NAVIGATING PPR POLICIES THROUGH CIRCULAR PACKAGING DESIGN STRATEGIES

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Abstract

This paper explores the transformative impact of Packaging Producer Responsibility (PPR) policies on materials design, selection strategies, and the broader implications for supply and value chains in transitioning to circular economy models. PPR policies, a subset of Extended Producer Responsibility (EPR) regulations, shift the burden of managing packaging waste from consumers to producers by imposing fees based on the environmental impact of packaging materials. Producers adopting recyclable, compostable, or otherwise sustainable designs are incentivized through reduced "eco-modulated" fees, encouraging innovation and waste reduction.

State-level PPR legislation in the U.S. has expanded significantly in recent years, the funding from which has catalyzed improvements in recycling and composting infrastructure. However, these policies lack uniformity in compliance requirements and evaluation standards, creating challenges for producers navigating diverse regulatory landscapes. In this paper, we provide an overview of active PPR laws in states like California, Minnesota, Oregon, Maine, and Colorado, alongside a forecast of future PPR policy developments. We also consolidate the various frameworks of eco-modulated fees applied to packaging into an actionable guide for producers. The guide organizes circular packaging design standards and compliance criteria per state into a clear matrix. These resources will help to drive the adoption of circular supply chains, optimized product life cycles, and advanced design approaches that minimize environmental impacts and regulatory costs.

This paper explores potential strategies to align packaging designs with PPR compliance, focusing on circularity principles that reduce waste, protect the environment, and enhance product value.

Introduction and Motivation

Over the past four years, the United States has undergone a surge of regulatory activity to reduce the mounting burden of consumer and industrial waste on the environment and human health. A popular method to deploy these regulations are Extended Producer Responsibility (EPR) laws, which shift accountability to producers for safely and sustainably managing the end-of-life of products. Currently enacted at the state-level, these laws aim to advance regional waste management infrastructure and incentivize product/packaging designs aimed at diverting waste from landfills into the circular economy. Most importantly, EPR laws deploy mandatory fees on producers to ensure that instilling and running any new or improved system does not come at the expense of municipalities or taxpayers. While the categories of products covered by EPR laws continue to diversify across the United States, legislative activity focused on packaging EPR is proliferating most rapidly.[1]

Packaging Producer Responsibility (PPR) laws, or EPR regulations focused on packaging, hold producers accountable to pay for managing and remediating waste stemming from packaging. This establishes multiple noteworthy principles on the roles companies have within the circular economy and converge them under one policy: (1) packaging is indelibly tied to the product design, (2) producers are accountable for the life cycle of packaging across their entire value chain, and (3) producers are liable stakeholders in the secondary materials market. As a result, producers and brands must fastidiously focus on finding the necessary procedures for adapting to these newfound responsibilities.

As seen in Figure 1, nearly half the country has engaged in state-level PPR legislative activity. The states of Maine, Oregon, California, Colorado, and Minnesota have successful enacted PPR laws,[2-6] but further legislation is expected among the other states over the next few years. In January of 2025 alone, four new PPR bills were introduced in Tennessee, Washington, New York, and New Jersey, which carry the momentum from years of legislative action. Additionally, the states of Maryland, Illinois, and Massachusetts have commissioned needs assessments intended to drive eventual PPR policy. Table 1 describes the status of PPR legislation in these highly active states, but others are worth watching as well based on earlier bill introductions, such as from Michigan and Rhode Island in 2024.

