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Reforming plastic packaging regulation: Outcomes from stakeholder interviews and regulatory analysis

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ABSTRACT

Regulators worldwide are considering how to significantly improve the regulation of plastic packaging in response to the world's plastic pollution crisis and the future UN treaty on plastics. In Australia, where plastic packaging regulations have remained largely unchanged for over two decades, the government now aims to introduce comprehensive reforms. This study, which brings together a team of chemists and lawyers, seeks to understand the key reform options and the ways in which these interventions should be designed to ensure accountability and sustainability and avoid unintended consequences. Semi-structured interviews were carried out with twenty-six (26) stakeholders within the plastic packaging sector from leading government, industry and civil society bodies. A qualitative analysis was conducted of the interviews to identify common ground among stakeholders regarding reform options and to develop an understanding of the various issues regulators would need to consider when developing new regulations for plastic packaging. This qualitative component was interlinked to a regulatory analysis of both the broad trends in laws and policies for plastic packaging worldwide and Australia's existing regulatory responses to plastic packaging. Results show that stakeholders commonly agree on several regulatory interventions, but that each intervention brings a host of complexities within the current system that regulators will need to address to ensure success. This paper's findings are valuable for actors seeking to improve plastic packaging regulation within their own jurisdiction.

1. Introduction

Regulators around the world are grappling with how to reform the regulation of plastics, and especially plastic packaging, given the plastics pollution crisis and the ongoing United Nations (UN) negotiations for the *Global Instrument to End Plastic Pollution*. Recent research highlights the difficulties companies face when trying to make packaging more sustainable in situations where top-down support, including standards and infrastructure, are lacking (Turkcu and Tura, 2023). Australia has not significantly changed its regulation of plastic packaging for over 20 years (Bousgas and Johnson, 2023a). Australian regulators are now considering a multitude of ways to improve domestic regulation of plastics.

The current contribution provides timely insights into what regulatory reforms are required, and what complexities need to be dealt with, drawing on a legal and qualitative analysis of interviews with leading Australian regulatory, industry and civil society stakeholders. The results can inform responses to plastics production and consumption around the globe and contribute to debates around implementing a future UN treaty on plastics. Scholarship on plastic packaging regulation in Australia is new and limited, but has mostly focused on identifying problems with the current regime as opposed to in-depth examinations of solutions (Bousgas and Johnson, 2023a; Jones and Head, 2023; Kourabas and Nagtzaam, 2023; Schuyler et al., 2022; Macintosh et al., 2020; Gock et al., 2018). The current article is the first to present empirical findings and analysis on reform options in Australia for plastic

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packaging waste. Thus, it is the first study to examine stakeholder perceptions of Australia's regulation of plastic packaging and is especially timely given Australia is currently considering how to improve its regulation of plastic packaging, seeking to develop a range of interventions (DCCEEW, 2023). While the current paper focused on Australia, it uses the findings to provide broad advice regarding the design of plastic packaging regulation more generally regardless of the specific jurisdiction (Thompson et al., 2024). Beyond the Australian context, studies on multi-stakeholder perceptions regarding plastic waste law and policy specifically are highly limited, which is discussed further in section 2.1. In terms of scientific relevance, then, this study contributes to scholarly understandings regarding the role and design of plastics regulation, which is currently an under-investigated topic in legal and social scientific research on plastics.

The current study is also the outcome of a transdisciplinary collaboration between chemists and lawyers studying the potential of law reform and tracing technologies for improving plastics management. Thus, it is an illustration of how transdisciplinary research in this space can be conducted. Providing such an example is important given the widely acknowledged need for greater transdisciplinary research across social and natural scientific domains to combat complex environmental challenges (see, Werlen, 2015), and the limited amount of research, especially on plastics, that does overcome the natural and social science divide (Johnson et al., 2022).

This article begins with a brief overview of plastic packaging regulation both globally and specifically in Australia. It subsequently details the methodology applied in this research, including how the transdisciplinary team functioned to enhance the rigour of the qualitative approach. The paper then provides the results, which focus on the reform options commonly proposed by stakeholders and details about the kinds of regulatory approaches required for each option. The paper concludes by detailing the kind of regulatory strategy for plastic packaging required and highlights the need to create regulatory processes that anticipate unintended consequences and work with existing limitations, including globalised supply chains and traceability issues. While these findings are specific to Australia, they represent common issues and opportunities facing countries worldwide in the global effort to combat plastic pollution.

2. Background and literature review

2.1. Plastics regulation

The regulation of plastics takes place at international, regional and national levels. Policy responses to plastic pollution at all levels have been growing steadily (Del Savio, 2022). At the international level, plastics is partially regulated by the 1989 *Basel Convention on the Control of Transboundary Movements of Hazardous Waste,* which provides rules for exporting certain plastics, and the World Trade Organisation Agreements, which influence how a country regulates plastics and the international flow of plastics. The UN's proposed *Global Instrument to End Plastic Pollution* will be the first treaty to develop State obligations to improve the regulation and management of plastics across supply chains. The current negotiated text of the *Global Instrument to End Plastic Pollution* will require nation-States introduce or extend existing regulatory responses, including by eliminating or minimising certain chemicals used in plastic packaging, creating rules to reduce certain problematic and avoidable plastic, and developing mandatory design and performance standards.

At the national level, we summarise regulatory responses to plastics packaging pollution as generally centring on: design standards (including labels); bans or restrictions of microbeads; bans of some single-use plastics; littering and dumping fines; taxation especially regarding plastic packaging manufacturing; and various interventions to improve plastics recycling such as the introduction of recycling targets and recycling infrastructure funding (Diana et al., 2022; Nayanathara Thathsarani Pilapitiya and Ratnayake, 2024; United Nations Environment Programme, 2018 [UNEP]). While regulatory responses usually fall into these categories, they differ in various and significant ways including in terms of what chemicals and polymers or plastic items are targeted, available exemptions, whether the regulatory response is voluntary or mandatory, and the types of enforceability and compliance mechanisms used. Fig. 1 below summarises the key types of regulatory interventions we identified and the ways in which they differ.

Extended producer responsibility (EPR) schemes are an increasingly common type of regulatory response for particular types of plastics in some nations (Nicholas Institute for Energy, Environment, and Sustainability, 2024; Mozak, 2023). They are especially well-developed in the European Union (EU), where the approach originates and where different member countries have had EPR schemes since the 1990s (Leal Filho et al., 2019; Lindhqvist, 2000). EPR schemes aim to internalise waste management costs by requiring manufacturer responsibility for the entire life cycle of their products, including recycling and disposal phases (Organisation for Economic Co-operation and Development, 2024 [OECD]). These schemes are typically grounded in environmental protection principles such as polluter pays, product stewardship and a circular economy (OECD, 2024; Gachenga, 2022).

There are multiple legislative and policy interventions that can be categorised as an EPR scheme. Take-back schemes (where the producer takes the product back at end-of-life and manages its recycling or disposal), advance disposal fees (the producer pays a levy for managing the product's end-of-life) and deposit refund schemes (whereby a deposit is refunded when the product is returned for disposal) are the most common EPR frameworks (Kaffine and O'Reilly, 2015). Taxes on the virgin production of plastic could also be considered a type of EPR (OECD, 2001). Depending on the type of EPR, an organisation, referred to as a Producer Responsibility Organisation (PRO), may be established. A PRO will have a number of roles that vary significantly depending on the type of EPR scheme. For instance, a PRO may be in charge of setting and collecting fees attached to particular types of products depending on the fee structure, ensuring producers are meeting other obligations under the EPR scheme and providing education and training (Mayers, 2007).

