was to extract that information by coding the available text material (project descriptions, brochures, other website content). Coding of the addressed SDGs and corresponding targets was done on a case-by-case basis based on the material. The available text material was coded deductively [54] using the SDG Goals and Targets which were taken from the SDG website (https://sdgs.un.org/goals/). In the process of coding, the references to the Targets were first identified. Coding a goal was considered appropriate when either an SDG was directly mentioned or the activities described were consistent with a specific SDG Target. As Targets are subordinate to the Goals, the identified Targets then yielded the SDGs that were addressed in a project.

Simple counts and percentages for defined subgroups of different compositions were used for the evaluation. Since it is not a randomized sample of projects from a defined population, but a set of projects that could be identified with the described methods, without clarity about the total number of matching projects in Germany, no stochastic methods for significance and reliability of the numbers are needed. At the same time, this does not allow any statement on the representativeness of the data. Instead, a weak form of representativeness can be assumed, provided that the search techniques do not contain systematic gaps that distort the composition of the hit list of CSS projects.

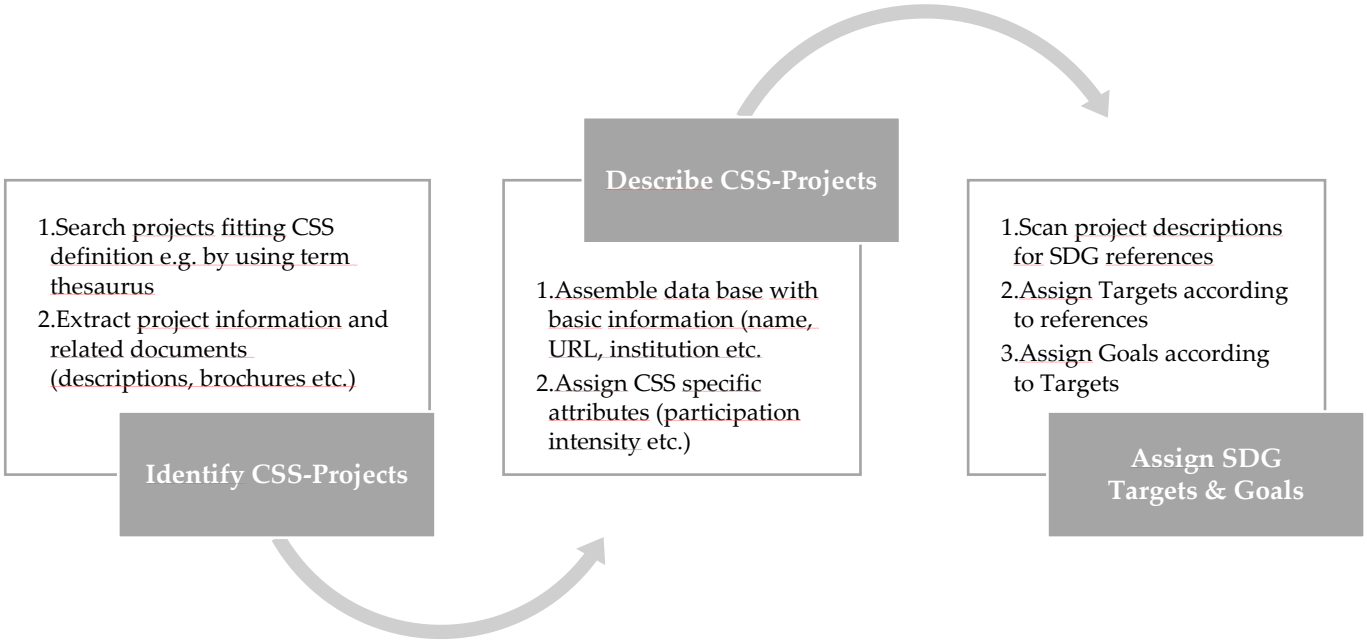

Figure 1. Research steps to analysing SDG Goals and Targets of CSS projects

4. Results

3.1 Key characteristics of the CSS projects

One aspect that has been observed previously [24] is that CSS often is initiated by non-academic actors that (in most cases also) collaborate with academic institutions, thus constituting a form of "uninvited participation" in CS [15]. Among the 122 CSS projects identified through the research, a majority projects had non-academic organizations leading the consortia. Thus, 61 percent (n=72) of the projects were led by a non-academic institution and 34 percent (n=43) were led by an intra-academic, i.e., a university or non-university research institution. In five percent of the cases (n=7), consortium leadership was evenly split. Among the leading non-academic institutions, municipalities are found in

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half of the cases (n=37), in addition there are associations (n=20), NGOs/foundations (n=9), interest groups (n=3) and other governmental institutions (n=3). Moreover, the size of the coordinating consortium varied across projects. The consortia in about two thirds of the cases consist of more than one participating institution. On average, there are 4.1 institutions (Median=2, σ=4.9), with non-academically led projects having more partners on average than intra-academic projects (4.6 vs. 2.9). This means, while mostly there are few partners, there are cases with a large number of partners in the consortium. [56],[16]

For the financing of the projects, it was possible to determine for most cases, but not all, from which side funding was received. The most important sponsor here is the federal government, in particular the Federal Ministry of Education and Research (BMBF), which was the main or co-funder in at least 56 of the 118 projects (47 %). The BMBF had several funding programs running at the time, among one specifically for Citizen Science[2], for "innovative Municipalities"[3] and "Future City"[4]. Other sponsors include the German Environment Agency ("Umweltbundesamt"), state ministries, EU authorities, municipalities and foundations.

