Safer Alternatives to PFAS in Food Packaging

Report to the Legislature pursuant to RCW 70A.222.070

Hazardous Waste and Toxics Reduction Program

Washington State Department of Ecology

Olympia, Washington

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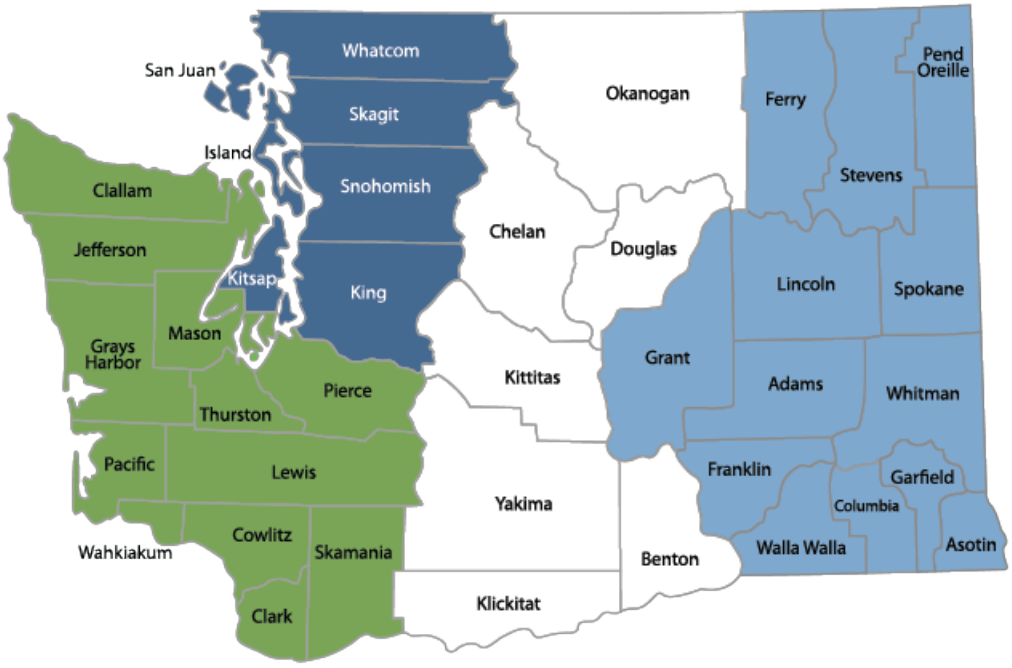

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Executive Summary

As directed by Revised Code of Washington (RCW) 70A.222.070,[2] Ecology conducted an alternatives assessment for various food packaging items containing intentionally added PFAS (per- and polyfluoroalkyl substances). This class of substances persist in the environment indefinitely, as there is no natural process that breaks them down. These substances can be toxic and are potentially linked to a variety of human health concerns, including increases in cholesterol levels, immune suppression, and lower birthweights. Higher exposures have also shown associations with some cancers, such as testicular and kidney cancers.

Following the Interstate Chemicals Clearinghouse (IC2) Alternatives Assessment Guide, Ecology assessed the hazard, exposure, performance, and cost and availability of ten food packaging applications (such as sandwich wraps, pizza boxes, and French fry containers). Ecology evaluated a variety of both chemical alternatives to PFAS as well as non-chemical options. That review found:

- Six chemical alternatives were less hazardous than PFAS.
- One chemical alternative was not less hazardous than PFAS.
- Available public data was insufficient for three chemical alternatives, so Ecology could not conduct an evaluation to reach a conclusion about their relative hazards. Although every effort was made to work with manufacturers to get necessary information, there were instances when Ecology was unable to gather enough data. In these cases, Ecology designated the alternative as having "insufficient data."

As directed by the statute, Ecology not only evaluated the hazard of each alternative but also assessed whether each alternative performed as well as the PFAS choice, whether the alternative was readily available, and whether it was comparable in cost to the PFAS choice.

As part of the assessment, Ecology conducted a formal stakeholder involvement process. Ecology sought input on a variety of issues, including:

- Project scoping, including categories of food packaging products to be evaluated.
- Evaluation methodologies derived from the IC2 Alternatives Assessment Guide and used in the assessment.
- Information on substance identity and formulation, both for PFAS-containing and PFAS-free food packaging alternatives.
- Establishing a Confidential Business Information (CBI) process to encourage voluntary participation by manufacturers.
- Additional resources, lack of publicly available data, areas of concern, and other issues requiring attention.

[2] https://app.leg.wa.gov/rcw/default.aspx?cite=70A.222

Ecology also engaged with stakeholders through a series of informational webinars and newsletter updates about the process and status. As part of regular project updates, Ecology posted documents related to the alternatives assessment, such as the statement of work, timeline, and methodology. Ecology invited comments from all stakeholders and provided a dedicated eComments webpage[3] to simplify comment submission. All comments submitted were visible to stakeholders on this comments page, and Ecology posted responses to comments when applicable.

The Washington State Academy of Sciences assembled a committee to conduct a peer review of the statutorily-mandated alternatives assessment. The peer reviewers all have expertise in some aspect of the review, including specialties in toxicology, alternatives assessments, and food packaging design. The peer review committee generally supported Ecology's conclusions and made various recommendations to further strengthen and enhance the assessment, which Ecology largely agreed with. A detailed list of each peer review comment, Ecology's response, and the changes made accordingly are Appendix A to this report. Appendix B is a copy of the original peer review comments and Appendix C is a copy of the committee's subsequent addendum.

Conclusions

Ecology's alternatives assessment determined there are less hazardous alternatives that are readily available at a comparable cost that meet performance requirements for four food packaging applications, as noted in Table 1:

Table 1. Safer alternatives identified for specific food packaging applications.

Application	Safer alternatives
Wraps and liners	Wax-coated options
Plates	Clay-coated and reusable options
Food boats	Clay-coated and reusable options
Pizza boxes	Uncoated options

As specified in RCW 70A.222.070(5),[4] the prohibition against manufacturing, sale, and distribution of PFAS-containing food packaging in these four food packaging applications will take effect two years from the date of submission of this report to the Legislature.

The alternatives assessment determined there was **insufficient information available** to find safer alternatives for:

- Bags and sleeves.
- Bowls.
- Trays.

[3] http://hwtr.ecology.commentinput.com/comment/extra?id=a8U4i
[4] https://app.leg.wa.gov/rcw/default.aspx?cite=70A.222.070

- French fry cartons.
- Clamshells.
- Interlocking folded containers.

Next steps

The legislation provides that if Ecology does not determine safer alternatives are available by January 1, 2020, the prohibitions would not take effect January 1, 2022.

Ecology did not complete the alternatives assessment by January 1, 2020, and therefore did not determine that safer alternatives are available by that date. Instead, this report is being submitted in 2021. Thus the prohibition against the sale of specified PFAS-containing food packaging applications will take place in 2023, two years from the date this report is submitted to the Legislature, in accordance with RCW 70A.222.070(5). This effective date will be slightly more than one year after the date listed in RCW 70A.222.070(1).

Starting in 2021, Ecology will continue the alternatives assessment process, as required by RCW 70A.222.070(5). This assessment will review:

- Food contact bags and sleeves, bowls, trays, French fry cartons, clamshells, and interlocking folded containers to determine if PFAS-free alternatives are readily available, in sufficient quantity, at a comparable price, with equivalent performance.
- Other substances and applications from the original assessment that had insufficient data.

Starting in 2023, Ecology expects to begin enforcing the restrictions on PFAS-containing food packaging for the four applications with identified safer alternatives noted above. We anticipate this will involve working with manufacturers, distributors, wholesalers, and retailers to ensure they comply with the law, as well as assisting them in achieving compliance, if necessary. Ecology will also engage with stakeholders, including manufacturing associations, grocery and retail associations, hospitality organizations, environmental advocates, and end users of affected products to promote the adoption of safer alternatives in all food packaging.

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Introduction

What are PFAS and why are they a problem?

PFAS (per- and polyfluoroalkyl substances) are a family of over 4,700 synthetic organic chemicals. One of the many uses for some of these chemicals is to provide oil, grease, and water resistance for paper-based foodservice products. Currently, 19 specific PFAS chemicals are approved by the U.S. Food and Drug Administration (FDA) for use in plant-based food packaging (EDF, 2018a); (21 CFR 176.160[5] and 21 CFR 173.170[6]).

Unfortunately, there is little toxicity or safety data for most of the commonly used PFAS chemicals, including those that are currently used in food packaging. Of the few that have been evaluated, some show harmful effects to people and wildlife. Animal studies show strong evidence of the association between exposure to several PFAS and developmental, liver, and immune toxicity. Epidemiological studies suggest links between PFAS exposure and several negative health outcomes in human beings, including immune suppression, increases in cholesterol levels, and lower birthweights. Higher exposures have also shown associations with some cancers, such as testicular and kidney cancers (CDC, 2020b); (Ecology, 2018). The most well characterized PFAS are associated with liver damage, increased cholesterol levels, thyroid problems, decreased antibody response to vaccines, increased risk of asthma, and problems with reproduction and development. While the newer PFAS have less toxicity or safety data available, as we learn more about them, we see some similar health concerns, particularly related to increases in cholesterol levels, decreased antibody response to vaccines, and liver damage (CDC, 2018).

In Washington, residents are exposed to PFAS through:

- The food they eat (including breastmilk).
- The water they drink and use to prepare food and beverages.
- Use of consumer products that contain PFAS.
- Workplaces that treat products with PFAS.
- Contaminated soil, indoor dust, and air.

Individuals are exposed to PFAS in food by "eating food that was packaged in material that contains PFAS" (CDC, 2020a).

Once they enter the environment, PFAS chemicals persist for a long time. No natural processes can break down these substances. These "forever chemicals" will continue to cause exposures for many decades after they are phased out of consumer and other products.

[5] https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?fr=176.160
[6] https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?fr=176.170

Legislation

In 2018, the Legislature adopted Substitute House Bill 2658, subsequently codified at RCW 70A.222.070.[7] This legislation provides that, beginning January 1, 2022, "no person may manufacture, knowingly sell, offer for sale, distribute for sale, or distribute for use in this state food packaging to which PFAS chemicals have been intentionally added in any amount."

In order for the prohibition to take effect:

1. Ecology must conduct a peer-reviewed alternatives assessment, following the guidelines issued by IC2. The assessment must evaluate chemical hazards, exposure, performance, cost, and availability.
2. Ecology must use the results of the alternatives assessment to determine that less hazardous alternatives are readily available in sufficient quantity and at a comparable cost, and that they perform as well or better than PFAS chemicals in a specific food packaging application. Options that meet all these criteria are considered safer alternatives.
3. Ecology must publish findings in the Washington State Register on whether safer alternatives are available for each assessed food packaging application.
4. Ecology must submit to the appropriate committees of the Legislature a report with its findings and the feedback from a peer review of the alternatives assessment. This report was due January 1, 2020.

The legislation also provides that if Ecology does not determine safer alternatives are available by January 1, 2020, the prohibitions would not take effect January 1, 2022.

Ecology did not complete the alternatives assessment by January 1, 2020, and therefore did not determine that safer alternatives are available by that date. Instead, this report is being submitted in 2021. Thus the prohibition against the sale of specified PFAS-containing food packaging applications will take place in 2023, two years from the date this report is submitted to the Legislature, in accordance with RCW 70A.222.070(5). This effective date will be slightly more than one year after the date listed in RCW 70A.222.070(1).

Food packaging market

RCW 70A.222.010(4)[8] defines a food package as "a package or packaging component that is intended for direct food contact and is comprised, in substantial part, of paper, paperboard, or other materials originally derived from plant fibers." This definition includes items used to enclose food (such as wraps or takeout boxes) and items used in the consumption of food (such as plates or trays). These products are also collectively referred to as foodservice items.

[7] https://app.leg.wa.gov/RCW/default.aspx?cite=70A.222.070
[8] https://app.leg.wa.gov/RCW/default.aspx?cite=70A.222.010

Common materials used to manufacture single-use foodservice items are plant-based fibers, plastics (which includes both Styrofoam-type products and bioplastics), and aluminum.

According to an industry market report published in the 2017 by The Freedonia Group, the U.S. market share of single-use foodservice items totaled approximately $18.6 billion in 2016, with eating and drinking establishments comprising 66 percent of the market. Quick service restaurants accounted for 61 percent of the single-use foodservice item market (Freedonia, 2017).

There are currently 19 different PFAS chemicals approved by the FDA for use in food packaging products. However, some nongovernmental organizations have challenged safety determinations for these substances. A number of challenges to specific PFAS chemicals have resulted FDA actions to remove approval for some uses of these PFAS in food contact materials. In 2016, the FDA revoked approval for three types of PFAS previously used in paper and paperboard food packaging (Nelter, 2016). In 2020, the FDA announced the voluntary phase-out of additional PFAS-containing chemicals used in food packaging due to potential health risks (FDA, 2020).

COVID-19 considerations

The COVID-19 pandemic has caused wide-ranging effects throughout the state. In addition to exacerbating and contributing to the delay in completing the initial alternatives assessment and this report, the pandemic has also created uncertainty that may need to be addressed in future alternatives assessments:

Restaurants and the shift from dine-in to take-out

In response to the COVID-19 pandemic, the state of Washington placed restrictions on indoor and outdoor dining for most of 2020. As a result, many food service establishments shifted their business to focus on takeaway and delivery. Businesses that did so may be affected more significantly by a ban on PFAS in food packaging. However, the longer-term impact of the pandemic on the food packaging market is unknown. As no definitive information was available during the preparation of Ecology's alternatives assessment, it does not make any assumptions about how the pandemic will affect the food packaging market in the future.

Endocrine disruption, COVID susceptibility, and vaccine response

In general, safer consumer products contribute to healthier overall communities, which makes us more resilient in the face of disease. As noted above, PFAS affect hormone and immune system functions and have also been linked to increased rates of asthma and decreases in vaccine response. Many studies have also shown associations between exposure to endocrine disruptors such as PFAS and diseases that increase COVID-19 susceptibility. At this time, any direct impact of PFAS on COVID-19 susceptibility needs further study. As scientific understanding of this issue increases in the future, it may become a more important consideration when evaluating possible safer alternatives in future assessments.

What are alternatives assessments and how do they work?

An alternatives assessment is "a process for identifying, comparing and selecting safer alternatives to chemicals of concern (including those in materials, processes or technologies) on the basis of their hazards, performance, and economic viability. A primary goal of alternatives assessment is to reduce risk to humans and the environment by identifying safer choices" (BizNGO, 2020). IC2 describes the objective of an alternatives assessment is "to replace chemicals of concern in products or processes with inherently safer alternatives, thereby protecting and enhancing human health and the environment" (IC2, 2017).

Clean Production Action, one of the key organizations involved with developing the alternatives assessment framework, based the assessment process on the following principles:

- Reduce hazards by substituting less dangerous options.
- Minimize exposure to chemicals of concern.
- Use the best available science and information when evaluating alternatives.
- Require disclosure from manufacturers and be transparent in dealings with stakeholders, when evaluating data, and when making decisions.
- Resolve trade-offs and collaborate with stakeholders to weigh decision-making criteria and possible mitigating factors.
- Take action to eliminate the need for hazardous chemicals or substitute safer alternatives.

Interstate Chemicals Clearinghouse

The IC2 describes itself as, "an association of state, local, and tribal governments that promotes a clean environment, healthy communities, and a vital economy through the development and use of safer chemicals and products. The IC2 is a program of the Northeast Waste Management Officials' Association (NEWMOA), which provides management and staff support for IC2 and serves as its fiscal agent" (IC2, 2014). Washington State is a member of IC2.

IC2 developed and published its first Alternatives Assessment Guide (the IC2 Guide) in 2014. As part of that work, the IC2 Guide "was created with an extensive stakeholder involvement process" including public comment periods (IC2, 2017). The IC2 Guide was updated (Version 1.1) and re-released in 2017.

As directed in the underlying legislation, Ecology followed the guidelines set forth in Version 1.1 of the IC2 Guide in preparing the alternatives assessment.

Alternatives assessment modules

The IC2 Guide states it should be implemented in the following distinct steps:

Identify the chemical of concern

The underlying legislation identified "PFAS" as the subject of the alternatives assessment. However, PFAS chemicals are not identical. Ecology determined it was necessary to identify specific PFAS chemicals so that PFAS could be compared to PFAS-free alternative chemicals. Ecology chose a representative PFAS chemical and its breakdown products that are likely contributors to PFAS exposure from food packaging, as described in more detail below.

Initial evaluation

The IC2 Guide identifies an "initial evaluation module" that should be conducted to determine whether an alternatives assessment is needed. Ecology did not formally conduct this module because the alternatives assessment is required by statute. Ecology did review the information and questions in the initial evaluation module and incorporated this information into the other modules where appropriate.

Scoping stakeholder involvement

The next step in the alternatives assessment is to determine what degree of stakeholder involvement is needed. The IC2 Guide gives three options:

- Level 1 – internal exercise. Stakeholder involvement is limited. This level is primarily applicable to internal corporate assessments and is not applicable to a public process.
- Level 2 – formal stakeholder process. This level involves significant stakeholder input and provides a structure for receipt of that input. Pertinent information is shared with stakeholders for review and comment. All comments are collected and responded to.
- Level 3 – open stakeholder process. This level establishes a structure where stakeholders are involved in the alternatives assessment decision-making process. Stakeholder involvement includes all aspects of the assessment and review of the final product.

Ecology determined that a Level 2 Stakeholder Process was appropriate for this alternatives assessment. Ecology also determined that a Level 3 Stakeholder Process would be an inappropriate delegation of the agency's authority and responsibilities as outlined in the statute. This is consistent with Ecology's 2015 alternatives assessment guide, which recommended that government organizations conducting alternatives assessments use a Level 2 stakeholder process (Ecology, 2015).

Identification of alternatives

The IC2 Guide includes a large variety of alternatives that should be included when performing an alternatives assessment. Chemical substitutions, alternative materials, and product redesign are all options that should be considered. As explained in more detail below, Ecology considered a variety of possible alternatives, including non-PFAS chemicals, alternate types of containers, and systemic choices like reusable options.

Evaluate alternatives

The IC2 Guide identifies four modules that should be completed, in order, to evaluate possible alternatives in all assessments:

1. Hazard. The goal of the hazard module is to determine what hazards exist for the chemical of concern and how they compare to potential alternatives. The most favorable alternatives are those with the lowest hazard.
2. Performance evaluation. The goal of the performance evaluation module is to ensure the alternatives under consideration meet the necessary performance requirements. Alternatives that are not technically feasible are less favorable.
3. Cost and availability. The goal of the cost and availability module is to evaluate whether alternatives are cost competitive and whether they are available in sufficient quantity to meet demand. Alternatives that are not sufficiently available or adequately priced are less favorable alternatives.
4. Exposure assessment. The goal of the exposure assessment module is to evaluate potential exposure scenarios and determine if alternatives pose a greater exposure risk to human health and the environment. Options that have the lowest risk are those that have both the lowest hazard and the lowest exposure potential.

The results of each of these modules is explained in more detail below.

The IC2 Guide also outlines three optional modules (materials management, social impact, and life cycle) that reviewers can conduct if appropriate for a given situation. Ecology determined these three modules were not needed for the food packaging evaluation because each addresses issues outside the scope of RCW 70A.222.070(3).[9]

Alternatives assessment framework

The IC2 Guide provides three possible frameworks for conducting an alternatives assessment:

- Sequential framework. Data is collected and evaluated one module at a time, in order, and only potential favorable alternatives continue through the process. Unfavorable alternatives are "screened out" and may not be evaluated in all modules.
- Simultaneous framework. Data from all modules are evaluated at the same time for all potential alternatives.
- Hybrid framework. Hazard and performance evaluation modules are performed sequentially, eliminating unfavorable alternatives. The remaining modules are then reviewed simultaneously.

Ecology selected a simultaneous framework as the preferred option for this assessment. This approach provides the most information for decision-making now and in future assessments.

[9] https://app.leg.wa.gov/RCW/default.aspx?cite=70A.222.070

Ecology's Alternatives Assessment Process

Ecology conducted the PFAS in food packaging alternatives assessment in partnership with the Washington State Department of Health from May 2018 to August 2020. Significant time was spent reviewing and selecting the food packaging types, relevant PFAS, and potential alternatives. The IC2 Guide and stakeholder feedback were key resources that supplemented Ecology's research and requests for information from chemical and product manufacturers.

Contractor

To assist with stakeholder engagement, data collection, and evaluation of alternatives according to the IC2 Guide, Ecology contracted with SRC, Inc. (SRC), a not-for-profit environmental consulting firm based in Syracuse, New York. SRC performs chemical-related work for a number of government organizations, including the U.S. Environmental Protection Agency (EPA), the Department of Defense, the National Library of Medicine – National Institutes of Health, and others.

Stakeholder involvement

Ecology and SRC worked together to develop a list of key stakeholders from industry and the environmental community. As noted above, Ecology decided that a Level 2 stakeholder process was appropriate for this alternatives assessment. A Level 2 process directs Ecology to:

- Identify potential stakeholders, such as chemical manufacturers, product manufacturers, retailers, end users, consumers, environmental advocates, and waste, composting, or recycling companies.
- Identify potential stakeholder concerns.
- Address or mitigate stakeholder concerns when possible or document the reasons if not possible.
- Incorporate stakeholder concerns into the decision-making process and document how that is done.
- Determine if stakeholder concerns are serious enough to identify an alternative as unfavorable.

With this in mind, Ecology sought stakeholder input on key items, such as:

- Project scoping, including categories of food packaging products to be evaluated.
- Evaluation methodologies derived from the IC2 Alternatives Assessment Guide and used in the assessment.
- Information on substance identity and formulation, both for PFAS-containing and PFAS-free food packaging alternatives.
- Establishing a CBI process to encourage voluntary participation by manufacturers.

- Additional resources, lack of publicly available data, areas of concern, and other issues requiring attention.

Ecology engaged with stakeholders through newsletter updates and a series of informational webinars about the process and status. As part of regular product updates, Ecology also posted documents related to the alternatives assessment on an EZview[10] webpage, including:

- Statement of work.
- Timeline.
- Deliverables.
- Hazard assessment methodology.
- Exposure assessment methodology.
- CBI process.
- Peer review committee information, bios, and confidentiality agreement.
- Webinar update recordings and slides.

Ecology invited comments from all stakeholders and provided a dedicated eComments webpage[11] to simplify comment submission. Ecology also made all comments visible to stakeholders on its comments page, and publicly posted responses to comments as applicable.

Food packaging assessment scope

Ecology originally planned to focus its analysis on food wraps and liners, such as the wrapper around a sandwich or hamburger. At that time, Ecology believed this scope was manageable given the expected timeline and budget, while still representing a significant portion of the single-use food packaging market. Adopting this limited scope—a single food packaging application—would have allowed Ecology to do the necessary alternatives assessment work and submit a report to the Legislature by the statutory due date.