Another way to understand EPR schemes is through the types of responsibilities they place on producers. Some EPR schemes will place purely financial responsibilities on producers. In this model, the producer only has to pay a levy but is not required to be physically involved in disposal (Kaffine and O'Reilly, 2015). Alternatively, an EPR scheme may impose partial or full operational/organisational responsibility on a producer (which may then be carried out by the PRO) meaning that the producer (or the PRO on behalf of producers) has a role in collecting, recycling or otherwise disposing of the waste (UNEP, 2017). This may involve the producer or PRO reaching contracts with local governments involved in waste management through to a situation where the producer or (more commonly) the PRO contracts with waste management businesses (or administers their own entity) to collect, recycle and dispose of the waste. Within one country and for one type of waste, there may be multiple PROs or one single PRO depending on the design of the scheme (Leal Filho et al., 2019).

Countries with established waste and recycling laws which include plastic EPR regulatory schemes generally have higher recycling rates (Tumu et al., 2023; Lorang et al., 2022). Yet, widespread adoption of EPR schemes across various types of plastic applications has not yet eventuated (UNEP, 2023), and the success of EPR schemes in terms of increased recycling rates varies significantly depending on the country and the scheme (da Cruz et al., 2014). For instance, studies indicate that schemes administered by a single PRO tend to perform better (Colelli et al., 2022), moreover schemes where the PRO has some organisational/operational responsibilities on behalf of the producer tend to perform better (Mallick et al., 2024, pp. 7–8). Additionally, EPR schemes are commonly limited in their effectiveness due to, for instance, local recycling capacity and lack of quality data and monitoring (Ezeudu,

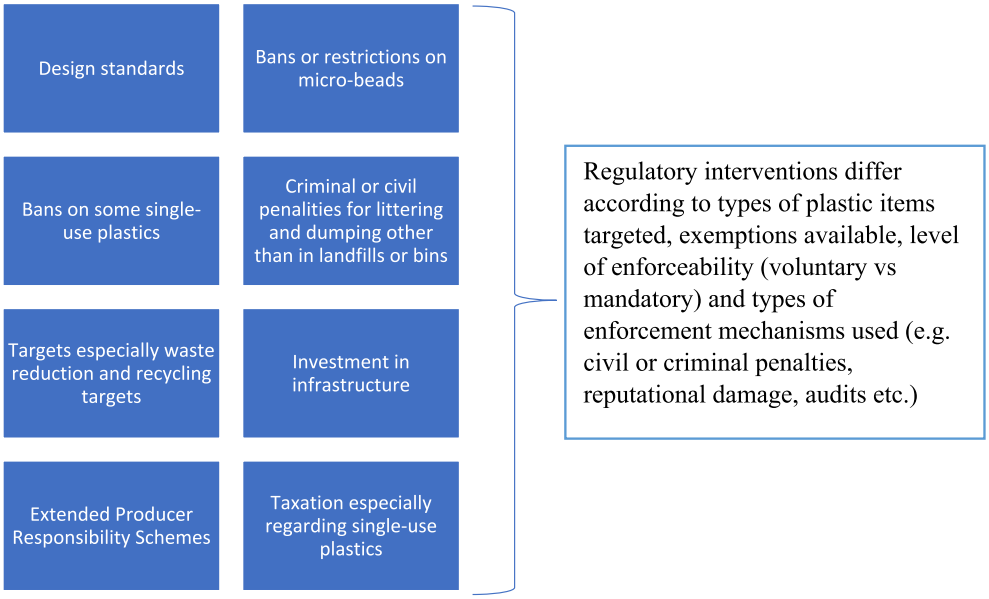

Fig. 1. Summary of common types of regulatory interventions into plastic packaging and key points of difference in their design.

2024; Leal Filho et al., 2019). There are also broader issues that EPR cannot address including that plastics cannot be recycled indefinitely, and it does not directly incentivise redesign and reduction (Vogt et al., 2021). Despite the regulatory action on plastics among nations, plastic pollution continues to increase and be a leading environmental and public health challenge (Ritchie et al., 2023) as well as becoming a lucrative form of transnational organised crime (Interpol, 2020). This indicates that regulatory approaches to date have not significantly addressed the issue and further regulatory, alongside technological and social, advancements are required. Thus, the focus of the current study on optimal regulatory interventions for plastics is timely and important.

Scholarship focused on stakeholder perceptions regarding plastics regulation has tended to focus on: (a) industry accounts of their supply chain practices (as opposed to specifically their perceptions of law and policy so at times regulation is addressed but not necessarily) (b) particular types of plastics (e.g. biodegradable plastics or application specific contexts) or (c) specific types of regulatory interventions (e.g. single-use plastic) (Cowan et al., 2021; Kakadellis et al., 2021; Steinhorst and Beyerl, 2021; Suphasomboon and Vassanadumrongdee, 2023). There is a need for research that specifically investigates multi-stakeholder perceptions of plastic packaging regulation as a whole. Such research is especially appropriate given the UN's *Global Instrument to End Plastic Pollution,* which will create broad obligations on states to create regulation that addresses plastics across the supply chain using a mix of regulatory approaches. Herein, we seeks to address this gap by investigating multi-stakeholder perceptions of plastics regulation across a range of measures and types of plastics. The study's focus on stakeholder perceptions of plastic regulation contributes to developing a more comprehensive understanding of the range of regulatory interventions required and how they should be designed. Accordingly, this forms the major contribution of the article to plastics regulation and governance scholarship.

More generally, this research contributes to regulatory studies, which is a broad area of research within socio-legal studies that examines the nature of regulation and how to design regulation (Black, 2001; Levi-Faur, 2005; Parker, 2002). Regulation can be broadly defined as prescriptive rules and the monitoring and enforcement of those rules by various actors, but it may also include any form of intervention designed to influence the behaviour of actors within a system (Koop and Lodge, 2017). As such law or rules and principles and the legal system as a whole is seen as part of a broader range of regulatory interventions available to the state when considering how to respond to market failures. Within this area of work, particular emphasis has been placed on developing broad principles for regulatory design in order to advance the effectiveness of regulatory systems. A key theory in relation to this is 'smart mixes' of regulatory instruments, that is, the need for multiple regulatory interventions that simultaneously work together to achieve particular outcomes (Gunningham et al., 1998; Gunningham and Sinclair, 1999b). Another prominent concept is 'responsive regulation', which conceptualises when and how to escalate regulatory interventions over time in response to regulatory failure such as where plastic packaging pollution does not reduce (Ayres and Braithwaite, 1992). Despite the centrality of regulatory studies to law and social science research, studies focused on plastics that draw links with key concepts within regulatory studies are limited, and this stems from more broadly a lack of law and social scientific work on plastics law and policy compared to issues such as climate change (cf Bousgas and Johnson, 2023b). The findings from this paper ultimately shows how concepts such as responsive regulation and smart mixes of regulation are relevant to the context of plastics. In particular, it identifies and evaluates what stakeholders view as the optimal combination of regulatory strategies, and design of each strategy, to improve the sustainability of plastics. Thus, it contributes to extending regulatory scholarship into the new domain of plastics regulation using empirically grounded analysis.

