Tech Footprint Toolkit: Supporting Designers in Anticipating Technology Impact

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Abstract

This work introduces the Tech Footprint Toolkit, an interactive toolkit for designers and developers to anticipate and address the impacts of digital technologies on humans and society. Although digital technologies can cause unintended harm to people, their complexity and unpredictability often discourage designers and developers from systematically reflecting on potential negative effects. Drawing on frameworks such as value-sensitive design, the Tech Footprint Toolkit supports designers' reflections on the potential impacts of digital systems through an iterative process comprising three phases: i) exploring potential technology impacts across eight dimensions of the human experience, ii) evaluating the system in relation to these dimensions, and iii) identifying design strategies to mitigate potential negative effects. We present the toolkit and its design process, together with insights from a preliminary evaluation, and outline challenges and recommendations to guide its future development.

CCS Concepts

• **Human-centered computing** → **Interactive systems and tools**; **HCI theory, concepts and models**.

Keywords

Technology Impact, Societal Impact, Technology Footprint, Value Sensitive Design, Reflective Toolkit

ACM Reference Format:
Sara Colombo, Qiulin Zhu, and Kacper Pietrzykowski. 2026. Tech Footprint Toolkit: Supporting Designers in Anticipating Technology Impact. In *Extended Abstracts of the 2026 CHI Conference on Human Factors in Computing Systems (CHI EA '26), April 13–17, 2026, Barcelona, Spain.* ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/3772363.3798662

1 Introduction

Consider fitness apps that track users' health metrics and offer personalized recommendations to improve their well-being. Although such systems are designed with the intention of supporting healthier lifestyles, they can inadvertently expose sensitive data, cause over-reliance, or reinforce unhealthy behaviors when their human and social impacts are not adequately considered in their design [9, 13].

The tension between the benefits of digital solutions and their potential negative effects extends across digital technologies, from smartphones to wearables, from virtual agents to social media - systems that increasingly shape the way we live. For instance, excessive smartphone use can lead to musculoskeletal strain and chronic attention fatigue [14, 37], and replacing in-person conversations with online exchanges often erodes the nonverbal empathy cultivated through face-to-face interaction [29]. Moreover, the increasing use of machine-learning algorithms influences critical life outcomes, such as job screening or credit decisions, raising concerns about the role of such technologies in transforming societal infrastructures and in amplifying inequalities [23]. These cases illustrate how digital technologies actively shape human experiences and societal systems, not as inherently good or neutral artifacts, but potentially bearing risks and negative implications.

Designers occupy a uniquely influential position in determining how technologies affect users and society. While designers may not anticipate all possible uses, they can shape a technology's trajectory by embedding certain values in its design and questioning its broader implications [17, 35]. From a design perspective, it is therefore relevant to investigate how the impacts of digital technologies on humans and society may be predicted and mitigated in their development.

Value-sensitive design offers guidance on incorporating values and ethical considerations into product development processes [17]. Feminist HCI further emphasizes the importance of considering values, power dynamics, and impacts on underrepresented communities, urging reflection on who benefits and who is marginalized by technology [1, 2, 36]. Frameworks and tools have also been developed to help designers anticipate and assess the broader impacts of technology. For instance, anticipatory ethics frameworks [6] and ethical technology assessment [24] offer structured approaches for identifying potential harms before they materialize. However, conceptual frameworks alone often fail to provoke and guide the nuanced discussions needed within design teams [17], and fall short in linking ethical concerns to actionable design decisions. Systemic envisioning methods, such as value scenarios [22], Future Ripples [15], and the Envisioning Cards [16], bring anticipatory thinking closer to the design process by prompting teams to explore long-term and indirect consequences of their systems. However, these tools primarily focus on envisioning future effects, without providing structured guidance for evaluating how a system's design aligns with or diverges from specific human values, or for identifying concrete mitigation strategies. Informed by work in value-sensitive

CHI EA '26, Barcelona, Spain

ACM ISBN 979-8-4007-2281-3/26/04
https://doi.org/10.1145/3772363.3798662

design [17, 19], ethics of technology [20, 30, 33, 35], and feminist HCI [1, 3, 11], we argue that designers require tools for three critical activities: understanding how digital solutions impact multiple dimensions of human experience and society [25, 35, 38], reflecting on the relation between values and impacts [26, 27], and identifying and mitigating negative effects [25].

