Construction and Building Materials 357 (2022) 129194

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Upcycling opportunities and potential markets for aluminium composite panels with polyethylene core (ACP-PE) cladding materials in Australia: A review

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ARTICLE INFO

Keywords:
Cladding
Waste
ACP
HDPE
rHDPE
Upcycling
Recycling
Circular economy

ABSTRACT

Many buildings worldwide have high fire-risk materials as part of their cladding. As governments in Australia strive to make buildings safer, it is expected that a large volume of end-of-life dangerous cladding will be replaced with safer materials. This high volume of hazardous materials might be upcycled into value-added products. This article presents a systematic market analysis and literature review in identifying current and potential uses for the raw materials used in hazardous ACP-PE cladding. The most promising areas were identified to be non-food-contact packaging (US$228 M p.a.), non-pressure pipes (US$30 M p.a.), footwear (US$5.29 M p.a.) and 3D printer filament (US$2.73 M p.a.)

1. Introduction and Background

In recent years, a problem of excessive waste generation and disposal at landfills has become a significant concern for many nations, and plastic waste is a big part of the problem. Many researchers and industry professionals are trying to find ways of bringing waste back to the material flow to make it more circular and sustainable. The construction industry is one of the largest contributors to waste and pollution, with a high amount of construction and demolition waste being disposed of every year. Governments around the world are forced to introduce new policies and regulations to minimise waste related to construction and demolition processes, as well as improve the safety of high-rise buildings. Although cladding materials do not contribute significantly to the waste stream from construction, they have become an urgent problem in many countries. In particular, highly flammable aluminium composite panels with polyethylene core (ACP-PE), that were commonly used in high-rise buildings, have caused multiple incidents around the globe. Shanghai fire in China in 2010, Al Tayer Tower fire in United Arab Emirates in 2012, Lacrosse Tower fire in Melbourne, Australia in 2014, Grenfell Tower fire in the United Kingdom in 2017 and other tragedies emphasised the need in changing the way we treat cladding. However, the Grenfell Tower incident is the one that gave rise to worldwide actions.

1.1. Grenfell Tower tragedy

The fire safety of cladding in buildings has been inadequately regulated until the Grenfell Tower incident that made governments change their view on cladding materials and building regulations. The Grenfell Tower incident was a tragic event that occurred on the 14th of June 2017 in London's neighbourhood of North Kensington. A fire had started shortly after midnight because of an ignition in a defective refrigerator on level 4 of the 24-storey apartment building [1]. The fire had quickly spread to other levels of the building and had taken over 60 hours to be completely extinguished by the fire brigade. The death toll of the incident was 72, and over 70 injuries were registered, having it declared as a "major incident" by the London Fire Brigade, and mentioned as "one of the UK's worst modern disasters" by BBC News [2].

The building had undergone renovations in 2015-2016 [3–5], and new cladding had been added to improve heating, energy efficiency and

Abbreviations: ACP, Aluminium Composite Panels; HDPE, High Density Poly Ethylene; rHDPE, recycled High Density Poly Ethylene.

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https://doi.org/10.1016/j.conbuildmat.2022.129194
Received 13 April 2022; Received in revised form 13 August 2022; Accepted 13 September 2022
Available online 18 October 2022

the overall appearance of the exterior. Two types of cladding materials had been used: Reynolux Aluminium sheets and Reynobond PE with a polyethylene core bonded with two coil-coated aluminium sheets [6]. The selection of these materials was primarily based on their relatively low cost [6].

This incident signified the start of the “cladding crisis” of the UK [7]. The tragedy stunned the entire global construction industry by the amount of damage made in such a short duration. Concerned parties were striving to know the causes of this incident, as well as finding ways to prevent similar tragedies. The UK took the first steps in paving the way for other countries. Immediately after the incident, the UK prime minister requested a public inquiry into the fire. The initial assessment identified ACM (aluminium composite material) cladding as one of the main reasons for such rapid destruction [4], and, as a result, ACP-PE (aluminium composite panel with a polyethylene core) cladding was announced non-compliant. Owners of social housing were asked to complete an audit of their buildings and send ACP (aluminium composite panel) samples for testing. Later, safety tests were announced to identify high-rise buildings at risk, and the government requested all cladding systems that had failed those safety tests to be removed from tall buildings. It was identified that over 600 of those high-rise buildings were fitted with high-risk cladding [8]. 120 buildings failed safety tests and were put forward for a rectification program as priority [9]. Following testing, a report published by Hackitt [10] called for significant changes to the regulatory system of buildings.

By mid-October, a ban on combustible cladding for tall buildings was introduced [11]. The “EWS1 (External Wall System) - Form” process and a “Waking Watch Relief Fund” were introduced to improve the safety of buildings [12,13]. Overall, £1.6B (equivalent to US$2.27 in January 2022) worth of funding was provided for the removal and replacement program of unsafe cladding from residential and private buildings [14,15]. By the end of 2020, all social sector and student buildings were fully remediated, and as of November 2021, 84% of identified buildings had completed remediation works [16].

1.2. Regulation on dangerous cladding in Australia

In Australia, the governments too changed the regulations related to cladding systems and public safety. Major changes were introduced to reform Victoria’s building regulatory system to ensure the safety of the community. The “Victorian Cladding Taskforce” was established by the Victorian Government on 3 July 2017 to investigate the amount of buildings with non-compliant cladding [17]. By 2020, the “State-wide Cladding Audit” was fully transferred from the Victorian Cladding Taskforce under the control of the Victorian Building Authority [18]. In response to the Grenfell Tower incident, the Australian government introduced a cladding rectification program in mid-2019 to remove all dangerous cladding from buildings and replace them with safer materials. This program is led by “Cladding Safety Victoria”, explicitly created for the administration and facilitation of this program [19]. Over 3200 buildings were inspected as part of Victoria’s “State-wide cladding audit” [20]. In 2018, the Building Minister’s Forum (BMF) commissioned a report emphasising the need to improve the effectiveness of compliance and enforcement systems for the building and construction industry in Australia [21]. As noted by Icon Plastics [22], one of the major problems in the Australian construction industry is product substitution which occurs after a builder wins a tender and tries to make savings (lower costs) by non-compliant products and systems [23]. DISER [24] highlighted the risks of product substitution without proper supervision and enforcement. Following this inquiry, building administrations of states and territories started making amendments to laws related to non-conforming and high-risk ACP products. The Australian Building Codes Board (ABCB) emphasised the need to improve clarity in the National Construction Code (NCC) and to remove loopholes in Australian Standards [17]. Over 3400 buildings in Australia were identified as having combustible cladding and became part of the cladding rectification program [25].

