

Abstract

The Fast-Moving Consumer Goods (FMCG) sector is a major source of greenhouse gas emissions and plastic waste, underscoring the urgency of systemic innovation in production and consumption. STARHAUS project, funded by the European Union, addresses this challenge by advancing a decentralized, human-centric, and circular model of manufacturing. Rooted in Industry 5.0 and the New European Bauhaus, it combines technological development with social sciences, artistic experimentation, and community co-design to create sustainable and inclusive innovation ecosystems.

This article examines STARHAUS's theoretical foundations, methodology, and emerging outcomes, situating them within the global sustainability agenda. Using grounded theory, document analysis, and early empirical evidence, it introduces the STARHAUS-SDG Alignment Framework, which demonstrates contributions to SDGs 9 (Industry, Innovation, Infrastructure), 12 (Responsible Consumption and Production), 13 (Climate Action), and 17 (Partnerships), with ripple effects on health, education, gender equality and sustainable urban development. Four industrial use cases – pet food, fertilizers, beverages, and cereals – illustrate the adaptability and replicability of its Manufacturing Demonstration Facilities.

Findings position STARHAUS as a replicable blueprint for socio-ecological transition, linking technological innovation, community engagement, and policy objectives. Beyond its industrial and technological focus, STARHAUS contributes to the modernization of public governance by providing evidence-based models for policy design, local innovation management, and citizen engagement. Its participatory approach demonstrates how sustainability transitions can be embedded in administrative decision-making and multi-level governance.

Keywords: STARHAUS, public policy, Fast-Moving Consumer Goods (FMCG), UN Sustainable Development Goals, Manufacturing Demonstration Facilities (MDF).

CRAFTING THE FUTURE: HOW STARHAUS INNOVATIONS ADVANCE SUSTAINABLE GOVERNANCE AND ALIGN WITH UN SDGs

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1. Introduction

The global economy faces a decisive turning point as climate change, ecological degradation, and social inequalities expose the limits of current production and consumption systems. The Fast-Moving Consumer Goods (FMCG) sector illustrates this challenge acutely, generating over one-third of global greenhouse gas emissions and nearly 40% of plastic waste. Its reliance on mass production, long-distance transport, and single-use packaging underscores the need for systemic reconfiguration, where manufacturing is understood as a socio-technical process rather than a purely industrial one.

Policy and academic debates converge on this demand. The European Green Deal and the New European Bauhaus emphasize sustainability, aesthetics, and inclusivity; Industry 5.0 highlights human-centric, participatory, and resilient innovation; and the Quintuple Helix model frames change as a multi-actor process involving government, academia, industry, society, and the environment. Yet these frameworks often lack empirical grounding. Within this policy ecosystem, public administration plays a pivotal role in coordinating multi-actor innovation and ensuring that sustainability objectives are operationalized through governance instruments, funding mechanisms, and territorial policies. STARHAUS provides an applied case of how local governments – such as those in Cluj-Napoca, Romania, and Coimbra, Portugal – can act as experimental governance hubs for circular and human-centric manufacturing.

This article addresses that gap through the case of STARHAUS, a Horizon Europe project that operationalizes these principles in the FMCG sector. Drawing on its first 18 months of implementation, it introduces the STARHAUS–SDG Alignment Framework, demonstrating explicit contributions to SDGs 9, 12, 13, and 17, alongside indirect ripple effects on health, education, gender equality, and sustainable urban development. STARHAUS’s decentralized Manufacturing Demonstration Facilities (MDFs) are shown to function both as technological testbeds and as living laboratories for behavioral change, providing a replicable model for linking innovation, community engagement, and policy objectives in support of socio-ecological transition.

2. A brief overview of STARHAUS

STARHAUS (Sustainable, Technological, Accessible and Resilient human-centric manufacturing supporting the New European Bauhaus), a project funded by the European Union under Horizon Europe, was launched in December 2023 and runs until November 2026. Its mission is to pioneer a decentralized and human-centric model of manufacturing that addresses the unsustainable practices of the Fast-Moving Consumer Goods (FMCG) sector, one of the largest contributors to greenhouse gas emissions and plastic waste worldwide. Building on the achievements of the DIY4U project, STARHAUS advances technologies from TRL 5 to TRL 6-7, with the ambition of transforming production and consumption patterns through localized, circular, and participatory approaches. DIY4U, funded by the European Union’s Horizon 2020 Research and Innovation

Programme, served as a precursor to STARHAUS, advancing the digital transformation of European industries involved in the formulation, production, and supply of particulate and liquid-based Fast-Moving Consumer Goods (FMCG). The proposed outcome of STARHAUS is the development of Manufacturing Demonstration Facilities (MDFs) that combine advanced engineering, modular hardware and software, and co-creation methodologies, creating infrastructures that function both as testbeds for innovation and as living laboratories for citizens and communities. This way, the project seeks not only to advance technological innovation but also to contribute to socio-ecological transition in line with the principles of the New European Bauhaus.

The general contribution of STARHAUS lies in its capacity to reduce the environmental footprint of FMCG products by at least 15%, empower citizens and SMEs as active co-creators of sustainable solutions, and provide evidence-based guidance for policymakers. Its primary beneficiaries span multiple levels of society and economy. Citizens are engaged not only as end users but also as participants in co-design workshops that encourage behavioral change toward more sustainable consumption. Small and medium-sized enterprises benefit from access to modular hardware and software platforms, as well as financial support through cascade funding schemes that already support six third-party projects. Municipalities, including Cluj-Napoca in Romania and Coimbra in Portugal, are directly involved as pilot sites for the establishment of MDFs, allowing them to act as frontrunners of circular, localized innovation. Researchers, artists, and local authorities are also deeply engaged, ensuring that the technological dimension of the project is integrated with social, cultural, and ethical perspectives.