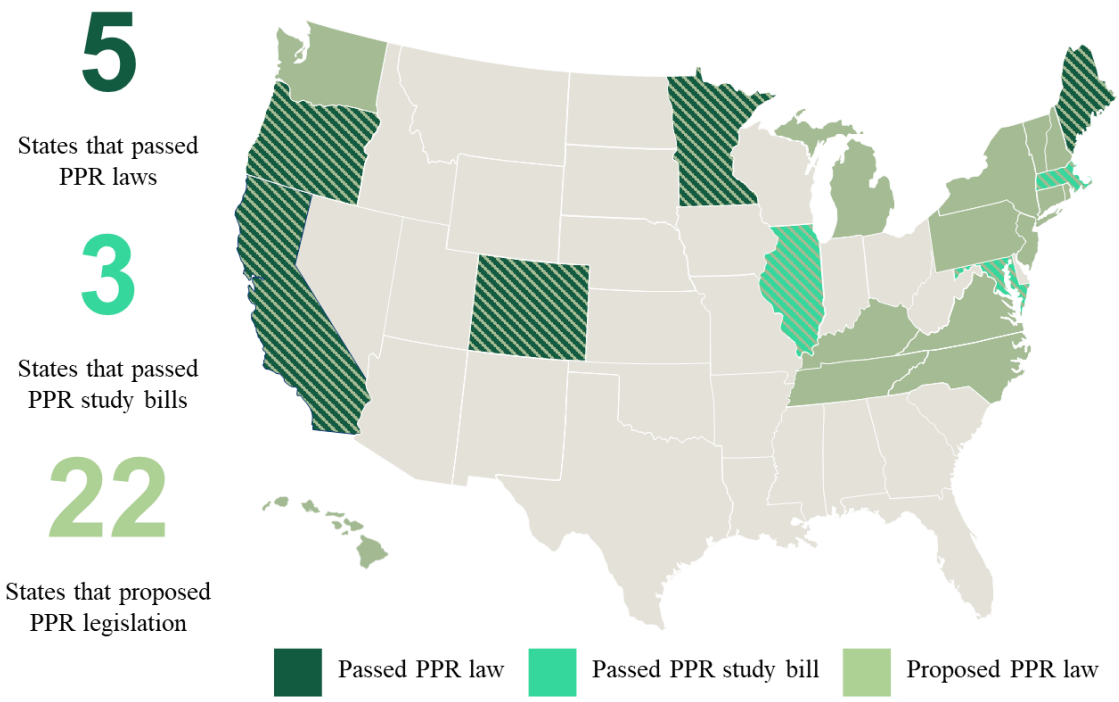

Figure 1) PPR legislative activity across the US states.

Table 1) Status of active PPR legislation in the US

State	PPR Status	Trajectory
California	Enacted PPR law SB54 on 6/30/22	CAA selected as PRO, plan approved, compliance enforcement in 2027
Colorado	Enacted PPR law HB22-1355 on 6/3/22	CAA selected as PRO, plan approval in 2025, compliance enforcement 2026
Maine	Enacted PPR law LD1541 on 7/12/21	Stewardship organization choice and producer registration deadline in 2026
Minnesota	Enacted PPR law HF3911 on 5/19/24	PRO selection in January 2025, producer registration in 2026, and plan approval in 2028
Oregon	Enacted PPR law SB582 on 8/20/21	CAA selected as PRO, plan approved, producer compliance enforced in 2025
Maryland	Passed study bill CH465SB222 on 5/8/23	CAA selected as PRO, advisory council to conduct needs assessment early 2025
Illinois	Passed study bill SB1555 on 7/28/23	Establishes advisory council to conduct needs assessment by December 2025
Massachusetts	Passed study bill S2967 on 11/20/24	Establishes commission to guide EPR legislation in 2026
New Jersey	Introduced PPR law SBA5009 on 11/14/24	Bill in senate committee, previously enacted packaging PCR mandate
New York	Introduced PPR law SB1464 on 1/9/25	Reintroduced 2024 bill, in senate committee
Tennessee	Introduced PPR law SB38 on 1/6/25	Reintroduced 2024 bill, pending senate committee appointments
Washington	Introduced PPR law HB1150 on 1/21/25	Bill in house committee, previously enacted packaging PCR mandate

*Producer Responsibility Organization (PRO) **Circular Action Alliance (CAA)

Current State of the Technology Industry Uses

Although PPR policies enacted between the states share intent, their scope of covered products and compliance requirements are largely inhomogeneous. Producers looking to comply across all state PPR regulations must face the challenging task of coalescing these different guidelines into a uniform implementation strategy. This harmonization begins by considering the broad range of products and packaging materials that is covered by PPR laws collectively across all the enacting states, which is summarized in Table 2.