2.2. *Australia's regulation of plastics*

Australia is a federation, so the regulation of plastic packaging occurs at varying levels. Generally, local governments are responsible for waste management operations, while state and territory governments develop waste management legislation and policies. The Federal government coordinates national responses and will have the primary responsibility for implementing Australia's obligations under the *Global Instrument to End Plastic Pollution*.

Australia's regulation of plastic packaging has been significantly critiqued by governments, industry, civil society and academia (Anderson and Gbor, 2024; Jones and Head, 2023; Nagtzaam and Kourabas, 2021; WWF Australia, 2023). An Independent Review of Australia's regulatory approach in 2021 concluded that significant reforms were required (MP Consulting, 2021). Meanwhile, a recent report for South Australia's Environmental Protection Agency summarised the issue with Australia's plastic packaging regulation as: 'Governments

have also been quite reluctant to regulate, and when they have its been inefficient and patchy, city by city or state by state. That mindset is changing, it would seem, but again appears to be too slow' (Levitzke, 2023, p. 24).

While initiative for plastics regulatory intervention has been slow, growth in consumption and market availability of plastic packaging has been significant (Anderson and Gbor, 2024; Australian Packaging Covenant Organisation, 2024 [APCO]; Charles and Kimman, 2023; Department of Climate Change, Energy, the Environment and Water, 2021 [DCCEEW]). Over the decade since 2000, plastic consumption has grown 60 % per capita in Australia (Anderson and Gbor, 2024). One million tonnes of Australia's annual plastic consumption is single-use plastic (DCCEEW, 2021). Only 13 % of plastic is recycled in Australia (DCCEEW, 2021), comparative to the United States (U.S. Plastics Pact, 2021, p. 7), but in contrast to the average 39.7 % recycling rate for plastic packaging of EU member states (Eurostat, 2023).

Australia's main regulatory response to plastic packaging, besides the introduction of kerbside recycling, was the creation of a co-regulatory framework comprised of the *Australian Packaging Covenant* and the *National Environmental Protection (Used Packaging Materials) Measure 2011* (Cth) (NEPM). The regime applies to any business actor, referred to as a 'brand owner', who consumes plastic packaging and has an annual turnover of AUD 5 million. A brand owner has the option of agreeing to comply with the Australian Packaging Covenant or otherwise being regulated under NEPM. Under the latter, brand owners must collect and process a certain amount of waste and there are fines for non-compliance. Under the former, brand owners must submit various kinds of reports and plans to the Australian Packaging Covenant Organisation (APCO).

The co-regulatory framework was designed to incentivise brand owners to sign up to the voluntary Australian Packaging Covenant to avoid more binding regulation by NEPM. However, a review found that key elements of NEPM 'have not been implemented or have not been operationalised effectively' (MP Consulting, 2021, p. 4). The Australian Packaging Covenant also has various weaknesses that have undermined its performance. These include: vague requirements; loopholes; lack of enforceability mechanisms; and too much discretion for brand owners to meet their obligations without significantly altering plastic use (Bousgas and Johnson, 2023a; MP Consulting, 2021; White et al., 2004). In sum, the co-regulatory regime has been the main regulatory response to plastic packaging from 1999 until present and has failed to improve plastic packaging recycling significantly or prevent growing levels of consumption and waste (Anderson and Gbor, 2024).

Australian states and territories have introduced bans on particular single-use plastics and administered container deposit schemes; while important, these schemes are inconsistent across Australia and are not necessarily successful at reducing overall plastic packaging waste (see Bering and Karasik, 2022). Despite these efforts from states and territories to address plastic pollution, Australia has a large regulatory gap regarding plastic packaging that the Federal Government has been trying to respond to in recent years. In particular, the Federal Government introduced a *National Plastics Plan* in 2021, which sets out a range of aspirational goals primarily focused on consumer information and recycling. It also introduced a ban on unsorted and raw material plastic waste exports (*Recycling and Waste Reduction Act 2020* (Cth) s 18). This ban was introduced following public accounts of plastic waste from Australia (and other high-income countries) ending up in south-east Asian countries without capacity to safely manage the waste (Zhou, 2019). However, fears that the export bans would result in more plastics ending up in landfill in Australia (Caceres Ruiz and Zaman, 2022) appear to be realised. The introduction of measures such as the Recycling Modernisation Fund (RMF), designed to expand Australia's capacity to recycle waste onshore, have not yet had an impact on recycling capacity (APCO, 2023; Evans, 2023).

More recently, the Federal Government has announced its intention to create mandatory laws regarding Australian packaging (DCCEEW, 2023). However, the form and design of these laws is still being developed by regulators, though they likely will include mandatory design requirements. This research will contribute to this regulatory development by advancing understanding of key stakeholder perspectives of reform options and related implications. The findings from this research can inform growing scholarship on plastic waste regulation, and also provide practical insights for regulators in Australia and globally regarding important considerations for plastic packaging regulation.

3. Research methods

3.1. Semi-structured interviews

The key question of our approach is: 'What are the perspectives of stakeholders regarding how to reform plastic packaging regulation in Australia?' Semi-structured interviews were chosen to answer this question because qualitative stakeholder research can provide richer and more novel insights than what might otherwise be observed in official policy discourse (Yanow, 2006). The interview question schedule was initially developed by reviewing academic, industry and policy literature, and consulting with both regulatory and chemistry experts in the research team. It was adapted over the course of the interviews, as is common in semi-structured data collection (Denscombe, 2014), thus affording flexibility for participants to express their perspectives and for researchers to respond to emergent topics. Table 1 provides a sample of the general interview protocol developed. The recruitment of participants, interviews, data analysis and management were all managed in accordance with ethics approval requirements

Table 1
Sample of interview questions.

Question Number	Question text	Purpose
1	What are the key issues which come to mind about the current state of plastic packaging and waste management in Australia?	Understanding of plastic packaging issues and related waste management in order to gauge what might be left out of, or what is important for, specific legal and policy interventions
2	What do you think about the current state of governance and regulation related to plastics?	Identifying weaknesses in the current approach to support the prior regulatory analysis and enable identification of opportunities
3	Who is responsible for plastic waste and how is that responsibility determined and enforced (or not enforced)?	Uncovering perceptions regarding government, industry, consumer and civil society responsibility that may shape regulatory responses
4	In your opinion, what should be some key features of Australia's regulatory response to plastic and plastic packaging?	Investigating the key interventions or levers supported by stakeholder and the specific ways in which these interventions should be designed according to the context highlighted and the perspectives engaged with
5	From your perspective, what does an ideal EPR scheme look like?	Identifying the aspects of an EPR scheme that stakeholders perceive as necessary for an effective EPR
6	What do you think about eco-claims on plastic products such as that the products use "ocean bound plastic", are "recyclable" or "biodegradable"? Should these be regulated and if so how?	Investigating the extent to which stakeholders understood environmental claims to be part of the regulation of plastic packaging and how regulators should response
7	What role do you think traceability has in the future of the plastics sector? Do you view it as an obstacle or an opportunity?	Understanding the impact of limited plastics traceability on regulatory systems

(Approval number 2023–7267-15,702). Note that all participants have been de-identified and allocated a number.

3.2. Overview of research participants

We sought participants from government, regulatory and advisory bodies, industry, and civil society that had (a) current roles focused on plastic packaging and (b) generally at least a decade in roles related to plastic packaging. A combination of purposive and snowball sampling in relevant networks were utilised, resulting in a total of 26 interviewees from the intended range of stakeholder groups. Table 2 provides a list of interview participants by group and identifying code. Categorising interviewees per stakeholder group was useful for data analysis and reporting because potential professional background bias could be accounted for and more transparent in results. All participants had led relevant programmes within their organisation, and most (except for four) were in organisational-level leadership positions. We note that in some ways identifying each participant as aligned with one stakeholder groups is reductive, as there was often a lot of richness in their experience across various groups. We also identified civil society as encompassing industry groups.