The tangible outcomes of STARHAUS are both technological and societal. By the end of the project, two fully operational MDFs will be established as permanent infrastructures, seven new hardware modules will be created to enable product personalization and circular use of materials, and a unified software ecosystem will be deployed to support customization and sustainability tracking. Four industrial use cases – pet food, fertilizers, beverages, and cereals – are being developed to demonstrate the adaptability and replicability of the model across different FMCG sectors. Alongside these outputs, the project generates policy briefs, peer-reviewed publications, guidelines for municipalities and SMEs, and open-access datasets that ensure its results can be replicated and scaled beyond the initial consortium. Cascade funding mechanisms and interdisciplinary co-creation methodologies reinforce the inclusivity and openness of the project, ensuring that innovation extends beyond the core partners and fosters community ownership of outcomes.

At present, STARHAUS is midway through its implementation. According to the mid-term review carried out at month 18 (June 2025), the consortium has already achieved key objectives and delivered the milestones on time. Four localized service models have been designed, seven novel hardware modules are in advanced simulation stages, and an integrated software ecosystem has been prototyped. Community engagement, through workshops, focus groups, and interdisciplinary collaborations, has involved citizens, SMEs, and municipalities across Europe, while dissemination efforts have produced open-access publications, international conference contributions, and a strong digital presence.

STARHAUS positions itself as a replicable socio-ecological model that combines advanced engineering and digital innovation with insights from the social sciences, arts, and humanities. By doing so, it explicitly contributes to the United Nations Sustainable Development Goals, with direct alignment to SDG 9 (Industry, Innovation, and Infrastructure), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 17 (Partnerships for the Goals), while generating indirect ripple effects on health, education, gender equality and sustainable urban development.

3. Theoretical foundations

STARHAUS is situated at the intersection of several complementary theoretical frameworks that provide both normative orientation and methodological guidance. These include the paradigm of Industry 5.0, the New European Bauhaus (NEB) initiative, the Quintuple Helix model of innovation, and traditions of human-centric design. Together, these perspectives position STARHAUS not merely as a technological experiment but as a socio-technical intervention with systemic implications for sustainability, inclusivity, and participatory governance.

The notion of Industry 5.0 has emerged in European policy discourse as a correction to the limitations of Industry 4.0. While Industry 4.0 emphasized efficiency through automation, digitization, and data-driven optimization, Industry 5.0 highlights resilience, sustainability, and human-centricity as the central pillars of industrial transformation (Breque, De Nul and Petridis, 2021). It represents not only a technological paradigm, but also a normative shift in which technology is reoriented toward serving human and ecological well-being (Nahavandi, 2019). STARHAUS operationalizes this paradigm through the development of Manufacturing Demonstration Facilities (MDFs), localized and modular infrastructures that integrate advanced engineering with social engagement. These MDFs are designed not solely to increase productivity but to embed ecological responsibility, adaptability, and community relevance at the heart of production processes.

The New European Bauhaus (NEB) initiative reinforces this orientation by framing innovation as simultaneously sustainable, inclusive, and aesthetically meaningful (European Commission, 2021). As a cross-cutting policy program, the NEB emphasizes the cultural and experiential dimensions of ecological transition, recognizing that technological advances must resonate with citizens' values and lived experiences. STARHAUS translates these principles into the design of MDFs and product prototypes, ensuring that sustainability metrics are complemented by attention to inclusivity, user experience, and design quality. In this way, the NEB functions as both a guiding value framework and an evaluative benchmark for STARHAUS outcomes.

At the systemic level, the Quintuple Helix model of innovation provides the conceptual architecture for stakeholder engagement. Expanding the earlier Triple Helix model of university–industry–government collaboration, the Quintuple Helix incorporates civil society and the natural environment as co-shapers of innovation (Carayannis and Campbell, 2010; Carayannis *et al.*, 2012). STARHAUS adopts this perspective by embedding

citizens, SMEs, municipalities, researchers, and civil society actors in co-design processes, while environmental sustainability is monitored through lifecycle assessments and ethical design frameworks. In doing so, the project ensures that its MDFs are not conceived as isolated technological platforms but as participatory socio-ecological systems.

The model's relevance for public administration lies in its capacity to institutionalize collaboration across governance levels – municipal, national, and European – turning innovation ecosystems into operational instruments of policy implementation. This transforms municipalities from passive regulators into active orchestrators of sustainability transitions.

Traditions of human-centric design provide the methodological foundation for STARHAUS. Originating in usability research (Norman, 1988), human-centered design has evolved into participatory and co-creative approaches that foreground the active role of users in shaping innovation (Stappers *et al.*, 2007, Sanders and Stappers, 2008). Related work on democratizing innovation (von Hippel, 2005) underscores the value of user-driven co-creation in producing both technological and social outcomes. STARHAUS applies these principles through its Social and Ethical Design Framework, co-creation toolkits, and participatory workshops with citizens and SMEs. Methodologically, the project integrates Social Sciences and Humanities (SSH) perspectives, employing surveys, semi-structured interviews, and focus groups to capture dimensions such as awareness, acceptance, trust, and safety. This approach ensures that innovation is not only technically feasible but also socially legitimate and ethically grounded.

These frameworks constitute the theoretical foundations of STARHAUS. Industry 5.0 provides the overarching paradigm of resilient and human-centric manufacturing; the NEB embeds normative and cultural principles that make innovation socially meaningful; the Quintuple Helix structures the multi-stakeholder ecosystem required for participatory experimentation; and human-centric design offers the methodological tools to translate these ambitions into practice. Their integration allows STARHAUS to contribute not only technical innovations – such as two fully operational MDFs, novel hardware modules, and a unified software ecosystem – but also broader societal outcomes, including citizen empowerment, SME competitiveness, municipal engagement, and measurable contributions to the United Nations Sustainable Development Goals. In this sense, STARHAUS advances a replicable model for socio-ecological transition that bridges engineering, culture, governance, and community practice. When interpreted through the lens of public administration, STARHAUS frameworks illustrate how adaptive governance and participatory management can translate high-level policy ambitions (such as the SDGs or NEB) into actionable, community-level innovations.