Unfortunately, as of June 2021, only 34% of private buildings had flammable cladding removed in Victoria, whereas 117 buildings are still underway [26]. Since waste disposal services are essential services in Victoria, they were not significantly affected by the restrictions because of the COVID-19 pandemic. However, the Victorian government tried to control the spread of the virus within the state by imposing restrictions, curfews, capacity limits and lockdowns [27]. The industry was also disrupted by vaccination-related protests of construction tradespeople, followed by a 2-week shutdown of the entire Victorian construction industry in September 2021 [28]. Therefore, it is expected that a large volume of end-of-life dangerous cladding will be replaced with safer materials in 2022-2023.

2 Research gap

Since cladding materials will be removed from Victorian buildings in such a large volume soon, there is a need to develop a solution for the safe and efficient treatment of cladding waste. Currently, most of the ACM waste is disposed of at landfills. There are organisations such as Recycled Aluminium Ltd (RE:AL) who are separating aluminium from the polymer core and providing recycled materials for further manufacturing. Their target is to recycle 100% of the ACP. However, even in the UK, who were the first to start the cladding removal initiatives, approximately 20% of ACM are still disposed of at landfills [29]. Therefore, there is an urgent need to develop solutions for dangerous cladding recycling and upcycling.

Cladding materials have a few upcycling benefits. First, large volumes of ACP-PE cladding will be made available through the cladding rectification programs. Therefore, upcycling facilities can be established for a large feedstock volume for new products. Additionally, cladding waste is homogenous, meaning that all ACP-PE panels contain aluminium and HDPE in them, making it easier to establish an efficient pre-processing (pre-sorting) line for recycling and upcycling.

There are several challenges related to ACP-PE cladding upcycling. One of them is the separation of aluminium sheets from the polymer core. This process is not fully developed in industry facilities yet, since previously, there was no urgent need to recycle these materials. Another problem is high flammability and combustibility of cladding materials that is creating fire safety complications in upcycling facilities. Also, when an elevated temperature is used to separate ACP-PE layers, toxic fumes could be released, adversely affecting both a factory’s nearby environment and the safety of the employees in a local context, as well as contributing to greenhouse gas emissions in the global context. When taking the processing complexity into consideration, there is considerable variation in the thickness of cladding produced by different manufacturers, which will require the adjustability in the separation process to cater to various sizes of panels to obtain recycled materials of suitable quality. Last, further research is required to evaluate the variance and all relevant statistical parameters in the quality of the HDPE core in panels from different manufacturers.

1.3. Aim and contribution of the present work

The aim of this work is to identify promising opportunities for ACP-PE cladding waste upcycling and analyse the suitability of this waste for the manufacturing of various products. The work contributes to our understanding of the potential recovery of ACP-PE cladding waste and its suitability for new applications. The novelty of the article is that it proposes strategies to upcycle hazardous ACP-PE cladding waste received from a cladding rectification program in order to redirect dangerous flammable claddings from landfills and make the construction waste industry more circular.

As follows, the rest of the article proceeds. Section 3 provides an overview of cladding materials, their composition, characteristics, and manufacturing processes. It also explains the difference between the terms “recycling” and “upcycling”, and how upcycling of claddings can contribute to the circular economy. Section 4 describes the methods used in this article. Section 5 presents the findings of the research. Section 6 discusses opportunities and challenges of cladding upcycling, as well as environmental, social, and economic benefits. Finally, Section 7 presents the conclusions, limitations and future research directions.

2. Cladding Materials

2.1. Cladding composition, characteristics and manufacturing processes

While cladding can be made of different types of materials, this article focuses primarily on Aluminium Composite Panels (ACP). ACP-PE is made of polyethylene (PE) Aluminium Composite Material (ACM) characterised by high flammability [30]. ACP-PE contains three main layers where one polymer core, which is usually 2 – 5 mm thick is sandwiched between two aluminium sheets which are usually 0.5 mm thick [31]. The polymer core is usually polyethylene of various grades. According to CSIRO [32], manufacturers usually use high-density polyethylene (HDPE) and low-density polyethylene (LDPE). This article will focus on ACP-PE cladding with a PE core comprising high-density polyethylene (HDPE). In the non-compliant ACP-PE cladding, the polymer core is up to 100% polyethylene which is highly flammable [33]. Safer alternatives to replace dangerous cladding exist, for example, ACP-FR (fire resistant) or solid aluminium panels. However, replacement works are still underway in Australia. The manufacturing process of ACP-PE is usually carried out under a formation line, precise coating line, and a continuous hot-rolling composite line [34].

Due to their composition, ACP-PE cladding is highly flammable and combustible [35]. ACP-PE cladding would ignite with any initial fire size over 500 kW [36], as air cavities between the wall and exterior cladding encourage radiative heat transfer where a chimney effect is created, promoting upward flame spread. ACM and PE materials show quick combustion after ignition [37]. A maximum heat release reaching 5 MW appears after 4 minutes [3] so those who live in buildings with unsafe cladding have a tiny chance of surviving a fire.

However, the risks of buildings with flammable cladding go beyond just homeowner physical vulnerability [38]. They also affect their wellbeing by increasing anxiety, and feeling stressed in an unsafe environment increases tension between neighbours [39]. Furthermore, Australian homeowners are at risk of potential costs for cladding rectification or in case of a fire, as well as double the insurance costs and rectification costs quoted between AU$30,000 and AU$12M (equivalent to US$21,500 and US$8.6M, respectively) [25].

