BIOTEXFUTURE TRANSITION LAB

TransitionLab White Paper – Scenarios, Perspectives, and Drivers

Abstract

The transformation of the textile industry into a bioeconomic and circular industry is one of the central challenges of sustainable innovation policy. As part of the BIOTEXFUTURE innovation space, the accompanying research project TransitionLab is investigating how social, technological, and political dynamics can activate or hinder this change. Based on the multi-relation perspective (Schmitt et al. 2023) and following Adams & Jeanrenaud (2016), three key dimensions of innovation – responsibility and behavioral change, technological innovations at the material level, and system change – are used as an analytical framework. Along this framework, two contrasting modular scenarios were developed that outline different development paths for the textile bioeconomy. The comparative analysis shows that transformation is not linear, but should be understood as a relational dynamic – at the interfaces between selected identities, institutional logics, and material innovations. The results can be used to derive recommendations for action in politics, research, and business that aim at cooperation, transparency, and long-term learning processes.

1 Introduction

The transformation of the textile industry is subject to many conditions. Against the backdrop of the national bioeconomy strategy (BMBF 2020) in particular, the development of bio-based materials plays a key role. The challenges are characterized by the high complexity of technical innovations, ranging from the substitution of petroleum-based fibers with bio-based fibers to the recyclability of new materials and textiles. An important prerequisite for successful and scalable innovations is to understand them as part of a transformative social dynamic that needs to be explored in detail. In their interconnectedness, innovations are always socio-technically mediated and must be understood in their specific context.[1]

Scenario analysis can be used to identify and ultimately analyze the challenges of socio-technical innovations in the circular bio-based textile industry as part of the transformation. Which challenges are particularly in focus depends not least on the perspective of the innovators, i.e., the actors involved. Influencing factors such as production and consumption have specific relevance in their respective spheres of influence and can provoke supportive or blocking dynamics between the identities involved. Actors, processes, materials, and thus a far greater number of entities help shape and determine the transformation to a bioeconomic, circular textile industry, which further underscores the complexity of the entire process. This requires a methodological approach that takes into account the processuality and relationality of change and adequately reflects the dynamic character of transformation processes.

Based on the multi-relation perspective (MRP) according to Schmitt et al. (2023), we have used scenario analysis to examine innovation developments as part of the bioeconomic and circular transformation of the textile industry in the BIOTEXFUTURE innovation space in the accompanying research project TransitionLab, funded by the BMFTR[3]. The aim of the analysis is to shed light on the dynamics and dependencies between different identities in different dimensions of innovation. The focus is on a scale-free view of non-subjective socio-

technical dynamics that can bring about change in the sense of Whites (2008) towards a bioeconomic circular textile industry. In addition, these dynamics are to be examined in terms of their scope with the help of various dimensions of innovation. The focus on specific groups of actors as identities opens up the possibility of identifying the role expectations of the groups in the design of the individual scenarios as so-called future stories, thus revealing the influence of expectations in different dimensions of innovation and in dynamic interaction with other identities in their effects.

The scenarios derived from this do not aim to create classic visions of the future that represent possible or probable developments. Instead, they are based on modular assumptions that have emerged from factor analyses, prospecting methods, and iterative testing. Their targeted combination reveals how different influencing factors can have a blocking or activating effect on change. The aim of this scenario analysis is to identify precisely these dynamics and to derive action-guiding impulses for a successful transformation.

The two modular scenario constructions presented below are based on different narratives that were discussed among experts during the transformation process. As so-called future stories, they show driving factors and identities in various dimensions of socio-technical innovation development, which interact dynamically with each other in a modular way and thus unfold a specific activating and blocking potential in the transformation, based on White's (2008: 289) "getting and blocking action." With a view to the transformation goal, potentials are referred to below as activating if they promote or facilitate transformation processes, while blocking potentials refer to inhibiting or contradictory dynamics. The activating and blocking potentials were identified with the help of bioeconomy experts and actors from the innovation space.

The scenario analysis used here differs from previous perspectives on the future of the bioeconomy in two respects:

First, it does not focus on classic economic or political drivers, but on material-based innovations as a starting point. Second, it is not based on linear, quantitatively supported development paths, but pursues a modular, qualitative design of different transformation logics. The present scenario analysis focuses on innovations in the field of material development, which thus becomes the starting point for modular assumptions and takes into account the research-led perspective on transformation. As a result, this analysis takes into account the research perspective in the BIOTEXFUTURE innovation space. This involves focusing on the research and development of bio-based and recyclable textiles, which, based on the value chain logic according to Richter et al. (2025), also address issues of feedstocks. In comparison, other analyses focus, for example, on the area of land acquisition or land use and related models (cf. Schaldach/Thrän 2019; Banse et al. 2020, among others), as well as the aspect of political measures (Wydra et al. 2020) or the comparison of consumer behavior and agricultural land use (Kimpeler et al. 2018; Banse et al. 2020, among others). Richter et al. (2025) expanded existing bioeconomy scenarios in Germany to include the aspect of circularity in their literature-based analysis.

The drivers identified in this analysis were systematized and classified according to the logic of the value chain. Subsequently, the methodological derivation and basis of the new modular scenario analysis are explained (Chapter 2) and, building on this, the individual scenarios are presented in terms of their dynamics (Chapter 3). Next, a comparison of both scenarios presents the blocking and activating potentials of different identities in the three dimensions of

innovation. Finally, recommendations for action derived from the analysis are presented, along with an outlook on the potential of the method (Chapters 4 and 5).

2 Scenario development: derivation and methodology

Building on the challenges outlined in Chapter 1, the TransitionLab in the BIOTEXFUTURE innovation space pursues a methodological-analytical approach to the transformation of the textile industry. The aim was to develop an in-depth understanding of possible development paths for a bioeconomic textile industry – in particular with regard to the question of which selected identities with which potentials actively promote or hinder transformative change. To investigate these dynamics, two contrasting scenario constructions were developed following Essia and Baudouin (2024), which serve as a methodological analysis tool.

As already mentioned, the scenarios developed do not represent predictions of the future, but are based on a modular structure with communication-led, socio-technical assumptions. They allow for a structured examination of responsibilities, transformation logics, and innovation dynamics – always from the perspective of specific identities. The scenarios do not unfold their potential as classic linear narratives, but as deliberately exaggerated constructions that reveal typical lines of conflict and scope for action in the bioeconomic textile transformation.

We developed various areas of tension during an internal TransitionLab workshop. These areas of tension include contrasting but plausible lines of development that capture central conflicts of interest and possible directions within the transformation of the textile industry. In our methodological approach, we identified the following overarching axes of tension: (1) an innovation-driven understanding of bio-based materials as a "technological duplicate of nature" versus (2) an approach focused on origin and naturalness as "origin in nature," (3) a production-oriented design logic with a focus on recyclability ("design for recycling" based on Hall 2021) versus (4) a market- and usage-driven perspective with a focus on durability and degradability, (5) an economic approach in which sustainability must pay off versus (6) a normatively based sustainability orientation, (7) transformation through political incentives versus (8) transformation through regulatory bans, and (9) strong public research funding with corresponding control versus (10) company-driven research without direct government influence. These areas of tension formed the framework for the further scenario analysis.

Building on these areas of tension, scenario development was implemented in a multi-stage methodological process, which is explained below along with the key steps involved:

The starting point was qualitative interviews with experts and initial workshop results from the BIOTEXFUTURE innovation space. On this basis, narrative axes of tension were identified that revealed key contrasts within the field of innovation. Following Adams & Jeanrenaud (2016: 9), three central dimensions of innovation were distinguished: Responsibility and Behavioral Change, Technological Innovations at the Material Level, and System Change. These dimensions structure the subsequent scenario analysis and enable a differentiated view of the specific identities and influencing factors.

Building on this, these areas of tension were evaluated in terms of their relevance, creative power, and plausibility. Key drivers for further scenario development were derived from this factor analysis.

In a next step, two contrasting projections were developed. These are characterized by their modular structure: assumptions about politics, design, consumption, research, and production

logic were systematically varied and compared with each other in order to model possible development paths and reveal dynamics.
The following figure illustrates this modular structure. Based on the two projections, it shows how different combinations of assumptions were linked together to form the basis for the two contrasting scenarios.

