TEXTE
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Final report

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Assessments of needs to act on chemical safety

by:

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publisher:
German Environment Agency

German Environment Agency

Umwelt Bundesamt

TEXTE 09/2022

Ressortforschungsplan of the Federal Ministry for the Environment,
Nature Conservation, Nuclear Safety and Consumer Protection

Project No. (FKZ) 3719 66 402 0

Report No. (UBA-FB) FB000641/ENG

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On behalf of the German Environment Agency

Imprint

Publisher
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06844 Dessau-Roßlau
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Fax: +49 340-2103-2285
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Internet: www.umweltbundesamt.de

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/umweltbundesamt

Report performed by:
Ökopol GmbH
Nernstweg 32-34
22765 Hamburg
Germany

Report completed in:
August 2021

Edited by:
Section IV 2.3 chemicals
Völker, Doris and Schwirn, Kathrin (Fachbegleitung)

Publication as pdf:
http://www.umweltbundesamt.de/publikationen

ISSN 1862-4804

Dessau-Roßlau, January 2022

Abstract: Thematic Conference Advanced Materials Thematic Conferences Advanced Materials

The project “Thematic Conferences on Advanced Materials” aimed at supporting the German Authorities in structuring the field of advanced materials and identifying work priorities related to chemical safety.

In the first part of the project, information on advanced materials was gathered via an extensive literature review, an online expert survey and expert interviews. In a second part, three international conferences were organised, of which one was separated into two online events, to invite stakeholders in the field to reflect on the research outcomes and involve in a discussion about chemical safety of advanced materials.

Overall, the project initiated discussions about advanced materials at global, EU and national level and promoted an active reflection on the potential safety challenges and sustainability, amongst others due to lack of data, methods and coverage of advanced materials in current regulation.

The report provides an overview of the work process and summarises the main discussion issues at the conferences.

Kurzbeschreibung: Themenkonferenz zu neuartigen Materialien

Das Projekt "Themenkonferenzen zu neuartigen Materialien und Werkstoffen" hatte zum Ziel, die deutschen Behörden dabei zu unterstützen, das Feld der neuartigen Materialien (im Folgenden „advanced materials“ genannt) zu strukturieren und bezüglich der Chemikaliensicherheit ihre Arbeitsschwerpunkte zu identifizieren und festzulegen.

Im ersten Teil des Projekts wurden in einer umfangreichen Literaturrecherche, sowie durch eine Online-Befragung und Interviews mit Personen, die im Feld der advanced materials eine ausgewiesene Expertise haben, Informationen erhoben. In einem zweiten Teil wurden drei internationale Konferenzen organisiert, von denen eine in zwei Online-Veranstaltungen aufgeteilt wurde. Mit diesen Konferenzen wurden die Stakeholder auf dem Gebiet der advanced materials eingeladen, über die Ergebnisse des Projektes zu reflektieren und sich an einer Diskussion über die Chemikaliensicherheit von advanced materials zu beteiligen.

Mit dem Projekt wurden Diskussionen über advanced materials auf globaler, EU- und nationaler Ebene angestoßen. Es förderte die gemeinsame Auseinandersetzung mit den potenziellen Herausforderungen von advanced materials für die Chemikaliensicherheit und die Nachhaltigkeit, die zum Beispiel aufgrund mangelnder Daten oder Methoden entstehen können oder weil die Materialien nicht durch bestehende Vorschriften abgedeckt sind.

Der Bericht gibt einen Überblick über den Arbeitsprozess und fasst die wichtigsten Diskussionspunkte auf den Konferenzen zusammen.

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List of abbreviations

AdMa	Advanced Material
BAuA	German Federal Institute for Occupational Safety and Health
BfR	German Federal Institute for Risk Assessment
BIAC	Business at OECD
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BUND	German Federation for the Environment and Nature Conservation
CIEL	Center for International Environmental Law
CLP	Regulation on classification, labelling and packaging of substances and mixtures
e.g.	For example
ECHA	European Chemicals Agency
EPA	US Environmental Protection Agency
etc.	Et cetera
EU	European Union
EuMaT	Platform for Advanced Engineering Materials and Technologies
EUON	European Union Observatory for Nanomaterials
i.e.	That is
ISC	Fraunhofer Institute for Silicate Research
ISR	Institute of Safety/Security and Risk Sciences
KEMI	Swedish Chemicals Agency
LCA	Life Cycle Assessment
NGO	Non-governmental organisation
NIA	Nanotechnology Industries Association
nm	Nanometre
NM	Nanomaterial
OC	Online Conference
oe-a	Organic and Printed Electronics Association
OECD	Organisation for Economic Co-operation and Development
OSH	Occupational safety and health
PTJ	Projektträger Jülich
R&D	Research and Development
REACH	Regulation on the Registration, Evaluation, Authorisation and Restriction of Chemicals
RIVM	Dutch National Institute for Public Health and the Environment
RMOA	Regulatory management option analysis
RRL	Regulatory readiness level
S&SbD	Safe and Sustainable by Design

UBA	German Environment Agency
VCI	Verband der Chemischen Industrie e. V. (German Association of the Chemicals Industries)
WHO	World Health Organization
WPMN	Working Party on Manufactured Nanomaterials
WPRPW	Working Party on Resource Productivity and Waste

Summary

Advanced materials are commonly understood as addressing a heterogeneous group of new or modified materials with improved or new properties. Advanced materials may be used in high-performance applications and are generally thought of being high-value products but also appear in everyday products. Several advanced materials are already in use. Neither a regulatory nor a scientific or technical definition of "advanced materials" exists. In the scope of this project, all materials which are rationally designed and fabricated in a targeted manner and in order to fulfil the functional requirements of a certain application are included under the term "advanced materials".

Although the regulatory situation of nanomaterials, a sub-group and important constituent of many advanced materials, has been defined to a broad extent (among others by the adaptation of REACH), it is unclear if a potential risk of other advanced materials are sufficiently addressed by existing legislation.

The project "Thematic Conferences on Advanced Materials" aimed at supporting the German Authorities in structuring the field of advanced materials and identifying work priorities related to chemical safety.

In the first part of the project, information on advanced materials was gathered via an extensive literature review, an online expert survey and expert interviews. A literature analysis was performed to describe the scale of research activities for the various (types of) advanced materials and identify key actors in the field and their relations. A proposal on how to cluster advanced materials, considering their composition and structure with a view to potential chemical safety aspects was developed. The information was also used to compile and elaborate a set of criteria for the assessment of the relevance of advanced materials that could be applied to identify priorities for a more in-depth assessment of advanced materials. The clustering approach of advanced materials was enriched by a set of factsheets, each of which provides basic information on a certain cluster of advanced materials. The factsheets list information on the composition and structure of the addressed advanced materials, their functionality and reactivity, the known application areas and current research activities as well as information on whether or not hazard and exposure data are available or not.

The second part of the project consisted of the organisation of an international stakeholder dialogue on advanced materials in the form of three thematic conferences. Due to the Covid-19 pandemic, only the first conference could be organised as a 2-day face-to-face event. The second conference was organised as two half-day online conferences and the final conference took place as a full-day online conference.

The first thematic conference was dedicated to discussing the field of advanced materials in general for getting an overview. In addition, some exemplary advanced materials were introduced. At the two online conferences constituting the second thematic conference, the discussions were about, amongst others: the relevance criteria, aspects about the circular economy of advanced materials, particular concerns about advanced materials and identification of advanced materials of which concerns are already identified. At the final conference, conclusions were drawn from the preceding discussions and questions about the governance of advanced materials were discussed. A respective discussion paper by the German Higher Federal Authorities was the basis of the discussions.

Overall, the project initiated discussions about advanced materials at global, EU and national level and promoted an active reflection on the potential safety challenges, amongst others due to lack of data, methods and coverage of advanced materials in current regulation.

Zusammenfassung

Unter advanced materials versteht man im Allgemeinen eine heterogene Gruppe neuer oder veränderter Werkstoffe mit verbesserten oder neuen Eigenschaften. Advanced materials können in Hochleistungsanwendungen eingesetzt werden und gelten als besonders hochwertige Produkte, kommen aber auch in Alltagsprodukten vor. Diverse advanced materials werden bereits eingesetzt. Es gibt weder eine gesetzliche noch eine wissenschaftliche oder technische Definition von „advanced materials“. Im Rahmen dieses Projekts werden unter dem Begriff alle Werkstoffe zusammengefasst, die gezielt gestaltet und hergestellt werden, um die funktionellen Anforderungen einer bestimmten Anwendung zu erfüllen.

Obwohl die rechtliche Situation von Nanomaterialien, die eine Untergruppe und ein wichtiger Bestandteil vieler advanced materials sind, weitestgehend geklärt wurde (u.a. durch die Anpassung von REACH), ist unklar, ob potenzielle Risiken anderer advanced materials durch die bestehende Gesetzgebung ausreichend berücksichtigt werden.

Das Projekt „Themenkonferenzen zu neuartigen Materialien und Werkstoffen“ hatte zum Ziel, die deutschen Behörden dabei zu unterstützen, das Feld der neuartigen Materialien (im Folgenden „advanced materials“ genannt) zu strukturieren und bezüglich der Chemikaliensicherheit ihre Arbeitsschwerpunkte zu identifizieren und festzulegen.