To address this gap, we developed and tested the Tech Footprint Toolkit: a three-phase interactive toolkit that combines sensitization on technology's potential negative impacts, value-based reflection on impact, and guidance for mitigation (Table 1). The toolkit is intended as a conversational scaffold to support reflective discussions within design teams, rather than an objective measurement instrument. By bridging conceptual analysis and empirical practice, the toolkit enables designers to identify potential negative impacts and address them. It also allows designers to reflect on whose values and perspectives are included or excluded and how value and design choices may affect different groups or communities. In this work, we present the toolkit, detailing its design rationale, development process, and results from a walkthrough demonstration [21] with four experts. We conclude by discussing future developments and we share the online, open-access toolkit prototype.

2 The Toolkit's Framework

2.1 Impact Areas

To facilitate a structured evaluation of the impacts of digital solutions on humans and society, we categorized their potential consequences into eight areas, grounded in human's core experiential dimensions. These areas synthesize research in human-centered and experience design, ethics of technology, and HCI, showing how digital technologies mediate embodied and psychological experience [7, 35], self-understanding and behavior [31], values and normative orientations [32], social interactions and culture [5, 12], and wider institutional and societal infrastructures [34]. The resulting impact areas - *body, mind, self-perception, behavior, values and beliefs, relationships, cultural identity, and societal structures* [10] - help designers tailor their reflections to specific aspects of human experience [20].

2.2 Human Values

Human values can serve as a useful instrument for shaping design ethical intentions in the early stages and for critically examining how solutions align with or diverge from those intentions [17]. To help designers assess and communicate their technology's impact through a value-based lens, the toolkit is structured around a list of human values that should guide technology design. The list was derived from value-sensitive and value-driven design [17, 18, 33].

In total, nineteen key values were identified: *welfare/wellbeing, cohesion, equality, inclusiveness, freedom from bias, universal usability, privacy, informed consent, safety, security, autonomy, identity, self-respect, calmness, courtesy, trust, presence, accountability* and *transparency*. This list is not exhaustive, but represents a starting point for scaffolding the reflective process.

2.3 Integrating Impact Areas and Human Values into a Reflective Framework

In our toolkit, values shape reflection within each impact area, allowing both dimensions to mutually inform the designers' analysis of a digital system under development. When reflecting on the impact of a digital solution on the human *body*, for insance, values such as *wellbeing, inclusiveness, safety*, and *autonomy* prompt distinct reflections. To support such reflections, one or more statements were developed for each value, helping designers consider how a system affects a given human dimension through that specific value lens. Each impact area includes between eight and twenty-four statements, framed in a positive tone. Designers indicate their agreement with each statement on a five-point Likert scale, ranging from 'strongly disagree' to 'strongly agree'. For instance, when analyzing the *body* dimension from the *identity* perspective, design teams assess the extent to which their system "supports users' ability to express and maintain their identity through their body". Whereas through the *wellbeing* value, they may evaluate statements such as "The solution prevents bodily fatigue, strain, or discomfort".

The specification of a predefined set of human values as heuristic anchors is intended to support a structured and consistent reflection across dimensions. However, this approach may also constrain the reflection process by implicitly elevating certain values over others, or limiting designers' ability to generate their own value sets during reflection [3, 17]. These limitations will be further addressed in the discussion section.

3 The Design Process

3.1 Cards and Canvases: The First Prototype

The first author developed the initial version of the card- and canvas-based toolkit (Appendix A). This prototype was first assessed in a 2-hour focus group involving 12 scholars from diverse disciplinary backgrounds, including ethics, social science, and public policy. Based on the feedback, the toolkit was refined and subsequently tested in two workshops with master's and bachelor's design students. These sessions focused on assessing the toolkit clarity, usability, and perceived validity. Insights from both expert and student evaluations informed the final iteration of the toolkit.