3.3. Interview process

All interviews were completed and recorded online via Zoom from January 2024 to March 2024 and were transcribed using Otter.ai, then reviewed and edited by the research team. Each interview was up to approximately 60 min in length, and the transcripts totalled 197,000 words. All interviews were conducted by at least one member of the law research team, with most interviews (19) attended by at least two researchers from this team, and 11 interviews attended by a chemistry research team member. Following each interview, the researchers would debrief, enabling a transdisciplinary dialogue and helping develop observations and ideas for data analysis and subsequent interviews (Leavy, 2011). These follow-up deliberations were important for enabling information-sharing among the disciplines to reach a common understanding and deepen analysis.

Table 2
Interview Participants.

Participant Identifier Code	Stakeholder Group
1	Civil society, Regulatory (former)
2	Civil society
3	Civil society, Regulatory (former)
4	Civil society
5	Industry
6	Industry
7	Civil society
8	Civil society, Industry (former)
9	Industry
10	Industry
11	Industry
12	Industry
13	Civil society, Regulatory (former) & Industry (former)
14	Industry
15	Industry
16	Industry
17	Regulatory
18	Industry
19	Industry
20	Civil society
21	Regulatory
22	Civil society
23	Civil society
24	Civil society
25	Industry
26	Regulatory

3.4. Data analysis

A grounded theory approach to data analysis was suited to the study because of the lack of existing studies on stakeholder perceptions regarding plastics law and policy especially in Australia. The approach is characterised by systematically and comparatively analysing patterns in observational data to derive theories about novel phenomena (Babbie, 2021). NVivo software was used for data coding and analysis. Analysis began with descriptive coding of common ideas and issues and axial coding, as codes began to be arranged by preliminary associations and subsumed into broader codes where appropriate, consistent with a grounded theory approach to handling qualitative data (Babbie, 2021). Chemistry team members provided feedback to the regulation academics on code development, informing the analytical approach. Transdisciplinary feedback cycles helped build intersubjectivity, improving the validity of data (Leavy, 2011). The process resulted in a list of 17 parent codes which were arranged around themes by the research team. While various themes emerged in this exploratory research, the current paper focuses on those themes related to regulatory reform options and issues.

The vulnerability for bias in researcher-participant qualitative research demands care and consideration of reliability and validity to ensure rigour in data analysis. This research was guided by widely recognised strategies for verification in qualitative analysis (Morse et al., 2002). This involved methodological coherence in research design practices, appropriate participant sampling from experienced stakeholders, iterative data collection and analysis, and thinking theoretically and reflexively about results (Morse et al., 2002). Fig. 2 below broadly summarises the research process.

4. Results

4.1. The problem is not plastic and the solution is not recycling

Interviewees commonly critiqued the political and regulatory focus on plastics as a problem material; that is, they were critical of the problem being framed as plastics itself rather than as (certain) material use. Interviewee 16, a senior recycling industry body representative, explained, 'I think that we need to stop being myopic about plastic. The fact is that once we start to ban certain formats, we can bring in others that have as much of a negative environmental impact, and probably less circular opportunities.' As part of this, participants across stakeholder groups emphasised the benefits of plastics (e.g. interviewees 1, 3, 11, 15, 17, 21, 26), and identified how bans on certain single-use plastics tended to have unintended consequences, namely they tended to lead to situations where consumption shifted to other plastics or materials that also posed disposal complications. This observation by interviewees also aligns with other studies on the impacts of plastic bag bans (e.g. Macintosh et al., 2020). These critiques also commonly highlighted the importance of a comprehensive analysis of alternative materials and their related environmental impacts before introducing bans.

Most commonly, however, interviewees identified excessive production and consumption of plastic as the problem, and the solution that followed from this understanding was the need to reduce plastic production and consumption when doing so was possible without causing adverse impacts to public health (e.g. interviewees 1, 4, 7, 11, 12, 13, 15, 17, 20, 21, 23). As part of this, they highlighted that Australia is unable to recycle most plastic being produced and consumed. Plastics recycling in Australia is affected by factors including limitations in collection and processing systems, sortability, technical recyclability and availability of end markets for recovered material. Only 42 % of plastic packaging in Australia is classified as having good recycling potential (APCO, 2024, p. 8). The emphasis by interviewees on reducing plastics first and foremost (and then turning to recycling) aligns with a broader shift in public discourse, supported by research, that has moved away from emphasising recycling as a solution towards prioritising material reduction

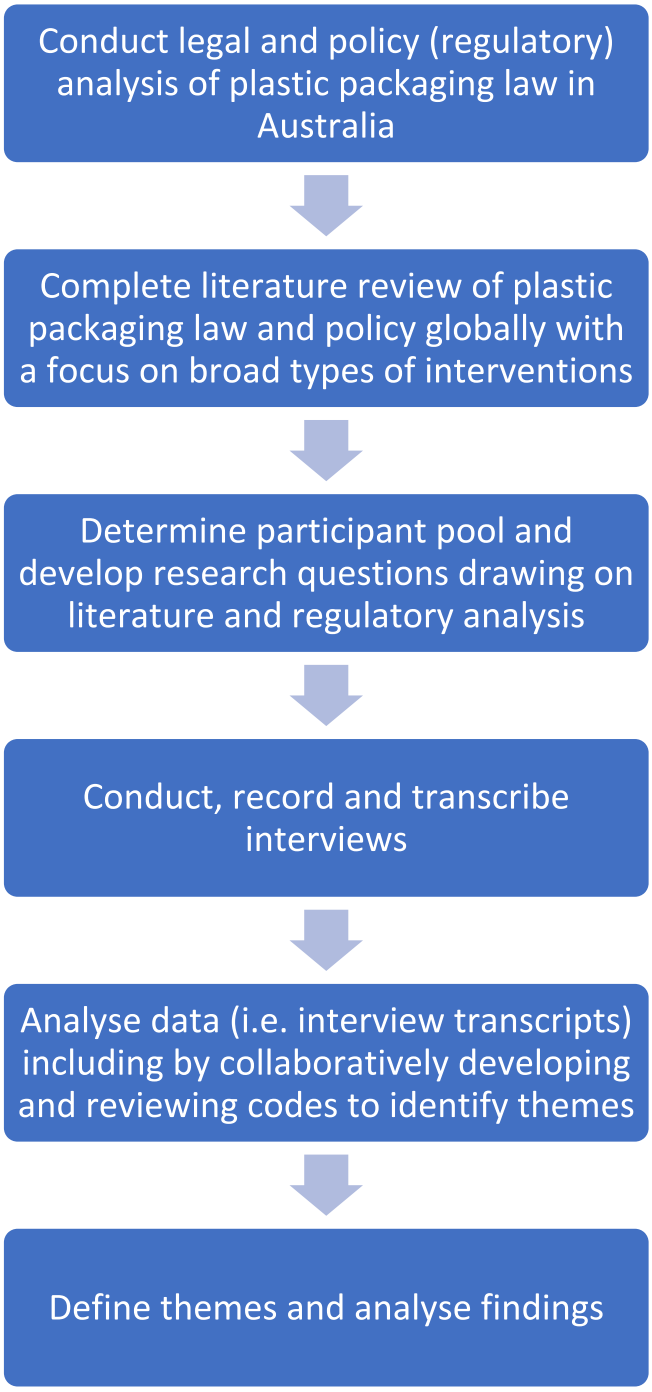

Fig. 2. Flowchart of broad research process.