However, in response to stakeholder input, we reconsidered this approach. Businesses and industry groups asked Ecology to collect more information from end users (like restaurants and retailers) about the availability, cost, and performance of PFAS-free food packaging products. Environmental groups asked Ecology to consider additional related food packaging product applications.

After considering all the input from interested parties, Ecology decided to accommodate both these stakeholder requests by broadening the scope of its assessment to include additional food packaging types like plates, bowls, trays, and related items, and by doing additional outreach to end users. This decision resulted in a delay of approximately one year in submitting this report to the Legislature, and thus a delay in the prohibition effective date for applicable

[10] https://www.ezview.wa.gov/site/alias__1962/37610/pfas_in_food_packaging_alternatives_assessment.aspx
[11] http://hwtr.ecology.commentinput.com/?id=a8U4i

food packaging products until 2023. Ecology did not make this decision lightly; however, the comments received were compelling and ultimately drove the decision to take the extra time to expand the scope of the alternatives assessment.

Ecology's final scope includes the following food packaging items, divided into three categories:

- Category: Food Contact Paper.
    - Wraps and liners.
    - Bags and sleeves.
- Category: Dinnerware.
    - Plates.
    - Bowls.
    - Boats.
    - Trays.
- Category: Containers.
    - Pizza boxes.
    - French fry cartons.
    - Clamshells.
    - Interlocking folded containers.

The alternatives assessment uses the phrase "food packaging application," which is a group of food packaging items that are used to hold food in a similar way (*e.g.*, a clamshell is a hinged container with a built-in closure, such as a tab that keeps the lid secure during transport).

Additionally, Ecology only considered versions of food packaging products intended for short-term storage or holding of freshly prepared food. Versions of these products that have been customized to store or hold freshly prepared food under special circumstances (*e.g.*, a wrap that holds food while it is being grilled) were not considered in this assessment.

Identification of a comparison chemical

As noted above, PFAS is not a single substance but is instead a group of chemicals that each contain a carbon-fluorine bond, 19 of which are FDA-approved for use in plant-fiber food packaging to provide oil, grease, and water resistance.[12] While the statute provides the authority for Ecology to evaluate all 19 PFAS chemicals, it was not possible to do so within the time and resources allocated to this project. As a result, Ecology consulted with a PFAS trade association and ultimately chose one of the most common PFAS used in food packaging

[12] PFAS chemicals can be applied to the machinery or molds that are used in the manufacture of food packaging as well as added directly to food packaging items. Those PFAS chemicals can then migrate to the packaging. Ecology did not assess alternatives that could be substituted for this use of PFAS chemicals.

applications as a representative PFAS, along with two of its known impurities and breakdown products, to represent the chemical of concern. We refer to this representative chemical as the "comparator" in the alternatives assessment.

To make this choice of the type of PFAS to be the comparator, Ecology reviewed the various PFAS chemicals used in food packaging in the United States. The agency used information that is publicly available to perform this review and focused on information about persistence, hazard, and exposure. Ecology looked at the chemical and physical properties of the various PFAS chemicals as well as their hazard and exposure concerns. We also sought stakeholder input about the current prevalence of these chemicals.

As a result of this work, Ecology chose the PFAS chemical with Chemical Abstracts Service Registry Number (CASRN) 863408-20-2,[13] along with a residual PFAS[14] and a breakdown product[15] of the original chemical, to be the "comparator" for the alternatives assessment.

Consideration of chemical and function

The function of PFAS in food packaging is typically to provide oil, grease, or water resistance. However, function can also be thought of in a broader sense:

- Is the function to provide a coating or chemical barrier to the product—in this case, food packaging? If so, then an alternative chemical might fulfill the function.
- Is the function to provide an end use—in this case, a means of safely transporting food? If so, then an alternative container might fulfill the function.
- Is the function to provide a service—in this case, protection against oil, grease, or water? If so, then a structural change in the system using food packaging might be able to provide the same service or eliminate the need for that service.

Ecology considered each of these approaches when identifying possible alternatives to PFAS coatings for food packaging.

Alternative options reviewed

Ecology compiled an initial inventory of possible alternatives by obtaining information from stakeholders and by consulting purchasing guides for PFAS-free products. Ecology prioritized the possible alternatives, giving preference to materials and substances that:

- Are used in many food packaging categories.
- Were previously identified as being of low hazard concern.
- Have a larger market share.

[13] Also known as the copolymer of perfluorohexylethyl methacrylate, 2-N,N-diethylaminoethyl methacrylate, 2-hydroxyethyl methacrylate, and 2,2'-ethylenedioxydiethyl dimethacrylate, acetic acid salt.
[14] The selected residual chemical is CASRN 647-42-7, also called 6:2 fluorotelomer alcohol.
[15] The selected breakdown product is CASRN 307-24-4, also known as perfluorohexanoic acid.

Ecology also researched the availability of PFAS-free alternatives under Washington's environmentally preferable purchasing programs. Ecology then matched these alternative materials and substances with food packaging applications to create a list of potential alternatives.

Using the framework above, Ecology considered ten alternatives to PFAS. As required by statute, Ecology considered both less toxic chemicals and non-chemical alternatives. For chemical alternatives, Ecology considered alternative coatings including:

- Bio-based plastics such as polylactic acid (PLA).
- Waxes such as beeswax or petroleum-based waxes.
- Clay-based coatings.
- Silicones and plastics, such as polyvinyl alcohols (PVOH and EVOH), polyethylene (PE), and polyethylene terephthalate (PET).

For process alternatives, Ecology considered mechanically densified paper, which does not require chemical additives. For material alternatives, Ecology considered different container materials, such as bio-based plastic (PLA). For system alternatives, Ecology considered reusable options, such as heavier reusable plastic containers, trays, and serving ware.

Ecology did not evaluate every possible food packaging application or food packaging alternative—this was not feasible due to time limitations and budget considerations. The scope of Ecology's assessment is based on input from stakeholder engagement and research about alternative chemicals and materials that are already established in the marketplace. We also restricted our review to products that have been tested for PFAS.

Chemical hazards evaluation

The first chemical evaluation module in the alternatives assessment is to determine the hazard associated with potential alternatives. The options are laid out in three levels:

- Level 1 – basic evaluation. This level uses a "Quick Chemical Assessment Tool" and readily available data sources to identify clearly hazardous potential alternatives.
- Level 2 – GreenScreen® evaluation. This level uses the free, publicly available GreenScreen® for Safer Chemicals hazard assessment tool to conduct a thorough hazard evaluation.
- Level 3 – expanded GreenScreen® evaluation. This level expands on the Level 2 review by requiring an independent, third-party verification and elimination of data gaps.

Ecology determined that a Level 2 review was appropriate for this alternatives assessment. Ecology also determined a Level 1 review would likely not produce enough information to support decision-making, and a Level 3 review (which often requires generating new hazard data) would be unrealistic given budget and time constraints.

GreenScreen®

The GreenScreen® evaluation tool is freely available to everyone on the internet and "standardizes the hazard assessment process" (IC2, 2017). It is a commonly used tool and "emphasizes the need for quality data before an alternative can be identified as better than the chemical of concern." The GreenScreen® review is not applied to substances that were already evaluated and found to be of low hazard concern.

Hazard traits reviewed

For substances that are not already known to be of low concern, the following data are assessed for an alternatives assessment level 2 review:

- Human health data.
    - Carcinogenicity.
    - Mutagenicity and genotoxicity.
    - Reproductive toxicity.
    - Developmental toxicity (including developmental neurotoxicity).
    - Endocrine activity.
    - Acute mammalian toxicity.
    - Systemic toxicity and organ effects (including immunotoxicity).
    - Neurotoxicity.
    - Skin sensitization.
    - Respiratory sensitization.
- Ecological data.
    - Acute aquatic toxicity.
    - Chronic aquatic toxicity.
- Environmental data.
    - Persistence.
    - Bioaccumulation.
- Physical data.
    - Reactivity.
    - Flammability.

Low-hazard substances

Ecology determined that it was unnecessary to conduct full hazard assessments on some potential alternatives because an authoritative body already deemed them to be of low hazard concern. This includes some products on EPA's Safer Chemicals Ingredients List (SCIL)—

chemicals that have been verified as meeting the Safer Choice criteria (USEPA, 2020). These criteria are publicly available and were developed with a stakeholder process (including a formal comment period) that included participation from industry, nongovernmental organizations, and government stakeholders.

For this assessment, the following alternatives were listed on the SCIL as low-hazard substances (designated on SCIL with a green circle):

- Cellulose and cellulose pulp (paper).
- Petroleum wax.
- Bio-based wax.
- Kaolin clay.
- PVOH.

The GreenScreen® evaluation tool and SCIL assessments use similar criteria and data, so low-hazard substances on the SCIL do not require an additional GreenScreen® assessment.

GreenScreen® results

Ecology reviewed eight substances using the GreenScreen® framework: the comparator chemical and its two related substances, plus the remaining five possible alternatives not on the SCIL green circle list. For full details about this work, please see the complete alternatives assessment report.[16] The results are summarized below. Table 2 shows the results from the hazard assessment of the comparator chemical as well as the residual chemical and breakdown product as noted on page 14:

Table 2. Comparator chemical and related substances GreenScreen® hazard results.

Item	CASRN	Approach	Hazard Assessment Result
Comparator chemical	863408-20-2	Insufficient information was available to evaluate using GreenScreen® for Safer Chemicals	Insufficient data provided to Ecology to allow a conclusion
Residual chemical of comparator	647-42-7	Evaluated using GreenScreen® for Safer Chemicals	Benchmark-1: Avoid – Chemical of High Concern
Breakdown product of comparator	307-24-4	Evaluated using GreenScreen® for Safer Chemicals	Benchmark-1: Avoid – Chemical of High Concern

[16] https://apps.ecology.wa.gov/publications/summarypages/2104004.html

Table 3 shows the results from the hazard assessment of the five possible alternative chemicals that do not appear on the SCIL green circle list:

Table 3. Alternative substances GreenScreen® hazard results.

Item	CASRN	Approach	Hazard Assessment Result
Siloxanes[17]	68083-19-2	Evaluated using GreenScreen® for Safer Chemicals	Benchmark-1: Avoid – Chemical of High Concern
PLA[18]	9051-89-2	Evaluated using GreenScreen® for Safer Chemicals	Consistent with Benchmark-3: Use but Still Opportunity for Improvement
PE	9002-88-4	Insufficient information was available to evaluate using GreenScreen® for Safer Chemicals	Insufficient data provided to Ecology to allow a conclusion
PET	25038-59-9	Insufficient information was available to evaluate using GreenScreen® for Safer Chemicals	Insufficient data provided to Ecology to allow a conclusion
EVOH	26221-27-2	Insufficient information was available to evaluate using GreenScreen® for Safer Chemicals	Insufficient data provided to Ecology to allow a conclusion

Both Table 2 and Table 3 note that Ecology was unable to reach a conclusion about the relative hazard of some chemicals because manufacturers were not forthcoming with the information needed to conduct a GreenScreen® evaluation. In these cases, we designated the alternative as having "insufficient data," denoting that we were unable to gather enough relevant data on an alternative and are thus unable to determine potential hazards. A hazard evaluation may be possible in future alternatives assessments if Ecology can obtain the relevant data.

Exposure evaluation

The exposure evaluation module in the alternatives assessment is used to determine whether risk is reduced even if exposure levels increase in the future. The IC2 Guide does not require an exposure evaluation if the hazard evaluation identified an alternative as much safer or too hazardous to be considered a viable alternative. As with the other modules, the options are laid out in three levels:

- Level 1 – basic comparative exposure evaluation. This level uses a qualitative assessment of readily available data sources to identify whether material differences exist between the chemical of concern and the potential alternatives.

[17] Assessed using vinyl silicone polymer.
[18] Assessed using residual chemicals and breakdown products.

- Level 2 – expanded comparative exposure evaluation. This level builds on the previous level by increasing the quality and quantity of information.
- Level 3 – detailed exposure evaluation. This level builds on the previous level and requires detailed scientific studies as the basis for decisions. If those studies are not available, they are conducted.

There is also an additional "Advanced" level, where a full exposure assessment (as defined by the National Academy of Sciences) is performed. Ecology determined that a Level 1 exposure evaluation was an appropriate use of available resources and met the requirements of RCW 70A.222.070.[19]

Preliminary screening questions

The preliminary questions for this module help researchers determine if an exposure evaluation is necessary. Those preliminary questions are:

1. Has the alternative been evaluated for hazard and determined to be of low concern (*e.g.*, EPA SCIL green circle or GreenScreen® Benchmark-3 or 4)? This question removes alternatives that are very low hazard where even high exposure is generally not a concern.
2. Does the alternative have persistence, bioaccumulation, and/or toxic properties of concern? This question removes alternatives that are very high hazard where even very low exposure would be of high concern.

Exposure evaluation results

Table 4 shows the results from exposure assessment of the comparator chemical as well as the residual chemical and breakdown product as noted on page 14:

Table 4. Comparator chemical and related substances exposure assessment determinations.

Item	CASRN	Hazard Concern	Exposure Assessment
Comparator	863408-20-2	Insufficient information was available to evaluate using GreenScreen® for Safer Chemicals	Insufficient data provided to Ecology to allow a conclusion
Residual chemical	647-42-7	Benchmark-1: Avoid – Chemical of High Concern	Very high persistence, very high systemic toxicity
Breakdown product	307-24-4	Benchmark-1: Avoid – Chemical of High Concern	Very high persistence, very high skin/eye irritation

[19] https://app.leg.wa.gov/rcw/default.aspx?cite=70A.222.070

Table 5 shows the results from the hazard assessment of the ten possible alternatives Ecology evaluated. This includes both chemicals that do not appear on the SCIL green circle list as well as the low hazard options:

Table 5. Alternative substances exposure assessment determinations.

Item	CASRN	Hazard Concern	Exposure Assessment
Uncoated paper	N/A	Non-chemical alternative – low concern	Low hazard concern – no exposure assessment required
Petroleum-based waxes	Various	US EPA Safer Chemical – low concern	Low hazard concern – no exposure assessment required
Bio-based waxes	Various	US EPA Safer Chemical – low concern	Low hazard concern – no exposure assessment required
Kaolin clay	1332-58-7	US EPA Safer Chemical – low concern	Low hazard concern – no exposure assessment required
PVOH	9002-89-5 and 25213-24-5	US EPA Safer Chemical – low concern	Low hazard concern – no exposure assessment required
Siloxanes[20]	68083-19-2	Benchmark-1: Avoid – Chemical of High Concern	Very high persistence, very high bioaccumulation – not considered for exposure differences
PLA[21]	9051-89-2	Likely consistent with Benchmark-3: Use but Still Opportunity for Improvement	Low hazard concern – no exposure assessment required
PE	9002-88-4	Insufficient information was available to evaluate using GreenScreen®	Insufficient data provided to Ecology to allow a conclusion
PET	25038-59-9	Insufficient information was available to evaluate using GreenScreen®	Insufficient data provided to Ecology to allow a conclusion
EVOH	26221-27-2	Insufficient information was available to evaluate using GreenScreen®	Insufficient data provided to Ecology to allow a conclusion

Based on the above results, Ecology determined it did not need to take further steps in the exposure evaluation.

[20] Based on vinyl silicone polymer.
[21] Based on degradation and residual breakdown products.

Performance evaluation

The performance evaluation module in the alternatives assessment aims to determine whether potential alternatives meet the functional needs of a product. As with the other modules, the options are laid out in three levels:

- Level 1 – basic performance evaluation. Identifies a few basic questions about whether the alternative performs the required function in the product.
- Level 2 – extended performance evaluation. Builds on the information obtained in Level 1 and uses quantitative information from existing data to evaluate alternatives.
- Level 3 – detailed performance evaluation. Uses quantitative information to evaluate alternatives based on specified tests that are reviewed and validated by experts.

Ecology determined that a Level 1 evaluation most closely aligned with the language in RCW 70A.222.070[22] related to performance, cost, and availability. Both Level 2 and Level 3 reviews require a technical expert review of performance data, which Ecology determined to be unrealistic given budget and time constraints.

Performance specifications

Ecology used questions derived from the IC2 Guide to determine whether the products meet the Level 1 performance standards:

1. Is the alternative being used for the same or similar function?
2. Is the alternative available on the commercial market?
3. Do promotional materials state the alternative provides the desired function?

If the answer to each of these three questions is "yes," the product is determined to be favorable. In cases where the answer to each of these questions is "no," the IC2 Guide provides additional lines of inquiry for determining whether alternatives meet the relevant performance specifications.

To determine if alternative products meet performance requirements, Ecology compiled an inventory of alternative products and reviewed the associated promotional and marketing material. Ecology evaluated whether alternative products claimed to provide oil and grease resistance and, where applicable, leak resistance. Key phrases in promotional materials that indicated performance standards included:

- Greaseproof.
- Oil and/or grease resistance or OGR.
- References to Kit Test levels or penetration rates.
- Non-stick.

[22] https://app.leg.wa.gov/rcw/default.aspx?cite=70A.222.070

- Moisture resistance.
- Leak resistance.
- References to wet strength.
- Products advertised as soup bowls or soup cups (where leak resistance would be vital).

In this case, further inquiries were unnecessary for most alternative products. The performance of a small subset of alternative products did require verification using expert opinions from end users and stakeholders. Except as noted below, all of the alternatives evaluated as part of this assessment met the performance standards.

Performance results

Detailed answers for each alternative are presented in the full alternatives assessment. Ecology was able to find promotional information or expert opinion for most of the possible alternatives that confirm each as having oil and grease resistance and, where applicable, leak resistance. Ecology could not identify performance information for the following alternatives:

- Uncoated plates.
- Uncoated clamshells.
- Clay-coated pizza boxes.
- Clay-coated French fry cartons.
- PE-coated or PET-coated products.

Ecology concluded that for all of the alternatives with identified performance information, performance standards were met.[23]

Cost and availability evaluation

The purpose of the cost and availability module in the alternatives assessment is to determine if alternatives that seem feasible are actually cost prohibitive or unavailable, rendering them unfavorable options. This module has four levels and, like the exposure module, also has an option for advanced analysis beyond Level 4:

- Level 1 – basic cost and availability evaluation. This level asks a few basic questions about whether the alternative is being used in cost competitive products.
- Level 2 – extended basic cost and availability evaluation. This level builds on Level 1 and considers how changes in the supply of an alternative affect its availability and cost effectiveness.

[23] Future alternatives assessments, especially ones evaluating molded-fiber products, may need to pursue to additional lines of investigation provided in the IC2 Guide.

- Level 3 – chemical and material cost and availability evaluation. This level further expands upon the previous level to include not only the cost and availability of the chemical, but also the material in which it will be used.
- Level 4 – chemical, material, and re-designed cost and availability evaluation. This level assesses cost and benefits associated with product redesign and incorporates life cycle costing.

The additional advanced analysis option would be a full cost/benefit analysis evaluation with a detailed life cycle cost evaluation, including externalities.

Ecology determined that, based on the information currently available, a Level 1 analysis was the most appropriate choice. We determined that the data requirements for reviews under Levels 2 – 4 exceeded the scope of the statute.

Cost and availability specifications

To complete this analysis, Ecology focused on three questions for each alternative, as outlined in the IC2 Guide:

1. Is the alternative currently used in the application of interest?
2. Is the alternative currently offered for sale for the application of interest?
3. Is the price of the alternative close to the current?

Ecology relied on a variety of sources to answer these questions, including product purchasing lists, compostable product databases, inquiries to manufacturers and distributors, contractor and individual research, and industry reports. Detailed information about this work is included in the full alternatives assessment report.[24]

In addition, Ecology developed additional criteria to address availability. RCW 70A.222.070(3)[25] goes further than the IC2 Guide and requires that alternatives be "readily available in sufficient quantity…." The statute does not contain any definitions of either "readily available" or "sufficient quantity."

We were able to find unrelated Washington State definitions for "readily available." Washington Administrative Code (WAC) 110-300-0005[26] regarding early learning program standards defines "readily available" to mean "able to be used or obtained quickly and easily." WAC 284-180-130[27] regarding pharmacy benefit managers defines "readily available for purchase" to mean "manufactured supply is held in stock and available for order by more than one pharmacy in Washington state when such pharmacies are not under the same corporate umbrella." We did not find any applicable Washington State definitions for "sufficient quantity," but feel the "readily available for purchase" definition is instructive nonetheless.

[24] https://apps.ecology.wa.gov/publications/summarypages/2104004.html
[25] https://app.leg.wa.gov/rcw/default.aspx?cite=70A.222.070
[26] https://app.leg.wa.gov/wac/default.aspx?cite=110-300-0005
[27] https://app.leg.wa.gov/WAC/default.aspx?cite=284-180-130

These definitions are similar to guidance from the Ontario Toxics Reduction Program (Ontario, 2019), which considers the following questions when analyzing the availability of alternative chemicals:

- Will it be relatively easy to obtain the alternative chemical, and is it available locally or only from suppliers that are great distances away?
- Are there multiple suppliers so that if one supplier shuts down, there are other options for obtaining the chemical?

Our alternatives assessment combined these questions with those in the IC2 Guide to address all of the availability elements required in the statute.

RCW 70A.222.070(3) also requires that a safer alternative "must be readily available in sufficient quantity and at a comparable cost…" The statute does not define "comparable cost." As of the date of this report, there is no definition of "comparable cost" in any existing Washington statute or administrative regulation, nor is there a definition of related phrases such as "similar cost" or "comparable price."

We were generally unsuccessful finding specific definitions from other state laws as well. However, we found the following laws about comparable costs to be informative:

Nebraska Revised Statute § 69-2011, passed in 2018, concerns a prohibition on the sale of disposable diapers that are not biodegradable. Similar to the prohibition requirements here, the Nebraska law requires the state environmental agency to find that alternatives "are readily available at a comparable price and quality." The statute defined "comparable price" as "at a cost not in excess of **five percent** above the average price for products of comparable quality which are not biodegradable or photodegradable."

New York State adopted three separate pieces of legislation[28] authorizing government agencies to purchase recycled products but only when "the price of such products is reasonably competitive…" The statutes define "reasonably competitive" as "the cost of the recycled product does not exceed a cost premium of **ten percent** above the cost of a comparable product that is not a recycled product or, if at least fifty percent of the secondary materials utilized in the manufacture of that product are generated from the waste stream in New York state, the cost of the recycled product does not exceed a cost premium of **fifteen percent** above the cost of a comparable product that is not a recycled product." (See, NY General Municipal Law § 104-A (2015), NY County Law § 626 (2014), and NY Village Law § 5-525 (2012).)

The U.S. Department of Commerce uses a methodology for identifying comparable prices when evaluating similar but not identical products. This approach is pursuant to 19 CFR 351.411,[29] and is sometimes referred to as the "difference-in-merchandise cap" or "DIFMER cap." In making these comparisons, the Department of Commerce uses a price difference of 20 percent.

