



# A Delphi-Régnier Study Addressing the Challenges of Textile Recycling in Europe for the Fashion and Apparel Industry

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DE LA HAUTE COUTURE  
ET DE LA MODE



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Technologies  
et Métiers

institut  
FRANÇAIS  
de la  
MODE



**Journées de Printemps de la SAGIP 2022**

May 25, 2022

- I. Research background
- II. Research questions, method and steps
- III. Research findings & conclusions
- IV. Perspectives and limitations

# I. Linear production and consumption model

02



**Accelerated fashion consumption and production** driven by the « fast fashion » phenomenon decreasing the garments' lifetime (Ellen MacArthur Foundation, 2017)

**Increasing amount of discarded garments in Europe** (Niinimäki et al., 2020; Koszewska, 2018)

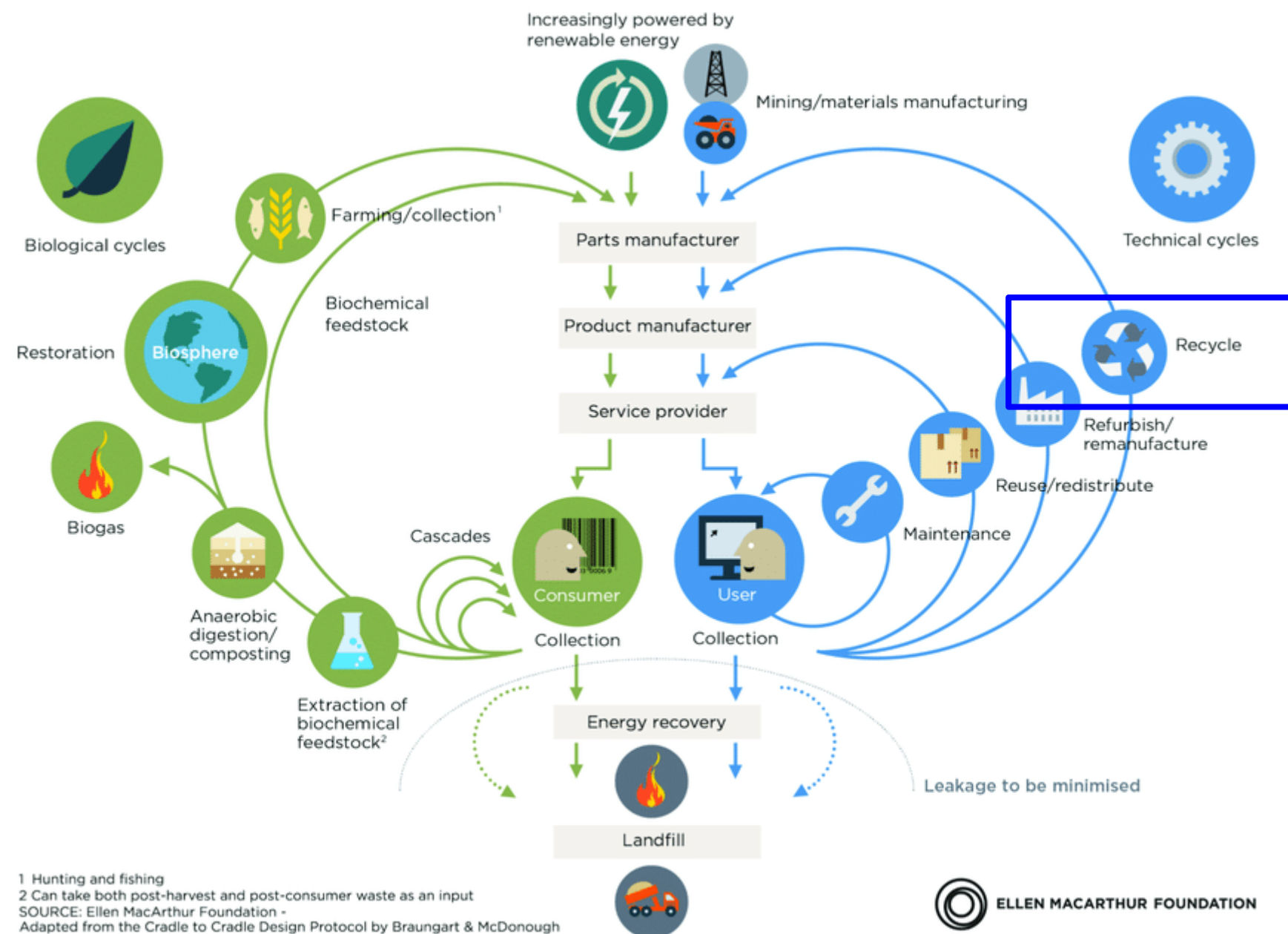
**Majority of reusable textiles exported abroad** (Ellen MacArthur Foundation, 2017)