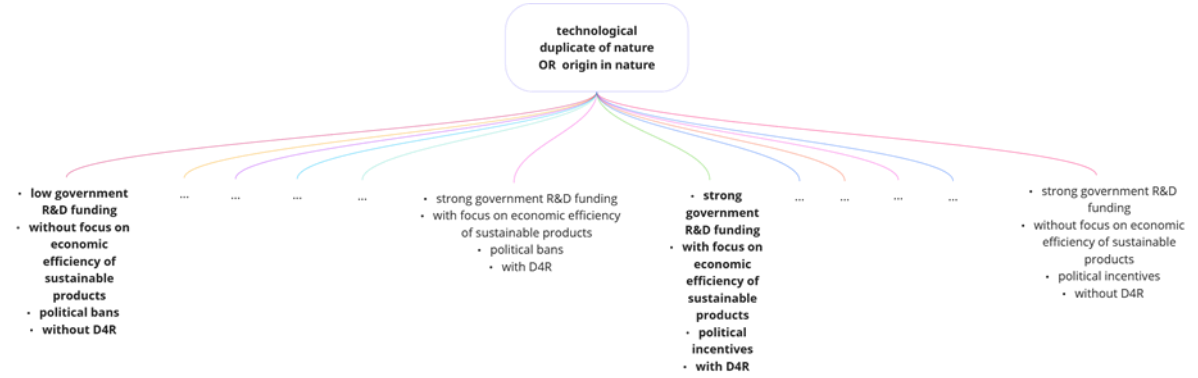

Fig. 1: Modular structure of the scenario assumptions

Central to this was the work with communication-led, socio-technical basic assumptions, which resulted in two contrasting scenarios:

Scenario 1 is based on the assumption that new materials are designed as technological duplicates of nature ("duplicate of nature"). Transformation is driven here by socio-technical innovations, government support measures, and design-for-recycling strategies.

Scenario 2, on the other hand, defines bio-based materials as those whose fibers are of natural origin ("origin in nature"). The focus is on degradability, politically mandated changes, and the expansion of necessary infrastructure—without direct links to economic exploitation logic.

The modeling of the two projections was based on these basic assumptions. Large language models (LLMs) such as ChatGPT were also used to systematically explore narrative variants and plausibility spaces. In an iterative process, the resulting scenarios were checked for internal consistency. Both internal project feedback and external expert assessments were incorporated into the plausibility check and refinement.

The finalized scenarios were discussed in workshops with participants from the innovation space and in interdisciplinary external rounds with stakeholders from science and industry. In particular, specific social situations were considered, such as clothing purchases, industrial production, and the provision of bio-based raw materials.

The results of these discussions and supplementary interview statements were then evaluated to identify activating and blocking potentials in both scenarios. These were processed and compared with each other along defined innovation dimensions and focused identities. For better comprehensibility, the methodological steps of scenario development described above are visualized once again in the following figure.

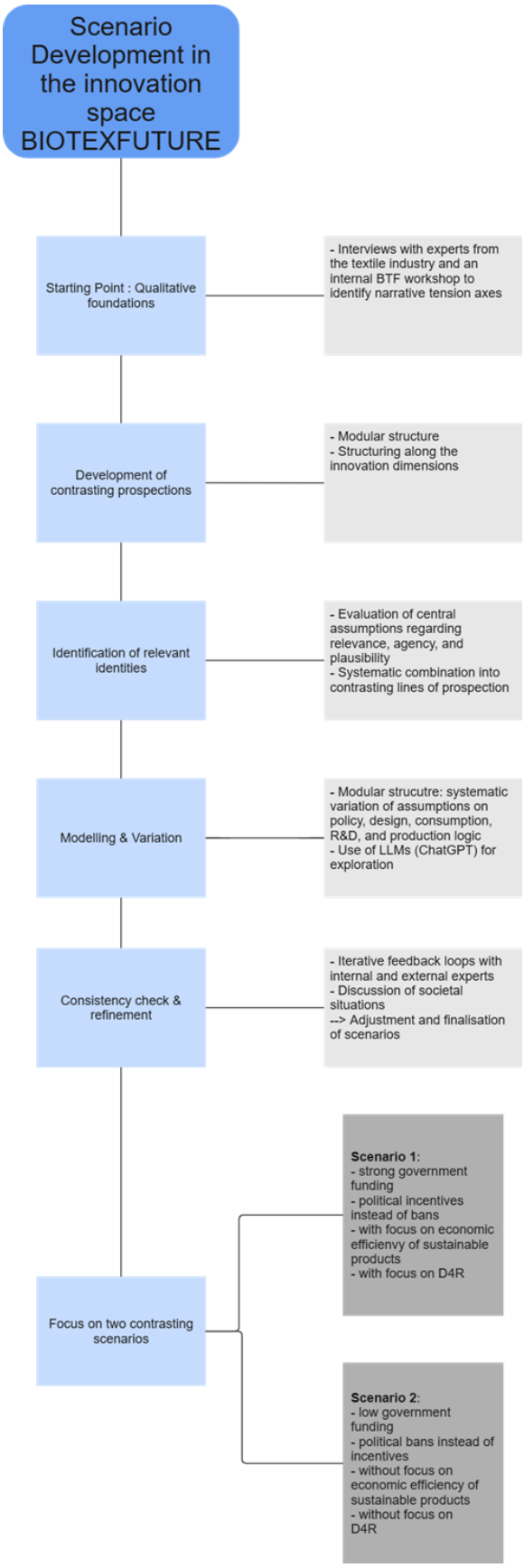

Fig. 2: Overview of scenario development in the BIOTEXFUTURE innovation space

Based on this methodological scenario development and the identified drivers, the next chapter provides an in-depth analysis of the two scenarios. The focus is on specific identities—such as

politics, business, research, design, or consumption—and their respective responsibilities, opportunities for influence, and interactions in the context of textile transformation.

3 Presentation of the scenarios

Based on the methodological steps described above and the areas of tension identified, this chapter is devoted to an in-depth analysis of the two scenarios developed. The first scenario envisages a transformation path for the bioeconomic textile industry that is primarily shaped by technology-oriented innovations, government research funding, and design strategies such as "design for recycling." The other scenario focuses on materials with an origin in nature, emphasizes political bans, and envisions transformation primarily through regulatory measures and infrastructure expansion – without any direct link to economic exploitation logic.

The analysis focuses on social identities, which are addressed in different ways by the modular assumptions underlying the scenario. Along the three central dimensions of innovation – Responsibility and Behavioral Change, Technological Innovations at the Material Level, and System Change – the potential for sustainable transformation is examined.

In the following, two modularly developed scenarios are analyzed that show different development paths for a sustainable textile industry. While Scenario 1 focuses more on technological innovation, government support, and design strategies, Scenario 2 focuses on political regulation, market-based control, and return systems.

3.1 Scenario 1

The first scenario is based on various assumptions that significantly influence the focused identities, among other things in their various roles. The inputs and effects and their mutual interaction are to be examined in more detail throughout the scenario as a modular assumption construct. In particular, the activating and blocking potentials of the various identities in the three dimensions are analyzed with regard to the resulting transformation dynamics. This scenario construct can be visualized as follows[4]:

Figure 1: Scenario 1, source ChatGPT

This scenario focuses on material-related innovations based on the idea of a technological duplicate of nature. The underlying assumption is that new fiber materials are specifically developed to mimic the functional properties of natural materials – but independently of biological raw materials. The focus is on a technologically driven understanding of sustainability that is not based on naturalness or origin, but on functionality and replaceability. The aim of these socio-technical innovations is to replace petroleum-based fibers with high-performance alternatives.

