# Biodegradability of plastics in the open environment

10 September 2020

## Expert workshop report

SAPEA
Science Advice for Policy by European Academies

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SAPEA

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# About SAPEA

SAPEA (Science Advice for Policy by European Academies) brings together outstanding expertise in engineering, humanities, medicine, natural and social sciences from over 100 academies, young academies and learned societies across Europe.

SAPEA is part of the European Commission's Scientific Advice Mechanism. Together with the Group of Chief Scientific Advisors, we provide independent scientific advice to European Commissioners to support their decision-making. We also work to strengthen connections between Europe's academies and Academy Networks, and to stimulate debate in Europe about the role of evidence in policymaking.

SAPEA is a consortium of five Academy Networks:

- Academia Europaea
- ALLEA: the European Federation of Academies of Sciences and Humanities
- EASAC: the European Academies Science Advisory Council
- Euro-CASE: the European Council of Academies of Applied Sciences, Technologies and Engineering
- FEAM: the Federation of European Academies of Medicine

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# Executive summary

SAPEA (Science Advice for Policy by European Academies) held a virtual expert workshop on 10th September 2020. Its purpose was to provide a critique by the wider expert community of the draft Evidence Review Report that informs the European Commission's Group of Chief Scientific Advisors. The Advisors have been asked by the College of Commissioners to produce a set of policy recommendations, contained in a Scientific Opinion, on the biodegradability of plastics in the open environment. The overarching policy question asked is:

> From a scientific point of view and an end-of-life perspective, and applying to plastics that biodegrade either in the terrestrial, riverine or marine environments, and considering the waste hierarchy and circular economy approach: what are the criteria and corresponding applications of such plastics that are beneficial to the environment, compared with non-biodegradable plastics?

The workshop followed the approach that is already well established by SAPEA. A keynote speaker made a presentation on the overall report. Two discussants then gave feedback on each of the main chapters, followed by the opportunity for open discussion.

The suggestions made by the invited experts are summarised at the end of each section in this report. The key points made were as follows:

- The report should put stronger emphasis on the future growth in plastics production and highlight the pollution problem that will be the consequence of it.
- The use of scientific and technical terms should be correct and consistent throughout the report. Examples of polymers given in the report need further consideration, with a focus on polymers that are environmentally biodegradable. The report could make clearer that conversion to $CO_2$ is the endpoint of microbial metabolism, and this should be the foundation of biodegradability.
- Degradation should be considered the least desirable option for plastics, particularly when taking into account the principles of resource efficiency or the environmental impacts from life cycle assessments that compare different end-of-life options. However, there are instances where biodegradable plastics could be a reasonable approach to adopt, such as where products are difficult or costly to retrieve. The value of biodegradable plastics is best reflected in the composting of waste streams, but this will require an expansion of composting infrastructures. Further examples of the potential applications of biodegradable plastics could be added to the report. The possible benefits of biodegradable plastic applications could be considered in relation to conventional plastics.
- It could be challenging to apply product testing across all environments, as it may need to be done for both conventional and biodegradable plastics. Simulation testing

is difficult, and testing on all products may not be required, but rather the focus could be on certain categories of materials and environments. 'Bulletproof' lab-based testing is needed as the foundation. A distinction could be made between those products where fast biodegradation is needed, and those where the biodegradation rate can be slower. The report's focus is on practical ways forward.

- The report should not imply that, simply because information is lacking, biodegradable plastics will fail. Instead, it could be said that more information is needed to complete the picture.
- More emphasis could be put on practices for handling biodegradable plastics, as well as their transfer to other environments. Risk assessment requires a multidimensional approach that emphasises both current and potential future risks.
- Some parts of the report could benefit from a more visual approach to presenting the information, as well as developing a more consistent narrative that focuses on the interplay between the physical and the ecological.
- Consumers are a heterogeneous group when it comes to certain behaviours such as purchasing, recycling and so on. The evidence shows that consumers are confused about biodegradable plastics, but so is the business sector.
- Biodegradable plastics should not be regarded as a given within the circular economy.
- Further reflection could be made on whether labelling is the answer to establishing biodegradable plastics in the market, or whether other means (e.g. pricing, intervention) could be employed.

Following the workshop, members of the SAPEA Working Group considered the feedback and agreed on the actions to be taken to address it. The draft Evidence Review Report was then revised, prior to undergoing formal peer review. The final version has been published as SAPEA Evidence Review Report number 8, and is available on the SAPEA website (https://www.sapea.info/topics/biodegradability-of-plastics/).

# Introduction

SAPEA's expert workshop is a vital part of the evidence review process. Its purpose is to provide critique by the wider expert community of the draft Evidence Review Report that informs the European Commission's Group of Chief Scientific Advisors. Feedback is given informally by the invited experts, offering constructive input for the SAPEA Working Group that is producing the report. It also helps to bridge from the evidence review stage to finalising the Advisors' policy recommendations (contained in a Scientific Opinion) for the European Commission. This workshop was also an opportunity to develop further the conclusions and evidence-based policy options in the Evidence Review Report.

Experts attended and gave their views in a personal capacity and not as representatives of their employer or any other organisation with which they are associated. Chatham House rules were observed, with no attribution to any individual. A list of attendees is given in the Annexes to this document.

Due to the travel restrictions made necessary by the COVID-19 pandemic, the workshop was conducted entirely online.

# Context

The Group of Chief Scientific Advisors provides independent scientific advice to the College of European Commissioners to inform its decision-making. The Advisors work closely with the SAPEA consortium, which conducts evidence reviews.

The scoping paper for the topic *Biodegradability of Plastics in the Open Environment* was published in December 2019[1]. The overarching question to be addressed by the Advisors is:

> From a scientific point of view and an end-of-life perspective, and applying to plastics that biodegrade either in the terrestrial, riverine or marine environments, and considering the waste hierarchy and circular economy approach: what are the criteria and corresponding applications of such plastics that are beneficial to the environment, compared with non-biodegradable plastics?

The SAPEA Working Group was asked to address a series of sub-questions for its evidence review. These were:

- How should 'biodegradable plastics' be defined? The following aspects should be addressed:
  - existing definitions and gaps, including not only polymers but additives etc.
  - testing standards and techniques which are used to define materials' biodegradation properties, according to the receiving environment
  - the timescale for biodegradation in the open environment: what is an acceptable timeframe for biodegradation in relation to environmental impacts, including under less favourable environmental conditions?