STARHAUS departs from hierarchical, efficiency-driven models by adopting adaptive and participatory leadership (Heifetz, 1994). Leaders act as facilitators, mobilizing municipalities, SMEs, researchers, artists, and citizens to co-create sustainable solutions.

Its governance is framed by Industry 5.0 (Breque *et al.*, 2021; Nahavandi, 2019) and the Quintuple Helix (Carayannis and Campbell, 2010, Carayannis *et al.*, 2012), balancing technological robustness with social legitimacy. Pilot sites such as Cluj-Napoca and

Coimbra illustrate polycentric governance, while artistic and cultural inputs reflect the New European Bauhaus vision (European Commission, 2021).

Consistent with Hinteá *et al.* (2015), STARHAUS integrates continuous feedback – surveys, interviews, workshops – into decision-making, ensuring institutional learning and adaptability. In this way, it offers a replicable model of distributed, ethically grounded leadership that underpins its contributions to the UN SDGs.

4. Methodology

This study adopts a qualitative and exploratory research paradigm, designed to capture the complex interplay between technological innovation, human-centric design, and socio-ecological transition. The central aim is to assess how STARHAUS translates its theoretical underpinnings – Industry 5.0, the New European Bauhaus (NEB), the Quintuple Helix model, and human-centric design – into practical contributions to the United Nations Sustainable Development Goals (SDGs).

Two research questions guide the analysis:

RQ1. How does STARHAUS align with and contribute to the SDGs, both in its declared objectives and in its early implementation outcomes?

RQ2. What empirical evidence from stakeholder engagement and industrial use cases supports the project’s claim to function as a replicable blueprint for socio-ecological transition?

The methodological design combines document analysis, survey-based data collection, and qualitative interviews in a phased and complementary structure.

The first phase consisted of a documentary analysis of the STARHAUS Project Proposal and the Mid-Term Review Report (M18), drawing on principles of grounded theory (Glaser and Strauss, 1967). Specific objectives were deconstructed into thematic codes through open coding, grouped into broader categories through axial coding, and synthesized into core narratives through selective coding (Corbin and Strauss, 2014). This process enabled a mapping of project intentions against the SDG framework and provided a baseline alignment of what STARHAUS proposes to achieve.

The second phase involved piloting an integrated stakeholder questionnaire in the first year of implementation. The instrument was designed to cover four thematic pillars – stakeholder satisfaction and involvement, adoption of solutions, technological innovation, and sustainability alignment – and was administered electronically via Google Forms. Responses were measured through Likert-scale items complemented by open-ended questions. Although only seven stakeholders completed the pilot, the results served a dual purpose: validating the relevance of the instrument and generating preliminary insights into stakeholder priorities.

The third phase incorporated structured interviews carried out in three national contexts – France, Portugal, and Romania – with an industrial cluster, a consultancy firm,

and a municipal authority. Guided by the STARHAUS Interview Guide, the interviews focused on market structures, competition, receptivity to innovation, and exploitation strategies for Manufacturing Demonstration Facilities (MDFs). These qualitative accounts added contextual nuance, highlighting both opportunities and barriers across diverse ecosystems.

By integrating these phases, the methodology enables a triangulated analysis: the project proposal captures declared objectives, the questionnaire validates indicators and stakeholder priorities, and the interviews provide contextual depth. This layered approach moves beyond description, linking STARHAUS's theoretical frames to its emerging empirical evidence. Industry 5.0 is reflected in stakeholder emphasis on human-centric and sustainable innovation; NEB values are visible in expectations for inclusivity and cultural relevance; the Quintuple Helix model is operationalized through the multi-stakeholder engagement underpinning the data collection; and human-centric design is reinforced by feedback that connects innovation with immediate social concerns such as working conditions.

The design is also longitudinal and iterative. The pilot data reported here form the first empirical layer. Subsequent project years will expand both the questionnaire sample and the number of interviews, enabling comparative and longitudinal analysis of stakeholder perceptions, adoption patterns, and sustainability impacts.

Ethical safeguards were applied across all instruments: participants were informed of the voluntary nature of their involvement, anonymity was guaranteed, and data processing complied with GDPR standards. Limitations are acknowledged, particularly the small size of the pilot sample and the exploratory scope of the first interview set. Nevertheless, these data provide an early empirical foundation that, when combined with the grounded analysis of objectives, demonstrate how STARHAUS has begun to operationalize its socio-ecological vision.

The methodological design also reflects public management principles, emphasizing transparency, accountability, and participatory decision-making. This ensures that empirical findings can inform policy cycles and guide administrative innovation in sustainability governance.

5. Results

The results presented in this section emerge from a combination of document analysis, pilot survey data, and structured interviews conducted during the first phase of STARHAUS implementation. Together, these sources provide both a conceptual and an empirical basis for understanding how the project advances its stated mission of fostering decentralized, human-centric manufacturing aligned with the United Nations Sustainable Development Goals (SDGs).

The first subsection focuses on STARHAUS's explicit and emerging alignment with the SDGs, followed by a discussion of preliminary findings from stakeholder engagement and industrial use cases.