[28] The relevant wording of each is identical.
[29] https://ecfr.federalregister.gov/current/title-19/chapter-III/part-351#section-351.411

We found each of these approaches consistent with the plain meaning of the words in Washington's statute. The state statutes' focus on an environmental restriction makes these two examples particularly applicable. Ecology found the range of five to 15 percent higher to be reasonable attempts to define a "comparable" range of costs, and based on these approaches, determined an alternative is available "at a comparable cost" when there is data to support the price of a PFAS-free alternative will not be more than ten percent above the cost of a comparable PFAS-containing product. Ten percent is the middle of the range found in the other state statutes (a low of five percent and a high of 15 percent) and is the same as the presumed comparable cost for the New York statutes.

Ecology did not adopt a 20 percent differential as the threshold for determining "comparable" costs because unlike the examples from the states, there was no direct environmental connection to the Commerce standard. The cost differential examples from Nebraska and New York each compare an environmentally preferable option against a standard option and were adopted for that specific purpose. In contrast, the DIFMER cap example is intended to compare products pursuant to federal antidumping regulations.

The decision to reject a 20 percent price differential had a direct impact on our conclusions: three food packaging options (kaolin clay-coated bowls, PLA-coated bowls, and PLA foam clamshells) each had a price differential of more than ten but less than 20 percent higher than the corresponding PFAS option. If a 20 percent price differential were used, bowls would be an additional food packaging application that has a safer alternative, along with the four applications noted in Table 1.

Cost and availability results

Ecology found PFAS-free options in each of the three main categories of food packaging under evaluation (food contact paper, dinnerware, and containers). For some food packaging products, Ecology only found options that were apparently PFAS-free, but PFAS options may also exist. In some cases, we found that some types or brands of PFAS-free alternative products were readily available, where others were not.

Ecology sought price information from manufacturers about alternative substances and products. We also collected unit price information from products in each food packaging application that were known to contain either PFAS or a specific alternative substance under consideration. Although limited, we were reasonably certain that the data collected were sufficient to make determinations for both the cost and availability of some PFAS-free alternatives at this time.

As shown in Table 6 through Table 15, Ecology was unable to obtain sufficient data to form a conclusion for some products. In some cases, while pricing information was publicly available, it could not be connected to a specific alternative material. Ecology found pricing information was frequently confidential and treated as a trade secret. In each of these cases, Ecology noted the option as "insufficient data," indicating Ecology was unable to find sufficiently reliable data for that alternative.

The tables below summarize Ecology's findings as to ready availability and comparable cost for each alternative identified. It is important to note that cost and availability of various products frequently change, and are accurate at the time of publication.

Table 6. Wraps and liners cost and availability assessment summary.

Alternative Material	Readily Available?	Comparable Cost?	Cost & Availability Assessment
Uncoated paper	Yes	No	Not favorable
Wax-coated	Yes	Yes	Favorable
Siloxane-coated	Insufficient data	Insufficient data	Insufficient data
PVOH-coated	Insufficient data	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Insufficient data

Table 7. Bags and sleeves cost and availability assessment summary.

Alternative Material	Readily Available?	Comparable Cost?	Cost & Availability Assessment
Uncoated paper	Yes	Insufficient data	Insufficient data
Wax-coated	Yes	Insufficient data	Insufficient data
Siloxane-coated	Insufficient data	Insufficient data	Insufficient data
PVOH-coated	Insufficient data	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Insufficient data

Table 8. Plates cost and availability assessment summary.

Alternative Material	Readily Available?	Comparable Cost?	Cost & Availability Assessment
Uncoated Paper	Yes	Yes	Favorable
Clay-coated	Yes	Yes	Favorable
PVOH-coated	Insufficient data	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Insufficient data
PE-coated	Insufficient data	Insufficient data	Insufficient data
PET-coated	Insufficient data	Insufficient data	Insufficient data
PLA foam	Insufficient data	Insufficient data	Insufficient data
PLA plastic	Yes	Insufficient data	Insufficient data
Reusable plates	Yes	Yes for some users	Favorable for some users

Table 9. Bowls cost and availability assessment summary.

Alternative Material	Readily Available?	Comparable Cost?	Cost & Availability Assessment
Clay-coated	Yes	Yes	Favorable
PVOH-coated	Insufficient data	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Insufficient data

Alternative Material	Readily Available?	Comparable Cost?	Cost & Availability Assessment
PE-coated	Insufficient data	Insufficient data	Insufficient data
PET-coated	Insufficient data	Insufficient data	Insufficient data
PLA-coated	Yes for some users	No	Not favorable
PLA foam	Insufficient data	Insufficient data	Insufficient data
Reusable bowls	Yes	Yes for some users	Favorable for some users

Table 10. Trays cost and availability assessment summary.

Alternative Material	Readily Available?	Comparable Cost?	Cost & Availability Assessment
Clay-coated	Yes	Insufficient data	Insufficient data
PVOH-coated	Insufficient data	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Insufficient data
PE-coated	Insufficient data	Insufficient data	Insufficient data
PET-coated	Insufficient data	Insufficient data	Insufficient data
PLA-coated	Insufficient data	Yes	Insufficient data
PLA foam	Insufficient data	Yes	Insufficient data
PLA plastic	Yes for some users	Yes	Favorable for some users
Reusable trays	Yes	Yes for some users	Favorable for some users

Table 11. Boats cost and availability assessment summary.

Alternative Material	Readily Available?	Comparable Cost?	Cost & Availability Assessment
Clay-coated	Yes	Yes	Favorable
PVOH-coated	Insufficient data	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Insufficient data
PE-coated	Insufficient data	Insufficient data	Insufficient data
PET-coated	Insufficient data	Insufficient data	Insufficient data
Reusable boats	Yes	Yes for some users	Favorable for some users

Table 12. Pizza boxes cost and availability summary.

Alternative Material	Readily Available?	Comparable Cost?	Cost & Availability Assessment
Uncoated paper	Yes	Yes	Favorable
Clay-coated	Yes	Yes	Favorable
PVOH-coated	Insufficient data	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Insufficient data

Table 13. French fry carton cost and availability summary.

Alternative Material	Readily Available?	Comparable Cost?	Cost & Availability Assessment
Clay-coated	Yes	Yes	Favorable
PVOH-coated	Insufficient data	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Insufficient data
PLA-coated	Yes for some users	Yes	Favorable for some users

Table 14. Clamshells cost and availability summary.

Alternative Material	Readily Available?	Comparable Cost?	Cost & Availability Assessment
Uncoated paper	Insufficient data	Insufficient data	Insufficient data
PVOH-coated	Insufficient data	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Insufficient data
PE-coated	Insufficient data	Insufficient data	Insufficient data
PLA foam	Insufficient data	No	Not favorable
PLA-coated	Insufficient data	No	Not favorable
PLA Plastic	Yes for some users	No	Not favorable
Reusable Clamshells	No	Insufficient data	Not favorable

Table 15. Interlocking folded containers cost and availability summary.

Alternative Material	Readily Available?	Comparable Cost?	Cost & Availability Assessment
Clay-coated	Insufficient data	Insufficient data	Insufficient data
PVOH-coated	Insufficient data	Insufficient data	Insufficient data
EVOH Copolymer-coated	Insufficient data	Insufficient data	Insufficient data
PE-coated	Yes	Insufficient data	Insufficient data
PLA-coated	Insufficient data	Yes	Insufficient data
Reusable containers	No	Insufficient data	Not favorable

Ecology Findings and Determinations

For each food packaging application, Ecology assessed each alternative separately to determine whether it met the criteria for a safer alternative. To be a safer alternative, the alternative:

- Must be less hazardous than the chemical of concern according to the hazard evaluation.
- Must have a lower exposure risk than the chemical of concern or be sufficiently less hazardous according to the exposure evaluation.
- Must perform as well or better than PFAS according to the performance evaluation.
- Must be readily available in sufficient quantity according to the cost and availability evaluation.
- Must be cost comparable with similar PFAS-containing products according to the cost and availability evaluation.

Based on results of the four evaluations, Ecology made one of the following findings for each alternative:

- Yes, this is a safer alternative that meets all five criteria.
- Yes, this is a safer alternative that meets all five criteria for some but not all users (such as a food truck being unable to accommodate reusable options).
- No, this is not a safer alternative, failing to meet at least one criterion.
- Ecology does not have sufficient data to reach a conclusion for at least one criterion.

Food packaging application: wraps and liners

Ecology evaluated five possible alternatives for wraps and liners and reached the following conclusions:

Table 16. Wraps and liners evaluation summary.

Item	Hazard	Exposure	Performance	Cost & Availability	Safer Alternative?
Uncoated paper	Low concern	Not applicable	Favorable	Not favorable	No
Wax-coated	Low concern	Not applicable	Favorable	Favorable	Yes
Siloxane-coated	High concern Benchmark-1	Not applicable	Favorable	Insufficient data	No
PVOH-coated	Low concern	Not applicable	Favorable	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Favorable	Insufficient data	Insufficient data

Findings

Ecology determined there is at least one safer alternative that is readily available in sufficient quantity, at a comparable cost, and that performs as well or better than PFAS-coated wraps and liners.

One alternative fails to meet the hazard criterion and is not considered safer.

Another alternative currently fails to meet the cost and availability criteria, so is not a safer alternative at this time.

Ecology had insufficient information to reach conclusions on two other alternatives.

Food packaging application: bags and sleeves

Ecology evaluated five possible alternatives for bags and sleeves and reached the following conclusions:

Table 17. Bags and sleeves evaluation summary.

Item	Hazard	Exposure	Performance	Cost & Availability	Safer Alternative?
Uncoated paper	Low concern	Not applicable	Favorable	Insufficient data	Insufficient data
Wax-coated	Low concern	Not applicable	Favorable	Insufficient data	Insufficient data
Siloxane-coated	High concern Benchmark-1	Not applicable	Favorable	Insufficient data	No
PVOH-coated	Low concern	Not applicable	Favorable	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Favorable	Insufficient data	Insufficient data

Findings

Ecology is unable to identify a safer alternative that is also readily available in sufficient quantity, at a comparable cost, and that performs as well or better than PFAS-coated bags and sleeves.

One alternative currently fails to meet the hazard criterion and is not safer.

Ecology had insufficient information to reach conclusions on four other alternatives.

Food packaging application: plates

Ecology evaluated nine possible alternatives for plates and reached the following conclusions:

Table 18. Plates evaluation summary.

Item	Hazard	Exposure	Performance	Cost & Availability	Safer Alternative?
Uncoated paper	Low concern	Not applicable	Insufficient data	Favorable	Insufficient data
Kaolin clay-coated	Low concern	Not applicable	Favorable	Favorable	Yes
PVOH-coated	Low concern	Not applicable	Favorable	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Favorable	Insufficient data	Insufficient data
PE-coated	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
PET-coated	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
PLA foam	Favorable Benchmark-3	Not applicable	Favorable	Insufficient data	Insufficient data
PLA plastic	Favorable Benchmark-3	Not applicable	Favorable	Insufficient data	Insufficient data
Reusable plates	Not applicable	Not applicable	Not applicable	Favorable for some users	Yes for some users

Findings

Ecology determined there is at least one safer alternative that is readily available in sufficient quantity, at a comparable cost, and that performs as well or better than PFAS-coated plates.

Reusable alternatives also qualify as meeting the requirements as a safer alternative for some users.

Ecology had insufficient information to reach conclusions on seven other alternatives.

Food packaging application: bowls

Ecology evaluated eight possible alternatives for bowls and reached the following conclusions:

Table 19. Bowls evaluation summary.

Item	Hazard	Exposure	Performance	Cost & Availability	Safer Alternative?
Kaolin clay-coated	Low concern	Not applicable	Favorable	Not favorable	No
PVOH-coated	Low concern	Not applicable	Favorable	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Favorable	Insufficient data	Insufficient data

Item	Hazard	Exposure	Performance	Cost & Availability	Safer Alternative?
PE-coated	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
PET-coated	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
PLA-coated	Favorable Benchmark-3	Not applicable	Favorable	Not favorable	No
PLA foam	Favorable Benchmark-3	Not applicable	Favorable	Insufficient data	Insufficient data
Reusable bowls	Not applicable	Not applicable	Not applicable	Favorable for some users	Yes for some users

Findings

Ecology is unable to identify a safer alternative that is also readily available in sufficient quantity, at a comparable cost, and that performs as well or better than PFAS-coated bowls.

Reusable bowls would qualify as meeting the requirements as a safer alternative for some users, but we cannot conclude that this alone currently meets the "readily available" requirement of the statute.

Two alternatives fail to meet the cost comparability criterion at this time.

Ecology had insufficient information to reach conclusions on five other alternatives.

We note that if "cost comparable" is defined as being within 20 percent instead of 10 percent of the PFAS cost, both kaolin clay-coated and PLA-coated bowls would be "cost comparable" and would be identified as safer alternatives.

Food packaging application: trays

Ecology evaluated nine possible alternatives for trays and reached the following conclusions:

Table 20. Trays evaluation summary.

Item	Hazard	Exposure	Performance	Cost & Availability	Safer Alternative?
Kaolin clay-coated	Low concern	Not applicable	Favorable	Insufficient data	Insufficient data
PVOH-coated	Low concern	Not applicable	Favorable	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Favorable	Insufficient data	Insufficient data
PE-coated	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
PET-coated	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data

Item	Hazard	Exposure	Performance	Cost & Availability	Safer Alternative?
PLA-coated	Favorable Benchmark-3	Not applicable	Favorable	Insufficient data	Insufficient data
PLA foam	Favorable Benchmark-3	Not applicable	Favorable	Insufficient data	Insufficient data
PLA-coated	Favorable Benchmark-3	Not applicable	Favorable	Favorable for some users	Yes for some users
Reusable trays	Not applicable	Not applicable	Not applicable	Favorable for some users	Yes for some users

Findings

Ecology is unable to identify a less hazardous alternative that is readily available in sufficient quantity, at a comparable cost, and that performs as well or better than PFAS-coated trays.

Reusable alternatives and PLA-coated trays would qualify as meeting the requirements as a safer alternative for some users, but we cannot conclude that this alone currently meets the "readily available" requirement of the statute.

Ecology had insufficient information to reach conclusions on seven other alternatives.

Food packaging application: boats

Ecology evaluated six possible alternatives for boats and reached the following conclusions:

Table 21. Boats evaluation summary.

Item	Hazard	Exposure	Performance	Cost & Availability	Safer Alternative?
Kaolin clay-coated	Low concern	Not applicable	Favorable	Favorable	Yes
PVOH-coated	Low concern	Not applicable	Favorable	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Favorable	Insufficient data	Insufficient data
PE-coated	Insufficient data	Insufficient data	Insufficient data	Favorable	Insufficient data
PET-coated	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
Reusable boats	Not applicable	Not applicable	Not applicable	Favorable for some users	Yes for some users

Findings

Ecology determined there is at least one safer alternative that is readily available in sufficient quantity, at a comparable cost, and that performs as well or better than PFAS-coated boats.

Reusable alternatives also qualify as meeting the requirements as a safer alternative for some users.

Ecology had insufficient information to reach conclusions on four other alternatives.

Food packaging application: pizza boxes

Ecology evaluated four possible alternatives for pizza boxes and reached the following conclusions:

Table 22. Pizza box evaluation summary.

Item	Hazard	Exposure	Performance	Cost & Availability	Safer Alternative?
Uncoated paper	Low concern	Not applicable	Favorable	Favorable	Yes
Kaolin clay-coated	Low concern	Not applicable	Insufficient data	Favorable	Insufficient data
PVOH-coated	Low concern	Not applicable	Favorable	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Favorable	Insufficient data	Insufficient data

Conclusion

Ecology determined there is at least one safer alternative that is readily available in sufficient quantity, at a comparable cost, and that performs as well or better than PFAS-coated pizza boxes.

Ecology had insufficient information to reach conclusions on three other alternatives.

Food packaging application: French fry cartons

Ecology evaluated four possible alternatives for French fry cartons and reached the following conclusions:

Table 23. French fry cartons evaluation summary.

Item	Hazard	Exposure	Performance	Cost & Availability	Safer Alternative?
Kaolin clay-coated	Low concern	Not applicable	Insufficient data	Favorable	Insufficient data
PVOH-coated	Low concern	Not applicable	Favorable	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Favorable	Insufficient data	Insufficient data
PLA-coated	Favorable Benchmark-3	Not applicable	Favorable	Favorable for some users	Yes for some users

Conclusion

Ecology is unable to identify a less hazardous alternative that is readily available in sufficient quantity, at a comparable cost, and that performs as well or better than PFAS-coated French fry cartons.

PLA-coated French fry cartons would qualify as meeting the requirements as a safer alternative for some users, but we cannot conclude this alone currently meets the "readily available" requirement of the statute.

Ecology had insufficient information to reach conclusions on three other alternatives.

Food packaging application: clamshells

Ecology evaluated eight possible alternatives for clamshells and reached the following conclusions:

Table 24. Clamshells evaluation summary.

Item	Hazard	Exposure	Performance	Cost & Availability	Safer Alternative?
Uncoated paper	Low concern	Not applicable	Insufficient data	Insufficient data	Insufficient data
PVOH-coated	Low concern	Not applicable	Favorable	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Favorable	Insufficient data	Insufficient data
PE-coated	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
PLA-coated	Favorable Benchmark-3	Not applicable	Favorable	Not favorable	No
PLA foam	Favorable Benchmark-3	Not applicable	Favorable	Not favorable	No
PLA plastic	Favorable Benchmark-3	Not applicable	Favorable	Not favorable	No
Reusable clamshell	Not applicable	Not applicable	Not applicable	Not favorable	No

Conclusion

Ecology is unable to identify a less hazardous alternative that is readily available in sufficient quantity, at a comparable cost, and that performs as well or better than PFAS-coated clamshells.

Four alternatives currently fail to meet the cost and availability criteria and are not considered safer alternatives at this time.

Ecology had insufficient information to reach conclusions on four other alternatives.

We note that if "cost comparable" is defined as being within 20 percent instead of 10 percent of the PFAS cost, PLA foam clamshells would be "cost comparable" and would be identified as a safer alternative for some users.

Food packaging application: interlocking folded containers

Ecology evaluated six possible alternatives for interlocking folded containers and reached the following results:

Table 25. Interlocking folded containers evaluation summary.

Item	Hazard	Exposure	Performance	Cost & Availability	Safer Alternative?
Kaolin clay-coated	Low concern	Not applicable	Favorable	Insufficient data	Insufficient data
PVOH-coated	Low concern	Not applicable	Favorable	Insufficient data	Insufficient data
EVOH copolymer-coated	Insufficient data	Insufficient data	Favorable	Insufficient data	Insufficient data
PE-coated	Insufficient data	Insufficient data	Favorable	Insufficient data	Insufficient data
PLA-coated	Favorable Benchmark-3	Not applicable	Favorable	Not favorable	No
Reusable container	Not applicable	Not applicable	Not applicable	Not favorable	No

Conclusion

Ecology is unable to identify a less hazardous alternative that is readily available in sufficient quantity, at a comparable cost, and that performs as well or better than PFAS-coated interlocking folded containers.

Two alternatives currently fail to meet the cost and availability criteria and are not considered safer alternatives at this time.

Ecology had insufficient information to reach conclusions on five other alternatives.

Determination summary

For all of the ten food packaging applications reviewed, Ecology determines there are alternative food packaging alternatives that are less hazardous and have a lower exposure risk than PFAS-based food packaging options. However, for some of these alternatives, Ecology is unable to demonstrate the less hazardous alternative is also readily available in sufficient quantity, is comparable in cost, and/or has equivalent performance to the PFAS options.

Ecology determines the following food packaging items have less hazardous alternatives that are also readily available in sufficient quantity, are comparable in cost, and have equivalent performance to PFAS-based options:

- Wraps and liners.
- Plates.
- Boats.
- Pizza boxes.

As noted above, if “cost comparable” is expanded to be defined as a price within 20 percent instead of within 10 percent of the PFAS option, bowls would also have less hazardous alternatives that are readily available in sufficient quantity, are comparable in cost, and have equivalent performance to PFAS-based options.

Peer Review

Peer review process

RCW 70A.222.070(1)[30] requires that any determination that safer food packaging alternatives exist must be "supported by feedback from an external peer review of the department's alternatives assessment…"

To obtain the necessary peer review, Ecology entered into an interagency agreement with the Washington State Academy of Sciences (Academy) to perform an external peer review of the alternatives assessment and resulting findings. Peer reviewers were chosen for their expertise in alternatives assessments, food packaging, or toxicology. The Academy independently selected the peer reviewers.

On seeing the list of peer reviewers, Ecology requested that the Academy add a state agency representative to the peer review committee. After discussing the request with Ecology, the Academy eventually chose a state agency employee from California.

The peer reviewers were:

Simona Balan

Dr. Simona Balan, Senior Environmental Scientist in the California Department of Toxic Substances Control. Dr. Balan is leading the Safer Consumer Products team on perfluoroalkyl and polyfluoroalkyl substances (PFASs). Dr. Balan previously managed international projects on the use of flame retardants and PFASs in consumer products. She was recognized by the Collaborative on Health and the Environment as one of 20 Pioneers under 40 in Environmental Public Health. Dr. Balan has a Ph.D. in Environmental Science, Policy and Management from the University of California, Berkeley.

Elaine Faustman (peer review chair)

Dr. Elaine Faustman is a toxicologist and Professor and Director of the UW Department of Environmental & Occupational Health Sciences. She is also Adjunct Professor in the UW Evans School of Public Policy and Governance. Dr. Faustman's research focuses on identifying biochemical mechanisms of developmental neurotoxicity and to develop new approaches for the evaluation and characterization of health risks from environmental agents. Her expertise is in risk assessment of chemical hazards and neurodevelopmental toxicology. Dr. Faustman received the 2019 Merit Award from the International Union of Toxicology and was elected into the Washington State Academy of Sciences. Dr. Faustman earned a PhD in Toxicology from Michigan State University.

Lauren Heine

Dr. Lauren Heine is Senior Science Advisor at Northwest Green Chemistry and is adjunct faculty at Gonzaga University. Dr. Heine applies green chemistry, green engineering, and multi-

[30] https://app.leg.wa.gov/RCW/default.aspx?cite=70A.222.070

stakeholder collaboration to the development of products and processes. She led development of GreenScreen® for Safer Chemicals, a method for chemical hazard assessment increasingly used worldwide. Dr. Heine drafted Policy Principles for Sustainable Materials Management for the OECD, and she helped develop criteria for the Design for the Environment (DfE) Safer Choice and Alternatives Assessment Programs for the EPA. Dr. Heine was technical advisor to the development of the Interstate Chemicals Clearinghouse (IC2) Alternatives Assessment Guide and the WA Alternatives Assessment Guide. She serves on the Apple Green Chemistry Advisory Board, and previously served on the California Green Ribbon Science Panel. Dr. Heine earned a PhD in Civil and Environmental Engineering from Duke University.

Pat Hunt

Dr. Patricia A. Hunt is Meyer Distinguished Professor in the School of Molecular Bioscience at Washington State University. Her primary research interest lies in human aneuploidy, mammalian germ cells and meiosis, and she is best known for showing the adversary effect of Bisphenol A and replacement bisphenols (BPS, BPF, BPAF, Diphenyl sulfone) on the reproductive system of mammalians. Dr. Hunt's current work centers on the reproductive effects of exposure to chemicals with estrogenic activity. She was elected into the Washington State Academy of Sciences. Dr. Hunt earned a PhD in Reproductive Biology from the University of Hawaii.