**Decline of the reusable rate of items** (ReFashion, 2020; Nørup et al., 2019)

**Only 12% of global material flows for clothing would be recycled** mainly through **mechanical recycling** and recycled textile outputs are limited to **“open-loop” applications** (i.e. insulation material, wiping cloths, or mattress stuffing)

**Chemical recycling** solutions are being developed to advance textile recycling for **“closed-loop” applications** but **only 1% would still be recycled for new clothes** (Ellen MacArthur Foundation, 2017)

# I. Increasing pressure to enhance textile recycling



Textile recycling identified as a critical priority in this wider transition towards a **circular economy** to reduce the **resource-pressure** while ensuring **viable business models** in the long-term facing up to resource scarcity (Sandvik & Stubbs, 2019; Koszewska, 2018; Allwood, 2014)

**Textile recycling targeted in the EU forthcoming policies** (i.e. separate collection mandatory by 2025, incorporation of recycled content, digital passport) (EU Strategy for Sustainable Textiles, 2021)



# I. Limited research area on textile recycling

04



**Limited research area mostly** explored from a **technical perspective** (Shirvanimoghaddam et al., 2020) whereas textile recycling relies on a complex value chain and its improvement is pointed out as requiring a system-level change (Ellen MacArthur Foundation, 2017)

Fragmented literature with **very few comprehensive research** and **limited empirical studies** impeding an explicit evidence-based state-of-the art on the current challenges in the sector

**Flourishing literature on textile-specific barriers** to the implementation of the **circular economy** (Brydges, 2021; Chen et al., 2021; Kazancoglu et al., 2020) **but failing to provide a systematic analysis** of the existing issues related to the textile recycling value chain

RQ1: What are the current bottlenecks in the textile recycling value chain ?

RQ2: What are the priority challenges to address in order to enhance textile recycling in the sector ?



**Systematic literature review** to identify the recurring challenges acknowledged in the existing literature



Purposely designed qualitative study using the **Delphi method** and applying the **Regnier Abacus** technique

It appeared as the most relevant method

To **advance empirical knowledge** on textile recycling while **outlining the priority challenges to address in the sector**

To **evaluate a series of wide-range assumptions** on the topic with a wide panel of experts and generate valid results in a **timely manner**

To **minimize the risk of bias** while **ensuring participation** due to distinct business interests and unaccustomed exchange of views of the different stakeholders involved

## What is it ?

Widely used-method pioneered by the Air-Force-sponsored Rand Corporation in the 50s to forecast the potential of military technology (Gordon, 1970)

Structured around an **anonymous, controlled and iterative feedback process** to **minimize the typical group interaction shortcomings** (Hsu & Sandford, 2007)

Suitable to investigate complex and multidisciplinary problems (Agrawal et al. 2019), to explore or expose underlying assumptions or information leading to differing judgements, and to seek out information that may generate a consensus (Delbecq et al., 1975)

## What are the key steps ?



Questionnaire submitted anonymously to an expert panel



Responses counted and processed



Questionnaire updated based on expert responses and submitted to the same participants along with a feedback report



Iterative process until common trends are achieved through consensus and dissensus