5.1. Document analysis

The first layer of results is based on a grounded theory–inspired analysis of the STARHAUS Project Proposal (2023) and the Mid-Term Review Report (M18). Following the stages of open, axial, and selective coding (Corbin and Strauss, 2014; Glaser and Strauss, 1967), the analysis distilled key concepts from the ‘How’ descriptions of the project’s Specific Objectives (SOs). For instance, SO1 emphasized local resource integration and community engagement, while SO10 highlighted human-centric design and trust. These codes revealed a circular structure: citizens act not only as consumers but also as co-creators, with their feedback systematically reintegrated into innovation processes, creating a continuous loop of design, validation, and behavioral change. Axial coding grouped objectives into broader categories such as technological infrastructure (e.g., modular hardware/software, DIY4U technology), methodological frameworks (S+T+ARTS, NEB), and community as agent of change. This highlighted that STARHAUS’s impacts derive directly from its methods: decentralized production (SO1) or co-design (SO6) generate both technological outputs and social transformation. Selective coding synthesized these interrelations into a core narrative: STARHAUS positions itself as a catalyst for socio-ecological transition, where systemic change emerges through localized, participatory, and human-centric ecosystems. Technology acts as an enabler, but the project’s distinctiveness lies in the fusion of engineering with social sciences, arts, and citizen engagement.

Table 1: How specific objective contributes to the three fundamental thematic pillars

Specific Objective (What STARHAUS Proposes)	Pillar 1: Human-Centric Innovation	Pillar 2: NEB & S+T+ARTS as a Methodology	Pillar 3: Circularity & Systems
SO1. Support decentralized manufacturing vision	Community and stakeholder engagement	Co-creation of sustainable systems	Decentralized production and consumption
SO2. Promote collaborative models (S+T+ARTS)	Collaborative models between experts	S+T+ARTS framework and cross-disciplinary cooperation	
SO3. Stimulate regeneration of manufacturing spaces	Co-creation with stakeholders	Stimulating the regeneration of spaces	Creation of innovation hubs
SO4. Enable growth of sustainable manufacturing methods	Human-centered approach		Repurposing and adapting technology
SO5. Measure behavioral change towards sustainability	Measuring behavioral change		Social and ecological impact assessment
SO6. Design and validate human-centered products	Human-centered design, co-creation		Focus on sustainability and circularity
SO7. Provide financial support to third parties (FSTP)	Financial support to third parties	Promoting S+T+ARTS	
SO8. Connect with EU/national projects	Connecting and collaborating		Synergies in innovation ecosystems
SO9. Raise the profile of manufacturing careers	Engaging youth, new skills		Back casting methodology
SO10. Apply a human-centric design approach	Human-centric approach, SSH approach		Integration of social and ethical aspects

Source: Authors’ synthesis based on axial and selective coding of STARHAUS Project Proposal (2023)

This integrated vision is captured in Table 1, which shows how each SO contributes across three thematic pillars – human-centric innovation, NEB & S+T+ARTS methodology, and circularity & systems – confirming STARHAUS as both a methodological innovation and a replicable model for sustainable transformation. From a governance perspective, the structured linkage between project objectives and SDG targets provides a model for policy monitoring and evaluation within public administration, showing how complex innovation programs can be translated into measurable public outcomes.

STARHAUS alignment with the UN Sustainable Development Goals: The initial set of findings stems from an analysis informed by grounded theory principles, applied to the STARHAUS Project Proposal (2023) and the Mid-Term Review Report (M18- June 2025). This approach makes it possible to distinguish between what STARHAUS set out to accomplish and what has already been achieved, offering clarity on its mission, beneficiaries, tangible results, and implementation stage. At the conceptual level, STARHAUS contributes directly to SDG 9 (Industry, Innovation and Infrastructure) by developing modular hardware and software (TRL6/7) that enable decentralized, resilient manufacturing. It advances SDG 12 (Responsible Consumption and Production) through circular models emphasizing personalization, refill, and reuse, with a commitment to reduce the life-cycle footprint of products by at least 15%. By embedding localized production and regenerative practices such as bio-waste valorization, the project supports SDG 13 (Climate Action). Finally, its seven-country consortium – uniting academia, SMEs, municipalities, civil society, and cultural actors – illustrates the principles of SDG 17 (Partnerships for the Goals). These human-centric models also generate indirect ripple effects across SDGs 3, 4, 5, and 11, reinforcing health, education, gender equality, and sustainable cities.

Empirical evidence from the mid-term review shows that these ambitions are already being operationalized. Four localized service models have been piloted, proving the adaptability of decentralized infrastructures (SDG 9). Seven new hardware modules reached advanced simulation stages, and an integrated software ecosystem has been prototyped, laying the foundation for sustainable production and consumption (SDG 12). More than 300 stakeholders have been engaged through workshops, surveys, and professional networks, enhancing inclusive governance and participatory collaboration (SDG 17, SDG 5). Early environmental assessments, together with the fertilizer use case based on bio-waste, provide tangible contributions to climate action (SDG 13). Table 2 maps these specific objectives against achievements at M18 and their linked SDGs, showing how STARHAUS is moving from stated ambitions to verifiable results.

The evidence summarized in Table 2 shows that STARHAUS remains closely aligned with its original objectives while also producing measurable progress midway through implementation. The explicit mapping of specific objectives to SDGs highlights both the strategic relevance of the project in the European and global policy context and its practical capacity to generate systemic change. This section thus provides the foundation for the following analysis of stakeholder data and industrial use cases, where the human-centric and socio-ecological impacts of STARHAUS can be observed in greater detail.