Im ersten Teil des Projekts wurden Informationen über advanced materials durch eine umfangreiche Literaturrecherche, eine Online-Befragung sowie Interviews mit Personen, die eine ausgewiesene Expertise im Feld der advanced materials haben, gesammelt. Es wurde eine Literaturanalyse durchgeführt, um den Umfang der Forschungsaktivitäten für die verschiedenen (Arten von) advanced materials zu beschreiben und die wichtigsten Forschenden in diesem Bereich und ihre wissenschaftlichen Beziehungen zueinander zu ermitteln. Es wurde ein Vorschlag entwickelt, wie advanced materials unter Berücksichtigung ihrer Zusammensetzung und Struktur und mit Blick auf mögliche Aspekte der chemischen Sicherheit in Gruppen zusammengefasst werden können. Die Informationen wurden auch zur Zusammenstellung und Ausarbeitung einer Reihe von Kriterien für die Bewertung der Relevanz von advanced materials verwendet, die zur Ermittlung von Prioritäten für eine eingehendere Bewertung von advanced materials herangezogen werden könnten. Die vorgeschlagene Clusterbildung von advanced materials wurde anhand von Datenblättern illustriert und ergänzt. Die Datenblätter enthalten die jeweils grundlegenden Informationen zu einem bestimmten Cluster, u.a. über die Zusammensetzung und Struktur der jeweiligen Materialien, ihre Funktionalität und Reaktivität, die bekannten Anwendungsbereiche und aktuelle Forschungsaktivitäten sowie Informationen darüber, ob Gefahren- und Expositionsdaten verfügbar sind oder nicht.

Der zweite Teil des Projekts bestand in der Organisation eines internationalen Stakeholder-Dialogs über advanced materials in Form von drei thematischen Konferenzen. Aufgrund der Covid-19-Pandemie konnte nur die erste Konferenz als zweitägige Präsenzveranstaltung organisiert werden. Die zweite Konferenz wurde in Form von zwei halbtägigen Online-Konferenzen organisiert und die letzte Konferenz fand als ganztägige Online-Konferenz statt.

Die erste thematische Konferenz diente dazu, einen Überblick über das Forschungs- und Entwicklungsfeld der advanced materials zu bekommen. Darüber hinaus wurden einige Materialien beispielhaft vorgestellt. Bei den beiden Online-Konferenzen, die die zweite thematische Konferenz bildeten, ging es unter anderem um folgende Themen: Relevanzkriterien, Aspekte der Kreislauffähigkeit von advanced materials, Identifizierung von Besorgnissen, die für advanced materials spezifisch sind und die Identifizierung von advanced materials, für die bereits eine Besorgnis besteht. Auf der Abschlusskonferenz wurden Schlussfolgerungen aus den

vorangegangenen Diskussionen gezogen und Fragen zur Governance von advanced materials erörtert. Ein entsprechendes Diskussionspapier der deutschen Bundesoberbehörden bildete die Grundlage der Diskussionen.

Mit dem Projekt wurden Diskussionen über advanced materials auf globaler, EU- und nationaler Ebene angestoßen. Es förderte die gemeinsame Auseinandersetzung mit den potenziellen Herausforderungen von advanced materials für die Chemikaliensicherheit und die Nachhaltigkeit, die zum Beispiel aufgrund mangelnder Daten oder Methoden entstehen können oder weil die Materialien nicht durch bestehende Vorschriften abgedeckt sind.

Der Bericht gibt einen Überblick über den Arbeitsprozess und fasst die wichtigsten Diskussionspunkte auf den Konferenzen zusammen.

1 Introduction

The EU Commission considers Advanced Materials (AdMas) as one of the "key enabling technologies" in its Horizon 2020 research framework programme. As part of its High-Tech Strategy 2025 (The German Government (2018)), the Federal Ministry of Education and Research funds various projects that focus on the application of AdMas.

In 2007, the higher federal authorities developed and published a joint strategy for research on the environmental and health risks of nanotechnologies (Federal Institute for Occupational Safety and Health, Federal Institute for Risk Assessment and Federal Environment Agency (2007)). The update of the joint research strategy in 2016 (German Environment Agency, Federal Institute for Risk Assessment, Federal Institute for Occupational Safety and Health, Federal Institute for Materials Research and Testing, National Metrology Institute (2016)) included an extension of the scope to "other innovative materials". This reflects the fact that material innovations are not limited to the size range of 1-100 nm and that risks to humans and the environment can also emanate from materials in larger dimensions. The updated research strategy refers to material innovations as a whole and contains four research priorities, including the (further) development of testing and assessment methods for materials, (risk) communication and the development of legal regulations and practical recommendations for the safe handling of material innovations.

This shows the necessity and relevance of addressing AdMas. Among other things, it must be clarified which types of materials and which applications can and should be included under the term AdMa, which potentials can be tapped for sustainable, technological development and which risks may be associated with the use of AdMas. Both substance-related risks and other challenges are relevant here, e.g., regarding the recyclability of materials.

The aims of the project "Thematic Conferences on Advanced Materials", which began on 23 April 2019 and ended on 30 September 2021, were to support the German Environment Agency (UBA) and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) in prioritising their own work on AdMas and to organise and provide technical support for an international discussion with stakeholders.

The project consisted of two partially overlapping work phases: In the first work phase information on AdMas and their applications was collected and an initial assessment of their relevance in the regulatory and scientific-technical context was carried out. In the second work phase experts, market actors and representatives from authorities were invited to exchange their views, experiences, and information about AdMas in the context of three dialogue events. The first event focussed on how to structure the field of AdMas. The later events placed more emphasis on the identification of relevant aspects of AdMas relating to potential concerns about chemical safety.

Due to the Corona pandemic, only the first thematic conference could be held as a two-day face-to-face event. The second thematic conference took place in the form of two 1-day online conferences and the final conference was held as a 1-day online conference.

2 Structuring the Field of Advanced Materials

The aim of the first project phase was to compile information about AdMas and the research and development activities, to structure the field. Information was gathered via a literature review, an online survey, and expert interviews.

In the scope of the literature review, a first bibliometric analysis was performed, deriving an indicator of relevance of AdMas from the respective scientific activity. A number of (combinations) of keywords were used to identify not only the recent publications but also to assess trends in publication activities and the relations between research groups. In addition, a qualitative analysis of relevant (review) articles was performed and information about AdMa was extracted.

The online survey was answered by about 30 experts. In addition to general questions on the structuring of the AdMas and their regulatory relevance, specific questions were asked about individual material types. The results of the survey were incorporated into the reports documenting the first project phase (see below). The detailed evaluation was made available to UBA as a pdf document and can be requested there.

The expert interviews aimed at deepening the understanding of information from the literature research and getting further inquiring about the relevance of materials as well as expected trends in research.

A second part of research concerned the development of criteria to measure the potential relevance of AdMas for chemical safety. Here, criteria and indicators discussed at an expert workshop on AdMas and documented in a report for the BMU (Reihlen A., Jepsen D. (2019)) were used as a starting point. Considering the specifics of AdMas and widening the scope of parameters to market information and scientific indicators, a modified and complemented set of indicators was developed and suggested for use to identify AdMas that should be further assessed regarding their chemical safety.

The activities of the project first phase were documented in the report "UBA Texte 132/2020: Advanced materials - Overview of the field and screening criteria for relevance assessment" (Giese et al. (2020)). It provides an overview of the research field of AdMas, discusses possible criteria for assessing the relevance of AdMas for chemical safety and proposes a way to assign AdMas to classes for regulatory review and processing. The annex to this report, published under the title "Advanced materials - overview of the field: Factsheets on selected classes of advanced materials" (Drapalik et al. (2020)), contains data sheets on the proposed AdMa classes, characterising them in terms of their properties. Both reports represent the status quo at the time of publication. The presentations and discussions of the first thematic conference were incorporated into both reports. Both reports were the basis for the following thematic conferences. The factsheets were updated once due to new information on one material class.

3 First Thematic Conference

The first thematic conference took place at the UBA premises in Dessau on 05th and 06th December 2019, and aimed at getting feedback on the initial research results on AdMas as well as establishing contacts to the research community and starting the stakeholder dialogue.

3.1 Programme of the First Thematic Conference

The session titles and presentation topics are presented below. Each session was ended with a discussion.

Advanced materials – Setting the scene

Advanced materials – different clustering options identified - interim results from ongoing research activities
Bernd Giese, Institute of Safety/Security and Risk Sciences (ISR)

Research Policy of the BMBF in the Area of Advanced Materials
Katrin Witten, Project Management Jülich (PTJ, Projektträger Jülich)

ECHA survey on the market for so called "next generation" nanomaterials
Abdelqader Sumrein, European Chemicals Agency (ECHA)

RIVM Survey on biological nanomaterials
Agnes Oomen, National Institute for Public Health and the Environment (RIVM)

Advanced materials – rational design and targeted fabrication of specific functionalities, overview and practical examples

Overview on mechanisms and tools for rational design processes; modelling and fabrication technologies
Winfried Keiper, Platform for Advanced Engineering Materials and Technologies (EuMaT)

Functionality by Structure: Mesomaterials, metamaterials and supraparticle systems
Karl-Heinz Haas, Fraunhofer Institute for Silicate Research (ISC)

Soft Magnetic Materials - Wires for Sensor Applications
Arkady Zhukov, Department of Material Physics, University of the Basque Country

Advanced Polymer Materials
Bernhard von Vacano, BASF

Advanced Carbon Fiber Composites
Michael Heine, Composite United

Hybrid Materials
Karl-Heinz Haas, Fraunhofer Institute for Silicate Research (ISC)

Printed Organics Electronics - consideration of recycling aspects during design process
Stephan Kirchmeyer, Organic and Printed Electronics Association (oe-a)

How to structure the field of advanced materials

Impulse Statements on Stakeholder perspectives regarding advanced materials

- Environmental NGO
  Rolf Buschmann (BUND)
- Member state authority
  Gregory Moore (KEMI)
- Chemical Industry
  Hans-Jürgen Klockner (VCI)
- Research-Network
  Winfried Keiper (EuMaT)

Possible approaches to structure the field of advanced materials for the further debate
Bernd Giese (ISR)

Break-out groups and reporting back

Lessons learned from the thematic conference 1

Feedback Panel - environmental NGO, consultant team; member state authority; chemical industry

3.2 Discussions at the Conference

In the following sub-sections, the discussions in the break-out groups are summarised as well as the main issues brought up in the plenary. The latter are organised topic-wise and do not correlate with the sequence of the presentations.

