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Review

Extended Producer Responsibility in the Australian Construction Industry

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Abstract: With the COVID-19 outbreak across the world, policymakers and authorities have realised that they cannot solve the emerging issues using conventional policies and practices. COVID-19 has severely affected many industries, including construction and demolition (C&D) waste management and C&D waste resource recovery sector. Extended Producer Responsibility (EPR) and schemes alike are policy instruments that prevent waste generation and promote a circular economy in the construction industry. These schemes are long adopted in various countries for different waste streams. EPR policy development and implementation, particularly for C&D waste, is still at an early stage in Australia. This study aims to review the Australian regulatory environment and practice to identify barriers and enablers towards successful policy development and implementation of C&D waste-related EPR. This study is based on secondary data that are publicly available. The document analysis was conducted to identify the level of regulatory and other stakeholders support in Australia. Following three rounds of examination of sources and applying multiple selection criteria, 59 different sources were reviewed in total. The results showed that there is widespread support among different stakeholders to develop EPR and expand the existing regulation to other materials. The barriers were cost and time implications for EPR policy establishment and enforcement, diversity of stakeholders involved, construction product lifecycle, responsibility of manufacturers, complexity in implantation of EPR regulations, modification inbuilt facilities and health and safety issues. Recommendations are made to alleviate these challenges. The outcome of this study could serve as a guideline for designing effective EPR policies.

Keywords: construction and demolition waste management; Australia; **c**onstruction industry; extended producer responsibility; take-back scheme; product stewardship; environmental policy and management; circular economy in built environment

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1. Introduction

Management of construction and demolition (C&D) waste has become a priority in many developed and developing countries. Improper management of C&D waste was found to have inflicted environmental, social and financial negative consequences. Until today, several models have been proposed to address these consequences through integrated and effective management plans. Many research studies demonstrated that an integrated and effective waste management system should consist of the following three components: encouragement (e.g., education, green rating systems), enforcement (e.g., landfill levy, illegal dumping penalty) and prevention (e.g., design waste out, extended producer responsibility) [1–5]. To ensure that a balanced waste management plan is considered and all stakeholders are given a level playing field, these three components should be applied concurrently.

With the COVID-19 outbreak across the world, policymakers and authorities have realised that they cannot solve the emerging issues using conventional policies and practices. COVID-19 has severely affected many businesses involved in construction and demolition activities, as well as in the C&D waste management and resource recovery sector [6–9]. For instance, Rahman, Kim and Laratte [8] indicated that on the world scale C&D waste recycling industry is affected due to low construction activities in different states and restrictions in shipping services reducing waste transfer to recycling destinations. Furthermore, the current pandemic has exposed the shortcomings of the construction industry such as poor-quality buildings, issues regarding affordability of decent housing and rigidity of the current building stock [10]; hence, the post-COVID era will involve extensive refurbishment and renovation of existing buildings to be more adaptable to cope with changing needs in certain circumstances and changes in construction-related technologies such as Building Information Modelling (BIM), 3D printing, prefabrication, Industry 4.0 and Digital Twining, that will dramatically impact the size and type of waste generated in this industry [9,11].

Extended Producer Responsibility (EPR) is found to be a successful market-based policy approach that can significantly contribute to a circular economy in the construction industry. EPR has been applied to different waste types and streams [12,13] and is able to prepare the construction industry and the relevant C&D waste recovery sector to accommodate drastic changes that are inflicted by adverse incidents such as widespread pandemics, climate crisis, trade wars and natural hazards [9,14]. Technically, EPR renders manufacturers responsible (financially and/or physically) for the entire lifecycle of their products during the supply chain of materials [15], including design, manufacture, recycling and final disposal [16]. EPR provides an opportunity to firstly prevent waste generation [17], secondly divert additional waste away from landfills to reuse and recovery [12] and thirdly creates and stimulates markets for C&D waste resources [1]. Ideally, EPR is recognised as an incentive for producers to take into account environmental considerations when designing their products, resulting in preventing waste at the source through better product design, technology development and incorporation of green design and effective waste management schemes into overall production arrangements [13,18,19]. Therefore, it can be argued that EPR is a market-based scheme, as producers internalise the costs of externalises and that it is considered as a "next generation" environmental policy that hinges on market incentives rather than traditional command-and-control obligations [19]. Some authors have cautioned the international community that overlooking EPR policies is a mistake with severe social and environmental negative consequences [9,20].

The idea of EPR originated in Germany in 1991 because of a landfill shortage. At the time, packaging made up 30% by weight and 50% by volume of Germany's total municipal waste stream [12]. To help slow down the filling of landfills, Germany created a law, the German Packaging Ordinance [19], that required manufacturers to be responsible for their own packaging waste through either (1) taking back their packaging from consumers and distributors; or (2) paying the national packaging waste management organisation to collect the packaging [21]. The formal introduction of this terminology, however, was made by Thomas Lindhqvist in Sweden in 1990 [22] in a report to the Swedish Ministry of Environment. Other variations of EPR are Product Take Back (PTB), Product Stewardship (PS) and Polluter Pays Principle (PPP). The main distinction between PS and EPR is the focus of EPR being on preventing rising levels of waste and pollution, whereas shared PS initiatives primarily enforce that producer cover a proportion of costs associated with management of waste at the end of a product's useful life. A common example of PS is container deposit laws whereby consumers are forced to pay extra when they buy beverages in cans/bottles: the amount that can be redeemed upon returning cans/bottles [23]. EPR is more comprehensive than PTB as it can take three forms: as reuse, buy back or recycling program, while PTB is limited to product buyback.

Despite the differences mentioned above, the main three objectives of EPR and its variations include a reduction in pollution prevention, decline in the extraction of natural resources and a drop in energy use for extracting and processing new materials [17,24,25]. The implementation of EPR and similar schemes has been repeatedly mentioned as an effective policy approach in the management of C&D waste in previous studies [17,19,26–30]. Until now, there is no universal and standard policy approach to implement and take advantage of EPR objectives for the C&D waste stream. A government report indicated that generally about 70 to 80% of the environmental impact of a product is locked in at the design phase [18]. The EPR in the construction industry enforces the price signal that ensures the entities that have the power to redesign their construction materials or to trade other materials play an active role in the management of waste generated. For this to be archived, producers should use instruments such as design for recyclability, reduced material usage, product disassembly, reduced or eliminated the usage of toxic materials and re-manufacturability [17].