The cards represent a curated set of technological issues covering the eight impact areas identified in our framework, illustrating potential negative technology consequences through examples. For each human impact dimension, the cards present a set of issues, described through images, concise descriptions and QR codes linking to additional resources for further exploration. Designers begin by engaging with the cards (Figure 1), which prompt awareness and reflection on technology impacts on human areas (Phase 1, Table 1).

The canvases guides users through three core activities (Phase 2 and 3, Table 1): selecting relevant impact areas, evaluating potential impact, and visualizing the resulting tech footprint on humans (Figure 1), which leads to identifying actions to mitigate negative effects. Users begin by selecting impact areas pertinent to their technological system, guided by a set of questions, then respond to value-based questions associated with each selected area. Upon completing the evaluation, users calculate the final scores for the

Table 1: Overview of the Tech Footprint Toolkit

	Goal	Process
Phase 1 – Sensitize	Sensitize designers on potential adverse effects of technology across the eight impact areas	Designers explore cards illustrating examples of the potential negative impacts of technologies, for each area.
Phase 2 – Evaluate	Prompt the designers to reflect on the potential impacts of their systems through series of statements addressing impact areas and human values	Designers rate statements related to the eight human impact areas and human values, based on a 5-point Likert scale from "strongly disagree" to "strongly agree".
Phase 3 – Mitigate	Guide the designers to analyze the overall potential footprint of their system, and identify specific opportunities for improving their solutions to reduce negative impacts or better integrate certain values.	Designers reflect on the aggregated outcomes from the assessment through a visual footprint and guiding questions; they generate ideas for future interventions.

impact areas they selected, as an average of the score assigned to all statements in that area (scores 1-2: negative impact; 3: neutral; 4-5: positive). A radar chart then visualizes the scores across all eight areas, providing a visual 'footprint' of the system's overall impact - both positive and negative (Appendix A, Figure 6). The toolkit also aggregates scores across underlying human values, providing a secondary visualization of value-related impacts. Together, these representations offer an overview of the system's impacts, both area- and value-based, supporting critical reflection and helping designers identify issues to address.

3.2 Expert Focus Group: Digital Prototype Evaluation

The second author developed a digital prototype and, together with the first author, conducted an online focus group with academic experts in the healthcare technology sector, approved by the university ethics board. While preserving the underlying structure of the toolkit, the prototype incorporates digital features that enable dynamic interactions. To assess the toolkit's relevance and usability, we conducted a focus group with an interdisciplinary research team working on the ethical risks of an AI system for risk prediction in primary healthcare. Four participants from academia with experience in the development of healthcare technology were involved, representing expertise in bioinformatics, bioethics, law, human–computer interaction, health policy, and applied ethics.

In the semi-structured focus group, supported by an online shared Miro board, we guided participants through four phases: preconception parking, toolkit demonstration, structured reflection, and future envisioning. We audio-recorded and transcribed the session to conduct a thematic analysis using statement cards and clustering. The resulting themes provide insights into the toolkit's strengths and limitations.

3.2.1 Strengths of the Toolkit. Participants recognized the toolkit's ability to translate complex frameworks for ethical assessment into an accessible and usable format. As one participant remarked,*"it's quite impressive because there's a lot of thinking behind the tool, but the tool itself does look very lean."* This suggests that the toolkit connects theoretical foundations with a structured approach to reflection, helping users navigate complexity without feeling overwhelmed.

Participants also appreciated the toolkit's interactive design features for their capacity to facilitate both reflection and actionable insight. Linking assessment to design actions for improving the system and mitigate negative impacts was particularly valued, with one participant stating,*"I especially like the last part in which you connect the first inventory with a constructive approach."* The visual representation of the assessment outcome was also praised as *"very helpful, especially for that reflection process."* These insights show that the toolkit can guide users from reflection toward design interventions, to mitigate negative impacts.