3.2.1 Break-out group on delimitation of advanced materials

In this break-out group, it was discussed how and why a delimitation of AdMas is needed. After discussing the pros and cons, the group concluded that no overall definition of AdMas is needed, but the identification and delimitation of subgroups of AdMas would be beneficial to identify and handle risks resulting from the material groups.

A strict delimitation of advanced from non-advanced materials was not regarded as possible because a clear borderline between what is considered to be advanced and non-advanced was found neither possible nor feasible. Such delimitation might also run the risk of excluding relevant materials from a closer look.

However, in a regulatory context, it was concluded that the use of the term “Advanced Material” could help to screen for “new, emerging or uncovered issues” related to new materials. Addressing AdMas could help to identify amongst others:

- Hazards/risks to humans or the environment connected to a specific material, such as with a particular composition
- Challenges for regulation or
- Challenges for the circular economy due to an inclusion of AdMas into products.

It was proposed to categorise materials falling under the broad term of advanced materials. Based on the categorisation, a strategic approach could be suggested to identify those subgroups which may imply the above-mentioned challenges ("observation fields") and thus afford a closer look.

It was discussed by the group that all actors, the public, industry, academia and regulators might need to distinguish between advanced and non-advanced materials. Various arguments were brought forward regarding the idea to make "A fence around advanced materials" to facilitate the debate about safety and sustainability.

Some participants found it useful to have an active dialogue about uncertainties (and potential risks) related to new materials. A need was expressed to get a better understanding of what types of uncertainties exist and what gaps are to be covered, i.e., regarding hazard information, regulatory coverage or market occurrence. There were some interventions highlighting the need to generally distinguish between material groups to identify concerns, regardless of whether they are advanced or not.

It was acknowledged that regulators need a definition to be able to regulate. As some identified issues do not fit into the normal regulatory process a proper assessment of challenges is necessary. A screening concept and prioritisation would be necessary to manage this task. Some potentially relevant materials are already identified as important "observation fields", such as DNA origami and synthetic biology with gaps in hazard information.

It was also discussed that the term "AdMa" is used as a selling argument and that the benefits of new materials should also be considered.

It was concluded that the needed identification of subgroups has to go beyond chemical characterisation and shall also take the following into account:

- Structure
  - not only related to new materials, but also from already chemically characterized materials which show not yet evaluated structural characteristics/ functionalities
- Product and context of application
- Methods on how to identify risks are important.

3.2.2 Break-out group: driving forces on the market

In this break-out group, it was discussed that there are several driving forces potentially triggering the development of new AdMas. The main one was commonly stated as being a particular societal or technical need. However, also (mere) scientific interest and commercial benefits are among the important drivers. In general, related innovation should help becoming more sustainable, including saving resources. Challenges in promoting innovation were said to include directing government funding and supporting entry to the market (economic promotion). Innovations are more likely to be successful on the market if they take up current trends, fulfil societal needs (clear benefits), it is proven that they can be practically applied, and consumer trust exists.

It was stressed by several participants that more stakeholder involvement would be useful in driving innovation trends on (the use of) AdMas, e.g., by integrative research platforms.

It was generally stated that the time to develop and introduce to the market of innovations would strongly depend on the need.

Among the driving forces of market trends, the break-out group participants saw the wish to solve societal and environmental/planetary problems as well as convenience and financial needs of companies and academia. Development goals related to AdMas would be part of the companies' vision of future income and/or cost-saving. Several factors were named as influencing the time-to-market from the initial invention:

- Need for a solution
- Region, where a product is invented
- Availability of infrastructure (installations, processes) and/or the availability of resources to invest in development
- Actors goals and priorities
- Efficiency of the research and development management process.

It was approximated that some few years are necessary for scientific development and prototyping, some few years for product development and an additional period of 5-10 years for market entry.

The group also discussed how communication on AdMas should look like and concluded that it is necessary to highlight the contribution they can have to solve societal problems in general. Communication should include specific messages in product promotion, highlight the new functionality and address both the interested (option to get specific information on the technology) and the less interested persons (provide general information). Simplicity, conciseness and credibility of communication were ranked important.

3.2.3 Break-out group: Integrating (pre-)caution and circular economy in rational design

The participants of the group discussed that there are several AdMas that are considered as important for technological progress but could pose risks due to their specific composition, structure or application area. Among those identified by the group are:

- Composites or new hybrid materials
- Certain metallic materials
- Biomaterials
- Low-density materials/aerogels
- Anisotropic materials/fibres
- Additive manufacturing and 3D-printers
- Next-generation NM and active materials.

Among the potential risks were, apart from (eco-)toxicological ones, challenges for the circular economy along the life cycle as well as the potential inability to assess particular (new) functionalities and/or properties with existing (risk assessment) methods. An expectation was outspoken that safety and sustainability should be integrated into the development and innovation process. Therefore, experts from different fields should work together in interdisciplinary teams.

In the discussion, it was mentioned that the use of the term "advanced material" is not helpful but that rather subgroups and signals that could cause concern should be addressed. Among the mentioned reasons for concerns were the composition, the activity of a material, its persistence and biodurability. The participants mentioned that 3D printing may result in materials being used in unknown applications/ uses making risk assessment difficult. Uncertainty is added by the fact that polymers are not covered by REACH and part of AdMas. It was also stated that risks from low-density materials may be underestimated if mass-defined thresholds for inhalation exposure are applied.

The group compiled design principles to integrate pre-caution in AdMa development, which included consideration of:

- The morphology for effects and behaviour
- Experience from the pharmaceutical sector regarding knowledge on safety, properties and function
- Integrating toxicity and risk assessment into the innovation process
- Avoiding exposure over the full life cycle

3.2.4 Discussion issues during the plenary sessions

Definitions

It was discussed in the plenary that it should be kept in mind that definitions depend on their purpose. Also, the term "advanced materials" was created with a certain intention.

While the need for and possibilities of developing an overall definition of AdMas was not expressed and supported, there were a lot of discussions about describing distinct groups of materials, applying the existing definitions under REACH (Regulation (EC) No. 1907/2006) as well as the recommendation for a nanomaterial definition by the European Commission.

Many speakers and participants stressed that an evaluation of the relevance of AdMas should include an assessment of which type of legal definition (i.e., substance, mixture or article) and which legal framework would apply. However, there may also be a need to re-think regulation for AdMas and e.g., consider addressing them as a "technology" or via their functionalities.

In all discussions, it was confirmed that unambiguous categorisation of AdMas appears impossible. Nevertheless, describing categories was considered important in order to be more concrete both in monitoring and in assessing regulatory needs.

AdMas aim at becoming commodities eventually.

Advantages of the current nanomaterial definition are that it is precise and hence unambiguous for regulatory and enforcement purposes.

The idea that nanomaterials and/or AdMas could be defined as articles created discomfort, in particular for the authorities. However, the degree to which structure determines the functionality of AdMas may result in respective cases. The ECHA study (Camboni et al. (2019)) concluded in many cases that active nanomaterials should be considered substances, but there were also other decisions or inability to decide. Some of the related issues could be solved by improved guidance.

Market information

Neither in the presentations nor the discussions, specific information was provided on the actual use of AdMas. While some overall use sectors were indicated (e.g., electronics, medicine, automotive), no concrete information was given on what types of materials and which amounts of them are used. It was also notable that all stakeholders were hesitant to predict future developments.

In addition to progress in science and technology, also the market itself directs innovation; hence, product prices and demands are also important. In the break-out group on market trends, the role of societal challenges in steering research and development was stressed.

Science and technology are more and more able to control the design of materials and it is unclear which direction innovation will take. Generally, implementing a "safe innovation approach" was commonly regarded as important.

The EUON[1] publishes information on nanomaterials on the market based on several information sources, including REACH registrations, notifications under the Cosmetics Regulation and national nanomaterial registers.

Horizon scanning and the close monitoring of (particular) AdMas was regarded as the only option to get a better picture of the market relevance of AdMas in the future.

Fibres

Issues around the carcinogenicity/toxicity of fibres were discussed in some occasions, where mainly authorities were of the opinion that fibre toxicity would also apply to (some of the) AdMas. Apparently, the information basis is insufficient for these materials to disprove respective toxicity. This was particularly debated for carbon fibres, which during recovery or waste treatment operations (pyrolysis) may undergo changes in structure. Here, it was unclear if their internal structure and related breaking behaviour could lead to toxic effects and/or or if they could form "WHO fibres".

Circular economy

In many contexts, stakeholders were critical about the possibility to reuse or recycle AdMas because:

- They frequently consist of intimately linked components, which can hardly be separated;
- Additional material streams may be created (e.g., organic electronics in packaging) providing functionalities which are not commonly regarded as necessary; thus material flows may become even more diverse or contaminated;
- There is neither infrastructure to identify and collect/separate AdMas (in products) from the overall waste stream nor relevant amounts that would enable efficient recycling;
- Value added lies in the structure of the materials, which means that chemical recycling does not make much sense.

Research

There is a feeling of a "common research community", which is united by the aim of creating something new and using new approaches to manufacturing.

[1] https://euon.echa.europa.eu/

Apart from the continuous improvement process in material science, there are disruptive inventions, where new materials are combined in a new way and where research identifies opportunities which were as yet unknown.

4 Second Thematic Conference

The second thematic conference was held as a two-part online conference due to the Corona pandemic. Both parts of the conference were prepared and conducted in coordination with the OECD.