Among different international organisations, the Organisation for Economic and Cooperation and Development (OECD), through its Working Party on Resources Productivity and Waste (WPRPW), has been heavily engaged in EPR activities for a long time [31]. Furthermore, the PPP was first mentioned in the OECD's May 1972 recommendation and was reaffirmed in its November 1974 recommendation [16]. Almost two decades later, it was laid down as Principle 16 of the UN Declaration on Environment and Development.

In Australia, the average national construction value growth rate shows that construction activities have steadily increased [32] to accommodate the growing urban populations' needs. Increased construction activities inevitably result in the generation of more C&D waste. According to the latest report [33], the Australian construction industry has generated 27 Mt of C&D waste in 2018–2019, accounting for 44% of the total waste generated in Australia. This amount has increased by 32% from 2006–2007 figures. The current national resource recovery rate for this quantity of waste is 47% [33]. EPR and similar schemes are new concepts for the management of C&D waste in Australia. The federal government, in collaboration with state governments, is working to develop a national EPR policy that can be applied throughout Australia. Therefore, this review study aims to provide necessary information about different aspects of EPR and similar initiatives that may inform policy development.

This review study forms part of a larger project (project 1.75. creation and stimulation of end markets for construction and demolition waste), which was supported by the Australia Sustainable Built Environment National Research Centre. This project endeavours to foster a holistic national approach to address C&D waste issues through various waste management techniques that will result in market development for C&D waste resources.

Research Objectives

In accordance with the aim mentioned above, the study objectives are as follows:

1. Review examples of EPR and similar policies application in relation to C&D waste;
2. Determine the position of Australia in developing EPR policies and other similar schemes legislation in Australia;
3. Explore the challenges in adoption of EPR and similar schemes in the Australian construction industry.

2. Materials and Methods

This review study is based on the secondary data that is publicly available. The document analysis technique was conducted to identify the level of regulatory and other stakeholders supports in Australia. It also reviewed the status quo of EPR application in other countries. For the Australia part, the sources reviewed include acts, policies, regulations and strategies that are mostly administrated by the Australia Environmental Protection Authority (EPA) and other state-specific authorities (e.g., Sustainability Victoria in

Victoria), plus reports and initiatives prepared for C&D waste management in eight states and territories of Australia: Australian Capital Territory (ACT), Northern Territory (NT), New South Wales (NSW), Queensland (Qld), Tasmania (Tas), South Australia (SA), Victoria (Vic) and Western Australian (WA). The sources selected for this review study underwent three stages of examination as follows:

Stage I: to acquire the relevant English language literature for this systematic review, a desktop search of six major databases was conducted: Google Scholar, Scopus, PubMed, Wiley Online Library, Water Resource Abstracts (ProQuest) and Web of Science. The keywords used were: "extended producer responsibility", "construction and demolition waste", "building", "take back", "product stewardship", "polluters pay principle", "Australia" and "waste management". The desktop search resulted in 72 outputs, including journal articles, PhD theses, industry reports, government documents and peer-reviewed conferences papers. To make sure that highly relevant sources were captured the references of selected sources' references were also explored. At the end of this stage, 105 were gathered.

Stage II: at this stage, the source that had highly relevant contents were shortlisted and their full texts downloaded. Particularly, the sources that had not considered using "construction and demolition waste", "extended producer responsibility" and "product stewardship" were excluded from examination. The full texts of selected sources were subsequently coded and archived for the third stage of examination.

Stage III: The third stage of examination involved checking the selected sources against three selection criteria; (1) scope focused on waste management through EPR and other similar schemes; (2) present information (e.g., regulatory framework and best practice management) that is valid and not outdated; and (3) contain lessons that can be translated to C&D waste stream. The sources not meeting these criteria were excluded from further consideration. The final number of sources reached 59 at the end of this stage.

3. Results

3.1. Considerations in the Development of EPR Policies

The development of EPR and other similar policies is not straightforward due to the complexities and wide range of stakeholders involved in product production, trade, delivery, consumption and waste management [34]. Furthermore, the methods through which EPR policies are applied can vary. Several previous research studies have attempted to model these complex factors to boost the performance of EPR policies in practice [14]. This section of results focuses on a few of these models. Dubois, de Graaf and Thieren [27] presented five criteria for the development and evaluation of the adequacy of EPR in the context of C&D waste management. Figure 1 depicts these five criteria.

Applying these criteria to the C&D waste stream in the Netherlands, the researchers indicated there is a motivation to implement EPR for only two criteria (e.g., environmental scope and political priorities). Acree Guggemos and Horvath [17] put forward a policy framework to better achieve EPR goals for C&D waste management. This framework, which is based on Thorpe and Kruszewska [35] model, consists of three types of policy instruments: regulatory, economic and information-based (Figure 2).