3.2.2 Limitations of the Toolkit. A tension arose between the toolkit's structured, impact-oriented assessment and the subjective, speculative, and reflective nature of anticipating technological impact. Participants highlighted this mismatch when reflecting on the toolkit's purpose. One participant noted, *"Do you want to try to determine what the actual effect is, or would you like to use this tool as a start of a conversation about potential impact?"* Another elaborated on this ambiguity, noting, *"So at first I thought this tool will help you to determine somehow what the potential impact might be. But now it is you who has to give an estimation yourself."* These insights emphasize the need to frame the toolkit as a conversational scaffold rather than a method for quantifying impact.

Participants also highlighted a critical need for guidance on contextualizing the toolkit within the broader design process. As one participant articulated: *"I think giving a bit context for where this tool is being used, or at least for the users to understand what time of design process implementation for process they're using it."* Participants also stressed the importance of validating the toolkit's applicability across different industry contexts. This concern led to practical suggestions for further testing, with one participant recommending: *"take a couple of examples and run it to see if it works for that type of technology or not."*

Another limitation identified during the discussion concerned the toolkit's value framework. First, participants noted possible conceptual inconsistencies in how values were classified, particularly regarding the distinction between values and norms. As one participant pointed out: *"So I saw quite a few having to do with Autonomy and I also saw a couple that I'm not sure are values. So, for instance, informed consent and to me is a norm, not a value."* Second, the predefined value list was perceived as potentially restrictive, prompting suggestions for greater flexibility. One participant asked, *"Would it be possible to include a section in which people can add*

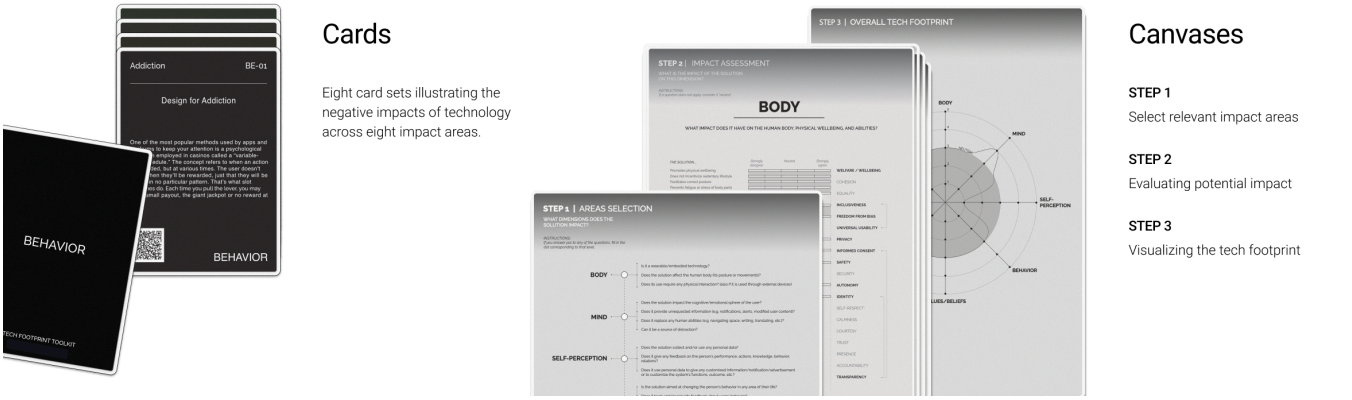


Figure 1: The first version of the toolkit consists of a set of cards and canvases.

something that they think is important?" These insights underscore the importance of supporting users' ability to engage with and interpret values in a way that resonates with their own context and understanding.