Another aspect is the disciplinary orientation of the projects. Here, a distinction can be made as to whether a social science, humanities or transdisciplinary perspective is taken. Projects were classified as transdisciplinary if their primary focus is on research fields that cover social science or humanities related research questions but also include disciplinary perspectives from the natural and technical sciences. Transdisciplinary research draws mostly from topics such as sustainability, education, culture and urban development. Projects could cover multiple disciplinary orientations, with the exception of transdisciplinary projects[5], hence combinations only applied for social science and humanities. In 29 percent (n=34), the projects were classified as social sciences, while 25 percent (n=30) were classified as humanities. Here, there were mainly projects on homeland research, genealogy, digitization (of cultural heritage). In thirteen cases, there was an overlap of social science and humanities.[6] For 60 percent (n=71) of the projects, a transdisciplinary orientation was found, thematically often linked to sustainability, education and urban development.

The type of citizen participation also varied in the projects. This assessment is based on the three-level classification of citizen participation in research according to Bonney et al. [55], which was applied to the identified projects. Thus, in 40 percent (n=48) of the cases, project descriptions and materials envisioned contributive participation, i.e. citizens contribute to the project primarily through opinions, assessments, collecting or counting data. About one-third (n=39) of the projects involved citizens collaboratively, i.e., in addition to collecting data, they also help refine the project design, analyze data, or disseminate results. Finally, 27 percent (n=32) exhibit characteristics of co-creative citizen participation, in which at least some citizens are actively involved in most or all steps of the scientific process. Compared to the study by Moczek et al. [9], where two-thirds of the managers of CS projects stated that citizen researchers had a collaborative role, the distribution here seems much more balanced across the three stages. This could be related to the fact that 62 percent of the projects there were assigned to the natural sciences, in which counting and collecting tasks play an important role.

2. https://www.bmbf.de/foerderungen/bekanntmachung-1224.html (in German, accessed: 8 July 2022)
3. https://www.bmbf.de/bmbf/shareddocs/bekanntmachungen/de/2020/03/2882_bekanntmachung (in German, accessed: 8 July 2022)
4. https://www.bmbf.de/bmbf/de/forschung/energiewende-und-nachhaltiges-wirtschaften/zukunftsstadt/zukunftsstadt_node.html (in German, accessed: 8 July 2022)
5. This decision was made as they transcend disciplinary boundaries, but those projects often tend lean towards either social sciences or humanities, in addition to their technical and natural science orientations.
6. The project "jewish-places.de", for example, collects historical information about Jewish heritage in Germany, but also contributes to improving relations between Jews and non-Jews.

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Table 2. Key characteristics of identified CSS projects

Disciplinary Affiliation		**Participation type***		**Consortium Leader**	
Social Sciences	29%	Contributory	40%	intra-academic	34%
Humanities	29%	Collaborative	33%	extra-academic	61%
Transdisciplinary Research	60%	Co-created	27%	equal	5%
N	**119**	**N**	**119**	**N**	**119**

Note: *) Classification according to [55]
Source: CSS project database

3.2 Addressing sustainability goals

In an evaluation of the project database, the project descriptions were taken as the basis for assigning the 17 sustainability goals. For the coding, the sub-goals assigned to the goals were used, which specify the scope of relevant activities in more detail.

To illustrate the coding with an example, the project "Novel Food versus Old Food"[7] is used. In this project, between 2017 and 2020, school students worked on both social and natural science issues related to sustainable food, for example, by self-conducted citizen surveys and experiments that examined, among other things, the acceptance of insect-based foods. The project thus contributed to Target 2.4 ("...ensure sustainable food production systems...") as well as Target 2.7 ("...learners acquire the knowledge and skills needed to promote sustainable development..."). Accordingly, SDGS 2 and 4 are considered addressed.

Of the 118 projects, 105 were attributed to the SDGs; for the remaining 13, a link to the subgoals of the SDGs was not sufficiently evident.[8] By far the most common was Goal 11, "Sustainable Cities and Communities", which applied in 58 percent of cases (n=71). This is followed at some distance by Goal 4 "Quality Education" at 37 percent (n=45). Behind that are Goal 9 "Industry, Innovation and Infrastructure" (18%), Goal 17 "Partnerships for the Goals" (15%) and Goal 3 "Good Health and Well-Being" (13%). Other SDGs are found in single-digit percentages of all projects. Overall, CSS projects addressing these goals were found for 13 of the 17 SDGs. (Figure 1)

7. https://www.biologiedidaktik.uni-osnabrueck.de/forschung/forschungsprojekte/nachhaltige_ernaehrung_in_und_um_osnabrueck.html (accessed: June 15 2022)
8. These worked especially thematically in the field of geneaology, sporadically archaeology and urban history.