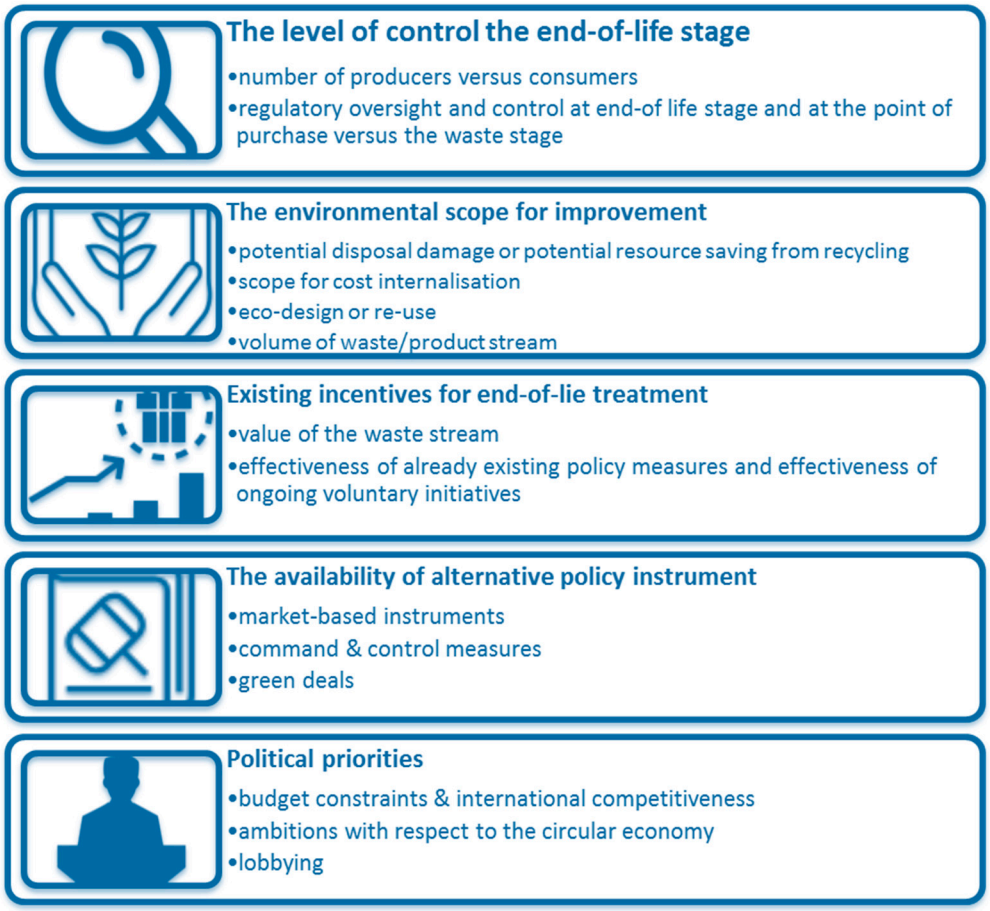

Figure 1. Five criteria suggested for the development of an EPR policy. Source: materials adopted from Dubois, de Graaf and Thieren [27].

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In addition to the models presented in Figures 1 and 2, there are other studies that have presented models with some similarities and differences [36–40]. Furthermore, some studies investigating factors that impact EPR's performance provided useful information on how to maximise the adequacy of EPR and similar schemes for waste management. For instance, Gupt and Sahay [41] conducted a comparative analysis on 26 case studies in developed and developing countries to identify the factors contributing to the success of EPR implementation and the main aspects of EPR development and implementation. The results revealed that the "financial responsibility of the producers", "separate collecting" and "recycling agencies" significantly contribute to the success of EPR. The main aspects of EPR were also found to be "regulatory provisions", "take-back responsibility" and "financial flow". In 2016, one study on the effectiveness of various environmental policies weighted and compared different policies in Maine, US [42]. The results showed that EPR policies are regarded as highly effective but that their acceptability is uncertain [42].

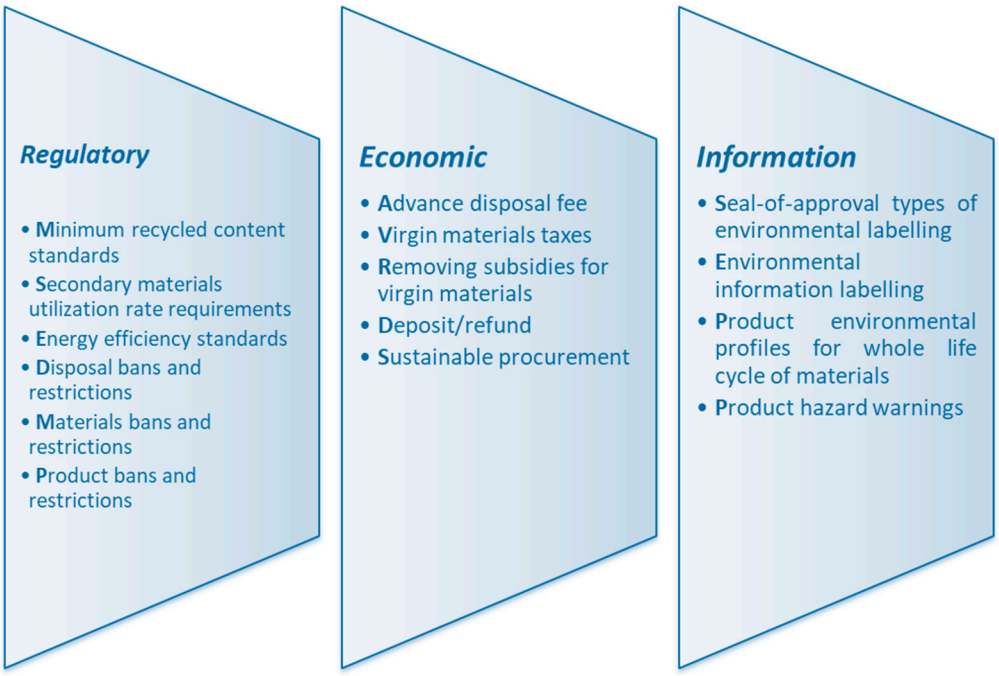

Figure 2. Three policy instruments that facilitate EPR implementation. Source: Adopted from Acree Guggemos and Horvath [17].

3.2. Considerations in the Development of EPR Policies in Australia

Australia has set ambitious waste management targets, and EPR plays an important role in achieving these targets. Under the National Waste Policy [43], Strategy 4: Product Stewardship, the Australian Government is responsible for leading a national approach to product stewardship. In the Australian regulatory framework, EPS is defined under the PS scheme [44]. The federal government continues to work with state and territory governments as well as with industry to consider possible product stewardship approaches for other products. The first Australian EPR legislation, Container deposit scheme 1997 [45], was introduced in SA that governs the management of beverage bottles in this state.

Currently, there is one PS primary legislation, Department for the Environment and Energy [46], the Act that is guided by the National Waste Policy [43]. This Act provides the framework to effectively manage the environmental, health and safety impacts of products and, in particular, those impacts associated with the disposal of products. Studies have demonstrated the success of this Act in National Television and Computer Recycling Scheme [47,48]. The program has 26 signatories who have committed to improving areas such as manufacturing emissions, additives and end-of-life management [49]. The Act operates through three types of stewardship: voluntary, co-regulatory and mandatory [46].

- Voluntary: Industries with government oversight can voluntarily take action to reduce the impact their products have. These schemes, which are funded and led by industry, facilitate the sustainable management of products without the need for regulation. Industry based schemes that obtain the federal government accreditation are monitored to ensure they are achieving agreed outcomes.
- Co-regulatory: These schemes are the product of industry action and federal government regulation. Government sets the minimum outcomes and operational requirements, while the industry has some discretion about how those requirements and outcomes are achieved.
- Mandatory: This imposes a legal obligation on stakeholders to take certain actions in relation to a product that leaves little or no discretion in how the requirements are to

be met. There are currently no fully mandatory product stewardship schemes in place under the Act.