New material developments not only consolidate socio-technical new technologies, such as biotechnologies, but also mean new information and knowledge production and dissemination for consumers or users, for example. These innovative developments are supported by strong government funding for research and development. The second important assumption in this framework focuses on the various support options and research approaches that are included by the government. In addition, the modular construct is based on the assumption that political regulations should accelerate the transformation as incentives rather than using bans. The assumptions underlying the scenario thus have a significant influence on the roles in which the various identities operate. The following analysis ties in directly with this scenario structure and explains how the respective potentials can have an activating or blocking effect on the transformation process. This provokes a certain type of dynamic influence that is relevant with regard to the individual identities and their relationships to one another.

A significant factor in the transformation of the textile industry into a more bioeconomic, circular industry is the highly regarded economy and the companies involved along the entire value chain. As part of the transformative dynamic, the relationship between (production) costs and sustainability is always at the forefront of corporate decision-making. In this scenario construct, ‘the’ corporate focus is on sustainability in the production of textiles and the resulting products that is more oriented towards economic efficiency. A frequently used instrument for measuring process-related or product-related sustainability in companies is life cycle assessment (LCA). [5]

The corporate focus triggers a dynamic with a view to the development of new materials, for example in research project networks. The last assumption ties in with the development and production process. In the underlying modularity, this scenario focuses on “design for recycling” (D4R). The involvement of designers plays a decisive and powerful role here.

These assumptions result in the following decision matrix:

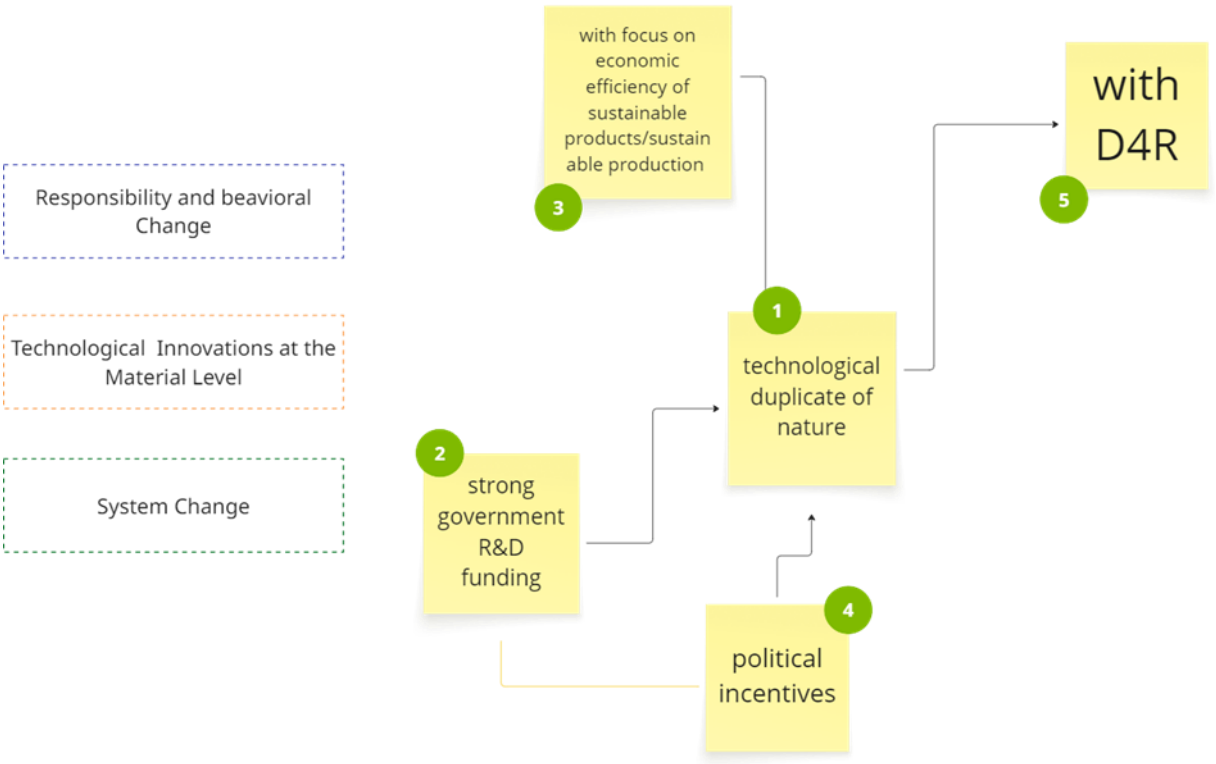

Fig. 3: Modular assumptions – Scenario 1

From the perspective of the experts surveyed, this construction triggers different dynamics that arise in relation to the various identities focused on and against the backdrop of the three dimensions of innovation in their socio-technical coupling and decoupling. From this, different activating and blocking dynamics can be derived, which are briefly described below.

In the first scenario, the role of consumers and users in the change process towards a bioeconomic textile industry is perceived as rather activating, but mostly located in the dimension of responsibility and behavioral change. They are seen as carriers of knowledge and design.

For example, farmers have a catalytic effect when they have a certain amount of material knowledge, including knowledge about the degradability of bio-nonwovens compared to conventional agravlies. At the same time, this knowledge must help to resolve contradictions between reuse and degradability. Such knowledge can significantly influence these users' decision to choose the new materials, thereby stimulating demand (BioVlies project).

Another aspect in this dimension concerns the design of new products. This is considered an important interface between research and development on the one hand and users and consumers on the other. It not only connects research on knowledge communication with the public, but can also materialize the innovations and special features of the product, making them directly tangible in the best case scenario.

In the GOLD project, design plays a fundamental role in translating research and development into the material and its design. Here, it forms the interface not only between material and research/development, but also between materialized innovation and consumers, in comparison to conventional textiles.

Innovations usually also mean higher costs in development, production, and ultimately also in sales. Consumers and users who have little knowledge of materials may be unsettled by this, especially in combination with higher prices. This uncertainty can reverse the originally activating role in the transformation process and have a blocking effect on the network. In addition, an overload of information can lead to excessive demands. However, in conjunction with strong research funding from the state together with cooperating companies, consumers and users can be seen as catalysts for transformation.

Companies, as part of the economy and closely linked to strong research and development funding, are also perceived as supporting change in the textile industry. This is particularly related to the link to government funding as a safeguard for investments. Especially with regard to information services, they are considered to play an important role in their responsibility for the successful transfer of innovations for change. In addition, companies are particularly emphasized in their responsibility to support innovations in the area of recycling systems. Companies are also relevant for international cooperation. In this context, companies can make an important contribution to shifting value chains toward more regional, i.e., EU-oriented chains. This addresses a systematic change in the textile industry.

Sustainability is considered more of a downstream issue in this scenario, but it offers added value for companies. Challenges, and thus the tendency to have a rather obstructive effect on the transformation processes, are the costs incurred in the production of new materials. In the case of innovations in the field of recycling, low material masses are an obstacle to innovation, which particularly affects the technological dimension in the classical sense, but which is always socio-technically constructed. In general, complex definitions of sustainability can be a hindrance because they offer too little guidance.

In this scenario, ‘politics’ has a strong activating effect through incentives and targeted cooperation. The focus is on subsidies for bioeconomic, bio-based, and recyclable textiles and innovations. Support for national and European cooperation tends to have an activating effect on the transformation process. Experts also believe that active incentive design has a positive effect on the process. At the same time, this also poses a risk, because productive incentive design reduces the pressure on other identities to take on greater responsibility. From the perspective of experts in the innovation space and the bioeconomy, a combination of incentives and prohibitive mechanisms on the part of politicians is considered to be more effective, especially for the production of textiles.

The area of research and development represents an important and activating potential. The integration of designers into research and development processes in the field of bioeconomic, bio-based, and recyclable textiles has a particularly activating effect on the transformation process. In particular, the design of research and development projects with a view to the scalability of innovations can provide impetus here. Material separation and research into recycling options are particularly relevant in this context. In terms of the bioeconomic circular economy, basic research projects and monomaterial research are considered particularly stimulating.

In the CircWool project, durable wool fibers were developed in the innovation dimension Technological Innovation at the Material Level. The natural fibers were modified using biotechnological processes.

In the GOLD project, collagen was used in the same innovation dimension to improve the performance and recyclability of materials.

