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CO-CREARE FUTURI SOSTENIBILI
Il MUSAE Factory model per un'innovazione con arte e tecnologia orientata agli SDG

CO-CREATING SUSTAINABLE FUTURES
The MUSAE Factory Model for SDG-oriented innovation through art and technology

Marita Canina, Tatiana Efremenko

Abstract

L'innovazione è centrale per l'avanzamento degli Obiettivi di Sviluppo Sostenibile e delle Agende europee, ma i modelli attuali faticano a confrontarsi con la complessità sistemica, i compromessi e le transizioni di lungo periodo. Il presente contributo illustra il progetto MUSAE e il suo Factory Model a codice aperto, un quadro operativo guidato dall'arte e orientato al futuro, coerente con il paradigma dell'Industria 5.0. Al suo centro si colloca il metodo Design Futures Art-driven (DFA), che integra analisi delle tendenze, visione, ideazione e prototipazione, combinando sperimentazione artistica, design, sviluppo tecnologico e co-creazione con l'intelligenza artificiale. Testato in residenze caratterizzate dalla presenza di arte e tecnologia nel contesto del 'cibo come medicina', MUSAE dimostra come visioni condivise del futuro possano generare prototipi fino al TRL5 e favorire sinergie sistemiche. Il modello interpreta l'SDG 9 come abilitatore di un'innovazione integrata, centrata sull'uomo e sul pianeta, in condizioni di incertezza.

Innovation is central to advancing the Sustainable Development Goals and European agendas, yet current models struggle to address systemic complexity, trade-offs, and long-term transitions. This contribution presents the MUSAE project and its open-source Factory Model, an art-driven, futures-oriented operational framework aligned with the Industry 5.0 paradigm. At its core is the Design Futures Art-driven (DFA) method, which integrates trend analysis, visioning, ideation, and prototyping by combining artistic experimentation, design, technological development, and co-creation with artificial intelligence. Tested through art-and-technology residencies in the context of 'food as medicine', MUSAE shows how shared visions of the future can generate prototypes up to TRL5 and foster systemic synergies. The model interprets SDG 9 as an enabler of integrated, human- and planet-centred innovation under conditions of uncertainty.

Keywords

collaborazione arte-tecnologica, innovazione anticipatoria, sviluppo sostenibile, industria 5.0, design orientato all'esplorazione dei futuri e guidato dall'arte

art-technology collaboration, anticipatory innovation, sustainable development, industry 5.0, art-driven design futures

Marita Canina, is an Associate Professor at the Department of Design, Politecnico di Milano (Italy), and the Scientific Director of the IDEActivity Center. Her research focuses on design studies, creativity, and a people- and planet-centred approach, with particular attention to Design and Futures Thinking. E-mail: marita.canina@polimi.it

Tatiana Efremenko, PhD in Design, is a Research Fellow at the IDEActivity Center, Politecnico di Milano (Italy). Her research explores Design Futures applied to post-human urban environments and to interactions between human and non-human beings. She contributed to the Horizon Europe MUSAE project and developed methodologies for assessing social capital with SILK in Kyrgyzstan. E-mail: tatiana.efremenko@polimi.it

I primi decenni del XXI secolo sono sempre più spesso descritti come una condizione di policrisi (Morin, 2020) nella quale il cambiamento climatico, la perdita di biodiversità, l'instabilità geopolitica, le emergenze sanitarie e le crescenti disuguaglianze socio-economiche interagiscono in modo interdipendente e si rafforzano reciprocamente. Più che come perturbazioni isolate queste dinamiche si manifestano come intrecci sistemici che mettono in luce le fragilità profonde dei sistemi globali di produzione e delle infrastrutture.

In questo contesto i processi di innovazione restano centrali per lo sviluppo economico, il progresso tecnologico e la trasformazione sociale. Nelle agende politiche internazionali l'innovazione occupa una posizione chiave in quadri di riferimento quali gli Obiettivi di Sviluppo Sostenibile (SDG) delle Nazioni Unite (UN, 2015), il Green Deal europeo (European Commission, 2019) e la strategia Farm to Fork (European Commission, 2020). In particolare l'SDG 9 promuove infrastrutture resilienti, innovazione e un'industrializzazione inclusiva, collocando lo sviluppo tecnologico come motore della trasformazione sostenibile. Esso può quindi essere interpretato non solo come un obiettivo settoriale ma anche come una leva trasversale in grado di influenzare molteplici dimensioni della sostenibilità.

Nonostante tali ambizioni i progressi verso i target dell'Agenda 2030 rimangono disomogenei: a meno di cinque anni dalla scadenza il Sustainable Development Goals Report 2023 delle Nazioni Unite (UN, 2023) segnala che solo il 15% circa dei target è in linea con le traiettorie previste, mentre per oltre un terzo i progressi si sono arrestati o invertiti rispetto ai livelli del 2015. La pandemia di Covid-19, l'accelerazione della crisi climatica, i conflitti geopolitici e le crescenti disuguaglianze economiche hanno eroso i progressi conseguiti nel decennio precedente. La sfida non consiste più nell'accelerare l'implementazione degli obiettivi ma nel ripensare i sistemi di innovazione attraverso cui lo sviluppo viene concepito e attuato: come documentato dall'OECD (2024) i progressi più lenti si registrano proprio negli obiettivi che richiedono trasformazioni strutturali dei sistemi produttivi e delle culture dell'innovazione, non semplici miglioramenti incrementali.

Come evidenziato dalla letteratura sulle 'transizioni socio-tecniche profonde' (Schot and Steinmueller, 2018) la sostenibilità implica trasformazioni di lungo periodo che vanno ben oltre semplici miglioramenti tecnologici incrementali. Tuttavia i modelli dominanti di innovazione restano in larga misura ancorati a logiche lineari di ricerca e sviluppo, orientate all'ottimizzazione di breve periodo e alla competitività di mercato. Tali approcci tendono a concepire l'innovazione come un esercizio tecnico volto a risolvere problemi, spesso disconnesso dalle più ampie dinamiche socio-ecologiche e poco attento, nel lungo periodo, alle questioni di equità, governance e impatto ambientale (Stirling, 2015; OECD, 2018), di conseguenza faticano a confrontarsi con le sinergie e i compromessi tra i diversi SDG.

L'accelerazione della trasformazione digitale intensifica ulteriormente queste tensioni: intelligenza Artificiale, manifattura avanzata, robotica e infrastrutture dei dati offrono opportunità senza precedenti ma, se inserite in modelli estrattivi o orientate esclusivamente alla crescita, rischiano di amplificare il consumo di risorse e le disuguaglianze sociali. In risposta, il framework europeo dell'Industria 5.0[1] propone un cambio di paradigma che supera una visione dell'efficienza centrata sull'automazione e pone al centro l'essere umano, la sostenibilità e la resilienza come principi guida della trasformazione industriale (European Commission, 2021), riconfigurando l'innovazione come processo orientato a valori e missioni.

Un simile cambiamento richiede modelli di innovazione capaci di abilitare forme di governance anticipatoria, integrando l'esplorazione dei futuri, la riflessione etica e la deliberazione collettiva nei processi di sviluppo tecnologico (Guston, 2014; Ahern, 2025; Tõnurist and Hanson, 2020). L'innovazione anticipatoria implica infatti la capacità di immaginare, discutere e negoziare collettivamente visioni e orientare le traiettorie tecnologiche in modo consapevole. In tale prospettiva le pratiche artistiche e il design possono contribuire ad ampliare le dimensioni cognitive e culturali dell'innovazione, mettendo in discussione assunti dominanti ed esplorando traiettorie alternative (Purg, Cacciatore and Gerbec, 2023). Nonostante questo potenziale le collaborazioni tra arte e tecnologia restano spesso episodiche e prive di strutture metodologiche stabili (EUNIC, 2019), limitando il loro impatto nei processi di innovazione industriale.

Si pone così una questione metodologica centrale: come integrare in modo sistematico tali dimensioni anticipatorie nei processi di innovazione industriale, evitando che restino marginali o residuali? Piuttosto che considerarlo un obiettivo puramente tecnico, l'SDG 9 può essere reinterpretato come un'infrastruttura abilitante per le transizioni sistemiche, in cui l'innovazione industriale evolve in dialogo con i limiti ecologici, l'equità sociale e l'immaginazione culturale?

Alla luce di tali premesse il contributo si propone di analizzare il modello MUSAE Factory, risultato del progetto europeo MUSAE, come infrastruttura metodologica a codice aperto per un'innovazione sistemica, orientata ai futuri e guidata dall'integrazione tra arte e tecnologia. In particolare l'articolo intende: a) discutere i limiti dei modelli di innovazione dominanti rispetto alla complessità delle transizioni sostenibili; b) presentare il MUSAE Factory Model e il metodo Design Futures Art-driven (DFA); c) analizzarne l'applicazione attraverso casi studio nel contesto 'cibo come medicina'; d) valutare il contributo del modello nel gestire sinergie e compromessi tra gli SDG. In questo contributo l'SDG 9 è considerato come obiettivo abilitante, a supporto dell'integrazione degli SDG 12, 13 e 15, che sono direttamente affrontati attraverso i casi studio presentati e il MUSAE Factory Model.

Il paper è articolato in quattro parti: una prima sezione ricostruisce lo stato dell'arte sui modelli di innovazione per lo sviluppo sostenibile; una seconda presenta il MUSAE Factory Model e il metodo DFA; una terza analizza il modello e lo confronta con altre metodologie; una quarta discute limiti, trasferibilità e implicazioni rispetto agli SDG. L'interesse del contributo per la comunità scientifica risiede nella proposta di un modello integrato e trasferibile che combina pratiche artistiche, esplorazione dei futuri e sviluppo tecnologico, offrendo strumenti operativi per affrontare la complessità delle transizioni sostenibili in condizioni di incertezza.

Modelli di innovazione per lo sviluppo sostenibile | La ricerca sull'innovazione riconosce che affrontare le sfide della sostenibilità richiede profonde trasformazioni sistemiche delle configurazioni socio-tecniche, più che semplici aggiornamenti tecnologici incrementali. I sistemi di produzione industriale e gli ecosistemi dell'innovazione modellano infatti i flussi di risorse, le opportunità economiche e le forme di inclusione sociale. In questa prospettiva l'SDG 9 può essere interpretato come una matrice strutturale capace di orientare la transizione verso ecosistemi industriali e infrastrutturali più resilienti e sostenibili, generando effetti a cascata su molteplici altri SDG.

Negli ultimi anni sono emersi diversi quadri concettuali per rispondere a questa esigenza di trasformazione sistemica. La letteratura sulle 'politiche di innovazione trasformativa' propone un passaggio dal tradizionale sostegno alla ricerca e sviluppo e alla competitività verso transizioni sociotecniche di lungo periodo, allineate alle grandi sfide sociali (Schot and Steinmueller, 2018). Analogamente i modelli di 'innovazione orientata da missioni' promuovono sforzi coordinati tra attori pubblici e privati per affrontare sfide di ampia portata, come la neutralità climatica o la trasformazione dei sistemi alimentari (Mazzucato, 2018), mentre gli approcci improntati a 'ricerca e innovazione responsabili' enfatizzano anticipazione, riflessività, inclusione e reattività come principi chiave per la governance dell'innovazione (Nazarko, 2019).

Nonostante rappresentino un'evoluzione significativa rispetto ai paradigmi lineari di ricerca e sviluppo, tali modelli presentano ancora alcune lacune rilevanti, evidenziate da una letteratura in rapida crescita sulle transizioni sostenibili e sull'innovazione sistemica. Molti framework trasformativi tendono a concentrarsi prevalentemente sul coordinamento delle politiche e sulla scalabilità tecnologica, trascurando le dimensioni culturali e immaginative necessarie per operare in condizioni di incertezza e di conflitto valoriale; inoltre, pur riconoscendo le sinergie tra gli obiettivi di sostenibilità, spesso non dispongono di strumenti operativi in grado di affrontare esplicitamente i compromessi e le sinergie tra gli SDG a livello di sperimentazione collaborativa. Infine, come evidenziato da studi recenti su innovazione aperta e transizioni sostenibili, gli ecosistemi dell'innovazione rimangono spesso frammentati, con un'integrazione limitata tra attori tecnologici, discipline creative e stakeholder della società civile.

A ciò si aggiunge una crescente attenzione nella letteratura più recente al ruolo delle pratiche di innovazione aperta e co-creazione come leve per affrontare la complessità sistemica (Barbero and Ferrulli, 2023), poiché ha trasformato i processi di produzione della conoscenza e creazione di valore, definendoli come un paradigma in cui le imprese combinano conoscenze interne ed esterne attraverso collaborazioni distribuite (Bogers, Chesbrough and Moedas, 2018; Nambisan, Wright and Feldman, 2019). Tuttavia alcune critiche evidenziano la tendenza a privilegiare scalabilità tecnologica ed efficienza di mercato rispetto alla riflessione etica, alla sostenibilità di lungo periodo e a forme di governance inclusive (Bogers, Chesbrough and Moedas, 2018). Parallelamente gli studi sul design per la sostenibilità e sulla transizione socio-ecologica hanno evoluto il proprio ruolo, sottolineando la necessità di integrare approcci sistemici (Irwin, 2015; Tonkinwise, 2015; Zannoni et alii, 2024), pratiche rigenerative (Escobar, 2018) e modelli circolari nei processi di innovazione (Ceschin and Gaziulusoy, 2016). In sintesi molti ecosistemi dell'innovazione faticano ancora a tradurre politiche di alto livello in metodologie operative capaci di coordinare collaborazione interdisciplinare e processi sperimentali: integrare sviluppo tecnologico, riflessione culturale, considerazioni etiche e visioni di lungo periodo continua a rappresentare una sfida strutturale per i sistemi industriali.

Il paradigma dell'Industria 5.0 rafforza ulteriormente questa traiettoria, richiamando la necessità di sistemi di innovazione centrati sulla persona, resilienti e sostenibili. Tuttavia rendere operativi tali principi richiede infrastrutture metodologiche concrete, in grado di integrare l'esplorazione dei futuri, la riflessione etica e la collaborazione intersettoriale nei processi industriali. La letteratura sulla governance anticipatoria sottolinea come l'innovazione debba spostarsi dalla risoluzione reattiva dei problemi a un'esplorazione proattiva di futuri alternativi, incorporando pratiche collettive di costruzione di visioni nei processi decisionali (Guston, 2014; OECD, 2018).

In questo quadro gli approcci interdisciplinari che mettono in relazione la ricerca tecnologica con le pratiche artistiche e culturali stanno acquisendo rilevanza: le collaborazioni tra arte e tecnologia hanno infatti dimostrato la capacità di attivare la riflessione critica, di ampliare gli immaginari e di mettere in discussione le narrazioni dominanti del progresso (Whitaker, 2016; Minski, 2020), contribuendo a rendere visibili le implicazioni sociali ed etiche dello sviluppo tecnologico attraverso pratiche sperimentali, narrative e prototipali: recenti ricerche hanno evidenziato come l'integrazione di tecnologia emotiva e pratiche narrative possa generare consapevolezza negli utenti rispetto a temi complessi come la transizione sostenibile (Valenti et alii, 2024).

Negli ultimi anni tali approcci si sono intrecciati con il crescente campo delle pratiche art-tech e delle collaborazioni tra industrie culturali e creative e settori tecnologici, evidenziando il ruolo della cultura come infrastruttura dell'innovazione (Klein, Gerlitz and Spychalska-Wojtkiewicz, 2021; Dolejsova et alii, 2021) sebbene la letteratura sottolinei che queste pratiche restano spesso marginali rispetto ai modelli industriali dominanti e raramente integrate in processi strutturati e scalabili.

Queste pratiche si intrecciano con l'ambito emergente del Design Futures che integra metodologie di design e studi sul futuro per esplorare trasformazioni sociali di lungo periodo (Bühring and Liedtka, 2018). Gli approcci di Design Futures (Canina and Monestier, 2023) utilizzano scenari speculativi, la costruzione partecipata di visioni e la prototipazione narrativa per indagare futuri possibili e desiderabili, consentendo alle organizzazioni di anticipare le sfide emergenti ed esplorare traiettorie alternative di sviluppo tecnologico (Candy and Dunagan, 2017; Dunne and Raby, 2013). Tali approcci, sempre più diffusi anche nei contesti di policy e innovazione pubblica, favoriscono una riflessione critica sulle implicazioni sistemiche dello sviluppo tecnologico, contribuendo a integrare dimensioni temporali, etiche e culturali nei processi decisionali.

Nonostante il loro potenziale queste metodologie guidate dall'arte restano spesso periferiche nei framework industriali dominanti, prive di modelli di implementazione strutturati, mentre il pensiero orientato ai futuri è raramente incorporato come componente operativa e continua nei processi di innovazione (Miller, 2018). Molte collaborazioni tra artisti, designer e tecnologi si sviluppano in contesti temporanei e sperimentali, senza disporre di metodologie in grado di generare impatti di lungo periodo (Monestier et alii, 2024; Schnugg and Song, 2020); di conseguenza il loro contributo alle transizioni sistemiche verso la sostenibilità rimane frammentato e solo parzialmente integrato nei processi mainstream di innovazione.

A questa criticità si aggiunge una limitata disponibilità di modelli valutativi in grado di misurare l'impatto delle pratiche interdisciplinari sulle transizioni sostenibili, tema sempre più rilevante nella letteratura recente sulla valutazione delle trasformazioni socio-tecniche e sull'impatto degli SDG (Nilsson, Griggs and Visbeck, 2016; Pham-Truffert et alii, 2020).