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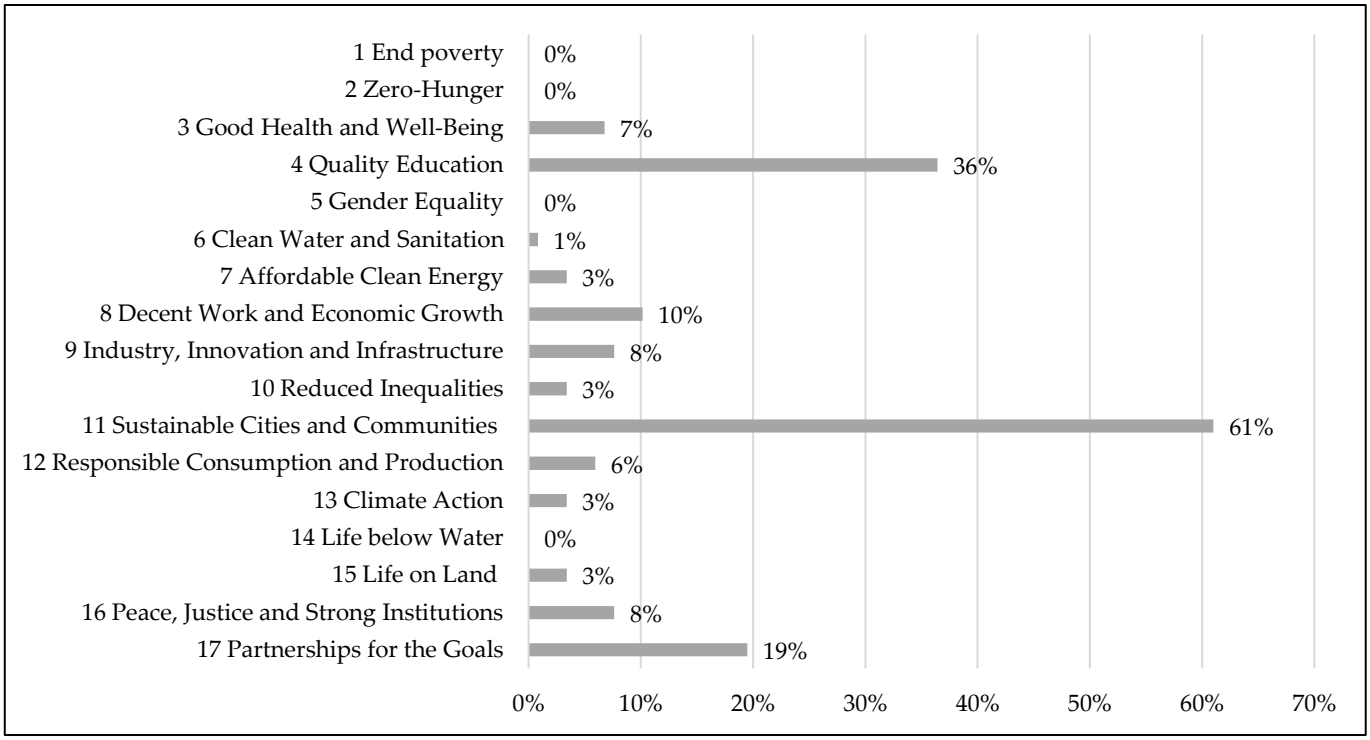

Figure 2. Share of CSS projects that address specific Sustainable Development Goals

Note: N=105. Thematic mapping of CSS activities based on Internet searches and self-descriptions; Source: CSS project database

In any case, the dominant position of sustainability-related projects in cities and municipalities as well as education-related projects is clearly recognizable. It must be taken into account that in almost all cases the CSS projects are not active globally, but predominantly regionally or within Germany. Together with the CS approach, which moreover primarily addresses social science and humanities issues, it should come as no surprise that not all SDGs are addressed equally. It is worth taking a closer look at which sub-goals are affected in order to highlight the specific strengths of CSS with regard to the SDGs. (Figure 2)

For example, sub-goal 4.7 was most frequently attributed to projects (n=38). This is explained by the relative breadth of the sub-goal: *"4.7: By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development."*

Several aspects led to the coding of individual projects: "global citizenship and appreciation of cultural diversity", "human rights, gender equality, promotion of a culture of peace and non-violence", "culture's contribution to sustainable development", and "knowledge and skills needed to promote sustainable development". The addressing of SDG No. 4 "Quality Education" is thus primarily shaped by cultural education aspects of sub-goal 4.7, which itself is only one of ten sub-goals with other education aspects. Moreover, 4.3, 4.4 and 4.5 were identified as additional sub-goals of SDG 4 in the projects.

The breakdown of SDG No. 11, on the other hand, was clearly coded more broadly along the subgoals. Subgoals 11.2 ("...access to safe, affordable, accessible and sustainable transport systems...", n=15), 11.3 ("...inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management…", n=27), 11. 4 ("...protect and safeguard the world's cultural and natural heritage", n=16) and 11.7 ("...access to safe, inclusive and accessible, green and public spaces...", n=9) and 11.a ("...links between urban, peri-urban and rural areas...", n=23).

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Because the other SDGs were assigned much less frequently, the breadth of sub-goals addressed is also less – mostly one or two sub-goals. Due to its frequency (n=18), sub-goal No. 17.17 ("Encourage ... public, public-private and civil society partnerships ...") is also worth mentioning.