The integration of conventional materials should also be taken into account. At the same time, digital tools and new production and infrastructure solutions are perceived as important and stimulating contributions. Although basic research is considered necessary here, it can have a rather inhibiting effect if the focus is one-sided and important factors such as scalability are not taken into account. Information gaps regarding new materials or their manufacture also have a negative impact on product acceptance. Especially when it comes to the sustainability of technically duplicated textiles, uncertainties about textile innovations can be exacerbated.

Designers are considered important drivers for a circular bioeconomic textile industry in this context, for example when they pursue systemic concepts such as ‘design for sustainability’. In this sense, special design factors such as modularity, a focus on monomaterials, and new recycling technologies are significant. They have a stimulating effect on transformative processes because they focus on embedding recyclability in the textiles themselves and support this through biotechnological processes. In addition, following Hall (2021), it is about the socio-technical proactive development of textiles. However, experts also recognize that textile recycling can lead to a loss of material quality. Such material losses can in turn have a rather inhibiting effect on the transformative network and thus on the entire process. Another factor that hinders the transformation process is when ‘design for recycling’ is conceived too narrowly as a concept. Designers were involved in the GOLD project to transfer research results into practical D4R product strategies. This has a far-reaching impact, extending into both the innovation dimension Technological Innovations at the Material Level and the dimension Responsibility and Behavioral Change. Responsibility for recycling and recovery infrastructures, for example, must be shared by all partners involved. This is particularly true for those identities that connect the partners and entities with each other. According to experts outside the innovation space, they play a significant role in this regard across all innovation dimensions.

From the experts' point of view, ‘politics’ plays the decisive key role. It is considered a central driver in the transition to a bioeconomic textile industry. The conditions and course are significantly influenced by ‘politics’ and administration in this relationally dynamic scenario construction.

This is closely followed by the importance of companies as part of the economy in the transformation process. They are highlighted as collaborative research partners because they play a significant role in implementation, both in the innovation dimension of responsibility and behavioral change and within the dimension of material innovation, and because they also perform a distributive function for innovations on the market, guiding consumers in their decisions.

This results in the following relationship matrix, which illustrates the dynamics in the innovation network of identities:

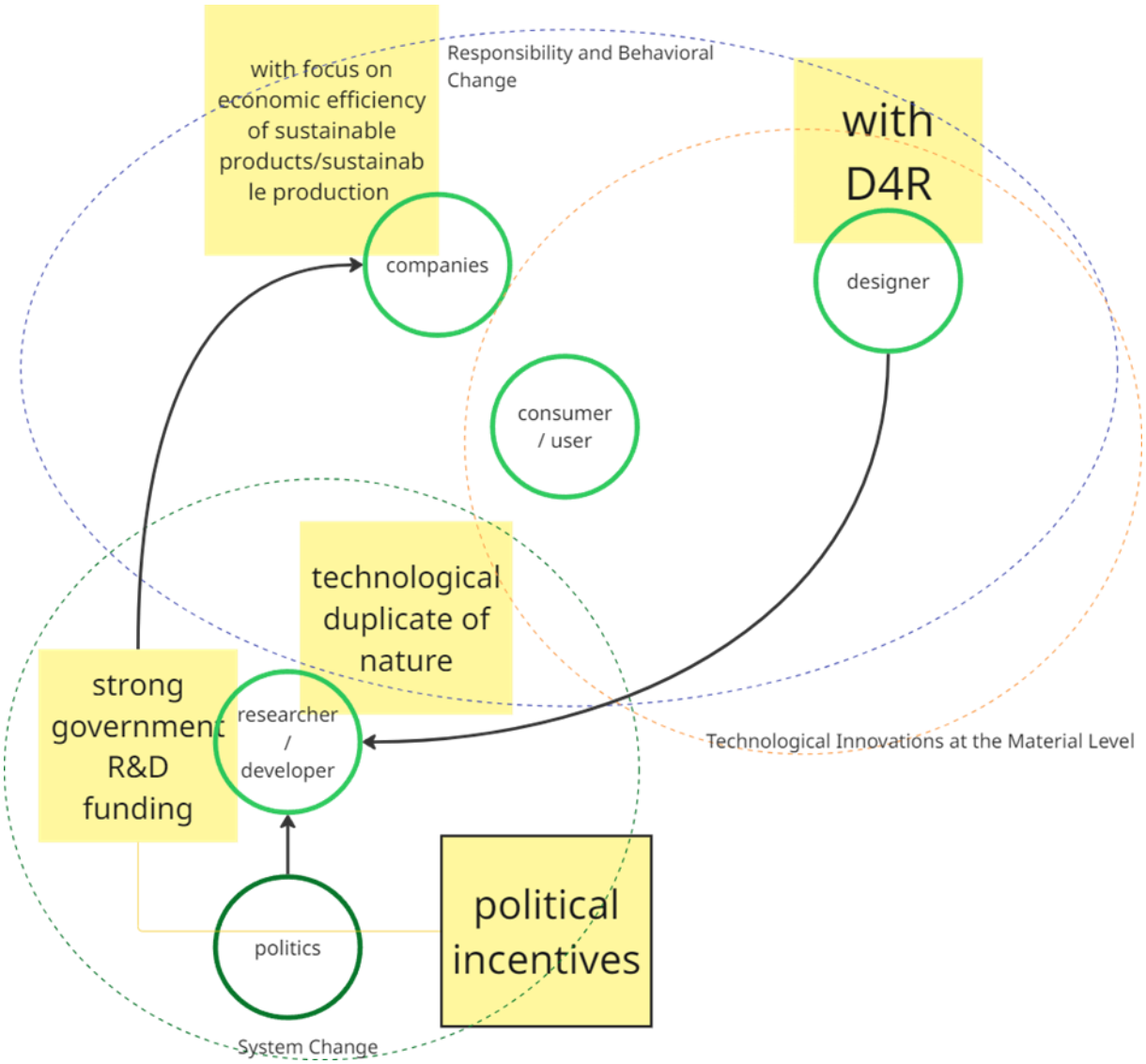

Fig. 4: Relationship matrix scenario 1

The matrix illustrates the dynamic and thus activating role of designers both in the dimension of Technological Innovations at the Material Level and in the area of responsibility (Responsibility and Behavioral Change). In relation to research and development, this can provoke further dynamic processes that activate systemic change in the textile industry. In this storyline, these depend on political influences through strong promotion of research in collaboration with companies. In the second scenario, other modular assumptions are used to develop a specific story. The dynamics and interdependencies of the various assumptions in terms of their potential to activate or block change are presented below.

3.2 Scenario 2

The analysis of identity-related potentials is carried out below along the three innovation dimensions introduced in Chapter 2: Responsibility and Behavioral Change, Technological Innovations at the Material Level, and System Change. The respective classification reflects the assessments from workshops and expert interviews and serves to capture the complexity of the transformation dynamics in a differentiated manner. As in Chapter 3.1, the structure follows

the identity-related roles, with the three dimensions of innovation systematically woven into the analysis.

Image 2: Scenario 2, source ChatGPT

The narrative underlying the scenario is based on the assumption that transformation will take place via a more regulated, politically mandated system. The focus is on mandatory repatriation mechanisms, the dismantling of state innovation funding, and a stronger market orientation. While consumers continue with their usual routines, companies, politicians, and researchers are held more accountable. This shift in roles changes the dynamics in the relationship structure of identities and influences their effectiveness within the transformation.