(Noor, 2024).

4.2. Develop an extended producer responsibility (EPR) scheme

A wide range of interviewees agreed that Australia should introduce an EPR scheme for plastics (e.g. interviewees 1, 2, 7, 13, 15, 19, 20, 21, 24, 25, 26). An EPR scheme was seen as particularly important for creating a level playing field for industry, as all businesses must take steps to reduce plastic pollution rather than a few companies voluntarily taking action and bearing the costs (e.g. interviewees 2, 4, 7, 11, 13, 15, 22). Interviewees tended to assume an EPR scheme based around predominantly financial as opposed to operational responsibility for producers whereby the producer would mostly be responsible for paying a levy. From this common viewpoint, interviewees focused on identifying a number of significant questions and difficulties for implementing an EPR scheme that regulators would need to resolve.

Partly, interviewees focused on who would be classified as the polluter that would bear the costs set by the EPR scheme, and what the mix of penalties and incentives should be. Most interviewees considered the brand owner as the polluter, which was interpreted as the company putting the packaged product onto the market.

Some interviewees emphasised the need for an EPR scheme to also apply to the original manufacturer of the plastic used in the packaging (e.g. interviewees 18, 24, 25). With a mix of imported and locally-made plastic in Australia, this would raise jurisdictional issues and possibly require a global EPR scheme as well as regulations in the home jurisdictions of resin producers. Relatedly, others saw an EPR scheme as something that should apply to each actor in a supply chain to varying degrees. Interviewee 17, a leader in the packaging regulatory and not-for-profit space, put this as, 'bringing every person who touches the thing into the program, so that they have a responsibility to keep the chain going.'

Four key features for an Australian plastic packaging EPR scheme were emphasised by interviewees. The first is that there should be a producer responsibility organisation (PRO) in charge of administering multiple programs, such as different levies and requirements, based on the type of packaging in the EPR scheme (e.g. interviewees 13, 17). The second is that additional support should be in place for small and medium-sized enterprises (SMEs) that lack the same capacity to carry the costs and comply with increased requirements such as data collection (e.g. interviewees 13, 14, 22).

The third feature emphasised by interviewees, particularly from the civil society perspective, is the need for trust in the scheme, with the PRO to be independent from industry and possibly also government (e.g. interviewees 2, 24). While some saw the PRO as having a dual role of administering the EPR and capacity-building for industry, others emphasised that it was important that these two roles be separated into two entities (e.g. interviewees 2, 5). A senior packaging industry manager, interviewee 5, explained:

'So you've got an entity whose objective is to administer the EPR scheme…But their objective is not to work with or provide technical support to the industry…their job is essentially to collect the money, and in my view, to report on the headline figures…And then what sits underneath that is that non-legislative activity, where you might, for example, have…an institution that has the practical skills that will help industry'.

Many interviewees with industry experience identified APCO, the co-regulatory entity responsible for managing and administering the Covenant (described in section 2.2), as the logical choice for the PRO (e.g. interviewees 5, 11, 12, 13, 15). This suggestion raises questions about how industry conceptualise independence, that is, independence from government only, or from government and industry. While APCO has extensive experience and expertise regarding plastic packaging, it currently works closely with industry, and has industry members on its board, so its independence to administer such a scheme may be questioned. This kind of co-regulatory model, coloured by overly cooperative relationships and reliance on industry for technical expertise, can risk vulnerability to capture and erosion of independence (Ayres and Braithwaite, 1992; Drahos and Krygier, 2017; Goodfellow, 2016). For independence from both government and industry, it may be better achieved by creating an independent PRO while ensuring APCO maintains its role in capacity-building. However, this was not something teased out by stakeholders.

Finally, a range of interviewees emphasised that the EPR scheme should have a mix of incentives and penalties (e.g. interviewees 1, 13, 15, 17, 23), and as part of this civil society and regulatory actors focused on eco-modulation (e.g. interviewees 1, 7, 13, 21). Eco-modulation refers to an EPR scheme that modulates its fees based on measurable product characteristics, such as recyclability, implying that companies

are financially incentivised to redesign their products to have lower end-of-life environmental costs, and those who do not pay more fees (Lifset et al., 2023).

In practice, there are a number of complexities with eco-modulation that would need to be grappled with by Australian regulators. These include that the characteristics focused on for eco-modulation (e.g. recyclability, durability and recycled content) do not necessarily translate to less total environmental impact once a lifecycle assessment is conducted (Vendries et al., 2020). Relatedly, a range of interviewees stressed the need for the EPR to take a full lifecycle approach to cost assessment (e.g. interviewees 2, 13, 15, 17, 19, 21, 23). Interviewee 2, managing director of a NGO, explained, 'So if we just dial up the recycling piece, does that fix that core problem? No, it doesn't. You've got to influence that whole lifecycle of the product.' The complexity of measuring environmental impacts, and unintended consequences of changing design features, also means that the outcomes of eco-modulation may be difficult to foresee and even identify as they occur. There are additional difficulties with eco-modulation that would need to be worked out (e.g. Lifset et al., 2023), which include reporting and data complexities. Interviewee 13, who has experience across civil society, regulatory, and industry activities, emphasised these as well: 'it should also be eco-modulated, based on either type of plastic as a proxy, or more specific, based on recyclability and or recycling. So that means all those data points need to be verified. Industry will need a lot of support to get those systems in place for high quality data.'

4.3. Introduce mandatory design requirements

Interviewees from civil society and regulatory backgrounds commonly supported the introduction of mandatory design standards in Australia (e.g. interviewees 4, 7, 8, 13, 17, 20, 23, 26), with most in favour seeing this as the starting point for change by regulators. Interviewee 18, an industry figure in favour of mandatory design requirements, explained their position as: 'It's the only way companies move. You know, I'm the last person philosophically that would be interested in legislative levers…However, what I've learned in 30 years in this space, that the brands are absolute experts, they pay people whose sole job it is to avoid change.' The key dimensions for new design requirements identified were: mandatory requirements to reduce packaging; requirements to simplify packaging; and design for recyclability.

Mandatory requirements for less packaging may focus on, for instance, prescribed maximum empty space in containers or maximum layers of packaging (e.g. interviewees 13, 23). Mandatory requirements for simplified packaging should, according to interviewees from all stakeholder groups, focus on removing dyes, additives and multi-polymer packaging (e.g. interviewees 3, 4, 7, 8, 18, 20, 24, 25). A civil society actor (interviewee 24) explained, 'I think simplification would just be such a great place [to start]'. So whether it's embossing your brand logo on plastic, rather than using dyes, or changing the shape of the product so it's easier to clean so you don't have contamination.' Interviewees further emphasised the need to mandate designing for recycling by simplifying polymers in the Australian supply chains and removing multi-layered materials that are not compatible with recycling (e.g. interviewees 5, 24).