A total of 126 people registered for the first part of the conference on 16th June 2020, and more than 90 people from a wide range of world regions were present in the virtual space at any given time. The first part of the online conference was mainly dedicated to the presentation and discussion of the proposals for the grouping of AdMas and the possible criteria for assessing the relevance of AdMas to chemical safety based on the reports produced in the project (see Section 2).

A total of 176 people registered for the second part of the conference on 15th September 2020, from a wide range of world regions, and more than 130 people were present in the virtual room at any given time. After the conference opening, challenges posed by AdMas for chemical safety were presented and discussed from a regulatory perspective and with the help of examples. In addition, based on three presentations on the circular economy, it was discussed how waste and recycling-related aspects can be integrated into the design of AdMas.

4.1 Programme of thefirst part of the Online-Conference (OC 2.1)

The session titles and presentation topics are presented below. Each session was ended with a discussion.

Overview of advanced materials

Advanced materials options to cluster and approach suggested by the project; overview of the different types of advanced materials - Results from the research activities
Bernd Giese, Institute of Safety/Security and Risk Sciences (ISR)

Advanced Materials - an industrial perspective from nanomaterials
Claire Skentelbery, Nanotechnology Industries Association (NIA)

Overview on possible criteria to screen advanced materials regarding their relevance

Results from the research activities
Antonia Reihlen, Ökopol GmbH

4.2 Discussions at the first part of the Online-Conference (OC 2.1)

4.2.1 Clustering and characterising (classes of) advanced materials

The approach of clustering AdMas developed in the project (Giese et al. (2020)) was presented. Several aspects were discussed and provided as feedback:

- It was clarified that metamaterials are considered as a distinct class (rather than being included in composite materials), because they exhibit properties that do not exist in nature.
- Other options to structure the field were proposed, such as based on toxicity or functionality.
- Advanced manufacturing (e.g., 3D printing) was mentioned as missing in the approach; it was clarified that the clustering approach focuses on materials rather than technologies; however, 3D printing was also considered in the project.

- The idea of clustering AdMas was generally supported. However, it was said that considering risk for clusters of materials may be challenging and misleading; this was also learned from respective approaches for nanomaterials.
- Several participants wondered whether or not AdMas could fall into different classes and if this may lead to problems for risk relevance. It was clarified that the project approach aims to be comprehensive (i.e. capturing all materials) rather than unambiguous and that therefore it is not important if a specific material could be included into more than one class.
- It was questioned how situations could be dealt with when different AdMas are combined and whether or not combined effects are considered. It was clarified that the level of detail in the factsheets is much lower than this.

Regarding the factsheets provided separately from the UBA report (Drapalik et al. (2020)), the conference participants gave the following main feedback:

- The factsheets were considered useful for giving a general overview of different types of AdMas. Their value would depend on whether or not they are kept up-to-date. Updating, which would have to include industry surveys for many of the information types, would have to be done according to clear parameters and on a regular basis.
- Proposals for additional information in the factsheets included:
  - Level of commercialisation of products, e.g., whether amounts are only for R&D or if production exceeds 1t/a etc. (obtaining this kind of information is very challenging or impossible, but important for exposure estimate)
  - Information on applicable legislative regimes (product legislation as well as international legal frameworks)
  - Workers exposure levels and health effects "early warning signal" regarding hazards
- It was suggested to prioritise the need to fill information gaps using exposure information, i.e., hazard assessment should be more targeted.
- Modelling as a method to fill information gaps was commented to be very complex and cumbersome as shown for nanomaterials and hence not applicable at a larger scale.
- Several participants supported the idea to work with specific examples to get a better understanding of the clustering approach, the information availability as well as the possibilities to identify priorities regarding risk management and/or information generation.
- Some participants supported the view that if "safe-by-design approaches" were implemented, any clustering of AdMas would not be necessary anymore.
- It was recommended to treat the factsheets as living documents.

4.2.2 Screening for relevance

The approach to developing criteria for relevance screening and the resulting set of criteria as published in the project report were presented to start the discussions.

- It was commented that the criteria used to screen the relevance of AdMas are similar to those of nanomaterials.

- In the Netherlands, two examples were elaborated (bionanomaterials and carbon metal hybrids in the energy sector) and similar aspects were addressed as in the screening criteria of the project. Aspects of circular economy hereby play an important role.
- Several participants highlighted that the (specific) application of an AdMa must be considered in any relevance screening (and subsequent assessments of potential concerns).
- Any relevance screening would, in the end, require the weighting of criteria against each other. The decision making on the weight of each criterion should be a societal process.
- Comments on specific criteria included:
  - The criteria are pragmatic
  - The novelty of a property is part of the definition; hence this criterion may not discriminate[2]
    (Improved) recyclability could also be considered as a novel property
  - The number of scientific publications can be misleading as there is no clear correlation between these and the actual relevance of a material in reality; here patent analysis may be a better indicator; however, there is a gap between patent application and market entry of app. 5 years
  - Missing criteria include: the number of exposed persons, the type of use (i.e., wide dispersive), relevant exposure routes, fire and explosion hazard
  - Biological hazards may be considered in addition (mainly biological materials)
- Regarding the criteria on circular economy, it was discussed that:
  - Future developments in recycling technologies should be taken into account, i.e., criteria should be developed that are also relevant in the future
  - Recyclability would not only depend on the material but also the availability of the processes and this would, among others, depend on the expectation of material amounts to be treated as investments would have to be made
- It was discussed whether a Life Cycle Assessment (LCA) could be a criterion for ranking of relevance. There was agreement that safety and sustainability should be viewed from a life cycle perspective in general. It was seen as an advantage that several aspects are covered by an LCA, including toxicity, waste, emissions etc. The participants were of different opinions:
  - Some stated that "simple LCA" methods exist that could/should be applied already early in the development process
  - Others stated that LCAs are very cumbersome (high number of data need) and would be applied at late stages of a material development in order to prevent doing them in vain

[2] The criterion does not aim at stating whether or not there is a novel property but rather to point out WHICH TYPE of property a material has, because this gives indications on the potential future uses of a material as well as an indication on a hazard potential.

4.2.3 Conclusions from the conference

In the concluding discussion, the main issues pointed out were that:

- Although having much improved, even the data basis for nanomaterials is not sufficient for a thorough ranking of nanomaterials. Some information is proprietary and therefore unlikely to be published. The situation is much worse for AdMas.
- From an occupational safety and health (OSH) perspective, fibres are of utmost importance, in particular with a view that asbestos causes more than 200.000 deaths per year
- AdMas are of an increased complexity as compared to nanomaterials. The persons participating in the discussions should not "only" be the nanomaterials community and additional expertise might be needed to work on the issues "beyond nano"
- Knowledge, methods and experience from working on nanomaterials are the starting point for AdMas. Also, in the OECD Working Party on Manufactured Nanomaterials (WPMN) the differences in how chemicals, nanomaterials and AdMas are treated with regard to hazard, exposure and risk assessment have to be pointed out.
- Nanomaterials are considered AdMas but that not all AdMas include nanomaterials;
- Actors working with AdMas use different languages, e.g., when looking at the field of nanomedicines, different terms are used and issues discussed; hence getting a better understanding of and across/between the various fields was regarded important.

In the wrap-up of the meeting, it was summarised that the field of AdMas is complex and diverse and will remain a "moving target". The factsheets were seen as a useful first attempt to give an overview of material classes, but that they are just one of many ways to structure and describe the field. More information and work would be need. There was a general agreement on the usefulness of the proposed relevance criteria but also a need for further refinement was observed, including adding criteria. The issue of "circular economy" was identified as more than just a side issue. Additionally, it was concluded that consideration should be given to the invitation of experts beyond the nanomaterial community to the discussions.

4.3 Programme of the second part of the Online Conference (OC 2.2)

The session titles and presentation topics are presented below. Each session was ended with a discussion.

Challenges of advanced materials regarding chemical safety

Chemical safety challenges from advanced materials - General considerations and research approaches

Advanced materials – Challenges for chemical safety: Perspective of UBA
Kathrin Schwirn, UBA

Review of work on advanced materials at EU level[A], with preliminary reflections from a recent workshop on safe and sustainable smart nanomaterials[B]
A – Andrej Kobe EC DG ENV, B – Hubert Rauscher EC DG JRC

Advanced Materials: First Insights of the German Project InnoMat.Life
Andrea Haase, BfR

Chemical safety challenges from advanced materials – examples

Systematic identification of emerging safety and sustainability issues of advanced materials: Nano-carbon-metal hybrids for application in the energy sector as a case study
Agnes Oomen, RIVM

Fibrous materials - a health risk at the workplace?
Rolf Packroff, BAuA

Challenges of advanced materials regarding the circular economy

Circular economy aspects of advanced materials and relevance criteria
Antonia Reihlen, Ökopol GmbH

OECD work on waste containing nanomaterials and tracing chemicals in products for improved end-of-life treatment
Peter Börkey, OECD WPRPW

Potentials and Risks in the Recycling and Recovery of Carbon Fibres
Manuela Wexler, Karlsruhe Institute of Technology

4.4 Discussions at the second part of the Online Conference (OC 2.2)

4.4.1 Chemical safety issues

The main issues that were mentioned by the auditorium in the comments and/or the questions and answers were:

- Not all new materials/AdMas are of concern; this should always be made clear
- The safety assessment of substances by regulators must consider the form/morphology of the materials (cf. titanium dioxide) as addressed under REACH and CLP; the current risk assessment approach may however have to be modified for fibres
- CNTs should be addressed in a differentiated manner, as not all of them are of concern (different rigidities[3], diameters, release behaviour etc.)
- AdMas are increasingly used, however, knowledge is missing. A current approach is to identify groups of potential concern and consolidate knowledge, including via LCAs; data infrastructure is needed to gather and share information
- While some participants were concerned about the lack of a definition of AdMas, others stated that currently no legal definition is needed as no legislation is planned so far. Nevertheless, the participants expressed a need for clear terminology to address the field and prioritise action needs.