Since ACP-PE cladding bears such a high risk, in compliance with the Australian federal and state regulations, they are required to be inspected and tested, and where necessary, be removed from the buildings and replaced with safer materials. Because of a cladding rectification program, 4 million square meters of non-compliant combustible ACP-PE cladding are to be removed from Australian buildings [40]. The critical treatment alternatives of end-of-life cladding include landfill disposal, export to developing countries, or recycling locally. Landfill disposal is hardly a desirable choice because of prolonged decay times and the high risk of combustibility and flammability. Further, because of high volumes of cladding, it will be a significant burden for Australian landfills. Export is also not a viable choice, especially after the waste export bans. Therefore, to ensure sustainability and a circular economy, there is a need to find ways of ACP-PE treatment locally in Australia. Recycling and upcycling opportunities for ACP-PE cladding exist. Therefore, this article explores upcycling options for high fire risk building cladding materials.

2.2. Upcycling vs Recycling (Definitions of "upcycling" and "recycling")

The difference and relationship between "recycling" and "upcycling" need to be identified. The term "recycling" is typically used to describe the process or action of converting waste into reusable materials. The term "upcycling", on the other hand, is commonly identified as reusing materials or objects in a way that creates a product of higher value or quality than the original one [41] . Upcycling has lots of benefits compared to normal recycling. It takes into consideration customers' needs and demands and creates a new product that is of high value and required by consumers. The trend of upcycling is emerging in various parts of the world, such as Hong Kong, Malaysia, the USA, and the UK [42]. However, there is not much evidence of upcycling facilities being developed in Australia, particularly for flammable cladding.

2.3. Cladding as part of the circular economy

The concept of circular economy has become increasingly popular in recent years in finding solutions to the scarcity of resources and various challenges arising from climate change. Many researchers are currently working on developing waste-to-resource strategies for various materials [43–45].

The most relevant review on end-of-life alternatives and targeted valorisation options for plastics was presented by Briassoulis et al. [46], however, it focused on bio-based materials and processing methods rather than regular HDPE, its promising products and markets. Another related review by K. Q. Nguyen et al. [47] presented possible testing methods for recycled HDPE (rHDPE) pipes which is essential because without appropriate inspection and quality control methods we will end up with non-compliant HDPE products again. Some researchers reviewed applications of plastic waste coming from landfill to manufacture new products. For example, Rahman et al. [48] and Sofi et al. [49] examined the application of HDPE to construction and road materials. Also, Ferdous et al. [50] considered using rHDPE from landfill waste to produce household containers, whereas Abeysinghe et al. [51] targeted the performance of recycled plastic in concrete. In the related areas of non-HDPE waste stream, Loh et al. [52] discussed the application of recycled plastic as void formers for the elements of façade. However, none of these articles covered upcycling opportunities for specifically cladding waste materials, their requirements, relevant standards and promising markets.

ACP-PE cladding materials can be a big part of the circular economy model because of their composition: both aluminium and HDPE are highly recyclable and valuable for further manufacturing (upcycling). Scrap aluminium is widely used in construction, aircraft manufacturing, as well as in various household items. Recycling of aluminium has been widely used since the early 1900s, coming to its peak after the second world war, while HDPE upcycling is still a developing field [53]. Since the volume of cladding that can be collected from demolished or retrofitted buildings is large, the potential for peripheral benefits, such as job creation and technological uptake is significant. However, there is a need to establish an effective business model of using cladding waste to create new value-added products and increase circularity. This article investigates the opportunities for ACM cladding waste to be used to manufacture value-added products.

3. Method

To achieve the aim of this work, the authors applied a six-step method (Fig. 1).

In Step 1, a preliminary literature review was conducted on cladding materials, their composition, key characteristics, and manufacturing processes. Additionally, the differences between recycling and upcycling, and the potential of cladding materials to contribute to the circular economy were reviewed. The outcomes of this review are presented in Section 3 of this article. HDPE was selected as the primary material because of the high amount of it being sent to landfills. Aluminium was excluded from this survey because of its high demand in Australia with many potential buyers and high price for scrap material depending on its grade, normally around AU$0.20 to AU$1.50 per kilogram (equivalent to US$0.14 and US$1.07, respectively) [54]. The authors acknowledge that there are other potential sources of HDPE

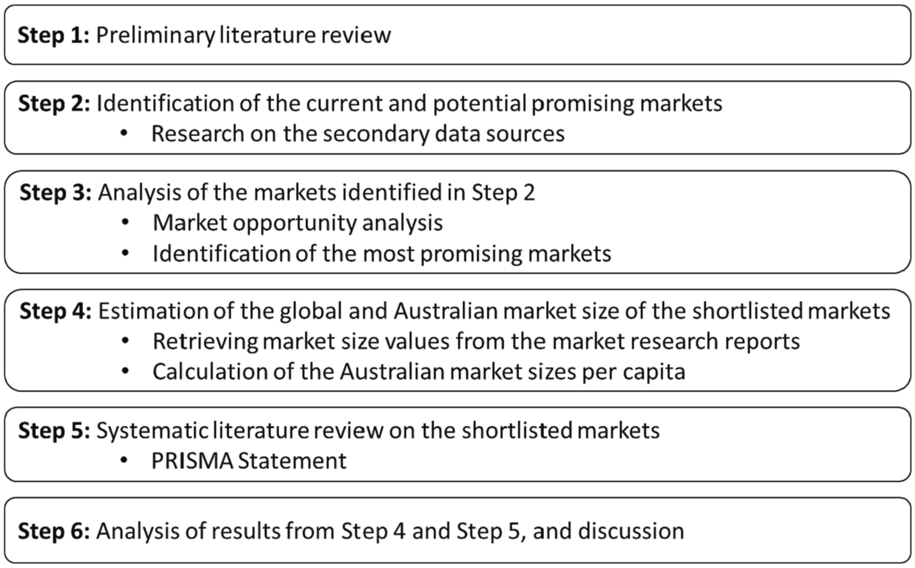

Fig. 1. Research steps followed

material. However, given the situation that waste cladding is going to impose a significant interim load on the landfill and environmental burden, this article focuses on how HDPE from cladding can be upcycled to reduce landfill burden. It is not the intention of this article to discuss the treatment and processes for HDPE coming from sources other than cladding.

In Step 2, based on the results of the preliminary literature review, the markets for rHDPE were identified through the use of secondary data sources. The secondary data sources included industry peak body reports, trade journals, manufacturers' websites, market reviews, governmental reports, white papers, and standards to which manufacturers comply. Besides the current markets, the markets identified included potential markets as well.