Table 2: STARHAUS: Specific Objectives, Achievements, and Contributions to the UN SDGs

Specific Objective (What STARHAUS Proposes)	What Has Been Achieved So Far (M18)	Linked SDGs
S01. Support decentralized manufacturing vision: Integrate local resources, reduce dependence on centralized supply chains, and engage communities in sustainable production and consumption (KPI: 100+ citizens engaged, 8 EU Climate-Neutral Cities targeted).	Four localized service models developed in FMCG domains (pet food, beverages, cereals, fertilizers). Active co-design workshops in pilot sites (Cluj-Napoca).	SDG 9 (Industry, Innovation and Infrastructure); SDG 11 (Sustainable Cities and Communities); SDG 12 (Responsible Consumption and Production)
S02. Promote collaborative models (S+T+ARTS): Foster co-creation among domain experts, artists, and technology providers (KPI: 8 NEB-based methods and models).	Three Open Innovation Calls completed; six third-party projects funded; two S+T+ARTS residencies launched.	SDG 17 (Partnerships for the Goals); SDG 9 (Innovation)
S03. Stimulate regeneration of manufacturing spaces: Transform spaces into hubs for innovation and sustainable production (KPI: New models piloted in at least 2 communities).	MDFs established as living labs; urban spaces redesigned for participatory production.	SDG 5 (Gender Equality, through inclusivity in collaboration); SDG 11 (Sustainable Cities and Communities); SDG 9 (Resilient Infrastructures)
S04. Enable growth of sustainable manufacturing methods: Develop modular hardware and software for circular and low-impact production.	Seven hardware modules advanced to the simulation stage; prototype of integrated software ecosystem completed.	SDG 9 (Industry, Innovation); SDG 12 (Sustainable Production); SDG 13 (Climate Action)
S05. Measure behavioral change towards sustainability: Longitudinal social impact assessment with consumers, producers, and policy-makers (KPI: 300+ survey participants).	First surveys and interviews launched; >300 stakeholders engaged via LinkedIn and workshops; early feedback loops created.	SDG 12 (Responsible Consumption); SDG 4 (Quality Education – awareness/skills); SDG 17 (Partnerships)
S06. Design and validate human-centered products: Co-design FMCG products embedding personalization, sustainability, and circularity.	Prototypes piloted: refillable cereals/beverages; fertilizer from bio-waste. Early environmental assessments are underway.	SDG 12 (Sustainable Consumption and Production); SDG 3 (Good Health and Well-being)
S07. Provide financial support to third parties (FSTP): Launch two Open Calls to fund SMEs/startups (KPI: ≥6 grants, €300K budget).	First Open Call completed; six external SME projects funded and supported.	SDG 17 (Partnerships); SDG 9 (Innovation ecosystems)
S08. Connect with EU/national projects: Organize cluster events and share practices with sibling projects (KPI: ≥1 cluster event).	First cluster events held; synergies documented with Horizon projects.	SDG 17 (Partnerships for the Goals)
S09. Raise the profile of manufacturing careers: Promote new occupational profiles and skills (KPI: 4 career days in urban regions).	Early dissemination campaigns and conference presence; >20 professional social media posts per year.	SDG 4 (Quality Education); SDG 8 (Decent Work and Economic Growth)
S010. Apply a human-centric design approach: Integrate SSH and participatory design to build trust, inclusivity, and acceptance.	Co-design workshops implemented with balanced gender representation; inclusivity embedded in pilot activities.	SDG 5 (Gender Equality); SDG 10 (Reduced Inequalities); SDG 12 (Responsible Production)

Source: Authors' own contribution based on the STARHAUS Project Proposal (Grant Agreement No. 101136027) and the Mid-Term Review Report (M18)

5.2. Stakeholder questionnaire (Pilot study)

The second phase of data collection involved piloting the integrated STARHAUS stakeholder questionnaire in the first year of implementation. The instrument was designed to assess four thematic pillars – stakeholder satisfaction and involvement, adoption of solutions, technological innovation, and sustainability alignment. The pilot study was completed by seven respondents and, while the small number precludes statistical generalization, it served two critical functions: validating the methodological tool and providing the first empirical evidence on how stakeholders perceive STARHAUS’s goals. The findings show a clear convergence between the project’s declared objectives and stakeholder expectations, directly informing RQ1 (‘How does STARHAUS align with and contribute to the SDGs, both in its declared objectives and in its early implementation outcomes?’). Most respondents rated stakeholder satisfaction, adoption of solutions, innovation, and sustainability as essential factors for success. This confirms that the indicators STARHAUS uses to measure progress are perceived as highly relevant by stakeholders. Importantly, the pilot also reveals that sustainability is understood in a broader, holistic sense, encompassing not only ecological goals but also social dimensions such as workplace well-being. Table 3 summarizes the main results of the pilot questionnaire, connecting them explicitly with the project’s conceptual frames and the SDG agenda.

Table 3: Pilot questionnaire results

Evaluated Dimension	Stakeholder Perceptions	Relevance for STARHAUS and RQs	Linked SDGs
Stakeholder satisfaction	Rated as essential for success	Confirms human-centric focus (Industry 5.0); validates RQ1 on alignment with human-centered innovation	SDG 9, SDG 11
Adoption of solutions	Considered highly important	Supports STARHAUS’s claim of practical transferability; contributes to RQ2 on early evidence of adoption	SDG 9, SDG 12
Technological innovation	Prioritized by respondents	Confirms alignment with innovation-driven SDGs; validates STARHAUS’s TRL6/7 developments	SDG 9
Sustainability	Viewed as essential	Confirms STARHAUS’s ecological focus; links directly to RQ1 on SDG alignment	SDG 12, SDG 13
Awareness, partnerships	Important, with mixed perceptions	Highlights conditions for scaling; points to need for stronger multi-actor governance (Quintuple Helix)	SDG 17
Open comments	‘Nice idea!’, ‘Don’t forget to improve the employee’s working environment’	Indicates that stakeholders equate sustainability with both ecological and social well-being; informs RQ2 on human-centric validity	SDG 5, SDG 8