1 Available at: https://ec.europa.eu/info/research-and-innovation/strategy/support-policy-making/scientific-support-eu-policies/group-chief-scientific-advisors/biodegradability-plastics-open-environment_en

- What applications can be recommended for biodegradable plastics, compared to non-biodegradable plastics? The following aspects should be taken into consideration:
  - applications in relation to waste management: is there a tipping point between waste management and biodegradable plastics, and can the relevant environmental conditions or criteria be determined?
  - benefits versus unwanted effects, and unintended consequences, of the use of biodegradable plastics compared to conventional
  - different geographic and socio-economic contexts (for example, developing countries, level of waste management systems performance)
  - is there a specific case for agricultural plastics, such as mulches?
  - applications where biodegradation should happen rapidly, or after a longer term
- Which behavioural aspects play a role? What and how should we communicate about biodegradable plastics? The following aspects should be included:
  - the risks of the incorrect disposal of biodegradable plastics, such as the contamination of waste streams, litter increase
  - labelling/instructions that should be used to orient consumers; are these sufficient to avoid incorrect disposal; are there other policy instruments and incentives?
  - context-specific factors such as variances in behaviour, collecting systems etc.

In answering these questions, the Working Group was asked to focus only on plastics (not substitution materials), the open environment (not industrial composting facilities) and only consider home composting as a secondary priority.

# Report of the workshop

## Welcome and brief introductions

***Professor Ole Petersen, Vice-President, Academia Europaea***

The workshop was opened by Professor Ole Petersen, who welcomed all participants on behalf of SAPEA.

# Quick overview of the Scientific Advice Mechanism

*Professor Nicole Grobert, Group of Chief Scientific Advisors*
*Professor Ole Petersen, Vice-President, Academia Europaea*

Ole Petersen gave a short introduction to the SAPEA consortium, which conducts interdisciplinary evidence reviews as part of the European Scientific Advice Mechanism. Nicole Grobert then described the work of the Group of Chief Scientific Advisors and the reasons for taking up the topic *Biodegradability of Plastics in the Open Environment*. In 2017, the Advisors published a Scientific Opinion, *Food from the Oceans*, which raised the issue of marine plastics pollution. This initiated the preparation of a further Scientific Opinion on *Environmental and Health Risks of Microplastic Pollution*, published in 2019[2]. The European Commission made use of this report, which led to the commissioning of work on the biodegradability of plastics in the open environment. The aim is to produce a critical review of what is known, the uncertainties, whether biodegradable plastics can be beneficial alternatives to conventional plastics, and, if so, what the boundary conditions are for using them, the associated risks and challenges.

# Keynote presentation

## *Introduction*

In this session, an invited keynote speaker presented an overall assessment of the report, with initial observations on strengths, possible limitations and gaps.

## *Summary of the keynote presentation*

All plastics could be regarded as biodegradable, given enough time and the appropriate environment. However, the real challenge is to identify a plastic that biodegrades faster than conventional plastics. In the 1970s, researchers began to raise concern about plastics appearing in the oceans, and plastics pollution of the environment remains one of the main areas of research, as can be seen with microplastics, for example.

The keynote speaker addressed five main areas of comment on the report:

- **Growth in plastics.** If we extrapolate the data, based on the use of plastics and population growth, we arrive at 960 million metric tonnes by 2050. However, some sources predict even larger increases. The NGO GRID-Arendal quotes 1800 metric tonnes by 2050[3] and the Ellen McArthur Foundation expects 1100–1200 metric tonnes

2 All Scientific Opinions are available at: https://ec.europa.eu/info/research-and-innovation/strategy/support-policy-making/scientific-support-eu-policies/group-chief-scientific-advisors_en#scientific-advice

3 See: https://www.grida.no/

by the same year[4]. Growth will not be uniform across the world, as it is dependent on production and use in each region. Lebreton and Andrady (2019) extrapolated the data on mismanaged waste generation and population size. Most of the US and Europe have relatively stable levels of mismanaged waste, but the real 'hotspots' will be China and the rest of Asia, the Middle East and Africa. Waste will end up in the environment, where it has serious impacts. Plastics production imposes an increased demand on non-renewable fossil fuel, creating a pollution load on air and water. There are also potential biological effects of microplastics on the environment, causing damage. Litter and waste management are a particular problem; 19% of packaging waste in Europe comes from plastics. Globally, there are 275 million tonnes of plastic waste generated each year, most of it ending up in coastal areas.

- **Degradation is the least desirable option for dealing with plastics.** Plastics should be recycled or reused in some way. Biodegradation does not provide the benefits of energy recovery, but instead leads to the production of $CO_2$ and, potentially, the release of toxic compounds. Accelerated degradation is therefore not a desirable strategy. However, there are specific instances where the use of biodegradable plastics might be a reasonable approach. The first is litter that is too small or expensive to collect or recycle. Examples include marine microplastics, fireworks debris and balloons of different types (e.g. weather balloons and celebratory balloons). The second is agricultural plastics that are too labour-intensive to collect. The third is fishing equipment (e.g. dolly rope, crab pots) that are never recovered and trap sea life. The final instance is the controlled release of fertilisers in turf management and agriculture.
- **Bio-based and fossil-based polymers.** Polymers present a complex picture, as some polymers can be very similar to each other. The term 'bio-based' can be problematic, as there are three basic categories. The first is biopolymers, made by natural materials; some are not very biodegradable, e.g. lignin. The second is bio-derived polymers that are made by living organisms and then modified chemically; not all are biodegradable. The third is bio-based, made with feedstock derived from biomass rather than fossil fuels, and these are not necessarily biodegradable.
- **Abiotic biodegradation.** The process of abiotic biodegradation leads to increased oxygen concentration, making biodegradation easier. During the course of abiotic degradation, some surface erosion takes place. Degradation is then often restricted to the surface, leading to abrasion and resulting in micro- and nanoparticles. For example, the experiment done on coffee cups by Lambert and Wagner (2016) found a large amount of microplastics.
- **Biodegradation is generally regarded to involve three steps.** In the first step, an active biofilm is formed, abiotic biodegradation takes place, microbes are attracted to the surface, and microorganisms secrete enzymes. It may be reasonable to combine

4 See: https://www.newplasticseconomy.org/

steps 1 and 2. Firstly, the polymer is affected by chemistry, crystallinity, geometry (particularly the size of the surface) and additives. Any claim of biodegradability for a polymer must refer to the environment in which it biodegrades. There should therefore be a separate step 1. Microorganisms must be in contact with the surface to have a high enough concentration of separate enzymes. For biodegradation to happen, it needs a succession of different microbial communities and a discrete step is needed for forming a biofilm. Environments are complex. Taking the ocean as an example, we have to consider the amount of available oxygen, UV radiation, temperature and fouling. In essence, plastics are required that biodegrade at a measurable rate in a given environment. We can use benchmarks from the open environment, for example, oak leaves, to evaluate degradation.