In Step 3, once the markets were identified as possible upcycling streams for HDPE material, these markets were thoroughly researched using secondary data sources and a market opportunity analysis. This analysis was used as suggested by [55] to identify the most attractive markets with the highest probability of success. As a result, the authors shortlisted the most promising opportunities for the application of rHDPE from cladding materials.

In Step 4, Australian and global market size values were obtained from market research reports between 2020 and 2021 to identify either the largest markets available or the niche markets with high potential for growth in the next few years. When Australian data was not available, local market sizes were calculated per capita using the latest numbers for the total population provided by the Australian Bureau of Statistics – 25,739,300 for Australia and 6,649,200 for Victoria [56]. Market sizes for 2022 and 2025 were estimated using compound annual growth rate (*CAGR*) using Equation (1):

$$Market\ Size_{Year\ n+1} = Market\ Size_{Year\ n}\ (1 + CAGR) \quad (1)$$

In Step 5, the results of the market analysis were further augmented by a systematic literature review of research articles in the appropriate target markets. The systematic review was conducted using the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)" statement since it improves transparency of a reported systematic review [57].

The literature search was carried out using abstract and citation databases: Scopus, Web of Science, and IEEE Xplore Digital Library for peer-reviewed articles published in English from January 2005 until November 2021, and comprised of the fields "article title"; "abstract"; and "keywords". Keywords for the search were identified based on a preliminary examination of the available literature and previous reviews that were conducted on related topics, an in-depth discussion about the commonly recurring themes. Appropriate synonyms for these keywords were identified based on an agreement of six authors to increase the probability of identification of all relevant publications. Boolean operators (AND, OR) were used to write syntax. The authors used the following search terms for query: ("recycl*" or "upcycl*") and ("hdpe*" or ("high-density" and "polyethylene") or ("high" and "density" and "polyethylene")) and (("packaging" or "container" or "tray" or "crate" or "box" or "bottle" or "plastic bag") or ("plumbing" or "pipe" or "pipes") or ("construction" or "composites" or "nanocomposites" or "cement" or "concrete" or "roof" or "flooring" or "insulation" or "road" or asphalt") or ("agriculture" or "horticulture") or ("textile" or "fabric" or "yarn" or "clothing" or "clothes" or "apparel") or ("shoe" or "footwear") or ("toy") or ("stationery" or "pen" or "pencil") or ("netting" or "mesh" or "fishnet" or ("fish" and "net") or ("oyster" and "mesh")) or (("3D" and "printing") or ("3D" and "printer" and "filament") or ("additive" and "manufacturing"))). Initial database searches generated 368 publications, including 19 additional studies that were sought from reference lists of retrieved studies and review articles (Fig. 2). Following the removal of duplicates, articles not written in English, and irrelevant citations based on fast screening, 175 publications were further assessed for selection. Given the study scope and data acquisition requirements, original studies were eligible to include in this review when the work: 1) met the raw material and manufacturing process criteria; 2) specified the products produced from HDPE. A total of 73 studies met all the selection criteria and were included in the final data synthesis of this review. Relevant documents were collected and organised in EndNote 20. Lastly, the findings were analysed and discussed in Step 6.

4. Findings

The most common types of HDPE processing such as extrusion, blown film extrusion, mesh extrusion, injection moulding, rotational moulding and blow moulding together with examples of resulting products are summarised in Fig. 3.

In total, 21 markets were analysed: plastic packaging and film, water supply and sewage, architecture and construction, agriculture and horticulture, medical and laboratory equipment, household items and furniture, safety and recreation, maritime and fishing, stationery and toys, shoes and apparel, aircraft manufacturing and 3D printing. The most promising markets were shortlisted. The market size varies significantly and is summarised in Fig. 4. The more detailed information