Interviewees also highlighted concerns around introducing uniform design requirements, raising questions regarding whether some design requirements should only apply to certain items/formats, sectors or applications, with exceptions for some e.g. hazardous material packaging or pharmaceutical packaging. As in many other jurisdictions, Australia has specific requirements regarding packaging that touches food, shaping the imposed the design requirements. Interviewees often did not indicate which approach would be preferable, however, some focused on a polymer-by-polymer approach (e.g. interviewees 5, 24). Much of the focus was on avoiding unintended consequences. For example, interviewee 15 from industry explained, '…you don't want to solve one problem and create a much bigger problem with food waste.' Interviewees often did not focus on aligning design requirements with local recycling capabilities directly, but this would be an important dimension to developing design requirements as only some types of plastics are recyclable in Australia as in other jurisdictions.

4.4. Introduce mandatory recycled content requirements

Interviewees widely supported the introduction of a minimum mandatory recycled content requirement for plastic packaging provided it was phased in over time to allow for technological and industry change (e.g. interviewees 1, 2, 3, 7, 8, 9, 10, 11, 12, 13, 16, 17, 18, 19, 26). However, they identified qualifications and issues to overcome in setting such a requirement. While some industry-experience interviewees strongly advocated that the recycled plastic must come from Australia (e.g. interviewees 16, 19), others pointed out that currently Australia does not have enough recyclate to meet a minimum standard (though presumably it could in the future) (e.g. interviewees 5, 8, 11, 13, 15). Interviewee 13 explained, 'We don't have sufficient supply. Even if we suddenly mandated food contact packaging had to have recycled content, there wouldn't be enough material available.' A middle-ground does exist whereby a minimum mandatory recycled content requirement could prioritise Australian recyclate but allow for imported recyclate where Australian recyclate is not available. This approach could be reviewed as Australia's recycling infrastructure and plastic consumption developed over time.

Many interviewees focused on how the cost of recycled plastic was far higher than virgin plastic, with the likelihood that the increase in production costs to meet a minimum recycled content requirement would be passed onto consumers. Interviewee 4 from the civil society stakeholder group explained, 'The focus has really got to be on how do we correct those cost externalities that the virgin producers are currently enjoying?' In other words, unless the low cost of virgin plastic is addressed, for example through a tax, it is difficult to impose a mandatory recycled content requirement that does not end up being politically unpopular. The negotiators of the *Revised draft text of the international legally binding instrument on plastic pollution* (2024) are grappling with obligations on countries regarding primary production of polymers, and the result of these international negotiations will be influential on the price of virgin plastics. The draft Article 1 contains a number of options including: (a) a specific reduction target for each country contained in the treaty or (b) countries identify their own plans to limit production of virgin plastic.

Rather than set a mandate to have a certain amount of recycled content, another option for Australia to incentivise the use of recycled plastics is to set a tax on plastic packaging that does not contain a certain amount of recycled content. This approach was taken in the United Kingdom (UK). The UK introduced the Plastic Packaging Tax in 2022 (*Finance Act*, 2021 (UK) part 2; *The Plastic Packaging Tax (General) Regulations 2022* (UK)), which applies to companies that have manufactured or imported 10 or more tonnes of finished plastic packaging in 12 months and where the plastic packaging contained less than 30 % recycled plastics. In 2024, the tax was £217.85 ($US 173.87) per tonne (HM Revenue and Customs, 2024). Interviewees from various groups suggested that the UK approach has not worked due to the tax being too low and recyclate lacking availability (e.g. interviewees 3, 15, 21). An industry actor (interviewee 15) explained, '…the recycled content that was available became so expensive, because of the demand, it was cheaper to just pay the tax.' This aligns with lobbying by Veolia, a waste management facility in the UK, which has been advocating for an increase in the tax (Veolia, 2024).

Interviewees also pointed out that a mandatory recycled content requirement may not work for certain applications or formats, such as food-grade and pharmaceutical packaging (e.g. interviewees 6, 11, 13, 17, 18, 21, 23, 26). Interviewee 21, a regulatory stakeholder, explained, 'There are really legitimate concerns from food manufacturers, or people who produce medicines and things, who say…we cannot accept

anything of a lower quality than what we're currently getting from virgin materials.'

As part of the solution to this, and in general to improve recycling rates especially for soft plastics, some interviewees with industry and academic expertise highlighted that developing chemical recycling (or advanced recycling) is an essential component of the solution to the plastic packaging problem (e.g. interviewees 12, 15, 22, 25). Perspectives among interviewees were divided, however, with some cautious about the viability of chemical recycling. For instance, interviewee 19 (an industry figure) explained, 'Chemical recycling has an important role to play in order to deal with things that cannot be mechanically recycled…. But it has to be clearly understood that chemical recycling comes at a higher cost and higher carbon emissions, significantly higher than mechanical recycling.'

These differing perspectives align with the broader global debate about chemical recycling, and as chemical recycling is only in its infancy, much of the discussion is unsettled (Quicker et al., 2022). Either way, regulators cannot rely on future and potential technological capabilities to determine plastics regulation now, especially given the time required to scale up such infrastructure, and given that the safety and environmental benefits are already questionable. Regardless, Australian governments have been contributing to the funding of chemical recycling facilities (Plibersek, 2023).

Traceability was a key focus of interviewees from industry and civil society in relation to a mandate on recycled content (e.g. interviewees 1, 5, 7, 9, 13, 15, 16, 19, 24). A senior industry stakeholder (interviewee 19) explained, 'Traceability for recycled content has to go hand-in-hand with a requirement to use recycled content.' In 2023, the Federal Government introduced a National Framework for Recycled Content Traceability, which comprises voluntary guidelines for businesses on how to collect and share information about recycled materials. However, voluntary approaches arguably will not be sufficient to support a mandate on recycled content, as there would have to be compulsory verification systems in place to prove compliance (given non-compliance would incur penalties). Regardless, the broad approach detailed in the guidelines would be a starting point for a regulated traceability system.

4.5. Responding to greenwashing

Interviewees from all stakeholder groups commonly agreed that greenwashing required a regulatory response (e.g. interviewees 7, 8, 12, 14, 15, 17, 18, 19, 20, 21, 22, 24). Greenwashing refers to marketing claims (either text or image-based or a combination) that are either demonstrably false, vague and open to misinterpretation, half-truths that leave out critical information, or a combination of these (Pabon, 2023; Kangun et al., 1991). Regulating these kinds of marketing claims has become a focus for regulators both in Australia and globally (UN, 2024; Australian Competition and Consumer Commission, 2023).

Interviewees identified greenwashing concerns regarding 'bioplastics' or 'plant-based' plastics, 'compostable plastics', 'biodegradable plastics' and 'ocean-bound plastics'. In relation to 'plant-based' or bioplastics and 'biodegradable' plastics, the issue is that consumers may think this means the plastic is better for the environment when that is not necessarily the case, or at least there are environmental costs that are not highlighted in such claims (Goel et al., 2021). For 'compostable' plastic, the issue is that most plastic packaging only breaks down in industrial composting facilities, not in home composting systems, and so in Australia this means that most compostable products end up in landfill, where they will not compost. Only around 0.3 % of plastic consumed annually in Australia is composted (Anderson and Gbor, 2024, p. 16). Similar issues exist for biodegradability, whereby certain environmental conditions are required to ensure degradation (Shen et al., 2020).

Interviewees identified a range of regulatory responses including introducing mandatory standards (including agreed terms), requiring independent certification by credible schemes and providing better education to consumers (e.g. interviewees 7, 12, 13, 14, 17, 18, 19, 21, 24). Other countries also provide useful examples of how Australia could regulate in this space. For instance, the EU recently prohibited the use of generic environmental claims on products, including 'biodegradable' and 'biobased' (*Directive 2024/825*).