Table 2) Examples of covered and exempt products included among PPR laws enacted by California, Colorado, Maine, Minnesota, and Oregon (non-exhaustive).

Covered Products	**Exempt Products**
• Plastic, paper, glass, metal, composite packaging • Single-use bags • Beverage bottles, cartons • Food service containers, clamshells • Single use cups, plates, utensils • Primary consumer good packaging • Shipping boxes, bins, and containers • Bubble wrap, packing peanuts, foams. • Envelopes, folders, pouches, mailers • Single-use trays, grocery packaging • Labels • Foils, films, wraps, or food serviceware • Printed paper, newspaper, magazines, flyers, brochures, booklets, catalogs	• Paint cans • Drugs or medical products • Sanitary and hygiene products • Bottle deposit beverage containers • Infant formula • Long-term products • Bound books • Pesticides • Propane, gas tanks • Napkins, paper towels • Pallets, tertiary B2B packaging • Manufacturing process products

The definition of covered packaging varies significantly between states, such as beverage containers, printed paper, food serviceware, and e-commerce packaging. In some instances, single states act as individual contributors of covered products, such as online shipping materials and compostable packaging by California. This also applies for exemptions, where inconsistencies between states can create confusion on producer obligations. For example, Washington includes hazardous product packaging while Colorado excludes such materials. Producers are left with the options of (1) implementing compliance strategies to the aggregate of all covered products amongst the state laws or (2) tailoring compliance strategies to a selection of products with the later risk of barred distribution of other products in certain states.

In addition to the variance among covered products between state PPR laws, the producer obligations vary as well. Figure 2 depicts the goals for PPR policy enacted within California, Colorado, Maine, Minnesota, and Oregon. These goals can be separated into two categories: (1) requirements beset on packaging materials and design, and (2) requirements beset on packaging end-of-life. While these laws align on the overall intent to divert waste and transition to circular materials, the non-uniformity for each category of goals poses challenges for producers. In particular, the criteria on packaging design and composition have massive ramifications on producers, considering the critical role packaging plays in performance of certain packaged goods. While some products (such as single-use food serviceware) have more flexible performance criteria, many products (such as soaps or dairy products) require strong barrier properties and durable materials to preserve the performance of the product during shipping and distribution. California and Maine include criteria to substantially reduce the weight of covered packaging, which forces design alterations to all covered products regardless of their packaging composition. The underlying complexity of the state-to-state PPR compliance framework is expected to continue as regulations advance rapidly at the state-level yet stagnate at the federal-level.

Another critical part of PPR policy that influences packaging design is the criteria for producer fee adjustments based on sustainability metrics, termed eco-modulation. Eco-modulation is included as an incentive for producers to alter their packaging designs to be more recyclable, reusable, compostable, and renewable. Such as it is with the PPR goals, the criteria for fee eco-modulation varies state-by-state. Figure 3 depicts the eco-modulation fee criteria mentioned in PPR laws enacted in the states of California, Colorado, Maine, Minnesota, and Oregon.

	Packaging material goals	Packaging recycling goals	Registration Deadline	Reporting Deadline	Fees Assigned
Oregon	None	70% recycling by 2050	March 2025	March 2025	July 2025
Colorado	5-40% recycled content by 2030 (based on material)	59% collection by 2035 55% recycling by 2035	October 2024	August 2025	January 2026
California	100% recyclable/compostable by 2032 25% reduced weight 25% reduced plastic	65% recycling by 2032	April 2025	August 2025	January 2027
Maine	100% recyclable/reusable/compostable by 2050 60% reduced weight 30% post-consumer recycled content	75% recycling by 2045 50% reuse by 2050 <15% packaging in litter	May 2026	May 2026	September 2026
Minnesota	target pending	target pending	May 2026	July 2026	January 2029

Figure 2) Compliance requirements for PPR laws enacted in the states of California, Colorado, Maine, Minnesota, and Oregon.