Affrontare le complesse sinergie tra gli SDG richiede pertanto non solo sperimentazione creativa, ma anche infrastrutture metodologiche in grado di coordinare la collaborazione interdisciplinare. Questa esigenza è resa ancora più urgente dal fatto che gli SDG in maggiore difficoltà – SDG 13, 14 e 15, ma anche gli SDG 2 e 3 – sono quelli che richiedono trasformazioni culturali e sistemiche profonde, non solo soluzioni tecniche.

Il rallentamento dei progressi documentato dal Global Assessment Report dell'UNDRR (2022) segnala che l'aumento della frequenza degli eventi climatici estremi sta erodendo le infrastrutture e i sistemi produttivi su cui si fondano molti altri obiettivi, in una dinamica di interdipendenza negativa che i modelli lineari di innovazione faticano ad affrontare. La sfida non consiste dunque semplicemente nel promuovere la sperimentazione interdisciplinare, ma nel progettare un'infrastruttura dell'innovazione che integri in modo sistematico l'esplorazione dei futuri, l'indagine artistica e lo sviluppo tecnologico all'interno di un quadro coerente e replicabile.

In questo contesto il contributo si propone di colmare il divario tra approcci sperimentali e applicazioni sistemiche, introducendo tre elementi di discontinuità rispetto alla letteratura esistente: in primo luogo il MUSAE Factory Model introduce un'integrazione strutturata tra pratiche artistiche e innovazione industriale, superando la dimensione episodica delle collaborazioni art-tech; in secondo luogo il metodo DFA adotta il 'futures thinking' come dispositivo operativo per orientare i processi di innovazione in condizioni di incertezza; in terzo luogo propone il passaggio da modelli di collaborazione

Fig. 1 | Participants in the MUSAE art-technology residency: artists, companies, and the MUSAE consortium (credit: the Authors, 2025).

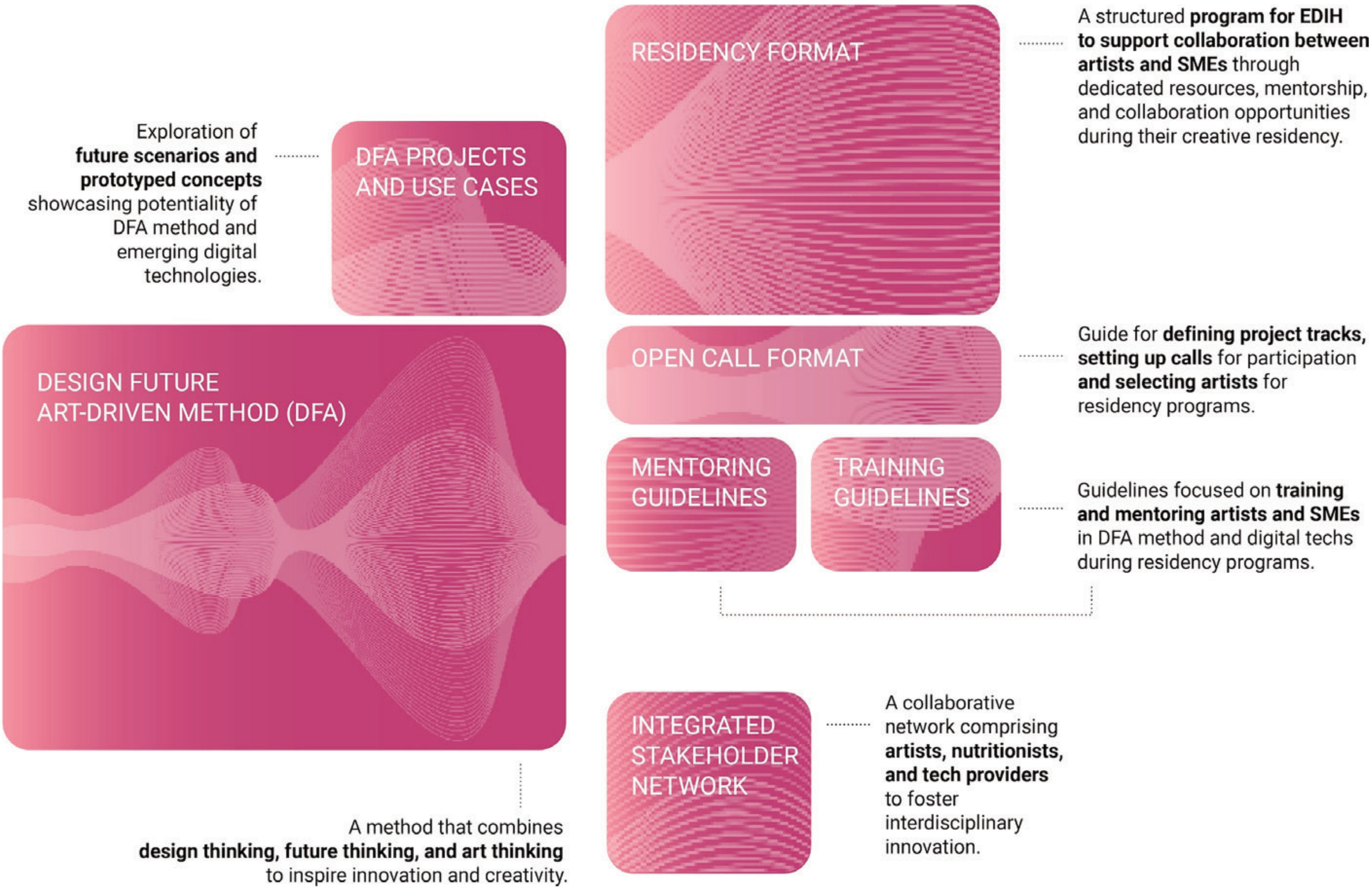


Fig. 2 | MUSAE Factory Model (credit: the Authors, 2025).

temporanei a un'infrastruttura metodologica trasferibile, capace di sostenere processi di innovazione sistemica e replicabile in contesti diversi.

MUSAE Factory Model | Il progetto Horizon Europe MUSAE (2022-2025), inserito nell'ecosistema STARTS, ha esplorato il contributo della collaborazione tra arte e tecnologia a un'innovazione sostenibile e centrata sulle persone e sul pianeta, rafforzando al contempo il ruolo degli European Digital Innovation Hubs (EDIH). Il focus è stato il dominio 'cibo come medicina', caratterizzato da forti sinergie con gli SDG 3, 9, 12 e 13. Attraverso due programmi di residenza in cui sviluppare la collaborazione arte-tecnologia, MUSAE ha coinvolto 23 artisti e 11 imprese di piccola e media dimensione (Fig. 1), producendo dodici scenari futuri e undici prototipi sviluppati fino al Technology Readiness Level 5, inteso come validazione del prototipo completo in ambiente rilevante, attestata dalla valutazione dei partner tecnologici del consorzio MUSAE, dai test effettuati con utenti finali e dalla mostra pubblica al Palazzo della Scienza di Belgrado.

La collaborazione artistica è stata concepita come componente strategica del processo: le barriere tipiche, i gap comunicativi, l'assenza di metodologie condivise e il disallineamento degli obiettivi sono stati affrontati attraverso un quadro metodologico replicabile in grado di bilanciare libertà creativa e rigore procedurale. L'esito principale di questo percorso è il MUSAE Factory Model: un framework a codice aperto per un'innovazione sistemica e orientata ai futuri, in linea con i principi dell'Industria 5.0. Il Factory Model non si configura come un singolo metodo ma come un ecosistema integrato (Fig. 2) articolato in tre componenti principali: 1) Risorse metodologiche, centrate sul metodo Design Futures Art-driven (DFA) e relativi strumenti; 2) Risorse organizzative che comprendono format di residenza, call aperte, linee guida delle attività di formazione e guida; 3) Risorse di comunità, ossia la rete che connette artisti, imprese, tecnologi, educatori ed esperti del dominio. Questa architettura risponde alla carenza di framework in grado di sostenere collaborazioni tra arte e tecnologia nel lungo periodo: integrando il processo artistico in una metodologia strutturata e in ambienti digitali collaborativi (come Figma[2] e Miro[3]) il modello trasforma la sperimentazione creativa in una sequenza operativa replicabile.

Al centro del Factory Model si colloca il metodo DFA (Efremenko et alii, 2025) che integra tre pratiche complementari: il Futures Thinking, per esplorare futuri alternativi e preferibili; il Design Thinking, per strutturare processi iterativi orientati alla prototipazione; l'Art Thinking, per introdurre dimensioni critiche, immaginative ed emotive (Fig. 3). Fondato sul modello del Double Diamond (Design Council, 2005) ed esteso attraverso il 'futures cone' di Voros (2003) il metodo si articola in quattro fasi: analisi delle tendenze, visione, ideazione e prototipazione. La prima fase analizza segnali emergenti e sfide sistemiche; la seconda costruisce scenari condivisi; la terza sviluppa concetti interdisciplinari ampliando lo spazio delle possibilità; la quarta traduce le idee in prototipi, sviluppati fino al TRL5.

L'IA generativa è utilizzata come collaboratore creativo nei processi di ideazione, visualizzazione e narrazione. L'originalità del metodo risiede nella sua capacità di rispondere a tre limiti dei modelli di innovazione dominanti:
1) Dal problema alla visione – il DFA supera l'approccio centrato sul problema e avvia il processo a partire da visioni condivise di futuri preferibili permettendo di valutare ex ante le implicazioni tecnologiche, ambientali e sociali e orientare le scelte verso esiti coerenti con la sostenibilità di lungo periodo;
2) Gestione delle sinergie e dei compromessi tra gli SDG – integra strumenti sistemici (STEEP+V, mappatura degli stakeholder anche non umani, matrici di incertezza) che rendono esplicite interdipendenze, sinergie e compromessi tra gli SDG, favorendo un confronto anticipato sugli impatti e superando logiche puramente antropocentriche;
3) Integrazione dell'intelligenza culturale ed emotiva – il DFA, insieme al MUSAE Factory Model, risponde a una delle principali lacune dei sistemi di innovazione contemporanei, reintegrando dimensioni culturali, etiche ed ecologiche nei processi di innovazione configurandosi come infrastruttura cognitiva e collaborativa per l'Industria 5.0 e orientando l'innovazione verso traiettorie sistemiche e responsabili.

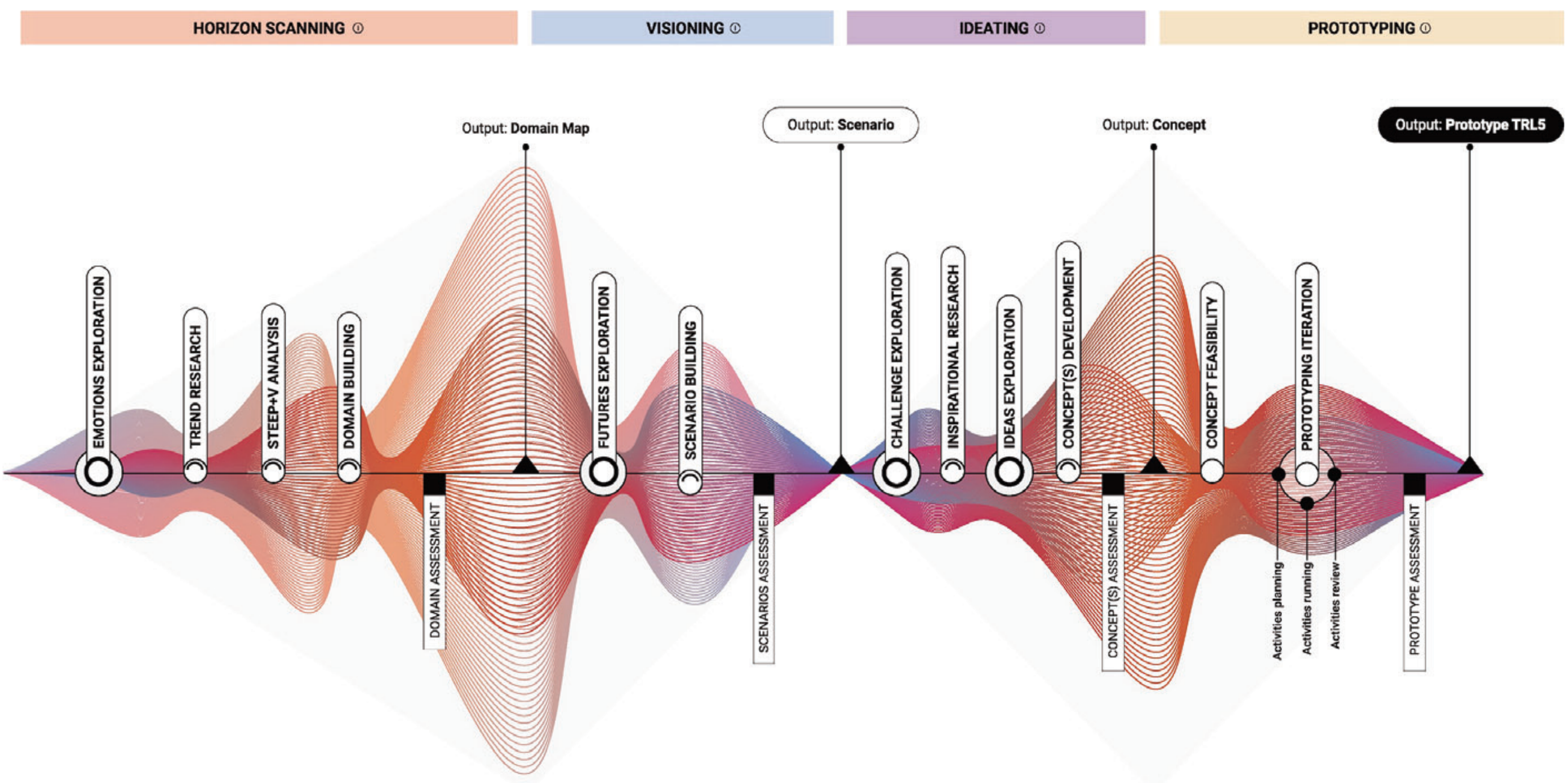


Fig. 3 | Design Futures Art-driven (DFA) method (credit: the Authors, 2025).

Posizionamento del MUSAE Factory Model nel panorama dei modelli di innovazione arte-tecnologia | Al fine di analizzare criticamente il MUSAE Factory Model il contributo adotta un approccio che distingue tra: a) il modello metodologico oggetto di analisi; b) casi studio sviluppati al suo interno, utilizzati come evidenze applicative; c) modelli e framework internazionali di riferimento, impiegati per il confronto critico. Questa analisi colloca il MUSAE Factory Model e il relativo metodo DFA all'interno dei framework esistenti di collaborazione arte-tecnologia e delle metodologie strutturate per l'innovazione industriale.

La selezione dei riferimenti internazionali è stata effettuata sulla base dei seguenti criteri: a) integrazione tra pratiche creative e innovazione tecnologica; b) presenza di approcci orientati ai futuri o anticipatori; c) rilevanza nel dibattito su sostenibilità e transizioni socio-tecniche; d) livello di strutturazione metodologica; e) potenziale di trasferibilità e replicabilità.

Sono stati selezionati quattro metodi o framework. Il primo, S+T+ARTS Initiative, ha sviluppato tre modalità collaborative, Art-Enabled Prototyping, Art-Influenced Science e Art-Driven Technology (van Vliet, 2020) che strutturano l'interazione tra artisti, scienziati e industria; pur rappresentando un avanzamento rispetto a collaborazioni precedentemente informali queste tipologie funzionano principalmente come strumenti di facilitazione, senza configurarsi come percorsi operativi di innovazione in quanto mancano fasi esplicite di 'futures thinking' e un collegamento sistematico tra sperimentazione artistica e prototipazione a livelli TRL definiti.

Il secondo è il metodo Art-Driven Innovation (ADI; Fig. 4; In4Art, 2020) che utilizza database di opere artistiche come punto di partenza per l'innovazione responsabile, collegando tecnologie e SDG attraverso i percorsi 'green' e 'care'; sebbene fortemente orientato alla sostenibilità, parte da opere esistenti piuttosto che da visioni future co-create, limitando in alcuni casi la capacità generativa in contesti ad alta incertezza.

Il ciclo di innovazione MAST (Tab. 1), sviluppato nell'ambito del programma Erasmus+, come terzo caso selezionato, pone l'Art Thinking prima del Design Thinking in un processo in dieci fasi (Castillo-Rutz and Purg, 2021); pur enfatizzando il ruolo centrale dell'indagine artistica rimane principalmente un modello educativo, con limitata applicazione documentata in contesti industriali e senza chiari riferimenti ai TRL.

L'ultimo è il progetto Better Factory (Fig. 5; van Vliet et alii, 2024), il più vicino al modello MUSAE in quanto struttura collaborazioni tra artisti, piccole e medie imprese e tecnologi in quattro fasi: definizione della sfida, 'matchmaking', sperimentazione iterativa e modellazione d'impresa, sebbene adotti un approccio guidato dai problemi e non includa una fase strutturata di pensiero orientato ai futuri.

Per sistematizzare il confronto tra il MUSAE Factory Model e i principali framework internazionali è stata sviluppata una sintesi comparativa basata su cinque dimensioni: punto di accesso all'innovazione, ruolo della pratica artistica, integrazione del futures thinking, applicabilità industriale e trasferibilità; la Tabella 2 sintetizza tali differenze evidenziando i posizionamenti e le criticità dei diversi approcci.