### *Discussion*

In the brief discussion period, there was a question on whether biodegradable plastic may serve as 'junk food' in the marine environment. The keynote speaker responded that the primary concern is around potential toxicity. In an anoxic environment, there can be a high level of anaerobic degradation, which will release considerable quantities of methane and hydrogen.

### *Summary of recommendations*

- The report should place greater emphasis on future growth in the production and use of plastics, with the consequential problem of pollution.
- In the view of the keynote speaker, degradation is the least desirable option for plastics, but there are instances where biodegradable plastics could be a reasonable option.
- The term 'bio-based' polymers can be problematic, so could be considered further.
- Abiotic degradation can lead to negative impacts, such as micro- and nanoplastics.
- Biodegradation is often seen as involving three steps, rather than two.

## Setting the scene (Chapter 2 of the Evidence Review Report)

***Dr Michael Sander, chapter lead***

### *Introduction*

The aim of this chapter is to provide the non-expert reader with generalisable concepts of plastics biodegradation, drawing on the literature. The chapter seeks to offer an adequate assessment of the technical aspects, whilst not distracting from the key arguments. The chapter structure covers the following: definitions; plastic biodegradability as a systems

property; biodegradation as a step process; and an overview of critical polymer and environmental characteristics.

### *Summary of comments by the first discussant*

The chapter should make the correct and consistent use of terms throughout, with reference to the most recent IUPAC definitions. Polymer names are used (for example, short names) that are not defined and these need to be described appropriately. When using an additive, the correct term is 'mixing' and not 'blending'. The report's definition of plastic biodegradation, with its focus on microbial activity, excludes biomedical applications and biomaterials. Some biomaterials are not biodegradable in the open environment.

The examples of polymers appear to be random and not chosen logically; additional polymers should be mentioned. Thermoplastics are not new; this should be corrected. Table 2.1 (*Examples of representative members of different classes of polymers*)[5] should be edited for errors, such as chemical structures. The structures should be more general, rather than precise.

If the focus is on environmentally biodegradable polymers, we must be careful about what we class as biodegradable polymers. If all organic constituents must break down to $CO_2$, then we exclude lignin-type polymers, which break down to humus, which is a fossil fuel. This definition must consider polymer architectures and blends adequately.

The discussant questioned the so-called 'traditional' view of biodegradation as an undesirable process that still holds today. The term 'societally acceptable' should be changed to 'environmentally acceptable'.

On Figure 2.3 (*Overview of steps involved in plastic biodegradation*), precise wording is needed. The discussant agreed that it should be a two-step biodegradation process. In place of the term 'depolymerisation', 'fragmentation' should be used, which is the commonly accepted term.

The measurement of $CO_2$ to show biodegradation is problematic. For example, lignin converts to humus, which may not produce $CO_2$. Some $CO_2$ becomes part of the biomass, some of it in soil, or minerals. For different polymers, we do not know how much is converted to $CO_2$ and how much to other substances.

### *Summary of comments by the second discussant*

In considering the biodegradation of plastics in the open environment, we are asking the question, 'can microorganisms present in that disposal environment utilise these carbon

5 Table 2.1 was changed in the final version of the report to Figure 2.2.

substrates as food and can they do it completely in that environment?'. The biology of how they do this is already well-established. $CO_2$ is the result of the microbial metabolic process.

The discussant was pleased with the definitions and arguments presented in the chapter discussion; he agreed with the summary points. He suggested substituting the word 'extensive' for 'complete' microbial utilisation. The report should document that $CO_2$ conversion is the endpoint of microbial metabolism. Biodegradation as a system property is important; it combines both the material and its receiving environment. The rate, extent and comparison of biodegradation are vital. The IUPAC definition of bio-based polymer needs to be replaced by an updated version, which is the one in the glossary.

The chapter has a clear definition of biodegradation but should consider using microbial 'utilisation', not 'conversion'. The end point is $CO_2$, and this must form the foundation of biodegradability. We cannot have a 'one-size-fits-all' approach, so the report could make clear it does not apply to biomedical applications but only to the open environment. The extent, the time period and the type of environment should all be specified. Inorganics need a different set of criteria and requirements. The discussant agreed that words like 'inherent', 'ready' etc should be excluded.

The value of biodegradability is best reflected in the composting waste stream; plastics that biodegrade under composting conditions are very useful. Currently, much of our waste goes into landfill and open dumps, and composting infrastructures must double in size to cope with increased quantities.

Bags labelled as 'biodegradable', but that do not fully biodegrade when composted, are falsely labelled. $CO_2$ must always be the endpoint. Regarding the statement made on the amorphous part of the material, it depends on the glass transition temperature (Tg), as glassy domains slow the rate of biodegradation.

In conclusion, biodegradable plastic is not a solution to littering and leakage of waste into the environment. However, it is an important attribute so that leaked materials have a short life. Their value in composting is a significant attribute.

### *Response and discussion*

Dr Sander thanked the discussants. A further remark was made that there are bacteria that may convert plastic to substances other than $CO_2$; we must be clear whether this makes the plastic biodegradable, or not.

### *Summary of recommendations*

- The use of terms must be correct and consistent throughout the report.

- Examples of polymers need further consideration, with greater detail provided.
- The chapter should give greater attention to polymers that are environmentally biodegradable.
- Measurement of $CO_2$ as the sole measure for biodegradation could be problematic, given that biodegradable polymers may break down into other substances, not just $CO_2$. The report should make clear that conversion to $CO_2$ is the endpoint of microbial metabolism; this should be the foundation of biodegradability.
- The value of biodegradable plastics is best reflected in the composting waste stream, with an increase required in the volume of composting infrastructures.

## Applications of biodegradable plastics: considerations relating to environments (Chapter 3 of the Evidence Review Report)

***Professor Richard Thompson, chapter lead***

### *Introduction*

Chapter 3 looks at possible applications of biodegradable plastics, providing general criteria that serve as a guide towards applications where there might be benefits compared to conventional plastics. The chapter also looks at the receiving environment and what happens if plastics end up where they should not.