4.4.2 Circular economy of advanced materials

On the topic of circular economy of AdMas, the participants discussed that:

- AdMas should be designed to meet the capabilities of the waste treatment technologies, in particular the less sophisticated processes, to ensure recycling and treatment is possible
- Complex materials are frequently linked to challenges in waste treatment; options to increase the product lifetime by using AdMas should address the challenges in the waste

[3] Cf. a recent paper on rigidity https://www.mdpi.com/2079-6439/8/5/31

stage; i.e. question whether or not a product actually needs AdMas or if a conventional material is sufficient.

- Industrial waste sources pose smaller challenges for waste treatment than municipal ones (many small items in a mixed waste stream). Information systems are challenged by the post-consumer wastes, as they might have to enable identification of (individual) waste items to be separated from the overall waste stream for potential separate treatment and/or recovery/recycling.

5 Third Thematic Conference

The 3rd thematic conference was originally to be held as an international conference in the atrium of the BMU on 04th and 05th May 2021. However, due to the Corona pandemic, the conference could only be organised as an online event. It took place online on 14th June 2021 from 9:00 to 16:00. A total of 178 people from 26 countries registered, of whom 150 participated.

The basis for the discussion at the conference was the draft document "Risk Governance of Advanced Materials: Considerations from the joint perspective of BAuA, BfR and UBA - Perspective of the German Higher Federal Authorities", which was sent to the participants before the event and presented in parts at the conference[4]. During the event, the participants were invited to take part in online surveys about the discussed issues. The results of these surveys are provided in the appendix of this report.

5.1 Programme of the Third Thematic Conference

The session titles and presentation topics are presented below. Each session was ended with a discussion.

Introduction to the discussion paper

Introduction to the Discussion Paper on Risk Governance of Advanced Materials
Doris Völker, German Environment Agency (UBA)

Identification of materials of concern and early warning systems

Ideas from the Discussion Paper on Risk Governance of Advanced Materials:
What means "Materials of Concern"?
Rolf Packroff, German Federal Institute for Occupational Safety and Health (BAuA)

Early Warning System: The German Working Group of the Higher Federal Authorities
Andrea Haase, German Federal Institute for Risk Assessment (BfR)

Presentation of the Risk Scoring System "NESSI"
Philipp Hebel, German Federal Institute for Risk Assessment (BfR)

Systematic Approach to the Identification and Prioritisation of Advanced Materials in view of Safety and Sustainability Issues
Agnes Oomen, Dutch National Institute for Public Health and the Environment (RIVM)

Regulatory Action Needs for (Specific) Advanced Materials

Ideas from the Discussion Paper on Risk Governance of Advanced Materials: Regulatory Action Needs
Lars Tietjen, German Environment Agency (UBA)

Regulatory Action Needs from the Industry's Perspective
Scott Brown, Business at OECD (BIAC)

Regulatory Action Needs from the NGO's Perspective
David Azoulay, Center for International Environmental Law (CIEL)

[4] The final version will be published at the UBA webpage at https://www.umweltbundesamt.de/en/topics/chemicals/nanotechnology/advanced-materials

Safe and Sustainable by Design

Ideas from the Discussion Paper on Risk Governance of Advanced Materials: The S&SbD Approach
Kathrin Schwirn, German Environment Agency (UBA)

Developing Criteria for S&SbD at the EU Level
Aleksandra Malyska, EU Commission, DG Research and Innovation

The use of S&SbD in Developing Advanced Materials from a Scientific Perspective
Klaus Kümmerer, Leuphana University, Lüneburg

Learnings, Take-Home and Recommendations

Mar Gonzales, Organisation for Economic Co-operation and Development (OECD)
Andre Kobe, EU Commission DG Environment
Alexandria Stanton; US Environmental Protection Agency (EPA)
Florian Deurer, Bernhardt Kunststoffverarbeitungs GmbH

5.2 Discussions at the Third Conference

5.2.1 Materials of concern – early warning systems

An early warning system was generally supported as a useful approach. The involvement of stakeholders into an infrastructure, like the presented working group of the German Higher Federal Authorities on AdMa, was commented to be important. The stakeholders expressed a wish to be involved.

There appeared to be high interest in the early warning systems from the stakeholders. It was pointed out that:

- It should be clear which objectives such systems should have (i.e., identification of data gaps, identification of research needs or development of policy options).
- Several hazard endpoints should be covered, including physical-chemical hazards, accident-related aspects, and persistence (durability).
- Human biomonitoring data could be used in the assessment,
- It should be clear what happens if no information is available to address an element of the early warning system.
- The early warning system should not only focus on nanomaterials.

The authorities clarified that they are currently analysing if and how the BfR and RIVM approaches for identification, scoring and prioritisation of AdMa presented at the conference (see 5.1) can be merged or may go hand-in-hand.

The EU Commission pointed out the relevance of the work on AdMas for the EU level and invited to feed any information and experience into the discussions about the chemicals strategy on sustainability (European Commission, 2020) and other related policies.

Information gathered for the early warning system and/or risk scoring tools should be made available (in the supply chain) to fill the existing data gaps.

5.2.2 Regulatory options

The benefit of regulation for innovation was discussed with different views on whether patents are a good indicator for this. It was stated that competitiveness in industries is very high (and there are only a few cooperative approaches) and therefore, knowledge protection is still necessary.

The concept of regulatory readiness as introduced at the meeting was stated to be very useful for determining the possibilities of assessment and management of the existing regulatory system and tools. It was said to be applied in the future in a regulatory management option analysis (RMOA) for persistent, respirable fibres. The determination of a regulatory readiness level (RRL) was observed as difficult, including because the state of scientific knowledge and the state of existence of guidelines may differ.

The development of testing methods was stressed as very important for regulatory readiness. All actors should be involved in this, and the speed should be accelerated. As the time-to-market decreased over the last decades, the speed with which new methods must be developed has to increase a lot.

5.2.3 Safe and Sustainable by Design (S&SbD)

The concept of S&SbD was commonly acknowledged as the cornerstone of chemicals management and hence, all related ongoing processes were welcomed in general. The aspects in the discussion paper were supported and found in line with the overarching principles as well as the discussions at EU level.

It was confirmed that sustainability is a process. Therefore, the fulfilment of S&SbD criteria would need to be viewed in comparison rather than as absolute achievements.

Sustainability would also require considering the benefits and societal challenges and values, not only the hazards of chemicals and/or AdMas; this should be reflected in any criteria on S&SbD according to the conference's discussions.

It was generally acknowledged that for some crucial functionalities the application of hazardous substances/materials will be inevitable, at least in the near and mid-term future. For these cases, a consensus should be built on whether the particular functionality (requiring the use of hazardous materials) is wanted and/or needed by society. If the use of hazardous material cannot be avoided, at least the data gaps should be closed, and solutions need to be found to manage the risk along all life cycle stages. Furthermore, design considerations may also be applied at the level of entire systems, e.g., reducing individual traffic can help to reduce the demand for batteries or, living a healthy life could help to avoid the need of taking certain pharmaceuticals.

The discussions on criteria for "essential uses" may contribute to a better understanding of functionalities which are needed and which are not.

6 Conclusions

The current project combined different methodologies to compile and analyse information on AdMas, including quantitative and qualitative literature research, online surveys and expert interviews. As a result, a report was published providing an overview of the field of AdMas. It includes not only an overview of scientific publication activities but also proposes a structure to cluster AdMas according to their composition, structure and main characteristics as well as criteria and indicators of relevance that can be applied to assess whether an AdMa should be subject to further scrutiny regarding chemical safety. Additionally, factsheets were developed for each of the identified relevant clusters (and sub-clusters) of AdMas that compile the relevant information on their composition, structure, functionality, application areas, regulatory status as well as basic considerations on potential risks.

While the two reports are a snapshot of the state of knowledge on AdMas at the time of publishing them, the considerations on structuring the field as well as the criteria for relevance assessment were intended and can be an inspiration for any future discussions on how to manage chemical safety of AdMas.

In the frame of the project, in total four dialogue events took place not only to discuss the research findings but to trigger an extensive experience exchange and inspire related discussions at national and international level. The high and increasing number of participants shows a large and increasing interest in understanding the issue and getting a better overview of what materials are used and how they might affect human health and the environment.

At national level, the project and its thematic conferences contributed to the BfR's interagency working group, which was established in November 2020. The discussion paper on governance needs for AdMas authored by members of this working group was based on the outcomes of the first and second thematic conferences. Its revised and final version was developed based on the feedback received at the final thematic conference and will serve as a thought-starter for further in-depth discussion.

The project also had an impact at the OECD level, where a new steering group on Advanced Materials to the OECD WPMN was established. The new Steering Group will systematically address safety issues related to novel materials as part of its work plan.