Donatien Pascal Kamdem

Dr. Donatien Pascal Kamdem is Professor in the School of Packaging at Michigan State University and works with Global Packaging Solutions LLC. His research interests include the chemical, physical, and mechanical properties of packaging made from wood, paper, and natural fibers, and technology to improve the performance and reduce cost of those products. Dr. Kamdem is an elected fellow of the International Academy of Wood Science. He has served as a witness expert, consultant, and reviewer on many projects regarding wood products. Dr. Kamdem earned a PhD in Wood Science from University Laval in Quebec, Canada.

Michael Skinner

Dr. Michael Skinner is Professor in the School of Biological Sciences at Washington State University. He has been on the faculty of Vanderbilt University and the University of California at San Francisco. Dr. Skinner's research focuses on the investigation of gonadal growth and differentiation, with emphasis in reproductive biology. His current research has demonstrated the ability of environmental toxicants to promote the epigenetic transgenerational inheritance of disease phenotypes due to abnormal germ line epigenetic programming in gonadal development. Dr. Skinner established and was the Director of the Washington State University and University of Idaho Center for Reproductive Biology, and established and was the Director of the Center for Integrated Biotechnology. He received the 2013 American Ingenuity Award from the Smithsonian. Dr. Skinner earned a PhD in Biochemistry from Washington State University.

Huqiu Zhang

Dr. Huqiu Zhang is Senior Scientist at Sevee & Maher Engineers. Dr. Zhang specializes in optimizing chemical testing programs, applying analytical methods, and implementing chemical controls in the manufacturing process, covering the entire supply chain of food packaging. She has international experience in regulatory compliance for consumer product chemical safety, food contact, and food packaging. Dr. Zhang's expertise includes chemical and material industry product supply chains and chemical management, particularly in paper, paperboard, and plastic products, as well as chemical hazard identification, exposure evaluation, and risk assessment. Dr. Zhang's early research was in perfluorine chemistry. Dr. Zhang earned a PhD in Organic Chemistry from the University of Tennessee, Knoxville.

Peer review results and Ecology response

The peer review results generally supported Ecology's evaluation and results. The peer reviewers recommended a number of revisions to help strengthen the report and its conclusions and they challenged some of Ecology's assumptions. However, some of the peer reviewers' comments were unclear. As a result, Ecology requested clarification from the committee and received an addendum in response. Appendix A contains the text of each of the committee's specific comments and Ecology's response to each (including an explanation of changes made). Appendix B is a copy of the committee's original comment report as submitted to Ecology. Appendix C is a copy of the committee's addendum as received by Ecology.

Data discrepancies identified after submission to peer review

Independent of the peer review comments, Ecology identified and corrected three data discrepancies in the "Cost and Availability" module of the alternatives assessment, which were found after the report was submitted to the peer review committee. Those discrepancies are:

- Data we originally relied on to determine whether PVOH-coated options were cost comparable were instead not limited to just PVOH-coated options. Based on this new information, we revised our findings about PVOH-coated options and determined that there was insufficient information to demonstrate those products are cost comparable.
- Data we originally relied on to determine kaolin clay-coated plates were cost comparable was likely incorrectly categorized. Instead, this information should have been categorized as poly-coated plates. As a result, we changed our cost comparison for large paper plates to compare nine-inch plates instead of ten-inch plates, as we have reliable data regarding costs of kaolin clay-coated options for this application.
- Data we originally relied on to determine kaolin clay-coated interlocking folded containers are readily available was likely incorrectly categorized. Instead, this information should have been categorized as poly-coated interlocking folded containers. As a result, we revised our findings about kaolin clay-coated interlocking folded containers and determined there was insufficient information to demonstrate those products are readily available and cost comparable.

Conclusion and Next Steps

Findings and results

Ecology reviewed the results of the alternatives assessment and found at least one safer alternative available for each of four applications. As a result, the restriction on sale and use of PFAS food packaging found in RCW 70A.222.070(1)[31] will apply to these food packaging applications only:

- Wraps and liners.
- Plates.
- Food boats.
- Pizza boxes.

Because Ecology was unable to find alternatives that met all five mandatory criteria[32] for bags and sleeves, bowls, trays, French fry cartons, interlocking folded containers, or clamshells, these food packaging applications do not meet the requirements for a restriction at this time.

Future work

The legislation provides that if Ecology does not determine safer alternatives are available by January 1, 2020, the prohibitions would not take effect January 1, 2022.

Ecology did not complete the alternatives assessment by January 1, 2020, and therefore did not determine that safer alternatives are available by that date. Instead, this report is being submitted in 2021. Thus the prohibition against the sale of specified PFAS-containing food packaging applications will take place in 2023, two years from the date this report is submitted to the Legislature, in accordance with RCW 70A.222.070(5). This effective date will be slightly more than one year after the date listed in RCW 70A.222.070(1).

When Ecology does not find safer alternatives for a particular food packaging application, RCW 70A.222.070(5) requires that application to be reevaluated each year until safer alternatives are found. Starting in 2021, Ecology will begin another alternatives assessment reviewing:

- Food contact bags and sleeves, bowls, trays, French fry cartons, clamshells, and interlocking folded containers to determine if PFAS-free alternatives are readily available, in sufficient quantity, at a comparable price, with equivalent performance.
- Other substances and applications from the original assessment that had insufficient data.

[31] https://app.leg.wa.gov/RCW/default.aspx?cite=70A.222.070
[32] Less hazardous, lower exposure, equivalent performance, readily available, and comparable price.

Ecology's 2021 alternatives assessment will give primary attention to applications where insufficient information previously prevented Ecology from making determinations (*i.e.*, bags and sleeves, bowls, trays, French fry cartons, interlocking folded containers, and clamshells).

Given the growing interest in PFAS-free packaging, we expect to see changes in the availability, cost, and performance of alternatives evaluated in this assessment. We also expect to see increased availability of PFAS-free alternatives in food packaging.

Starting in 2023, Ecology expects to begin enforcement of the restrictions on PFAS-containing food packaging for the initial four food packaging applications where safer alternatives were found. We anticipate this will involve working with manufacturers, distributors, wholesalers, and retailers to ensure they comply with the law and, when necessary, assisting them in achieving compliance. Ecology will also engage with stakeholders, including not only manufacturing associations and environmental advocates, but also grocers, retailers, hospitality organizations, and other end users of affected products. Ecology's outreach efforts may include developing focus sheets, web pages, and other educational materials.

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Appendix A. Peer Review Comments and Ecology Responses

October 5, 2020 Summary of Review comments

The peer review results generally supported Ecology's evaluation and results. The peer reviewers recommended a number of revisions to help strengthen the report and its conclusions and they challenged some of Ecology's assumptions. The following comments are direct quotes from the peer review report, including any numbering as in the original. Ecology's response to each comment directly follows.

At the beginning of peer review comments sent to Ecology, the peer review committee included a summary of their review. This summary highlights what the committee identified as the key points Ecology should consider when revising the alternatives assessment.

Reviewer comment

> Summary of Review
>
> The committee recognizes the complexity and lack of complete information inherent in the process of conducting alternatives assessments. However, the report's conclusions would be stronger if the report included clearer and more transparent descriptions of the kinds of information and science (or data or analysis) that support them.
>
> The committee has several comments and suggestions about the alternatives assessment process as applied in this report. The key points include:
>
> **1. Justify more clearly the choice of the chemical of concern.** The report mentions that stakeholder opinions were conflicted about whether to use a single representative chemical of concern, but does not fully explain why Ecology nevertheless decided to take this approach.

Ecology response

In the "Selection of a representative PFAS" section of the alternatives assessment, we have now provided a more thorough explanation of stakeholder opinions we received regarding how to assess PFAS for the purposes of this alternatives assessment. Stakeholder opinions were divided on the subject of whether or not to identify a specific PFAS to evaluate hazard and exposure risks. Ecology ultimately made the decision to identify a commonly used PFAS in food packaging that could be used in the hazard and exposure assessment modules. In our revisions, we discussed this justification in more detail.

Reviewer comment

> The only explanation provided is that the "C6-based fluorinated polymers are the predominant PFAS used in U.S. food packaging materials"; however, the FDA announced on July 31, 2020 that all C6-based fluorinated polymers, including the selected chemical of concern, will begin a voluntary three-year phase out in January 2021.

Ecology response

The explanation we provided was based on stakeholder input we received from the FluoroCouncil that these were the most common PFAS used in food packaging at that time.

The decision to identify a commonly used PFAS from this group as a comparator for the chemical of concern and our subsequent decision of which PFAS to use were made in 2019, approximately a year prior to the FDA's announcement. Our report acknowledges the FDA phase-out announcement. Given the voluntary phase-out may last until 2024, we believe the phase-out strengthens our decision to compare alternatives to these PFAS (particularly since the phase out was in response to new evidence about the hazards of the PFAS impurities we had studied). Ecology acknowledges that in future assessments we may choose to evaluate hazard and exposure risks for PFAS differently.

Reviewer comment

> Some of the remaining PFASs that will not be phased out are perfluoropolyethers (PFPEs). The report would benefit from a clear statement of why PFPEs are expected to have a similar hazard and exposure potential as the C6-based compound selected as the chemical of concern.

Ecology response

We have revised our discussion of the PFAS into a general review of PFAS that are currently used to provide oil and grease resistance to food packaging in the United States. This discussion includes information on PFPEs, and literature that details the environmental and health concerns associated with all PFAS chemicals, such as their persistence.

Reviewer comment

> **2. Review alternative compounds more thoroughly**. To document that alternatives are not potentially as harmful as the banned products, the committee suggests including substantive evidence from the peer-reviewed literature (examples are provided below).

Ecology response

Ecology chose to perform a Level 2 Hazard evaluation. At this level, the IC2 Alternatives Assessment Guide recommends using the GreenScreen® evaluation tool. The GreenScreen® evaluation tool is a commonly used, freely available tool that uses peer-reviewed literature as well as other information about chemicals to evaluate their hazard risks. GreenScreen® provides a systematic method for integrating peer reviewed studies and government reports, managing conflicting findings and employing a strength of evidence approach to draw conclusions. Ecology contracts with licensed GreenScreen® assessors to evaluate the alternatives as needed. For alternatives that had not already been identified as low concern, Ecology decided to use GreenScreen ® as the only hazard evaluation tool, so that we could easily compare the hazard risks between the different alternatives and PFAS. The decision was clarified in the hazard assessment module and a more detailed explanation of the peer-reviewed science relied upon was also provided. Ecology paid for a GreenScreen® evaluation of Lactide, and examples of the types of data used in that report have been included in the discussion.

Reviewer comment

> In particular, the report relies heavily on concluding that there is "insufficient information" despite a body of evidence on the alternatives. For example, PE and PET could be evaluated as generic substances using information in the peer reviewed literature about typical chemical constituents without having to obtain full ingredient disclosure from a manufacturer.

Ecology response

Ecology clarified the meaning of "insufficient information." In order to perform a GreenScreen® evaluation, an assessor needs information about the alternative that is typically considered a trade secret by manufacturers. Although every effort was made to work with manufacturers to get this information, there were instances when we were unable to gather enough information to conduct a GreenScreen® evaluation. In these cases, we designated the alternative as having "insufficient information" or "insufficient data" and did not evaluate it. This was not a comment on the hazard concerns associated with the alternative and does not preclude a hazard evaluation in future alternatives assessments. We clarified both our rationale and its impact on the hazard assessment module in the alternatives assessment.

Ecology acknowledges that there is likely hazard information about these alternatives in published, peer-reviewed literature. We did not use this information in lieu of a GreenScreen® because doing so would have been inconsistent with our GreenScreen® approach for other alternatives being evaluated. We have clarified both our method for assessing hazards and our definition of what insufficient data means in this alternatives assessment.

Reviewer comment

> The report would also be strengthened by providing an explanation of why Ecology chose those specific alternatives to be assessed, and how it reached the conclusions of the assessment.

Ecology response

Ecology added more detail on the alternatives to PFAS that were evaluated in this assessment in the scoping section, where we discussed the process of identifying alternatives. In the original scoping section, we discussed the selection criteria Ecology used to identify alternatives. In the revised alternatives assessment, we provide additional background information on each alternative and state which of the selection criteria each chosen alternative met.

Reviewer comment

> In addition, the report's analysis would benefit from a more thorough assessment to strengthen the conclusion that the safe alternatives are available in sufficient quantities, as per the legislation.

Ecology response

This comment was well taken. In response, we have altered our method. We continued to look at the general availability of alternatives to PFAS within a food packaging type. In addition, we collected more information on how many manufacturers made each food packaging type using each specific alternative and whether those manufacturers hold a large share of the plant-based food packaging market. After applying these additional criteria to the alternatives reviewed, we found several that no longer met the criteria for availability and so no longer meet the criteria for safer alternatives.

Reviewer comment

> **3. Provide the full rationale for the chosen assessment levels for each module.** In particular, there are items out of scope for a Level 1 Exposure assessment that could be valuable for this report.

Ecology response

Ecology originally provided a brief rationale for the assessment levels chosen in the introduction. In response to this comment we have added a subsection to each assessment module discussion that summarizes Ecology's rationale for the level chosen for that assessment module. Our choices were based on the levels described by the IC2 Alternatives Assessment

Guide, the requirements given in RCW 70A.222.070,[33] and the feasibility of accomplishing the analysis based on data, time, and budget limitations.

Reviewer comment

> The report would also benefit from providing the rationale for the Cost and Availability Assessment level and how the analysis supports the assessment.

Ecology response

Chapter 70A.222 RCW directs Ecology to perform a PFAS alternatives using IC2 guidance, but also requires that, "the safer alternative must be readily available in sufficient quantity at a comparable cost." After reviewing the guiding questions posted for each level, we determined that a Level 1 cost and availability evaluation was sufficient to meet our directive. A more thorough explanation was added to the cost and availability assessment module of the alternatives assessment.

Reviewer comment

> **4. Clearly present a rationale for the choice of the decision framework used in the assessment.** Figure 1 of Ecology's draft report shows one version of a decision framework presented in the IC2 Alternatives Assessment Guide; others are also mentioned in the guide.

Ecology response

This image was replaced with a revised image that better depicts Ecology's process for this alternatives assessment and our use of the simultaneous decision framework.

Reviewer comment

> The committee suggests including a) a section at the beginning of the report with an explanation of the rationale for choosing the simultaneous decision framework to evaluate data from the four modules; and b) a section at the end of the report presenting the results of applying the decision framework and then integrating the data gathered in each module into the framework to make recommendations.

Ecology response

Ecology used a simultaneous decision framework for this assessment. This has been stated more clearly in the final version of the alternatives assessment. We included an introduction to the simultaneous decision framework that includes our rationale for this choice, adjusted the structure of the alternatives assessment to better fit with the stated framework, and provided

[33] https://app.leg.wa.gov/RCW/default.aspx?cite=70A.222.070

more information on how the simultaneous decision framework was used to identify safer alternatives in the Summary of Results section.

Reviewer comment

> **5. Structure the report to show more clearly the logical flow of evidence and decision-making.** In order to do so, the report should follow the structure of the IC2 Alternatives Assessment Guide, starting with scoping, including descriptions of the stakeholder involvement module and decision framework, then working sequentially through the other four modules, and ending with a summary of results from applying the decision framework to the data gathered in each module, followed by one consolidated reference section.

Ecology response

The original report followed the general structure recommended by the peer review committee, except for the summary of results which was placed prior to the four assessment modules. The summary of results has now been moved to the end of the alternatives assessment. As suggested, references have now been consolidated into a single section.

Reviewer comment

> In addition to restructuring, the report would benefit from removing redundancies and improving readability.

Ecology response

When identified, these changes were made.

October 5, 2020 peer review detailed comments

Following the summary, the peer review committee also provided more detailed comments on several topics.

Reviewer comment

> **Scope of the Assessment Process**
>
> Ecology's draft report included four assessments: Exposure, Performance, Cost and Availability, and Hazard. We suggest that Ecology provide the rationale for the levels of assessment chosen. As outlined in this report, Ecology used a Level 1 assessment for the Exposure, Performance, and Cost and Availability assessment modules, and a Level 2 assessment for Hazard and Stakeholder Engagement. Ecology referred to its Washington State Alternatives Assessment Guide to justify the use of these levels, and that guide recommends "The alternatives with the lowest hazard are evaluated further using the three remaining modules, i.e., Performance, Cost and Availability, and Exposure. As a

minimum, Level 1 is recommended for these three modules. Assessors may use higher levels if they have the resources or expertise." (page 4, Washington State Alternatives Assessment Guide 2015).

A Level 1 Exposure assessment is a basic exposure evaluation that identifies potential exposure concerns and includes a qualitative assessment using readily available data. Items out of scope for a Level 1 assessment that could be valuable for this report include accounting for cumulative exposure from other PFAS sources and of life-cycle components such as breakthrough and compounds used for coating. Given the complexity of information available on PFAS, and realizing that Ecology has limited time and budget for the assessment of safer alternatives to per- and polyfluoroalkyl substances in plant fiber-based food packaging, the committee understands that there may be a rationale for a Level 1 Exposure assessment; this rationale would simply need to be written in the report.

Ecology response

As suggested, Ecology added explanations for each assessment level chosen and included a new subsection in the exposure assessment module to explain the rationale for performing a Level 1 Exposure assessment. While we agree the items noted would be of keen interest, we determined that the exposure assessment components suggested are beyond the scope of this alternatives assessment. We direct readers to the PFAS Chemical Action Plan for more information on cumulative PFAS exposure in Washington State.

Reviewer comment

Regarding the Cost and Availability assessment, Question 2 of the analysis, "Is the alternative currently offered for sale for the application of interest?" (Appendix O, page 1) may address the requirement in RCW 70A.222.070 for "readily available" but does not appear to address the requirement of "sufficient quantity" (also referenced in Appendix O, Table 9 on page 20), thus raising the question of whether applying Level 1 of the "cost and availability" module is adequate. The report would also benefit from providing the rationale for the choice of a Level 1 Cost and Availability Assessment, and how the questions in the analysis support the assessment.

Ecology response

Ecology added a new subsection in the cost and availability assessment module that includes the rationale for performing a Level 1 cost and availability assessment. After reviewing the guiding questions posted for each level, we determined that a Level 2 cost and availability evaluation would meet our statutory directive but would also impose additional assessment requirements that go beyond our current mandate. As a result, we have added additional

criteria and considerations to the Level 1 review that we believe addresses the "sufficient quantity" requirement.

Reviewer comment

> The Executive Summary outlines the scope of the assessment, but is unclear about some specific points, such as: 1) Is all plant fiber-based packaging included? and 2) Are mold release agents not considered intentional PFAS additions? Page 57 states that "Third-party verification has demonstrated that most molded fiber products on the market contain PFAS"; the PFAS in these molded fiber products might also originate from mold release agents (California Safer Consumer Products, Public Workshop on Food Packaging with PFASs, January 14 2020 [transcript]; Work Plan Implementation, October 2019). Even if non-PFAS alternatives are used for oil and grease resistance (OGR) and leak resistance, some molded fiber products may continue to contain PFAS unless the mold release agents are also substituted.

Ecology response

RCW 70A.222.010 defines food packaging as including "paper, paperboard, or other materials originally derived from plant fibers." The section "Prioritizing Alternatives to PFAS in Food Packaging" includes several alternative plant fiber materials that were not ultimately included as candidate alternatives in the assessment. We have clarified in this section that Ecology prioritized evaluating those materials and uses that were most broadly applicable to the food packaging types considered.

In this alternatives assessment, Ecology used performance requirements that were a) identified as high priority by a number of stakeholders and b) were broadly applicable to the food packaging types identified. A mold release agent and the performance of a release agent was not identified as a necessary performance requirement for any food packaging type. Although PFAS added as a mold release agent may transfer to molded fiber products and constitute an intentional addition of PFAS, the alternatives evaluated in this assessment were largely alternative chemical coatings that were applied to paper or paperboard. If Ecology evaluates alternatives that are specific to molded fiber products, we may decide it is necessary to evaluate the performance of mold release agents at that time.

Reviewer comment

> **More Thorough Assessment of Alternative Compounds**
>
> Inclusion of Peer-Reviewed Literature
>
> More references to peer-reviewed scientific literature about the hazards, toxicity and general safety of suggested alternative compounds are needed to support the more general information provided from EPA Safer Chemicals lists.

Ecology response

The EPA Safer Chemical Ingredients List submission process requires a qualified third-party profiler to evaluate hazard concerns using a number of data sources, including peer-reviewed literature. The profiler then submits a recommendation as to whether the chemical passes the criteria for Safer Chemical Ingredients. These submissions are reviewed by EPA Safer Choice staff before a final decision is made. To be considered a green circle chemical on SCIL, the chemical must be verified to be of low concern based on experimental and modeled data. Ecology determined it would not be a prudent use of public funds to re-examine alternatives that have already undergone extensive review through the process for listing chemicals as "green circle" on SCIL. This information about the SCIL process has been included in the hazard assessment module.

Reviewer comment

> In addition, a more thorough review of the scientific literature about the compounds and compound classes listed as alternatives, the potential toxicity of the alternatives, their breakdown products (including microplastics, where applicable), and their precursors is also needed.

Ecology response

Our decision to use only the GreenScreen® evaluation tool was clarified in the hazard assessment module. Ecology determined a Level 2 Hazard evaluation was the most appropriate. At this level, the IC2 Alternatives Assessment Guide recommends using the GreenScreen® evaluation tool. The GreenScreen® evaluation tool is a commonly used, freely available tool that uses scientific literature as well as other information about chemicals to evaluate their hazard risks. GreenScreen® reports also document the quality of the data used. Ecology contracts with licensed GreenScreen® assessors to evaluate the alternatives as needed. For alternatives that had not already been identified as low concern, Ecology decided to use GreenScreen® as the only hazard evaluation tool, so that we could easily and transparently compare the hazard risks between the different alternatives and PFAS. We determined that evaluating alternative chemicals with an additional review of the scientific literature would not be consistent with this methodology. The law requires us to identify safer alternatives, but not to characterize the hazards of all possible alternatives in order to determine that some safer alternatives exist.

Reviewer comment

> Furthermore, the literature review should distinguish peer-reviewed technical reports and papers from materials with a lower standard of evidence.

Ecology response

GreenScreen® evaluations include appropriate citations for all the materials used. Furthermore, the GreenScreen® methodology includes a process for characterizing the quality of the data used to evaluate each hazard type. We have clarified this in the hazard assessment module.