3.3 Web-Based Tech Footprint Toolkit: Open-Access Version

Based on feedback from the focus group and further design iterations, several changes were implemented in a web-based, open-access version [1] (Figure 2): i) we clarified the toolkit objective as reflection and self-assessment, ii) we added a positionality statement about our values selection iii) we streamlined the workflow by adding instructions and guidance from impact area selection to footprint visualization iv) we facilitated results communication by offering downloadable reports both to support reflections and design changes and to enable discussions with stakeholders on the ethical considerations underlying design decisions. The open-access toolkit is available online, and will be further developed to improve usability, value selection and framing, and evaluate its applicability in different product development environments.

4 Discussion and Conclusion

In response to the growing need for technology responsible development, we created the Tech Footprint Toolkit to support design teams in reflecting on the impacts of their solutions on people and society. Our approach integrates theoretical frameworks from human-centered design, value-sensitive design, and feminist HCI, translating values into assessment heuristics. By making values explicit, the toolkit places digital solutions within a sphere of value-driven considerations [19, 35] that are often overlooked in technological innovation. By focusing on impact areas and providing footprint visualizations, the toolkit surfaces technology implications that might otherwise remain abstract, grounding reflection and advocating reflection-in-action [8].

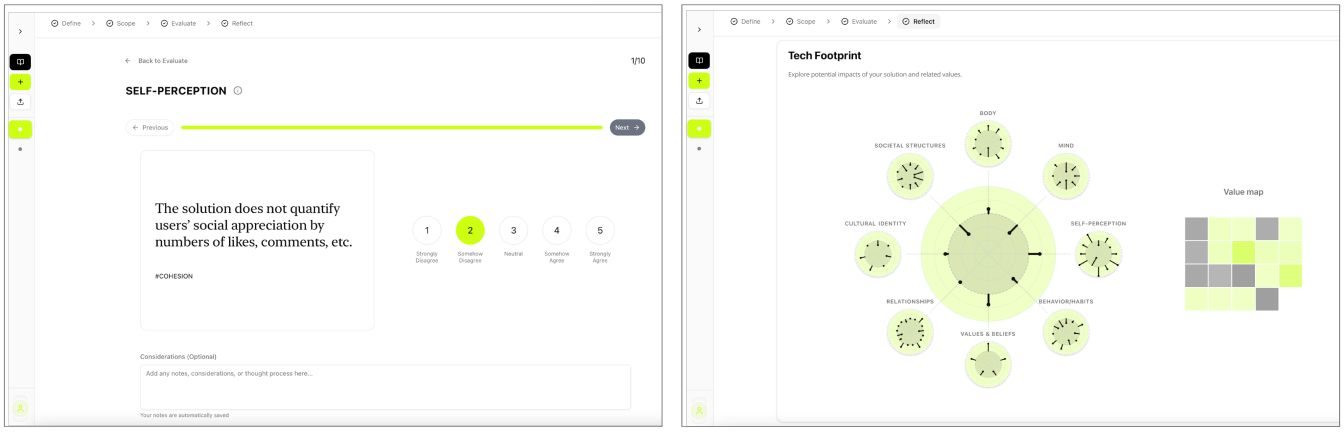
However, it is important to acknowledge the potential risks associated with this approach. The toolkit may be interpreted as a checklist, even though the values and statements it includes are neither universal nor encompassing, but are intended as an instrument for guided and context-specific reflection. Experts also highlighted the inconsistent nature of some values, which stems from deriving them from different research domains, where values and norms are defined differently. Although we adopted a practice-oriented approach, this inconsistency needs to be addressed at a conceptual level. Finally, we need to clearly articulate the toolkit's role as a facilitator of reflection and dialogue in teams, rather than an objective measurement tool, to avoid misuses and ethics-washing practices. To this aim, we will explore, among others, alternatives to the use of numerical scores, to highlight the qualitative nature of reflection.

Selecting values for the toolkit proved challenging, as we navigated the tension between providing generalizable heuristics and avoiding the reduction of diverse human perspectives, needs, and beliefs to a list of "universally accepted" values for technology design. Although this tension remains unsolved in value-sensitive design [3], we addressed it by stating our positionality and explaining our values selection. Moving forward, we see a need to explore how such a toolkit can become more adaptable to different contexts and users, centering values that matter to diverse communities and stakeholders. Some options include allowing design teams to add context-based value definitions, or identifying values with end-users through participatory processes. Moreover, the current framework focuses on how digital technologies impact human experience and society. Extending it to incorporate more-than-human perspectives, for instance by accounting for environmental consequences [4, 28], represents a valuable direction for future development of the toolkit.