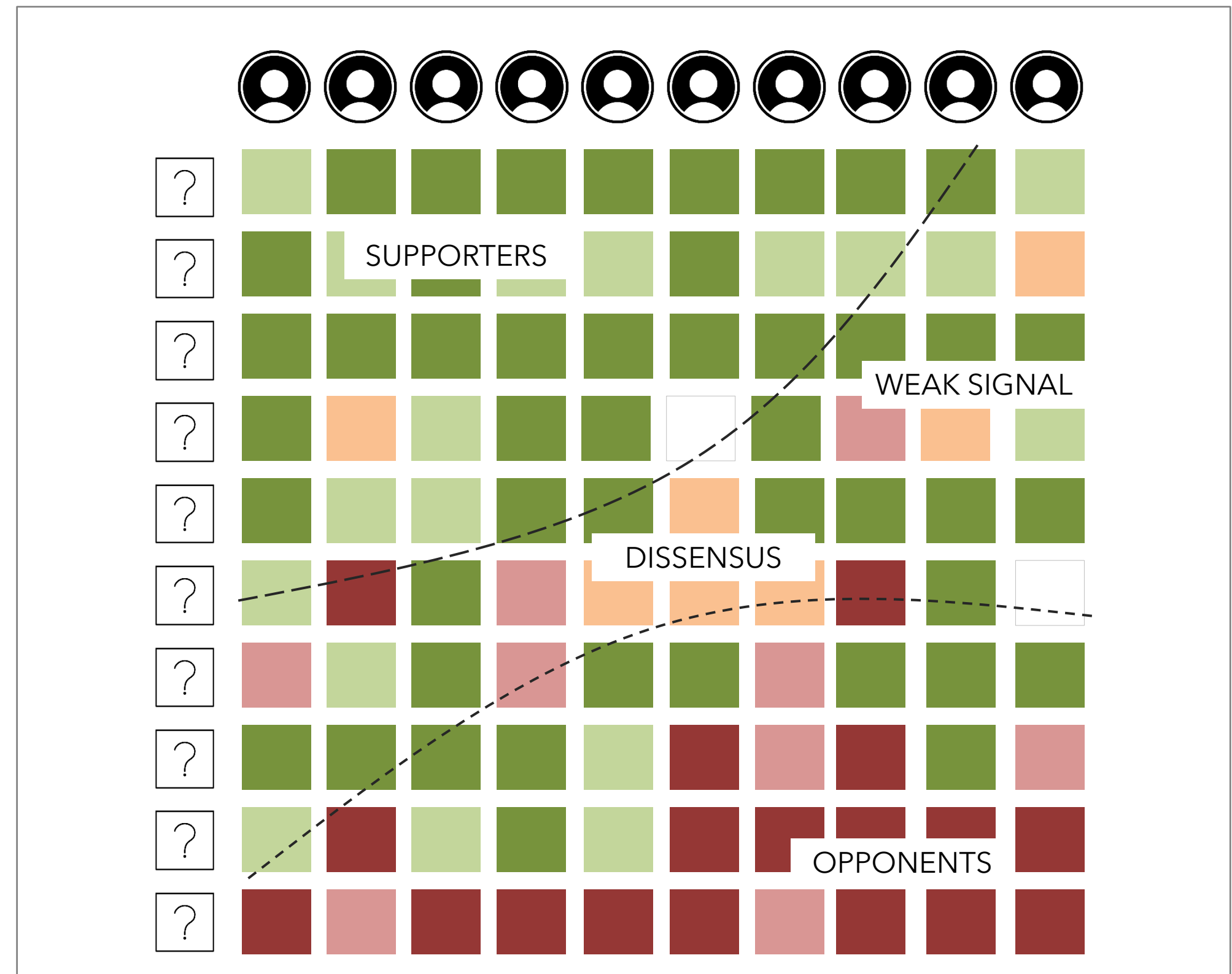
# II. The Régnier Abacus technique








What is it ?

Developed by P. François Régnier in the 1970s in the medical field to offset usual drawbacks of working groups (Régnier, 1983)

Based on the **"traffic signals" logic** with a **color panel** to collect and share opinions on a topic in order to promote constructive debates and **facilitate decision-making**

How does it work ?



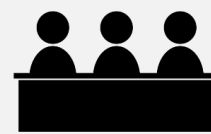
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**Literature review**  
on textile recycling  
challenges and  
**formulation of**  
**23 corresponding**  
**statements**



**Selection of a panel**  
of **28 experts**  
engaging with the  
management of  
textile recycling for  
the fashion and  
apparel industry



**1st round**  
**Votes and**  
**comments** on the  
23 statements  
*100% of experts*  
*participation*



**Revision of the**  
**statements**  
based on the  
experts' votes  
and comments



**2<sup>nd</sup> round**  
**Votes and comments** on  
**21 revised statements**

*86% of experts*  
*participation - no new*  
*responses decision to*  
*close the questionnaire*



**Results analysis**  
through [ColorInsight](#)  
based on the experts'  
votes and comments  
from both rounds



# II. Literature review & formulation of statements

## PRODUCT & MATERIAL

The profusion of material mix and fiber blends



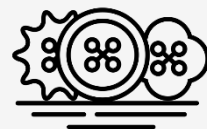
The use of chemical substances during the manufacturing process



The yarn and fabric construction complexity



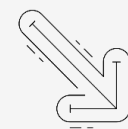
The presence of external disruptors



The increasing introduction of new materials



The loss of recycled output quality during the recycling process



The detrimental effects of use conditions on the recycled output quality



The limited recyclability of current recycled output



## TECHNOLOGIES & INFRASTRUCTURES

Insufficient infrastructures for textile collecting waste



Poor accuracy and speed efficiency in current manual product sorting



The lack of recycling technologies towards high value applications



The insufficient maturity of new recycling technologies



The lack of manufacturing technologies for an ease disassembly



The absence of disassembling technologies to efficiently separate the product components



The absence of digital solutions to connect supply and demand

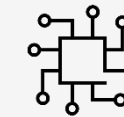


The lack of demonstrable environmental performance of end-of-life treatment



## INFORMATION

The lack of information on material and chemical content through tracking technologies