Source: Authors’ own contribution based on pilot research results

The feedback provides a critical perspective on RQ2 (‘What empirical evidence from stakeholder engagement and industrial use cases supports the project’s claim to function as a replicable blueprint for socio-ecological transition?’). While stakeholders supported STARHAUS’s objectives, they also highlighted practical expectations: sustainability must

not remain an abstract principle, but must deliver concrete improvements in work environments and daily life. This interpretation resonates strongly with Industry 5.0 and human-centric design, where social well-being is inseparable from technological innovation. These preliminary results demonstrate that STARHAUS's declared objectives are well aligned with stakeholder perceptions, and they provide the first empirical confirmation that the project is moving toward its goal of creating a replicable, socio-ecological innovation model. Although exploratory, the pilot validates both the questionnaire as a methodological tool and the project's underlying claim that its framework can resonate with real-world actors. These stakeholder perceptions also provide valuable insight for public administrators seeking to design participatory policies that balance technological efficiency with social legitimacy.

5.3. Structured interviews (France, Portugal, Romania)

The third phase of empirical research consisted of structured interviews with three types of stakeholders in different national contexts: an industrial cluster in France, a consultancy firm in Portugal, and a municipal authority in Romania. The purpose of these interviews was to explore how STARHAUS's objectives resonate across diverse ecosystems, capturing perceptions of market structures, barriers, and opportunities for decentralized, human-centric manufacturing.

The interviews provide valuable evidence for RQ1 ('How does STARHAUS align with and contribute to the SDGs?') by showing that sustainability, innovation, and personalization are recognized as priorities across all contexts. At the same time, they provide insight into RQ2 ('What empirical evidence supports STARHAUS's claim to function as a replicable blueprint for socio-ecological transition?') by highlighting both enabling factors and structural constraints that affect replication and scalability. Despite contextual differences, a common thread across all three cases is receptivity to sustainable and innovative production models. Respondents consistently underlined the importance of product quality and consumer trust as prerequisites for adoption. At the same time, significant barriers were identified: saturation by dominant global players in France, scalability issues in Portugal's fragmented markets, and bureaucratic obstacles and infrastructure gaps in Romania.

These insights confirm STARHAUS's alignment with SDG 9 (Industry, Innovation, and Infrastructure) and SDG 11 (Sustainable Cities and Communities) by emphasizing the importance of localized, adaptive manufacturing models. They also reinforce the centrality of SDG 17 (Partnerships for the Goals): success in each national context depends on building multi-actor alliances tailored to local market dynamics and institutional realities. Most importantly, the interviews provide empirical confirmation for RQ2: STARHAUS's model is adaptable but context-dependent. Its promise as a replicable blueprint lies not in a one-size-fits-all approach, but in its flexibility to be reconfigured according to local market structures, consumer expectations, and institutional frameworks.

The interviews confirm both convergence with global sustainability goals and the contextual challenges that must be addressed to realize systemic change. The findings

Table 4: Structured interview results

Country / Context	France (Industrial Cluster)	Portugal (Consultancy Firm)	Romania (Municipal Authority, Cluj-Napoca)
Market Structure	Highly competitive, dominated by large global players (e.g., BASF, Solvay)	Fragmented, service-oriented market	Fragmented, dominated by SMEs, constrained by bureaucracy
Opportunities	Interest in recycling, green chemistry, and sustainable alternatives	Flexibility and adaptability valued; demand for personalized solutions	Potential for urban innovation hubs and local partnerships
Challenges	Market saturation, entry barriers for new actors	Difficulty in scaling innovations in fragmented contexts	Administrative barriers, weak infrastructure
Strategic Implications for STARHAUS	Sustainability and innovation must be core differentiators to gain legitimacy	STARHAUS must design flexible, modular MDFs to penetrate niche markets	Partnerships with municipalities and SMEs are essential for adoption and impact
Linked SDGs	SDG 9, SDG 12, SDG 13	SDG 9, SDG 11, SDG 17	SDG 9, SDG 11, SDG 17

Source: Authors' own contribution based on pilot research results

underline that administrative structures, regulatory frameworks, and inter-institutional collaboration are decisive in enabling or constraining decentralized innovation, reaffirming the importance of adaptive public governance.

6. Discussion

This section integrates the theoretical, methodological, and empirical findings to show how STARHAUS translates its vision into practice. Using document analysis, surveys, and interviews, the discussion highlights how decentralized manufacturing, human-centric design, and circular production are realized in industrial use cases, setting the stage for the study's research questions.

6.1. Industrial use cases and transformations

Building on the foundation established by the DIY4U project, STARHAUS has expanded the concept of Manufacturing Demonstration Facilities (MDFs) from a single customized product line to a diversified, multi-sector model. While DIY4U focused exclusively on personalized detergent powders, STARHAUS reconfigured and scaled the MDF concept to accommodate four entirely new use cases – fertilizers, pet food, beverages, and breakfast cereals. This transformation represents a shift from a narrowly defined, single-material process to a flexible platform capable of addressing multiple production contexts with differing physical properties, safety standards, and end-user expectations.

To enable these new applications, several advanced modules are being designed and tested. These include systems for dispensing, visual inspection of bottle cleanliness using cameras, feeding, storage, and robotic gripping, all of which are being adapted to different industrial environments and material types. The automation layer of STARHAUS is

being upgraded accordingly, integrating new control algorithms and user-friendly mobile interfaces. Unlike DIY4U's web-based application, STARHAUS develops four dedicated mobile apps, one for each product line, to enhance accessibility, user interaction, and real-time monitoring of production parameters. At this stage, the MDFs are in the design and testing phase, with validation focusing on ensuring interoperability between hardware modules and digital interfaces. These efforts target Technology Readiness Levels (TRL) 6–7, preparing the groundwork for future exploitation and real production in pilot sites. The introduction of these new modules and control systems signals the technological maturation of the MDF concept – from proof of concept to an integrated platform.