Finally, we see potential for sharing the Tech Footprint outputs with end-users to increase transparency about a system's values and potential impacts, empowering them with greater awareness and agency when engaging with new digital systems.

The Tech Footprint Toolkit represents a novel approach to anticipate and mitigate the potential negative impacts of digital technology, scaffolding reflection and enabling value-driven design considerations. Despite limitations in value selection, the toolkit

[1] The toolkit prototype can be accessed at: https://tech-footprint-tool.vercel.app



(a) (b)

Figure 2: The web-based toolkit interface. (a) An example of statement rating from the self-perception impact area; (b) Overall footprint visualization, where inward indicators show negative impacts and outward indicators show positive impacts. Each dimension node contains a smaller chart showing the distribution of values associated with that impact area.

serves as a boundary object that can enable discussion within the HCI community on how design teams can be guided in reflecting on technology impacts across human dimensions. It also invites reflection on the potential applications, benefits and risks of using values as heuristics in anticipating, discussing, and communicating technology impacts.

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Appendix A Examples of the Cards and Canvases

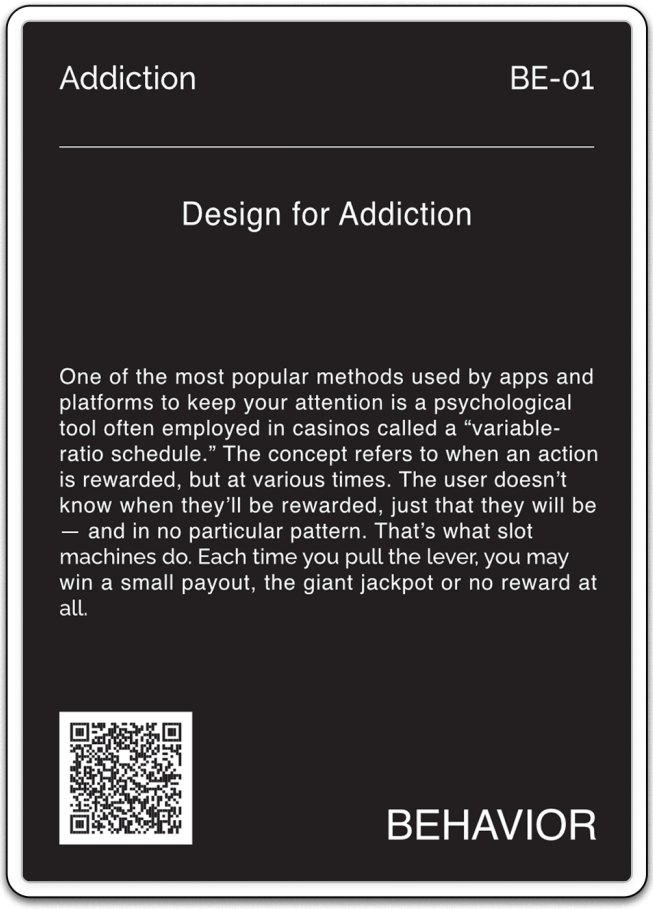

Figure 3: Example of a card from the canvas-based version of the toolkit, which includes a concise description of a negative impact of technology, a complementary visual, and a QR code linking to additional resources.

Figure 4: The first canvas is aimed at self-assessing which human diamensions are being impacted by the digital solution under evaluation. A dimension is considered relevant if at least one of its questions receives a positive response.