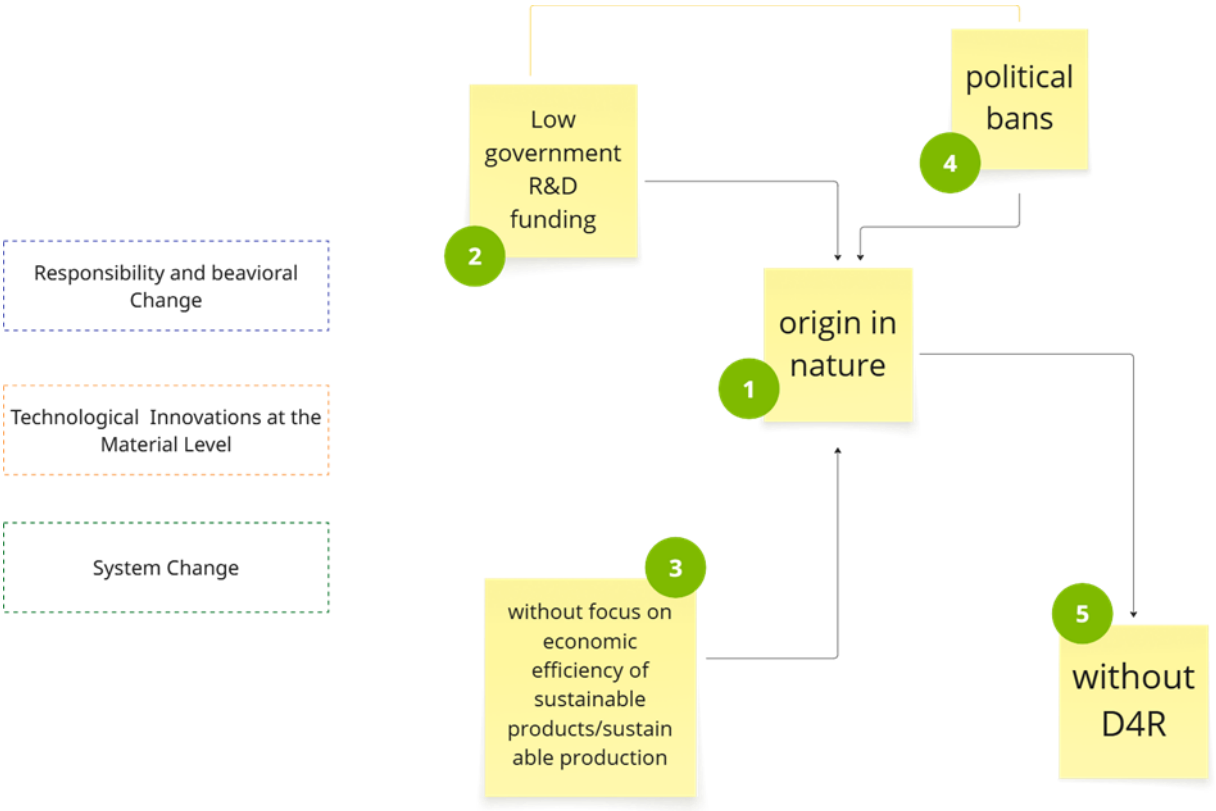

Fig. 5: Modular assumptions – Scenario 2

The role of consumers and users is assessed differently in the second scenario. While they are considered to be activatable in specific cases from an internal perspective – for example, through their involvement in recycling systems – the overall assessment is that their role remains very limited. External experts tend to see them as an easily influenced group whose decisions are guided by other groups of actors such as politicians or companies. A lack of guidance, contradictory information, and uncertainties about product quality also tend to have a blocking effect. Added to this are conflicting goals such as the limited color variety of nature-based products, greenwashing risks, and unclear statements about compostability, which make it difficult to make an informed purchase decision. Design can play a mediating role here, for example through the comprehensible design of product information or modular product concepts. Overall, however, the activating potential of consumers remains limited in this scenario. Their role is primarily located within the dimension of responsibility and behavioral change, but has clear limitations.

Designers also operate within this dimension, particularly at the interface between consumption, design, and information transfer. Their role encompasses the visual and functional translation of sustainable innovations. However, challenges such as limited customization options or processing costs limit their effectiveness, especially if there are no accompanying standards and return systems in place. A potential activating effect can arise if systemic concepts such as “design for sustainability” become more firmly established – but this requires the appropriate structural conditions. As in Chapter 3.1, it is clear here too that designers can build bridges between research, product, and consumption through design and communication.

Companies are under strong pressure to change in the second scenario. Political bans create pressure to innovate, but at the same time there is a lack of economic incentives and long-term support structures. This leads to uncertainty in planning and implementation. Smaller companies in particular are confronted with financial risks. Although private investors can support innovations in specific areas, these funds are often selective and market-oriented. External experts emphasize that economic objectives continue to guide action. If these are not linked to sustainability goals, there is a risk of withdrawal from transformative processes. At the same time, however, there is also potential for action: for example, the revival of regional value chains and old raw material paths (e.g., hemp, flax) is seen as an opportunity to establish new business models for renewable products. Companies are thus assigned a central role, both as the target of political steering measures and as potential drivers of innovation.

With regard to the dimension of technological innovations at the material level, it is clear that new materials—especially plant-based alternatives—are often fraught with uncertainty: questions about compostability, competing uses, or recyclability (see BioTurf, FungalFibers) are at the forefront. Technical requirements for processing, service life, and performance have also not been conclusively clarified. The FungalFibers project, for example, shows that bio-based origin alone is not enough and that technical performance must be ensured through suitable biotechnological processes. BioTurf also illustrates that monomaterials from bio-based sources do not necessarily perform better than fossil alternatives in terms of their life cycle assessment. These examples demonstrate that technical performance remains a critical factor in material innovation, even when bio-based origins are given.

Politics and administration form the structural framework of the scenario. They are identified in the scenario construct as key drivers that can accelerate system changes through clear prohibition mechanisms. This steering effect can have an activating effect through economic pressure – for example, when import bans strengthen regional markets. At the same time, there are risks: a lack of or inconsistent steering impulses can block technological developments or shift responsibility for change to other actors. Focusing solely on bans is also viewed critically, as this can lead to long-term development goals being neglected. The feedback from experts reveals a tension between effective bans and the need for supportive structures. The European chemicals regulation REACH was cited as a positive example of innovation-promoting regulation. This regulation illustrates that clearly defined framework conditions can indeed promote innovation – an aspect that becomes particularly relevant in the tension between steering and enabling.

Research and development (R&D) is assigned an ambivalent role in this scenario. Internally, it is seen as a fundamental driver of technological innovation, especially when it is closely coordinated with design, politics, and market interests. At the same time, external constraints are pointed out: a lack of government funding, unclear responsibilities, and inflexible structures can cause innovation processes to stall or be outsourced to the private sector. New materials, especially plant-based alternatives, raise additional questions—for example, regarding compostability, competing uses, or recyclability. Technical issues, such as material properties or processing, are also identified as challenges. Nevertheless, it is clear that when research is approached in an interdisciplinary and transdisciplinary manner and receives structural support, it can have a stimulating effect on the design of new, systemic solutions.

Research and development—at the intersection of Technological Innovations at the Material Level and System Change—remains central, but is more dependent on structural conditions than in the first scenario. There is a risk of outsourcing to the private sector or of an innovation bottleneck. R&D has a stimulating effect, especially when it is interdisciplinary and cooperates closely with design, politics, and business. In the CircWool project, for example, the use of waste from fiber development contributes to circular system solutions. AlgaeTex also points to conflicts of use in fiber cultivation, which can only be assessed and resolved through targeted research. These examples show that system change also requires material, infrastructural, and political frameworks—and in practice, it often cannot be achieved by a single group of actors alone.

Another aspect concerns the provision of bio-based raw materials. Agricultural actors are identified as key players here, especially when it comes to integrating cultivation options and developing regional cycles. The CircWool and AlgaeTex project examples illustrate that agricultural identities are closely linked to the dimension of system change – whether through regional value creation or the structural anchoring of new raw materials.