In 2018, the Australian Environment and Communications References Committee [18] provided some recommendations for the federal government with respect to the implementation of PS schemes:

- PS schemes under the Act should be mandatory, and such an obligation should be applied to tyres, mattress, e-waste and photovoltaic panels.
- Extend producer responsibility under this Act through improved design.

The federal government supports PPP through the National Environment Protection Council Act 1994 [50], under Section 3.5.4 (improved valuation, pricing and incentive mechanisms Section). This Act maintains that:

> "…polluter pays, i.e., those who generate pollution and waste should bear the cost of containment, avoidance, or abatement the users of goods and services should pay prices based on the full life cycle costs of providing goods and services, including the use of natural resources and assets and the ultimate disposal of any wastes" (National Environment Protection Council Act 1994 [50, p. 40]).

According to this Act, the PS schemes and regulations were developed for multiple products including e-waste (Product Stewardship (Televisions and Computers) Regulations 2011) [51], batteries, tyres (Tyre Stewardship Australia), oil (Product Stewardship (Oil) Amendment Act 2000) [52], used packaging (the Australian Packaging Covenant: co-regulatory scheme), agricultural chemicals and containers (Drum Muster: voluntary scheme), lamp with mercury content (FluoroCycle scheme) and paint (National Paint Product Stewardship Scheme) [53]. The latest product list, released in 2020–21, targets "plastic microbeads and products that contain them", "batteries", "child car seats", "photovoltaic systems", "electrical and electronic products" and "plastic oil containers" [54]. The National Environment Protection (Used Packaging Materials) Measure 2011 (NEPM) [55] obligates companies that sell or produce packaged products to implement innovative design practices that result in more recycling or reusability of packaging. It also underpins the Australian Packaging Covenant Organisation's work, which is to promote shared responsibility, recycling and circular economy. There is no specific EPR driven legal instrument for the C&D waste stream in Australia; nor are there any nationally adopted EPR regulations.

At the jurisdictional level, except for in the NT, relevant primary and secondary legislations have acknowledged the need for having EPR and similar schemes in place (Table 1). Only three jurisdictions—ACT, TAS and SA—included the EPR definition and its principles in their relevant legislation. Among the jurisdictions, the most developed legislation occurred in Qld, NSW and WA; these states allocated at least one section detailing the requirements and circumstances under which a product is regulated or managed a PR/EPR programs. In Qld, particularly, the Waste Reduction and Recycling Act 2011 provides the relevant conditions through which an industry can be accredited to launch a voluntary PS program; it also explains how regulations and monitoring of a PR scheme can take place.

Table 1. Regulatory framework supporting EPR and similar schemes in different Australian states.

Regulation	State	Summary
Environment Protection Act 1997 Waste Management and Resource Recovery Act 2016	**ACT**	Part 1—Preliminary 3R principles applying to Act. The principles of EPR (only in EPA act 1997) and PP for the environment are enshrined in these acts.
Not relevant statements in legislation	**NT**	N/A
Waste Avoidance and Resource Recovery Act 2001	**NSW**	Part 3—Objects of acts (e) to ensure that industry shares with the community the responsibility for reducing and dealing with waste Part 4—Responsibilities with respect to industry waste reduction (15) Extended producer responsibility schemes (16) Regulations for implementation and operation of schemes (17) Circumstances in which schemes may be implemented (18) Priorities with respect to the implementation of schemes
Waste Reduction and Recycling Act 2011	**Qld**	The principles of PS are enshrined. Chapter 4 Management of priority products and priority waste Part 1—responsibility the purpose of this chapter is to (a) to encourage and circumstances to require, persons who are involved in the life cycle of a product to share responsibility Part 2—(objectives of the Act): (d) to ensure a shared responsibility between government, business and industry and the community in waste management and resource recovery Part 3—Product stewardship schemes Division 1 Product stewardship schemes generally Division 2 Accreditation of voluntary product stewardship schemes Division 3 Product stewardship schemes by regulation Division 4 Monitoring of schemes
Environment Protection Act 1993	**SA**	Part 2—Objects of Act/10-vi: allocate the costs of environmental protection and restoration equitably and in a manner that encourages responsible use of and reduced harm to, the environment with polluters bearing an appropriate share of the costs that arise from their activities, products, substances and services.
Environmental Management and Pollution Control Act 1994	**TAS**	PART 2—Objectives of the Act/ (d) to allocate the costs of environmental protection and restoration equitably and in a manner that encourages responsible use of and reduces harm to, the environment, with polluters bearing the appropriate share of the costs that arise from their activities.
Environment Protection Act 1970 Environment Protection (Resource Efficiency) Act 2002 Sustainability Victoria Act 2005	**Vic**	The principles of EPR (1G) and PS (1H) are enshrined in the Act. 49AH—The Authority may also require the person, in relation to the enterprise, process, products or service to assess alternative practices and product stewardship approaches to improve the use efficiency of specified resources or to reduce any ecological impacts identified by the Authority; 49AN—The Authority may produce and publish guidelines concerning product stewardship approaches; 49AO—Authority may conduct audits to provide an assessment of product stewardship approaches The functions of Sustainability Victoria are to (b) foster a stewardship ethos in relation to the use of resources
Waste Avoidance and Resource Recovery Act 2007	**WA**	Part 5—Product stewardship 45. Product stewardship plans 46. Extended producer responsibility schemes 47. Statements with regard to extended producer responsibility schemes Schedule 3—Matters in respect of which regulations may be made Division 3—Product stewardship

Source: Authors.