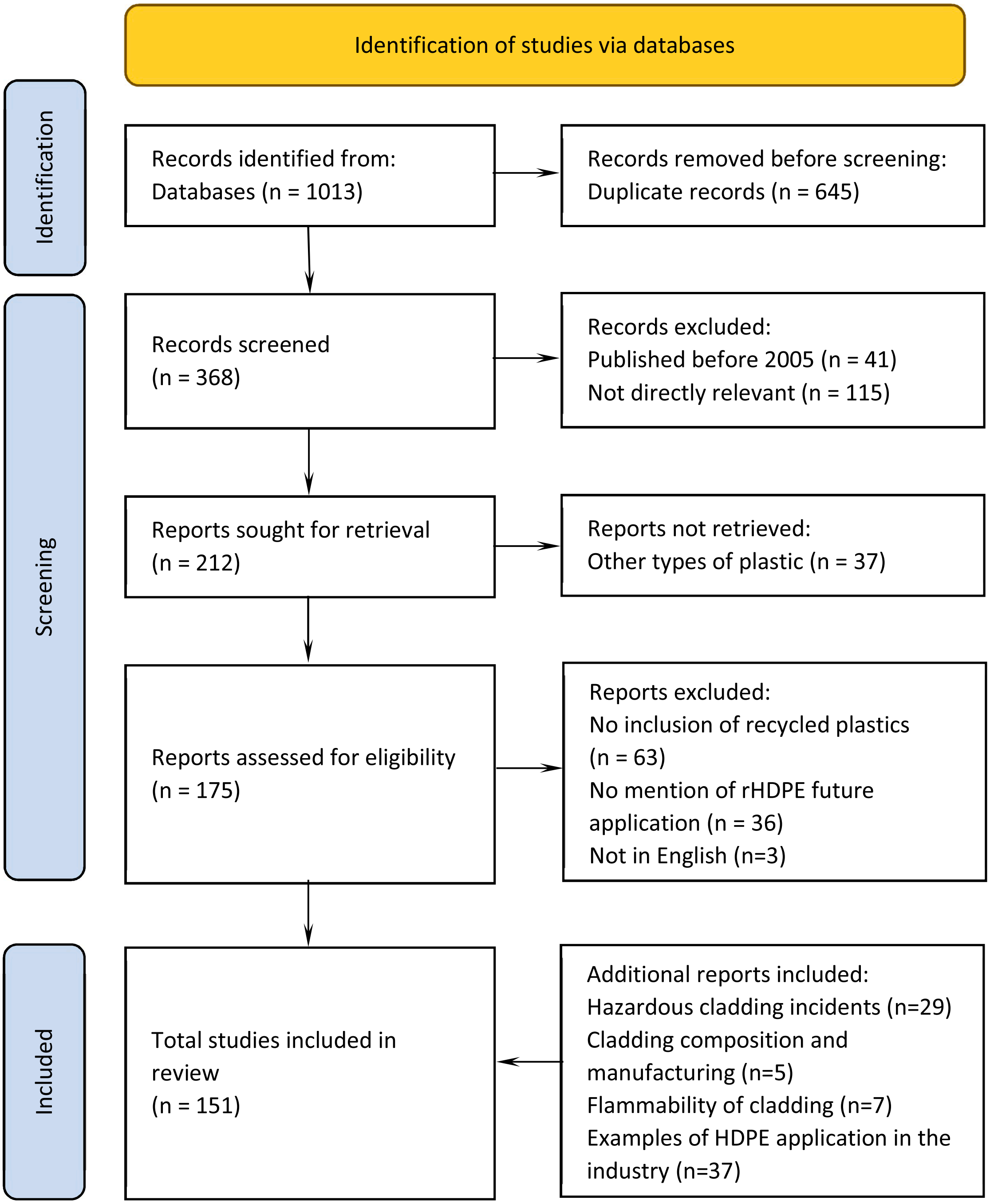

Fig. 2. PRISMA flow diagram

is provided in Supplemental File Table 1.

Further analysis of available literature enabled to shortlist the most well-researched markets to identify limitations and challenges that could affect HDPE upcycling. The markets with the most significant research include packaging, construction, piping, 3D printing, agriculture, shoes, toys and textiles and they are presented in Table 1.

5. Discussion

From our findings, a few promising potential areas are identified for further discussion. These areas were chosen based on the upcycling potential in the markets identified as well as the ability to reduce the burden on landfills.

5.1. Packaging

The most prospective market identified by this work is plastic packaging (both household and industrial applications), with a total market size in 2022 forecasted to reach US$2.82 B p.a. in Australia and US$728.93.06 M p.a. in Victoria (Fig. 4). The packaging market would include such products as bottles, containers, trays, squeezable tubes, and flexible plastic. In particular, the retail volume for HDPE bottles in Australia is estimated to reach 886.79 M units p.a. by 2025 (Fig. 4). When analysing the biggest market segment suitable for cladding upcycling, which is home care packaging, the retail volume in Australia is estimated to reach 251.31 M units p.a. in 2025 with 177.86 M units p.a. related directly to HDPE bottles (Fig. 4).

Further, there is a high demand for packaging owing to the growth in

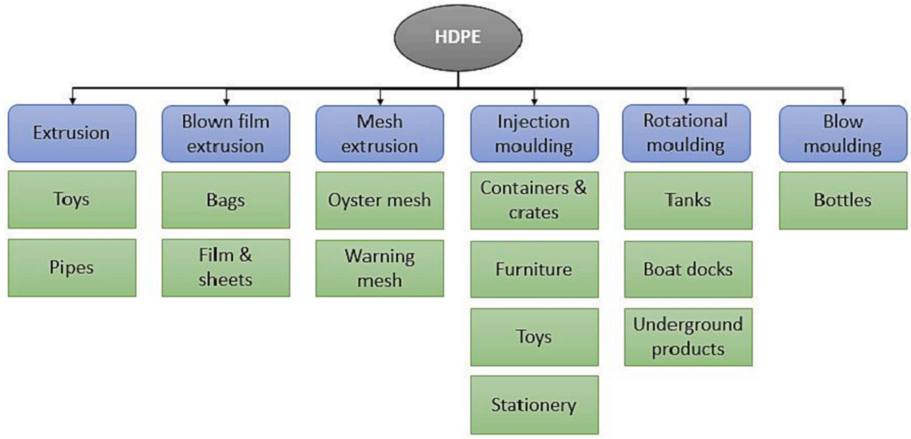

Fig. 3. Products manufactured from HDPE by processing type

Fig. 4. Potential markets and their respective estimated market sizes in Australia

eCommerce during the COVID-19 pandemic. With Melbourne spending almost 9 months in lockdowns, many including those who may have preferred offline shopping before the pandemic were forced to make their purchases online, and online household sales showed a sharp increase. This shift from offline to online shopping would require extra plastic packaging. For example, when purchasing clothes in-store, Melburnians would either buy a plastic bag to fit all the items or use their own reusable bag. In contrast, when ordering clothes online, each item is typically packed in its individual plastic bag and then compiled in either another plastic bag or a cardboard box. Therefore, plastic packaging demand in eCommerce can be expected to show further growth. Moreover, since this shift to eCommerce has been occurring over the last two years (2020-2021), there is a chance of a permanent change in customers' behaviour and a continuing increase in online shopping in

Table 1
Current knowledge and required further research.