Reviewer comment

> The following are examples from the committee of a brief review of PubMed literature on some of the safety and toxicity information of proposed alternatives. The committee suggests that this kind of information be included in the Report:
>
> Alternative PLA -- This is poly(lactide) which is often used with poly(ethylene glycol) PEG. These are safe compounds that have been used for drug delivery and nanoparticle in therapeutics (Part Syst Charact. 2013 Apr;30(4):365-373. doi: 10.1002/ppsc.201200145. Epub 2013 Feb 28. PMID: 27642231). No literature on toxicity or hazards of this class of compounds was found.
>
> Alternative PVOH -- This is polyvinyl alcohol PVA or PVOH with polyethylene glycol PEG or other compounds to generate microparticles and coatings. These are generally safe, but some toxicity has been observed (Food Chem Toxicol. 2013 Jul;51 Suppl 1:S7-S13. doi: 10.1016/j.fct.2012.12.033. Epub 2013 Jan 7. PMID: 23306789). Although there are many types of these compounds for coating and particles, a more thorough description of what they are and potential toxicity was not presented.
>
> Alternative PET -- This is polyethylene terephthalate (PET) that is used with other compounds for coating food containers. This is generally safe (Food Addit Contam Part A Chem Anal Control Expo Risk Assess. 2017 Jul;34(7):1239-1250. doi: 10.1080/19440049.2017.1322221.), but some toxicity has been observed in various applications (Biomaterials. 2010 Apr;31(11):2999-3007. doi: 10.1016/j.biomaterials.2009.12.055. Epub 2010 Jan 15. PMID: 20074795).

Ecology response

We appreciate that the committee provided peer-review literature that we could include in this report. However, Ecology believes reporting exclusively on the peer-reviewed toxicity literature for an alternative when there is insufficient information to perform a GreenScreen® does not align with Ecology's stated methods. Using only GreenScreen® evaluations ensures there is consistency and transparency in how potential hazards were assessed. It also ensures that conclusions are drawn in a systematic manner and that a weight of evidence approach is used to integrate results from multiple studies.

Reviewer comment

> The report also needs to include basic compound name, chemical composition, past use, and safety information for alternatives proposed.

Ecology response

Except for the safety information, which was included in the hazard assessment, this information has been collected in a table in the section on alternative options.

Reviewer comment

> It is essential that alternatives not be suggested that are potentially as harmful or more harmful than the PFASs banned (an industry example of this is the selection of BPS as the alternative for the plastic compound BPA, as BPS is potentially more toxic). Any hazards previously observed should be highlighted to allow the reader to conclude that the report is thorough in its assessments of alternatives.

Ecology response

We wholeheartedly agree with the committee that it is essential to avoid regrettable chemical substitutions for PFAS in food packaging. To avoid this, we used the GreenScreen® evaluation tool to provide a consistent, transparent method for evaluating the hazards of both PFAS and alternatives to PFAS. When it was not possible to conduct a GreenScreen® for an alternative that has not already been identified as a low hazard concern, that alternative could no longer met Ecology's criteria for a safer alternative unless it is a SCIL chemical.

Reviewer comment

> Furthermore, a lack of information is often indicated in tables as "insufficient data," but this phrase is not defined in the report.

Ecology response

In order to perform a GreenScreen® evaluation, an assessor needs information about the alternative that is typically considered a trade secret by manufacturers. As noted above, although every effort was made to work with manufacturers to get this information, we were unable to do so in some instances. When we could not gather sufficient information to conduct a GreenScreen® evaluation, we designated the alternative as having "insufficient data." Alternatives that had "insufficient data" in the hazard assessment module could not be identified as safer alternatives in this alternatives assessment. This is not a comment on the hazard concerns associated with the alternative and does not preclude a hazard evaluation in future alternatives assessments. We clarified both our rationale and its impact on the hazard assessment module in the alternatives assessment.

Reviewer comment

> Relying solely on precursors and breakdown products for toxicity analysis is inappropriate. It is important to note that lack of information is not evidence of lack of toxicity. [NB: please see additional discussion of this comment in the peer review addendum discussion and response below.]

Ecology response

Ecology did not rely solely on precursors and breakdown products for its toxicity analysis for all alternatives. As noted above, the GreenScreen® method used looks at a variety of peer-reviewed and other scientific data to evaluate a variety of toxicological endpoints.

Ecology only evaluated precursors and breakdown products when we were unable to evaluate the complete polymer. The chemical and product formulation information needed to perform GreenScreens® is considered a trade secret by manufacturers. Every effort was made to obtain this information for the alternatives the committee identified (such as PLA or PET), but Ecology does not have the authority under this law to require manufacturers to provide confidential business information. Thus, we were unable to access this data to conduct a GreenScreen® hazard assessment in time for this report. In the absence of this information, or information for a generic version of the alternative, we sought GreenScreens® for polymer impurities, such as residual monomers and likely by-products from polymer degradation, which would have been considered in the GreenScreen® evaluations of the polymers. If the residual monomers and degradation products are hazardous, then the polymer would be characterized as hazardous. We believe this is especially appropriate given peer-reviewed studies showing these breakdown products can leach out of food packaging and into food. This point is discussed further in the peer review addendum section below.

Reviewer comment

> Gaps in Hazard Assessment of Particular Materials
>
> The report also has gaps in its assessment of particular materials. For example, there is a gap in the draft report in assessing PE- and PET-coated materials as potential safe alternatives. In the Hazard module, the report simply concluded that there is “insufficient information” around PE and PET (page 38: “insufficient public data were available at the time of this assessment to evaluate PE, PET, and EVOH copolymers”), but this statement is questionable. PE and PET have long been used in food packaging, before PLA, and there should be plenty of publicly available research literature and information about the precursors, degradation, residue by-products, monomers or oligomers for PE and PET, as well as microplastics.

Ecology response

While these alternatives have been on the market for a long time, we were unable to access data on product formulations and exact chemical identities. This meant that we also were unable to identify potential breakdown products, precursors or residual monomers, as we did with other alternatives. As stated above, when we could not gather enough information to conduct a GreenScreen® evaluation on an alternative, or could not gather information in time to conduct the evaluation, we designated it as having "insufficient data." Alternatives that had "insufficient data" in the hazard assessment module could not be identified as safer alternatives in this alternatives assessment. A notation of "insufficient data" was not intended to suggest there are no hazard concerns associated with the alternative. It also does not preclude a hazard evaluation in future alternatives assessments. We clarified both our rationale and its impact on the hazard assessment module in the alternatives assessment.

Reviewer comment

> Although precursors and degradation products are not a substitute for a toxicity analysis of the substance itself, and PLA also contributes to microplastic contamination, which is a hazard that should be considered in the discussion of this material, it is not clear why the same method applied to PLA could not also be applied to PE, PET, and EVOH in this report (page 37: "Due to a lack of information about specific proprietary versions of the candidate chemicals, both the PFAS COC [chemical of concern] and PLA were evaluated using precursors and degradation products, and siloxanes were evaluated using a representative substance."; page 39: "In the absence of polymer information, both the PFAS COC and PLA were evaluated using precursors and degradation products").

Ecology response

In the absence of the information needed to assess several alternative substances, Ecology sought GreenScreens® on impurities and breakdown products, which would have been evaluated as a part of the GreenScreens® of the alternative substances. Scientific literature has been included that supports our decision to look at GreenScreens® of impurities and breakdown products. However, we did not have enough time to do this for all alternative polymer substances. We prioritized PLA because GreenScreens for PLA impurities had been conducted recently and are publicly available. Also, previous analyses PLA in food packaging indicated PLA has lower hazard risks than other plastics.

Reviewer comment

> These gaps throw into question the final Safe Alternative conclusions; the committee recommends that the authors conduct additional research literature review and analysis to close these gaps. [NB: please see additional discussion of this comment in the peer review addendum discussion and response below.]

Ecology response

Our inadequate explanation of the term "insufficient data" led the peer reviewers to mistakenly conclude that we were commenting about data gaps they believe should be filled. We use the term "insufficient data" to indicate that we didn't have enough information to show it was a safer alternative right now, but that doesn't mean it isn't a safer alternative or couldn't be identified as one in the future. As noted above, Ecology was actually using this phrase to reflect situations where additional research was not possible given our methodology. As GreenScreen® evaluations are based primarily on peer-reviewed research literature, we interpreted this comment to mean Ecology should more clearly explain our use of the term "insufficient data" in our alternatives assessment and more clearly list the peer-reviewed research literature relied on by the GreenScreen® evaluation. This point is discussed further in the peer review addendum section below.

Reviewer comment

> Gaps in Cost and Availability Assessment of Particular Materials
>
> The Cost and Availability Assessment includes the statement "The prevalence of non-PFAS-containing products in each food packaging application...indicates that PFAS-free alternatives are readily available" (Appendix O, page 8). This statement references Table 5 of Appendix O, which shows the PFAS testing results of products that are already on the market. However, the test results in Table 5 do not show which materials are present in these PFAS-free products. Specifically, the data in Table 5 of Appendix O does not indicate that PVOH and PLA-coated are the predominant PFAS-Free products tested; it is possible that some other material, including PE- or PET-coated may be the predominant materials in the PFAS-Free products listed in Table 5 of Appendix O.
>
> Therefore, the conclusion of "sufficient supply" in the Cost and Availability Assessment module, which leads to the conclusion of Safe Alternative for the materials listed in Tables 7-16 of the draft report (summarized by this committee in Table 1 below) and also suggests that the predominant PFAS-Free Safer Alternatives will be PVOH and PLA-based materials, while appearing to exclude PE and PET, becomes questionable.

Ecology response

This comment is well taken. In response, we have altered our method to determine whether specific alternatives were readily available in sufficient quantity within a given type of food packaging. We continued to look at the general availability of alternatives to PFAS within a food packaging type as described above. In addition, we also collected information on how many manufacturers make that food packaging type using a specific alternative and whether those manufacturers hold a large share of the paper food packaging market. We used this additional

information to determine whether a specific alternative demonstrated that it was readily available in sufficient quantity for a specific type of food packaging.

After applying these additional criteria to our alternatives, we found several alternatives that no longer met the criteria for availability and so are no longer considered safer alternatives.

It is also worth noting that we were unable to assess the availability of several alternative products because we lacked either confirmation that the products were PFAS-free or clarity about the chemical identity of an alternative. Both of these limitations were noted in the alternatives assessment.

Reviewer comment

> PE and PET plastics have a long history of safe use in food contact applications. They both were cleared by FDA for food contact uses in 1977, PET in 21CFR177.1630 and PE in 21CFR177.1520. The first FDA clearance for food contact uses of PLA was in 2002, Food Contact Notification 178. As such, PE and PET should be thoroughly assessed in the Cost and Availability Assessment module.

Ecology response

Both PE and PET were included as alternatives in the cost and availability assessment module. As is discussed in the module, many manufacturers using the term poly-coated or polycoating to describe products that have been coated with a number of chemicals, including PE and PET but also EVOH and PVOH. Ecology had no legal ability to compel manufacturers to share product information that would clarify which chemical was used. As such, much of the information that was collected on poly-coated products for the cost and availability evaluations could not be used in this alternatives assessment. Should more specific information about these products and their coatings become available in the future, Ecology may be able to revisit this evaluation.

Reviewer comment

> Report Structure and Presentation of Evidence
>
> Decision Framework
>
> It is unclear in this report which of the three decision analysis frameworks from the IC2 Alternatives Assessment Guide was applied, and the justification for why this particular framework was chosen. This is a critical oversight. Figure 1 (page 3 of Ecology's draft report) shows one version of a decision framework presented in the IC2 Alternatives Assessment Guide; others are also mentioned in the guide. The committee suggests fully explaining this figure.

Ecology response

Ecology used a simultaneous decision framework for this alternatives assessment. This has been more clearly addressed in the introduction and also addressed again in the summary of results section, where the data from each assessment module is reviewed to identify safer alternatives. Figure 1 has been replaced with a figure that more explicitly shows Ecology's process and use of the simultaneous decision framework.

Reviewer comment

> In the IC2 Alternatives Assessment Guide, there is some emphasis on decision analysis in the beginning of the process, as part of scoping, to clarify the decision framework that is used. Primarily, the IC2 Alternatives Assessment Guide relegates decision analysis to the end of the process and makes use of the data and the analysis associated with each module.
>
> The committee suggests including a) a section at the beginning of the report with an explanation of the rationale for choosing the simultaneous decision framework to evaluate data from the four modules; and b) a section at the end of the report that clearly describes the decision framework, how the data from each module were integrated into the decision framework, and the results of applying the decision framework to make recommendations.

Ecology response

Ecology agrees with this comment. These recommended changes were made in the revised alternatives assessment.

Reviewer comment

> Report Structure
>
> The report's readability would benefit from a structure that shows more clearly the logical flow of evidence and decision-making and from eliminating the redundancy of multiple overview sections and reference sections.
>
> The IC2 Alternatives Assessment Guide provides an example of such a structure, starting with scoping, including descriptions of the stakeholder involvement module and decision framework, then working sequentially through the other four modules, and ending with a summary of results from applying the decision framework to the data gathered in each module, followed by one consolidated reference section.
>
> The committee suggests changing the report structure to follow more closely the approach in the IC2 Alternatives Assessment Guide (page 6 of Interstate

Chemicals Clearinghouse Alternatives Assessment Guide Version 1.1), with items from the IC2 guide in **bold**:

1. Scoping

a. Stakeholder module: It is not clear if the stakeholder module presented is as part of the IC2 Alternatives Assessment Guide, or if stakeholder engagement was part of the general approach, separate from the IC2 Alternatives Assessment Guide. In the guide, stakeholder involvement is a module and should be presented accordingly. This would indicate that Ecology's Alternatives Assessment used 5 modules rather than 4.

b. Decision framework decision: As noted in Decision Framework above, this section needs more explanation about which of the three approaches is used, and why.

2. Framework modules (Hazard, Exposure, Cost and availability, Performance)

3. Summary of results from application of decision framework: This report needs to be clear about which decision framework was used and how that relates to the findings from each module.

4. References: The committee suggests putting references in a single reference section at the end of the document rather than at the end of each section. The current presentation of references with a reference list in each section makes it challenging to find citations, difficult to see which resources were considered in the entire report, and invites redundancy and unnecessary verbosity.

Ecology response

This comment is well taken. Ecology has clarified that this alternatives assessment used five modules, four of which are assessment modules, in the introduction. The stakeholder involvement module has been moved to Section 1 to better reflect the IC2 Alternatives Assessment Guide structure and to introduce our process for engaging with stakeholders before using information provided by stakeholders. The summary of results was moved after the four assessment modules and consolidated at the end.

Reviewer comment

In addition, the conclusions of the Summary of Assessment Modules Outcomes (Section 7) would be greatly clarified by consolidating Tables 7-16 (similar to Table 1 in this committee's review).

Ecology response

While we acknowledge that the tables in the summary of results are large, we do not believe reducing them to one table as suggested by the committee would be beneficial. These tables represent Ecology's simultaneous analysis of the results of the four assessment modules. Ecology's charge was to identify if safer alternatives that met the criteria outline in RCW 70A.222.070 for "specific food packaging applications." We also believe reducing these tables as suggested could make the document less accessible for visually impaired readers. We also believe keeping the tables separate helps with Ecology's "plain talk" goals.

As a result, we did not make this change as suggested. A similar table to what the committee suggested was included in the Executive Summary.

Reviewer comment

> The report would also benefit from ensuring that the brief introduction addresses the project as a whole rather than repeating material, and that each chapter on the four (or five) modules includes an overview of the module's content and provides any needed scope of background information. The report could then be much shorter and more clearly state the evidence and conclusions.

Ecology response

This comment is also well taken. To the extent possible, these recommendations were made. Ecology did include some repetition of definitions and explanations in recognition of the overall size of the document.

Reviewer comment

> Choice of Chemical of Concern
>
> Chosen Chemical of Concern
>
> The choice of the copolymer of perfluorohexylethyl methacrylate, 2-N,N-diethylaminoethyl methacrylate, 2-hydroxyethyl methacrylate, and 2,2'-ethylenedioxydiethyl dimethacrylate, acetic acid salt (Chemical Abstracts Service Registry Number 863408-20-2) as the chemical of concern, and the decision to use a single representative compound for this alternative assessment, requires clearer justification.
>
> The report states that "Stakeholder opinions were conflicted about whether to use a single, representative PFAS compound for this AA." (page 7). Given the differences in opinion of stakeholder input, the report would be strengthened by more complete description and justification of the decision to use a single representative compound for this alternative assessment.

Ecology response

In the "Selection of a representative PFAS" section, we provided a more thorough explanation of stakeholder opinions regarding how to assess PFAS for the purposes of this alternatives assessment. Stakeholder opinions did not point to either a) a consensus opinion or b) an opinion strong enough to discard a potential method to assess PFAS. Ecology ultimately made the decision to identify a commonly used PFAS in food packaging that could be used in the hazard and exposure assessments. We present our rationale in more detail in this section.

We decided to use specific PFAS for the hazard and exposure assessment modules, given a) that there are large data requirements for the hazard and exposure assessment methods, b) that we could prioritize PFAS that were widely in use and therefore had the largest exposure risks and c) that the hazard concerns associated with PFAS as a class of chemicals would likely be present in the individual PFAS chosen. To the extent possible, this section was revised to make this decision clearer.

Reviewer comment

> The only explanation provided is that "C6-based fluorinated polymers are the predominant PFAS used in U.S. food packaging materials." (page 6). However, FDA announced on July 31, 2020 that all C6-based side-chain fluorinated polymers that contain 6:2 FTOH as an impurity (including the one selected by Ecology as the chemical of concern) will begin a voluntary three-year phaseout in January 2021 (FDA announcement). The phaseout is a result of FDA research finding that 6:2 FTOH has a biopersistent and toxic intermediate degradation product. The chemical of concern used as a benchmark for comparison to the alternatives, per the IC2 guide, is one of the compounds that is being phased out.
>
> The committee believes it is important for the report to emphasize that the PFASs that are not being phased out, some of which have a different chemical structure than the selected chemical of concern, are of similar concern. Four of the remaining PFASs that will not be phased out are perfluoropolyethers (PFPEs).

Ecology response

As noted above, the decision to identify this commonly used PFAS as a comparator for the chemical of concern and our subsequent decision of which PFAS to use were made in 2019, approximately a year prior to the FDA's announcement. We decided what PFAS to use as a chemical of concern based on a) how widespread the use of that PFAS was in food packaging (according to input from chemical manufacturers) and b) how available chemical and physical information were. Our report acknowledges the FDA phase-out announcement. Ecology believes the phase-out strengthens our decision to compare alternatives to these PFAS (particularly since the phase out was in response to new evidence about the hazards of the PFAS impurities we had studied). Ecology acknowledges that in future assessments we may choose to evaluate hazard and exposure risks for PFAS differently.

Reviewer comment

The hazard traits of PFPEs may be to some extent different from those of 6:2 fluorotelomer compounds, but they include extreme persistence, multiple data gaps, and potentially toxic impurities, degradation, and combustion products. See for instance:

- Carol F. Kwiatkowski, David Q. Andrews, Linda S. Birnbaum, Thomas A. Bruton, Jamie C. DeWitt, Detlef R. U. Knappe, Maricel V. Maffini, Mark F. Miller, Katherine E. Pelch, Anna Reade, Anna Soehl, Xenia Trier, Marta Venier, Charlotte C. Wagner, Zhanyun Wang, and Arlene Blum. Scientific Basis for Managing PFAS as a Chemical Class. Environmental Science & Technology Letters 2020 7 (8), 532-543. DOI: 10.1021/acs.estlett.0c00255

- Wang, D. Z., Goldenman, G., Tugran, T., McNeil, A., & Jones, M. (2020). Per- and polyfluoroalkylether substances: identity, production and use (Nordiske Arbejdspapirer). Copenhagen: Nordisk Ministerråd. https://doi.org/10.6027/NA2020-901

Ecology response

To address these concerns, we expanded our discussion of PFAS to discuss hazard and exposure concerns associated with all PFAS. We included the recommended sources and several others.

Reviewer comment

The committee recognizes that some stakeholders recommended the use of this particular chemical of concern, supports Ecology's approach of selecting the PFAS with most available data as the chemical of concern, and understands that the assessment of alternatives is the most critical item in the committee's review of the report. Nevertheless, the committee believes that the report would be strengthened by a more complete description and justification of the choice of the chemical of concern and the decision to use a single representative compound for this alternative assessment.

Ecology response

In recognition of the committee's comments, we have made changes to the discussion of PFAS in our alternatives assessment accordingly.

Reviewer comment

Survey of PFAS Currently Used in Food Packaging

The draft report contains inaccuracies and incomplete information about the chemicals considered in the survey of PFAS currently used in food packaging.

> The committee recommends revising the last paragraph of page 7 and the first paragraph of page 8 to make the statements and numbers more accurate, and referencing the July 31, 2020 FDA announcement mentioned above. For example, the last sentence of the first paragraph on page 8, "leaving 16 FCNs" [food contact notification] does not seem accurate. In addition, the statement on page 7 regarding "an initial list of 35 FCNs for 25 PFAS compounds" should be changed to "28 FCNs and 7 CFRs."

Ecology response

We have edited our section describing PFAS approved for use in food packaging to more accurately reflect current approvals, and have marked which current Food Contact Notifications are covered by the voluntary phase-out agreement announced in July 2020.

Reviewer comment

> In addition, the logic is not clear about why PFPEs were removed from consideration (page 8: "perfluoropolyethers were also removed from consideration, leaving 16 FCNs") and requires additional explanation. (More in Chosen Chemical of Concern, above.)

Ecology response

As stated above, Ecology prioritized identifying a chemical of concern that was widely used in food packaging. According to the FluoroCouncil, a "C6 fluoromethacrylate formulation" would be more widely used that PFPEs. This justification was emphasized in the alternatives assessment.

Reviewer comment

> Finally, there were inaccuracies in referencing a study (page 8: "This claim is also supported by published food packaging monitoring studies, which have detected 6:2 FTOH, a degradation product of concern for C6 PFAS polymers (Schaider et al., 2017b;"). This study does not confirm this claim. The study did not measure 6:2 FTOH. Four of the 20 samples tested contained polyfluorinated ethers, and most contained a large percentage of unknown PFASs (Schaider et al 2017).

Ecology response

The reference to 6:2 FTOH was made in error. The reference and has been corrected to refer instead to PFHxA.

Reviewer comment

> Note about Chemical Naming

The committee understands that the legislation governing this report indicates that the terminology that "Perfluoroalkyl and polyfluoroalkyl substances" or "PFAS chemicals" means, for the purposes of food packaging, a class of fluorinated organic chemicals containing at least one fully fluorinated carbon atom. Thus, the report's terminology is consistent with the terminology used in the law. The committee notes, however, that there are multiple definitions of the PFAS class, and it would be helpful for this report to define up front what exactly is meant by "PFAS" in the scope of the assessment.

Ecology response

Ecology uses the definition of PFAS provide by RCW 70A.222. This definition of PFAS chemicals was provided in the introduction and the section on PFAS in Food Packaging. Ecology has added definitions of specific groups of PFAS as needed and has stated that these definitions are based on Buck et al. (2011) "Perfluoroalkyl and Polyfluoroalkyl Substances in the Environment: Terminology, Classification, and Origins."