Currently, there are only two states that have a specific EPR policy in place. NSW was the first jurisdiction to establish an EPR policy in 2004 [44] under the NSW Environmental Protection Authority Act [56]. Under this Act, the EPA is required to publicly announce an EPR priority every year. The latest EPR priority statement was released in 2010, and 17 priority materials were identified. From these 17, only treated timber, packaging and PVC are from the C&D waste stream. In 2008, the WA Municipal Waste Advisory

Group prepared a Policy Statement on Extended Producer Responsibility 2008 for WA. According to the second outcome of this policy, EPR is linked with an improved valuation, pricing and incentive mechanism; it enables the market to better communicate the environmental and social costs of waste and makes waste minimisation an attractive action to producers and consumers [1]; it eventually furthers the attractiveness of reusing and recycling materials. Additionally, there are various PS schemes across the Australian jurisdictions. For instance, in Vic, Sustainability Victoria has led several schemes, including ByteBack (Computers) BatteryBack (batteries), PaintBack (paint) and FlashBack (compact fluorescent lights). Other programs include Cartridges 4 Planet Ark, MobileMuster, Coffee Pod Recycling (Nespresso), REDCycle (soft plastics recycling), Soft Landings mattress recycling and drumMUSTER (agricultural and veterinary chemicals containers).

3.3. Support from Jurisdictional Waste Strategy Documents in Australia

Most jurisdictions have a strategy document [57] that guides government organisations and industries in improving waste management over the strategy period. In many cases, strategies set targets for resource recovery or other waste performance indicators. They also underpin waste management legislation in the respective jurisdiction. Among the states and territories, Vic does not have a current waste strategy document. In SA and WA, EPR is a long-term objective; EPR related schemes are supposed to be developed in the future. Table 2 presents a summary of support from different states and territories of Australia reflected in jurisdictional waste management strategy documents

Table 2. Support for the development and implementation of EPR schemes in Australia.

Document	State	Relevance to C&D Waste
ACT Waste Management Strategy: Towards a sustainable Canberra 2011–2025	ACT	EPR is recognised among the areas of improvements for further waste management and resource recovery Strategy 1.4. Reducing packaging: waste a commitment to product stewardship by the supply chain and other signatories
Waste Management Strategy for the Northern Territory 2015–2022	NT	No mention of EPR and PTB NT will facilitate and promote product stewardship programs for recycling and treating nationally significant waste streams
NSW Waste Avoidance and Resource Recovery Strategy 2014–21	NSW	No mention of EPR and PTB NSW will continue to work with the Australian government to introduce product stewardship initiatives at the national level under the Commonwealth Product Stewardship Act 2011
South Australia's waste strategy 2015–2020	SA	Long term objectives: Avoid and reduce wasteful use of resources in production processes and products, such as leaner production, design for the environment and EPR Promote the adoption of EPR, including State-based approaches where considered necessary and encourage continuous improvement in existing producer responsibility and related schemes. Encourage reuse of waste fill, and intermediate level contaminated soils where appropriate as a priority and remediate low level and high-level contaminated soils for reuse Priorities for Action: Problematic and hazardous waste target: effective PS schemes in place by 2020
Queensland's Waste Reduction and Recycling Strategy 2010–2020	Qld	Strategy principles: Making better use of finite resources (energy, water, materials) by encouraging waste avoidance and improving recovery through PS or PTB schemes Implement state-wide action such as PS schemes on priority waste Qld government aims to encourage and support PS arrangements work with industry sectors to help build on achievements made through existing schemes and help promote PS activities work with other industry sectors to foster new PS arrangements
The Tasmanian Waste and Resource Management Strategy 2009	Tas	Strategic actions: Participate in and support the development of EPR and PS programs Tasmanians will have an increasing role and responsibility in environmental stewardship
Waste Strategy 2030: Western Australia's Waste Strategy	WA	We will support PS and EPR as part of our approach to shared responsibility.

National Waste Policy 2018: Less Waste, More Resources	Australia	Strategy 4 Product stewardship: Develop and implement partnerships across government and business to ensure ownership and responsibility for action to minimise the negative impacts from products, ensure the minimisation of waste and maximise reuse, repair and recycling of products and materials throughout their life cycle

Source: Shooshtarian, Maqsood, Wong, Yang and Khalfan [2].

3.4. Application of EPR in the Australian C&D Waste Management System

National industry associations have a key role in promoting EPR application across Australian states and territories. In 2019, The National Waste and Recycling Industry Council (NWRIC) affirmed its policy for EPR schemes to be applied uniformly across jurisdictions and be regulated, enforceable and enforced in order to operate effectively [58]. In 2021, Waste Management and Resource Recovery Association of Australia (WMRR) has highlighted their ongoing commitment to advocating for a mandatory EPR scheme and other best practices and policies across all areas of the waste hierarchy [59]. There is limited research exploring the perception of Australian C&D waste stakeholders of EPR schemes [1,49,60,61]. Zaman [60] reported that waste experts based in SA mostly agree with the implementation of EPR schemes for all waste streams. A study investigating the Australian C&D waste stakeholders' views on the strategies improving C&D waste market revealed that PS (EPR) schemes are not considered as a top priority [1]. Participants in another study indicated that EPR schemes are poorly applied in Australia, and the country is lagging behind other leading countries such as the UK [61].

In terms of examples showcasing the industry-led application of EPR to the C&D waste stream, there are limited cases that only address particular C&D waste materials. Table 3 provides information on EPR schemes that target C&D waste materials in Australia.

Table 3. C&D waste EPR schemes in Australia.

Material	Ref.	Summary
Brick and concrete	[62–64]	BGC's Brikmakers® has returned all clay brick production waste back into the product mix since it was established in 2007. It also utilises wastes from its concrete and fibre cement manufacturing operations back into its concrete paver and backing block products. Furthermore, the Austral Bricks® plant in Victoria has markedly reduced the instance of malformed or off-specification green (unfired) bricks; it is reported that any such units are automatically recycled into the clay mix rather than going to landfill.
Carpet	[49]	Since 1985, Ontera Modular Carpets through Ontera's EarthPlus® environmental program guarantees to take the product back at the end of its first life for reuse or recycling at no cost to the customer. This program operates without any destructive processes or measurable additional energy input. Ontera reported that this program has resulted in creating reputation and market stature, improved economic returns, reduced utility and landfill costs.
Gypsum	[49]	CSR Gyprock™ through a gypsum board take-back scheme collect offcuts and demolition material. According to the instruction provided in this scheme upon completion of gypsum board installation fixing contractor arranges collection with CSR Gyprock™'s recycling contractor who charges builder the reasonable fee. It is claimed that such a scheme could reduce the cost of site clean-up and landfill fees, facilitate better on-site waste management and save builders time and money.
PVC	[49]	Since 2002, the Vinyl Council of Australia has voluntarily agreed to apply EPR principles and comply with the Product Stewardship Act 2011 requirements. Armstrong Australia, the world's largest manufacturer of resilient PVC flooring products, collects the offcuts and end-of-life flooring materials that would have otherwise sent to landfill for recycling and processing into a new product.
Timber	[65]	The timber industry has formed the National Timber Product Stewardship Group in 2007 to address the environmental impacts from the disposal of timber products and to increase their post-consumer recovery.
Waffle pod	[49]	Expanded Polystyrene Australia and its Pod Group members through a product stewardship scheme (the Pod Scrap Bag program) target reduction of expanded polystyrene (EPS) waste from waffle pod offcuts on construction sites. Within this program builders are supplied with scrap bags to separate EPS waste from other materials; the bags are then collected and transferred to EPS manufacturer who is claimed to produce new EPS with 40% of recycled materials content.