In questo quadro i progetti SOIL e Growing Futures sono analizzati come casi applicativi del modello MUSAE, mentre il confronto critico è sviluppato rispetto a modelli e pratiche internazionali affini. La comparazione evidenzia come il MUSAE Factory Model si distingua per l'integrazione simultanea di tre dimensioni raramente presenti congiuntamente nei modelli analizzati: 1) un punto di accesso orientato alla visione e basato sulla costruzione condivisa di scenari futuri; 2) una formalizzazione metodologica esplicita che struttura il processo in fasi replicabili; 3) una connessione operativa con contesti industriali che consente di tradurre visioni speculative in prototipi a livelli TRL intermedi.

Di contro i modelli analizzati tendono a sviluppare queste dimensioni in modo parziale: le metodologie STARTS privilegiano la flessibilità ma mancano di una percorsi operativi strutturati; ADI introduce un forte orientamento alla sostenibilità ma limita la generatività futura; MAST enfatizza il ruolo dell'arte ma resta confinato a contesti educativi; Better Factory garantisce applicabilità industriale ma adotta un approccio prevalentemente guidato dai problemi, privo di una fase anticipatoria esplicita.

Da questa lettura emergono due implicazioni principali: in primo luogo il pensiero orientato al futuro risulta sistematicamente sottoutilizzato come dispositivo operativo nei processi di innovazione, nonostante il suo potenziale nel gestire incertezza e complessità; in secondo luogo i modelli orientati alla visione e guidati dai problemi appaiono complementari poiché mentre il primo abilita trasformazioni di lungo periodo, il secondo facilita l'adozione industriale nel breve termine. Il MUSAE Factory Model si colloca in questa tensione, proponendo un'integrazione tra dimensione anticipatoria e applicazione operativa. Permangono tuttavia alcune criticità condivise con la letteratura, in particolare in relazione alla scalabilità del modello, alla validazione su larga scala e alla misurazione degli impatti nel lungo periodo, aspetti che richiedono ulteriori sviluppi metodologici ed empirici. Le sezioni successive analizzano come il framework sia stato reso operativo nelle residenze di MUSAE, con particolare attenzione ai due progetti rappresentativi SOIL e Growing Futures, mostrando come l'SDG 9 possa agire da abilitatore sistemico della trasformazione industriale sostenibile.

Casi applicativi del MUSAE Factory Model: SOIL e Growing Futures | In coerenza con il posizionamento del contributo rispetto agli SDG, in cui l'analisi ha evidenziato una convergenza prevalente verso l'intersezione tra gli SDG 9, 12, 13 e 15, con l'SDG 9 inteso come obiettivo abilitante, la selezione dei casi studio è stata orientata a rendere esplicite tali relazioni attraverso evidenze applicative. È importante chiarire che i criteri utilizzati per la selezione dei casi derivano direttamente dal sistema di valutazione sviluppato dal consorzio MUSAE per verificare la completezza e la qualità degli undici progetti realizzati. Tali criteri sono stati comunicati fin dall'inizio ai team partecipanti che, attraverso i cinque deliverable previsti, erano chiamati a dimostrare il loro effettivo soddisfacimento lungo l'intero processo di sviluppo.

La selezione di SOIL e Growing Futures risponde dunque a criteri valutativi consolidati. Entrambi i progetti hanno ottenuto i punteggi più elevati nelle due principali fasi di valutazione del progetto MUSAE: la valutazione del concept e quella del prototipo finale. La prima ha considerato sette dimensioni: maturità del concetto, tecnologia, esperienza utente, collaborazione, etica, sostenibilità e fattibilità finanziaria, mentre la seconda ha attestato il raggiungimento del TRL5 sulla base di quattro aree principali: impatto positivo (settoriale, sociale e ambientale), innovazione, interazione con l'utente e gestione del rischio. Il materiale oggetto di valutazione comprendeva sia i prototipi funzionanti a TRL5 sia i cinque deliverable finali prodotti dai team, che documentano in modo sistematico lo sviluppo del processo.

Nel contesto del progetto MUSAE il TRL5 indica il raggiungimento di un prototipo completo validato in un ambiente rilevante attraverso un processo strutturato e condiviso che ha coinvolto l'intero consorzio tecnologico e la validazione con utenti finali. In particolare la validazione ha coinvolto agricoltori nel caso di SOIL e designer nel caso di Growing Futures. È tuttavia necessario precisare che tale livello non corrisponde a una validazione in ambiente operativo reale (TRL6-7), che richiederebbe test su ampia scala, ingegnerizzazione avanzata e certificazione, ma a una validazione in condizioni simulate o controllate, sufficiente a dimostrare la fattibilità tecnica e la coerenza del prototipo rispetto ai criteri di impatto, usabilità e sostenibilità.

I due casi sono stati selezionati anche per la loro capacità di rappresentare in modo complementare le dimensioni centrali del modello. SOIL esemplifica il rapporto tra visione futura, sensoristica ambientale e pratiche agricole rigenerative, con una forte connessione agli SDG 13 e 15; Growing Futures illustra invece l'integrazione tra biofabbricazione, robotica avanzata e design post-antropocentrico, con rilevanza diretta per gli SDG 9 e 12. Considerati congiuntamente i due casi mostrano come il DFA possa generare traiettorie innovative di tipo trasformativo, piuttosto che incrementale, in contesti caratterizzati da elevata incertezza ecologica e tecnologica.

Allo stesso tempo essi consentono di delimitare con maggiore precisione ciò che il MUSAE Factory Model ha effettivamente dimostrato, ovvero la capacità di guidare collaborazioni arte-tecnologia fino allo sviluppo di prototipi maturi e validati, rispetto a ciò che rimane ancora un potenziale da sviluppare nelle fasi successive, in particolare il passaggio verso livelli di maturità tecnologica più elevati e forme stabili di adozione industriale e diffusione su larga scala.

SOIL: agricoltura rigenerativa | Il progetto SOIL (2025), frutto della collaborazione tra l'artista Letizia Artioli, l'impresa Uptoearth, un agricoltore e una designer di moda, affronta il tema del degrado del suolo, una delle principali sfide ambientali contemporanee, strettamente connessa alla perdita di biodiversità, al cambiamento climatico e ai modelli insostenibili di produzione alimentare. Il progetto trae origine dallo scenario futuro 'Soil Skinships'[4], sviluppato da Lisa Mandemaker, che immagina una relazione sensoriale tra esseri umani e suolo mediata da dispositivi tecnologici. Coerentemente con il DFA il progetto prende avvio da una visione condivisa di futuro piuttosto che da un problema tecnico predefinito.

Attraverso un'esplorazione speculativa il suolo viene reinterpretato come infrastruttura vivente inserita in sistemi socio-ecologici complessi; l'esito è un prototipo indossabile che traduce i dati del suolo in stimoli sensoriali percepibili dal corpo umano. Il dispositivo integra sensori ambientali in grado di rilevare parametri quali l'umidità, la temperatura e altre condizioni del terreno (Figg. 6-8); i dati raccolti vengono convertiti in segnali tattili e sonori, percepiti direttamente dall'agricoltore attraverso l'indumento, trasformando le misurazioni astratte in un'esperienza corporea.

Il progetto propone un paradigma alternativo in cui l'infrastruttura agricola diventa relazionale ed esperienziale, superando modelli basati esclusivamente sul controllo remoto; in tal modo, attraverso l'innovazione, SOIL sostiene le pratiche agricole rigenerative, rafforzando la consapevolezza ecologica e integrando dimensioni tecnologiche e ambientali.

Growing Futures: habitat rigenerativi tra micelio e robotica | Il progetto Growing Futures (2025) esplora le relazioni tra materiali biologici, fabbricazione robotica e design rigenerativo. Sviluppato dall'artista e designer Daniela Amandolese con il Basque Biodesign Center il progetto indaga come i processi di crescita biologica e le tecnologie di fabbricazione avanzata possano essere combinati per generare nuove forme di infrastruttura sostenibile; si basa sullo scenario 'What the World Eats – Agro-Technologies in Earthly Futures'[5] sviluppato da Peter Andersen che immagina infrastrutture ibride tra sistemi biologici e tecnologici operanti in modo simbiotico. Anche in questo caso il progetto parte da una visione futura, mettendo in discussione la separazione tra naturale e artificiale e reinterpretando l'infrastruttura come sistema vivente.

Il progetto combina la crescita biologica del micelio con la fabbricazione robotica: i sistemi robotici guidano e modellano lo sviluppo del micelio, replicando strutture reticolari naturali e consentendo la creazione di forme spaziali complesse. Il risultato è un prototipo di habitat bio-responsivo, capace di adattarsi e auto-rigenerarsi, integrandosi nei cicli ecologici (Figg. 9-11). Il progetto evidenzia un passaggio verso approcci post-antropocentrici in cui processi naturali e tecnologici operano in modo integrato.

Gestire sinergie e compromessi attraverso un modello guidato dall'arte | I due progetti pur operando in ambiti differenti condividono la stessa logica metodologica del MUSAE Factory Model. In entrambi i casi l'innovazione parte da scenari futuri condivisi che riconfigurano l'infrastruttura come sistema vivente e relazionale. Questo approccio supera una logica lineare e soluzionista a favore di una riformulazione anticipatoria: invece di ottimizzare l'efficienza all'interno di paradigmi industriali consolidati, il metodo DFA amplia lo spazio del problema attraverso pratiche di analisi delle prospettive e di visione, per convergere poi nella fase di prototipazione. Senza queste fasi i progetti avrebbero probabilmente seguito traiettorie tecnologiche convenzionali, con risultati incrementali anziché trasformativi. Il confronto discusso in precedenza chiarisce questo aspetto: il DFA è tra i pochi approcci che utilizzano gli scenari futuri come dispositivo generativo del processo, mentre altri framework operano su sfide predefinite o contenuti esistenti.

Il modello risponde alla frammentazione degli ecosistemi di innovazione integrando dimensioni tecnologiche, ecologiche e culturali in un unico processo. Gli artisti agiscono come co-designer delle traiettorie di innovazione, mettendo in discussione assunti industriali dominanti e favorendo un dialogo intersettoriale più ampio. Proprio per queste ragioni il metodo DFA è stato selezionato per l'ADI Design Index 2025 come uno dei più rilevanti progetti italiani di ricerca nel design nella categoria Ricerca per l'Impresa[6]. Questo riconoscimento conferma la crescente rilevanza di approcci innovativi, anticipatori e immaginativi nell'innovazione industriale e aziendale.

L'aspetto più significativo riguarda la riconfigurazione dell'innovazione come leva per le transizioni sistemiche verso la sostenibilità; in questa prospet-

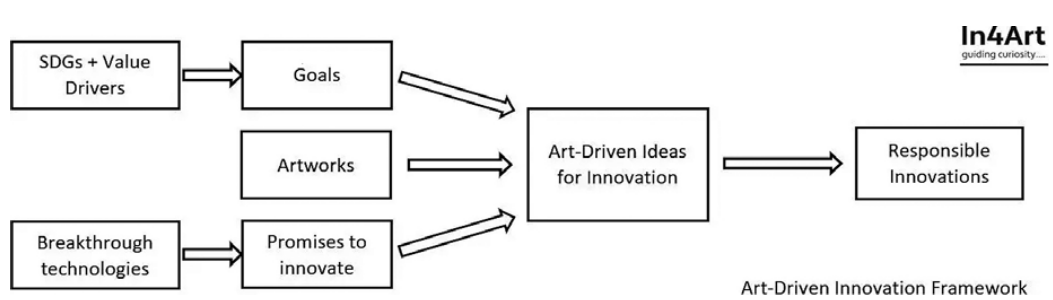


Fig. 4 | Art-Driven Innovation (ADI) framework (source: In4Art, 2020).

No.	Method	Description
1	Challenge	Identify the topic by determining a set of relevant questions that lead to a deep understanding of the issue at stake
2	Team	Create a varied expert group (artists, designers, entrepreneurs, scientists, inventors, philosophers, researchers, etc., whether they are individuals, groups or institutions) in order to establish an innovation team
3	Rules	Creating a scaffolding of policies, strategies, laws, conventions and values, in order to arrive at a clear ethical framework for the process and its results (including defining common grounds, creating a manual of conduct and envisioning social sustainability)
4	Mapping	Mapping of the existing cases, good and bad practices, their theory and implementation; understanding of these cases inside of their ecosystem(s), i.e. in the cultural, historical, political economical context
5	Beneficiaries	Deeply understanding the beneficiaries and finding out how to negotiate the values involved (with decision-makers and final users), making them understand the existing practices mapped; deciding about the time-frame of the process of innovation
6	Art Thinking	By referring to already known artistic ideations, the perspectives on the topic are changed; artworks and artistic ideas are explored to create a mind shift and inspire, generating different and new questions
7	Design Thinking	Understanding and utilizing the possibilities in creative solutions, the potential scenarios, demos, prototypes, models etc. which brings about multiple possible solutions
8	Modelling	Designed solutions (as proposals) are chosen or prioritized; creating more detailed scenarios, demos, pre-testing etc.; in the design paradigm this is usually called prototyping (of both non-functional and functional kind). At the end, one solution is chosen
9	Applicability	Testing the full solution (prototype) in the real and tangible context; this might show the need for iteration of any of the previous 'stages'; the solution is applied, implemented for real and in the real
10	Impact	Final evaluation of change or transformation, leading to lessons learned, and several kinds of legacy (experience, skills / knowledge, network, data sets etc.) as well as sustainability (longevity) solutions

Tab. 1 | MAST innovation cycle: a ten-stage process integrating Art Thinking and Design Thinking (source: Castillo-Rutz and Purg, 2021).

tiva l'innovazione non è più una fonte di esternalità che compromettono altri obiettivi ma diventa il mezzo attraverso cui costruire sinergie. Ciò che distingue questi casi non è soltanto l'allineamento con più SDG ma anche l'integrazione concreta delle loro sinergie nel processo di innovazione. Attraverso una riflessione orientata ai futuri il DFA consente agli stakeholder di anticipare potenziali compromessi tra accelerazione tecnologica e integrità ecologica, riorientando di conseguenza le traiettorie progettuali. Il valore aggiunto del modello risiede meno nei singoli prototipi e più nella sua capacità di trasformare i processi e la cultura dell'innovazione, proponendo un'infrastruttura metodologica trasferibile.

Questa capacità di generare e rendere visibili tali dinamiche è emersa con particolare evidenza nella mostra finale del progetto MUSAE, 'Grow, Cook, Code – Rethinking Food Futures', ospitata presso il Palazzo della Scienza di Belgrado. L'evento ha funzionato non solo come vetrina dei risultati, ma anche come dispositivo di validazione pubblica e sociale: oltre 2.000 visitatori tra cittadini, artisti, imprese, ricercatori e Istituzioni hanno interagito con 11 prototipi funzionanti, esplorandone potenzialità e criticità.

Questa dimensione pubblica riveste una rilevanza metodologica per almeno tre ragioni: in primo luogo l'interazione diretta ha consentito di testare la comprensibilità delle visioni progettuali, trasformando oggetti tecnologici complessi in strumenti di mediazione tra domini diversi; in secondo luogo ha contribuito a rafforzare la fiducia nelle tecnologie emergenti, evidenziandone l'orientamento verso obiettivi sociali ed ecologici; infine ha reso tangibile il potenziale del MUSAE Factory Model come infrastruttura non solo per l'innovazione industriale ma anche per la partecipazione pubblica alle traiettorie tecnologiche, in linea con approcci di governance anticipatoria.

I prototipi esposti hanno dimostrato come tecnologie esistenti possano essere ricombinate attraverso visioni orientate al futuro per affrontare sfide sistemiche nel dominio 'cibo come medicina'. Tra questi Sprout to Flourish supporta la transizione verso pratiche agricole rigenerative attraverso simulazioni interattive (Fig. 12); Remedy Garden propone un'architettura bio-inclusiva per la coltivazione urbana di piante medicinali (Fig. 13); Neurocooking utilizza il biofeedback per trasformare la cucina in un'esperienza terapeutica (Fig. 14); Nourish connette nutrizione e stati cognitivi attraverso l'analisi EEG (Fig. 15).

Nel loro insieme questi esempi mostrano come il MUSAE Factory Model e il metodo DFA siano in grado di generare traiettorie di innovazione distinte ma coerenti, combinando struttura metodologica ed esplorazione creativa, una tensione produttiva che rappresenta uno degli elementi più distintivi del modello.

Verso sistemi di innovazione rigenerativi e anticipatori | Il divario persistente tra l'ambizione degli SDG e i progressi disomogenei registrati verso il 2030 evidenzia non solo difficoltà di implementazione, ma anche limiti strutturali radicati nelle culture e nei modelli dominanti di innovazione. I paradigmi tecno-economici convenzionali, spesso orientati al breve termine e caratterizzati da frammentazione e scarsa capacità di anticipazione, faticano infatti ad affrontare le sinergie sistemiche e i compromessi che attraversano l'intera agenda degli SDGs. Il MUSAE Factory Model risponde a questa esigenza introducendo un framework che integra immaginazione speculativa, anticipazione strutturata e prototipazione collaborativa. Attraverso il metodo DFA, l'innovazione viene riorientata attorno a visioni condivise di futuri preferibili, anziché vincolata esclusivamente a parametri tecnici predefiniti.

I casi analizzati mostrano come tali approcci possano integrare dimensioni ecologiche e tecnologiche e supportare traiettorie di innovazione più coerenti. In questo quadro il modello contribuisce a riallineare sviluppo tecnologico e sostenibilità, proponendo un approccio operativo in contesti di incertezza sistemica.

Per evitare che il riferimento agli SDG rimanga puramente dichiarativo è necessario esplicitare il contributo del MUSAE Factory Model rispetto all'intero sistema degli SDG 1-17. In questa prospettiva il modello non agisce in modo lineare su singoli obiettivi ma come dispositivo di innovazione anticipatoria capace di attivare sinergie, rendere visibili compromessi e orientare le traiettorie progettuali in relazione a una pluralità di SDG.