4.6. Regulatory challenges: Global supply chains and traceability

A wide spectrum of interviewees saw the fact that Australia, like all other countries, operates in a global plastics market, as a key limitation on Australian regulatory responses (e.g. interviewees 1, 3, 4, 5, 6, 11, 15, 16, 19, 21, 24, 26). Of the 1.28 million tonnes of plastic packaging put on the Australia market in 2021–22, about 40.8 % was locally manufactured from overseas resin, 29.2 % arrived as empty packaging from overseas, 8.2 % was imported filled packaging, and only 21.8 % was locally manufactured from local materials (APCO, 2024, p. 87).

The globalised nature of the plastics supply chain was positioned as a problem in part because it meant that a tax on virgin plastic resin pellets introduced by Australia would be limited in its reach. Interviewee 26 from a co-regulator viewpoint explained, 'You've got the Australian context, and then you've got the international context. So if it's Australian made, that could be quite easy. But if it's globally sourced, then who are we going to chase? And who's responsible for that? …Who do you send the bill to?'

Industry actors identified that the globalised structure of the plastics market was a key barrier to the effectiveness of Australian plastic packaging regulation because of Australia's inability to control the standards of plastics coming in and the capacity to trace and verify their composition (e.g. interviewees 11, 12, 15). Interviewee 24 from civil society similarly explained, '[Y]ou don't control what packaging comes in unless you put in hard regulations'. Such restrictions, we should note, may or may not be compliant with trade agreements and could be susceptible to WTO challenges. Interviewee 15 (industry) also observed:

'So you've got a huge chunk of packaged goods coming into the country from sources you're never going to regulate, to be honest, to any great extent - it's going to be extremely difficult… You're still going to get a really big mix of sources of materials moving into recycling facilities, so you're not going to want to discard half of what's going in there because it hasn't got a traceability technology associated with it.'

This issue highlights the criticality of effective international responses to plastic packaging, which ideally the proposed treaty for plastics pollution will advance (see also, Raubenheimer and Urho, 2020 who propose a global EPR scheme). It also underscores the significance of how countries that host large plastic (namely resin) manufacturers regulate the sector and the importance of having traceability systems for plastics (as part of e.g. EPR schemes and design standards enforcement) that are capable of gathering information globally. Interviewee 12 from industry explained, 'Systems have to be interoperable, and be able to share information with one another. That is absolutely critical.'

5. Discussion

This research engaged with interviewees from a cross-section of stakeholder groups, and each interviewee has their own interests and values that shape their responses. For instance, generally, we might expect to see industry stakeholders less supportive of regulation, especially mandatory regulation, given the potential economic costs. Likewise, we interviewed regulatory actors involved in regulating plastics, and we might expect these groups to view existing approaches as sufficient or have a bias towards more regulation or specific kinds of interventions. Ultimately, we found strong agreement among stakeholders, regardless of their affiliations, that Australia's regulation of plastic packaging needed significant reforms. This is consistent with responsive regulation, a concept within regulatory studies, which suggests that once less interventionist measures are shown to not be

working, in this case Australia's co-regulatory approach to plastics regulation, than government intervention should escalate (Ayres and Braithwaite, 1992).

Moreover, stakeholders commonly agreed on the types of interventions required. Specifically, most stakeholders generally agreed that Australia should introduce a mandatory recycled content requirement, introduce other design requirements across the areas identified, develop an EPR scheme for plastic packaging and respond to greenwashing. While sometimes a stakeholder did suggest a measure that was not discussed in-depth by other stakeholders (e.g. tax resin production), commonly stakeholders focused on the same kinds of interventions. The implication for policy and regulation here is that there is potential for common ground among stakeholders about what kinds of interventions are required, which should make it more politically palatable to bring in new regulations. It also suggests that there is support for a 'smart regulation' approach whereby a mix of regulatory interventions are developed to work together simultaneously as opposed to one regime (Gunningham and Sinclair, 1999a). Table 3 summarises some of the key interventions identified and issues or features regarding these interventions.

While this is the outcome from our study, interviewees may change their views depending on the context and their interests, and so it is possible that stronger differences will emerge among the stakeholder groups once regulatory proposals progress. Interviews may also be viewed by research participants as opportunities to perform an idealised image of their industry, particularly where there is significant public and political pressure to operate more sustainably (as is the case for the plastic industry). This can produce research capturing an unrealistically optimistic portrayal of an industry's willingness and urgency to act.

The regulatory interventions favoured by stakeholders illustrate an emphasis on the in-puts used, product design and recycling capacity and technologies, as opposed to an emphasis on plastic pollution (e.g. addressing littering and pollution once it exists) and plastic consumption. This emphasis does align with circular economy principles (Ellen MacArthur Foundation and UNEP, 2018). There is a risk of over-emphasising recycling, given the technical limits to recycling and the environmental costs associated with recycling (Anderson and Gbor, 2024). However, many stakeholders also emphasised the need to think more broadly about production and consumption away from just plastics, but more generally towards how many materials are being used and in what ways can we reduce material production and consumption as a whole. This perspective aligns with ecological regulation, which is a regulatory theory that emphasises, among other things, regulating so that production and consumption stays within ecological limits and adopting comprehensive analyses of options to address environmental issues rather than focusing on a narrow set of solutions (Parker, 2021).

Another implication of our findings is that a multifaceted regulatory approach is appropriate. This kind of regulatory approach, where there are a number of interventions, aligns with regulatory scholarship, which generally positions optimal regulatory design as involving a mix of instruments that work together to achieve public interest aims and which involve periodic reviews to allow for changes based on external factors (Parker and Haines, 2018; Gunningham et al., 1998; Ayres and Braithwaite, 1992).

Although a few industry participants did not support mandatory regulations, most stakeholders (including from industry) agreed that mandatory rules regarding plastic packaging are required. Moving to a more mandatory approach to plastics regulation would be supported by regulatory theory, given the more voluntary approach to plastic packaging has not worked (Ayres and Braithwaite, 1992). Mandatory as opposed to voluntary regulation is also supported within plastics regulation literature as a preferred approach given the particular market dynamics and the scale of plastic production, consumption and pollution (Eckert et al., 2024; Quinn and Sinclair, 2006; Syberg et al., 2021). Moreover, mandatory plastic packaging regulation has also been supported by examinations of Australia's plastic packaging regulation (Bousgas and Johnson, 2023a; Jones and Head, 2023). Part of the reason these interventions need to be mandatory is to create a level playing field and ensure compliance.

While we found that our interviewees were commonly supportive of

Table 3
Summary of interventions raised and features or issues discussed.