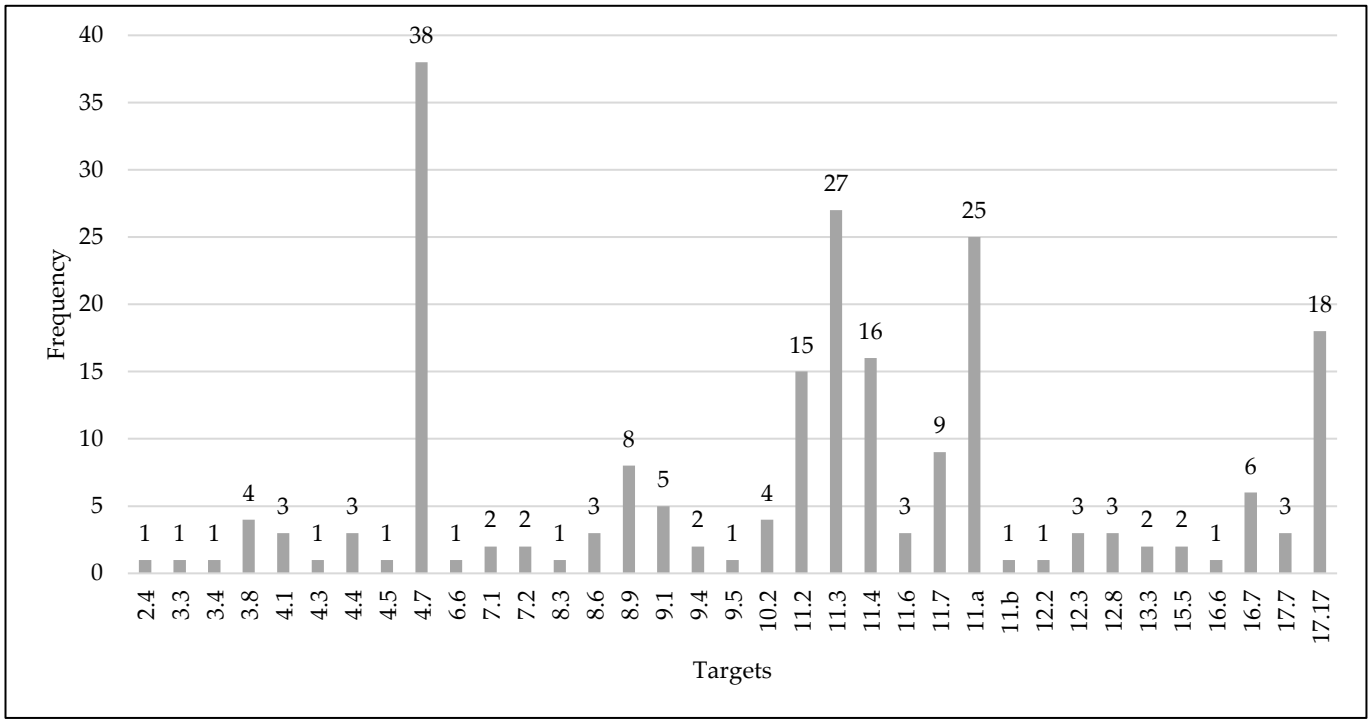

Figure 3. Number of CSS projects that address specific SDG targets

Note: N=105. Thematic mapping of CSS activities based on Internet searches and self-descriptions; Source: CSS project database

The SDGs are not equally served by the CSS projects and there are differences related to structural features. This is particularly evident in the organizational design and the participation approach. These present themselves as follows (Figure 3):

- In comparison, projects initiated within academia are more strongly aligned with SDG 4 ("Quality Education") (48% of projects in this group vs. 28%), while non-academic projects are overrepresented in SDG 17 ("Partnerships for the Goals") in particular and active with a higher proportion within their group in SDG 11 ("Sustainable Cities and Communities") compared to the intra-academic projects.
- Smaller project consortia with up to three partners are slightly less likely to be active in SDGs 4, 11 and 17 – and are more broadly distributed across all identified SDGs (see Figure 1). However, the differences between the two groups are not particularly striking, so consortium size appears to have little impact on addressing SDGs.
- Contributive projects are comparatively frequently associated with SDG 17 and SDG 8 ("Decent Work and Economic Growth"); for other SGDs, they are roughly on par with the other two participation levels. Collaborative projects are again distributed very similarly to co-creative projects along the frequently identified SDGs.