Market Identified	Segment identified	Significant research identified	Further research is needed in this area	References
Packaging	Wide-application packaging materials	Research is available on the deterioration of thermal properties of the polymer material. Mechanical properties (tensile strength, compressive and flexural strengths) for raw and recycled HDPE (rHDPE) are equivalent. To reach the optimum properties, the polymer should have a mix with lower than 50% of rHDPE. To prolong the useful cycle of a final product, co-extrusion with virgin PE and ethylene-vinyl alcohol are recommended.	Impact of adding post-consumer rHDPE to different virgin feedstocks on final product performance need to be investigated. Rheological properties of virgin and rHDPE need to be further explored.	[58–67]
	Contact with food packaging	Recycled plastic can be used for contact with food packaging at room temperatures and below. However, a closed and controlled loop is required when no contamination is ensured. It is acceptable to use rHDPE 99% of which was obtained from end-of-life packaging in food applications.	Contact with food of different mixes of rHDPE should be further investigated. Degradation products of additives and polymers need to be further investigated.	[68,69]
	Milk bottles	Contamination levels of post-consumer flake samples are similar to virgin HDPE. Direct food contact is possible in bottle-to-bottle systems. Degradation is less relevant for bottles because of their lifespan. Recycling single type of plastics provides higher quality rPE.	Shelf-life testing and migration testing are further needed. Other types of contaminants that are not removed during washing: glue residues, printing ink residues, additives should be further explored.	[70–73]
	Non-contact food packaging	rHDPE is appropriate to produce non-contact food packaging. When blended with virgin resins, high temperature causes high creep behaviour.	The odours related to detergent bottle production should be further researched.	[60,61,66,74]
	Film	rHDPE can be used to produce the plastic film. To reduce defects, the processing temperature needs to be increased and twin-screw extruders should be used.	Defects in recycled materials should be further investigated.	[75]
Construction	Mortar, cement, concrete	rHDPE can be used to produce composite mortar, cement mixtures, and as coarse aggregate in self-compacting concrete. rHDPE reduces compressive strength and ultrasonic pulse velocity (UPV) but increases ductility. Overall mechanical performance is lower than HDPE-free mortar. When mixed with cement, it improves its workability.	rHDPE can be used in cementitious materials, but further investigation of its acoustic insulation is necessary.	[76–79]
	Blocks, beams, bars, panels, railings, decking, flooring, roofing	Multiple studies focus on composite materials made of rHDPE that can be used for various building blocks, beam structures, panels, bars, boards, railings, trellis, roofing battens, fencing, retaining walls, bearers and joints for decking and flooring. rHDPE has the potential to at least partly replace concrete, timber, steel because of its weather and UV resistance.	It is difficult to ensure the quality of the feedstock. There are also concerns about uneven mixing at the processing stage, voids clusters, and therefore lower impact strength. It is necessary to identify what is the optimal way of processing and what additives can improve the quality of the products.	[51,58,76,80–93]
	Natural fibre composites	Studies focusing on environmentally friendly composites with rHDPE reinforced with natural fibres such as hemp or banana pseudo stems. Different formulations are investigated. These materials have a strong potential to be used for low load-bearing structures.	Further investigation is needed to identify what formulations can provide stronger mechanical properties. Further studies are needed to investigate residue elimination in rHDPE in order to improve mechanical properties.	[82,94–96]
	Agricultural waste composites	Multiple studies focus on composites containing rHDPE and various types of agricultural waste: durian peel fibres, peanut hulls, wheat straw flour, chicken feathers. In these formulations, composites have improved flexural properties and tensile elastic modulus	Further research can focus on the improvement of the impact strength of composite materials from rHDPE and agricultural waste.	[97–100]
	Nanocomposites	rHDPE can be used in nanocomposites. The melt flow index of rHDPE is increasing after being recycled three times. With an increase in the frequency of recycling, there is a decrease in crystallinity and the average molecular weight of rHDPE.	Nanocomposites containing rHDPE have lower mechanical properties with an increase of rHDPE content.	[101,102]
	Road materials	rHDPE can be used in road construction materials with a percentage of up to 2% as a modifier for road aggregates and 5-10% in bitumen and asphalt. rHDPE improves temperature susceptibility, elasticity, rutting performance indicator and fatigue performance	Increased content or rHDPE without compromising Marshall stability and flow need to be further researched. Various mix designs of asphalt concrete and bitumen need to be further investigated.	[81,83,84,103,104]

(*continued on next page*)

Table 1 (*continued*)

Market Identified	Segment identified	Significant research identified	Further research is needed in this area	References
	Electrical applications	There are a few studies on how rHDPE can be used in electricity-related applications, including electrical insulation, high-voltage supercapacitors, electromagnetic interference shielding.	How can mechanical, thermal, and processing qualities of rHDPE be improved by various additives.	[105–107]
	Green roof drainage	rHDPE has the potential to be used as a drainage layer in green roof designs because of its low weight.	Further tests are needed to ensure the most optimal specifications for this application.	[108]
Pipes and fittings	High and moderate pressure pipes	Pressure pipes and pipes with moderate pressure: 2-step extrusion method to process rHDPE into pipe-grade HDPE by adding antioxidants in the second step to avoid reaction with the dicumyl peroxide DCP can be used as an initiator agent that decomposes into free radicals under thermal treatment to capture the hydrogen molecules of the polyethylene chain.	Further research required to obtain rHDPE providing the same functionality as virgin plastic.	[109–111]
	Gravity pipes, drainage, culverts	rHDPE is suitable for gravity sewer pipelines, culverts and drainage applications since they have less strict quality requirements. Service-life expectancy and durability of rHDPE vs virgin HDPE pipes. LCA – rHDPE drainage pipes would require low energy requirements and production costs.	To improve the qualities of material of recycled HDPE, need to reduce contamination levels and improve the sorting and recycling process to increase the amount of tie molecules in HDPE materials.Effect of environment and service conditions on the pipe service life. Innovative recycling processes need to be developed so that rHDPE has equivalent performance to the virgin HDPE pipes. The life cycle cost of bio-HDPE is higher than virgin HDPE because of processing and might be less favourable to the manufacturers because of higher costs.	[59,112–118]
	Landfill leachate pipes	rHDPE is more suitable for landfill leachate collection pipes than for pressure pipes. The addition of recycled HDPE compounds has no significant effect on the behaviour of gravity pipes since the pipe deflection ratio and settlement of the soil surface are almost equivalent to the virgin HDPE.	More research is required on the durability of landfill leachate pipes from rHDPE.	[112]
3D printing	3D printed items	rHDPE can be used up to 45% of the formulation to achieve appropriate tensile strength, compressive strength to be used in 3D printing. HDPE is currently used less often than acrylonitrile butadiene styrene plastic pellets. However, it has good potential because of its recyclability.	In 3D printed housing, concrete of a flat roof, compared to archer one, fails because of the maximum tensile strength.The influence of temperature, the distance between layers, deposition speed on final product characteristics need to be further tested.	[119–127]
Agriculture, forestry and fishing	Particleboards, wetted pads	In agricultural applications, rHDPE can be used for netting covering, particleboards and Wetted pads for evaporative cooling systems. Particleboards made with 20% rHDPE have higher water resistance and mechanical strength.	HDPE netting showed 13% less weed infestation than PP covers and did not affect the chemical composition of zucchini.Water resistance of particleboards could be further improved by adding wax and surface finishing processes.	[128–130]
	Fishing nets	rHDPE can be used to produce fishing nets		[131]
Footwear	Shoes	rHDPE is suitable for shoe outsoles because of its flexibility.	Nanocomposites for shoe soles could be further developed by investigating various material mixes for better mechanical properties.Limited research has been done on rHDPE application for footwear application.	[58]
Toys	Plastic toys	Rapid identification of different types of plastics (LDPE, HDPE, rHDPE) can be used for toy manufacturing through laser-induced breakdown spectroscopy.	Studies on rHDPE application for toys and the required characteristics is required.	[132]
Textiles	Textiles	Nonwoven fabric can be produced from rHDPE.	More research on the performance of rHDPE for textile application is required, including durability and environmental resistance.	[61,84,133,134]
Automotive	Automotive parts	A variety of automotive parts could be produced from rHDPE.	More research on the performance of rHDPE for automotive applications is required, particularly in relation to safety requirements.	[133]
Sports equipment	Rails, attachment hooks, playgrounds	rHDPE is appropriate for sports equipment application.	More research on the performance of rHDPE for sports equipment application is required.	[133]

the following years.