Types of interventions implicitly or explicitly raised by stakeholders	Targeted activity/ outcome	Example of issues or features to consider raised by stakeholders or implicated in the measure proposed
Tax on virgin plastic production	Reduce plastic production	• Jurisdictional limitations • Unintended environmental or social consequences and ways to address these consequences
Bans on certain material uses as opposed to bans on specific materials	Reduce unsustainable consumption as a whole rather than in a material-specific way	• Political palatability • Potential trade agreement issues • Unintended environmental or social consequences
Introduce an EPR scheme for plastic packaging that is more developed than the existing approach	Eco-design and reduce amount going to landfill	• Importance of a mandatory approach • Independence of PRO • Financial responsibility as opposed to operational/ organisational • Eco-modulation • Data gathering limitations • Additional support required for SMEs
Design Requirements	Eco-design, increase recycling rates and life-cycle approach	• Requirements to reduce packaging • Requirements to simplify packaging (e.g. dyes, additives, polymers) • Design for recyclability • Difficult to effectively impose design requirements on imported plastic packaging • Need to account for different design requirements based on application/use and local recycling infrastructure
Mandatory minimum recycled content requirements	Increase recycling rates	• Difficulties regarding supply and cost of recycled plastics • Uncertainties around role of imported recycled content and how to incentivise domestically produced recycled content
Tax on plastic packaging that does not contain a certain amount of recycled content	Increase recycling rates	• Tax would have to be set sufficiently high to incentivise use of recycled content • Need to ensure recycled content is being produced at a level to support such a tax
Mandatory standards for eco-claims e.g. 'biodegradable'	Sustainable consumption	• Initial cost on manufacturers • Difficulties of effectively enforcing given the large amount of imported plastics

mandatory regulations, we may find that in practice industry stakeholder groups will advocate for voluntary approaches. Indeed, Australia recently introduced a National Framework for Recycled Content Traceability, which is a voluntary initiative and industry groups tended to advocate for a voluntary approach in relation to this framework (DCCEEW, 2023). However, their support for a voluntary framework could have been because of the technical difficulties of plastics traceability, which we will discuss more.

Mandatory does not mean unadaptable to circumstances. As the outcomes of this study show, it is critical that regulators incorporate ways to make mandatory specifications relevant to different sectors and applications. In particular, the results reflect the complexity of regulating plastic, as each different type of polymer and application or use raises a unique set of circumstances that need to be considered when implementing a particular intervention. Moreover, there is a need to align certain regulatory responses, such as an EPR, with existing local recycling capabilities, suggesting that regulators need to put forward a mandatory approach, but subsequently collaborate with stakeholders on specific requirements and have built-in provisions that allow for periodic revision of requirements as circumstances change.

Another important consideration is the need for comprehensive environmental impact assessments, including lifecycle analyses, when introducing a new regulation of plastic packaging (such as mandatory recycled content or an EPR scheme) to avoid unintended consequences. For instance, there is a risk in mandating design requirements that consumption could shift to alternatives that are more resource intensive to produce or manage at end-of-life.

The risk of unintended consequences, combined with more broadly unsustainable consumption rates in high-income countries, may also reflect the need to debate bans on entire applications of materials. These measures may include, for instance, bans on single-use cups of any kind from takeaway establishments or bans on supermarkets providing any bags. These more radical regulatory options would require further deliberation in terms of their impact on marginalised groups and how to operate to avoid loopholes and unintended consequences. While the above was not something stakeholders generally contemplated, they did emphasise the need to not view plastics as the problem, but rather the amount of plastic being produced and consumed and where/how it was being consumed.

In relation to EPR and mandated recycled content requirements, plastics traceability, in the sense of being able to know what a plastic product chemically was comprised of (e.g. polymer and dyes/additives) and from which sources did these chemicals originate, was often raised as a fundamental component. While some interviewees saw a role for AI, digital watermarks and blockchain, another possible component in a traceability scheme for plastics (to operate under e.g. an EPR) is to trace plastics on a chemical level (Johnson et al., 2022).

Chemical traceability systems range from using inherent chemical information pertaining to a specific type of plastic material to the addition of information rich bespoke (macro)molecules to the plastic material at a specified point during the production process. An ideal approach to a chemical traceability system for plastics is to blend a specific molecular additive into the polymer resin during manufacturing. The additive would allow polymers to be imparted with a unique identifier, akin to DNA in biological systems, enabling even small amounts of plastic to be traced and identified, including microplastics.

While coding information into such a plastics tracing additive is technically possible, reading the encoded information out while the code is embedded in the plastic material is highly challenging (Yu et al., 2023). In general, for sorting plastic waste, technologies that use optical sorting methods are arguably preferable because they tend to be easy to use, faster and more affordable (Adarsh et al., 2024). If a plastics tracing additive was employed by companies and regulators, developing an optical read-out approach would have these same benefits. Shining a light onto plastic containing such an additive would lead to the emission of a set of wavelengths which could be read like a code that identifies the additive and thus the plastic material it is embedded in. The code would need to be correlated via a database to a set of standardized and ideally legislated information about the plastic that is being traced. The encoded information could include the manufacturer, manufacturing date, batch number, the chemical composition of the plastic material as well as information to which end user the particular batch has been sold and an indication of what dyes and additives have been added. However, chemical tracing will face difficulties at the recycling stage, due to the amount of intermixing.

6. Conclusions

For regulators and policymakers, our findings evidence broad agreement among interviewees about what kinds of regulatory interventions are required to reduce plastics pollution from plastics packaging and shared support for mandatory responses. This agreement tends to emerge from a desire for a level playing field among industry actors as otherwise only some actors bear the costs of more sustainable packaging design. It also emerges from an understanding of the pressing need to address plastic pollution and the public support for such action. These findings, therefore, should support regulators as they move to create mandatory, comprehensive plastic packaging reforms. It is possible, however, that stakeholder opinions will become more divided once particular measures are proposed by the government and especially if they are mandatory.

The findings also illustrate the difficulty of intervening in plastics production and design given the many different applications of plastics, the global nature of plastics supply chains and also the unintended consequences that can follow from banning certain types of plastics or imposing certain design requirements. These complexities illustrate the need for an approach to setting requirements that is adaptable to different applications and industries, based on comprehensive analyses of materials and environmental impacts (including of alternatives) and periodically reviewed in light of new evidence. It also underscores the need for a global response to plastics and the importance of ensuring that countries with significant plastic manufacturing impose certain measures to restrict virgin plastic production. Such measures and obligations are currently being considered by the UN.

As well as dealing with these complications, regulators must also contend with the technological limitations to creating alternatives, to recycling and to tracing plastics. This requires an approach to regulatory design that is iterative and capable of anticipating future adjustments based on technological development. Generally, this would require governments periodically consult with stakeholders regarding technological and infrastructural capacities and monitor and review how their regulations are operating. Australia has had a consultative approach to plastic packaging, and one which was periodically reviewed. Yet, there is an inability within the current regime to scale up responses over time in response to evidence regarding plastics production, consumption and pollution and, as we observed in our regulatory analysis, industry was given to much power to determine the objectives and ways to achieve them. As Australia and other countries look to bring in comprehensive reforms regarding plastic packaging, there is need for a more adaptive and responsive approach to develop but one that is supported by mandatory requirements and effective enforcement and compliance.

The findings from this research also contribute to the currently limited bodies of work examining stakeholder perceptions of plastics regulation and regulatory strategy in the context of plastics. Future research could involve a mixed qualitative and quantitative approach in Australia, and elsewhere, whereby stakeholders are presented with specific reform options and asked to weigh the interventions. Noting that stakeholder perspectives are influenced by various factors, such an approach would, nonetheless, help to further reveal what overall regulatory mix is required to effectively improve the sustainability of plastic packaging and what specific design features are required within

particular regulatory interventions.

CRediT authorship contribution statement

Hope Johnson: Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Katherine Keane:** Writing – review & editing, Investigation, Formal analysis, Data curation. **Laura McGillivray:** Writing – review & editing, Project administration, Methodology. **Afshin Akhtar-Khavari:** Writing – review & editing. **Lewis Chambers:** Writing – review & editing, Formal analysis, Data curation. **Christopher Barner-Kowollik:** Writing – review & editing, Funding acquisition. **Mark Lauchs:** Writing – review & editing. **James Blinco:** Writing – review & editing.

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