Biodegradable plastics should be considered within the context of the waste hierarchy. The focus should really be on a reduction in the use of materials, rather than making plastics biodegradable. In the chapter, we give examples of where an application might have benefits if it is biodegradable. The chapter also considers societal benefits, as well as trade-offs.

The chapter looks at the possible abuse of biodegradable plastic applications. Biodegradable plastics are not a solution to littering; in this, we consider carrier bags and single-use packaging. Finally, it looks at labelling and the possible distortion of messaging to users. The understanding of 'fake' biodegradability is not always obvious to a policymaker or a consumer.

### *Summary of comments by the first discussant*

The discussant agreed with the keynote speaker's point about the higher future growth in plastics production and pollution. He particularly liked the description of biodegradable plastics as a system property. He liked Box 3.1 (*Potential considerations in making a holistic evaluation in terms of the waste hierarchy and potential environmental benefits or risks*), which provides criteria for evaluating potential biodegradable plastics.

The discussant put forward a number of recommendations. In Table 3.1 (*Alternative end-of-life disposal scenarios for biodegradable plastics and the potential for success*), recycling streams should be considered in a more systemic way; for example, by making appropriate use of excellent sorting technologies so that biodegradable plastics can then be identified easily.

The discussant recommended the addition of more potential applications, perhaps naming them but not going into too much detail. Examples include trimmer lines, brushes for pavement cleaning, geotextiles, other agricultural films such as silage wrapping, and coffee capsules. He questioned whether stickers (example (d) in the report) should be banned, instead of being made biodegradable. We should look holistically at bags for compostable food, given that we have composting facilities. Bags can be designed to cope with variations in local composting facilities.

Labelling is important. However, the points made in Chapter 3 should be shortened and aligned with those in Chapter 6.

Oxo-degradable plastics should not appear in Chapter 3. They are mentioned in Chapter 2, which is sufficient.

There are lots of false claims made on biodegradability, but these should not be muddled with the discussion around truly certified compostable materials. The presentation of results from scientific evaluations of biodegradation should clearly point at the false claims, rather than discussing the poor degradability of materials labelled 'compostable'.

The discussant did not agree with the point that if materials biodegrade slowly, they are not likely to have benefits over conventional plastics; rather, biodegradables are better because they will degrade more quickly than conventional materials.

Finally, on the carrier bag example, any indication of doubt (as in 'This may be because the product was inappropriately or inadequately tested and /or labelled') should be discounted.

### *Summary of comments by the second discussant*

The discussant appreciated the holistic approach to determining what might work and the 'what ifs', rather than listing applications that may or may not be suitable; this would be very challenging. He also agreed that the advantages are reduced when the product ends up in an environment for which it was not designed. Generally, more emphasis could be given to the perspective that the advantages of biodegradable plastics may be small, yet we should see them in relation to the alternatives. In most cases, biodegradable plastics are not worse than conventional ones and may be better. The risks could therefore be put in comparison to conventional plastics. There is a real

problem on how to deal with littering; biodegradable plastics could help, but not always, as there are environments where biodegradation will not take place.

Table 3.1 (*Alternative end-of-life disposal scenarios for biodegradable plastics and the potential for success*) may be difficult to understand, especially the columns. For example, do the negative indicators imply that biodegradable plastics are worse than the conventional plastics they replace?

On Box 3.1 (*Potential considerations in making a holistic evaluation*), the discussant liked the summary of considerations. However, he disagreed with Point 5 (*Considerations require accredited testing and certification to assess biodegradation across all relevant receiving environments*). He understood the sentiment behind it, but if a product ends up in an environment for which it was not intended, why should it be tested across all such environments? It may be seen as unfair to the products, as conventional products would have to be similarly tested. Regarding applications where biodegradable plastics may bring benefit, the danger with being too general is that there are a lot of examples that are not considered. He recommended increasing the list of examples, without going into detail. He also missed a reference to products intended for a specific environment (such as in agriculture), where the plastics are hidden. Examples are seed coatings and fertiliser coatings for controlled release, as well as teabags. Oxo-degradable plastics are not appropriate for this chapter but could be mentioned somewhere, most logically in Chapter 2, where they are already addressed to some degree.

### *Response and discussion*

Responses were given to some of the points made. When comparing biodegradable with conventional plastics, the Working Group contended that if something biodegrades in 200 years rather than 2000, then the advantage to the environment is marginal. The justification for an application is that it will biodegrade in an appropriate timescale. If care is not exercised, a loosely-defined approach could be misused, and the actual benefit may be small.  It could even lead to the proliferation of plastics in some cases, making the situation worse.

Some of the text on labelling could be moved, although the issue covers aspects beyond the social sciences.

The Working Group also has very strong concerns about oxo-degradable plastics; the issues with these are articulated from a technical perspective in Chapter 2. So that these concerns are not lost when we discuss applications, the Working Group decided to retain the reference to oxo-degradable plastics in Chapter 3 and refer back to Chapter 2.

In the discussion, one expert mentioned that biodegradable plastics used as a component in products could be an asset, such as teabags and toilet paper. Soluble plastics, like those used for dishwashing tablets, for example, should be biodegradable.

### *Summary of recommendations*

- Recycling streams could be appraised in a more systemic way.
- More potential applications of biodegradable plastics could be added, without going into too much detail.
- The discussion on labelling could be shortened in this chapter and aligned with Chapter 6.
- Oxo-degradable plastics should not be covered in this chapter, but rather in Chapter 2.
- The potential benefits of biodegradable plastic applications could be considered in relation to conventional plastic.
- Table 3.1 might be revised, as it is difficult to understand.
- Product testing should not necessarily be applied across all environments, as it would need to be done for both conventional and biodegradable plastics.

## Testing, standards and certification (Chapter 4 of the Evidence Review Report)

***Dr Miriam Weber, chapter lead***

### *Introduction*

This chapter is trying to explain the evidence but also highlight knowledge gaps and suggest solutions to them.  It makes clear that it is imperative to come up with a testing schema for biodegradability. It then summarises how to assess biodegradation rates under different environmental conditions. It is vital to model lifetimes as part of a Life Cycle Assessment (LCA) and to agree on how to assess the effects on the environment. We need specifications on the open environment, be it on the level of ecosystem, habit or specific conditions; how to do this has not been clarified within the scientific community. We must develop those standards that are missing, and a catalogue of criteria for test selection, as well as the necessary datasets, so that LCA can be applied.