Regarding recycled products and sustainable packaging, Ranta et al. [77] believe there are significant cultural and cognitive barriers to a shift to recycled products, since people tend to choose those products that they are familiar with rather than selecting new products. However, with an increase in environmental awareness, care for the planet and a recent trend of so-called environmentalism, there is a high chance of increasing demand for recycled materials and sustainable packaging by both brands and consumers. A recent survey [135] showed that a third of consumers were more likely to choose a product if its packaging contained recycled materials. Therefore, proper communication and advertising are necessary to improve consumers' awareness and increase sales of packaging made of rHDPE.

From an economic perspective, there are other factors affecting the demand for recycled plastic packaging. Demand for recycled plastic material is generally affected by the procurement decisions of the raw material depending on the required volumes, quality and price [135]. Therefore, collaboration with potential buyers would increase the commercial viability of recycled plastic packaging production. Further, the competitive viability of HDPE recycling depends on the crude oil prices as often brands are reluctant to pay a premium for recycled materials. It was estimated that a crude oil price of US$63 - US$69 would ensure the price advantage of recycled plastics [136]. Moreover, some legislations introduce special taxes and regulations in relation to recycled materials. For example, the UK government announced a tax on plastic packaging containing less than 30% of the recycled component to go into effect in Spring 2022 [135]. If Australia follows the UK example, a substantial increase in recycled plastic for packaging can be expected.

However, there are also a few risks that need to be considered prior to entering the plastic packaging market. With the recent trends of plastic waste reduction, there is a possibility of a decline in the market. For example, ALDI stores in the UK and Ireland substituted plastic packaging of toys with paper [137]. Similarly, John Lewis & Partners removed plastic wrapping from the greeting cards sold in their UK stores [137].

In terms of manufacturing processes and costs of plastic packaging, there are three main types of processes: blow moulding, blown film extrusion and injection moulding. Blow moulding is used for the manufacturing of various types of bottles. The process is relatively easy and requires the installation of blow moulding machines in the production line. Blown film extrusion is used to produce different types of bags, such as grocery bags, resealable bags and freezer bags, as well as film and sheets. It requires a blown film extrusion machine. Injection moulding has wider use. An injection moulding machine can produce various containers and crates, as well as plastic furniture (tables, chairs, waste bins), toys, stationery and safety railings. Therefore, injection moulding machines in the production line would help to diversify the company's portfolio.

Lastly, it is essential to note that the lifespan of a new upcycled product should be taken into consideration. Some containers and trays could be used up to 50 years, whereas most bags and flexible packaging normally have single to multiple uses. Therefore, stronger demand for these products can be expected.

The plastic packaging market would be the most beneficial direction for companies whose strategy relies on broad targets because of a high volume of products in demand.

5.2. Pipes and fittings

Pipes for water supply and sewerage, as well as plastic fittings, were identified as another promising area for HDPE upcycling. The HDPE pipes market is estimated to reach US$403M p.a. in Australia and US $104.11M p.a. in Victoria by 2025 (Fig. 4). Future growth is assured by increased urbanisation and infrastructural development. As forecasted by The City of Melbourne [138], by 2040, the population of Melbourne is expected to grow by 80%, which would require over 56,000 new dwellings to be built each year to accommodate the increasing population. Essentially, new developments would require all the utilities, including potable water supply, sewerage and drainage to be provided.

Another potential use is in upgrading of the current water supply and sewage systems. For example, Barwon Water, a company based in Geelong, Victoria, replaces up to 20 km of damaged or old pipes every year [139]. As pipes gradually degrade over time, it is expected that the demand for HDPE pipes will be quite steady in the following years.

Even though a lot of research has been done on how rHDPE can be used to produce pipes, rHDPE pipes are still inferior to pipes made of virgin resins. Various studies have worked on finding a perfect blend with acceptable qualities, and 50% rHDPE to 50% virgin HDPE has showed the most optimal performance and durability (Table 1). However, rHDPE pipes still have a higher risk of cracking compared to pipes produced from raw HDPE. As shown in Table 1, the most suitable segments for upcycled HDPE are gravity sewer systems and drainage pipes. This is due to lower quality requirements for their use and consequent lower processing costs. For these applications, rHDPE pipes have an appropriate deflection ratio and settlement of the soil surface. However, additional research is required to investigate further on how different blends of rHDPE with virgin HDPE provide the optimal mechanical properties, as well as high durability and service-life expectancy. More studies are needed to identify what additives could enhance tensile strength, flexural performance and impact resistance of the pipes made of recycled resins.

The plastic pipes and fittings market would mostly benefit companies whose strategic direction aligns with broad targets and relatively low cost.

5.3. Footwear

Another promising area identified by the authors is footwear, in particular shoe manufacturing. Because of the peak of fast-fashion trends, we can see increased footwear consumption rates [140], with the market size estimated to reach US$20.49M p.a. in Australia and US $5.29M p.a. in Victoria by 2025. It is particularly true because of the changes in the population composition, with Generation Z now covering approximately 50% of growth in consumer spending [141]. Also, currently, there is a high demand for customisation, first, for comfort and second, to express individuality and show personal fashion style [142]. rHDPE could be used as a material for shoe soles, as well as the outer skin of the shoe and various decorations. Several companies such as Nike, Feetz and United Nude are developing shoe customisations over the use of 3D printing technologies [143].