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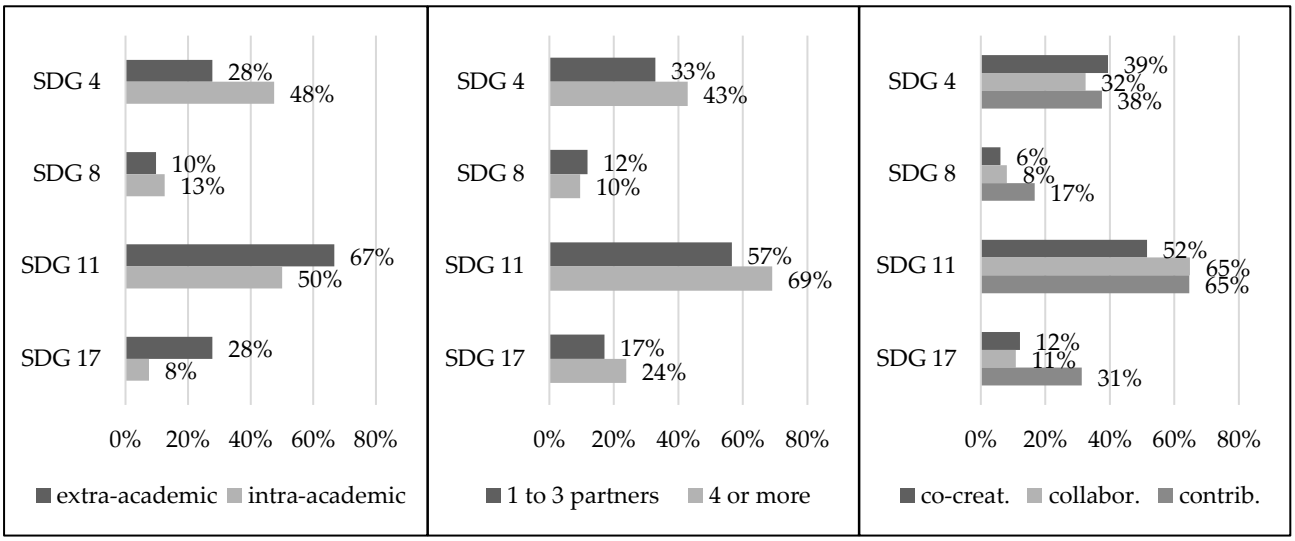

Figure 4. Consortium leader, consortium size and participation type for frequent SDGs (% within groups)

Note: N=105. Thematic mapping of CSS activities based on Internet searches and self-descriptions; only SDGs that have been coded at least 10 times in total are shown; own calculations.
Source: CSS project database Source: CSS project database

Further differences become apparent when these characteristics are now considered for the frequently identified SDG targets in the CSS projects (Figure 4):

- Target 4.7, which dominates for SDG 4, is also overrepresented in intra-academic initiated projects, analogous to the previous figure. Conversely, extra-academic projects are comparatively common for Target 17.17. In contrast, no striking deviations can be observed in the subgoals of SDG 11.
- With regard to the size of the consortium, consortia with up to three partners are visibly underrepresented in Targets 4.7, 11.3 and 11.4, while they are significantly overrepresented in Target 11.a. For larger consortia, Targets 11.4 and 4.7 in particular are relatively more frequent.
- Co-creative projects are comparatively often represented in Target 4.7. For collaborative projects, this applies to Target 11.2. Contributive projects, in turn, are comparatively overrepresented in Targets 11.3, 11.a and 17.17.

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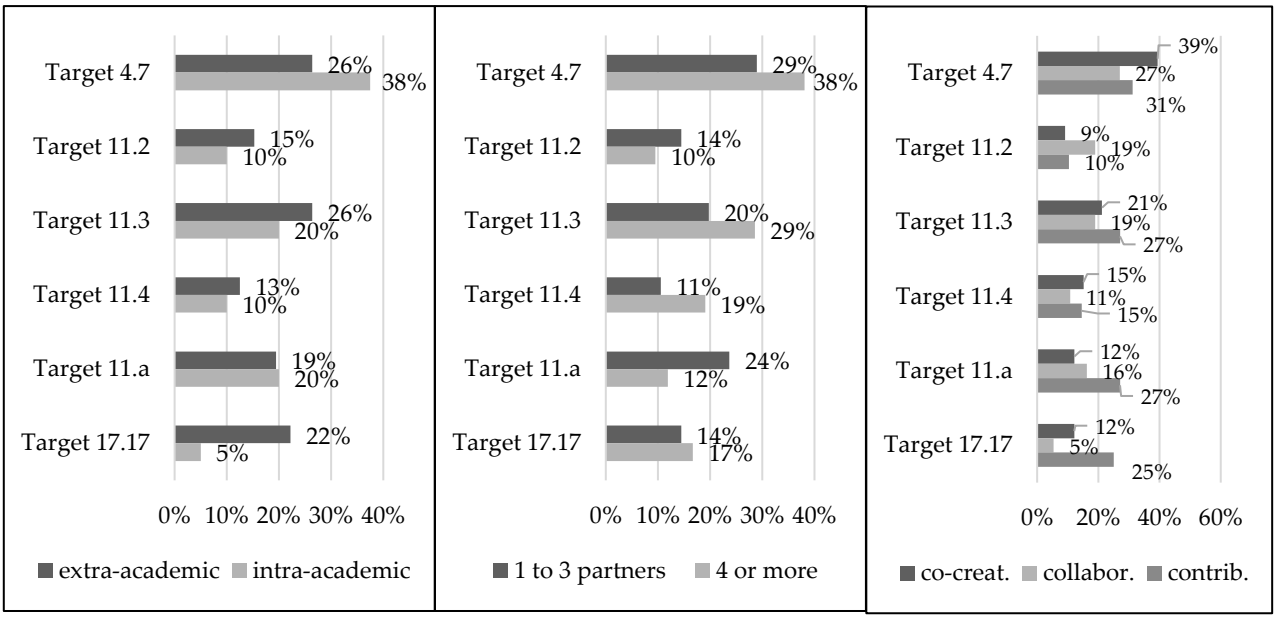