### *Summary of comments by the first discussant*

In the chapter, radio-label testing is presented as a solution to how carbon is behaving, but C14 cannot be used to distinguish between biomass and residue. Throughout the report, there is a duality between controlled laboratory testing (which is needed for

reproducible results) and simulation tests, to show whether biodegradation happens under real conditions. In the view of the discussant, we have to be careful what we ask from each product, as there are hundreds of products that could be biodegradable. Simulation testing is challenging, so we need 'bulletproof' lab testing that could be extended to simulation testing to show that biodegradation takes place. There are not more than fifteen families of biodegradable plastics, so we should not require testing on all products. Simulation tests are useful, but not for each and every product. Instead, we should distinguish between two types of product; materials where we want rapid biodegradation (in a few weeks) for products of a short lifespan, and those where biodegradation can happen over the course of a few years for products of a longer lifespan. We should also consider reference materials that are close to the product concerned, and similar to plastic. The role of different microorganisms is important, not only enzymes but others, such as fungi, as it can lead to different biodegradation results across a range of environments.

### *Summary of comments by the second discussant*

The second discussant agreed with the points made by the first. The chapter is an extensive overview and done well. It demonstrates that a lot of data is still unavailable. It explains how to extrapolate data to open environments and also how to assess impact (which is also covered in Chapter 5). It could give more emphasis to the fact that information is also missing for conventional plastics, which makes it even more difficult to say which solutions will work. The chapter gives the impression that biodegradable plastics will fail because we do not know enough about them. Instead, it would be fairer to say that it is difficult to assess the advantages and that more information is needed for the total picture. It will be impossible to design tests that are applicable across all open environments, so tests will be required for certain categories. These will have to be limited, for practical reasons, but how far should we go? The report goes quite far in its recommendations. This may not be necessary because we know biodegradation progresses quite slowly in some environments. Where is the boundary of what is needed as a method of measurement? The report is very ambitious and it may need to skip some things, for practical reasons.

### *Response and discussion*

Miriam Weber thanked the discussants. She confirmed that the report would be clearer about the lack of data for all polymers in the open environment and not give the impression that biodegradable polymers could fail because of a lack of data. In terms of how far the recommendations go, the Working Group had been asked to identify 'low-hanging fruits', from the cheapest to the most expensive testing regimes. It is a question for society to consider what is acceptable and how much testing is enough. These are matters that should be taken up by another expert group in the future.

A member of the Working Group asked the first discussant about an intermediate rate of biodegradation. The discussant responded that he had been one of the authors of a publication that addressed this; they had slowly biodegraded a polymer at different temperatures, finding that the law of Arrhenius is applicable. 90% biodegradation will be achieved under optimal conditions, with the same at a different temperature. However, it is imperative to know the material very carefully and it requires an elaborate testing scheme, with details of the sample being tested. The view was expressed that in the history of biodegradation tests, the measurement endpoint has always been that the material does not persist. Another expert remarked that one method mentioned is changing molecular weight. However, this is not the proof of biodegradation. In surface degradation, we do not expect a change in molecular weight. Biodegradation is defined not only by a change in molecular weight but also a change in mechanical properties and a decrease in mass. The first discussant concluded that we need precise test methods and specifications, not relying on definitions which can be misused. Regulation should be based on this approach.

### *Summary of recommendations*

- Simulation testing is challenging and testing on all products may not be required, but rather a focus on certain categories of materials and environments. 'Bulletproof' lab-based testing is needed as the foundation. We should distinguish between those products where fast biodegradation is needed, and those where the biodegradation rate can be slower. The report's focus is on practical ways forward.
- The report should not imply that, simply because information is lacking, biodegradable plastics will fail. Instead, it is preferable to say that more information is needed to complete the picture.

## Ecological risk assessment (Chapter 5 of the Evidence Review Report)

***Dr Gunhild Bødtker, chapter lead***

### *Introduction*

Chapter 5 looks at risk assessment in the context of biodegradable plastics. The chapter contains a section on ecotoxicology, including microbial ecotoxicology, together with consideration of the potential impact of biodegradable plastics on the environment, based on what is known regarding conventional plastics. In assessing the potential risks of biodegradable plastics, we look at biodegradation rates and the potential ecological risk, according to what is known from the literature. We also consider possible long-term consequences and recovery. The chapter concludes by outlining a preliminary risk assessment approach, along with a list of knowledge needs.

### *Summary of comments by the first discussant*

The discussant noted that differences in practices in handling biodegradable plastics can have a knock-on effect on biodegradation. For example, particle shape and size could have an increased impact on how it biodegrades. She also felt that more emphasis is needed on the potential for products or fragments to be transported to other environments. Agricultural plastics, such as mulch film fragments, are one example of this. The section on risk assessment principles is very useful, but it could be more visual, so that it stands out (for example, by using boxes, tables etc). Regarding the dosage, the current low level of biodegradable plastics production assumes the dosage is lower but, conversely, there could be a higher potential for some of these plastics to enter the environment. There is also a higher risk that they will fragment into microplastics. Risk assessments need to be specific to the environment, and it is also possible that plastics could be transferred to other environments (e.g. in the case of agricultural plastic). It would be useful to have a short section on the risks of additives, in the same way that conventional plastics are covered. Regarding studies in soil environments, the report should make clear whether any conclusive results have been found, whether there are any negative effects and what these initial studies point to in terms of what we should be testing for, and where. Regarding the discussion on conventional versus biodegradable plastics, and in the context of cold environments, it needs more detail on the release of particles. For example, biodegradable agricultural mulch film is usually ploughed in and not rolled up (as conventional plastics are). There are a lot of unknowns in cold environments, and fragments may stay in the soil for longer. There is a geographical context to the conventional versus biodegradable debate, as well as in the practices and functions of biodegradable plastics. For example, might we be releasing more persistent products into the soil? There could be more said in the report on other types of agricultural products, such as seed coatings and controlled release fertilisers. The chapter could also consider the issue of aesthetic damage to the environment and say more on visual impacts, which could be a socially negative aspect. Figure 5.2 (*Benefits versus risks*)[6] would be good as a visual; it could be put on two axes to make it easier to understand. Some colour coding would also be useful. The concluding summary is quite repetitive of what is said at the start of chapter, so could be expanded further.