7 Literature

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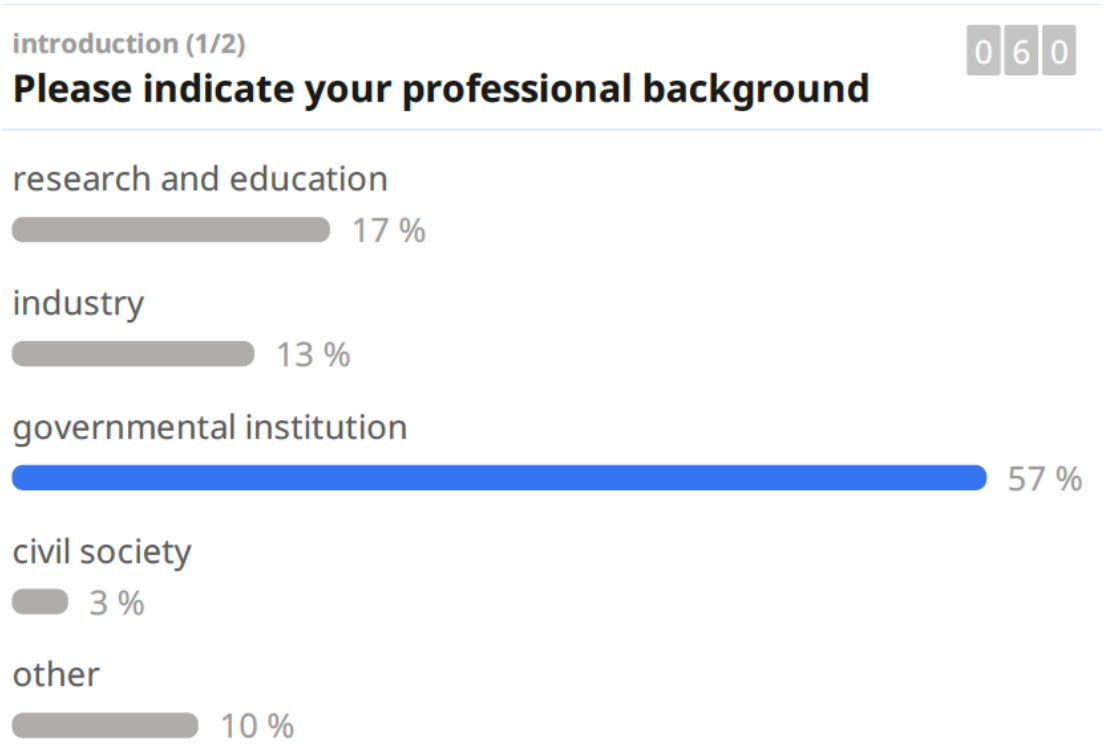
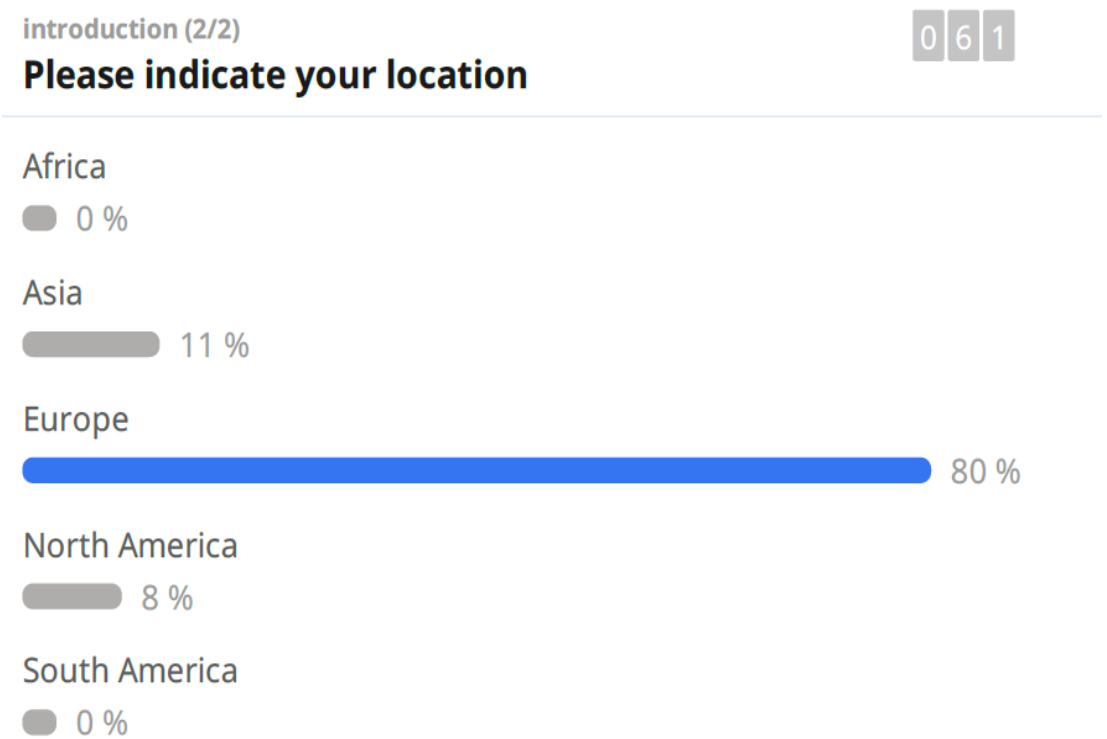
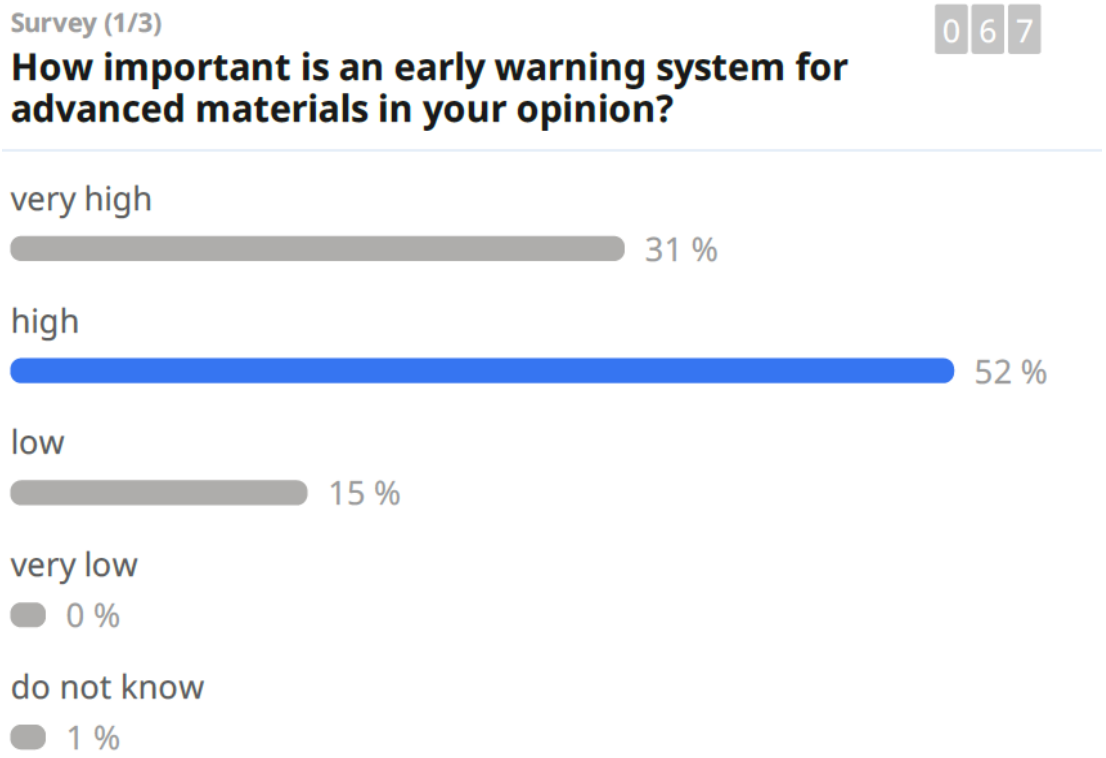
A Appendix: Results of the online surveys conducted during the final thematic conference

A.1 Participants





A.2 Session 1: Early warning system



Survey (3/3)

Which elements should an Early Warning System include? Please type up to 3 key words into the form.

0 2 4

A.3 Session 2: Regulation

Survey (1/3)

Which of the following statements do you agree with?

(1/2)

0 6 3

Existing legislations in my region sufficiently cover advanced materials.

10 %

Specific adaptions might be needed in my region to enable existing regulations to sufficiently cover future advanced materials.

57 %

New regulations specific for advanced materials are needed in my region to ensure appropriate regulatory coverage.

2 %

Both adaptions of existing regulations and new specific regulations on advanced materials are needed in my region

43 %

Survey (1/3)

Which of the following statements do you agree with?

(2/2)

0 6 3

I am not sufficiently aware of the legal situation to judge this.

5 %

Survey (2/3)

Which participant(s) of the value chain should be obliged to provide data on potentially hazardous properties of advanced materials?

(1/2)

0 7 0

Manufacturer of building blocks/substances

64 %

Importer of building blocks/substances

47 %

Manufacturer of advanced materials

89 %

Importer of advanced materials

66 %

Importer of an article containing advanced materials

43 %

Survey (2/3)

0 7 0

Which participant(s) of the value chain should be obliged to provide data on potentially hazardous properties of advanced materials?
(2/2)