La Tabella 3 propone una mappatura sistematica di tale relazione, articolata in cinque categorie analitiche: SDG direttamente attivati, indirettamente coinvolti, potenzialmente sinergici, associati a rischi o compromessi e marginali rispetto al perimetro del modello. Gli SDG 'direttamente attivati' sono quelli per i quali il modello produce contributi dimostrabili attraverso i progetti esemplari e la struttura metodologica. Gli SDG 'indirettamente coinvolti' sono quelli che beneficiano delle ricadute del modello senza esserne l'obiettivo esplicito. Gli SDG con 'possibili sinergie' sono quelli per i quali il modello mostra potenziale connessione, condizionata dal contesto applicativo o da sviluppi futuri.

Gli SDG nei confronti dei quali possono emergere 'compromessi o rischi' sono quelli per i quali l'innovazione tecnologica guidata dal modello può generare tensioni o esternalità irrisolte. Gli SDG 'marginali o non direttamente pertinenti' sono infine quelli che esulano dall'ambito di applicazione del modello nei casi analizzati, pur non essendo esclusi in linea di principio da applicazioni future in domini diversi. L'obiettivo non è rivendicare una copertura estesa degli SDG ma rendere esplicite e argomentate le relazioni effettive tra il modello e l'Agenda della sostenibilità.

È infine importante precisare che questa mappatura si riferisce alla configurazione attuale del MUSAE Factory Model, sviluppata nel dominio 'cibo come medicina' e validata attraverso gli undici prototipi realizzati, tra cui SOIL e Growing Futures; la trasferibilità del modello ad altri domini potrebbe modificare il profilo di rilevanza rispetto agli SDG, ampliando gli ambiti di attivazione diretta o introducendo nuovi potenziali compromessi.

Limiti, barriere e trasferibilità del modello | Nonostante il potenziale trasformativo del MUSAE Factory Model, emergono alcune criticità rilevanti in relazione alla scalabilità e alla trasferibilità dei risultati. I prototipi sviluppati nei casi analizzati si collocano prevalentemente a livello TRL5, corrispondente a una validazione in ambiente rilevante ma ancora distante da forme stabili di adozione industriale. È infatti necessario un chiarimento concettuale preliminare per comprendere correttamente i limiti del modello.

MUSAE Factory Model non è concepito come un percorso di sviluppo prodotto orientato alla commercializzazione immediata, né i prototipi a TRL5 rappresentano versioni preindustriali di prodotti o servizi pronti per il mercato. L'obiettivo del modello è di natura diversa e per certi versi più ambiziosa sul piano sistemico: immaginare traiettorie future possibili e preferibili, identificare sfide emergenti, mappare interdipendenze tra dimensioni tecnologiche, ecologiche e sociali, anticipare impatti e compromessi prima che le traiettorie di innovazione si consolidino in forme difficilmente reversibili. In questa prospettiva i prototipi non sono prodotti incompiuti ma dispositivi cognitivi e culturali: strumenti per rendere tangibili visioni altrimenti astratte, per facilitare il dialogo tra stakeholder eterogenei e per testare la coerenza interna di un'idea rispetto a criteri di sostenibilità, usabilità ed etica.

Questa distinzione è rilevante non solo per valutare correttamente il modello ma anche per evitare un fraintendimento frequente nella letteratura sull'innovazione che tende a misurare il valore di un processo creativo dalla sua prossimità al mercato. Il MUSAE Factory Model opera a un livello diverso della catena dell'innovazione: quello dell'esplorazione orientata, in cui la domanda centrale non è 'questo prodotto è commercializzabile?' ma 'questa visione è desiderabile, sostenibile e tecnicamente percorribile?' Il passaggio eventuale verso TRL superiori e verso forme di adozione industriale è possibile ma richiede condizioni, attori e risorse che esulano dal perimetro del modello stesso e che costituiscono una scelta metodologica consapevole, coerente con un approccio di governance anticipatoria (Guston, 2014) dell'innovazione.

Il MUSAE Factory Model evidenzia il potenziale di un approccio integrato tra arte, tecnologia e 'futures thinking' ma anche limiti strutturali e condizioni di validità legate al contesto in cui è stato sviluppato. In particolare il modello nasce in condizioni specifiche: finanziamento Horizon Europe, dominio 'cibo come medicina', infrastruttura basata su European Digital Innovation Hubs (EDIH) e un contesto europeo favorevole alla collaborazione arte-tecnologia che risultano determinanti e non sempre replicabili.

Il modello si colloca prevalentemente a livelli intermedi di maturità tecnologica (TRL4-5), evidenziando difficoltà nel passaggio dalla prototipazione alla diffusione su larga scala; sebbene integri fin dalle fasi iniziali considerazioni su scalabilità e contesto regolatorio il raggiungimento di livelli TRL superiori richiede ulteriori supporti finanziari, norma-

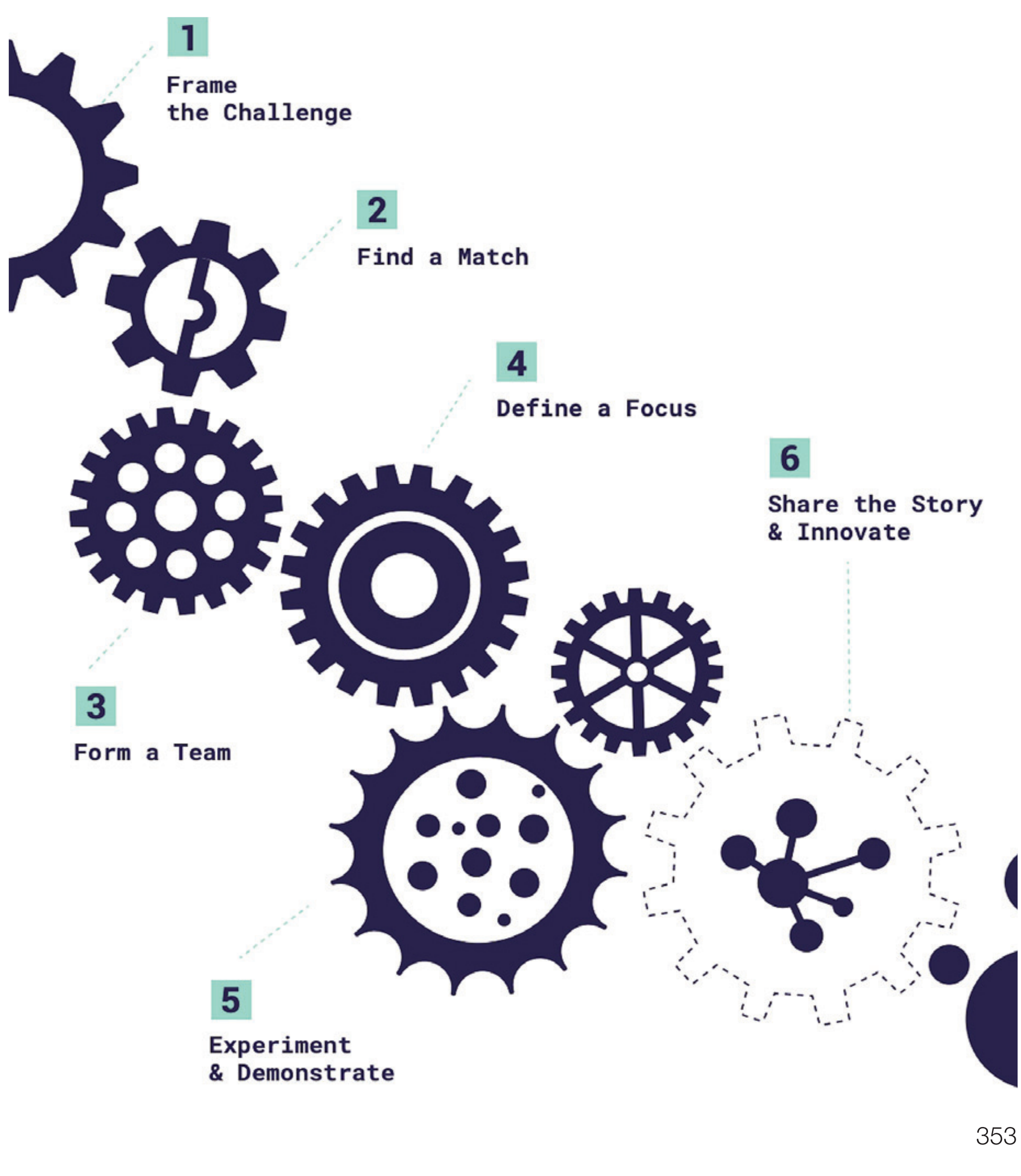


Fig. 5 | Better Factory project method (source: van Vliet et alii, 2024).

Method / framework	Entry point to innovation	Role of artistic practice	Integration of futures thinking	Industrial applicability and TRL	Transferability and main limitations
DFA (MUSAE Factory Model, Horizon Europe, 2022-2025)	Vision-oriented: shared future scenarios are developed before the industrial challenge is defined	Structural co-designer: co-creates future scenarios and co-develops prototypes	Systematic: Horizon Scanning and Visioning are dedicated phases	23 art-technology collaborations; 11 prototypes at TRL5	High: open-source, transferable, and validated in the 'food as medicine' domain; requires medium-to-high innovation maturity
STARTS methodologies (EU STARTS, 2016-ongoing)	Variable: challenge-oriented (art-enabled prototyping), insight-oriented (art-influenced science), and mission-oriented (art-driven technology)	Reframing agent (prototyping), source of insight (science), and responsible validator (technology)	Implicit: not structured; integrated only in the mission-oriented type	No defined TRL; outcomes vary according to the type of collaboration	Medium: typological clarity and broad adoption; lacks an integrated end-to-end innovation pipeline
Art-Driven Innovation Method (In4Art / ADI, Netherlands, 2018-ongoing)	Driven by existing artworks, analysed as starting points for identifying innovation directions	Source of ideas and interpreter of value: artworks reveal the potential of technological and social innovation	Limited: no structured phase for analysis or vision development is provided	Applied in Better Factory; 19 innovation at TRL4–5	High: globally accessible database; limited by dependence on the existing artistic corpus
MAST Innovation Cycle (Erasmus+ EU / University of Nova Gorica, 2018-2020)	Challenge-oriented: a social challenge in which Art Thinking precedes Design Thinking	Epistemic parity between art and design	Weak: no dedicated analysis; future orientation is implicit in the Art Thinking phase	Educational context; TRL not defined; application to SMEs documented only to a limited extent	Medium: strong theoretical argument in favour of art preceding design; predominantly educational; industrial adoption requires adaptation
Better Factory method (H2020, 2020-2024)	Problem-oriented: the existing industrial challenge of SMEs is the starting point; the artist reframes it	Creative reframer and amplifier of solutions: the artist becomes part of the team	No dedicated phase: the market and the challenge context define the future horizon	19 innovations at TRL4-5	High: publication of the guide Creativity Meets Industry; replicable for manufacturing SMEs; limited for anticipatory innovation

Tab. 2 | Comparative analysis of innovation models and of the MUSAE Factory Model (credit: the Authors, 2026).

tivi e istituzionali. In particolare il superamento della soglia TRL5 implica una serie di passaggi critici che eccedono il perimetro attuale del MUSAE Factory Model: 1) validazione dei prototipi in ambienti operativi reali (TRL6-7), ad esempio contesti agricoli diversificati per SOIL o sistemi di biofabbricazione su scala per Growing Futures; 2) ingegnerizzazione e standardizzazione delle soluzioni, necessarie per garantirne replicabilità, affidabilità e conformità normativa; 3) sviluppo di modelli di business sostenibili, capaci di sostenere la transizione da prototipo sperimentale a prodotto o servizio scalabile; 4) accesso a finanziamenti e infrastrutture adeguate per sostenere fasi avanzate di testing e industrializzazione; 5) coinvolgimento di attori istituzionali e regolatori, indispensabile per affrontare vincoli normativi, certificazioni e accettabilità sociale.

Questi passaggi evidenziano una tensione strutturale tra la natura esplorativa e anticipatoria del modello, orientata alla generazione di visioni e prototipi, e i requisiti necessari per la loro implementazione su larga scala, configurando il MUSAE Factory Model come un'infrastruttura abilitante per le fasi iniziali dell'innovazione sistemica, piuttosto che come un dispositivo completo per la sua industrializzazione. La sua efficacia dipende inoltre da specifiche condizioni abilitanti: ecosistemi collaborativi strutturati, competenze interdisciplinari e un livello medio-alto di maturità innovativa delle organizzazioni coinvolte. In assenza di tali condizioni, e in particolare di attori intermedi capaci di facilitare il dialogo, le differenze culturali, temporali e operative tra artisti, tecnologi e imprese possono ostacolare l'efficacia dei processi.

La diffusione del modello è ulteriormente limitata da barriere di natura sistemica, riconducibili a cinque dimensioni principali: culturali, legate alla distanza tra linguaggi e pratiche disciplinari; organizzative, connesse alla difficoltà di integrare processi esplorativi in strutture orientate al breve termine; economiche, relative ai costi e ai tempi delle attività sperimentali; tecnologiche, legate alla complessità e integrazione delle tecnologie emergenti; normative, dovute alla carenza di strumenti regolativi e valutativi adeguati.

Analogamente la trasferibilità del modello oltre il dominio 'cibo come medicina' dipende dalla capacità di adattarne strumenti e processi a contesti applicativi differenti, caratterizzati da diversi livelli di maturità tecnologica, assetti istituzionali e condizioni di mercato. Sebbene la natura 'aperta' e modulare del framework ne favorisca l'adattabilità la sua implementazione efficace richiede la presenza di ecosistemi di innovazione avanzati che non sono uniformemente distribuiti. Questo aspetto rappresenta una barriera significativa alla diffusione del modello in contesti meno strutturati, rendendo necessario sviluppare strategie di adattamento e semplificazione per garantirne un'applicazione più ampia ed equa.

In questo quadro il MUSAE Factory Model mostra un'elevata trasferibilità in contesti caratterizzati da ecosistemi di innovazione avanzati, settori ad alta intensità di conoscenza e organizzazioni aperte alla sperimentazione. Al contrario la sua applicabilità risulta più limitata in contesti a bassa maturità tecnologica, in settori fortemente regolati o in organizzazioni con modelli decisionali rigidi.

Dal punto di vista degli Obiettivi di Sviluppo Sostenibile il contributo del modello si colloca principalmente nell'intersezione tra SDG 9, 12, 13 e 15, con l'SDG 9 come obiettivo abilitante. Il MUSAE Factory Model favorisce sinergie tra innovazione industriale, sostenibilità ambientale e trasformazione dei sistemi produttivi ma rende anche evidenti alcuni compromessi, generando tensioni tra innovazione tecnologica e consumo di risorse, conflitti tra scalabilità e sostenibilità e difficoltà nel bilanciare obiettivi economici e impatti di lungo periodo. Nel complesso questi limiti indicano la necessità di ulteriori sviluppi del modello orientati a rafforzare le connessioni tra sperimentazione, validazione e implementazione, nonché a supportarne l'applicazione in domini e contesti diversi, contribuendo a una più ampia integrazione tra innovazione anticipatoria e processi di trasformazione sistemica.

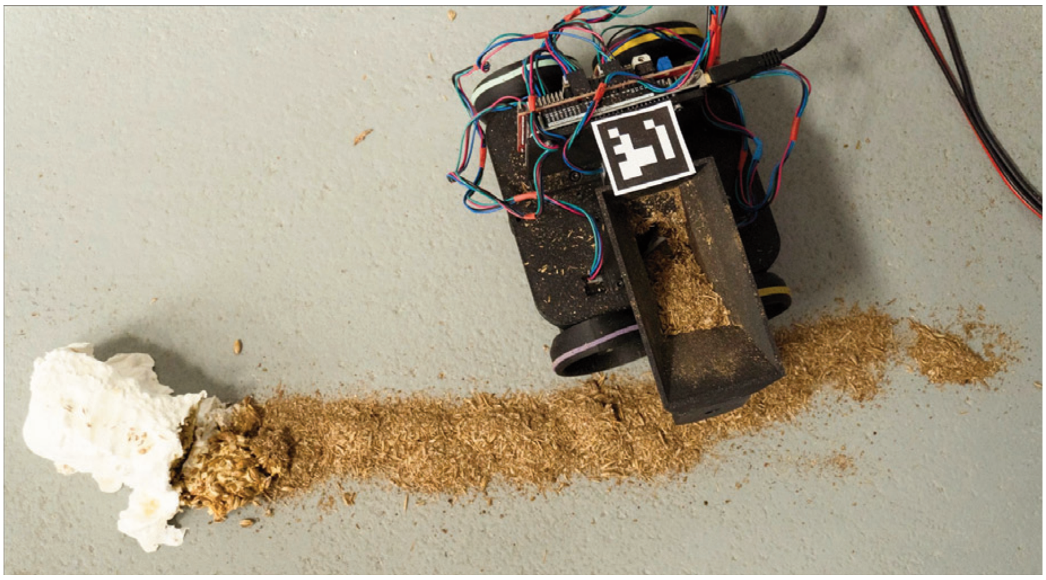
Conclusioni | Il contributo ha analizzato il MUSAE Factory Model come proposta per un'innovazione sistemica capace di integrare pratiche artistiche, sviluppo tecnologico ed esplorazione dei futuri. Più che un modello orientato alla produzione di soluzioni pronte per il mercato, esso opera come dispositivo di orientamento delle traiettorie di innovazione, intervenendo nelle fasi in cui le scelte progettuali restano ancora aperte e reversibili. In questa prospettiva i prototipi sviluppati non rappresentano esiti incompiuti ma strumenti per rendere operative visioni di lungo periodo, facilitare il confronto tra attori eterogenei e testare la coerenza sistemica delle soluzioni emergenti.