### *Summary of comments by the second discussant*

The discussant remarked that the comparative approach between conventional and biodegradable plastics is good but pointed out that the state-of-play for conventional plastics is still inadequate. It makes the benchmark fragile in some of its aspects, as conventional and biodegradable plastics have drawbacks in different ways. The risk assessment should hold onto a multidimensional approach, as there are trade-offs

6 This figure was later deleted from Chapter 5 and replaced by explanatory text.

when it comes to geographies, temporal scales, social and ecological contexts. This echoes some of the messages in Chapter 3. This chapter warrants making a clearer contrast between the situation now and potential future innovations. There could be new hazards, particularly with an increased reliance on biodegradable plastics, in addition to the effects of new exposure to old hazards. Policy requires the integration of some of these risks, rather than dealing with them separately. The current risk assessments are well equipped for some of these new aspects, but poorly equipped for others. A more policy-flavoured text would be helpful; this is about wordsmithing rather than a radical change to the chapter. The opening policy points are framed very scientifically and may not be understood by policymakers. For example, instead of 'standardisation', talk about 'regulation and monitoring'. The chapter puts a lot of emphasis on the science-policy interface when it comes to linking food, environment and health; this can be drawn out more. When talking about emerging risks, the chapter could talk about precaution, education, environmental monitoring. Failures of implementation could address infrastructure and industrial policy. These policy contexts could be signalled early and cross-referenced to other chapters. An infographic could be a good way to lead the reader through the story. Plastic is seen as both the physical and the ecological; it would be preferable to change the motif of the text so that this connection comes through. Chapter 2 does this well. Consistency in the use of language will make the chapter sparkle. It requires blunt messages; people are becoming aware of the macro risks of microplastics, for example. Risk assessments for conventional plastics are stretched already, and there is a meta question of how risk assessment thinks much more systemically about risk itself. There is an opportunity for cross-links and cross-references throughout the document (e.g. Figure 2.3) and the text needs a roadmap to guide the reader through.

### *Response and discussion*

Dr Bødtker thanked the discussants. She agreed that it was difficult to compare between conventional and biodegradable plastics, when so little is known even about conventional plastics. There are challenges in reaching conclusions, based on the published studies. She agreed that more should be said about fertilisers and mulch films, and to be clearer about the transportation of plastics. It is challenging to go very deep into this, given that much more research is needed to draw conclusions. The second discussant praised Section 5.5.1 (*Risks on ecological and ecosystem level*) as a really useful piece of text.

With reference to Section 5.5.2 (*Toxicological risks of additives*), the comment was made that the chemical compounds named are not those added intentionally. Additives could be addressed further, as there is leaching of low molecular additives. The chapter should consider stabilisers, lubricants etc that are added to biodegradable plastics, as some of these may not biodegrade. Another comment was that the chapter focus is on ecotoxicology but did not cover aspects like soil function. Gunhild Bødtker

responded that it is mentioned in the chapter, and there are examples of studies of crop yields. However, there are not many long-term studies on biodegradable mulch. It is a concern, as there is a danger of biodegradable mulch film accumulating over time. The accumulation of conventional mulch already affects the soil, and the consequences can be the same with biodegradable mulch, particularly if it does not biodegrade before new mulch is added. The expert followed up by asking if it would be possible to detect biodegradable plastic in environmental matrices in an organised way, as a way of advising policymakers.

### *Summary of recommendations*

- More emphasis could be put on practices in handling biodegradable plastics, as well as their transfer to other environments.
- Some parts of the chapter could benefit from a more visual-based approach to presenting the information, such as an infographic. The use of more policy-oriented language and terminology could be helpful. An underlying narrative that speaks to the interplay between the physical and the ecological would draw the chapter together.
- Further mention could be made of certain risks, and the risk assessment requires a multidimensional approach that emphasises both current and potential future risks.

## Social, behavioural and policy aspects (Chapter 6 of the Evidence Review Report)

***Professor Wouter Poortinga, chapter lead***

### *Introduction*

Chapter 6 tries to consolidate the evidence from the social sciences on how biodegradable plastics are perceived and used by different societal actors. The chapter is based on an extensive literature search, with about 150 scientific papers considered for this chapter. The focus of the chapter is on consumers, where most of the literature was found. Many of the applications covered are related to packaging. It is important to note that many of the definitions in the social sciences literature do not necessarily align with technical usage of the terms. Nonetheless, those writing this chapter had tried to be consistent in the use of terms. The group sought to place the chapter within the context of the circular economy, although there is little published on waste management and related topics within the social sciences. It also considered the diffusion of biodegradable plastics as a new technology but there is little published evidence on this either. Policy options in the chapter are mostly focused on the social and behavioural effects of policies. The authors found positive attitudes and perceptions, mostly around the word 'bio', but also widespread confusion about the terminology. There is a mismatch between

attitudes and behaviours. They also looked at various unintended consequences, such as economic, environmental etc. Labelling is covered in the chapter, but it is not considered a panacea. It provides the provenance of products and disposal options, but labelling is not clear on end-of-life functionality. More labelling and information are not necessarily beneficial, as it adds to the existing confusion.

### *Summary of the first discussant*

The chapter is as comprehensive as it can be at this present moment. The focus on consumers is right because that is where the evidence base is. However, business is also asking same questions and B2B (business-to-business) needs to be included or at least the report should say that businesses are having the same conversation. Businesses do not know what they are buying and are as confused as the consumers. Terminology is often meaningless for communication purposes. There is too much focus on the term 'bioplastic'; it is not a good term so should not be used. It looks as though terms are being used interchangeably. The report says that bioplastics are difficult to recycle but that is only true for some plastics. When it comes to communication, the subtext is that their use is for composting. However, what about plastics that are supposed to be biodegradable in the open environment? Do we inform consumers on that, or will they litter more as a result? The consumers' willingness to pay for 'bio' products does not mean that they are right because they hold that view. 'Bio' does not necessarily mean 'better' and it is a case of perception versus reality. Regarding the circular economy, it is not a given that these products are part of the circular economy, particularly within the open environment. It is more of a linear pathway. On communication and labelling, in California it is forbidden to use the word 'biodegradable' unless it can be scientifically proven; this is an effective measure.