Equally important, STARHAUS operationalizes its human-centric vision by embedding co-creation and participatory design throughout the process. Interviews were applied in Portugal, France, and Romania, and workshops and collaborative sessions were organized with stakeholders, including citizens, SMEs, and municipalities, to ensure that the manufacturing solutions developed reflect local priorities, social acceptance, and environmental responsibility. The resulting model positions MDFs as both engineering infrastructures and as living laboratories for social innovation, connecting technology, community, and sustainability in tangible ways.

The modifications introduced included a shift from centralized mass production toward decentralized and localized hubs in urban contexts, embedding human-centered design into the production process, and integrating sustainability and circularity principles throughout the product lifecycle. The transition from centralized mass production to decentralized, localized hubs demonstrates SDG 9's focus on resilient infrastructure, while the integration of circularity across product lifecycles operationalizes SDG 12.

The outcomes of these adaptations demonstrate the systemic potential of STARHAUS. Localized manufacturing reduced the environmental footprint of production by lowering transportation needs and waste generation, while personalization encouraged behavioral shifts toward more sustainable and conscious consumption. Moreover, the establishment of collaborative ecosystems involving SMEs, municipalities, citizens, and researchers strengthened trust and inclusivity in line with SDG 17. The results thus confirm that MDFs are not only technologically viable but also socially impactful, offering a replicable model for sustainable urban production.

6.2. Human-centric approach in practice

The methodological focus on human-centric design and co-creation (SO1, SO6, SO10) is realized through participatory workshop activities in Italy, France, and Romania. Grounded theory coding had revealed the centrality of 'community as an agent of change', and this was borne out in workshops where citizens co-designed product features. Ingredient selection in cereals and pet food linked customization with health and sustainability, while region-specific fertilizer formulations reduced environmental runoff, aligning practice with SDG 3 and SDG 13. These participatory methods confirmed that end-users can play an active role not merely as consumers but as co-creators, embedding community-driven

values into production systems. The urban integration of MDFs further underscores the human-centricity of STARHAUS. Locating facilities within cities allowed citizens to take greater ownership of consumption patterns, reinforced by the experiential dimension of product personalization. This localized presence also made sustainability more tangible, as individuals could directly observe and participate in the processes that affect their daily lives. For public administration, these participatory processes illustrate how local governments can institutionalize co-creation as a governance tool, bridging the gap between administrative planning and citizen-driven innovation.

6.3. Innovative production processes

In addition to its participatory aspects, STARHAUS demonstrated innovation in its production processes. By repurposing MDFs for four highly distinct product categories, the project confirmed the adaptability and scalability of its model. The integration of digital manufacturing techniques enabled rapid customization without compromising cost-efficiency or speed, bridging the gap between personalization and industrial viability. Sustainability was embedded into the process from the outset, with bio-waste valorization in fertilizers providing a clear case of how circular design can reduce environmental pressures while maintaining efficiency.

These results illustrate that STARHAUS goes beyond theoretical ambition. Its combination of human-centric design, advanced digital tools, and circularity has begun to yield measurable results, confirming the viability of its proposed production model. The resulting model offers public authorities practical insights into how regulatory frameworks, procurement policies, and local partnerships can stimulate circular and sustainable production.

6.4. Comparison with similar initiatives

The novelty of STARHAUS becomes clear when positioned in comparison to FabLabs, micro-factories, and distributed platforms. While all emphasize decentralization and digital integration, STARHAUS extends these models by embedding the NEB's values of inclusivity and aesthetics, and by scaling human-centric design across multiple FMCG domains. This is consistent with the Quintuple Helix framework: technology is not developed in isolation but co-evolves with societal needs, cultural values, and ecological constraints. Like these initiatives, STARHAUS emphasizes local production, digital integration, and consumer engagement.

However, several distinctive features set it apart. First, the project advances human-centric design at scale, involving citizens not just as users but as active co-creators of products that reflect local values and sustainability priorities. Second, it demonstrates cross-sector adaptability, successfully applying its MDFs to four highly diverse product categories. Third, STARHAUS emphasizes urban integration, placing production facilities directly within cities to influence consumption habits and make sustainable manufacturing a visible, everyday practice. Finally, it fosters a dynamic feedback loop between production and

consumption, where community preferences directly inform design choices, and manufacturing capabilities evolve in response to shifting values.

These contributions highlight the novel positioning of STARHAUS in the landscape of decentralized production: it is not merely a platform for digital fabrication or product personalization, but a socio-technical ecosystem where technology, citizens, and sustainability co-evolve.

6.5. Fundamental questions of the study

The discussion is also structured around the two research questions that guided this study.

RQ1. How does STARHAUS align with and contribute to the United Nations Sustainable Development Goals (SDGs)?

The document analysis confirmed that STARHAUS was designed to advance SDG 9 (Industry, Innovation and Infrastructure), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 17 (Partnerships for the Goals), embedding these targets in its objectives on decentralized manufacturing, circularity, and multi-actor collaboration. Coding of objectives revealed a systemic vision that integrates Industry 5.0's human-centric paradigm, the New European Bauhaus (NEB) emphasis on sustainability and inclusivity, and the Quintuple Helix model of innovation ecosystems. Mid-term results further demonstrate progress. Localized service models and modular technologies advance SDG 9 and SDG 12, while bio-waste valorization for fertilizers contributes to SDG 13. Stakeholder engagement—over 300 participants across workshops and networks—anchors SDG 17, with inclusivity in activities contributing to SDG 5. These results show STARHAUS has begun to operationalize its commitments, though long-term impacts remain to be assessed.

RQ2. What empirical evidence supports STARHAUS as a replicable blueprint for socio-ecological transition?