## COORDINATION

The deficient awareness and education on textile recycling



## MARKETS

The high research and investment costs to integrate innovative technologies



The missing alignment between the stakeholders



The lack of profitability for recycled output



The missing clear regulatory framework to support textile recycling



# II. Literature review & formulation of statements

## PRODUCT & MATERIAL

The profusion of material mix and fiber blends



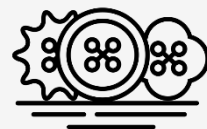
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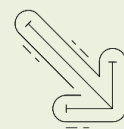
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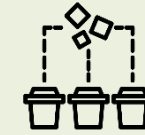


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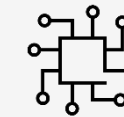


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# II. Selection of the experts' panel

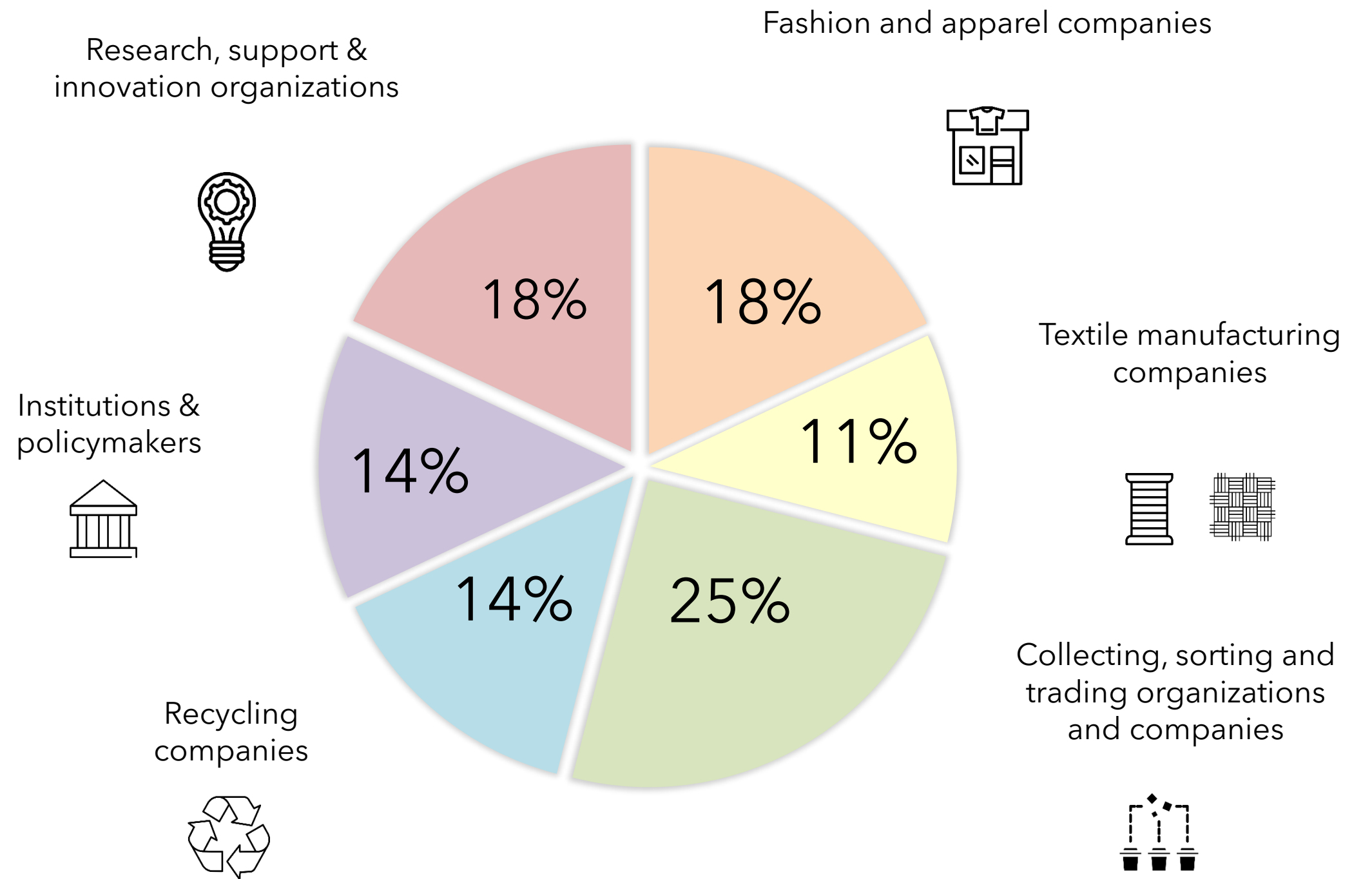
Panel of **28 experts representative of the different stakeholder groups** in Europe to confront their views on this system-level topic

How did we proceed ?