		California	Colorado	Oregon	Minnesota	Maine
LCA	Life Cycle Impacts	No	No	Yes	No	No
Packaging Design	Recycled Content	Yes	Yes	Yes	Yes	Yes
	Reduced Packaging	Yes	Yes	Yes	Yes	Yes
	Materials Toxicity	Yes	Yes	Yes	Yes	Yes
	Disposal Labeling	Yes	No	No	No	Yes
Waste Management	Recyclability	Yes	Yes	Yes	Yes	Yes
	Compostability	Yes	No	TBD*	Yes	No
	Reusability	Yes	Yes	Yes	Yes	Yes
	Reduced Litter	No	No	No	No	Yes

*Pending review of state-mandated compostability study to conclude in December 2026

Figure 3) Eco-modulation criteria for fees imposed on producers subject to PPR laws enacted in the states of California, Colorado, Maine, Minnesota, and Oregon.

Producer Responsibility Organizations (PROs) handle orchestrating harmonized compliance plans for PPR laws. Circular Action Alliance (CAA) was founded in 2022 by 20 producers representing the food, beverage, consumer goods, and retail industries, and serves as the PRO for California, Oregon, and Colorado.[7] CAA was also selected by the state of Maryland to spearhead a needs assessment to inform future EPR legislation, which is scheduled to report its final EPR recommendations by January 2025. Although some states allow for multiple PROs to coordinate on implementation plans, CAA currently stands as the lone organizer for producers facing PPR obligations. CAA recently released its implementation plan for PPR compliance in Oregon, including the fee eco-modulation criteria.[8] Oregon is the only state that currently mandates a life cycle evaluation, based on a life cycle assessment (LCA) on products to assess the environmental impact of their packaging, to calculate a bonus rewarded to producers for sustainable practices in the form of a discount producer fees. The bonuses are introduced in two tiers:

- Bonus A - rewards producers for performing and disclosing LCAs,
- Bonus B - incentivizes impactful packaging changes proven through LCAs.

This system is regarded as a preliminary incentive intended to manage financial risks in the program's initial stages while still encouraging circular packaging designs and programs. CAA also mentions its intent to expand the eco-modulation structure in later stages, opening the door for more specific criteria following the recommended metrics included in the PPR laws. Therefore, a proactive implementation approach must consider the specific metrics to direct specific design and program initiatives related to packaging.

Technology Approach

A comprehensive strategy towards PPR compliance must jointly consider (1) the categories of stakeholders across the producer value chain, and (2) the available options for instilling circular solutions. Figure 4 gives a concentric model depicting the opportunities for circular solutions across the life cycle of the product that have implementation opportunities at various stages of the value chain.