Empirical evidence from the industrial use cases confirms that STARHAUS is evolving into a replicable model of socio-ecological transition by demonstrating adaptability, stakeholder inclusion, and cross-sector scalability. The transition from DIY4U's single-use case for customized detergent powders to STARHAUS's four industrial domains—pet food, fertilizers, beverages, and breakfast cereals—illustrates the project's capacity to generalize its Manufacturing Demonstration Facility (MDF) model across distinct production environments. The introduction of advanced modules for dispensing, visual inspection, feeding, storage, and gripping, alongside automation and user-friendly mobile interfaces, demonstrates both technological maturity (targeting TRL 6–7) and systemic integration of Industry 5.0 principles.

Survey results highlighted stakeholder priorities of satisfaction, adoption, innovation, and sustainability—echoing the Industry 5.0 emphasis on human-centric design. Open-ended feedback added expectations for improved working conditions, reflecting

the inclusive ethos of the New European Bauhaus (NEB). The organization of co-design workshops with citizens, SMEs, and municipalities ensured that these technological developments were anchored in participatory processes, where local perspectives shaped design choices and production workflows. These activities substantiate that STARHAUS's 'human-centricity' is not conceptual but procedural, embedded in each phase of design and validation. Structured interviews across France, Portugal, and Romania further revealed contextual dynamics shaping replication potential. French stakeholders emphasized sustainability and competitiveness in saturated markets; Portuguese partners pointed to flexibility as key in fragmented market contexts; and Romanian respondents underscored bureaucratic barriers yet highlighted strong potential for urban innovation through municipal collaboration. Despite these differences, all cases exhibited receptivity to localized and sustainable manufacturing models, confirming the MDF's flexibility as a core asset.

Together, these findings indicate that STARHAUS's blueprint for socio-ecological transition lies in its convergence of technological scalability, participatory governance, and contextual adaptability. The MDFs serve as both engineering testbeds and social laboratories, where new production modules and human-centric practices co-evolve. Success thus depends not only on automation or digital innovation, but equally on governance, cultural acceptance, and multi-actor collaboration—underscoring the ongoing relevance of the Quintuple Helix framework in guiding STARHAUS toward a systemic, sustainable transformation.

7. Conclusions and recommendations

The present study demonstrates that STARHAUS is not only aligned with the United Nations Sustainable Development Goals but is actively beginning to operationalize them through concrete actions and verifiable results. The qualitative analysis confirmed that STARHAUS's declared objectives, as outlined in the project proposal, translate into measurable contributions to SDG 9 (Industry, Innovation, and Infrastructure), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 17 (Partnerships for the Goals), while generating positive spillover effects on SDGs 3, 4, 5, and 11.

Empirical evidence from the industrial use cases reinforces these findings. The transformation of the Manufacturing Demonstration Facilities (MDFs) from the single-use DIY4U prototype for customized detergent powders into four fully developed use cases—pet food, fertilizers, beverages, and breakfast cereals—demonstrates STARHAUS's ability to scale its model across multiple Fast-Moving Consumer Goods (FMCG) sectors. New modules for dispensing, feeding, visual inspection, storage, and robotic gripping were designed and tested, accompanied by the introduction of four dedicated mobile applications that replace the earlier web-based system. These technological upgrades signal not only an increase in Technology Readiness Levels (TRL 6–7) but also confirm that decentralization and adaptability are achievable in diverse production contexts.

Equally significant is the project's human-centric orientation. Through co-design workshops, participatory design sessions, and stakeholder consultations, STARHAUS ensured that technological innovation evolved in parallel with community values, ethical considerations, and local priorities. This participatory framework—rooted in the principles of the New European Bauhaus (NEB) and the Quintuple Helix model—anchors STARHAUS's approach in real social contexts, transforming its MDFs into living laboratories for socio-ecological innovation.

The pilot survey and structured interviews further validate this human-centered and systemic approach. Stakeholders consistently emphasized sustainability, innovation, and adoption as core success factors, while open-ended feedback reflected expectations for improved working conditions and inclusivity—clear indicators of alignment with the Industry 5.0 paradigm. Despite contextual barriers such as cost structures, market saturation, and administrative constraints, a shared understanding emerged across national contexts of the need for localized, circular, and flexible manufacturing models.

From these findings, several conclusions emerge. STARHAUS provides evidence that decentralized, participatory, and digitally enhanced manufacturing ecosystems can advance the SDGs in practice. Its dual focus on technological infrastructure and social co-creation shows that innovation can be both economically viable and socially transformative. Stakeholder priorities—satisfaction, adoption, innovation, and sustainability—mirror global sustainability targets, confirming STARHAUS's relevance beyond its immediate industrial domains.

Looking ahead, the project would benefit from embedding quantitative SDG metrics into its monitoring processes to ensure that each pilot and use case contributes measurable progress toward specific indicators such as carbon footprint reduction, waste minimization, resource reuse, and gender inclusivity. Expanding longitudinal stakeholder engagement will be essential to assess not only short-term outputs but also long-term impacts on behavior, governance, and market readiness. Translating these practices into policy instruments, including guidelines and policy briefs for municipalities and SMEs, can further support replication across Europe.

STARHAUS continues to connect technological achievements with societal narratives that resonate across SDG-focused communities. Through the integration of modular technology, mobile accessibility, and participatory design, STARHAUS positions itself as a reference model for sustainable and human-centric industrial transformation, offering a scalable blueprint that bridges Horizon Europe innovation with the global 2030 Agenda. For public administration, STARHAUS offers an evidence-based model for integrating sustainability into governance systems. By aligning technological experimentation with participatory governance, the project illustrates how municipalities and policy institutions can act as catalysts for socio-ecological transformation, bridging the gap between innovation policy and everyday public management.

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