Figure 5. Consortium leader, consortium size and participation type for frequent SDG-Targets (% within groups)

Note: N=105. Thematic mapping of CSS activities based on Internet searches and self-descriptions; only SDGs that have been coded at least 10 times in total are shown; own calculations.
Source: CSS project database Source: CSS project database

5. Discussion

The analysis of the CSS database according to the Sustainable Development Goals (SDGs) shows clear focal points of the projects studied along individual SDGs. By and large, the results confirm work done by other authors on the topic. While "Good Health and Well-Being", "Quality Education", and "Life on Land" are central themes in Moczek et al. [9], "Quality Education", "Sustainable Cities and Communities" and "Climate Action" are central themes in Shulla et al. [48]. Here again, it is primarily "Sustainable Cities and Communities" and "Quality Education". So there is an overlap despite the different approaches in determining such figures. One factor that is weighted higher in this study is "Partnerships to achieve the goals". This has to do with the fact that many of the projects are so-called "Future City" ("Zukunftsstadt"), a BMBF funding program for the development and implementation of sustainable spatial development concepts with a strong emphasis on citizen participation. There, mainly alliances of municipalities, business and civil society organizations have been established – hence the grouping here to this specific SDG. It should also be added that the SDGs were coded somewhat more sparingly here than in Moczek et al. [9] and Shulla et al. [48]: while more than four SDGs are served on average per project there, here there are 1.7 SDGs per project. This is probably also due to the fact that concrete SDG Targets were first identified here, from which the SDGs then were derived. In contrast, the respondents in the other two studies were asked about the SDGs, which are formulated more generally than the Targets. However, the respondents may have had information on sustainability aspects of their projects that were not in the project descriptions and could not be considered in the coding of this study.

Looking at the Targets of the SDGs, there is a strong concentration on one Target in the case of SDG "Quality Education", while in the case of SDG "Sustainable Cities and Communities" there is a whole series of Targets addressed. In the former case, it should be noted that SDG 4 "Quality Education" focuses on formal education and related goals. This is usually outside the scope of CS. In sub-goal 4.7, informal or non-formal education is mapped along a wide range of topics, which is why the connection to CS and its dif-

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ferent topics is relatively easy to establish. In SDG 11 "Sustainable Cities and Communities", on the other hand, there are more points of contact for CSS. The Targets describe different fields of action that can be addressed by CS: Mobility, participatory urban planning, integration of urban and rural development, housing, cultural and natural heritage. Here, the transdisciplinary character of CSS comes to the fore: the connection of technical and social development goals. Compared to Fraisl et al. 2020 [10], the weighting of the SDG targets is different here. They had identified numerous indicators for Targets, especially for SDGs 15, 11, 6, 7 and 1, for which CS could make significant contributions, but "Quality Education" does not play a major role there. For the differences it is essential that a) the authors focus on the measurability of the Targets, i.e. that impacts that are difficult to measure are relegated to the background and b) the entire breadth of CS is included and not only CSS.

A distinctive feature of CSS that has rarely been considered in the debate on CS is the participation of governmental and civil society partners in the projects. In the description of the sample, it was pointed out that half of the projects are composed of more than two partners, including cases with more than ten partners. This also has to do with the tasks of the projects, in which networking of different actors (municipality, civil society, companies) or cooperation of several municipalities is often of central importance. In this respect, the frequent identification of SDG 17 "Partnerships for the Goals" and Target 17.17 is not surprising, but rather proves this. This circumstance does not come to the fore with such conciseness in studies that discuss CS in its breadth.

Another observation from the findings that needs to be classified is that the participation intensity is comparatively high for projects related to SDG 4 and often lower for projects related to SDG 11 and 17. The context here is that the sample also includes a number of CSS projects from the BMBF's "Zukunftsstadt" funding program. In this program, projects with participation concepts were particularly successful in the application process. Some of these participation formats met the CSS criteria, which is why they were included in the database. All of these projects were active in the area of SDG 11 and most of them were also active in SDG 17. In the vast majority of these projects, participation was designed to be contributive or collaborative. This is probably because the management of these projects was always in the hands of the municipalities and the CS project is one component of several in the overall project. For the municipalities, such projects are embedded in larger urban development strategies and thus in a political framework for action. In this respect, it seems reasonable to assume that CSSs initiated outside academia are not always particularly deliberative. Rather, it seems the other way around, because intra-academic CSS projects are particularly often present in SDG 4 and that is where co-creative projects are most likely to be. Intra-academic SDG 4 projects serve a wide range of topics (democracy, urban development, health, nutrition, history) and one can assume that academic initiators deliberately focus on intensive collaboration with co-researchers due to the educational component of their projects. At the same time, unlike municipalities, research institutions are freer to design projects that do not have to be aligned with overarching political goals. At the same time, the majority of extra-academic SDG 4 projects are thematically active in history and the majority of participation is contributive. The majority of co-creative non-academic pro-jects serve SDG 11. In short, intra-academic projects rely much on co-creative research in SDG 4, non-academic ones mainly in SDG 11.