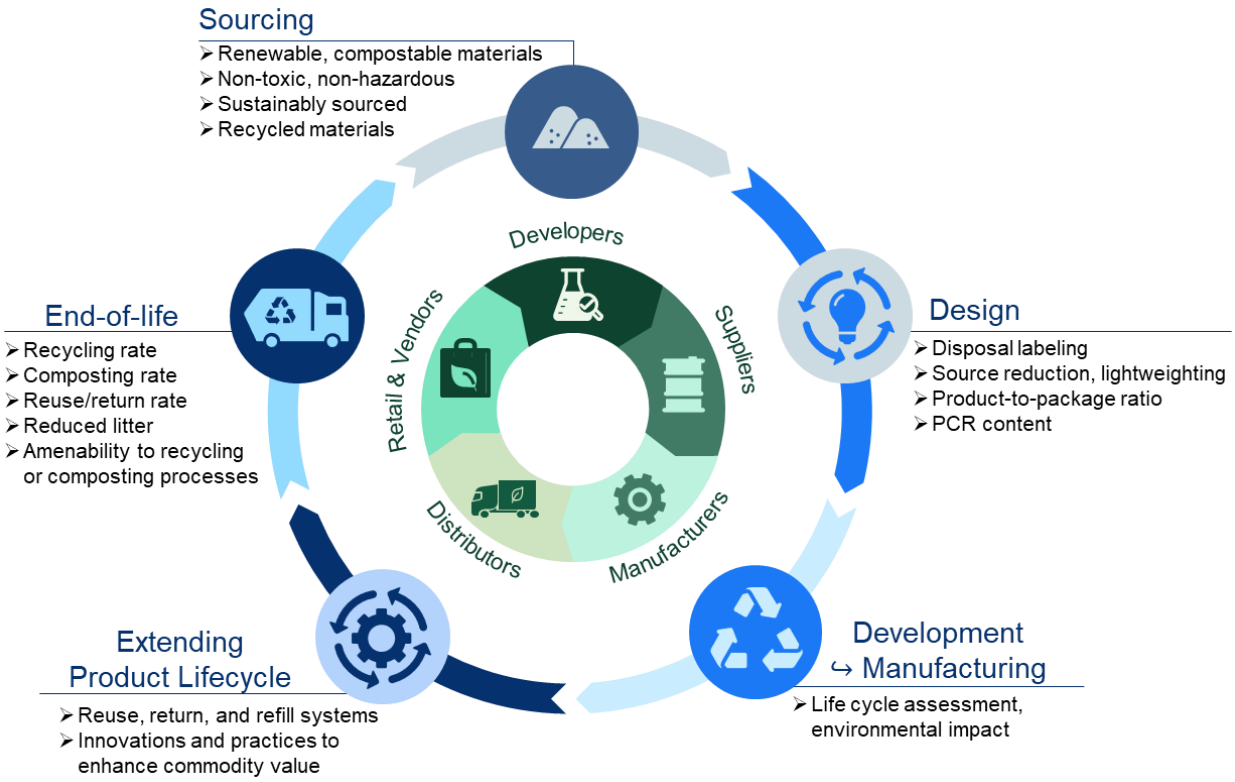

Figure 4) Packaging compliance considerations across the value chain of consumer packaged goods in accordance with fee eco-modulation criteria and related metrics within enacted PPR laws in the states of California, Colorado, Maine, Minnesota, and Oregon.

The eco-modulation metrics listed in the PPR laws California, Colorado, Maine, Minnesota, and Oregon are grouped based on where within the product/packaging life cycle they are primarily measured. In this model, the life cycle is grouped into five stages: sourcing, design, development-to-manufacturing, life extension, and end-of-life. The value chain of a packaging producer facing PPR obligations is summarized by five primary stakeholders: developers, suppliers, manufacturers, distributors, and retail plus vendors. While this is likely an oversimplification of the complex value chains across all relevant brands and producers, this model serves as an accurate representation of what circularity project categories exist to influence packaging compliance and helps visualize where within the value-chain that these solutions most aptly take shape.

Discussion

Sourcing

Raw materials choices set the baseline for later packaging designs and end-of-life. Incorporating renewable materials for packaging is critical but can take many forms. Compostable materials typically take the form of cellulose or biomaterials but must be certified by the Fiber Box Association as paper recyclable or by BPI/TUV as compostable to be accepted by collection sites in the US. Paper, plastic, glass, and metal are all recyclable materials, but are often sourced as virgin feedstocks for packaging manufacturing. Sourcing recycled raw materials is a major hurdle for packaging developers and producers to tackle, but suppliers are continuously developing high quality alternatives to virgin materials.