Reviewer comment

The siloxane selected from a group of silicone material is CAS# 68083-19-2. It is a dimethylsiloxane which is vinyl terminated; the vinyl group is a small portion of the polymer backbone. The draft report calls this compound "vinyl silicone polymer," which may not be an adequate description.

Ecology response

We have changed the name to Vinyl dimethylsiloxy-terminated polydimethylsiloxane to provide a more adequate description. For ease of reading for a non-technical audience, we kept the phrase "vinyl silicone polymer" for this Report to the Legislature.

Reviewer comment

Choice of Alternatives to Assess

The Introduction lists the other states that are regulating PFAS in food packaging and are looking for alternatives, although it appears Washington State is leading on alternatives assessment. We suggest that this section be supplemented with some material and lists of alternatives to consider that have been developed elsewhere, including from a new report by the Organization for Economic Cooperation and Development (OECD (2020), PFASs and Alternatives in Food Packaging (Paper and Paperboard) Report on the Commercial Availability and Current Uses, OECD Series on Risk Management, No. 58, Environment, Health and Safety, Environment Directorate, OECD.) None of this information is in the report, and it needs to be listed and expanded on to help validate the recommendations in Ecology's report.

For example, the California Safer Consumer Products program identified the following alternatives in their research (Safer Consumer Products. Chemical Profile for Food Packaging Containing Perfluoroalkyl or Polyfluoroalkyl Substances. July 2020. California Environmental Protection Agency & Department of Toxic Substances Control):

1. Physical barriers, which can be made of plastic such as polyethylene, polyethylene terephthalate (PET), polyvinyl alcohol, or polylactic acid (PLA), as well as of silicone, aluminum, clay, wax, or biowax such as Clondalkin ECOWAX.

2. Alternative processing, such as machine-finished paper (e.g., natural greaseproof paper and vegetable parchment), mechanical densification, or mechanical glazing.

3. Alternative chemical barriers, such as starch, carboxymethyl cellulose, aqueous dispersions of copolymers such as styrene and butadiene, aqueous dispersions of waxes, water-soluble hydroxyethylcellulose, chitosan, alkyl ketene dimer, alkenyl succinic anhydride, silicone, and several proprietary coatings of unknown composition.

4. Alternative materials, such as palm leaf, bamboo, and various plastics.

It is important to note that the relative safety of these alternatives has not been assessed in California's process. If one or more plant fiber-based food packaging products containing PFASs are listed as Priority Products in the California Code of Regulations, those entities who wish to continue selling the product in California will have to submit an Alternatives Analysis (AA) to the California Department of Toxic Substances Control (DTSC).

Ecology's report provides a list of alternatives, but more information on why they were selected and how the conclusions were made need to be provided. Each alternative needs a review summarizing its known toxicity and biological impacts, and whether it is available in sufficient quantities.

Ecology response

The introduction has been updated to include these references to other alternatives to PFAS.

Ecology conducted research to identify what alternatives would be considered in this alternatives assessment in 2019. We included both resources used to identify alternatives as well as what criteria were used to select alternatives. To clarify our process, we have added a table that identifies which criteria each selected alternative met.

Reviewer comment

Stakeholder Engagement

The stakeholder engagement section of the report was very thorough. It should probably be placed before the other modules in this report, as this is the order presented in the IC2 AA Guide. While the process of engaging stakeholders was clear, it was not clear what specific input they provided for the report and thus for Ecology's assessment.

Ecology response

We have tried, when possible, to identify when information was provided by stakeholders as well as the name or organization of the stakeholder. We have also made our discussion of stakeholder engagement the first section following the introduction.

Reviewer comment

Including the full list of stakeholders that commented in this report is important for transparency. Additionally, a plot showing growth in stakeholder participation with each call/webinar would be helpful for visualization.

Ecology response

To encourage stakeholders to share information with Ecology, we provided the option for organizations to supply information for the alternatives assessment without receiving recognition in the report. However, stakeholders were also informed that their names might be revealed through a formal records request. We believe the records request process provided sufficient transparency. The number of stakeholders that participated in each webinar is listed in the Alternatives Assessment Appendix F.

Reviewer comment

Additional Comments on Report Content

Hazard Assessment

ListTranslator scores were incorrectly interpreted in the Hazard assessment. For example, the statement "LT-UNK, meaning these substances were present on some lists, but a ListTranslator score could not be calculated" (page 40) is an incorrect interpretation. LT-UNK indicates that the chemical is not on any high hazard lists that would score it as LT-1 or even LT-P1. Chemicals rated as LT-UNK may be of low hazard (thus why they are not on any high hazard lists) or this score may mean that there is very little information on the chemical and that it is not well tested.

Ecology response

This statement was made in error and has been corrected.

Reviewer comment

Performance Assessment

The performance assessment results tables indicate products that are "favorable." The definition and metrics for favorability need to be defined up front in this assessment. In one example, page 56 states that "For each prioritized alternative, promotional data was found that identified that alternative as have OGR and/or leak resistance." From this statement it seems that only one of these criteria is sufficient for an alternative to be identified as favorable.

Ecology response

This statement was corrected to say that for some food packaging types leak resistance was not a necessary performance requirement. All food packaging types required proof of oil and grease resistance to be found favorable. The document was clarified to make the metrics for favorability more apparent.

Reviewer comment

The statement on page 58 that "PFAS has likely led to a standard of over-engineered performance expectations in the food packaging industry" is an important consideration.

Cost & Availability

The databases from the Biodegradable Packaging Institute or the Compost Manufacturer's Alliance are key references in the Cost and Availability Assessment (page 11 of Appendix O). The draft report also added some focus on reusable products in Appendix O. The draft report appears to make some effort to consider sustainability; however, the concept of recycling is ignored. It is not clear to the committee how Ecology weighted considerations on biodegradability, compostability, and recyclability; there needs to be more description to justify the decision.

Ecology response

We have clarified that although many alternative products that we evaluated do meet these criteria, evaluating an alternative's biodegradability, compostability, and recyclability was determined to be outside the scope of the alternatives assessment. The cost and availability assessment module does use the above compostability certification databases because they now include standards to ensure products are PFAS-free.

Reviewer comment

The report does not effectively distinguish PFAS added on the wet end of the production process from coatings that are added later on in the production process. The technology needed for both types of coating strategies is very different and will lead to differences in production cost.

Ecology response

Our assessment of comparable cost was only focused on comparing unit prices of products, which indicated the cost to an end-user. We determined it was not necessary to evaluate production costs for PFAS-containing or PFAS-free products.

Reviewer comment

The report also states conclusions that may not be explained by the evidence presented. For example:

- The statement on page 71 that "This difference may be due to differences in PFAS levels between wrappers and liners versus bags" does not indicate how variances between products explains the difference. Another factor to consider is how many different food establishments use these products. For instance, if 100% of 10 bags collected from different locations of the same fast food chain contain PFAS, that only tells you that this one fast food chain uses PFAS-treated packaging, but doesn't tell you how widespread the use of PFAS-treated packaging is across fast food chains.

Ecology response

The data this comment refers to are divided by food packaging type, not specific product. In the table that lists the percentage of products that were identified as having fluorinated chemicals, we have added in information on the number of chains sampled to show that samples were typically taken from multiple chains.

Reviewer comment

- The statement on page 73 that "Conventional sandwich bags, which were not tested for PFAS and therefore not available in the Center for Environmental Health database, had an average unit price of 2 cents. This difference indicates that wax-coated bags are not cost comparable" does not explain that conclusion, given that it's unclear whether the 2 cent bags contain PFAS.

Ecology response

We have clarified that we do not know whether the conventional products do or do not contain PFAS.

Reviewer comment

- The statement on page 78 that "Particularly because the cost of labor and cleaning are minimized, reusable boats are likely a cost-comparable alternative" is unclear on how the cost of labor and cleaning is minimized for reusable boats compared to single-use products.

Ecology response

This statement was made to say that the labor and cleaning cost associated with reusable boats is likely minimal in comparison to other reusable dinnerware such as plates. However, upon revision, this statement was removed because Ecology was unable to find any direct comparisons of the cost associated with using only single-use versus reusable boats.

Reviewer comment

- The statement in Appendix O page 5 that "Schaider et al (2017) found PFAS in approximately half of 42 dessert/bread food contact papers tested, but only in approximately one-third of...sandwich/burger contact paper products tested. This difference may be due to differences in PFAS levels between wrappers and liners versus bags" seems to indicate that more than one-third of wrappers tested in this study may contain PFAS. This would contradict the statement in Appendix O page 7 that "The results of these studies can be found in Table 5 above and highlight a significant percentage of the market is already using PFAS-free products." If Ecology believes these results may be inaccurate, how can it conclude based on these data that a significant percentage of the market is already PFAS-free? Additionally, it is our understanding that if PFASs are intentionally added to food packaging, they are added at levels high enough to be detected by PIGE, the test method used in Schaider et al. (2017). Smaller amounts would be impurities, thus not covered by the Washington food packaging law.

Ecology response

Ecology does not believe the results of these studies are inaccurate. We do not argue that these differences are caused by impurities. We have clarified that a possible reason the prevalence of fluorinated chemicals is different in dessert/bread food contact paper (*e.g.*, pastry bags) is different from sandwich/burger contact paper (*e.g.*, wraps), both of which are types of food contact paper, is due to differences in product type.

Reviewer comment

- The statement in Appendix O page 11: "As such, it was difficult to identify any PFAS-containing items" is difficult to accept, given that PFAS were found in 22% of the wrappers tested by Toxic-Free Future in 2020.

Ecology response

We have clarified that we do not believe this is because no PFAS-containing wrapper or liners exist. Instead, as we discuss in this section, we could not identify any wrappers that were confirmed to contain PFAS. Manufacturers are not required to publicly list the chemicals used in food packaging. Under this law Ecology does not have the authority to require this information from manufacturers of PFAS, alternative substances, or food packaging products.

Reviewer comment

- The statement in Appendix O page 12 that "PFAS-containing bags are in regular use (Table 5)" needs clarification about what is being referred to. What is the difference between sandwich bags, sandwich/burger food contact paper, and sandwich wrappers? Do sandwich food contact paper and wrappers fall under Product Category 1, because they are sheets of paper wrapped around the sandwich, rather than bags? Which entry in Table 5 is being referenced?

Ecology response

Both bags and wraps (or wrappers) fall under the food packaging category of "Food Contact Paper." We have made efforts to clarify which types of food contact paper refer to bags and which refer to wraps in this section of the alternatives assessment.

Reviewer comment

- The statement in Appendix O page 12 that "Therefore, this difference indicates that wax-coated bags are not cost comparable" is a major conclusion made without any solid data. Was it not possible to test a sample of the conventional sandwich bags for total F?

Ecology response

Ecology did not perform any tests for the presence of fluorinated chemicals for this assessment. However, we did revise this statement to say that we have insufficient data to identify whether wax-coated bags are cost comparable, since the presence of fluorinated chemicals in the conventional bags we identified is unknown.

Reviewer comment

- The statement in Appendix O page 11 that "Of note, paper products coated with non-PET polymers (which includes PVOH, EVOH, PE, and polypropylene coatings) appear to be cost comparable with PFAS-containing paper products" does not have a clear explanation of how this conclusion is reached. Is PET-coated excluded because PET-coated is more expensive, or because no information about PET-coated is available?

Ecology response

The term non-PET polymer was supplied by the chemical manufacturer to describe their products and meant those products could be coated with PVOH, EVOH, PE, or polypropylene. This means Ecology had insufficient information to determine which specific alternative coatings were cost comparable with PFAS-containing paper products. We have clarified this statement in the text and have determined that, because this cost comparison does not list a specific alternative, this information is not specific enough to be used in the cost comparability evaluation.

Reviewer comment

- It is not clear in Appendix O Table 7 (page 11) which product categories are referenced in the "Difference in price" column.

Ecology response

This table referred to a number of conversations with chemical or product manufacturers where the manufacturer mentioned the price of their alternative chemical or product compared to PFAS or a PFAS-containing product. We turned this table into text and have clarified what is meant by "difference in price" in the relevant text.

Reviewer comment

Inconsistencies between Appendix O and Cost and Availability Conclusions in Report

The data in Appendix O appear to be inconsistent with the conclusions in the Cost and Availability section of the report. For example:

- Appendix O page 12: "EVOH-coated sheets were identified as cost comparable"
    - In table 7 on page 27 of the draft report, EVOH is listed as "Insufficient data" for this module. This is inconsistent with the conclusion here.

- Appendix O page 12: “EVOH-coated bags should qualify as a cost-comparable alternative.”
    - This is inconsistent with the conclusion in Table 8 on page 28 of the draft report.
- Appendix O page 12: “EVOH-, and PE-coated plates were also identified as cost comparable”
    - This is inconsistent with table 9 on page 29 of the draft report.
- Appendix O page 14: “EVOH-, and PE-coated bowls were identified as cost comparable.”
    - This is inconsistent with table 10 on page 30 of the draft report.
- Appendix O page 15: “EVOH-, and PE-coated trays were also identified as cost comparable.”
    - This is inconsistent with table 11 on page 31 of the draft report.
- Appendix O page 15: “PVOH-, EVOH-, and PE-coated boats were cost comparable”
    - In table 12 on page 32 of the draft report, “PET coated” is listed, but it is not listed here.
- Appendix O page 16: “EVOH-, and PE-coated paper clamshells were also identified as cost comparable”
    - This is inconsistent with table 15 on page 35 of the draft report.
- Appendix O page 17: “EVOH-, and PE-coated food containers were also identified as a cost-comparable alternative”
    - This is inconsistent with table 16 on page 36 of the draft report.
- Appendix O page 20-22: Tables 9-11
    - The committee recommends verifying information consistency between these tables and tables 7-16 in the draft report.

Ecology response

While the PFAS in food packaging alternatives assessment was undergoing peer review, Ecology received last minute information about the cost comparability of certain alternative coatings that required us to revise the full cost and availability evaluation. This evaluation was sent to the peer review committee as Appendix O and featured the changes noted above. However, while these changes were communicated to the committee, the fact they replaced the cost and availability assessment originally provided, was not. Appendix O was incorporated into the final cost and availability assessment. We confirmed that the inconsistencies identified here were no longer present in the final report.

The clarification that we received stated that the cost comparison data Ecology had included for PVOH-, EVOH-, and PE-coated alternatives could not actually be tied to a specific alternative. Since this clarification meant Ecology could not identify which specific alternative chemical the data applied to, we decided that is insufficient data to identify whether PVOH-, EVOH-, and PE-coated alternatives were cost comparable with PFAS for the purposes of this alternatives assessment.

October 23, 2020 peer review addendum/clarification

Reviewer comment

> To clarify the statement "Relying solely on precursors and breakdown products for toxicity analysis is inappropriate," the committee intended to communicate that it is insufficient to rely solely on precursors and breakdown products for toxicity analysis when publicly available data exist about the polymer (either the specific polymer as defined by trade name or a generic example of the compound). Thus, Ecology's process of conducting a hazard evaluation on only the impurities/residuals of certain alternatives does not fully assess the hazard of those alternatives.

Ecology response

Ecology agrees with the intent of the comment. If enough information were available about the specific polymer to evaluate it using the GreenScreen® method, it would be insufficient to solely analyze precursors and breakdown products of that polymer when performing a toxicity analysis. In this case, Ecology attempted to evaluate the comparator polymer, but did not collect enough data to do so. Given this lack of information, Ecology then looked to the precursors and breakdown products of that polymer in order to perform a hazard analysis.

Reviewer comment

> Standard practice would have Ecology use the following procedure to do due diligence in assessing all viable alternatives:
>
> 1. Attempt to evaluate the polymer in question
>   a. The first priority is to assess the specific compound sold as a trade-named substance.
>   b. If specific compound information is unobtainable due to confidential business information or other considerations, assessments could be performed on generic compounds that serve as proxies for commodity polymers such as PE, PET, and EVOH, to assess the polymer.
>   c. The consideration of relatively small molecular weight species of the polymer (e.g. oligomers) or functional groups to inform the assessment.
> 2. Evaluate relevant precursors and breakdown products (for example, using publicly available generic information about precursors and degradation products for commodity polymers like PE and PET)

Ecology response

Ecology agrees with that this procedure represents best standard practice, and mirrors the methods Ecology used when assessing alternatives. The hazard assessment now clarifies that Ecology attempted to assess polymers, but ran into difficulties collecting information about the polymers used in food packaging applications. Ecology then attempted to assess other relevant

components such as precursors and breakdown products. Here, Ecology's evaluation was limited by both a lack of available information and time.

Reviewer comment

> The report would benefit from greater transparency on how hazard analysis was or was not performed on the polymer. For example, the report could state that a compound was evaluated but not enough data was found to form a conclusion, or that literature suggests that a polymer does not pose a hazard.

Ecology response

Ecology has made edits to the results of the hazard assessment to provide greater transparency. First, for alternatives that ultimately were not assessed (and were labeled as "insufficient data" in the hazard assessment) available information was included along with an explanation as to why the available information was insufficient to assess the alternative. Second, Ecology acknowledged that there were time and staffing limitations that impact which alternatives were assessed in the absence of specific product formulations.

Reviewer comment

> Use of GreenScreen® Methodology
>
> Explanation in report
>
> The committee appreciates Ecology's detailed and coherent explanation in its letter on October 14, 2020 of why and how GreenScreen® assessments were used in the hazard evaluation module. This explanation could also be included in the Report or Appendices. The committee also recognizes that there are structural and resource limitations in conducting the alternatives assessment, and suggests including a detailed explanation of the overall decision process, and especially related to addressing these limitations.

Ecology response

We have added additional detail regarding Ecology's choice to use GreenScreen® assessments and the overall decision process as suggested.

Reviewer comment

> The committee also concludes that Ecology's report would benefit from a clearer explanation of the use of the term "insufficient data" to specify that this means that an existing GreenScreen® is not available, rather than stating that there is no publicly available data on the chemical for which a GreenScreen could be developed.

Ecology response

We have added additional detail regarding our use of the term “insufficient data” and its relation to lack of publicly available data.

Reviewer comment

> While the report currently includes a link to the GreenScreen® website containing the relevant hazard evaluation, the report could also (1) more clearly list the peer-reviewed literature referenced in the GreenScreen®; (2) more clearly note the dates of existing GreenScreen® evaluations that were cited, and (3) if the screens are not current (more than 3 or 4 years old) also show the results of a literature search for any relevant studies published since the GreenScreen® report was produced.

Ecology response

To demonstrate the types of data included in a GreenScreen®, Ecology has added examples from the GreenScreen® for Lactide (which Ecology paid a third party, licensed GreenScreen® assessor to update for this alternatives assessment). Ecology has included citations for each GreenScreen® included in this assessment, which include the year the GreenScreen® was conducted. Ecology followed the GreenScreen® terms of use, which state that GreenScreen® evaluations expire after five years unless they are for substances that have been identified as chemicals of high concern (Benchmark-1).

Reviewer comment

> The committee also suggests that the report include clarifying statements that existing GreenScreen® assessments were the sole hazard evaluation tool used for the alternatives assessment, and that Ecology continues to seek information to perform GreenScreen® or other hazard evaluations for these alternatives.

Ecology response

Additional clarifying statements have been added.

Reviewer comment

> The abovementioned clarifications would partially address the committee’s comments. Changes in the assessment process, as noted below, would address the committee's other comments.
>
> **Changes in assessment process**
>
> The committee recognizes that the IC2 AA guide for a Level 2 Hazard Assessment indicates use of the GreenScreen® methodology for evaluation, and the committee supports its use to evaluate alternatives. The committee did not find,

however, that the GreenScreen® methodology was used to conduct a new hazard assessment. Its use seems to have been limited to examining existing GreenScreens®.

Ecology response

Ecology did conduct an additional GreenScreen® evaluation on the breakdown chemical Lactide.

Reviewer comment

A Level 2 Hazard Evaluation would use the GreenScreen® method to evaluate hazard information, not only rely on existing publicly available GreenScreen® evaluations. If information pertaining to a trade-name compound is unavailable, Ecology can acknowledge the unavailability of confidential business information and instead use generic chemical information and publicly available literature about typical formulations to conduct an assessment with the GreenScreen® tool. For transparency and to strengthen its conclusions, Ecology could document how far they were able to get in the GreenScreen® assessment and outline what data is and is not available.

Ecology response

Additional information and explanation has been added.

Reviewer comment

By stating "These gaps throw into question the final Safer Alternative conclusions," the committee intended to call attention to the need to support Ecology's conclusion that there is insufficient information to readily assess PE, PET, and EVOH. It is not accurate to report "insufficient data" and end the assessment at that point when publicly available data exist that can be used to evaluate a compound; it is important for the alternatives assessment to convey accurate information.

At the very least, the committee suggests that Ecology do due diligence by conducting a brief literature review to supplement the existing GreenScreen® evaluations and more completely assess potential hazards of the alternative suggested. When existing GreenScreen® reports are not available, a review of the published peer-reviewed literature search should be done to confirm the alternatives suggested have limited hazard. All chemical alternatives should undergo a consistent hazard assessment, whether or not there is an existing GreenScreen®.

Ecology response

Ecology improved documentation of the hazard assessment process to demonstrate how some alternatives were identified as having insufficient data for the evaluation. Ecology has also added peer-reviewed literature that assesses the hazard concerns associated with plastics, to highlight the complexity of these alternatives and the benefit of having access to specific product information.

Reviewer comment

> A literature review would strengthen the report by being a proactive approach to carefully determine the safety of the proposed alternatives. Related methods of hazard assessment such as the Globally Harmonized System of Classification and Labelling of Chemicals [GHS] and governmental hazard information databases could be used to fill in gaps in information and fit within the GreenScreen® framework without adding an excessive burden.

Ecology response

While Ecology recognizes that there are other methods to assess chemical hazards, Ecology determined that introducing additional assessment methods would make the hazard assessment less transparent. However, Ecology did conduct List Translator assessments on all candidate alternative substances. List Translator reviews authoritative government lists that identify chemicals with known or potential hazard concerns. These lists include GHS assessments. However, these lists could not provide enough information to act as a substitute for GreenScreen® evaluations, which additionally use peer reviewed literature and government reports to evaluate hazards.

Appendix B. Copy of Peer Review Comments

WASHINGTON STATE
Academy of Sciences
Science in the Service of Washington State

Review of PFAS in Food Packaging Alternatives Assessment

Prepared for the Washington State Department of Ecology
By WSAS PFAS in Food Packaging Committee

October 2020

1

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Appendix A: WSAS Committee on PFAS in Food Packaging 18

Committee Charge

The Washington State Department of Ecology (Ecology) requested that the Washington State Academy of Sciences (WSAS) conduct an independent peer review of a report prepared by Ecology related to the identification of safer alternatives to per- and polyfluoroalkyl substances (PFAS) in plant fiber-based food packaging. Ecology's alternative assessment was conducted per RCW 70A.222.070 (formerly RCW 70.95G.070), which refers to PFAS as PFAS chemicals.

In response to Ecology's request, the WSAS convened a seven-member committee of disciplinary experts (referred to in this document as "the committee" or "we") with the charge to conduct an independent peer review. The Committee performed its review between August 18 and October 5, 2020. Committee members are listed below and their full bios are in Appendix A.