**Definition of the relevant stakeholder groups** reflecting the different actors involved in the recycling value chain

**Database of experts** built based on professional recommendations and a review process

**Contact of each expert** with a summary document to gauge interest and availability



# II. Providing feedback: experts' votes and comments

[ColorInsight](#) open-source solution

The screenshot shows a web browser window with the URL `engineidoli.colorinsight.fr`. The page title is "Second-round ... : P 8". A progress bar at the top indicates "100% progression". The interface is titled "1 > Vote".

There are six voting items, each with a title, a comment box, and a set of colored buttons (green, yellow, red, white, black) for voting. The items are:

- \* EDITED : No separation at collection points (e.g. mix of textiles with different compositions...) is a barrier to recycling value chain efficiency**  
Comment: "There is always sorting before recycling to editify and separate the reusable from the recycling. The separation has to be done by expert sorters at sorting not at collection points."  
2818 remaining characters
- \* EDITED : The lack of available and accurate information on material and chemical content prevents access to appropriate recycling channels**  
Comment: "current reading label is not costefficient and not reliable (false information. Need exact identification for higher recycling)"  
2874 remaining characters
- \* EDITED : The lack of automated identification and sorting technologies (such as optical sorting and artificial intelligence technologies) is a barrier to recycling value chain efficiency**  
Comment: "All in pilote stage, no industrial yet. Not enough demand for this sorted material though"  
2911 remaining characters
- \* EDITED : The use of product tracking technologies (e.g. digital passports) by fashion companies seems unrealistic to ensure information traceability on composition and chemical substances until end-of-life**  
Comment: "It would need to be the same technology for every producers and importers. If not mandatory it won't happen"  
2893 remaining characters
- \* EDITED : The lack of innovative manufacturing solutions prevents performant disassembling (e.g. use of disoluble yarns by fashion companies etc...)**  
Comment: "The yarn or fiber available should be used with same spinning and manufacturing process as today"  
2904 remaining characters
- \* EDITED : The deficiency of automated disassembling technologies (meaning separation technologies prior to recycling) hinders recycling cost-efficiency**  
Comment: "Still pilot so still high cost"  
2970 remaining characters