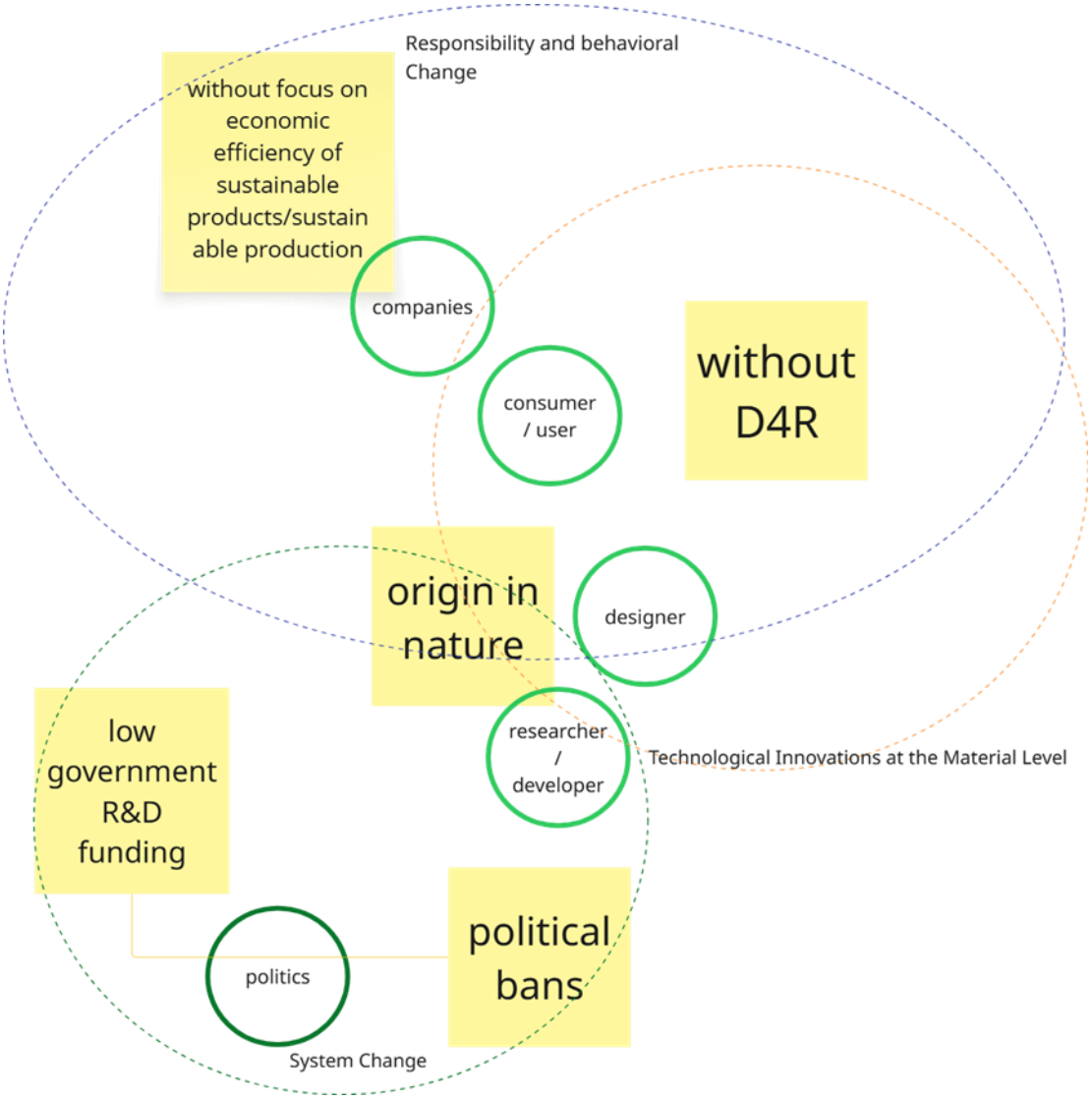

Fig. 6: Relationship matrix for scenario 2

Figure 6 visualizes the central assumptions, stakeholder groups, and innovation dimensions of the second scenario in their interrelationships. The illustration serves as an integrative overview and highlights the areas of tension and role shifts that come into play within the scenario.

Based on this constellation, a scenario emerges in which changes are initiated less by civil society dynamics and primarily by political control and economic frameworks. Responsibility and scope for action are shifting: While government control, investment, and regulatory measures are identified as key levers on the one hand, other identities—such as smaller companies, consumers, or designers—come under pressure or are dependent on supportive structures.

The innovation dimensions illustrate that potential arises above all where cross-sector cooperation, accompanying support structures, and clear guidance are in place. Research needs new funding models, designers need applied solutions, and consumers need reliable guidance. Scenario 2 shows that transformation can be initiated by pressure – but does not necessarily lead to coherent or sustainable results if accompanying structures are lacking. The decisive factor will be whether it is possible to link the different identities via functioning recycling, education, and value creation systems in such a way that they not only react but can also proactively contribute to shaping a bio-based and circular textile industry. Only then can a primarily reactive dynamic give rise to a systemically effective transformation path.

3.3 Summary

The analysis of both scenarios shows that transformation is not a linear process, but rather the expression of complex negotiations between political, economic, and civil society stakeholder groups. The modular scenarios illustrate different assumptions about the distribution of responsibilities, dynamics along the value chain, and the necessary prerequisites for bio-based innovations. It becomes apparent that individual identities—such as consumers, designers, or agricultural actors—are not only activated or blocked depending on the structural framework and innovation dimension, but can also themselves have an activating or blocking effect on the transformation process.

A central element of reflection concerns the relevance of identity perspectives within real project contexts. Workshops made it clear that statements on consumer behavior, technology acceptance, or political framework conditions only gain analytical depth by focusing on different identity perspectives—e.g., from the perspective of a company, a research institution, or an agricultural stakeholder. This difference in perspective forms the basis for a differentiated assessment of innovation potential. At the same time, it is apparent that identities often overlap across several dimensions of innovation – for example, when designers take responsibility for both information transfer (responsibility) and material design (technological innovation).

Identifying activating and blocking potentials proves to be a helpful tool for making the impact of individual assumptions comprehensible. In contrast to conventional scenarios, which are constructed as consistent narratives of possible futures, the modular scenario analysis in this project is understood as an analytical toolbox. This allows for a reflective observation of the interaction of key drivers within the bioeconomic and circular transformation of the textile industry.

In addition, the classification by the experts plays an important role: while internal voices primarily use the scenarios as an analytical tool, they are sometimes read externally as visions of the future with an implicit claim to reality. In this context, scenario 1 in particular is considered comparatively more likely – especially due to its focus on security of supply and return systems.

One critical reflection concerns the time horizon of the scenarios: according to many experts, structural changes such as those outlined in both narratives will require significantly more time than the estimated 5–10 years. Realistically effective change is more likely to take place within 20 years and requires cross-generational strategies. Short-term impulses alone – whether political, technological, or social – are not enough to anchor systemic changes in the long term.

4 Analysis of activating and blocking potentials in the scenarios

The significance of the scenarios in their respective combinations of modular assumptions shows different effects on the identities focused on in the transformation process in the two analyses presented as examples and also opens up the consideration of dynamic relationships.

The modular approach to scenario development, as pursued in the TransitionLab project in the BIOTEXFUTURE innovation space, not only reveals important identities involved in the transformation process of the textile industry towards a bioeconomic and circular industry, but also makes it possible to observe their activating or blocking potential in their respective relationships with each other and to derive recommendations for action from this. The different perspectives of experts within BIOTEXFUTURE and experts in the bioeconomy outside the innovation space enabled comprehensive consideration of the two scenarios presented above. This resulted in certain storylines that emerged from the work with the language models. Based on the socio-technical innovations, marketing-oriented stories were created. In these different stories, the various modular assumptions and the focus set by the language models highlight different characteristics for each identity. These were reinterpreted in the workshops with the experts from their respective perspectives and enriched along the three dimensions of innovation.

It became clear what activating or blocking potential was attributed to the individual identities in the transformation network. The influences change significantly depending on their embedding in the transformation process and their dependencies on other factors. In the following comparison of the two analyses with each other and in addition to further projections that were developed in advance using the language models, blocking and activating dynamics can be viewed and identified in relation to each other.

When comparing the results presented above, the focus on the potential of identities in the process becomes clear and emphasizes once again that these scenarios should not be viewed as images of the future that are more or less likely to occur, i.e., in the classic sense of scenario analysis. Rather, they are intended to highlight the potential dynamics between the identities affected by the transformation, focusing in particular on the development of new materials.