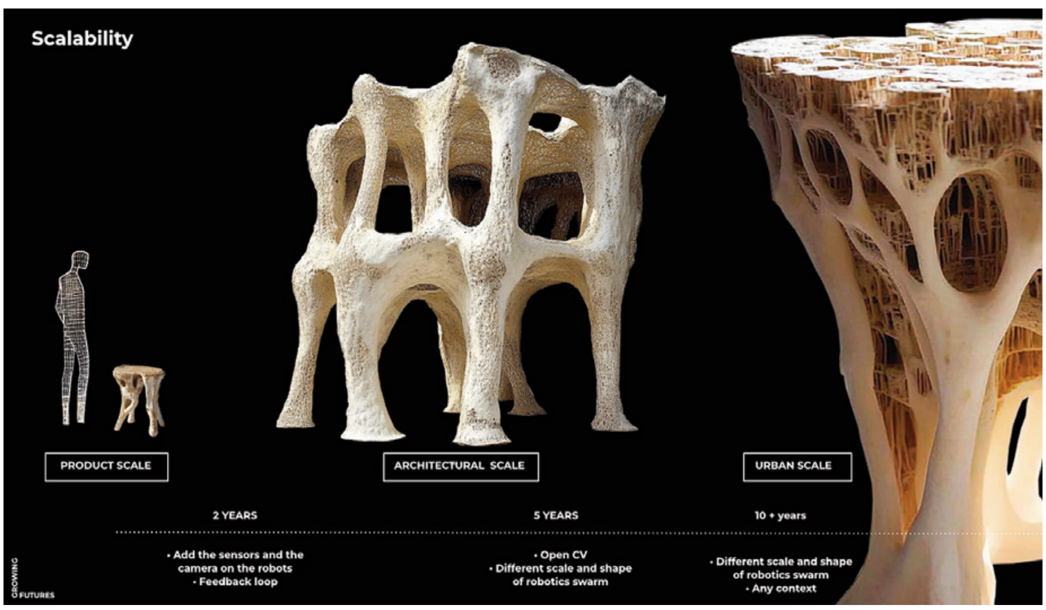
Dal punto di vista teorico la ricerca contribuisce al dibattito sull'innovazione per la sostenibilità proponendo un'integrazione tra approcci trasformativi, governance anticipatoria e analisi delle interdipendenze tra SDG, ancora raramente tradotta in dispositivi operativi. Il MUSAE Factory Model mostra come tali dimensioni possano essere incorporate in un framework progettuale strutturato, spostando il ruolo dell'innovazione da fattore di ottimizzazione a leva per la costruzione di sinergie sistemiche e l'anticipazione dei compromessi nelle fasi iniziali del processo. In tal senso il contributo rafforza una prospettiva emergente nel design e negli studi sull'innovazione che riconosce il valore di approcci anticipatori e transdisciplinari come condizioni necessarie per affrontare sfide sistemiche.

Sul piano metodologico il MUSAE Factory Model propone un'infrastruttura replicabile per la co-creazione transdisciplinare, superando la natura episodica delle collaborazioni arte-tecnologia e integrando costruzione di scenari, esplorazione progettuale e sviluppo prototipale in un processo coerente. Il suo contributo principale risiede nella capacità di connettere immaginazione e operatività, abilitando forme di innovazione orientate al lungo periodo pur mantenendo un ancoraggio a contesti applicativi concreti. Tuttavia tale integrazione rimane ad oggi prevalentemente confinata alle fasi iniziali del processo innovativo, evidenziando la necessità di ulteriori sviluppi per estenderne l'efficacia lungo l'intero ciclo di vita dell'innovazione.

Allo stesso tempo emergono limiti e condizioni di validità rilevanti. Il modello è stato sviluppato in un contesto specifico, infrastrutture EDIH, finanziamenti europei, ecosistemi collaborativi avanzati, che ne condizionano la replicabilità. Inoltre i prototipi si collocano a livelli intermedi di maturità tecnologica (TRL4-5) e il passaggio verso livelli superiori richiede un insieme di condizioni, validazione in contesti reali, ingegnerizzazione, modelli d'impresa, supporto normativo, che eccedono il perimetro del framework. Questa discontinuità evidenzia una tensione strutturale tra la natura esplorativa del modello e le logiche di implementazione su larga scala che rappresenta uno dei principali nodi aperti.

Figg. 6-8 | SOIL: wearable technology for transforming environmental data into sensory experience (credits: L. Artioli and Uptoearth, 2025).





Figg. 9-11 | Growing Futures: bio-responsive habitat prototype capable of adaptation and self-regeneration within ecological cycles (credits: D. Amandolese, Basque Biodesign Centre, 2025).

In questo quadro la ricerca futura potrà svilupparsi lungo quattro direttrici principali: 1) estensione intersettoriale del modello oltre il dominio attuale per verificare la trasferibilità del framework in contesti con diversi livelli di maturità tecnologica e regolatoria, così come in contesti geografici e istituzionali diversi da quello europeo; 2) studi longitudinali per analizzare l'evoluzione dei progetti oltre il TRL5 e comprendere quali traiettorie seguano i prototipi dopo la fase di residenza e in quali condizioni i passaggi verso livelli di maturità superiori diventino praticabili; 3) sviluppo di metriche di impatto, capaci di valutare non solo gli esiti progettuali ma anche gli effetti cognitivi, organizzativi e culturali del modello; 4) integrazione con approcci orientati al mercato, per esplorare configurazioni ibride tra innovazione anticipatoria e implementazione industriale.

Nel complesso il MUSAE Factory Model si configura come un contributo rilevante alla definizione di modelli di innovazione capaci di operare in condizioni di complessità e di incertezza sistemica. La sua proposizione centrale, secondo cui l'innovazione sostenibile richiede non solo efficienza tecnologica ma anche immaginazione culturale, riflessione etica e orientamento ai futuri, non rappresenta un esito consolidato ma un programma di ricerca e sperimentazione ancora aperto.

The first decades of the twenty-first century are increasingly described as a condition of polycrisis (Morin, 2020), in which climate change, biodiversity loss, geopolitical instability, health emergencies, and growing socio-economic inequalities interact in mutually reinforcing ways. Rather than isolated disruptions, these dynamics appear as systemic entanglements that expose the deep fragilities of global production systems and infrastructures. In this context, innovation processes remain central to economic development, technological progress, and social transformation. In international policy agendas, innovation occupies a key position within frameworks such as the United Nations Sustainable Development Goals (SDGs; UN, 2015), the European Green Deal (European Commission, 2019), and the Farm to Fork strategy (European Commission, 2020). In particular, SDG 9 promotes resilient infrastructure, innovation, and inclusive industrialisation, positioning technological development as a driver of sustainable transformation. It can therefore be interpreted not only as a sectoral goal, but also as a transversal lever capable of influencing multiple dimensions of sustainability.

Despite these ambitions, progress towards the targets of the 2030 Agenda remains uneven. Less than five years before the deadline, the United Nations Sustainable Development Goals Report 2023 (UN, 2023) indicates that only around 15% of targets are on track, while progress on more than one third has stalled or regressed compared with 2015 levels. The Covid-19 pandemic, the acceleration of the climate crisis, geopolitical conflicts, and growing economic inequalities have eroded the progress achieved over the previous decade. The challenge no longer lies simply in accelerating the implementation of the goals, but in rethinking the innovation systems through which development is conceived and enacted: as documented by the OECD (2024), the slowest progress is being recorded precisely in those goals that require structural transformations of production systems and innovation cultures, rather than incremental improvements alone.

As the literature on 'deep socio-technical transitions' has shown (Schot and Steinmueller, 2018), sustainability entails long-term transformations that go far beyond incremental technological improvements. However, dominant innovation models remain largely anchored in linear research and development logics, oriented towards short-term optimisation and market competitiveness. These approaches tend to conceive innovation as a technical exercise in problem-solving, often disconnected from broader socio-ecological dynamics and insufficiently attentive, to long-term issues of equity, governance, and environmental impact (Stirling, 2015; OECD, 2018). As a result, they struggle to engage with synergies and trade-offs across different SDGs.

The acceleration of digital transformation further intensifies these tensions. Artificial intelligence, advanced manufacturing, robotics, and data infrastructures offer unprecedented opportunities, but, if embedded in extractive models or oriented solely towards growth, they risk amplifying resource consumption and social inequalities. In response, the European Industry 5.0[1] framework proposes a paradigm shift that moves beyond an automation-centred understanding of efficiency and places human beings, sustainability, and resilience at the centre as guiding principles of industrial transformation (European Commission, 2021), thereby reframing innovation as a value- and mission-oriented process.

Such a shift requires innovation models capable of enabling forms of anticipatory governance by integrating futures exploration, ethical reflection, and collective deliberation into technological development processes (Guston, 2014; Ahern, 2025; Tõnurist and Hanson, 2020). Anticipatory innovation entails the ability to collectively imagine, discuss, and negotiate visions, and to steer technological trajectories more deliberately. From this perspective, artistic practices and design can help expand the cognitive and cultural dimensions of innovation by challenging dominant assumptions and exploring alternative trajectories (Purg, Cacciatore and Gerbec, 2023). Despite this potential, art-technology collaborations often remain episodic and lack stable methodological structures (EUNIC, 2019), limiting their impact within industrial innovation processes.

A central methodological question therefore emerges: how can these anticipatory dimensions be systematically integrated into industrial innovation processes, rather than remaining marginal or residual? Instead of being regarded as a purely technical objective, SDG 9 can be reinterpreted as an enabling infrastructure for systemic transitions, in which industrial innovation evolves in dialogue with ecological limits, social equity, and cultural imagination.

Against this background, the contribution aims to analyse the MUSAE Factory Model, developed through the European MUSAE project, as an open-source methodological infrastructure for systemic, futures-oriented innovation driven by the integration of art and technology. More specifically, the article seeks to: a) discuss the limitations of dominant innovation models in relation to the complexity of sustainable transitions; b) present the MUSAE Factory Model and the Design Futures Art-driven (DFA) method; c) analyse its application through case studies in the 'food as medicine' context; and d) assess the contribution of the model in managing synergies and trade-offs among the SDGs. In this contribution, SDG 9 is considered an enabling goal that supports the integration of SDGs 12, 13, and 15, which are directly addressed through the case studies presented and through the MUSAE Factory Model.

The paper is structured in four parts: the first section reconstructs the state of the art on innovation models for sustainable development; the second presents the MUSAE Factory Model and the DFA method; the third analyses the model and compares it with other methodologies; and the fourth discusses limitations, transferability, and implications in relation to the SDGs. The article contributes to the scientific debate by proposing an integrated and transferable model that combines artistic practices, futures exploration, and technological development, offering operational tools to address the complexity of sustainable transitions under conditions of uncertainty.

Innovation models for sustainable development | Innovation research recognises that addressing sustainability challenges requires profound systemic transformations of socio-technical configurations, rather than simple incremental technological upgrades. Industrial production systems and innovation ecosystems shape resource flows, economic opportunities, and forms of social inclusion. From this perspective, SDG 9 can be interpreted as a structural matrix capable of guiding the transition towards more resilient and sustainable industrial and infrastructural ecosystems, generating cascading effects across multiple other SDGs.

In recent years, several conceptual frameworks have emerged in response to this need for systemic transformation. The literature on 'transformative innovation policy' proposes a shift from traditional support for research and development and competitiveness towards long-term socio-technical transitions aligned with major societal challenges and long-term public value (Schot and Steinmueller, 2018). Similarly, 'mission-oriented innovation' models promote coordinated efforts among public and private actors to address large-scale challenges, such as climate neutrality or the transformation of food systems (Mazzucato, 2018), while approaches grounded in 'responsible research and innovation' emphasise anticipation, reflexivity, inclusion, and responsiveness as key principles for innovation governance (Nazarko, 2019).

Although these models represent a significant evolution beyond linear research and development paradigms, they still present relevant gaps, as highlighted by a rapidly expanding literature on sustainable transitions and systemic innovation. Many transformative frameworks focus predominantly on policy coordination and technological scalability, overlooking the cultural and imaginative dimensions needed to operate under conditions of uncertainty and value conflict. Moreover, although they recognise synergies among sustainability goals, they often lack operational tools capable of explicitly addressing trade-offs and synergies among the SDGs at the level of collaborative experimentation. Finally, as recent studies on open innovation and sustainable transitions have shown, innovation ecosystems often remain fragmented, with limited integration among technological actors, creative disciplines, and civil-society stakeholders. This is compounded by growing attention in the recent literature to open innovation and co-creation practices as levers for addressing systemic complexity (Barbero and Ferrulli, 2023), since they have transformed processes of knowledge production and value creation by defining a paradigm in which firms combine internal and external knowledge through distributed collaborations (Bogers, Chesbrough and Moedas, 2018; Nambisan, Wright and Feldman, 2019). However, some critiques point to a tendency to privilege technological scalability and market efficiency over ethical reflection, long-term sustainability, and inclusive forms of governance (Bogers, Chesbrough and Moedas, 2018). In parallel, studies on design for sustainability and socio-ecological transition have expanded their scope, stressing the need to integrate systemic approaches (Irwin, 2015; Tonkinwise, 2015; Zannoni et alii, 2024), regenerative practices (Escobar, 2018), and circular models into innovation processes (Ceschin and Gaziulusoy, 2016).

In summary, many innovation ecosystems still struggle to translate high-level policies into operational methodologies capable of coordinating interdisciplinary collaboration and experimental processes: integrating technological development, cultural reflection, ethical considerations, and long-term visions continues to represent a structural challenge for industrial systems.

The Industry 5.0 paradigm further reinforces this trajectory by emphasising the need for human-centred, resilient, and sustainable innovation systems. However, operationalising these principles requires concrete methodological infrastructures capable of integrating futures exploration, ethical reflection, and cross-sector collaboration into industrial processes. The literature on anticipatory governance stresses that innovation should move from reactive problem-solving to the proactive exploration of alternative futures, embedding collective practices of vision-building within decision-making processes (Guston, 2014; OECD, 2018). Within this framework, interdisciplinary approaches that connect technological research with artistic and cultural practices are gaining relevance.

Art-technology collaborations have shown the capacity to activate critical reflection, expand imaginaries, and challenge dominant narratives of progress (Whitaker, 2016; Minski, 2020), helping to make visible the social and ethical implications of technological development through experimental, narrative, and prototypical practices. From this perspective, recent research has shown that integrating emotional technology and narrative practices can raise users' awareness of complex issues such as sustainable transition (Valenti et alii, 2024).

In recent years, these approaches have intersected with the growing field of art-tech practices and collaborations between cultural and creative industries and technological sectors, highlighting the role of culture as an infrastructure for innovation (Klein, Gerlitz and Spychalska-Wojtkiewicz, 2021; Dolejsova et alii, 2021), although the literature stresses that these practices often remain marginal to dominant industrial models and are rarely integrated into structured and scalable processes.

These practices intersect with the emerging field of Design Futures, which integrates design methodologies and futures studies to explore long-term social transformations (Bühring and Liedtka, 2018). Design Futures approaches (Canina and Monestier, 2023) use speculative scenarios, participatory vision-building, and narrative prototyping to investigate possible and desirable futures, enabling organisations to anticipate emerging challenges and explore alternative trajectories of technological development (Candy and Dunagan, 2017; Dunne and Raby, 2013). These approaches, which are increasingly widespread in policy and public innovation contexts, foster critical reflection on the systemic implications of technological development and help integrate temporal, ethical, and cultural dimensions into decision-making processes.

Despite their potential, these art-driven methodologies often remain peripheral within dominant industrial frameworks and lack structured implementation models, while futures-oriented thinking is rarely embedded as a continuous operational component of innovation processes (Miller, 2018). Many collaborations among artists, designers, and technologists develop in temporary and experimental settings, without methodologies capable of generating long-term impacts (Monestier et alii, 2024; Schnugg and Song, 2020); consequently, their contribution to systemic transitions towards sustainability remains fragmented and only partially integrated into mainstream innovation processes.

This limitation is accompanied by the restricted availability of evaluative models capable of measuring the impact of interdisciplinary practices on sustainable transitions, an issue that is increasingly relevant in recent literature on the evaluation of socio-technical transformations and SDG impact (Nilsson, Griggs and Visbeck, 2016; Pham-Truffert et alii, 2020).

Addressing the complex synergies among the SDGs therefore requires not only creative experimentation, but also methodological infrastructures capable of coordinating interdisciplinary collaboration. This need is made even more urgent by the fact that the SDGs facing the greatest difficulties – SDGs 13, 14, and 15, but also SDGs 2 and 3 – are those that require deep cultural and systemic transformations, not merely technical solutions.

The slowdown in progress documented by the UNDRR Global Assessment Report (2022) indicates that the increasing frequency of extreme climate events is eroding the infrastructures and production systems on which many other goals depend, creating a dynamic of negative interdependence that linear innovation models struggle to address. The challenge, then, is not simply to promote interdisciplinary experimentation, but to design an innovation infrastructure that systematically integrates futures exploration, artistic inquiry, and technological development within a coherent and replicable framework.

In this context, the contribution seeks to bridge the gap between experimental approaches and systemic applications by introducing three elements of discontinuity with the existing literature: first, the MUSAE Factory Model introduces a structured integration between artistic practices and industrial innovation, moving beyond the episodic nature of art-tech collaborations; second, the DFA method adopts 'futures thinking' as an operational device to orient innovation processes under conditions of uncertainty; and third, it proposes a shift from temporary collaboration models to a transferable methodological infrastructure capable of sustaining systemic and replicable innovation processes across different contexts.