# III. Research findings: 1st & 2<sup>nd</sup> rounds

1

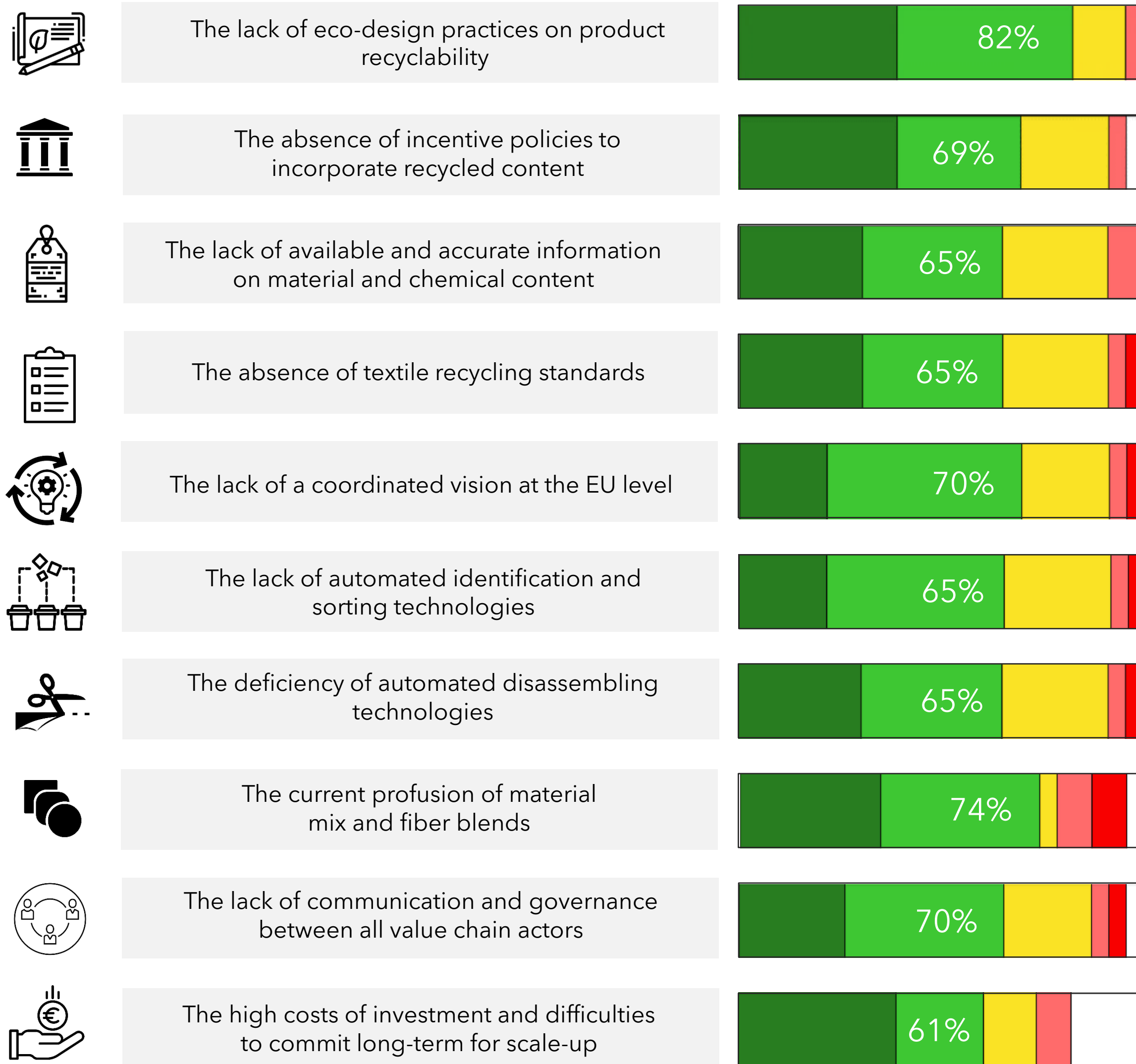
the diversity of blended materials is a major barrier as it limits opportunities for textile recycling	Green	Light green	Orange	Light red	Red	White
the lack of efficient and cost-effective automated sorting technologies, able to provide well-defined and homogeneous feedstocks	Green	Light green	Orange	Light red	Red	White
the missing clear regulatory framework from policy-makers fails to support the improvement of textile recycling	Green	Light green	Orange	Light red	Red	White
the presence of external accessories (such as buttons, zipper, care labels...) is another important disruptor of the recycling process	Green	Light green	Orange	Light red	Red	White
enhancing recycling further requires advanced information systems to exchange data across the value chain on the precise composition of materials	Green	Light green	Orange	Light red	Red	White
the absence of technologies enabling an eased disassembling process hinders the development of textile recycling	Green	Light green	Orange	Light red	Red	White
the lack of collaboration and alignment between all the stakeholders (collectors, sorters, recyclers, manufacturers)	Green	Light green	Orange	Light red	Red	White
the use of chemical substances contribute to disrupt the recycling process by decreasing the value of the recycled materials	Green	Light green	Orange	Light red	Red	White
the limited profitability of textile recycling is a significant bottleneck in textile recycling, preventing recycled content from being used in new products	Green	Light green	Orange	Light red	Red	White
the available mechanical recycling technologies shortens the fibers during the process, preventing to provide a wide range of recycled materials	Green	Light green	Orange	Light red	Red	White
the development of textile recycling is restrained by a limited public awareness, implying low collection rates	Green	Light green	Orange	Light red	Red	White
the insufficient connection between demand and supply of textile waste inhibits resource availability and effectiveness	Green	Light green	Orange	Light red	Red	White
the washing and wearing conditions degrade the fibers and hampers the sorting and recycling process affecting the quality of recycled materials	Green	Light green	Orange	Light red	Red	White
the high costs of research and development associated with the development of new recycling technologies	Green	Light green	Orange	Light red	Red	White
the lack of dedicated and separate collection infrastructures in several countries for textile waste prevents the recycling process	Green	Light green	Orange	Light red	Red	White
the lack of innovative manufacturing technologies prevents eased disassembly of the product at the end-of-life	Green	Light green	Orange	Light red	Red	White
the current limited recycling technologies prevent the development of textile recycling towards high-value products	Green	Light green	Orange	Light red	Red	White
the development of textile recycling is restrained by the insufficient maturity of new recycling technologies	Green	Light green	Orange	Light red	Red	White
the construction of the yarn or the fabric is an important potential disruptor to the recycling process	Green	Light green	Orange	Light red	Red	White
the lack of accurate demonstration of environmental performance for innovative recycling technologies and the overall impact on the environment	Green	Light green	Orange	Light red	Red	White
the increasing introduction of new materials in the industry is a potential inhibiting factor by creating challenges for recycling	Green	Light green	Orange	Light red	Red	White
the development of textile recycling is restrained by the uncertain end-market opportunities	Green	Light green	Orange	Light red	Red	White
the available mechanical recycling technologies only provides outputs with limited recyclability	Green	Light green	Orange	Light red	Red	White