Producer who uses advanced materials to produce an article

60 %

Other users of advanced materials

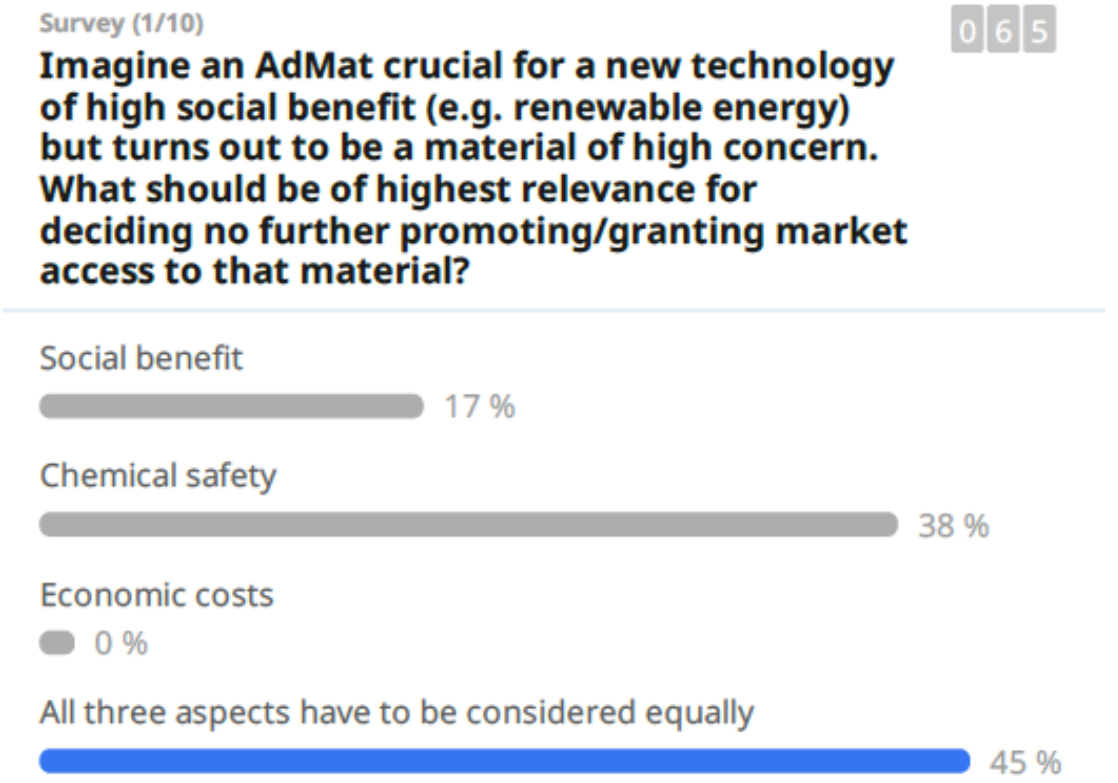
20 %

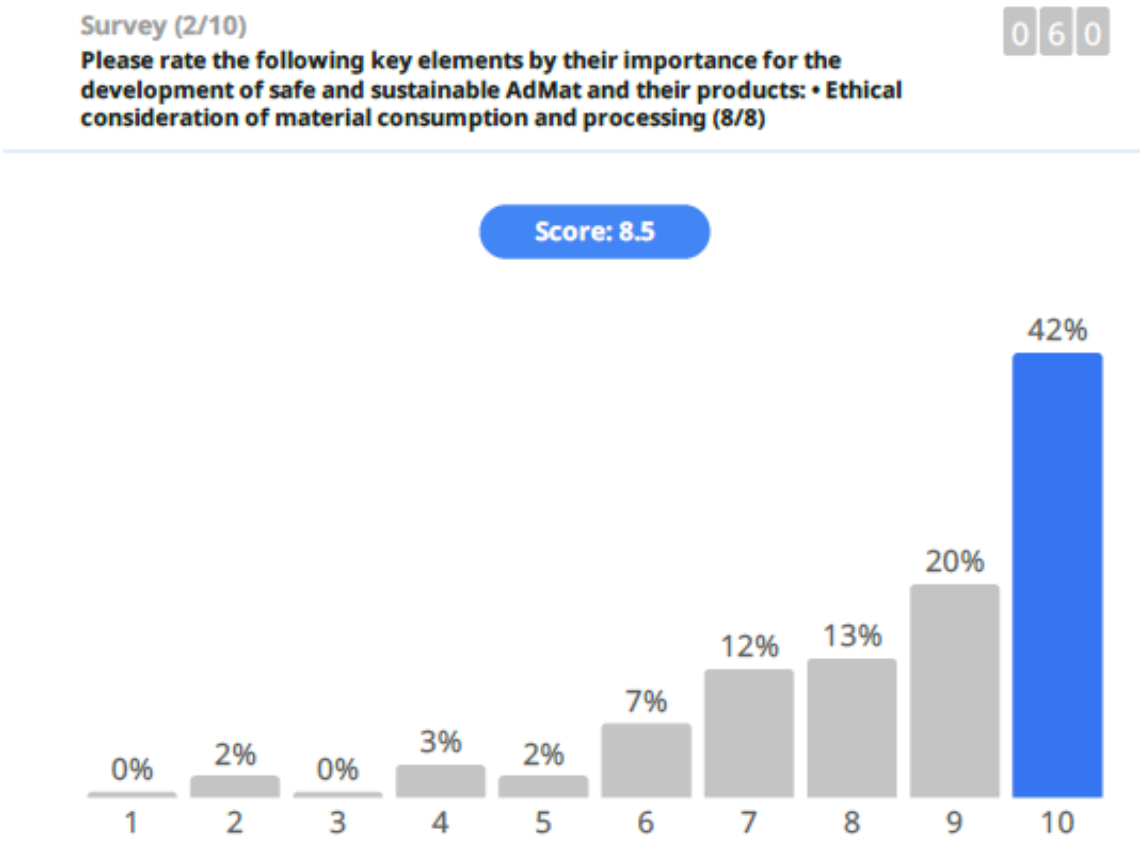
Survey (3/3)

0 6 5

Which priorities do you see in regulatory research? Please provide up to 3 priorities.

A.4 Session 3: Safe and Sustainable by Design



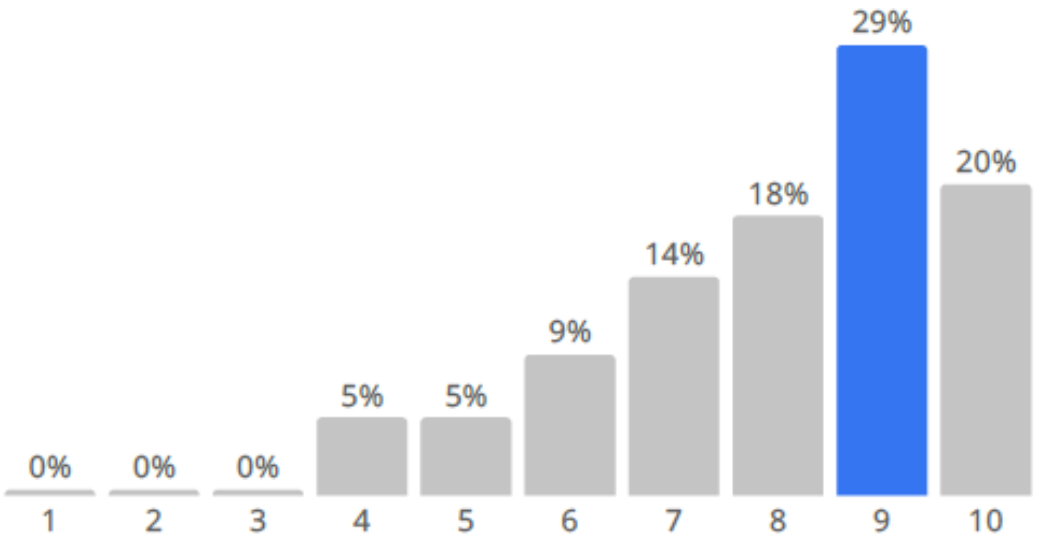


Survey (3/10)

Please rate the following key elements by their importance for the development of safe and sustainable AdMat and their products: • Other ecological footprints (7/8)

0 5 6

Score: 8.0

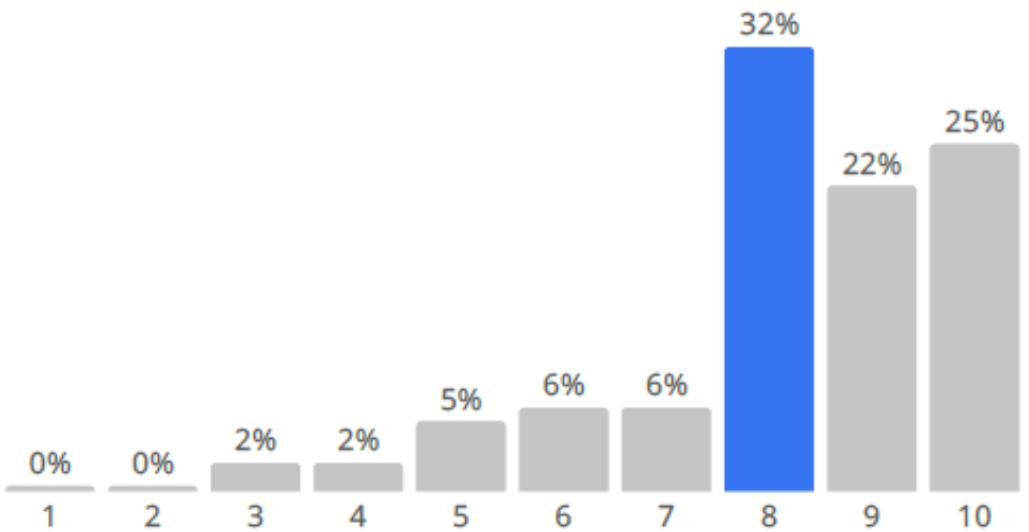


Survey (4/10)

Please rate the following key elements by their importance for the development of safe and sustainable AdMat and their products: • Resource consumption (6/8)