MUSAE Factory Model | The Horizon Europe MUSAE project (2022-2025), embedded in the STARTS ecosystem, explored the contribution of art-technology collaboration to sustainable innovation centred on people and the planet, while also strengthening the role of European Digital Innovation Hubs (EDIHs). Its focus was the 'food as medicine' domain, characterised by strong synergies with SDGs 3, 9, 12, and 13. Through two art-technology residency programmes, MUSAE involved 23 artists and 11 small and medium-sized enterprises (Fig. 1), producing twelve future scenarios and eleven prototypes developed up to Technology Readiness Level 5, understood as the validation of a complete prototype in a relevant environment, as confirmed by the assessment of the technological partners of the MUSAE consortium, tests with end users, and the public exhibition at the Palace of Science in Belgrade.

Artistic collaboration was conceived as a strategic component of the process: typical barriers – including communication gaps, the absence of shared methodologies, and the misalignment of objectives – were addressed through a replicable methodological framework capable of balancing creative freedom and procedural rigour. The main outcome of this pathway is the MUSAE Factory Model: an open-source framework for systemic and futures-oriented innovation, aligned with the principles of Industry 5.0.

The Factory Model is not configured as a single method, but as an integrated ecosystem (Fig. 2) articulated around three main components: 1) Methodological resources, centred on the Design Futures Art-driven (DFA) method and its related tools; 2) Organisational resources, including residency formats, open calls, training guidelines, and mentoring activities; and 3) Community resources, namely the network connecting artists, enterprises, technologists, educators, and domain experts. This architecture responds to the lack of frameworks capable of supporting long-term art-technology collaborations: by integrating the artistic process within a structured methodology and collaborative digital environments (such as Figma[2] and Miro[3]), the model transforms creative experimentation into a replicable operational sequence.

At the centre of the Factory Model is the DFA method (Efremenko et alii, 2025), which integrates three complementary practices: Futures Thinking, to explore alternative and preferable futures; Design Thinking, to structure iterative processes oriented towards prototyping; and Art Thinking, to introduce critical, imaginative, and emotional dimensions (Fig. 3). Based on the Double Diamond model (Design Council, 2005) and extended through Voros's 'futures cone' (2003), the method is articulated in four phases: trend analysis, visioning, ideation, and prototyping. The first phase analyses emerging signals and systemic challenges; the second builds shared scenarios; the third develops interdisciplinary concepts by expanding the space of possibilities; and the fourth translates ideas into prototypes developed up to TRL5.

Generative AI is used as a creative collaborator in ideation, visualisation, and narrative processes. The originality of the method lies in its capacity to respond to three limitations of dominant innovation models:

1) From problem to vision – the DFA moves beyond a problem-centred approach and starts the process from shared visions of preferable futures, making it possible to assess ex ante the technological, environmental, and social implications, and to orient choices towards outcomes consistent with long-term sustainability;
2) Managing synergies and trade-offs among the SDGs – it integrates systemic tools (STEEP+V, mapping of stakeholders, including non-human stakeholders, and uncertainty matrices) that make interdependencies, synergies, and trade-offs among the SDGs explicit, encouraging anticipatory discussion of impacts and moving beyond purely anthropocentric logics;
3) Integrating cultural and emotional intelligence – the DFA, together with the MUSAE Factory Model, responds to one of the main gaps in contemporary innovation systems by reintegrating cultural, ethical, and ecological dimensions into innovation processes, configuring itself as a cognitive and collaborative infrastructure for Industry 5.0 and orienting innovation towards systemic and responsible trajectories.

Positioning the MUSAE Factory Model within the landscape of art-technology innovation models | In order to critically analyse the MUSAE Factory Model, the contribution adopts an approach that distinguishes among: a) the methodological model under analysis; b) the case studies developed within it, used as applied evidence; and c) international reference models and frameworks, used for critical comparison. This analysis positions the MUSAE Factory Model and the related DFA method within existing frameworks for art-technology collaboration and structured methodologies for industrial innovation.

The selection of international references was based on the following criteria: a) integration between creative practices and technological innovation; b) presence of futures-oriented or anticipatory approaches; c) relevance to the debate on sustainability and socio-technical transitions; d) level of methodological structuring; and e) potential for transferability and replicability.

Fig. 12 | Sprout to Flourish: interactive simulations for the transition towards regenerative agricultural practices (credit: M. Mojsiejuk and Odd Data & Design studio, 2025).

Four methods or frameworks were selected. The first, the S+T+ARTS Initiative, developed three collaborative modes, Art-Enabled Prototyping, Art-Influenced Science, and Art-Driven Technology (van Vliet, 2020), which structure the interaction among artists, scientists, and industry. Although they represent an advance beyond previously informal collaborations, these typologies function mainly as facilitation tools and do not amount to operational innovation pathways, since they lack explicit 'futures thinking' phases and a systematic connection between artistic experimentation and prototyping at defined TRL levels.

The second is the Art-Driven Innovation method (ADI; Fig. 4; In4Art, 2020), which uses databases of artworks as a starting point for responsible innovation, connecting technologies and SDGs through 'green' and 'care' pathways. Although strongly oriented towards sustainability, it starts from existing works rather than from co-created future visions, which in some cases limits its generative capacity in highly uncertain contexts.

The MAST innovation cycle (Tab. 1), developed within the Erasmus+ programme and selected as the third case, places Art Thinking before Design Thinking in a ten-stage process (Castillo-Rutz and Purg, 2021). Although it emphasises the central role of artistic inquiry, it remains primarily an educational model, with limited documented application in industrial contexts and without clear references to TRLs.

The last is the Better Factory project (Fig. 5; van Vliet et alii, 2024), which is the closest to the MUSAE model because it structures collaborations among artists, small and medium-sized enterprises, and technologists in four phases: challenge definition, 'matchmaking', iterative experimentation, and business modelling. However, it adopts a problem-driven approach and does not include a structured phase of futures-oriented thinking. To systematise the comparison between the MUSAE Factory Model and the main international frameworks, a comparative synthesis was developed around five dimensions: entry point to innovation, role of artistic practice, integration of futures thinking, industrial applicability, and transferability. Table 2 summarises these differences, highlighting the positions and strengths and limitations of the various approaches.

Within this framework, the SOIL and Growing Futures projects are analysed as applied cases of the MUSAE model, while the critical comparison is developed in relation to related international models and practices. The comparison shows that the MUSAE Factory Model is distinguished by the simultaneous integration of three dimensions that are rarely present together in the models analysed: 1) a vision-oriented entry point based on the shared construction of future scenarios; 2) an explicit methodological formalisation that structures the process into replicable phases; and 3) an operational connection with industrial contexts that makes it possible to translate speculative visions into prototypes at intermediate TRL levels.

Conversely, the models analysed tend to develop these dimensions only partially: STARTS methodologies privilege flexibility but lack structured operational pathways; ADI introduces a strong sustainability orientation but limits future generativity; MAST emphasises the role of art but remains confined to educational contexts; and Better Factory ensures industrial applicability but adopts a predominantly problem-driven approach, lacking an explicit anticipatory phase.

Two main implications emerge from this reading: first, futures-oriented thinking is systematically underused as an operational device in innovation processes, despite its potential for managing uncertainty and complexity; second, vision-oriented and problem-driven models appear complementary, since the former enables long-term transformations, while the latter facilitates short-term industrial adoption. The MUSAE Factory Model is positioned within this tension, proposing an integration between the anticipatory dimension and operational application. Some strengths and limitations shared with the literature nevertheless remain, particularly in relation to the scalability of the model, large-scale validation, and the measurement of long-term impacts, all of which require further methodological and empirical development. The following sections analyse how the framework was operationalised in the MUSAE residencies, with particular attention to the two representative projects SOIL and Growing Futures, showing how SDG 9 can act as a systemic enabler of sustainable industrial transformation.

Applied cases of the MUSAE Factory Model: SOIL and Growing Futures | In line with the contribution's positioning in relation to the SDGs, in which the analysis identified a prevailing convergence towards the intersection of SDGs 9, 12, 13, and 15, with SDG 9 understood as an enabling goal, the selection of case studies was oriented towards making these relationships explicit through applied evidence. It is important to clarify that the criteria used for case selection derive directly from the evaluation system developed by the MUSAE consortium to assess the completeness and quality of the eleven projects produced. These criteria were communicated from the outset to the participating teams, who were required, through the five expected deliverables, to demonstrate their effective fulfilment throughout the entire development process. The selection of SOIL and Growing Futures therefore responds to consolidated evaluative criteria. Both projects obtained the highest scores in the two main evaluation phases of the MUSAE project: concept evaluation and final prototype evaluation. The first considered seven dimensions: concept maturity, technology, user experience, collaboration, ethics, sustainability, and financial feasibility, while the second certified the achievement of TRL5 on the basis of four main areas: positive impact (sectoral, social, and environmental), innovation, user interaction, and risk management. The material assessed included both the functioning TRL5 prototypes and the five final deliverables produced by the teams, which systematically document the development process.

Within the MUSAE project, TRL5 indicates the achievement of a complete prototype validated in a relevant environment through a structured, shared process involving the entire technological consortium and validation with end users. More specifically, validation involved farmers in the case of SOIL and designers in the case of Growing Futures. However, it must be specified that this level does not correspond to validation in a real operational environment (TRL6-7), which would require large-scale testing, advanced engineering, and certification, but rather to validation under simulated or controlled conditions, which are sufficient to demonstrate the technical feasibility and coherence of the prototype in relation to criteria of impact, usability, and sustainability.

The two cases were also selected for their capacity to represent the central dimensions of the model in complementary ways. SOIL exemplifies the relationship among future vision, environmental sensing, and regenerative agricultural practices, with a strong connection to SDGs 13 and 15. Growing Futures instead illustrates the integration of biofabrication, advanced robotics, and post-anthropocentric design, with direct relevance to SDGs 9 and 12. Considered together, the two cases show how the DFA can generate transformative rather than incremental innovation trajectories in contexts characterised by high ecological and technological uncertainty.

Fig. 13 | Remedy Garden: bio-inclusive architecture for the urban cultivation of medicinal plants (credit: Baum & Leahy and Blast Studio, 2025).

At the same time, they make it possible to delineate more precisely what the MUSAE Factory Model has actually demonstrated, namely the capacity to guide art-technology collaborations up to the development of mature and validated prototypes, as distinct from what remains potential to be developed in subsequent phases, particularly the transition towards higher levels of technological maturity and stable forms of industrial adoption and large-scale diffusion.

SOIL: regenerative agriculture | The SOIL project (2025), the result of collaboration among the artist Letizia Artioli, the company Uptoearth, a farmer, and a fashion designer, addresses soil degradation, one of the major environmental challenges of the contemporary age, closely linked to biodiversity loss, climate change, and unsustainable models of food production. The project originates from the future scenario 'Soil Skinships'[4], developed by Lisa Mandemaker, which imagines a sensory relationship between humans and soil mediated by technological devices. In keeping with the DFA, the project starts from a shared vision of the future rather than from a predefined technical problem. Through speculative exploration, soil is reinterpreted as a living infrastructure embedded in complex socio-ecological systems. The outcome is a wearable prototype that translates soil data into sensory stimuli perceptible by the human body. The device integrates environmental sensors capable of detecting parameters such as humidity, temperature, and other soil conditions (Figg. 6-8); the data collected are converted into tactile and sound signals that are perceived directly by the farmer through the garment, thereby transforming abstract measurements into an embodied experience. The project proposes an alternative paradigm in which agricultural infrastructure becomes relational and experiential, moving beyond models based exclusively on remote control. In this way, through innovation, SOIL supports regenerative agricultural practices, strengthens ecological awareness, and integrates technological and environmental dimensions.

Growing Futures: regenerative habitats between mycelium and robotics | The Growing Futures project (2025) explores the relationships among biological materials, robotic fabrication, and regenerative design. Developed by the artist and designer Daniela Amandolese with the Basque Biodesign Center, the project investigates how biological growth processes and advanced fabrication technologies can be combined to generate new forms of sustainable infrastructure. It is based on the scenario 'What the World Eats – Agro-Technologies in Earthly Futures'[5], developed by Peter Andersen, which imagines hybrid infrastructures between biological and technological systems operating symbiotically. Here too, the project starts from a future vision, questioning the separation between natural and artificial and reinterpreting infrastructure as a living system.

The project combines the biological growth of mycelium with robotic fabrication: robotic systems guide and shape mycelial development, replicating natural reticular structures and enabling the creation of complex spatial forms. The result is a bio-responsive habitat prototype capable of adapting and self-regenerating, while integrating into ecological cycles (Figg. 9-11). The project highlights a shift towards post-anthropocentric approaches, in which natural and technological processes operate in an integrated manner.

Managing synergies and trade-offs through an art-driven model | Although the two projects operate in different fields, they share the same methodological logic of the MUSAE Factory Model. In both cases, innovation starts from shared future scenarios that reconfigure infrastructure as a living and relational system. This approach moves beyond a linear and solutionist logic in favour of anticipatory reframing: instead of optimising efficiency within consolidated industrial paradigms, the DFA method expands the problem space through perspective analysis and visioning practices, before converging in the prototyping phase.

Without these phases, the projects would probably have followed conventional technological trajectories, leading to incremental rather than transformative outcomes. The comparison discussed above clarifies this point: the DFA is among the few approaches that use future scenarios as a generative device within the process, while other frameworks operate on predefined challenges or existing content.

The model responds to the fragmentation of innovation ecosystems by integrating technological, ecological, and cultural dimensions into a single process. Artists act as co-designers of innovation trajectories, challenging dominant industrial assumptions and fostering broader cross-sector dialogue. For these reasons, the DFA method was selected for the ADI Design Index 2025 as one of the most relevant Italian design research projects in the Research for Enterprise category[6]. This recognition confirms the growing relevance of innovative, anticipatory, and imaginative approaches in industrial and business innovation.

The most significant aspect concerns the reconfiguration of innovation as a lever for systemic transitions towards sustainability. From this perspective, innovation is no longer a source of externalities that undermine other goals, but becomes the means through which synergies can be built. What distinguishes these cases is not only their alignment with multiple SDGs, but also the concrete integration of their synergies into the innovation process. Through futures-oriented reflection, the DFA enables stakeholders to anticipate potential trade-offs between technological acceleration and ecological integrity, and to reorient design trajectories accordingly. The added value of the model lies less in the individual prototypes than in its capacity to transform innovation processes and cultures by proposing a transferable methodological infrastructure.

This capacity to generate and make these dynamics visible emerged particularly clearly in the final exhibition of the MUSAE project, 'Grow, Cook, Code – Rethinking Food Futures', hosted at the Palace of Science in Belgrade. The event functioned not only as a showcase for the results, but also as a device for public and social validation: more than 2,000 visitors, including citizens, artists, enterprises, researchers, and institutions, interacted with 11 functioning prototypes, exploring their potential and strengths and limitations.

This public dimension has methodological relevance for at least three reasons: first, direct interaction made it possible to test the intelligibility of the design visions, transforming complex technological objects into mediation tools among different domains; second, it helped strengthen trust in emerging technologies by highlighting their orientation towards social and ecological goals; and third, it made tangible the potential of the MUSAE Factory Model as an infrastructure not only for industrial innovation, but also for public participation in technological trajectories, in line with anticipatory governance approaches.

The prototypes exhibited demonstrated how existing technologies can be recombined through futures-oriented visions to address systemic challenges in the 'food as medicine' domain. Among them, Sprout to Flourish supports the transition towards regenerative agricultural practices through interactive simulations (Fig. 12); Remedy Garden proposes a bio-inclusive architecture for the urban cultivation of medicinal plants (Fig. 13); Neuro-cooking uses biofeedback to transform cooking into a therapeutic experience (Fig. 14); and Nourish connects nutrition and cognitive states through EEG analysis (Fig. 15).

Taken together, these examples show how the MUSAE Factory Model and the DFA method are capable of generating distinct yet coherent innovation trajectories, combining methodological structure and creative exploration – a productive tension that represents one of the most distinctive elements of the model.

Towards regenerative and anticipatory innovation systems | The persistent gap between the ambition of the SDGs and the uneven progress recorded towards 2030 points not only to difficulties of implementation, but also to structural limitations rooted in dominant innovation cultures and models. Conventional techno-economic paradigms, often oriented towards the short term and characterised by fragmentation and limited anticipatory capacity, struggle to address the systemic synergies and trade-offs that cut across the entire SDG agenda. The MUSAE Factory Model responds to this need by introducing a framework that integrates speculative imagination, structured anticipation, and collaborative prototyping. Through the DFA method, innovation is reoriented around shared visions of preferable futures, rather than being bound exclusively to predefined technical parameters.

The cases analysed show how these approaches can integrate ecological and technological dimensions and support more coherent innovation trajectories. Within this framework, the model contributes to realigning technological development and sustainability by proposing an operational approach in contexts of systemic uncertainty.

To prevent reference to the SDGs from remaining purely declarative, it is necessary to make explicit the contribution of the MUSAE Factory Model in relation to the full SDG 1-17 system. From this perspective, the model does not act linearly on individual goals, but as a device for anticipatory innovation capable of activating synergies, making trade-offs visible, and orienting design trajectories in relation to a plurality of SDGs.