### *Summary of the second discussant*

A good job has been done at collecting and combining literature from diverse research areas. Regarding consumer decisions to buy biodegradable products, the chapter should clarify whether they are buying biodegradable packaging or the product itself. For example, is the consumer buying the yoghurt or the pot it is in? The chapter could also consider the differences between offline and online shopping. When it comes to transparent information about the benefits of biodegradable plastics, clear messages do not always exist, and the real picture can be complex. It is difficult to establish systems for the recycling of biodegradable products. Regarding farmers, the chapter might also mention gardens and horticulture, for example, the use of biodegradable pots in greenhouses. On pricing, the discussant agreed that consumers want lower prices but there is heterogeneity amongst consumers. Environmentally aware consumers know that prices will not be lower for the 'best' products. We do not understand many aspects of recycling behaviours and we do not know what drives people in a certain way. On the

rebound effects, what about moral licensing effects? Regarding by-products, there are often established applications for these products already, leading to a new set of trade-offs and competition between application areas. The discussant declared that he is not a fan of labelling. Are there other ways of communicating, and does digitisation help? The consumer cannot have the job of sorting out so many different types of plastic; it requires clear certification and standardisation. Unfortunately, labelling can lead to even more chaos. Price is more likely to have an impact than information, along with other intervention tools.

### *Response and discussion*

Wouter Poortinga thanked the discussants and he agreed with most of the points put forward. He noted that one chapter had to cover the whole of the social sciences. The chapter group is small and further expertise would be needed to address all issues. He agreed with the point made on 'bioplastics' but pointed out that a lot of the literature is imprecise. He agreed on the point about willingness to pay and the comment on packaging versus product. Consideration of online versus offline is relevant but no literature had been uncovered. Regarding heterogeneity among consumers, the chapter group was aware of it, but there is a complexity of studies relating to different countries, actors etc.

A comment was made about the overemphasis on attitudes and choice, as opposed to the reality of economic constraints for many people, and the widening gap between the middle classes and the poor. The word 'consumer' is not specific enough. Instead, consider issues like gender. Household waste is handled by women, as part of unpaid labour. Most teachers are women at primary school level, so education falls on women. Wouter Poortinga indicated his awareness of attitudes and choices. However, the social sciences are incredibly broad. Areas like sociology and business should be part of the chapter, but these areas of expertise are not represented.

Another expert agreed that the chapter was very impressive. However, this report is intended to be a European study and we have many different waste collecting systems throughout Europe. It is difficult to put this on a European level, given the challenge of drawing conclusions from single studies. A further expert pointed out that the price of biodegradable plastics may fall as production volumes increase.

### *Summary of recommendations*

- The report could mention that businesses are similarly confused in the way that consumers are about biodegradable plastics.
- Biodegradable plastics are not a given within the circular economy, the current pathway is a linear one.

- The chapter could emphasise the heterogeneity of consumers when it comes to certain behaviours, such as purchasing certain products, recycling plastics etc. The chapter could also consider variables such as online and offline shopping.
- The example of plastic use in gardening and horticulture should be considered.
- Further reflection could be made on whether labelling is the means of establishing biodegradable plastics in the market, or whether other means (e.g. pricing, intervention) could be employed.

# Conclusions and evidence-based policy options

***Professor Ole Petersen***

## *Introduction*

This chapter was yet to be written, and therefore the session should serve as input to its drafting.

## *Summary of the first discussant*

The discussant explained that she had gone back to the scoping question and looked at it from a regulatory approach. This requires us to consider the available scientific evidence for present, proposed or new regulation, and/or exceptions to the regulation. Is there scientific evidence for any environmental benefits and do these justify specific regulation and/or exemptions? The discussant returned to the governing principles on environmental regulation in the EU and looked at the reports on microplastics that had already been mentioned. The principles cover the prevention of pollution, suitable precaution, proportionality and 'polluter pays'. We should also consider the level of risk or harm, circularity, the waste hierarchy and safety.

The policy options could thus include:

- Research to fill in knowledge gaps, but meanwhile apply the Precautionary Principle when making exceptions or regulation.
- The Prevention Principle and the development of 'essential use' criteria for applications; is it essential to use biodegradable plastic for this product and this use? Disposal is the last option in the waste hierarchy; the emphasis is on recycling or reduce. Look at 'essential use' as a concept.
- Regulation: we already have regulation. In REACH[7], polymers are still exempted from registration as a chemical substance. The view is that polymers are of low concern. Their exemption should be reviewed. Clarity of definition is required for regulation. The discussant agreed that there is a lot of confusion amongst consumers and business.

7 See: https://ec.europa.eu/environment/chemicals/reach/reach_en.htm

Exemptions for biodegradable plastics in existing and proposed regulation, such as in the SUP directive, should be based on scientific evidence to prevent pollution by biodegradable plastics.

- International harmonised standards: a global treaty should be considered.
- Innovation: consider applications where microplastics occur through wear e.g. tyres and textiles. Could technology help here? This is about eco-design and safety-by-design approach.

### *Summary of the second discussant*

The second discussant had taken a comprehensive look at the main questions and sub-questions, as well as policy options chapter-by-chapter. In his presentation, he went through this in further detail. He emphasised that the structure of the report's text should be harmonised. He was satisfied that there is certainly evidence within the text that could be developed into policy options. Some of the options are potentially conflicting, such as the usefulness (or not) of labelling, and some options are still to be developed. The discussant had looked for an overall message for the report. He suggested it might be 'Conventional plastic cannot be replaced by biodegradable plastics as a viable strategy to solve the plastic pollution problem. In certain applications, biodegradable plastics may have environmental advantages when compared to conventional plastics.'

### *Response and discussion*

The Working Group Chair expressed her view that the required timescale for the disappearance of a plastic is not a question for a scientist but rather a policymaker. One of the invited experts thought it necessary to be future-focused and that time rate and environment are the critical criteria. Another discussant emphasised the comparison with non-biodegradable plastic; if something is not known, do not treat it as an exception. Another expert agreed, saying that conclusions have to be reached on a product-by-product basis, such as agricultural mulch films. Comparisons should be made with conventional plastics but also consideration given to manufacturing something in a material other than plastic. The Working Group Chair emphasised that knowledge was constantly shifting in this field. The first discussant explained that in REACH, polymers are defined as a group, and hence biodegradable plastics are treated as a polymer, like conventional plastics. There would have to be exemptions or criteria for their exclusion, but these are not well-defined. One expert remarked that biodegradable plastics would need to be defined, depending on their application. A certain polymer might be good for mulch film, but not for something else. In future, the definition of biodegradation should be application- and environment-focused. A member of the Working Group agreed, adding that the possibility for future development remained open. We should not use a lack of knowledge as a way of treating biodegradable plastics in the same

way as conventional plastics. An expert added that Chapter 2 captures biodegradability correctly. If something ends up in the environment, we know whether that material will be removed by microorganisms or not, through testing. Any biodegradable product should be completely removed by microorganisms in that environment, and it must be possible to prove this. The microorganism should be able to use the carbon substrate as food; this is fundamental biology. The endpoint is $CO_2$. The definition is Chapter 2 is constrained by the environmental perspective; to claim biodegradability of a plastic, it must be demonstrated that it is completely removed. There should be no compromise on this. The principle is the same in composting; the biodegradable plastic should be removed by microorganisms. The final statement by a discussant was that REACH should include all polymers, both biodegradable and conventional, and we should look at the environmental effects of all polymers.