Per- and polyfluoroalkyl substances (PFAS) are facing widespread bans in food packaging, which was used historically as a barrier layer and surface treatment on many paper packaging materials (e.g., popcorn bags, takeout containers, soup and beverage cartons, cardboard boxes). Ensuring raw materials or components are "PFAS-free" is critical to ensuring packaging is safe and recyclable/compostable. Furthermore, many inks and adhesives used for labeling are disruptive to recycling/composting. Incorporating packaging design materials that are circular, such as compostable inks and biodegradable labels is just as important as sourcing circular structural materials.

Design

Lightweighting is already used by many brands (e.g., Nestlé, Coca-Cola, Procter & Gamble, SC Johnson) to reduce plastic in packaging without detrimental impact on packaging performance. More materials reduction opportunities exist for secondary packaging and bulking materials. This can be achieved through structural optimization, such as thinner walls or innovative folding techniques, while maintaining durability. Compact packaging designs, concentrated products, and reusable formats refine product-to-package ratios and minimize transportation inefficiencies.

Clear and consistent labeling guides consumers on proper disposal pathways, increasing recycling and composting rates. Adopting standardized labels, such as the How2Recycle label in the U.S., ensures packaging meets local waste management protocols. These labels are intended to reduce contamination, enhancing the efficiency of recycling and composting systems. Recent updates to How2Recycle labeling introduce QR codes that provide localized disposal instructions, which are expected to improve consumer engagement and reduce confusion.[9]

Incorporating PCR materials reduces virgin material demand and supports secondary materials markets. Partnerships with suppliers offering high-quality PCR plastics or recycled paper enable producers to meet PPR requirements while advancing circular economy goals. Nestle, Mars, Pepsi, Coca-Cola, and other major CPG brands have released primarily PCR packaging for a variety of products. Additionally, advances in biodegradable materials (e.g. seaweed alginate, mycelium, silk fibroin) enable compostable options for PPR compliant packaging. While these solutions address key sustainability concerns, they often present trade-offs in cost, scalability, and sometimes performance. Further development of recycled or compostable materials with good barrier performance and durability is critical.

Paper fiber-based packaging offers another practical alternative to plastic and Styrofoam, especially for foodservice and CPG applications. Coca-Cola and Kraft-Heinz both released 100% paper bottles, while Mars and Nestle have introduced 100% paper flexible snack wrappers. These designs replace significant plastic waste and introduce fully recyclable alternatives to single-use small packaging. While its recyclability and biodegradability are clear benefits, challenges to paper-fiber packaging include its reliance on virgin pulp, water-intensive manufacturing, and performance limitations under high-moisture conditions. Innovations in coatings and fiber blends are helping overcome these barriers, making fiber-based solutions increasingly attractive to producers seeking circularity.

Development → Manufacturing

The environmental impact of alternative materials and processes must be accurately assessed to confirm implementation strategies have the desired outcome. Computational models and analytical methods like LCAs help assess the total impact of packaging materials and design throughout its lifecycle, including impact on including impact on carbon, water, waste, and biodiversity factors like eutrophication. Brands must coordinate with product developers, packaging converters, and procurement managers to ensure that recyclable designs or renewable materials result in holistically sustainable systems and effectively sustain their interests within target markets. Collaborating with solutions providers on protypes or pilot programs in key regions is a standard tactic, but scaling beyond that takes strong collaboration upstream to ensure technical solutions can meet large commercial demands.

Extending Product Life Cycles

Extending the value of packaging is to prolong its use without significant downcycling. Fulfilling these criteria requires two things: (1) packaging that is designed for refilling or reusing, and (2) programs that collect and return packaging for it to be used again. This can entail both technical and systems-based solutions. Reverse logistics programs, or take-back programs, are appearing for a variety of products, such as textiles, electronics, and household goods. These programs rely on operational systems that collect and return post-consumer products and designs that enable those products to be revitalized and recirculated. The same principles can apply to used packaging. Bounded environments like event venues, schools, casinos, and airports offer ideal forums for closed-loop systems that can take advantage of reusable cups, containers, or serviceware. The National Football League introduced such a program with the Chicago Bears in collaboration with Dr. Pepper, providing reusable cups in replacement of single-use, which are collected, cleaned, and reused by stadium vendors. Additional examples exist internally within a company's own suppl chain, such as reusable business-to-business packaging (e.g. pallets, drums).