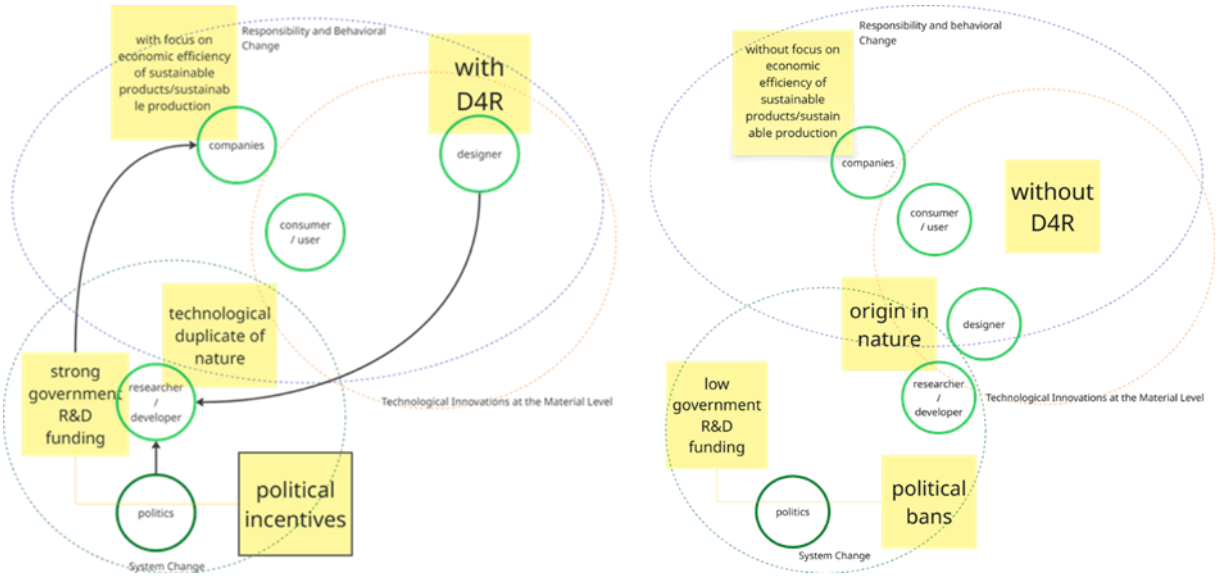

Fig. 6: Comparison of relationship matrices

Consumers and users as a heterogeneous group are positioned diametrically differently in the transformation process, depending on the scenario construction. In the first scenario, they are regarded as knowledge carriers and catalysts who have an activating effect on the processes. In the second scenario, on the other hand, they are framed as an overwhelmed group of actors who are more likely to be 'moved' by other identities and whose attitude tends to block change. Another important aspect that is addressed in relation to consumers and users is the cost of new bio-based and recyclable products. Costs are an important basis for decisions on purchasing bio-based and recyclable clothing or agricultural fleece, for example, as highlighted in the BioVlies project cited as an example in the first scenario (section 3.1).

Consumers are primarily considered in terms of their responsibility and behavior, and rarely in relation to fundamental system change. The attribution that consumers would strongly drive change and thus bear an enormous burden of responsibility must therefore be differentiated and considered in the various dimensions of innovation. On the one hand, consumers can be informed and empowered to create important path dependencies through the consumption of bioeconomic and recyclable products, or they can be viewed as a heterogeneous group of "executors." Either way, the transfer of information and knowledge is perceived as a means of empowerment in this heterogeneous identity.

As already shown in Chapter 3, the role of consumers varies significantly between the scenarios. While in the first scenario they appear as active knowledge and decision-makers who help shape transformation processes through informed purchasing decisions and feedback mechanisms, in the second scenario they remain rather reactive and influenced by external conditions. It is crucial that consumers are involved in innovation processes at an early stage – for example, through transparent information and communication structures – as this can have a potentially activating influence on the direction of development of new materials.

Companies as part of the economy are considered in the two scenario constructs in the three different innovation dimensions. The assumption of responsibility by companies is particularly dynamic when coupled with politically distributed responsibility. Operationalized, for example, in bans enshrined in law or through the creation of incentives such as subsidies, political

identities influence the assumption of responsibility by companies. Not surprisingly, the pressure generated by politically enacted bans on, for example, elastane plays an important role in activating innovations, which in turn are created by and with companies. In the coupling of companies and politics, this pressure can also lead to rather blocking dynamics if, despite opportunities from investors and regional structures, few leading corporate initiatives emerge.

In contrast, incentive structures and strong government support seem to trigger more productive and activating dynamics as well as responsibility-taking among companies. While political bans can exert increased pressure on companies, how this pressure is accepted or passed on also depends on other identities in the transformation network, such as the promotion of research and development by government institutions or private foundations. In the case of bans that can also be considered strong drivers of innovation, such as the EU's REACH regulation (Registration, Evaluation, Authorization, and Restriction of Chemicals) on the use of chemicals, it is important that they are embedded and guided by specific support measures. With the focus on innovation, the close link between research institutions and companies in the existing system via the interface of government funding for research projects understandably plays an important role.

In both scenarios, companies play a central role in their blocking or activating potential in the transformation process.

In the first scenario, their embedding between strong government funding of research and development tends to classify them as activating in their effect on the transformation process. Large companies also appear to have the potential to act as multipliers. In the second scenario, companies are viewed in a more differentiated way in a modular compilation. On the one hand, they have the potential to activate the transformation process of national textile value creation.

On the other hand, the interplay of bans imposed by political identities and low government funding for research and development also increases the risk of companies relocating to other countries, for example to avoid high costs.

This ambivalent picture of companies and their role in the transformation process addresses various dimensions of innovation. The responsibility of companies can be supported in particular by politically driven economic efficiency of sustainable materials and related innovations, which can be promoted through targeted bans. In addition, companies would also have to develop new service and business models, which in turn would have to be supported by political identities. The latter extend into the dimension of technological change at the material level, which can drive innovation but also act as a barrier.

The role of ‘politics’ and administration is ambivalent when comparing the two scenario analyses. In both scenarios, they are characterized as not being so dependent on other identities, but they can have a significant activating or blocking effect on the transformation network. While politics plays an activating role in the first scenario through incentives and cooperation and their strengthening, its role in the second scenario is perceived as more of a blocking factor. This scenario sends mixed signals. On the one hand, bans become drivers of transformation, but on the other hand, research and development funding is severely restricted. The pressure created by bans on other identities to take responsibility can have a significant activating effect, but it can also lead to skepticism and uncertainty.

Bans would therefore have to be structurally embedded and also become internationally effective in order to prevent companies from leaving. The enforcement of such legislation by the administrative level would also have to be designed for the long term in order to ensure planning security, among other things. Political identities are considered here in terms of their responsibility to provide orientation and impetus. Import bans, for example, are seen as a possible measure to strengthen European markets. Another important aspect of political orientation is clarifying the tension between durability and degradability.

A comparison of the two scenario constructs shows that 'politics' plays a key role in the transformation process. While this is significantly broader in the first construct and has a high impact in all dimensions, its role is more polarized in the second construct.

Viewed in isolation, the area of research and development in its current form is highly dependent on government support. This is not surprising, especially from the perspective of the innovation space. What is interesting, however, when comparing the roles in the modularized constructs is the orientation of research. While the first scenario features a broad, supportive research and development landscape that places a strong focus on scaling new socio-technical innovations and infrastructure in the field of textile bioeconomy, the heterogeneous identity in the second scenario is under considerable pressure. Among other things, it is dependent on private investors who can dictate specific orientations. These relational dynamics are perceived as inhibiting the transformation process. Basic research can thus be pushed into the background, even though it is considered an important factor in the transformation process in both scenarios. In their interdependence, research and development can actively stimulate the transformation process through their networks, their innovation impulses, through education, and through their influence on the media and thus on civil society. In contrast, their role in the second scenario is more focused on technological innovation and coordination with politicians and designers, which means less broad social integration.