3.5. EPR Related Legislation in Other Countries

EPR and similar schemes have largely targeted hazardous materials, and there are limited examples of their specific application to the C&D waste stream. Australia is a member of OECD and can benefit from the experiences of those signatory countries that have successfully implemented EPR policies. The following table (Table 4) is extracted from the guideline issued by OECD showcases the application of EPR and similar schemes [16]:

Table 4. Examples of implementation of EPR schemes overseas.

Country/Region	Legislation	Materials
European Union	All member states have PTB (EPR) systems. The framework is established through the EU, but operational aspects are advised by states	Four main types in all states: packaging, batteries, end-of-life vehicles and Waste Electrical and Electronic Equipment. Some states also have different material lists
United States	There is no national EPR policy Individual states develop and implement their own policy. Today there are 89 EPR laws in 33 US states	A wide range of materials
Canada	Occurs at provinces/territories level Canada-wide Action Plan for (EPR). There are more than 30 federal and provincial producer stewardship programs in Canada	A wide range of materials
China	The new EPR policy was introduced in 2016–17 by China's State Council	Certain materials: electrical products, batteries, vehicles
Japan	Home Appliance Recycling Act	A wide range of materials including C&D waste
Korea	Resource Saving and Recycling Promotion Act 1992 Resource Circulation of Electrical and Electronic Equipment and Vehicles 2008	Household and industrial materials

Source: OECD [16].

In European countries, EPR principles first appeared in policy and law in the early 1990s [19,66]. Several EU directives refer to EPR as a recommended policy instrument. Particularly, the Waste Framework Directive 2018/851 aims to effectively decouple economic growth from waste production [13,67]. At the European Union (EU) level, all Member States have implemented EPR schemes on the four waste streams: packaging, batteries, end-of-life vehicles and electrical and electronic equipment. EU policies suggest the establishment of Producer Responsibility Organisations (PRO) serving to perform the actual EPR responsibility, which results in economies of scale in waste management activities [68]. Within the US context, between 1991 and 2015, states have developed and implemented 89 EPR policies that require manufacturers to launch EPR schemes [16,42]. Özdemir, et al. [69] reported that twenty-three states in the US have adopted EPR-based legislation for end-of-use treatment of products. In addition to the mandatory programmes, voluntary programs are in place by manufacturers to collect and recover their product. In Canada, legislation regarding waste occurs at four tiers of government (federal, provincial, territorial and local governments). EPR is largely regulated at the provincial (territorial) level; however, in 2009, a national council has developed a Canada-wide Action Plan (CAP) for EPR to harmonise EPR approaches taken by different jurisdictions across the country [70]. This council also issued an EPR evaluation tool guideline [70] that systematically allows the user to consider launching an EPR program for one or more candidate products by answering a series of questions (criteria).

Since 2012, China's EPR regulations have rendered producers of some electrical products to contribute to government recycling funds according to the quantity of their production [71]. These funds are meant to provide subsidies to certified e-waste recyclers by the government. Critics have questioned the adequacy of this system as it provides little incentive for a design change or take-back actions by the producers [72]. However, the subsidies have created market niches that attract investment and entrepreneurship devoting to recycling. China's State Council introduced the first robots plan for China's EPR policy in 2017. In 2019, this council sought to build a credit information collection system in order to extend the responsibility of producers; it is expected that by 2020 a framework for EPR policy will take shape and corresponding legislation will be finalised. In Japan, different EPR policies are applied to various items; there are variations in who is financially or physically responsible in these policies. For instance, for automobiles and home appliances, the target stakeholders are manufacturers and producers and retailers, respectively [73]. Japan and Europe have PTB policies in place for different products, including some C&D waste materials. In Korea, through the Resource Saving and Recycling Promotion Act 1992, households are required to comply with volume-based garbage rate system requirements. Using the concept of polluter pays, this system urges each household to buy designated garbage bags at a supermarket, and waste can only be discharged using the prepaid bags [74]. The successful implementation of this act motivated the expansion of legislation to cover industrial waste, including C&D waste and to make companies fully accountable for all the waste they produced [75]. As of late, EPR programs have begun to be introduced in some developing countries, such as Brazil [76], Sri Lanka [20], Colombia [77], Ethiopia [78] and India [79].

3.6. C&D Waste Specific EPR Programs

The general trend for the development of EPR policy for C&D waste largely targets particular construction materials (e.g., PVC, glass, asphalt and packaging waste) rather than collective C&D waste. One example of specific C& D waste EPR legislation takes place in the Flanders region of France, where collaboration agreements with producers have been achieved to recycle C&D waste [27]. These agreements also require producers of several materials to set up logistic schemes or invest in infrastructure to collect used materials as input for new materials: gypsum, autoclaved aerated concrete, bituminous roofing, PVC and mineral wool.

Another successful implementation of C&D source EPR policy is the Netherland's float glass EPR scheme, which showcases how an EPR policy for C&D waste can work efficiently. This EPR scheme imposes an environmental fee of EUR 0.5/m^2 for new double-glazed windows to financially support the management of float glass (i.e., collection and recycling of waste) [27]. In some countries, such as Malaysia, local C&D waste legislation exists that functions as an EPR policy with shared similar principles [28].

3.7. Challenges of the Application of EPR and Similar Schemes to the C&D Waste Stream

There are several challenges identified that can act as a barrier to the extensive adoption of EPR and similar schemes in the construction industry [17,80,81]. As a result, not all EPR instruments shown in Figure 3 works equally well for C&D waste management. The following section explains the main challenges for effective development and implementation of an EPR policy in the construction industry.