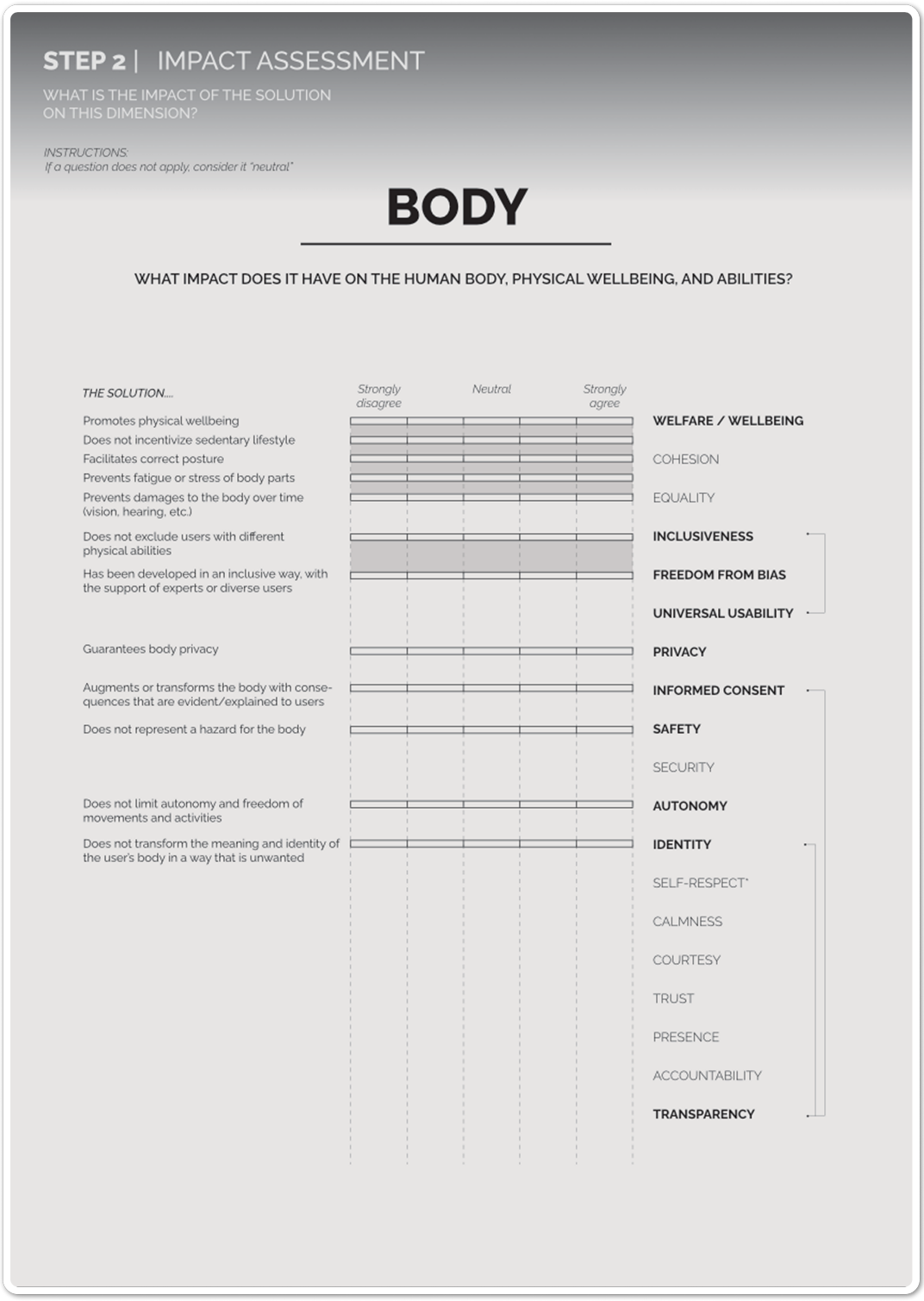

Figure 5: An example canvas of Step 2: Impact assessment. The user reviews each statement on the left and, based on their self-evaluation, rates it. The corresponding values are displayed on the right side of the canvas.