For open environments, traceability of reusable containers becomes paramount. As the dawn of digital product passport requirements approaches from the EU, product tracking technology and services have rapidly grown. Radio frequency identification (RFID) device technology, QR codes, smart labeling, and resource mapping software can converge to give brands, retailers, and vendors the ability to incorporate reusable containers for their products. These programs rely on packaging designs that are durable and non-contaminable, so they can be washed and reused for many iterations. These programs may also rely on collaboration between brands/producers and consumer-facing partners (i.e., retailers, vendors), such as those facilitated by Loop to source reusable containers for grocery retail partners.[19]

End-of-life

Recycling and composting centers rely on standard certified processes, which forces them to reject materials that are not amenable. Added materials (e.g. inks), non-recyclable plastic components mixed into the packaging design (e.g. bottle caps, plastic liners), non-degradable paper coatings (e.g. wax treatments), and contaminants (e.g. processing aids, soiled/stained paper, components containing PFAS) can cause entire collection batches of recyclable/compostable materials to get rejected. With the advent of PPR regulation, producers are now accountable for ensuring careful collection, sorting, and handling processes are enacted within their value chains. This is especially critical in Maine, where litter audits are commissioned to decide the contribution of packaging in litter.

The preferential end-of-life for packaging continues to cause debate. In the United States, the infrastructure for composting biodegradable packaging is substantially weaker than that for recycling, which may set the precedent for some producers in their implementation strategies. The definition of "biodegradability" of packaging is broad and can lead to incidents of greenwashing when claims of biodegradability misrepresent the compatibility of materials with composting processes. Furthermore, industrially compostable materials require specific processing, making it a contaminant in standard municipal compost standard municipal recycling streams. According to Oregon PPR, the order of preference is reuse, then recycling, then composting.

Conclusions and Recommendations

Synthesizing a harmonious PPR implementation strategy from the aggregate of compliance criteria among enacting states is critical for producers. Guidelines and advocacy provided by CAA and other stewardship organizations are helpful, but producers must internalize implementation strategies based on their producer roles and value chains. Fortunately, the emergence of paper-based alternatives, non-toxic materials, packaging design innovations, and circular systems provide compelling case studies of commercial packaging solutions that correlate to PPR compliance requirements and fee modulation metrics (Figure 5). Producers must conduct exact life cycle assessments to ensure the integration of circular materials, designs, and/or systems can achieve the intended effect of eradicating packaging waste within their value chain without unforeseen harm to the environment or disruption to existing recycling/composting infrastructure. Converters or materials developers supplying compliant packaging solutions to brands must consistently verify all critical performance metrics are met to keep the value of products to consumers. Most importantly, producers and their partners must take a proactive approach to transforming their products, packaging, and systems to accommodate circular models, thus ensuring that they profit from the enhanced recycling infrastructure and secondary materials markets that will materialize from the expansion of EPR in the US.

However, the challenges of PPR compliance expand beyond the packaging materials and waste management systems. Mandatory disclosures of product packaging composition, use, and waste management force an unprecedented amount of data to be collected and managed by producers. In many cases, brands face significant gaps in supply chain transparency or reliance on high performance plastics to keep product quality. Collaboration with suppliers, manufacturers, and distributors to instill new product transparency practices (i.e., life cycle assessment, digital product passports, correct labeling, materials flow analytics) can results in a resilient value chain amongst the shifting regulatory pressures influencing product/packaging designs.