2

the lack of design practices on circularity by fashion brands is a major obstacle to developing a circular economy	Green	Light green	Orange	Light red	Red	White
the absence of incentive policies to incorporate recycled content is limiting the demand for recycled materials	Green	Light green	Orange	Light red	Red	White
the lack of available and accurate information on material and chemical content prevents access to appropriate recycling technologies	Green	Light green	Orange	Light red	Red	White
the absence of textile recycling standards (such as : recyclability, recycled content, disruptors to recycling)	Green	Light green	Orange	Light red	Red	White
the lack of a coordinated vision at the EU level fails to support the improvement of textile recycling	Green	Light green	Orange	Light red	Red	White
the lack of automated identification and sorting technologies (such as optical sorting and artificial intelligence technologies)	Green	Light green	Orange	Light red	Red	White
the deficiency of automated disassembling technologies (meaning separation technologies prior to recycling)	Green	Light green	Orange	Light red	Red	White
the current profusion of material mix and fiber blends in the industry reduces the market opportunities	Green	Light green	Orange	Light red	Red	White
the lack of communication and governance between all the value chain actors obstructs the improvement of textile recycling	Green	Light green	Orange	Light red	Red	White
the reduction of fiber length during the mechanical recycling process brings limitation to end-market opportunities	Green	Light green	Orange	Light red	Red	White
the low quality of post-consumer feedstock impedes closed-loop recovery	Green	Light green	Orange	Light red	Red	White
the high costs of investment and difficulties to commit long-term for scale-up hinders the development of textile recycling	Green	Light green	Orange	Light red	Red	White
recycled content is not competitive enough compared to low priced virgin materials for garment applications	Green	Light green	Orange	Light red	Red	White
the presence of external accessories (e.g. buttons, zippers...) is a major barrier to recycling value chain	Green	Light green	Orange	Light red	Red	White
the lack of innovative manufacturing solutions prevents performant disassembling (e.g. use of disoluble yarns)	Green	Light green	Orange	Light red	Red	White
no separation at collection points (e.g. mix of textiles with different compositions...) is a barrier to recycling	Green	Light green	Orange	Light red	Red	White
the use of product tracking technologies (e.g. digital passports) by fashion companies seems unrealistic to ensure in the long term	Green	Light green	Orange	Light red	Red	White
the current presence of chemical substances in textiles limits market applications, specifically by hampering the recycling process	Green	Light green	Orange	Light red	Red	White
failure to identify appropriate feedstocks through digital platforms is limiting open-loop recycling	Green	Light green	Orange	Light red	Red	White
the scarcity of available recycled products is due to the lack of scaled-up thermal and chemical recycling	Green	Light green	Orange	Light red	Red	White
the lack of efficient way to compare the recycling process between them does not promote the use of recycled materials	Green	Light green	Orange	Light red	Red	White

Items matrix (based on Colorinsight classic mode) displaying items from the most consensual item (top) to the least one (bottom)