0 6 3

Score: 8.3

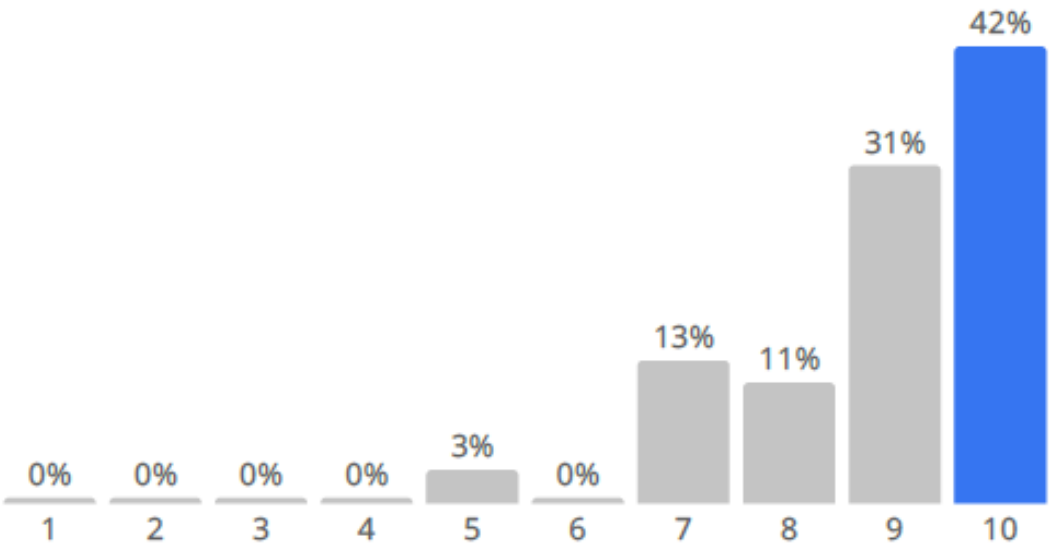


Survey (5/10)

Please rate the following key elements by their importance for the development of safe and sustainable AdMat and their products: • Recyclability of materials and their products (5/8)

0 6 2

Score: 8.9

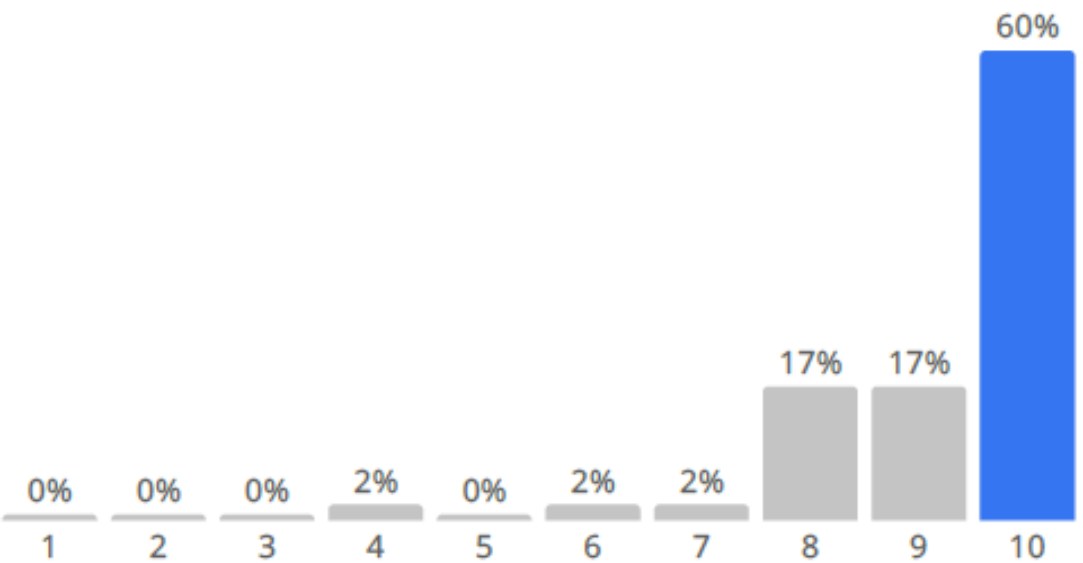


Survey (6/10)

Please rate the following key elements by their importance for the development of safe and sustainable AdMat and their products: • Safe and sustainable production processes (4/8)

0 6 3

Score: 9.3

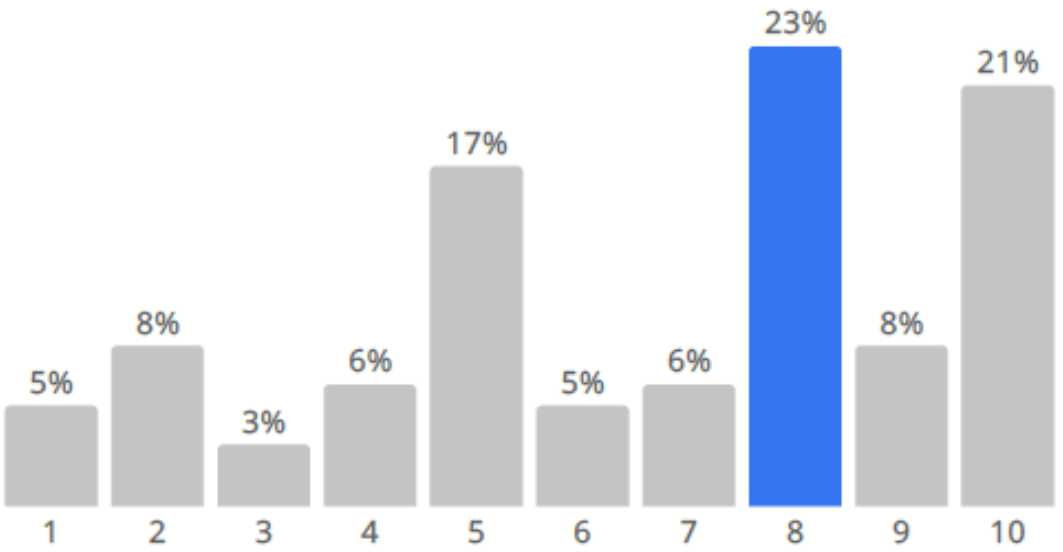


Survey (7/10)

Please rate the following key elements by their importance for the development of safe and sustainable AdMat and their products: • Service oriented business models to reduce the use of chemicals/materials (3/8)

0 6 6

Score: 6.7

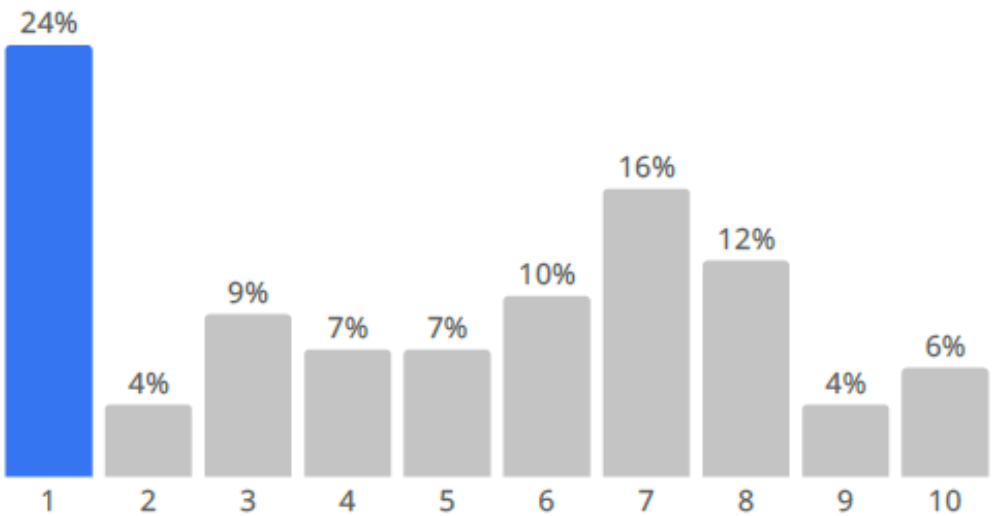


Survey (8/10)

Please rate the following key elements by their importance for the development of safe and sustainable AdMat and their products: • Consideration of non-chemical alternatives (2/8)

0 6 8

Score: 4.9



Survey (9/10)

Which information should be available to improve recyclability of advanced materials and their applications? Please provide 3 key types of information.

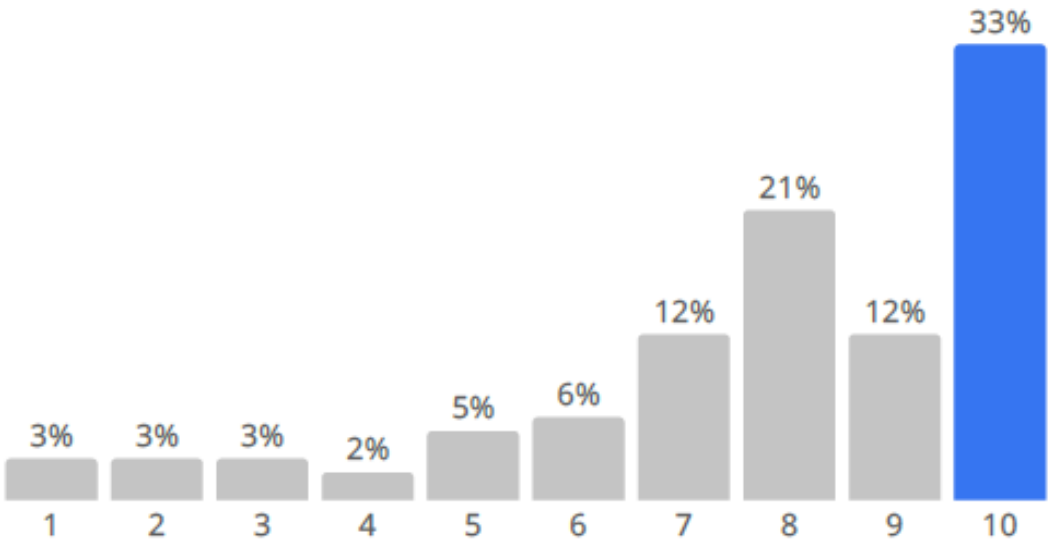
0 5 7

Survey (10/10)

Please rate the following key elements by their importance for the development of safe and sustainable AdMat and their products (1 star= not important at all, 10 stars = very important): • Use of less hazardous substances (1/8)

0 6 6

Score: 7.8



A.5 Session 4: Conclusions

What are the three most important key words that you take home with you today? 055

How will the information obtained during the conference affect your work? 058