Table 3 proposes a systematic mapping of this relationship, articulated into five analytical categories: directly activated SDGs, indirectly involved SDGs, potentially synergistic SDGs, SDGs asso-

Fig. 14 | Neuro-cooking: biofeedback system applied to the therapeutic culinary experience (credit: A. Rosinke and mbraintrain, 2025).

ciated with risks or trade-offs, and SDGs that are marginal to the scope of the model. The 'directly activated' SDGs are those for which the model produces demonstrable contributions through the exemplary projects and the methodological structure. The 'indirectly involved' SDGs are those that benefit from the model's spillover effects without being its explicit objective. The SDGs with 'possible synergies' are those for which the model shows a potential connection, conditioned by the application context or by future developments.

The SDGs for which 'trade-offs or risks' may emerge are those for which technological innovation guided by the model may generate unresolved tensions or externalities. Finally, the 'marginal or not directly relevant' SDGs are those that fall outside the scope of application of the model in the cases analysed, although they are not excluded in principle from future applications in other domains. The aim is not to claim extensive SDG coverage, but to make the effective relationships between the model and the sustainability agenda explicit and well argued.

It is finally important to specify that this mapping refers to the current configuration of the MUSAE Factory Model, developed in the 'food as medicine' domain and validated through the eleven prototypes produced, including SOIL and Growing Futures. The transferability of the model to other domains could modify its relevance profile in relation to the SDGs, expanding the areas of direct activation or introducing new potential trade-offs.

Limits, barriers, and transferability of the model | Despite the transformative potential of the MUSAE Factory Model, several relevant strengths and limitations emerge in relation to the scalability and transferability of the results. The prototypes developed in the cases analysed are predominantly positioned at TRL5, corresponding to validation in a relevant environment, but still distant from stable forms of industrial adoption. A preliminary conceptual clarification is therefore needed in order to interpret the limits of the model correctly.

The MUSAE Factory Model is not conceived as a product-development pathway oriented towards immediate commercialisation, nor do TRL5 prototypes represent pre-industrial versions of products or services ready for the market. The objective of the model is different and, in some respects, more ambitious at the systemic level: to imagine possible and preferable future trajectories, identify emerging challenges, map interdependencies among technological, ecological, and social dimensions, and anticipate impacts and trade-offs before innovation trajectories consolidate into forms that are difficult to reverse. From this perspective, the prototypes are not unfinished products, but cognitive and cultural devices: tools for making otherwise abstract visions tangible, facilitating dialogue among heterogeneous stakeholders, and testing the internal coherence of an idea against criteria of sustainability, usability, and ethics.

This distinction is relevant not only for assessing the model correctly, but also for avoiding a frequent misunderstanding in the innovation literature, which tends to measure the value of a creative process by its proximity to the market. The MUSAE Factory Model operates at a different level of the innovation chain: that of oriented exploration, where the central question is not 'is this product marketable?' but 'is this vision desirable, sustainable, and technically feasible?' Any subsequent move towards higher TRLs and forms of industrial adoption is possible, but it requires conditions, actors, and resources that lie outside the perimeter of the model itself and that, in this reading, constitute not an intrinsic limitation, but a conscious methodological choice consistent with an anticipatory governance approach to innovation (Guston, 2014).

The MUSAE Factory Model highlights the potential of an integrated approach among art, technology, and 'futures thinking', but also reveals structural limits and conditions of validity linked to the context in which it was developed. In particular, the model emerged under specific conditions: Horizon Europe funding, the 'food as medicine'

Fig. 15 | Nourish: connection between nutrition and cognitive states through EEG analysis (credit: S. Šikoparija and StarLab, 2025).

domain, an infrastructure based on European Digital Innovation Hubs (EDIHs), and a European context favourable to art-technology collaboration, all of which are decisive and not always replicable.

The model is located primarily at intermediate levels of technological maturity (TRL4-5), highlighting difficulties in the transition from prototyping to large-scale diffusion. Although it integrates considerations of scalability and regulatory context from the early phases, reaching higher TRL levels requires further financial, regulatory, and institutional support.

In particular, moving beyond the TRL5 threshold implies a series of critical steps that exceed the current perimeter of the MUSAE Factory Model: 1) validation of prototypes in real operational environments (TRL6-7), for example diversified agricultural contexts for SOIL or scaled biofabrication systems for Growing Futures; 2) engineering and standardisation of the solutions, necessary to ensure replicability, reliability, and regulatory compliance; 3) development of sustainable business models capable of supporting the transition from experimental prototype to scalable product or service; 4) access to adequate funding and infrastructure to support advanced testing and industrialisation phases; and 5) involvement of institutional and regulatory actors, which is essential for addressing regulatory constraints, certification, and social acceptability. These steps reveal a structural tension between the exploratory and anticipatory nature of the model, oriented towards the generation of visions and prototypes, and the requirements needed for their large-scale implementation, configuring the MUSAE Factory Model as an enabling infrastructure for the early phases of systemic innovation, rather than as a complete device for its industrialisation. Its effectiveness also depends on specific enabling conditions: structured collaborative ecosystems, interdisciplinary competences, and a medium-to-high level of innovation maturity among the organisations involved. In the absence of these conditions, and particularly of intermediary actors capable of facilitating dialogue, the cultural, temporal, and operational differences among artists, technologists, and enterprises may hinder the effectiveness of the processes.

The diffusion of the model is further limited by systemic barriers attributable to five main dimensions: cultural, linked to the distance between disciplinary languages and practices; organisational, connected to the difficulty of integrating exploratory processes into short-term-oriented structures; economic, relating to the costs and timeframes of experimental activities; technological, associated with the complexity and integration of emerging technologies; and regulatory, due to the lack of adequate regulatory and evaluative tools.

Similarly, the transferability of the model beyond the 'food as medicine' domain depends on the capacity to adapt its tools and processes to different application contexts, characterised by varying levels of technological maturity, institutional arrangements, and market conditions. Although the 'open' and modular nature of the framework supports its adaptability, effective implementation requires the presence of advanced innovation ecosystems, which are not uniformly distributed. This aspect represents a significant barrier to the diffusion of the model in less structured contexts, making it necessary to develop strategies of adaptation and simplification to ensure broader and more equitable application.

Within this framework, the MUSAE Factory Model shows high transferability in contexts characterised by advanced innovation ecosystems, knowledge-intensive sectors, and organisations open to experimentation. Conversely, its applicability is more limited in contexts with low technological maturity, in highly regulated sectors, or in organisations with rigid decision-making models. The model therefore needs to be adapted according to the context, sector, and maturity level of the reference ecosystem.

From the perspective of the Sustainable Development Goals, the contribution of the model is located mainly at the intersection of SDGs 9,

SDG	Relationship with MUSAE	Rationale
1 NO POVERTY	Indirect	Possible indirect effects on reducing economic vulnerability through inclusive innovation and new models of local production. The model involves SMEs and creative actors in collaborative processes that may contribute to generating economic opportunities and strengthening territorial ecosystems, with potential effects on socio-economic resilience. However, access to the model depends on specific enabling conditions, such as European funding, EDIH infrastructures, and advanced innovation ecosystems, which limit its redistributive scope, particularly in more fragile contexts. Poverty reduction is not an explicit objective of the model, but emerges as a possible indirect effect whose realisation requires targeted adaptation and inclusion strategies.
2 ZERO HUNGER	Indirect / synergistic	Indirect connection with sustainable food systems and food security. The 'food as medicine' application domain, together with the SOIL and Growing Futures cases, addresses issues relevant to SDG 2, particularly through attention to soil health, the regeneration of agricultural ecosystems, and the development of alternative biological materials, which intersect with structural dimensions of food vulnerability and production sustainability. However, the model does not intervene directly in the causes of hunger or in mechanisms of food access and distribution; its application to the food system remains primarily oriented towards technological and design innovation rather than food security in the strict sense.
3 GOOD HEALTH AND WELL-BEING	Indirect	Relevant to the 'food as medicine' domain, but not directly demonstrated by the cases. SDG 3 provides the thematic reference for the MUSAE programme as a whole, which operates in the 'food as medicine' domain and assumes health as a horizon of meaning and as an interpretative framework for design activities. However, in the SOIL and Growing Futures cases analysed in this contribution, the connection with human health is not supported by direct empirical evidence: SOIL focuses on soil health and regenerative agricultural practices, while Growing Futures explores the development of biological materials and alternative production processes. SDG 3 therefore remains a relevant conceptual background, but not an objective directly activated or demonstrated by the cases considered.
4 QUALITY EDUCATION	Synergistic	Activated through transdisciplinary learning and capacity-building. The MUSAE Factory Model promotes non-formal learning processes based on collaboration among artists, technologists, and enterprises, supporting the development of hybrid skills that are difficult to acquire through traditional educational pathways. The residency programmes, training activities, and teaching materials associated with the DFA method configure an experimental learning environment oriented towards practice. In addition, the community component of the model, which connects artists, researchers, educators, and experts, contributes to the construction of a shared learning ecosystem with intrinsic and transferable educational potential.
5 GENDER EQUALITY	Marginal	Potential integration into participatory and inclusive processes. The MUSAE Factory Model does not explicitly address gender, either in selection criteria, team composition, or evaluation tools. Although it is not structurally exclusionary, the absence of active gender-mainstreaming measures represents a relevant gap in relation to SDG 5. In this sense, the model shows potential alignment with gender-equity objectives, but this dimension is not currently activated in a systematic manner. Future research could investigate the extent to which the artistic and collaborative practices integrated into the model facilitate or hinder equitable participation in innovation processes, helping to orient its evolution in a more inclusive direction.
6 CLEAN WATER AND SANITATION	Indirect	Indirect relevance to agro-ecological systems and regenerative practices. The SOIL case integrates environmental sensors for monitoring soil parameters such as moisture, temperature, and ground conditions, which are indirectly connected to the sustainable management of water resources in agriculture. However, water is not addressed as an explicit objective, either in the cases analysed or in the methodological structure of the model. A possible extension of the framework to application domains specifically oriented towards water management could strengthen its alignment with SDG 6 more directly.
7 AFFORDABLE AND CLEAN ENERGY	Marginal	The energy-transition dimension, which is central to SDG 7, does not fall within the application domain of the cases analysed or within the current configuration of the MUSAE Factory Model. The model does not explicitly consider energy production, distribution, or accessibility as design dimensions. However, the adoption of the framework in application fields beyond the 'food as medicine' domain could open up more direct integrations with sustainable-energy issues, broadening its field of relevance.
8 DECENT WORK AND ECONOMIC GROWTH	Indirect	Synergies with new creative and technological value chains, with potential tensions between growth and sustainability. The MUSAE Factory Model supports forms of collaboration among SMEs, artists, and technologists that may contribute to generating new employment opportunities and strengthening local innovation ecosystems. However, these effects in terms of work and sustainable economic growth depend on conditions that exceed the perimeter of the model, particularly the transition towards higher Technology Readiness Levels and the capacity to translate prototypes into stable forms of industrial adoption. In this sense, a possible tension emerges between the model's experimental and anticipatory dimension and its effective integration into logics of economic growth, highlighting the need for further development to ensure lasting employment impacts consistent with sustainability principles.
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	Directly activated / enabling	The core of the model: an infrastructure for systemic and transdisciplinary innovation. SDG 9 constitutes the enabling objective of the MUSAE Factory Model, conceived as an open methodological infrastructure for industrial innovation that is futures-oriented and people-centred, in line with the principles of Industry 5.0. Through the involvement of SMEs, cross-sector collaboration, and the development of prototypes up to TRL5, the model contributes to building more resilient and inclusive innovation ecosystems capable of integrating technological, social, and ecological dimensions. The open-source nature of the framework further strengthens its potential for dissemination and adaptation. In this sense, SDG 9 operates as a transversal lever capable of activating systemic effects and generating indirect impacts on multiple other goals of the 2030 Agenda.

SDG	Relationship with MUSAE	Rationale
10 REDUCED INEQUALITIES	Trade-off / risk	Inclusion of diverse actors and participatory approaches, with potential tensions related to equitable access. The MUSAE Factory Model promotes collaboration among heterogeneous actors, including SMEs, artists, and technologists, fostering participatory and transdisciplinary dynamics. However, its implementation depends on specific enabling conditions, such as the presence of EDIH infrastructures, access to European funding, and the availability of organisations open to experimentation. This dependence risks reproducing or amplifying inequalities between geographical and institutional contexts with different levels of innovation maturity. The adoption of the model in less technologically developed contexts therefore presents significant barriers, which may result in the concentration of benefits in already advantaged systems. In this sense, a structural tension emerges between the model's capacity to generate systemic innovation and its actual accessibility, configuring equity of access as a critical dimension to be addressed in future developments of the framework.
11 SUSTAINABLE CITIES AND COMMUNITIES	Synergy	Potential applicability to sustainable urban and territorial contexts. The Growing Futures case explores bio-responsive materials and hybrid infrastructures between biological and technological systems, opening up possible applications in architecture and sustainability-oriented urban contexts. However, this connection with SDG 11 is not supported by direct evidence in the cases analysed, since the prototypes were neither developed nor tested in urban settings. SDG 11 therefore represents a future development direction for the framework, particularly for applying the model to the design of regenerative infrastructures and more resilient urban systems.
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Directly activated	Development of practices and prototypes oriented towards the sustainability of production systems. SDG 12 is directly activated in the cases analysed, which propose alternative paradigms of production and resource use. SOIL reinterprets agricultural infrastructure as a relational and experiential system, promoting regenerative practices based on soil care and the circularity of processes. Growing Futures, by contrast, experiments with mycelium-based biological materials as alternatives to conventional synthetic materials, contributing to the reduction of the environmental impact of production. At the methodological level, the DFA integrates criteria of sustainability, circularity, and impact assessment from the initial phases, orienting innovation trajectories towards more responsible models of production and consumption.
13 CLIMATE ACTION	Directly activated	Integration of the climate dimension into anticipatory and design processes. SDG 13 is directly activated in the cases analysed, which address climate change through strategies of mitigation and environmental-impact reduction. SOIL acts on soil degradation as one of the main climate challenges, promoting regenerative agricultural practices that contribute to carbon reduction and to strengthening ecosystem resilience. Growing Futures explores low-impact biological materials as alternatives to carbon-intensive production processes. At the methodological level, the DFA integrates systemic-analysis tools, such as STEEP+V and the mapping of non-human stakeholders, which make it possible to anticipate and make explicit potential trade-offs between technological development and climate integrity, orienting innovation trajectories towards more sustainable solutions.
14 LIFE BELOW WATER	Marginal / indirect	Not directly addressed in the case studies analysed. Aquatic ecosystems do not fall within the application domain of the MUSAE Factory Model in its current configuration. Any indirect connections, for example through reduced soil pollution in the SOIL case or the substitution of plastic materials in Growing Futures, remain implicit and are not supported by empirical evidence. SDG 14 therefore represents a non-activated area, although it may become potentially relevant in future applications of the framework in domains related to the management of marine and coastal resources.
15 LIFE ON LAND	Directly activated	Strongly supported by the cases analysed. SDG 15 is directly activated through systemic attention to terrestrial ecosystems, biodiversity, and regenerative processes. The SOIL case centres on soil health understood as a living infrastructure, addressing issues such as degradation, fertility, and regenerative agricultural practices. Growing Futures integrates biological processes, particularly mycelium growth, into technological systems, proposing a post-anthropocentric paradigm in which the natural and the artificial operate symbiotically and interdependently. Taken together, the two cases show how technological innovation can be oriented not towards the replacement of natural ecosystems, but towards their regeneration and valorisation, contributing to a redefinition of the relationship between production systems and ecological integrity.
16 PEACE, JUSTICE AND STRONG INSTITUTIONS	Marginal	Not explicitly addressed by the model. The MUSAE Factory Model introduces elements that can be associated with anticipatory governance and participatory decision-making processes through interdisciplinary co-creation practices, shared construction of future scenarios, and collective deliberation on the ethical and social implications of technological development. These dynamics may contribute indirectly to strengthening more transparent and inclusive organisational cultures, in line with some principles of SDG 16. However, the model does not explicitly address issues related to justice, peace, or institutional governance, which remain outside its application perimeter.
17 PARTNERSHIPS FOR THE GOALS	Directly activated	Multi-actor collaboration lies at the centre of the MUSAE Factory Model. SDG 17 is directly activated, since the model is founded on cross-sector partnership as a generative principle: collaboration among artists, SMEs, technologists, researchers, and civil-society stakeholders constitutes the operational core of the framework. The open-source nature and community architecture of the model support its replicability and adaptability in different contexts, contributing to the strengthening of collaborative networks for innovation at European and international scales.

Tab. 3 | The MUSAE Factory Model and SDGs 1-17 (credit: the Authors, 2025).

12, 13, and 15, with SDG 9 acting as an enabling goal. The MUSAE Factory Model fosters synergies among industrial innovation, environmental sustainability, and the transformation of production systems, but it also makes certain trade-offs visible, generating tensions between technological innovation and resource consumption, conflicts between scalability and sustainability, and difficulties in balancing economic objectives with long-term impacts. Overall, these limits indicate the need for further developments of the model aimed at strengthening the connections among experimentation, validation, and implementation, as well as supporting its application in different domains and contexts, thereby contributing to a broader integration between anticipatory innovation and systemic transformation processes.

Conclusions | The contribution has analysed the MUSAE Factory Model as a proposal for systemic innovation capable of integrating artistic practices, technological development, and futures exploration. More than a model oriented towards producing market-ready solutions, it operates as a device for orienting innovation trajectories, intervening in the phases in which design choices remain open and reversible. From this perspective, the prototypes developed do not represent incomplete outcomes, but tools for making long-term visions operational, facilitating exchange among heterogeneous actors, and testing the systemic coherence of emerging solutions.