Figure 3. The main challenges toward the effective application of EPR to the C&D waste stream.

3.7.1. Time and Cost

Despite the proven financial benefits yielded from the application of EPR schemes [19,82], the costs associated with the establishment and enforcement of EPR programs tend to be high [13,80,83]. The higher costs are associated with required changes in product design (e.g., design for disassembly) and technology and infrastructure improvements in manufacturing phase [13], collect and produce mandatory information [19] and administrative expenses to action, monitor and enforce EPR requirements [83]. The later costs could grow significantly if waste resources were to be managed within regions which are subject to multiple regulatory frameworks imposing different legal requirements [82]. Some researchers also advocate assigning the responsibility of costs associated with raising public's and stakeholders' awareness of EPR objectives and benefits [13]. Zorpas [84] argued that without any motivations, citizens and businesses do not follow any proposed waste minimising activities. Lastly, in the construction industry, recovered waste materials are generally more expensive than conventional materials [34,85], reducing their marketability and producers' profit expected from the application of EPR principles.

EPR schemes also can be time-consuming for both domestic producers, and a fortiori for importers [17] as C&D waste resources are generated in a mix. The selective demolition, otherwise known as de-construction is necessary to separate mixed materials and accordingly determine the responsible producer. This process is usually is lengthier than normal demolition [86]. Furthermore, it is reported that meeting EPR policies involves cumbersome practices such as mandatory data collection and reporting to public authorities [87].

3.7.2. Construction Material Lifecycle

The long product life of construction materials being designed to typically last for more than ten years is another problem making it difficult to apply EPR principles. The longer lifecycle also impacts the reusability and recyclability of these materials. However, reducing the quantity of waste prior (i.e., at design, planning and procurement stages) and during construction operations remains the responsibility of those who are involved in construction activities. The longer life of construction materials also brings about a regulatory issue where EPR policies are based on the retroactive requirements that demand producers to abide by EPR principles for products that were produced before these policies are in effect [88]. Indeed, the products that were previously created were not designed with EPR requirements in mind, nor did producers take into account the costs associated with the management of waste from their products [17].

3.7.3. Diversity of Stakeholders

The other instinctive barrier in construction is the diversity of players involved in construction activities relative to other industries. Traditionally, a producer is not responsible for product design in construction [89]; architects and engineers share the responsibility of design and material selection, and a builder (contractor) builds the designed, built environment. The disjointed practice of design and construction, therefore, makes it difficult to determine the responsibility for a product. These players also have their own concerns that impede the consistent application of EPR. For instance, architects' designs focus on function and aesthetics; engineers aim to satisfy structural and safety requirements; clients pay attention to budget, quality and time; and builders are mostly concerned with time, cost and profit [17,34]. One piece of research that studied two case studies in the US reported that designers have more control over the recyclability of a building (with control over 12 of the 15 areas [81]. Due to the complex nature of construction activities, it is a common practice that builders acting as the main contractor engage sub-contractors to complete different activities. As expected, it is a challenging task to keep track of the performance of tens of contractors involved in a construction project to make sure they are fully abiding by EPR principles.

3.7.4. Enforcement of EPR within a Heterogeneous Regulatory Framework

Currently, there is no universal standard for construction materials that can be implemented for different contexts [17]. This can be even more complex in the Australian context, where waste management legislation is formulated by different jurisdictions. EPR policies require manufacturers/importers to provide detailed reports that demonstrate compliance with the EPR requirements; if these vary across jurisdictions, they would be burdened with the task of complying with the EPR requirements in each country/jurisdiction where their product is to be sold. This also can undercut the financial performance of EPR-abiding manufacturers in markets without EPR implementation. The need for harmonised legislation was previously highlighted in studies related to the European context [13,82,84]; in one study, participants indicated that the current lack of harmonisation across the European Union leads to higher costs for producers and limited impact of incentives for improved design [82].

3.7.5. Assignment of Producers' Responsibility

Project contractors generally source numerous materials from different suppliers, plus the materials required differ from one project to another. As a result, it is not always easy to identify suppliers from the assessment of materials. Many materials do not have markings that show the manufacturers [17]. Indeed, without knowing the producer, the responsibility for the material cannot be assigned, and a fortiori at the end of the material lifecycle.

3.7.6. Modification Inbuilt Facilities

Another problem with the EPR application comes from modifications that can take place during maintenance or renovation of a built facility. Modifications are typically performed every 10–15 years, which may end up in adding to, removing from or changes to the facility [17]. These changes are unlikely to be made by the original architecture, engineer and contractors, adding to the already complex task. However, having well-documented as-built and as-renovated plans can assist the compliance officer to identify those responsible for the product.

3.7.7. Hygiene, Health and Safety Issues

Contamination by other materials in C&D waste mix is a common issue, particularly during demolition operations [34]. Furthermore, the separation of C&D waste for collection on construction/demolitions sites bears safety risks [90]. Therefore, a higher level of safety measures must be taken when offcuts or demolished materials are to be collected. These higher safety measures understandably have cost implications that impede the effective implementation of EPR in construction projects. Lastly, the real and perceived safety issues pertaining to using low quality or contaminated recycled C&D waste products, recovered under EPR schemes, can discourage producers from engaging in such activities due to the limited market for these products.

4. Discussion

This section discusses the ways to tackle the issues identified around the application of EPR scheme in the construction industry, followed by a proposal for future directions. The information provided can aid policymakers to develop a national C&D waste EPR policy that is sustainable and well-perceived by key stakeholders.

4.1. Recommendations for Alleviating Issues with EPR Implantation

As identified in the review, there are challenges towards the implementation of C&D sourced EPR policies. The following are some recommendations for minimising the impact of these challenges.

4.1.1. An Efficient Supply Chain System

A reverse logistics system has to be developed to return the product from the individual consumer to the producer [17]. This system has more complications than the original logistics wherein producers deliver a product to a local retailer, and the consumer takes care of the final distribution leg from the store to home. Several studies have shown that the cost to run a reverse logistic-based supply chain system runs several times higher than the usual supply chain [91–93]. Therefore, future efforts must target cost reductions for reverse logistics operations. There are successful examples of such operations for other waste materials in Australia that can inspire the C&D waste approach. For instance, the DHL Supply Chain Product Stewardship Program [87] has efficiently delivered PS objectives in partnership with big Australian retailers (e.g., Target, Officeworks and Harvey Norman) under the National Television and Computer Product Stewardship Program [51]. This program has achieved all targets in the first three years of operation by establishing an effective collection network from 177 permanent drop zones.