It is also revealing what is not covered by the projects. One striking aspect of the CSS sample is that the topic of gender is never addressed directly in the sample. Although the project descriptions repeatedly mention inclusive or non-discriminatory education/citizen participation/infrastructure, etc., in none of the projects gender is a core objective. The data cannot really explain this observation directly, but it can be assumed that the topic of gender for CSS in Germany had not yet been properly tapped at the time of data collection. The gender related SDG 5 is represented with upper-middle frequencies in Moczek et al. [9] and Shulla et al. [48]. In this specific case and due to the focus of the study

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on German projects, it can be said that most of the CSS projects depend on fixed-term funding and it is thus ultimately also a question of funding policy priorities.

A general difficulty for the use of the SDGs is that the linking of project goals and impacts has so far been little formalized, i.e., projects rarely have concrete SDGs formally in their list of goals [43]. This also makes it difficult to assign them to specific sustainability goals. This does not only affect the SDG indicators. The question of CS data quality is a fundamental challenge that must always be solved on a project-by-project basis [57]. However, this does not yet guarantee that the sustainability issues addressed will be included in the monitoring of the SDGs. Here, the question arises whether such a convergence of data needs, to be provided in a decentralized manner by many CSS projects, is at all practical or desirable. Ultimately, the pressure to standardize could also severely hamper creativity and motivation in the projects. Also, such an instrumentalization of the CSS landscape could further fuel concerns that science uses CS to serve as an army of unpaid volunteers who help solve current scientific problems at a lower price [51].

The relative frequency of a few of the SDGs in the CSS projects also corresponds with the observation of Sprinks et al. [43] that "the broad scope and global nature of certain SDGs ... also result in a lack of connection to certain projects." Many of the SDGs are geared to problems that are particularly serious in developing countries. Goals such as “No Poverty” or “Zero Hunger” are also relevant for Germany, but possibly due to a combination of low awareness of the problems and a lack of established CS approaches, there are currently almost no corresponding activities. Here, too, the question arises whether public funding should pay more attention to CS, which also addresses the overcoming of poverty or food security. In this regard, it must also be taken into account that public participation is about facts as well as values.The linkage of scientific analysis and public deliberation has best potentials for effectively incorporating both facts and values into decision-making processes [58]. The extent to which the value reference, expressed for example in the democratization claim of CS, can really be fulfilled is controversial. For this, interests and opportunities for participation of the population would have to be evenly distributed [51]. CSS certainly has good opportunities to reach target groups that have not been reached very much so far, but primarily through their thematic interest, less through their scientific framing [24].

Even if addressing the SDGs does not always lead to concrete quantifiable results, it is also relevant as a building block of sustainability-related scientific communication. Only a minority of the projects considered here specifically called out their specific SDG contributions. CS stands in contrast to passive conceptions of science such as ‘scientific literacy’, since communication here takes place through active exchange and negotiation with the co-researchers in the very heterogeneous sub-publics [59]. By opening up the research process to non-professional researchers, CS is always also science communication, in which all participants can learn what is otherwise outside their everyday worlds [60]. In the data of this study, the potentials are evident, because the project consortia are very diverse in composition – research institutions, municipalities, civil society, business. Moreover, CSS is not initiated by research institutions alone, but also by non-academic actors. This means that all the key players are together for an exchange on the paths and goals of the transformation to a sustainable world. What is missing is a more consistent operationalization of these goals via the SDGs.

This leads further into a broader context of this study, namely the question of the legitimacy of knowledge about its relevance for sustainability challenges. And this is established here through the cooperation of science with organizations outside of science. According to Suchman [61], organizations legitimize themselves through the fit of their actions, or more precisely the perception of these actions by the environment, with social expectations and norms. The communication of scientific institutions through participation in CS is strategic in that it pursues goals that support their legitimacy and thus maintain their ability to act [62]. In this regard, the participatory nature of CS is an important factor. Changes toward more sustainable everyday worlds cannot be ordered by politics alone, even if it relies on scientific facts. CS, as a bottom-up approach, is suited to increase

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the acceptance and legitimacy of sustainable transformations in society [8]. With CSS, scientific institutions demonstrate that through the multi-stakeholder processes typical of CSS, they are able to establish the transfer of scientific results to application contexts [63]. In doing so, they simultaneously recognize that legitimate knowledge, namely knowledge that follows scientific principles, is also generated in the non-academic world: "If participatory research can transform *how* knowledge is being produced, at a deep epistemological level, then it could hold important potential for transforming *who* can produce legitimate knowledge and *what* we know about the natural world."[51] The findings of this study provide further evidence that this coupling of science and society already exists, although it does not yet cover the thematic breadth of the SDGs. This could be further encouraged if CS gained more prominence in academic curricula.