Designers in both scenarios are strongly oriented toward the respective innovation developments of new materials. In the first scenario, in which innovations are developed through technological duplication and are less reliant on natural feedstocks, designers are more involved as creators of recyclable products and systemic approaches. They play an important translator role when it comes to understanding and using new materials. Both areas are to be directly 'woven' into the new material. In the second scenario, their role is interpreted less fundamentally. In the case of materials that are more origin in nature, designers face the technical challenge of, for example, processing heterogeneous materials in a modularized way in textiles and developing them in such a way that they can be easily separated from each other, i.e., they are considered more of a form of design for cyclability (cf. Hall 2021). In doing so, they unlock the potential for innovation in the area of infrastructure, which is needed in this context for recycling or reuse. In the first scenario, designers thus play an indirect key role beyond the area of research and development and in the context of circularity at the material level. Through the dimensions of Technological Innovation at the Material Level, they can unleash the potential to change the system. In the second scenario, they are explicitly addressed in their responsibility for finding solutions for specific material properties and limitations of natural fibers. The integration of designers into the transformation process as early as the

material development stage is activating in every respect in the modular anchoring of the identified drivers.

The comparison of identities along the three dimensions of innovation illustrates that activating potential often arises where responsibility, technological innovation, and systemic anchoring are considered together. Blocking effects, on the other hand, arise when one dimension dominates and others are neglected—for example, when technical solutions are lacking to implement political objectives.

In addition to comparing the two scenario constructions, looking at untested stories developed with an LLM provides additional insights into the modularity of the identified drivers as a space for variation.

The modular composition of technological duplicate of nature with strong government support, but without a focus on the economic viability of sustainable products or sustainable production, and without a focus on a form of design for recycling, results in a prospectus that strongly emphasizes multidimensional transformation. In this prospectus, both the quality and durability of new materials are particularly emphasized. It is interesting to note here that design for recycling is not considered a possibility, but rather that the lack of focus on D4R in construction has been reinterpreted as a compulsion to recycle. This interpretation of compulsion is ultimately rejected in the story because it has an inhibiting effect on textile innovations in terms of their durability and recyclability.

In the composition of the same modular assumptions mentioned last, but with the difference that the innovations should be origin in nature and thus based on natural feedstocks, the story developed by the LLM nevertheless shows a very technology-driven transformation with positive connotations. It emphasizes economic and structural impacts. In the modular composition, i.e., the use of strong government support, the use of political incentives instead of bans, and without a focus on the economic viability of sustainable products or more sustainable production, as well as without a focus on design for recycling, it is striking that consumers do not play an explicit role.

This insight into other projections not only highlights the narrative focus based on the modular composition, but also emphasizes the potential dynamics of the various drivers. The use of an LLM makes it possible, on the one hand, to incorporate established ideas into the stories and, on the other hand, to create observation spaces to explore the dynamics of the drivers in relation to each other. Based on this, various courses of action can be derived from the analysis of the two relationship matrices alone, which provide insight into how different activities can dynamically support the transformation process.

5 Conclusions and outlook

The modular scenarios developed in the TransitionLab show that the transformation of the textile industry into a bioeconomic and circular industry is not a straightforward process. Rather, it is driven by a multitude of interlocking dynamics emanating from actors, institutions, and technologies. Change occurs where different identities interact, influence each other, and negotiate new forms of responsibility and cooperation. A comparison of the two scenarios makes it clear that the transformative potential depends less on individual measures and more

on how politics, business, research, design, and consumption are coordinated—and whether a sustainable balance can be found between control, incentives, and openness.

It is particularly evident that transformation always gains momentum when social and socio-technical innovations interact. New materials play a central role in this. They combine scientific knowledge with economic implementation and social appropriation. Whether they ultimately have an activating or blocking effect depends less on their technological properties than on the structures in which they are embedded. This is where design plays a key role: it translates research into form, application, and communication and can thus create trust and acceptance—provided that transparency and traceability are the focus.

In both scenarios, the political framework acts as an essential lever for transformation. While funding-oriented approaches can promote the development of innovation, highly regulatory measures create pressure for change in the short term but often leave uncertainty in their wake. Smaller companies and research institutions in particular need stability and guidance. Against this backdrop, it makes sense to design policy instruments in such a way that they combine incentives and regulations and leave room for learning processes. Programs that allow flexibility and promote knowledge transfer could help to understand transformation as a joint development process.

Furthermore, it is clear that sustainable change can only succeed if cooperation across institutional boundaries is made possible. Intermediary spaces, such as those created in the BIOTEXFUTURE innovation space or in the TransitionLab, can establish such connections. They are not only places where knowledge is produced, but are themselves part of the transformation: this is where perspectives are negotiated, trust is built, and new forms of cooperation are tested. Experience suggests that it could be helpful to perpetuate such structures in the long term in order to ensure continuous exchange between science, politics, and business.

Furthermore, the results make it clear that transformation takes time. Structural changes, as outlined in the scenarios, can hardly be realized in just a few years. They require long-term, cross-generational strategies. Funding programs can provide important impetus, but should be supplemented by permanent institutional support structures that enable reflection, adaptation, and evaluation. This would prevent individual innovation drives from fizzling out without having a systemic impact.

Looking back on the workshops and expert interviews, it became clear that the chosen scenario methodology was met with some irritation. Some participants expected more deterministic visions of the future with clear probabilities of occurrence, while the modular approach was explicitly aimed at openness and reflection. This methodological decision deliberately sets itself apart from classic, often quantitative scenario methods that focus on target images or linear development paths. Instead, a flexible space for thinking was created in which narrative elements, identities, and decision axes can be combined to reveal the complex interplay of various transformation factors. It was surprising that certain aspects—such as social issues or power asymmetries—were hardly mentioned in the feedback. This raises questions about implicit expectations, disciplinary perspectives, or even blind spots in the collective imagination regarding transformation.

Conclusions can also be drawn from the scenarios in terms of methodology. They should be understood less as predictions of the future and more as spaces for reflection in which actors can recognize and re-explore their own roles and options for action. Modular scenario analysis offers a suitable tool for this, as it allows assumptions and relationships between actors to be varied, thus revealing the complexity of change. In the future, it could be worthwhile for researchers to combine qualitative scenario work with quantitative methods or AI-supported prospecting procedures in order to capture interactions even more precisely. Likewise, the continuous observation of real transformation processes can help to empirically verify assumptions and further develop the methodological tool.

To make progress in the transformation more measurable, it would be conceivable to develop new indicators that take material, social, and institutional aspects into account equally. Such an approach could help to evaluate the quality of innovations not only in terms of efficiency or resource use, but also in terms of cooperation and learning ability. This would shift the focus from purely technological performance to the system's ability to shape change in the long term.

Overall, the results indicate that the transformation of the textile industry cannot be driven purely by technology or politics alone. It arises from the interplay of knowledge, design, and responsibility—and it succeeds where actors are empowered to actively shape this process. Politics can provide guidance, research can open up new perspectives, and design can make innovations tangible. Transformation is not a state, but an ongoing negotiation process in which roles, goals, and means are constantly being redefined.

Transformation succeeds where material, social, and political innovations intertwine – and where scenarios are understood not as predictions, but as shared spaces for reflection that enable both orientation and design.

Modular scenario analysis can thus be understood as a tool for learning-based transformation policy that focuses less on rigid targets and more on the quality of the change itself. Depending on their orientation, innovations in the circular bioeconomy take on different roles: they function partly as strategic narratives for market differentiation and partly as carriers of sustainable values. The difference between technology-driven sustainability approaches and an understanding of innovation that is more closely related to naturalness and origin appears to be particularly relevant here.

6 Literature

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[1] Contrary to “classical” innovation theory and analytical approaches, we do not want to view innovations as purely technical phenomena that develop in niches, for example, and possibly diffuse into more abstract social levels. Instead, we see them as socio-technically grounded in their interconnectedness and respective embedding.

[2] Following H. C. White, identities refer to any observable form and source from which activity appears to originate and which is perceived as such (cf. Häußling 2012: 232). Identities can take many different forms and scales and can refer to people, scientists, consumers, but also textiles, machines, or legislation, depending on the area of investigation.

[3] BMFTR is the abbreviation for the Federal Ministry of Research, Technology, and Space.

[4] This visual representation is AI-generated. It was created with ChatGPT.

[5] This method requires critical evaluation and analysis. It has also been used in various projects in the BIOTEXFUTURE innovation space. Source for the guideline

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