The committee reviewed Ecology's use of the assessment modules delineated in the Interstate Chemicals Clearinghouse Alternatives Assessment Guide (IC2 AA Guide) (Version 1.1, January 2017, as required for Ecology's assessment), whether suitable alternatives were considered, and the draft report's conclusions regarding alternatives for food packaging containing PFAS. The committee interpreted its charge as commenting on both the process used and the science documented in the draft report. The goal of the committee's comments is to strengthen the report.

The draft report includes a detailed description of the stakeholder outreach and engagement process used during the alternative assessment. As noted in the IC2 AA Guide, stakeholder engagement is an important element in the overall process (see Stakeholder Involvement Module). However, inasmuch as stakeholder engagement does not directly involve scientific or technical questions, the committee concluded that with the exception of minor comments at the end of this review, detailed review of that process was outside the scope of this review.

This document is organized as a summary of the committee's review, followed by comments on the report as a whole and specific comments on report sections. Page numbers correspond to the PDF versions of Ecology's draft report and Appendixes A-N, and the Word document of Appendix O.

Committee Members

Dr. Elaine Faustman *(chair),* Professor & Director, Department of Environmental & Occupational Health Sciences, Adjunct Professor, Evans School of Public Policy and Governance, University of Washington
Dr. Simona Balan, Senior Environmental Scientist, California Department of Toxic Substances
Dr. Lauren Heine, Senior Science Advisor, Northwest Green Chemistry; Adjunct Faculty, Gonzaga University
Dr. Patricia A. Hunt, Meyer Distinguished Professor, School of Molecular Bioscience, Washington State University
Dr. Donatien Pascal Kamdem, Professor, School of Packaging, Michigan State University; Global Packaging Solutions LLC
Dr. Michael Skinner, Professor, School of Biological Sciences, Washington State University
Dr. Huqiu Zhang, Senior Scientist, Sevee & Maher Engineers

Summary of Review

The committee recognizes the complexity and lack of complete information inherent in the process of conducting alternatives assessments. However, the report's conclusions would be stronger if the report included clearer and more transparent descriptions of the kinds of information and science (or data or analysis) that support them.

The committee has several comments and suggestions about the alternatives assessment process as applied in this report. The key points include:

1. **Justify more clearly the choice of the chemical of concern.** The report mentions that stakeholder opinions were conflicted about whether to use a single representative chemical of concern, but does not fully explain why Ecology nevertheless decided to take this approach. The only explanation provided is that the "C6-based fluorinated polymers are the predominant PFAS used in U.S. food packaging materials"; however, the FDA announced on July 31, 2020 that all C6-based fluorinated polymers, including the selected chemical of concern, will begin a voluntary three-year phaseout in January 2021. Some of the remaining PFASs that will not be phased out are perfluoropolyethers (PFPEs). The report would benefit from a clear statement of why PFPEs are expected to have a similar hazard and exposure potential as the C6-based compound selected as the chemical of concern.

2. **Review alternative compounds more thoroughly**. To document that alternatives are not potentially as harmful as the banned products, the committee suggests including substantive evidence from the peer-reviewed literature (examples are provided below). In particular, the report relies heavily on concluding that there is "insufficient information" despite a body of evidence on the alternatives. For example, PE and PET could be evaluated as generic substances using information in the peer reviewed literature about typical chemical constituents without having to obtain full ingredient disclosure from a manufacturer. The report would also be strengthened by providing an explanation of why Ecology chose those specific alternatives to be assessed, and how it reached the conclusions of the assessment. In addition, the report's analysis would benefit from a more thorough assessment to strengthen the conclusion that the safe alternatives are available in sufficient quantities, as per the legislation.

3. **Provide the full rationale for the chosen assessment levels for each module.** In particular, there are items out of scope for a Level 1 Exposure assessment that could be valuable for this report. The report would also benefit from providing the rationale for the Cost and Availability Assessment level and how the analysis supports the assessment.

4. **Clearly present a rationale for the choice of the decision framework used in the assessment.** Figure 1 of Ecology's draft report shows one version of a decision framework presented in the IC2 AA Guide; others are also mentioned in the guide. The committee suggests including a) a section at the beginning of the report with an explanation of the rationale for choosing the simultaneous decision framework to evaluate data from the four modules; and b) a section at the end of the

report presenting the results of applying the decision framework and then integrating the data gathered in each module into the framework to make recommendations.

5. **Structure the report to show more clearly the logical flow of evidence and decision-making.** In order to do so, the report should follow the structure of the IC2 AA Guide, starting with scoping, including descriptions of the stakeholder involvement module and decision framework, then working sequentially through the other four modules, and ending with a summary of results from applying the decision framework to the data gathered in each module, followed by one consolidated reference section. In addition to restructuring, the report would benefit from removing redundancies and improving readability.

Scope of the Assessment Process

Ecology's draft report included four assessments: Exposure, Performance, Cost and Availability, and Hazard. We suggest that Ecology provide the rationale for the levels of assessment chosen. As outlined in this report, Ecology used a Level 1 assessment for the Exposure, Performance, and Cost and Availability assessment modules, and a Level 2 assessment for Hazard and Stakeholder Engagement. Ecology referred to its Washington State Alternatives Assessment Guide to justify the use of these levels, and that guide recommends "The alternatives with the lowest hazard are evaluated further using the three remaining modules, i.e., Performance, Cost and Availability, and Exposure. As a minimum, Level 1 is recommended for these three modules. Assessors may use higher levels if they have the resources or expertise." (page 4, Washington State Alternatives Assessment Guide 2015).

A Level 1 Exposure assessment is a basic exposure evaluation that identifies potential exposure concerns and includes a qualitative assessment using readily available data. Items out of scope for a Level 1 assessment that could be valuable for this report include accounting for cumulative exposure from other PFAS sources and of life-cycle components such as breakthrough and compounds used for coating. Given the complexity of information available on PFAS, and realizing that Ecology has limited time and budget for the assessment of safer alternatives to per- and polyfluoroalkyl substances in plant fiber-based food packaging, the committee understands that there may be a rationale for a Level 1 Exposure assessment; this rationale would simply need to be written in the report.

Regarding the Cost and Availability assessment, Question 2 of the analysis, "Is the alternative currently offered for sale for the application of interest?" (Appendix O, page 1) may address the requirement in RCW 70A.222.070 for "readily available" but does not appear to address the requirement of "sufficient quantity" (also referenced in Appendix O, Table 9 on page 20), thus raising the question of whether applying Level 1 of the "cost and availability" module is adequate. The report would also benefit from providing the rationale for the choice of a Level 1 Cost and Availability Assessment, and how the questions in the analysis support the assessment.

The Executive Summary outlines the scope of the assessment, but is unclear about some specific points, such as: 1) Is all plant fiber-based packaging included? and 2) Are mold release agents not considered intentional PFAS additions? Page 57 states that "Third-party verification has demonstrated that most molded fiber products on the market contain PFAS"; the PFAS in these molded fiber products might also

originate from mold release agents (California Safer Consumer Products, Public Workshop on Food Packaging with PFASs, January 14 2020 [transcript]; Work Plan Implementation, October 2019). Even if non-PFAS alternatives are used for oil and grease resistance (OGR) and leak resistance, some molded fiber products may continue to contain PFAS unless the mold release agents are also substituted.

More Thorough Assessment of Alternative Compounds

Inclusion of Peer-Reviewed Literature

More references to peer-reviewed scientific literature about the hazards, toxicity and general safety of suggested alternative compounds are needed to support the more general information provided from EPA Safer Chemicals lists. In addition, a more thorough review of the scientific literature about the compounds and compound classes listed as alternatives, the potential toxicity of the alternatives, their breakdown products (including microplastics, where applicable), and their precursors is also needed. Furthermore, the literature review should distinguish peer-reviewed technical reports and papers from materials with a lower standard of evidence.

The following are examples from the committee of a brief review of PubMed literature on some of the safety and toxicity information of proposed alternatives. The committee suggests that this kind of information be included in the Report:

> Alternative PLA -- This is poly(lactide) which is often used with poly(ethylene glycol) PEG. These are safe compounds that have been used for drug delivery and nanoparticle in therapeutics (Part Part Syst Charact. 2013 Apr;30(4):365-373. doi: 10.1002/ppsc.201200145. Epub 2013 Feb 28. PMID: 27642231). No literature on toxicity or hazards of this class of compounds was found.
>
> Alternative PVOH -- This is polyvinyl alcohol PVA or PVOH with polyethylene glycol PEG or other compounds to generate microparticles and coatings. These are generally safe, but some toxicity has been observed (Food Chem Toxicol. 2013 Jul;51 Suppl 1:S7-S13. doi: 10.1016/j.fct.2012.12.033. Epub 2013 Jan 7. PMID: 23306789). Although there are many types of these compounds for coating and particles, a more thorough description of what they are and potential toxicity was not presented.
>
> Alternative PET -- This is polyethylene terephthalate (PET) that is used with other compounds for coating food containers. This is generally safe (Food Addit Contam Part A Chem Anal Control Expo Risk Assess. 2017 Jul;34(7):1239-1250. doi: 10.1080/19440049.2017.1322221.), but some toxicity has been observed in various applications (Biomaterials. 2010 Apr;31(11):2999-3007. doi: 10.1016/j.biomaterials.2009.12.055. Epub 2010 Jan 15. PMID: 20074795).

The report also needs to include basic compound name, chemical composition, past use, and safety information for alternatives proposed. It is essential that alternatives not be suggested that are potentially as harmful or more harmful than the PFASs banned (an industry example of this is the selection of BPS as the alternative for the plastic compound BPA, as BPS is potentially more toxic). Any hazards previously

observed should be highlighted to allow the reader to conclude that the report is thorough in its assessments of alternatives.

Furthermore, a lack of information is often indicated in tables as "insufficient data," but this phrase is not defined in the report. Relying solely on precursors and breakdown products for toxicity analysis is inappropriate. It is important to note that lack of information is not evidence of lack of toxicity.

Gaps in Hazard Assessment of Particular Materials

The report also has gaps in its assessment of particular materials. For example, there is a gap in the draft report in assessing PE- and PET-coated materials as potential safe alternatives. In the Hazard module, the report simply concluded that there is "insufficient information" around PE and PET (page 38: "insufficient public data were available at the time of this assessment to evaluate PE, PET, and EVOH copolymers"), but this statement is questionable. PE and PET have long been used in food packaging, before PLA, and there should be plenty of publicly available research literature and information about the precursors, degradation, residue by-products, monomers or oligomers for PE and PET, as well as microplastics.

Although precursors and degradation products are not a substitute for a toxicity analysis of the substance itself, and PLA also contributes to microplastic contamination, which is a hazard that should be considered in the discussion of this material, it is not clear why the same method applied to PLA could not also be applied to PE, PET, and EVOH in this report (page 37: "Due to a lack of information about specific proprietary versions of the candidate chemicals, both the PFAS COC and PLA were evaluated using precursors and degradation products, and siloxanes were evaluated using a representative substance."; page 39: "In the absence of polymer information, both the PFAS COC and PLA were evaluated using precursors and degradation products"). These gaps throw into question the final Safe Alternative conclusions; the committee recommends that the authors conduct additional research literature review and analysis to close these gaps.

Gaps in Cost and Availability Assessment of Particular Materials

The Cost and Availability Assessment includes the statement "The prevalence of non-PFAS-containing products in each food packaging application...indicates that PFAS-free alternatives are readily available" (Appendix O, page 8). This statement references Table 5 of Appendix O, which shows the PFAS testing results of products that are already on the market. However, the test results in Table 5 do not show which materials are present in these PFAS-free products. Specifically, the data in Table 5 of Appendix O does not indicate that PVOH and PLA-coated are the predominant PFAS-Free products tested; it is possible that some other material, including PE- or PET-coated may be the predominant materials in the PFAS-Free products listed in Table 5 of Appendix O.

Therefore, the conclusion of "sufficient supply" in the Cost and Availability Assessment module, which leads to the conclusion of Safe Alternative for the materials listed in Tables 7-16 of the draft report (summarized by this committee in Table 1 below) and also suggests that the predominant PFAS-Free Safer Alternatives will be PVOH and PLA-based materials, while appearing to exclude PE and PET, becomes questionable.

Table 1: Summary of safer alternatives conclusions from Tables 7-16 of the draft report. The numbers indicate the number of alternatives identified in the report

Use of Material	Wrap/ Liner	Bags/ Sleeves	Plates	Bowls	Trays	Boats	Pizza Box	Open Carton	Clamshells	Containers	Total
Uncoated	1		1				1				3
Wax	1										1
PVOH		1	1	1	1	1	1	1	1	1	9
Clay			1	1		1				1	4
PLA			1		2		1	1	1	1	7

PE and PET plastics have a long history of safe use in food contact applications. They both were cleared by FDA for food contact uses in 1977, PET in 21CFR177.1630 and PE in 21CFR177.1520. The first FDA clearance for food contact uses of PLA was in 2002, Food Contact Notification 178. As such, PE and PET should be thoroughly assessed in the Cost and Availability Assessment module.

Report Structure and Presentation of Evidence

Decision Framework

It is unclear in this report which of the three decision analysis frameworks from the IC2 AA Guide was applied, and the justification for why this particular framework was chosen. This is a critical oversight. Figure 1 (page 3 of Ecology's draft report) shows one version of a decision framework presented in the IC2 AA Guide; others are also mentioned in the guide. The committee suggests fully explaining this figure.

In the IC2 AA Guide, there is some emphasis on decision analysis in the beginning of the process, as part of scoping, to clarify the decision framework that is used. Primarily, the IC2 AA Guide relegates decision analysis to the end of the process and makes use of the data and the analysis associated with each module.

The committee suggests including a) a section at the beginning of the report with an explanation of the rationale for choosing the simultaneous decision framework to evaluate data from the four modules; and b) a section at the end of the report that clearly describes the decision framework, how the data from each module were integrated into the decision framework, and the results of applying the decision framework to make recommendations.

Report Structure

The report's readability would benefit from a structure that shows more clearly the logical flow of evidence and decision-making and from eliminating the redundancy of multiple overview sections and reference sections.

The IC2 AA Guide provides an example of such a structure, starting with scoping, including descriptions of the stakeholder involvement module and decision framework, then working sequentially through the other four modules, and ending with a summary of results from applying the decision framework to the data gathered in each module, followed by one consolidated reference section.

The committee suggests changing the report structure to follow more closely the approach in the IC2 AA Guide (page 6 of Interstate Chemicals Clearinghouse Alternatives Assessment Guide Version 1.1), with items from the IC2 guide in **bold**:

1. **Scoping**
    a. **Stakeholder module:** It is not clear if the stakeholder module presented is as part of the IC2 AA Guide, or if stakeholder engagement was part of the general approach, separate from the IC2 AA Guide. In the guide, stakeholder involvement is a module and should be presented accordingly. This would indicate that Ecology's Alternatives Assessment used 5 modules rather than 4.
    b. **Decision framework decision:** As noted in Decision Framework above, this section needs more explanation about which of the three approaches is used, and why.
2. **Framework modules** (Hazard, Exposure, Cost and availability, Performance)
3. **Summary of results from application of decision framework:** This report needs to be clear about which decision framework was used and how that relates to the findings from each module.
4. **References**: The committee suggests putting references in a single reference section at the end of the document rather than at the end of each section. The current presentation of references with a reference list in each section makes it challenging to find citations, difficult to see which resources were considered in the entire report, and invites redundancy and unnecessary verbosity.

In addition, the conclusions of the Summary of Assessment Modules Outcomes (Section 7) would be greatly clarified by consolidating Tables 7-16 (similar to Table 1 in this committee's review).

The report would also benefit from ensuring that the brief introduction addresses the project as a whole rather than repeating material, and that each chapter on the four (or five) modules includes an overview of the module's content and provides any needed scope of background information. The report could then be much shorter and more clearly state the evidence and conclusions.

Choice of Chemical of Concern

Chosen Chemical of Concern

The choice of the copolymer of perfluorohexylethyl methacrylate, 2-N,N-diethylaminoethyl methacrylate, 2-hydroxyethyl methacrylate, and 2,2'-ethylenedioxydiethyl dimethacrylate, acetic acid salt (Chemical Abstracts Service Registry Number 863408-20-2) as the chemical of concern, and the decision to use a single representative compound for this alternative assessment, requires clearer justification.

The report states that "Stakeholder opinions were conflicted about whether to use a single, representative PFAS compound for this AA." (page 7). Given the differences in opinion of stakeholder input, the report would be strengthened by more complete description and justification of the decision to use a single representative compound for this alternative assessment.

The only explanation provided is that "C6-based fluorinated polymers are the predominant PFAS used in U.S. food packaging materials." (page 6). However, FDA announced on July 31, 2020 that all C6-based side-chain fluorinated polymers that contain 6:2 FTOH as an impurity (including the one selected by Ecology as the chemical of concern) will begin a voluntary three-year phaseout in January 2021 (FDA announcement). The phaseout is a result of FDA research finding that 6:2 FTOH has a biopersistent and toxic intermediate degradation product. The chemical of concern used as a benchmark for comparison to the alternatives, per the IC2 guide, is one of the compounds that is being phased out.

The committee believes it is important for the report to emphasize that the PFASs that are not being phased out, some of which have a different chemical structure than the selected chemical of concern, are of similar concern. Four of the remaining PFASs that will not be phased out are perfluoropolyethers (PFPEs).

The hazard traits of PFPEs may be to some extent different from those of 6:2 fluorotelomer compounds, but they include extreme persistence, multiple data gaps, and potentially toxic impurities, degradation, and combustion products. See for instance:

- Carol F. Kwiatkowski, David Q. Andrews, Linda S. Birnbaum, Thomas A. Bruton, Jamie C. DeWitt, Detlef R. U. Knappe, Maricel V. Maffini, Mark F. Miller, Katherine E. Pelch, Anna Reade, Anna Soehl, Xenia Trier, Marta Venier, Charlotte C. Wagner, Zhanyun Wang, and Arlene Blum. Scientific Basis for Managing PFAS as a Chemical Class. Environmental Science & Technology Letters 2020 *7*(8), 532-543. DOI: 10.1021/acs.estlett.0c00255
- Wang, D. Z., Goldenman, G., Tugran, T., McNeil, A., & Jones, M. (2020). Per- and polyfluoroalkylether substances: identity, production and use (Nordiske Arbejdspapirer). Copenhagen: Nordisk Ministerråd. https://doi.org/10.6027/NA2020-901

The committee recognizes that some stakeholders recommended the use of this particular chemical of concern, supports Ecology's approach of selecting the PFAS with most available data as the chemical of concern, and understands that the assessment of alternatives is the most critical item in the committee's review of the report. Nevertheless, the committee believes that the report would be strengthened by a more complete description and justification of the choice of the chemical of concern and the decision to use a single representative compound for this alternative assessment.

Survey of PFAS Currently Used in Food Packaging

The draft report contains inaccuracies and incomplete information about the chemicals considered in the survey of PFAS currently used in food packaging.

The committee recommends revising the last paragraph of page 7 and the first paragraph of page 8 to make the statements and numbers more accurate, and referencing the July 31, 2020 FDA announcement mentioned above. For example, the last sentence of the first paragraph on page 8, "leaving 16 FCNs" does not seem accurate. In addition, the statement on page 7 regarding "an initial list of 35 FCNs for 25 PFAS compounds" should be changed to "28 FCNs and 7 CFRs."

In addition, the logic is not clear about why PFPEs were removed from consideration (page 8: "perfluoropolyethers were also removed from consideration, leaving 16 FCNs") and requires additional explanation. *(More in Chosen Chemical of Concern, above.)*

Finally, there were inaccuracies in referencing a study (page 8: "This claim is also supported by published food packaging monitoring studies, which have detected 6:2 FTOH, a degradation product of concern for C6 PFAS polymers (Schaider et al., 2017b;"). This study does not confirm this claim. The study did not measure 6:2 FTOH. Four of the 20 samples tested contained polyfluorinated ethers, and most contained a large percentage of unknown PFASs (Schaider et al 2017).

Note about Chemical Naming

The committee understands that the legislation governing this report indicates that the terminology that "Perfluoroalkyl and polyfluoroalkyl substances" or "PFAS chemicals" means, for the purposes of food packaging, a class of fluorinated organic chemicals containing at least one fully fluorinated carbon atom. Thus, the report's terminology is consistent with the terminology used in the law. The committee notes, however, that there are multiple definitions of the PFAS class, and it would be helpful for this report to define up front what exactly is meant by "PFAS" in the scope of the assessment.

The siloxane selected from a group of silicone material is CAS# 68083-19-2. It is a dimethylsiloxane which is vinyl terminated; the vinyl group is a small portion of the polymer backbone. The draft report calls this compound "vinyl silicone polymer," which may not be an adequate description.

Choice of Alternatives to Assess

The Introduction lists the other states that are regulating PFAS in food packaging and are looking for alternatives, although it appears Washington State is leading on alternatives assessment. We suggest that this section be supplemented with some material and lists of alternatives to consider that have been developed elsewhere, including from a new report by the Organization for Economic Cooperation and Development (OECD (2020), PFASs and Alternatives in Food Packaging (Paper and Paperboard) Report on the Commercial Availability and Current Uses, OECD Series on Risk Management, No. 58, Environment, Health and Safety, Environment Directorate, OECD.) None of this information is in the report, and it needs to be listed and expanded on to help validate the recommendations in Ecology's report.

For example, the California Safer Consumer Products program identified the following alternatives in their research (Safer Consumer Products. Chemical Profile for Food Packaging Containing Perfluoroalkyl or Polyfluoroalkyl Substances. July 2020. California Environmental Protection Agency & Department of Toxic Substances Control):

1. Physical barriers, which can be made of plastic such as polyethylene, polyethylene terephthalate (PET), polyvinyl alcohol, or polylactic acid (PLA), as well as of silicone, aluminum, clay, wax, or biowax such as Clondalkin ECOWAX.
2. Alternative processing, such as machine-finished paper (e.g., natural greaseproof paper and vegetable parchment), mechanical densification, or mechanical glazing.

3. Alternative chemical barriers, such as starch, carboxymethyl cellulose, aqueous dispersions of copolymers such as styrene and butadiene, aqueous dispersions of waxes, water-soluble hydroxyethylcellulose, chitosan, alkyl ketene dimer, alkenyl succinic anhydride, silicone, and several proprietary coatings of unknown composition.
4. Alternative materials, such as palm leaf, bamboo, and various plastics.

It is important to note that the relative safety of these alternatives has not been assessed in California's process. If one or more plant fiber-based food packaging products containing PFASs are listed as Priority Products in the California Code of Regulations, those entities who wish to continue selling the product in California will have to submit an Alternatives Analysis (AA) to the California Department of Toxic Substances Control (DTSC).

Ecology's report provides a list of alternatives, but more information on why they were selected and how the conclusions were made need to be provided. Each alternative needs a review summarizing its known toxicity and biological impacts, and whether it is available in sufficient quantities.