### *Summary of recommendations*

- Policy options could include research to fill in knowledge gaps; the development of 'essential use' criteria for applications; the inclusion of polymers within REACH; clarity of definitions that can be applied to regulation; international harmonised standards; innovation through eco-design and safety-by-design approaches
- The structure of the report should be harmonised, with a strong underlying key message, such as: Conventional plastics cannot be replaced by biodegradable plastics as a viable strategy to solve the plastic pollution problem. In certain applications, biodegradable plastics may have environmental advantages, when compared with conventional plastics.

# Annexes

## References cited

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## List of attendees

### *Invited experts*

- Professor Seema Agarwal, APL Professor, University Bayreuth
- Professor Anthony Andrady, Adjunct Professor, North Carolina State University
- Dr Claus-Gerhard Bannick, Head of Unit, Federal Environment Agency Berlin
- Dr Sarah Cornell, Associate Professor, Stockholm Resilience Centre
- Simon Hann, Principal Consultant, Eunomia
- Professor Myra Hird, Full Professor, Queen's University Canada
- Dr Rachel Hurley, Researcher Scientist, Norwegian Institute for Water Research
- Dr Stephan Kabasci, Head of Department Circular and Bio-Based Plastics, Fraunhofer Institute
- Esther Kentin, Lecturer, Leiden University
- Professor Klaus Menrad, Chair of Marketing and Management of Biogenic Resources, Weihenstephan-Triesdorf University of Applied Sciences
- Professor Ramani Narayan, MSU University Distinguished Professor, Michigan State University
- Dr Maarten van der Zee, Senior Scientist, Wageningen University & Research
- Dr Bruno de Wilde, Lab Manager, Organic Waste Systems (Belgium)

### *SAPEA Working Group*

- Professor Ann-Christine Albertsson (Chair)
- Dr Gunhild Bødtker
- Professor Antal Boldizar
- Professor Tatiana Filatova

- Professor Katja Loos
- Professor Wouter Poortinga
- Professor María Auxiliadora Prieto Jiménez
- Dr Michael Sander
- Professor Jukka Seppälä
- Professor Richard Thompson
- Dr Miriam Weber

### *Group of Chief Scientific Advisors*

- Professor Nicole Grobert

### *European Commission (observers)*

- Dr Werner Bosmans, DG Environment
- Dr Blagovesta Cholova, SAM Unit
- Silvia Forni, DG Environment
- Jacques Verraes, SAM Unit
- Ingrid Zegers, SAM Unit

### *SAPEA representatives*

- Louise Edwards, Academia Europaea
- Dr Mildred Foster, Academia Europaea
- Dr Nina Hobbhahn, EASAC
- Professor Ole Petersen, Vice-President, Academia Europaea

### *Other guests*

- Frederico Rocha, Cardiff University

# Programme

All times are given in Central European Summer Time.

| | |
|---|---|
| 12:00 | Welcome and brief introductions<br>*Professor Ole Petersen* |
| 12:10 | Quick overview of the Scientific Advice Mechanism<br>Background to the topic<br>*Professors Nicole Grobert and Ole Petersen* |
| 12:20 | Keynote: overview of the SAPEA Evidence Review Report, with observations on strengths, possible limitations and gaps, with short Q&As |
| 12:50 | Chapter 2: Setting the scene; definitions of plastics and polymers, biodegradation and the open environment; steps involved in plastics biodegradation; factors affecting its biodegradation in the open environment<br>■ Overview of Chapter 2 (5 minutes) — *Lead author(s) for Chapter 2*<br>■ Response by first discussant (10 minutes)<br>■ Response by second discussant (10 minutes)<br>■ Discussion (15 minutes) |
| 13:30 | Break |
| 14:00 | Chapter 3: Applications of biodegradable plastics: considerations relating to environments: waste hierarchy and where biodegradable plastics fit in; influence of the receiving environments; examples of applications; the importance of information<br>■ Overview of Chapter 3 (5 minutes) — *Lead author(s) for Chapter 3*<br>■ Response by first discussant (10 minutes)<br>■ Response by second discussant (10 minutes)<br>■ Discussion (15 minutes) |
| 14:40 | Chapter 4: Testing and certifications: history; testing schema; how to assess; data and extrapolation of results; criteria to select tests; available standards; certification; case examples; gaps in data and information<br>■ Overview of Chapter 4 (5 minutes) — *Lead author(s) for Chapter 4*<br>■ Response by first discussant (10 minutes)<br>■ Response by second discussant (10 minutes)<br>■ Discussion (15 minutes) |
| 15:20 | Break |
| 15:40 | Chapter 5: Risk assessment; ecotoxicology; plastics in the environment and associated risks; potential risks of biodegradable plastics; risk assessment of biodegradable plastics; conclusions and identified knowledge needs<br>■ Overview of Chapter 5 (5 minutes) — *Lead author(s) for Chapter 5*<br>■ Response by first discussant (10 minutes)<br>■ Response by second discussant (10 minutes)<br>■ Discussion (15 minutes) |
| 16:20 | Chapter 6: Social, behavioural and policy aspects; unintended consequences (economic, behaviour, environmental); labelling; policy options and regulation<br>■ Overview of Chapter 6 (5 minutes) — *Lead author(s) for Chapter 6*<br>■ Response by first discussant (10 minutes)<br>■ Response by second discussant (10 minutes)<br>■ Discussion (15 minutes) |
| 17:00 | Break |
| 17:10 | Discussion of conclusions and evidence-based policy options to be included in the report |
| 17:50 | Next steps and final remarks<br>*Professor Ole Petersen* |
| 18:00 | Close |

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