From a theoretical perspective, the research contributes to the debate on innovation for sustainability by proposing an integration of transformative approaches, anticipatory governance, and analysis of SDG interdependencies, which are still rarely translated into operational devices. The MUSAE Factory Model shows how these dimensions can be incorporated into a structured design framework, shifting the role of innovation from a factor of optimisation to a lever for constructing systemic synergies and anticipating trade-offs in the early phases of the process. In this sense, the contribution reinforces an emerging perspective in design and innovation studies that recognises the value of anticipatory and transdisciplinary approaches as necessary conditions for addressing systemic challenges.

Methodologically, the MUSAE Factory Model proposes a replicable infrastructure for transdisciplinary co-creation, moving beyond the episodic nature of art-technology collaborations and integrating scenario-building, design exploration, and prototypical development into a coherent process. Its main contribution lies in its capacity to connect imagination and operability, enabling forms of long-term-oriented innovation while remaining anchored to concrete application contexts. However, this integration remains, to date, largely confined to the early phases of the innovation process, highlighting the need for further developments to extend its effectiveness across the entire innovation life cycle.

At the same time, relevant limits and conditions of validity emerge. The model was developed in a specific context – EDIH infrastructures, European funding, and advanced collaborative ecosystems – which conditions its replicability. Moreover, the prototypes are positioned at intermediate levels of technological maturity (TRL4-5), and the transition towards higher levels requires a set of conditions – validation in real contexts, engineering, business models, and regulatory support – that exceed the perimeter of the framework. This discontinuity reveals a structural tension between the exploratory nature of the model and the logics of large-scale implementation, which represents one of the main unresolved issues. Within this framework, future research may develop along four main directions: 1) cross-sector extension of the model beyond the current domain, in order to verify the transferability of the framework in contexts with different levels of technological and regulatory maturity, as well as in geographical and institutional contexts other than the European one; 2) longitudinal studies to analyse the evolution of projects beyond TRL5 and to understand which trajectories prototypes follow after the residency phase, and under which conditions transitions towards higher maturity levels become practicable; 3) development of impact metrics capable of assessing not only design outcomes, but also the cognitive, organisational, and cultural effects of the model; and 4) integration with market-oriented approaches, in order to explore hybrid configurations between anticipatory innovation and industrial implementation.

Overall, the MUSAE Factory Model is configured as a relevant, but still evolving, contribution to the definition of innovation models capable of operating under conditions of complexity and systemic uncertainty. Its central proposition, namely that sustainable innovation requires not only technological efficiency, but also cultural imagination, ethical reflection, and futures orientation, is not a consolidated outcome, but an open programme of research and experimentation.

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Notes

1) For more information, see the webpage: research-and-innovation.ec.europa.eu/research-area/industrial-research-and-innovation/industry-50_en [Accessed 8 April 2026].

2) For more information, see the webpage: figma.com/proto/Aq1pAgjJL1aEdewDlcwgLt/DFA-platform—-FINAL-VERSION?node-id=4435-2296&t=2pBoQ24nGEP2oiOp-1 [Accessed 8 April 2026].

3) For more information, see the webpage: miro.com/templates/design-futures-artdriven-method/ [Accessed 8 April 2026].

4) For more information, see the webpage: musae.starts.eu/musae/2nd-open-call-scenarios-by-lisa-mandemaker/ [Accessed 8 April 2026].

5) For more information, see the webpage: musae.starts.eu/musae/2nd-open-call-scenarios-by-peter-andersen/ [Accessed 8 April 2026].

6) For more information, see the webpage: adi-design.org/2025_i00871 [Accessed 8 April 2026].

References

Ahern, D. (2025), "The New Anticipatory Governance Culture for Innovation – Regulatory Foresight, Regulatory Experimentation and Regulatory Learning", in *European Business Organization Law Review*, vol. 26, issue 1, pp. 241-283. [Online] Available at: doi.org/10.1007/s40804-025-00348-7 [Accessed 8 April 2026].

Barbero, S. and Ferrulli, E. (2023), "Transizione ecologica e digitale – Il Design Sistemico nei processi di innovazione aperta delle PMI | Ecological and digital transition – Systemic Design in SMEs open innovation processes", in *Agathón | International Journal of Architecture, Art and Design*, vol. 13, pp. 269-280. [Online] Available at: doi.org/10.19229/2464-9309/13232023 [Accessed 27 April 2026].

Bühring, J. H. and Liedtka, J. (2018), "Embracing systematic futures thinking at the intersection of Strategic Planning, Foresight and Design", *in Journal of Innovation Management*, vol. 6, issue 3, pp. 134-152. [Online] Available at: doi.org/10.24840/2183-0606_006-003_0006 [Accessed 8 April 2026].

Bogers, M., Chesbrough, H. and Moedas, C. (2018), "Open innovation – Research, practices, and policies", in *California Management Review*, vol. 60, issue 2, pp. 5-16. [Online] Available at: doi.org/10.1177/0008125617745086 [Accessed 12 April 2026].

Candy, S. and Dunagan, J. (2016), "Designing an experiential scenario – The People Who Vanished", in *Futures*, vol. 86, pp. 136-153. [Online] Available at: doi.org/10.1016/j.futures.2016.05.006 [Accessed 8 April 2026].

Canina, M. and Monestier, E. (2023), "Design Futures to support Sustainable Food practices", in De Sainz Molestina, D., Galluzzo, L., Rizzo, F. and Spallazzo, D. (eds.), *IASDR*

2023 – Life-Changing Design, 9-13 October, Milan, Italy, pp. 1-15. [Online] Available at: doi.org/10.21606/iasdr.2023.521 [Accessed 12 April 2026].

Castillo-Rutz, N. and Purg, P. (eds) (2021), *MAST Manual – Education for innovation through social values*, Akademija Umetnosti – School of Arts. [Online] Available at: mastmodule.eu/wp-content/uploads/2021/03/MAST_manual_www.pdf [Accessed 12 April 2026].

Ceschin, F. and Gaziulusoy, I. (2016), "Evolution of Design for Sustainability – From Product Design to Design for System Innovations and Transitions", in *Design Studies*, vol. 47, pp. 118-163. [Online] Available at: doi.org/10.1016/j.destud.2016.09.002 [Accessed 12 April 2026].

Design Council (2005), *The Double Diamond design process model*, Design Council, London. [Online] Available at: designcouncil.org.uk/our-resources/the-double-diamond/ [Accessed 12 April 2026].

Dolejsova, M., Ampatzidou, C., Houston, L., Light, A., Botero, A., Choi, J., Wilde, D., Altarriba Bertran, F. A., Davis, H., Gil, F. G. G. and Catlow, R. (2021), "Designing for transformative futures – Creative practice, social change and climate emergency", in Sas, S. and Maiden, N. (eds), *Proceedings of the 13th Conference on Creativity and Cognition – C&C'21, Venice, Italy, June 22-23, 2021*, Association for Computing Machinery, New York (NY), article 3, pp. 1-9. [Online] Available at: doi.org/10.1145/3450741.3465242 [Accessed 8 April 2026].

Dunne, A. and Raby, F. (2013), *Speculative Everything – Design, Fiction, and Social Dreaming*, The MIT Press, Cambridge (MA).

Efremenko, T., Bruno, C., Monestier, E. and Canina, M. (2025), "The Design Futures Art-driven (DFA) Method – Structuring Art-Tech Collaboration for Sustainable Future of Food System", in Ahram, T., Karwowski, W. and Kalra, J. (eds), *Human Factors in Design, Engineering, and Computing – AHFE (2025) International Conference*, vol 199, AHFE International, USA, pp. 93-104. [Online] Available at: doi.org/10.54941/ahfe1006821 [Accessed 8 April 2026].

Escobar, A. (2018), *Designs for the pluriverse – Radical interdependence, autonomy, and the making of worlds,* Duke Press University, United States.

EUNIC – EU National Institute for Culture (2019), *Art + Tech Report – Stakeholder investigation*. [Online] Available at: eunic.eu/media/site/4f725e1ad1-1753182943/art-tech-report-2019_eunic-silicon-valley.pdf [Accessed 24 March 2026].

European Commission (2021), *Industry 5.0 – Towards a sustainable, human-centric and resilient European industry*, Publications Office of the European Union, Luxembourg. [Online] Available at: data.europa.eu/doi/10.2777/308407 [Accessed 8 April 2026].

European Commission (2020), *A Farm to Fork strategy for a fair, healthy and environmentally-friendly food system*. [Online] Available at: food.ec.europa.eu/system/files/2020-05/f2f_action-plan_2020_strategy-info_en.pdf [Accessed 10 April 2026].

European Commission (2019), *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions – The European Green Deal*, document 52019DC0640, COM/2019/640 final. [Online] Available at: eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019DC0640 [Accessed 8 April 2026].

Guston, D. H. (2014), "Understanding 'anticipatory governance'", in *Social Studies of Science*, vol. 44, issue 2, pp. 218-242. [Online] Available at: doi.org/10.1177/0306312713508669 [Accessed 8 April 2026].

In4Art (2020), *Art-driven innovation – A new path to innovation-led sustainable growth*. [Online] Available at: in4art.eu/wp-content/uploads/2020/02/In4Art-ADI-Whitepaper.pdf [Accessed 10 April 2026].

Irwin, T. (2015), "Transition design – A proposal for a new area of design practice, study, and research", in *Design and Culture*, vol. 7, issue 2, pp. 229-246. [Online] Available at: doi.org/10.1080/17547075.2015.1051829 [Accessed 10 April 2026].

Klein, M., Gerlitz, L. and Spychalska-Wojtkiewicz, M. (2021), "Cultural and creative industries as a boost for innovation and sustainable development of companies in cross-innovation process", in *Procedia Computer Science*, vol. 192, pp. 4218-4226. [Online] Available at: doi.org/10.1016/j.procs.2021.09.198 [Accessed 8 April 2026].

Mazzucato, M. (2018), "Mission Oriented Innovation Policy – Challenges and Opportunities", in *Industrial and Corporate Change*, vol. 27, issue 5, pp. 803-815. [Online] Available at: doi.org/10.1093/icc/dty034 [Accessed 8 April 2026].

Miller, R. (ed.) (2018), *Transforming the Future – Anticipation in the 21st Century*, Routledge, London. [Online] Available at: doi.org/10.4324/9781351048002 [Accessed 8 April 2026].

Minski, K. (2020), *Collaboration in experimental art – Case studies in co-creation, transdisciplinarity, and art-science practice at Ars Electronica Futurelab*, Doctoral Thesis, University of Newcastle, Callaghan. [Online] Available at: doi.org/10.13140/RG.2.2.34658.66242 [Accessed 8 April 2026].

Monestier, E., Efremenko, T., Fiore, M. and Canina, M. (2024), "Beyond Boundaries – Art-Tech Collaboration Driving Future-Oriented Innovation", in Markopoulos, E., Goonetilleke, R. S. and Luximon, Y. (eds), *Creativity, Innovation and Entrepreneurship – Proceedings of the 15th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences, Nice, France, July 24-27, 2024*, AHFE International, New York, AHFE International Book Series, vol. 125, pp. 134-143. [Online] Available at: doi.org/10.54941/ahfe1004729 [Accessed 8 April 2026].

Morin, E. (2020), "Per l'uomo è tempo di ritrovare sé stesso", interview by Scialoja, A., in *Avvenire.it*, 15/04/2020. [Online] Available at: avvenire.it/agora/pagine/per-luomo-tempo-di-ritrovare-se-stesso [Accessed 8 April 2026].

Nambisan, S., Wright, M. and Feldman, M. (2019), "The digital transformation of innovation and entrepreneurship – Progress, challenges and key themes", in *Research Policy*, vol. 48, issue 8, pp. 1-9. [Online] Available at: doi.org/10.1016/j.respol.2019.03.018 [Accessed 10 April 2026].

Nazarko, Ł. (2019), "Responsible research and innovation – A conceptual contribution to theory and practice of technology management", in *Business | Theory and Practice*, vol. 20, pp. 342-351. [Online] Available at: doi.org/10.3846/btp.2019.32 [Accessed 8 April 2026].

Nilsson, M., Griggs, D. and Visbeck, M. (2016), "Policy – Map the interactions between Sustainable Development Goals", in *Nature* vol. 534, pp. 320-322. [Online] Available at: doi.org/10.1038/534320a [Accessed 8 April 2026].

OECD – Organisation for Economic Co-operation and Development (2024), *7th OECD World Forum on Well-being – Summary of key messages*. [Online] Available at: oecd.org/content/dam/oecd/en/networks/oecd-well-being-world-forums/7wf/7wf-summary-key-messages.pdf [Accessed 27 April 2026].

OECD – Organisation for Economic Co-operation and Development (2018), *OECD Science, Technology and Innovation Outlook 2018 – Adapting to Technological and Societal Disruption*, OECD Publishing, Paris. [Online] Available at: doi.org/10.1787/sti_in_outlook-2018-en [Accessed 8 April 2026].

Pham-Truffert, M., Metz, F., Fischer, M., Rueff, H. and Messerli, P. (2020), "Interactions among Sustainable Development Goals – Knowledge for identifying multipliers and virtuous cycles", in *Sustainable Development*, vol. 28, issue 5, pp. 1236-1250. [Online] Available at: doi.org/10.1787/sti_in_outlook-2018-en [Accessed 8 April 2026].

Purg, P., Cacciatore, S. and Gerbec, J. C. (2023), "Establishing ecosystems for disruptive innovation by cross-fertilizing entrepreneurship and the arts", in *Creative Industries Journal*, vol. 16, issue 2, pp. 115-145. [Online] Available at: doi.org/10.1080/17510694.2021.1969804 [Accessed 8 April 2026].

Schnugg, C. and Song, B. (2020), "An organizational perspective on ArtScience collaboration – Opportunities and challenges of platforms to collaborate with artists", in *Journal of Open Innovation | Technology, Market, and Complexity*, vol. 6, issue 1, article 6, pp. 1-20. [Online] Available at: doi.org/10.3390/joitmc6010006 [Accessed 8 April 2026].

Schot, J. and Steinmueller, W. E. (2018), "Three frames for innovation policy – R&D, systems of innovation and transformative change", in *Research Policy*, vol. 47, issue 9, pp. 1554-1567. [Online] Available at: doi.org/10.1016/j.respol.2018.08.011 [Accessed 8 April 2026].

Stirling, A. (2015), *Emancipating transformations – From controlling 'the transition' to culturing plural radical progress*, STEPS Centre, University of Sussex, Brighton. [Online] Available at: steps-centre.org/wp-content/uploads/Transformations.pdf [Accessed 8 April 2026].

Tonkinwise, C. (2015), "Design for transitions – From and to what?", in *Design Philosophy Papers*, vol. 13, issue 1, pp. 85-92. [Online] Available at: doi.org/10.1080/14487136.2015.1085686 [Accessed 8 April 2026].

Tõnurist, P. and A. Hanson (2020), *Anticipatory innovation governance – Shaping the future through proactive policy making*, OECD Publishing, Paris. [Online] Available at: doi.org/10.1787/cce14d80-en [Accessed 8 April 2026].

UN – United Nations (2023), *The Sustainable Development Goals Report 2023 – Special Edition*, United Nations, New York. [Online] Available at: unstats.un.org/sdgs/report/2023/The-Sustainable-Development-Goals-Report-2023.pdf [Accessed 27 April 2026].

UN – United Nations (2015), *Transforming our World – The 2030 Agenda for Sustainable Development*. [Online] Available at: sdgs.un.org/2030agenda [Accessed 8 April 2026].

UNDRR – United Nations Office for Disaster Risk Reduction (2022), *Global Assessment Report on Disaster Risk Reduction 2022 – Our world at risk – Transforming governance for a resilient future*. [Online] Available at: undrr.org/media/79595/download?startDownload=20260429 [Accessed 27 April 2026].

Valenti, A., Scalisi, F., Sposito, C., Dellamotta, L. and Masserdotti, A. (2024), "Energia, tecnologia emotiva e valore culturale dei dati – Creare consapevolezza nell'utente con lo storytelling | Energy, emotional technology and cultural value of data – Creating user awareness through storytelling", in *Agathón | International Journal of Architecture, Art and Design*, vol. 15, pp. 70-83. [Online] Available at: doi.org/10.19229/2464-9309/1552024 [Accessed 27 April 2026].

van Vliet, R. G. (2020), *S+T+ARTS – Collaboration toolkit*, STARTS Ecosystem. [Online] Available at: starts.eu/wp-content/uploads/starts-toolkit-13july2020.pdf [Accessed 10 April 2026].

van Vliet, L. G., Coto, M., Duarte, M., Soldati, M., Wierinck, N., van Vliet, R. G. and Birsel, Z. (2024), *Creativity meets industry – A practical guide to transformative partnerships*, Better Factory. [Online] Available at: starts.eu/wp-content/uploads/Better-factory-toolkit.pdf [Accessed 10 April 2026].

Voros, J. (2003), "A generic foresight process framework", in *Foresight*, vol. 5, issue 3, pp. 10-21. [Online] Available at: doi.org/10.1108/14636680310698379 [Accessed 10 April 2026].

Whitaker, A. (2016), *Art thinking – How to carve out creative space in a world of schedules, budgets and bosses*, HarperBusiness, New York.

Zannoni, M., Succini, L., Rosato, L. and Pasini, V. (2024), "Transitional industrial designer – La responsabilità di progettisti e imprese per una transizione sostenibile | Transitional industrial designer – The responsibility of designers and companies for a sustainable transition", in *Agathón | International Journal of Architecture, Art and Design*, vol. 15, pp. 332-343. [Online] Available at: doi.org/10.19229/2464-9309/15282024 [Accessed 27 April 2026].