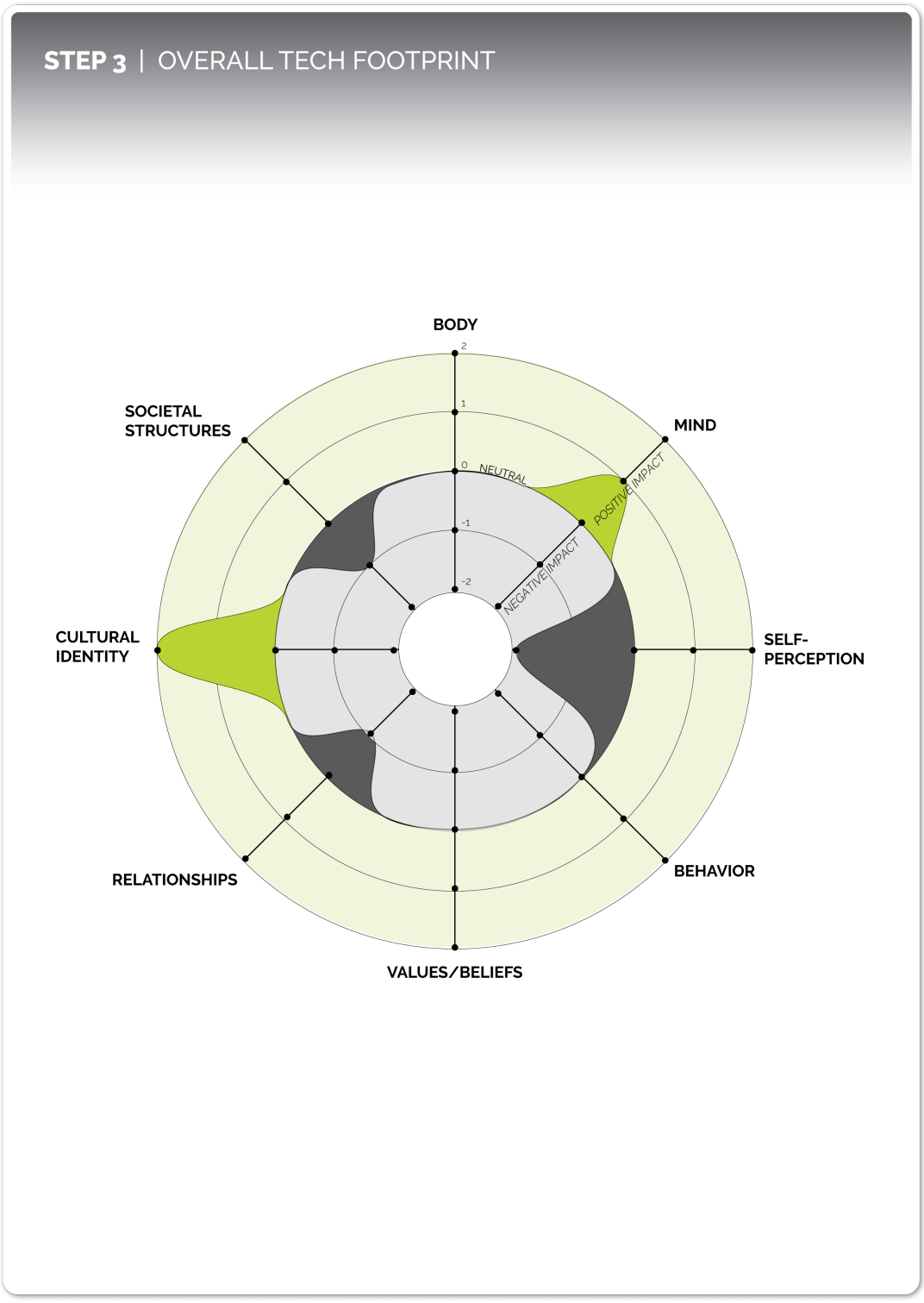

Figure 6: The canvas representing the final aggregated results, visualized as a tech footprint. Gray areas represent anticipated negative impacts, while green areas represent potential positive impacts.