Main SDGs addressed by CSS	CSS Features by SDG	Barriers & Potentials to addressing SDGs in CSS
• **SDG 11. "**Sustainable Cities and Communities", with high range of Targets • **SDG 4. "**Quality Education", mostly covering Target 4.7 • **SDG 17.** "Partnerships to achieve the goals", mostly Target 17.17 • Other SDGs much less frequent	• CSS addressing SDG 4 mostly **intra-academic** projects with more **co-creative** participation • CSS addressing SDG 11 & 17 dominated by **municipalities** & **civil society** with more **contributive** & **collaborative** participation	• **Barriers:** Little formalization of SDGs in projects and risk of instrumentalization; Broad scope of some SDGs hampers implementation • **Potentials:** CSS has opportunities of broadening the base for participation by thematic interest; multi-stakeholder: in CSS, all the key players for sustainable development are together; CSS can help legitimizing public research institutions' efforts to promote sustainability transformation

Figure 6. Overview of the main results

The approach used here was to map the identified CSS projects in Germany to SDGs and their respective Targets based on publicly available information. This differs from other authors who identified the SDGs based on self-assignments of project participants. In this respect, the knowledge base for the assignments was limited on the one hand by the available public information. On the other hand, it was rule-governed and avoided subjectively varying evaluation logics through the individual cases. In addition, the validity is limited in the sense that it is unclear how representative the sample of CSS projects is, since the population is unknown. However, no evidence has emerged that there is a systematic bias in the search strategy.

6. Conclusion

This paper examined which sustainability goals CSS projects in Germany adress within the SDG taxonomy. The results showed that CSS is delivering on some SDGs, but not across the board. Depending on the characteristics of the projects, different SDGs and related Targets were addressed. The Several implications can be drawn from the findings. First, CSS is actively involved in fewer SDGs than CS in general. This suggests that there is a need for stronger links with technical and scientific topics, and thus potential for making CSS even more transdisciplinary. Second, the strength of CSS is its distinct multi-stakeholder approach, which also indicates potentials of transformative impacts of projects in the already addressed fields. Third, the low formalization of SDG contributions is a significant gap in current project designs. Here, it would be obvious that funding agencies pay more attention to ensuring that projects make their contributions to the SDGs more explicit. Fourth, participation in CS, which pursues concrete impacts with a view to sustainability, is a promising resource of social legitimacy for the participating scientific

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institutions. In the field of CSS, this is reinforced by a comparatively intensive participation of co-researchers in the research process. This may go some way toward dispelling critical voices in the scientific community that express doubts about the scientific quality of CS, because public engagement through CS secures the social relevance of science and thus ultimately its endowment. Fifth, stronger coverage and monitoring of the SDGs cannot be shifted to the projects alone. If CS is to be used more extensively to address the SDGs, then intermediary structures are needed to collect data from CSS projects and process it for SDG monitoring, provide advice and tools for SDG-related data needs, and ideally provide specific funding for this purpose.[9]

As mentioned before, the greatest limitation of this study is that is based on publicly available information. This means, valuable tacit information from participants and stakeholders could not be harnessed here. Further exploration on this topic could proceed in two directions not yet covered here. First, the approach of identifying SDGs through targets could also be undertaken through a survey of CSS managers themselves. This could be further deepened by querying the SDG indicators assigned to the targets, as pursued by Fraisl et al. [10] for CS in general. On the other hand, the identification of CSS projects could also be attempted by using computer-assisted mass data analysis in order to expand the database for further analyses. Possibilities include public funding databases, social media evaluations, or citation analyses. It may be assumed that many more CSS projects are currently active than were identified by the manual research here. A major obstacle to identification remains, however, that the projects rarely self-identify themselves as CS, i.e. we still have to identify them using a corpus of associated research practices.

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Data Availability Statement: The data used for this study will be made available upon specific request.

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Apendix

Table A1. Labels of SDG Goals and Targets that were identified in the data

Target	Label
2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture	
2.4	By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality
3. Ensure healthy lives and promote well-being for all at all ages	
3.3	By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, waterborne diseases and other communicable diseases
3.4	By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being
3.8	Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all
4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	

[9] The need for such centers has recently been reiterated by Rick Bonney [39].

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Target	Label
4.1	By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes
4.3	By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university
4.4	By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship
4.5	By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations
4.7	By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development
6. Ensure availability and sustainable management of water and sanitation for all	
6.6	By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes
7. Ensure access to affordable, reliable, sustainable and modern energy for all	
7.1	By 2030, ensure universal access to affordable, reliable and modern energy services
7.2	By 2030, increase substantially the share of renewable energy in the global energy mix
8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	
8.3	Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services
8.6	By 2020, substantially reduce the proportion of youth not in employment, education or training
8.9	By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products
9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	
9.1	Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all
9.4	By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resourceuse efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities
9.5	Enhance scientiꝏc research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending
10. Reduce inequality within and among countries	
10.2	By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status
11. Make cities and human settlements inclusive, safe, resilient and sustainable Target	
11.2	2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums
11.3	By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries
11.4	Strengthen efforts to protect and safeguard the world's cultural and natural heritage
11.6	By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management
11.7	By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities
11.a	Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning
11.b	By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, holistic disaster risk management at all levels
12. Ensure sustainable consumption and production patterns	
12.2	By 2030, achieve the sustainable management and efficient use of natural resources
12.3	By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses

Target	Label
12.8	By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature
13. Take urgent action to combat climate change and its impacts	
13.3	Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning
15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	
15.5	Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species
16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	
16.6	Develop effective, accountable and transparent institutions at all levels
16.7	Ensure responsive, inclusive, participatory and representative decision-making at all levels
17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	
17.7	Promote the development, transfer, dissemination and diffusion of environmentally sound technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed
17.17	Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships

Source: https://sdgs.un.org/goals (accessed: 8 July 2022)

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