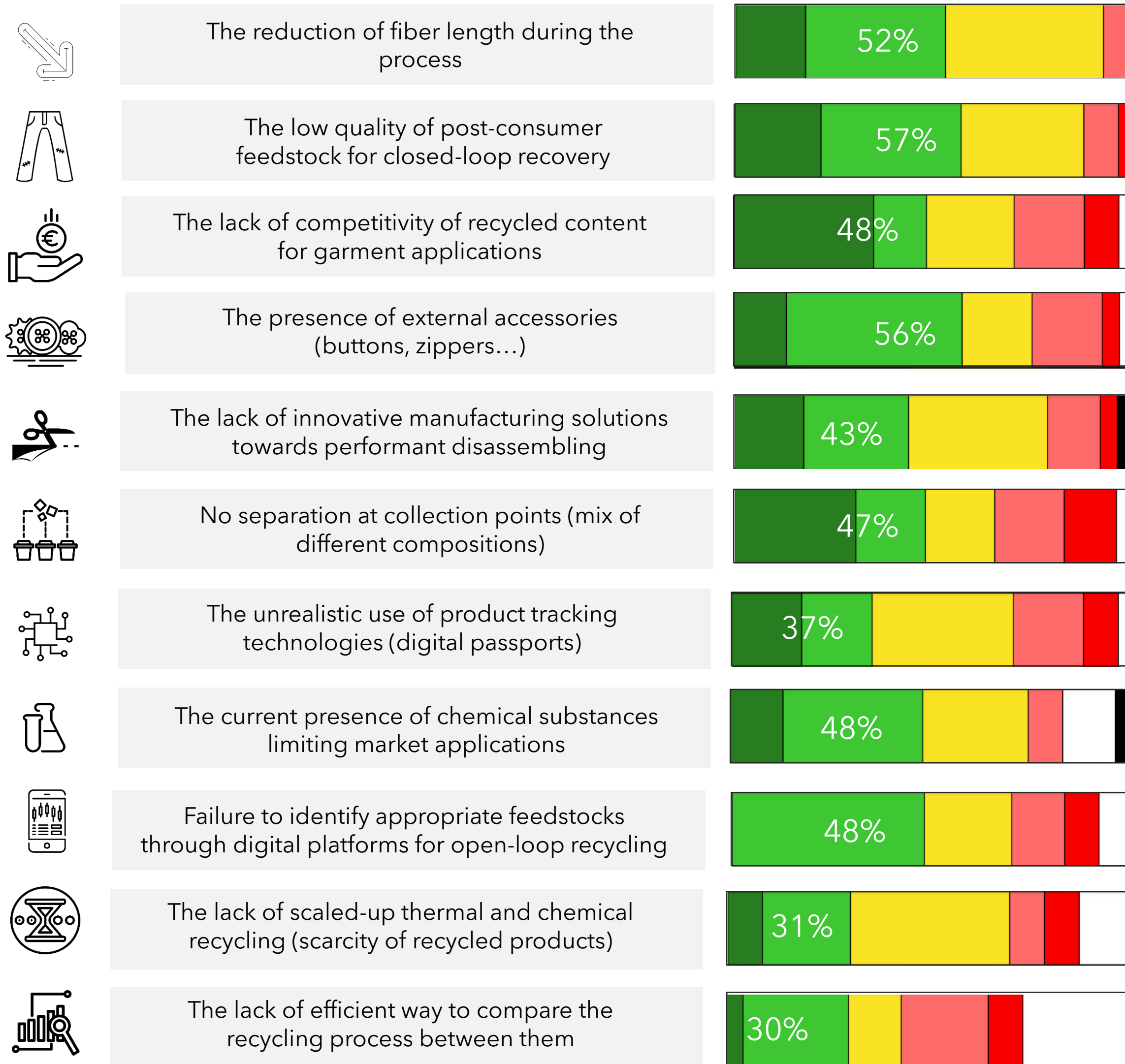
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### III. Significant alignment on several statements

Results of the second round\*

Consensus considered reached once 60% of answers in favor (green) or against (red) was observed



### III. Persistent disagreements

Results of the second round\*

Consensus considered reached once 60% of answers in favor (green) or against (red) was observed



# III. Research takeaways per key topic



## PRODUCT & MATERIAL INPUT

The lack of **eco-design practices** in the sector is a major challenge of textile recycling improvement

The profusion of **materials blends** emerges as the most impactful design features

The impact of the use of **chemical substances** on the recycling process remains unclear



## TECHNOLOGIES

The current **manual sorting process** is an important bottleneck as not set up for material composition sorting

The use of **optical sorting technologies** appears more promising than product **tracking technologies**

The deficiency of **automated disassembling technologies** prior to recycling is hindering textile recycling cost-efficiency

**Recycling technologies** are available for most material streams, but it is rather a challenge of investment and support to reach industrial scale



## MARKET

The current state of **demand and economic viability** of textile recycling is inconclusive

There is a need for policies and collective actions to increase demand for recycled content



## COORDINATION

The lack of **standards** on textile recycling is failing to promote eco-design strategies

The lack of **coordinated vision** at the EU level and the **lack of collaboration and governance** between the stakeholders are also preventing an improvement of textile recycling



## INFORMATION

There is a major challenge regarding **information availability** on the **product components** (*labels cut off, inaccurate, illegible..*)

Information on product components is essential to sort to appropriate recycling routes and to enhance recycling applications

# III. Key conclusions to enhance textile recycling



1

The need to enhance eco-design practices with respect to reusability and recyclability

2

The strong need of public policy action and better coordination between stakeholders

3

The necessity to address the deficiencies related to the current manual sorting system

## Numerous potential research avenues



Exploration of **traceability** with regards to **circularity** and especially to investigate the **supporting role of traceability solutions** and other **identification technologies** at the sorting stage



Investigation on **multi-stakeholder initiatives** to provide valuable insights on governance and collaborative challenges associated with such innovative and large-scale management of textile material streams



Exploration of **innovative business models** to analyze the implementation of circular strategies with regards to the tensions between **durability and recyclability**

## Some inherent limits of the method



The choice of a **panel-based methodology** necessarily entailing shortcomings - especially the likely unevenly distribution of expertise among the experts



The lack of **consumer's perspective**



The bias associated with the **designed questionnaire**



The use of a **qualitative method** based on expert feedback rather than **statistical analysis**

Thank you for your attention !

Any question ?