Figure 5) Case studies of commercial packaging employing circular solutions that fulfill the fee modulation criteria for PPR laws enacted in California, Colorado, Maine, Minnesota, and Oregon [10-19]

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References

1. Sustainable Packaging Coalition, Guide to EPR Proposals, https://epr.sustainablepackaging.org/policies, 2025.
2. State of Maine. (2021). An Act To Support and Improve Municipal Recycling Programs and Save Taxpayer Money by Extending the Responsibility for Packaging Waste to Producers (Public Law Chapter 455). Maine Revised Statutes, Title 38, Chapter 18, §§2146-2149. https://legislature.maine.gov/legis/statutes/38/title38ch18sec0.html
3. State of Oregon. (2021). Plastic Pollution and Recycling Modernization Act (Senate Bill 582). Oregon Laws 2021, Chapter 102, §§1-45. https://olis.oregonlegislature.gov/liz/2021R1/Downloads/MeasureDocument/SB582/Enrolled
4. State of California. (2022). Plastic Pollution Prevention and Packaging Producer Responsibility Act (Senate Bill 54). California Public Resources Code, Division 30, Part 3, Chapter 6, §§42041-42064. https://leginfo.legislature.ca.gov.
5. State of Colorado. (2021). Producer Responsibility Program for Statewide Recycling Act (House Bill 21-1162). Colorado Revised Statutes, Title 25, Article 17, Part 5. https://leg.colorado.gov/bills/hb21-1162
6. State of Minnesota. (2024). Packaging Waste and Cost Reduction Act (House File 1906). Minnesota Statutes, Chapter 115A, §§115A.1310-115A.1330. https://www.revisor.mn.gov/statutes/
7. Circular Action Alliance. Circular Action Alliance: Driving Packaging Circularity. https://circularactionalliance.org/
8. Oregon Department of Environmental Quality. (n.d.). Recycling Modernization Act: Producer Responsibility Program Plan, Version 2. https://www.oregon.gov/deq/recycling/Documents/RMA-proplanv2.pdf.
9. The Recycling Partnership, State of Recycling Report, January 12, 2024, https://recyclingpartnership.org/wp-content/uploads/dlm_uploads/2024/01/Recycling-Partnership-State-of-Recycling-Report-1.12.24.pdf.
10. Derrick, M. (2024, November 7). 300m Cadbury bars to be wrapped in 80% recycled plastic. Sustainability Magazine. https://sustainabilitymag.com/sustainability/mondelez-amcor-partner-on-recycled-wrapping.
11. Lyubomirova, T. Lactalis, Tetra Pak share industry-first packaging innovation. Dairy Reporter. https://www.dairyreporter.com, 2025
12. The Recycling Partnership. America's Most Recognized Recycling Label to Offer Real-Time, Localized Disposal Instructions on Packaging Across the U.S. https://recyclingpartnership.org, 2024
13. Reusables.com. Uber Eats Partners with Reusables.com for Sustainable Packaging in Vancouver. https://reusables.com. 2023
14. Reynolds, M. Mars' MasterFoods pilots new paper-based squeeze-on packs in Australian first. Packaging World. https://www.packagingworld.com, 2024.
15. Packaging Reporter. Amazon Fresh pilots food-safe bio-based bags in Spain. Packaging Reporter. https://www.packagingreporter.com, 2025.
16. The Earthshot Prize. Prince William visits Notpla as they unveil new Earthshot-branded product and prepare for major fundraising round. https://earthshotprize.org, 2023.
17. Rachal, M. Keurig brewing up compostable K-Rounds as alternative to plastic coffee pods. Packaging Dive. https://www.packagingdive.com, 2024.
18. Pyzyk, K. Chicago Bears, Keurig Dr Pepper add to reusable cups trend at sports venues. Packaging Dive. https://www.packagingdive.com, 2024.
19. Mohan, A. Loop Reusable Packaging Platform Now in 25 Kroger Stores. Packaging World. https://www.packagingworld.com, 2022.

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