4.1.2. Encouraging Design for Disassembly

Manufacturers need to be motivated to consider the requirements of design for disassembly. This design arrangement can go a long way in separation and collection of products at the end of their useful lifetime. Furthermore, designs can be made to facilitate the collection of offcuts during construction activities. Accordingly, designers can collect information on materials lifetime and recyclability in the region, reducing the number of materials used and component sizes, using two-stage building systems and recording

changes during construction and operation [81]. The key to effectively encourage manufacturers to design with disassembly in mind is the development of a market for recycled C&D waste materials [1] and the engagement of builders in EPR schemes and utilisation of recycled materials [34].

4.1.3. Determining Responsible for C&D Waste

Currently, in Australia, there are no clear policies assuming stakeholders responsible for waste coming from C&D waste activities. Upon determining responsibility, a policy can equate them to polluters that need to contribute to the management of the end-of-life product. Therefore, communicating the responsibility of each of the stakeholders in a coordinated manner is crucial [82]. Even if an EPR policy is designed to make multiple stakeholders responsible, cost affordability for each stakeholder to fulfil their obligation should be taken into consideration.

4.1.4. Health and Safety Risk Management

Public authorities such as Safe Work Australia (SWA), the main authority responsible for managing construction worker health and safety (WHS) issues [94], can take a proactive role in developing policies for safe and hygienic separation and collection of C&D waste in Australia. Policies such as How to Safely Remove Asbestos Code of Practice 2011[95] and Recycling Construction and Demolition Material 2007 [96] would facilitate the successful implementation of EPR. The application of new technologies has been reported to result in improved management of WHS risks in relation to handling C&D waste materials. For instance, working conditions during demolition operations managed by BIM software is considered to be safer and is generally less expensive [97,98].

Government support and incentives for producing high-quality recycled C&D waste products with minimum safety concerns by producers that are registered to EPR programs, not only stimulate markets for these materials but also encourage other producers to engage in EPR schemes.

4.1.5. Product Documentation

Product labelling (documentation) is found to be an important step to achieve EPR objectives [13]. In the context of the construction industry, developing and keeping as-built and as-renovated plans, including a bill of quantities, should be mandatory. Having these registered in a permanent database would assist the task of application of EPR and similar schemes at later stages. The utilisation of new technologies such as BIM can facilitate construction product documentation. BIM can store and provide information on the composition and location of materials used in the built environment [99].

4.2. Future Direction for EPR Policy Development in Australia

From the review of the literature, it can be inferred that there is a general consensus among various stakeholders of waste and resource recovery in Australia on developing and implementation of EPR policies. Indeed, the relevance of EPR is gaining momentum in policy circle and several industries, including the construction industry. However, there exist certain caveats that need full consideration to achieve EPR primary objectives. The following are some recommendations for better development of EPR policies:

(1) The approach recommended particularly at the 2018 December 7th meeting of Environment Ministers urges the federal government to take the lead in the development of consistent national EPR policies instead of varied jurisdictional legislation [43]. EPR policy is usually most efficient when implemented nationally, as most companies affected by EPR operate at the national level [100]. To date, only a small number of schemes have been introduced nationally, but this must change urgently.
(2) As suggested by many wastes and resource recovery stakeholders, the policy approach on EPR has to shift from voluntary to mandatory arrangements [18,59].

(3) Any procedure taken towards the development of EPR policies must ensure that input from different stakeholders is obtained prior to implementation. An extensively agreed EPR policy would guarantee its sustainable application and successful outcome. Fourthly, due to the complex and particular nature of C&D waste management, the EPR policy developed must be specific to the setting of this stream. Such a policy can specifically take into account the common issues in C&D waste management. Therefore, it is worth engaging in research organisations such as universities to better determine the strategies required to overcome these precise issues.
(4) There are successful examples of EPR application in the construction industry and other sectors in Australia and overseas for individual waste materials. Learning from these experiences and building on the policies governing them would enhance the viability of potential EPR policies for C&D waste stream.

5. Conclusions

Sustainable management of C&D waste resources has become a priority in Australia and overseas. COVID-19 repercussions have urged policymakers to think differently to address the emerging issues relating to resource efficiency. Therefore, policymakers are now shifting towards a circular economy across various industries, including the construction industry. One of the policies that can assist with the implementation of CE within the construction industry is EPR. EPR schemes are also significant motivators for the creation and stimulation of market for C&D waste materials. Australia has set ambitious waste management targets, and EPR plays an important role in achieving these targets. Despite the successful application of EPR in non-C&D waste streams, notably e-waste materials for a few decades, Australia has a long way to establish a C&D waste specific national EPR policy. This could be primarily rooted in the complex nature of C&D waste management system and poor performance of the federal government in the design and imposition of relevant obligations.

This study sought to review the position of Australia in the design and implementation of EPR for C&D waste management both in practice and regulations. The study contributes to the body of knowledge in the "building construction management and project planning" (Australian and New Zealand Standard Research Classification Field of Research (FOR) code: 330202), "waste management, reduction, reuse and recycling" (FOR Code: 401106) disciplines. Currently, C&D waste is not considered as a priority waste stream in extant EPR schemes. The results of the review, however, showed that Australia has good potential for taking a leading role worldwide in the application of C&D waste-related EPR schemes. The review also highlighted the key role of producers (supplier and importers), government and public authorities (policymakers), industry associations, designers and architects, builders (construction contractors and workers) and the public in the development and implementation of EPR across Australia. Identifying the primary barriers towards the implementation of such EPR schemes, the study proposed five strategies that can assist in overcoming these barriers. The findings in this study serve to inform the development of EPR policies in Australia. Furthermore, the study proposes further studies in several areas pertaining to an EPR scheme policy and practice, including:

1. Studying the effectiveness of EPR in the Australian C&D waste management system;
2. Analysis of the impact of the implementation of an EPR scheme on key stakeholders;
3. Investigation of a construction materials supply chain model that is underpinned with an EPR scheme;
4. Exploring the industry's awareness and readiness for the implementation of an EPR scheme.

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