Stakeholder Engagement

The stakeholder engagement section of the report was very thorough. It should probably be placed before the other modules in this report, as this is the order presented in the IC2 AA Guide. While the process of engaging stakeholders was clear, it was not clear what specific input they provided for the report and thus for Ecology's assessment.

Including the full list of stakeholders that commented in this report is important for transparency. Additionally, a plot showing growth in stakeholder participation with each call/webinar would be helpful for visualization.

Additional Comments on Report Content

Hazard Assessment

ListTranslator scores were incorrectly interpreted in the Hazard assessment. For example, the statement "LT-UNK, meaning these substances were present on some lists, but a ListTranslator score could not be calculated" (page 40) is an incorrect interpretation. LT-UNK indicates that the chemical is not on any high hazard lists that would score it as LT-1 or even LT-P1. Chemicals rated as LT-UNK may be of low hazard (thus why they are not on any high hazard lists) or this score may mean that there is very little information on the chemical and that it is not well tested.

Performance Assessment

The performance assessment results tables indicate products that are "favorable." The definition and metrics for favorability need to be defined up front in this assessment. In one example, page 56 states that "For each prioritized alternative, promotional data was found that identified that alternative as have OGR

and/or leak resistance." From this statement it seems that only one of these criteria is sufficient for an alternative to be identified as favorable.

The statement on page 58 that "PFAS has likely led to a standard of over-engineered performance expectations in the food packaging industry" is an important consideration.

Cost & Availability

The databases from the Biodegradable Packaging Institute or the Compost Manufacturer's Alliance are key references in the Cost and Availability Assessment (page 11 of Appendix O). The draft report also added some focus on reusable products in Appendix O. The draft report appears to make some effort to consider sustainability; however, the concept of recycling is ignored. It is not clear to the committee how Ecology weighted considerations on biodegradability, compostability, and recyclability; there needs to be more description to justify the decision.

The report does not effectively distinguish PFAS added on the wet end of the production process from coatings that are added later on in the production process. The technology needed for both types of coating strategies is very different and will lead to differences in production cost.

The report also states conclusions that may not be explained by the evidence presented. For example:

- The statement on page 71 that "This difference may be due to differences in PFAS levels between wrappers and liners versus bags" does not indicate how variances between products explains the difference. Another factor to consider is how many different food establishments use these products. For instance, if 100% of 10 bags collected from different locations of the same fast food chain contain PFAS, that only tells you that this one fast food chain uses PFAS-treated packaging, but doesn't tell you how widespread the use of PFAS-treated packaging is across fast food chains.
- The statement on page 73 that "Conventional sandwich bags, which were not tested for PFAS and therefore not available in the Center for Environmental Health database, had an average unit price of 2 cents. This difference indicates that wax-coated bags are not cost comparable" does not explain that conclusion, given that it's unclear whether the 2 cent bags contain PFAS.
- The statement on page 78 that "Particularly because the cost of labor and cleaning are minimized, reusable boats are likely a cost-comparable alternative" is unclear on how the cost of labor and cleaning is minimized for reusable boats compared to single-use products.
- The statement in Appendix O page 5 that "Schaider et al (2017) found PFAS in approximately half of 42 dessert/bread food contact papers tested, but only in approximately one-third of...sandwich/burger contact paper products tested. This difference may be due to differences in PFAS levels between wrappers and liners versus bags" seems to indicate that more than one-third of wrappers tested in this study may contain PFAS. This would contradict the statement in Appendix O page 7 that "The results of these studies can be found in Table 5 above and highlight a significant percentage of the market is already using PFAS-free products." If Ecology believes these results may be inaccurate, how can it conclude based on these data that a significant percentage of the market is already PFAS-free? Additionally, it is our understanding that if PFASs are intentionally added to food packaging, they are added at levels high enough to be detected by PIGE, the test

method used in Schaider et al. (2017). Smaller amounts would be impurities, thus not covered by the Washington food packaging law.

- The statement in Appendix O page 11: "As such, it was difficult to identify any PFAS-containing items" is difficult to accept, given that PFAS were found in 22% of the wrappers tested by Toxic-Free Future in 2020.
- The statement in Appendix O page 12 that "PFAS-containing bags are in regular use (Table 5)" needs clarification about what is being referred to. What is the difference between sandwich bags, sandwich/burger food contact paper, and sandwich wrappers? Do sandwich food contact paper and wrappers fall under Product Category 1, because they are sheets of paper wrapped around the sandwich, rather than bags? Which entry in Table 5 is being referenced?
- The statement in Appendix O page 12 that "Therefore, this difference indicates that wax-coated bags are not cost comparable" is a major conclusion made without any solid data. Was it not possible to test a sample of the conventional sandwich bags for total F?
- The statement in Appendix O page 11 that "Of note, paper products coated with non-PET polymers (which includes PVOH, EVOH, PE, and polypropylene coatings) appear to be cost comparable with PFAS-containing paper products" does not have a clear explanation of how this conclusion is reached. Is PET-coated excluded because PET-coated is more expensive, or because no information about PET-coated is available?
- It is not clear in Appendix O Table 7 (page 11) which product categories are referenced in the "Difference in price" column.

Inconsistencies between Appendix O and Cost and Availability Conclusions in Report

The data in Appendix O appear to be inconsistent with the conclusions in the Cost and Availability section of the report. For example:

- Appendix O page 12: "EVOH-coated sheets were identified as cost comparable"
  - In table 7 on page 27 of the draft report, EVOH is listed as "Insufficient data" for this module. This is inconsistent with the conclusion here.
- Appendix O page 12: "EVOH-coated bags should qualify as a cost-comparable alternative."
  - This is inconsistent with the conclusion in Table 8 on page 28 of the draft report.
- Appendix O page 12: "EVOH-, and PE-coated plates were also identified as cost comparable"
  - This is inconsistent with table 9 on page 29 of the draft report.
- Appendix O page 14: "EVOH-, and PE-coated bowls were identified as cost comparable."
  - This is inconsistent with table 10 on page 30 of the draft report.
- Appendix O page 15: "EVOH-, and PE-coated trays were also identified as cost comparable."
  - This is inconsistent with table 11 on page 31 of the draft report.
- Appendix O page 15: "PVOH-, EVOH-, and PE-coated boats were cost comparable"
  - In table 12 on page 32 of the draft report, "PET coated" is listed, but it is not listed here.
- Appendix O page 16: "EVOH-, and PE-coated paper clamshells were also identified as cost comparable"
  - This is inconsistent with table 15 on page 35 of the draft report.
- Appendix O page 17: "EVOH-, and PE-coated food containers were also identified as a cost-comparable alternative"
  - This is inconsistent with table 16 on page 36 of the draft report.
- Appendix O page 20-22: Tables 9-11

- The committee recommends verifying information consistency between these tables and tables 7-16 in the draft report.

Addendum: Copy-Editing & Minor Comments

The report should aim to be well documented, clear, and concise.

The report could use a close eye to proofreading – the use of extraneous punctuation and capitalization, inconsistent use of plural vs singular "data," and other grammatical errors, were distracting to the reviewers. We recommend ensuring that:

- All figures, tables, and appendices have citations in the body of the report.
- All acronyms are defined at first use.
- All hyperlinks in the report work.

It would also be helpful to have a continuous page numbering system through the entire document for ease of providing review.

A visual timeline for the project to illustrate both the regulatory requirements and the different elements of the alternative assessment would be helpful to clearly show the process and save a lot of words.

Throughout the report, the products evaluated (for example, listed in tables) remain unnamed and "anonymous." It's not clear why this is the case, as publicly available promotional materials were used to evaluate the products.

Comments corresponding to specific pages

- Executive Summary page viii: "a single PFAS chemical and the products of its breakdown were identified" is unclear.
- Page 1: Regarding the list of other states and countries that are regulating PFAS in food packaging and are looking for alternatives, "regulate" would be more correct than "restrict." The California DTSC action might not necessarily restrict the use of PFAS in food packaging.
- Page 1: "degrade into products such at 6:2 fluorotelomer alcohol (FTOH)" - The phrasing in this report is inconsistent about whether these polymers can degrade into 6:2 FTOH, or whether 6:2 FTOH is a manufacturing impurity. Using the language in the FDA July 31, 2020 announcement would make the language of this report more consistent and accurate.
- Page 1: "all 6:2 fluorotelomer alcohols (FTOH) in food packaging, both the chemical and all polymer compounds" is confusing. Are alcohols plural? Was 6:2 FTOH intentionally used in food packaging?
- Page 2: "the selection of a regrettable substitute is further reduced." This language is unclear.
- Page 3: Could use a separate subtitle starting at "The following recurring issues and confounding factors should be considered when reviewing this AA."
- Page 6: "RCW 70.95G.070 prohibits the sale of all PFAS in food packaging" or the sale of all food packaging with PFAS?

- Page 7: second to last paragraph, "(FDA, 2015)" should be "(FDA, 2016)." FDA removed these 5 substances from CFR, as noted in the table, and should not be cited here.
- Page 10: Since Stakeholder Involvement is a module of IC2 Guide, should we call the current "Section 2. Stakeholder Outreach and Engagement" an IC2 module?
- Page 11: "identify the alternative as unfavorable" -> characterize.
- Page 15: "PFAS and PFAS-free" -> PFAS-treated and PFAS-free.
- Page 20: "Product producers appeared apprehensive" Use food packaging producers or chemical producers instead?
- Page 24: Is there test data for foodservice containers to show the % of this category product containing PFAS?
- Page 27-36: It would make more sense for Tables 7-14 and associated text to be part of the summary and conclusions. These tables fall in the middle of the report; out of alignment with the IC2 guidance approach.
- Page 41: "(Fengler et al., 2011; Müller et al., 2012; Tier et al., 2017)."
    - Many of the studies summarized in Trier et al. (2017) are from older formulations containing diPAPs, which would suggest that the 2011 and 2012 studies were, too. When were diPAPs officially phased out?
    - Trier et al is also not in this section's list of references.
- Page 42: table 9, recommend to define "DG."
- Page 48: "(Trier, Taxvig, Rosenmai, & Pedersen, 2017)." Is this different from Trier et al 2017?
- Page 48: "the PFAA load in streams" -> waste streams.
- Page 48: "The PFAA was leachable to pore water (25–49%) and was strongly correlated with the PFAA load (Choi et al., 2019)."
    - The PFAA was strongly correlated with the PFAA load? This is unclear.
- Page 48: "In addition, 6:2 FTOH is often used as a precursor to PFAS polymers used in food packaging products and can be present as a residual (Boucher, 2020)."
    - This seems to contradict earlier statements about the reason for the presence of 6:2 FTOH in food packaging.
- Page 48: "Although the magnitude cannot be predicted, a decrease in exposure to certain PFAS via food packaging is expected with increased use of safer alternatives; however, there are many routes of exposure to PFAS, so exposure to these chemicals would not be completely eliminated."
    - This statement is unclear.
- Page 54: "Leak resistance: Ability of a product to resist grease or other fluid by either the ability to reduce permeation AND transfer through the substrate, or the ability to resist leaks through folds or seals (e.g., folded paperboard products)." -> delete "the ability to" and add "ing" to both parts.
- Page 54: "products that are certified compostable by Biodegradable Products Institute."
    - Specify when BPI started certifying products that are PFAS-free. Products certified before that date may not be PFAS-free. Give details of the specification; e.g. is there a threshold for F that is tested?
- Page 56: "For each prioritized alternatives, promotional data was found that identified that alternative as have OGR and/or leak resistance" alternatives -> alternative, have -> having.
- Page 56: "and this treated paper can easily be developed into bag or sleeve products" Reference for this statement?

- Page 69: "Eleven manufacturers comprise half of the single-use foodservice market." How many manufacturers are there in total? And how about for single-use packaging?
- Appendices Page 49: "Highly persistent and/or highly bioaccumulative and/or toxic alternatives" This says and/or, but there's no vP or vB or T option listed in the brackets.
- Appendix O Page 4: "across three different organizations" The Schraider et al 2017 study is from 9 different organizations.
- Appendix O Page 9: "noted that their product uses a new technology that is starch and cellulose based" Specify what type of product: food contact paper, dinnerware, or takeout container.
- Appendix O Page 10: Paragraph beginning with "Using a conservative 5-10% cost increase as a benchmark, ..." Rephrase the first sentence, as it is unclear how the two halves of the sentence are connected. It is not clear why the last sentence starts with "Instead."
- Appendix O Page 18: "In several of these case studies, expected investments from companies." Why "expected?" Looks like those were actual investments made in some case studies.
- Appendix O Page 23: "ReThink Disposable. 2018. Business Cost Impacts from disposable food service items. Clean Water Action Fact Sheet." Is there a link to this resource?

Appendix A: WSAS Committee on PFAS in Food Packaging

For questions related to the peer review process, contact:
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Dr. Simona Balan is a Senior Environmental Scientist in the California Department of Toxic Substances Control. Dr. Balan is leading the Safer Consumer Products team on perfluoroalkyl and polyfluoroalkyl substances (PFASs). Dr. Balan previously managed international projects on the use of flame retardants and PFASs in consumer products. She was recognized by the Collaborative on Health and the Environment as one of 20 Pioneers under 40 in Environmental Public Health. Dr. Balan has a Ph.D. in Environmental Science, Policy and Management from the University of California, Berkeley.

Elaine Faustman (*chair*) – faustman@uw.edu

Dr. Elaine Faustman is a toxicologist and Professor and Director of the Institute of Risk Analysis and Risk Communication in the University of Washington (UW) Department of Environmental & Occupational Health Sciences. She is also Adjunct Professor in the UW Evans School of Public Policy and Governance. Dr. Faustman's research focuses on identifying biochemical mechanisms of developmental neurotoxicity and to develop new approaches for the evaluation and characterization of health risks from environmental agents. Her expertise is in risk assessment of chemical hazards and neurodevelopmental toxicology. Dr. Faustman received the 2019 Merit Award from the International Union of Toxicology and was elected to the Washington State Academy of Sciences in 2019. Dr. Faustman earned a PhD in Toxicology from Michigan State University.

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Dr. Lauren Heine is Senior Science Advisor at Northwest Green Chemistry and is adjunct faculty at Gonzaga University. Dr. Heine applies green chemistry, green engineering, and multi-stakeholder collaboration to the development of products and processes. She led development of GreenScreen® for Safer Chemicals, a method for chemical hazard assessment increasingly used worldwide. Dr. Heine drafted Policy Principles for Sustainable Materials Management for the OECD, and she helped develop criteria for the Design for the Environment (DfE) Safer Choice and Alternatives Assessment Programs for the EPA. Dr. Heine was technical advisor to the development of the Interstate Chemicals Clearinghouse (IC2) Alternatives Assessment Guide and the WA Alternatives Assessment Guide. She serves on the Apple Green Chemistry Advisory Board, and previously served on the California Green Ribbon Science Panel. Dr. Heine earned a PhD in Civil and Environmental Engineering from Duke University.

Pat Hunt – pathunt@wsu.edu

Dr. Patricia A. Hunt is Meyer Distinguished Professor in the School of Molecular Bioscience at Washington State University. Her primary research interest lies in human aneuploidy, mammalian germ cells and meiosis, and she is best known for showing the adversary effect of Bisphenol A and replacement bisphenols (BPS, BPF, BPAF, Diphenyl sulfone) on the reproductive system of mammalians. Dr. Hunt's current work centers on the reproductive effects of exposure to chemicals

with estrogenic activity. She was elected to the Washington State Academy of Sciences in 2015. Dr. Hunt earned a PhD in Reproductive Biology from the University of Hawaii.

Donatien Pascal Kamdem – kamdem@msu.edu

Dr. Donatien Pascal Kamdem is Professor in the School of Packaging at Michigan State University and works with Global Packaging Solutions LLC. His research interests include the chemical, physical, and mechanical properties of packaging made from wood, paper, and natural fibers, and technology to improve the performance and reduce cost of those products. Dr. Kamdem is an elected fellow of the International Academy of Wood Science. He has served as a witness expert, consultant, and reviewer on many projects regarding wood products. Dr. Kamdem earned a PhD in Wood Science from University Laval in Quebec, Canada.

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Dr. Michael Skinner is Professor in the School of Biological Sciences at Washington State University. He has been on the faculty of Vanderbilt University and the University of California at San Francisco. Dr. Skinner's research focuses on the investigation of gonadal growth and differentiation, with emphasis in reproductive biology. His current research has demonstrated the ability of environmental toxicants to promote the epigenetic transgenerational inheritance of disease phenotypes due to abnormal germ line epigenetic programming in gonadal development. Dr. Skinner established and was the Director of the Washington State University and University of Idaho Center for Reproductive Biology and established and was the Director of the Center for Integrated Biotechnology. He received the 2013 American Ingenuity Award from the Smithsonian and was elected to the Washington State Academy of Sciences in 2019. Dr. Skinner earned a PhD in Biochemistry from Washington State University.

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Dr. Huqiu Zhang is Senior Scientist at Sevee & Maher Engineers. Dr. Zhang specializes in optimizing chemical testing programs, applying analytical methods, and implementing chemical controls in the manufacturing process, covering the entire supply chain of food packaging. She has international experience in regulatory compliance for consumer product chemical safety, food contact, and food packaging. Dr. Zhang's expertise includes chemical and material industry product supply chains and chemical management, particularly in paper, paperboard, and plastic products, as well as chemical hazard identification, exposure evaluation, and risk assessment. Dr. Zhang's early research was in perfluorine chemistry. Dr. Zhang earned a PhD in Organic Chemistry from the University of Tennessee, Knoxville.

Appendix C. Copy of Peer Review Addendum

WASHINGTON STATE
Academy of Sciences
Science in the Service of Washington State

Addendum to Peer Review by PFAS in Food Packaging Committee Washington State Academy of Sciences

Thank you for your questions and request to clarify our review transmitted on October 5, 2020. The committee's intent in the peer review process is to provide constructive feedback for Ecology's Alternatives Assessment report. The committee agrees with the report's overall conclusions; our comments in our original review and in this clarification are intended to strengthen the evidence supporting the report's conclusions to ensure that the methods used and the information on which they are based are thoroughly described, transparent, and well-documented.

Peer Review Process

The committee's peer review in its entirety reflects a consensus view. No portion of it should be construed as an individual committee member's suggestion.

Generally speaking, the WSAS Committee peer review process aims to make comments and suggestions on a work product as presented, rather than recommendations derived from a study committee, which is a different kind of project, and thus a different process. The latter requires a longer, more in-depth project with iterative deliberations that are beyond the scope and timeline of this independent peer review.

Precursors and Breakdown Products

To clarify the statement "Relying solely on precursors and breakdown products for toxicity analysis is inappropriate," the committee intended to communicate that it is insufficient to rely solely on precursors and breakdown products for toxicity analysis when publicly available data exist about the polymer (either the specific polymer as defined by trade name or a generic example of the compound). Thus, Ecology's process of conducting a hazard evaluation on only the impurities/residuals of certain alternatives does not fully assess the hazard of those alternatives.

Standard practice would have Ecology use the following procedure to do due diligence in assessing all viable alternatives:

1. Attempt to evaluate the polymer in question
    a. The first priority is to assess the specific compound sold as a trade-named substance.
    b. If specific compound information is unobtainable due to confidential business information or other considerations, assessments could be performed on generic compounds that serve as proxies for commodity polymers such as PE, PET, and EVOH, to assess the polymer.
    c. The consideration of relatively small molecular weight species of the polymer (e.g. oligomers) or functional groups to inform the assessment.
2. Evaluate relevant precursors and breakdown products (for example, using publicly available

generic information about precursors and degradation products for commodity polymers like PE and PET)

The report would benefit from greater transparency on how hazard analysis was or was not performed on the polymer. For example, the report could state that a compound was evaluated but not enough data was found to form a conclusion, or that literature suggests that a polymer does not pose a hazard.

Use of GreenScreen® Methodology

Explanation in report

The committee appreciates Ecology's detailed and coherent explanation in its letter on October 14, 2020 of why and how GreenScreen® assessments were used in the hazard evaluation module. This explanation could also be included in the Report or Appendices. The committee also recognizes that there are structural and resource limitations in conducting the alternatives assessment, and suggests including a detailed explanation of the overall decision process, and especially related to addressing these limitations.

The committee also concludes that Ecology's report would benefit from a clearer explanation of the use of the term "insufficient data" to specify that this means that an existing GreenScreen® is not available, rather than stating that there is no publicly available data on the chemical for which a GreenScreen could be developed. While the report currently includes a link to the GreenScreen® website containing the relevant hazard evaluation, the report could also (1) more clearly list the peer-reviewed literature referenced in the GreenScreen®; (2) more clearly note the dates of existing GreenScreen® evaluations that were cited, and (3) if the screens are not current (more than 3 or 4 years old) also show the results of a literature search for any relevant studies published since the GreenScreen® report was produced. The committee also suggests that the report include clarifying statements that existing GreenScreen® assessments were the sole hazard evaluation tool used for the alternatives assessment, and that Ecology continues to seek information to perform GreenScreen® or other hazard evaluations for these alternatives.

The abovementioned clarifications would partially address the committee's comments. Changes in the assessment process, as noted below, would address the committee's other comments.

Changes in assessment process

The committee recognizes that the IC2 AA guide for a Level 2 Hazard Assessment indicates use of the GreenScreen® methodology for evaluation, and the committee supports its use to evaluate alternatives. The committee did not find, however, that the GreenScreen® methodology was used to conduct a new hazard assessment. Its use seems to have been limited to examining existing GreenScreens®.

A Level 2 Hazard Evaluation would use the GreenScreen® method to evaluate hazard information, not only rely on existing publicly available GreenScreen® evaluations. If information pertaining to a trade-name compound is unavailable, Ecology can acknowledge the unavailability of confidential business information and instead use generic chemical information and publicly available literature

about typical formulations to conduct an assessment with the GreenScreen® tool. For transparency and to strengthen its conclusions, Ecology could document how far they were able to get in the GreenScreen® assessment and outline what data is and is not available.

By stating "These gaps throw into question the final Safer Alternative conclusions," the committee intended to call attention to the need to support Ecology's conclusion that there is insufficient information to readily assess PE, PET, and EVOH. It is not accurate to report "insufficient data" and end the assessment at that point when publicly available data exist that can be used to evaluate a compound; it is important for the alternatives assessment to convey accurate information.

At the very least, the committee suggests that Ecology do due diligence by conducting a brief literature review to **supplement** the existing GreenScreen® evaluations and more completely assess potential hazards of the alternative suggested. When existing GreenScreen® reports are not available, a review of the published peer-reviewed literature search should be done to confirm the alternatives suggested have limited hazard. All chemical alternatives should undergo a consistent hazard assessment, whether or not there is an existing GreenScreen®.

A literature review would strengthen the report by being a proactive approach to carefully determine the safety of the proposed alternatives. Related methods of hazard assessment such as the Globally Harmonized System of Classification and Labelling of Chemicals and governmental hazard information databases could be used to fill in gaps in information and fit within the GreenScreen® framework without adding an excessive burden.