More importantly, a recent trend in environmental responsibility in Generation Z is increasing customer loyalty to environmentally-focused companies with a solid commitment to sustainability [144]. Therefore, a strong connection can be built between the customers and a shoe manufacturer using materials from sustainable sources.

Using rHDPE for custom shoe manufacturing would cover only a small segment of the market. However, upcycling would ensure a strong competitive advantage, and a high premium for new products could be applied. This would be a good choice for a company with a strategy of having a differentiated product or occupying a market niche.

5.4. 3D printing

With the popularity of additive manufacturing in recent years, 3D-printed products have become more common in our lives. HDPE can be used as a filament (thermoplastic feedstock) for 3D printing because of its low price, versatility and recyclability. With the trends of sustainability and circular economy, there is a need to use sustainably-sourced materials for 3D printing. rHDPE from cladding can be used to produce a wide variety of products, from simple plastic toys to complex models. Simple forms required by products such as toys can be manufactured by injection moulding. However, complex shapes may need a more sophisticated process, like 3D printing. Recent advancement in 3D printing technology has allowed complex shapes to be formed in a short time in a cost-effective manner. The recycling company can choose to either produce 3D printer filaments and sell them to manufacturers or install printers next in the processing line to upcycle cladding HDPE and create new, value-added products.

Although the local Australian and Victorian markets for 3D printing are relatively small (expected to reach US$10.57M p.a. in Australia and US$2.73M p.a. in Victoria by 2025), it is a fast-growing market with a CAGR of 28.1% [145]. As 3D printing can be used to manufacture items with customised complex designs, it would be a great choice for a company-differentiator who wants to take a niche market by creating unique products. For example, RJ Models took a niche of architectural model making with a model cost from US$100,000 to over US$1M [80]. This segment is an emerging market, and the competition is still quite low [146]. However, the biggest advantage of product complexity can also be the biggest challenge for a company entering this market. Since architectural models can be so complex, a workforce with appropriate skills, training and extensive experience is required to succeed in this market. Also, each design is unique and requires an individual approach to achieve the product requested by the buyer. Moreover, a lot of additional equipment is required for moulding, cutting and colouring the parts of the models. Therefore, establishing a 3D printing facility for architectural models will require a high initial investment.

5.5. Other products and markets

Construction industry could be a good target market for the use of rHDPE from cladding. The market size is relatively large, estimated to reach US$28.11M p.a. in Australia and US$7.26M p.a. in Victoria by 2025. A great amount of research has been done on the use of HDPE in composites as well as cement, concrete and asphalt for various applications. However, the authors do not include this market in the primary recommendation because of a scattered application and, thus, high variability of feedstock quality requirements.

The toy market, although big (estimated to reach US$99.03M p.a. in Australia and US$25.58M p.a. in Victoria by 2025), is not recommended because of safety concerns and toxicity issues related to materials recycled from construction waste. Since children, particularly of preschool age, tend to explore the world by putting various items in the mouth [147], toys made of rHDPE from cladding could cause significant health problems.

Textile, stationery and sports equipment markets are not recommended because of small Australian market sizes of US$1.15M, US $0.28M and US$1.4M p.a., respectively (estimation for 2025). Although agriculture and furniture have relatively large markets in Australia (US $33.74M and US$16.87M p.a., respectively), they are not recommended because of limited availability of research on the performance of rHDPE and quality requirements for these applications.

Medical and laboratory equipment could be a promising market for HDPE products. However, safety and chemical resistance are the main concern. More research is required to identify what additives would ensure rHDPE in a laboratory would not cause undesired chemical reactions.

Regarding automotive parts and aircraft manufacturing, safety is the main concern. If the material does not satisfy all the requirements, there is a high chance of cracks or other defects. These defects could cost people's lives.

The items described above all require product material to be of a certain purity for it to be used. Because of regulatory compliance requirements, the current state of technology does not allow plastics to be recycled safely in a cost-effective manner [148]. Therefore, these markets do not represent an economically viable choice for recycling plastic materials in cladding.

Another critical concern is aluminium waste from removed cladding. The initial assessment was conducted to identify the potential for aluminium upcycling. However, it was decided that aluminium could be just sold after being separated from the PE core. As per Scraps Metal [54], the scrap metal price for Aluminum in Australia varies between AU $0.20 and AU$1.50 (equivalent to US$0.14 and US$1.07, respectively). Aluminum is a highly demanded material, and there are a lot of potential buyers within Australia. Therefore, it is financially reasonable to sell it instead of establishing a production line for recycling and creating a new product. However, a more thorough make or buy analysis should be conducted to estimate all the costs and benefits related to aluminium upcycling.

5.6. Environmental, social, and economic benefits of cladding upcycling

A lot of plastic materials are buried in landfills every year in Australia. Leakages from landfills can contaminate the groundwater and aquifer. Also, this causes soil pollution, which has an adverse effect on crops and the food industry. Furthermore, waste decay is inevitably accompanied by emissions of carbon dioxide. This causes significant air pollution, degrades the quality of air and contributes to climate change.

Plastic can degrade over more than a thousand years [149]. Therefore, it is crucial to reduce the amount of potentially recyclable materials that are sent to landfill. The adverse environmental impacts can be significantly reduced if the materials sent to landfills is decreased.

There are two sides to the social benefits of cladding upcycling. First, if there is an opportunity for cladding upcycling, more cladding will be removed from the buildings in a short time. This will decrease social vulnerability for those over 64, under 5 and people with disabilities having a low chance of surviving a fire in a building with flammable cladding [38].

Second, upcycling essentially creates value-added products that are needed by the consumers [150]. Therefore, by upcycling cladding, we can meet consumers' specific demands in quality products.

The economic benefit is related to costs related to landfill maintenance. As of 2021, the waste levy rate for 2022-2023 is AU$110.79 per ton, and the fee for 2023-24 is 7.15 fee units for industrial waste in premises not in prescribed municipal districts [151] (one fee unit is AU $15.03, equivalent to US$10.75). Therefore, it will be more economically beneficial to send removed cladding to an upcycling facility instead of a landfill.

6. Conclusions

There are several opportunities for upcycling of polyethylene from hazardous aluminium composite panels with polyethylene core received from the cladding rectification program in Victoria. Depending on the stakeholders' strategic direction and competitive advantage, few promising upcycling areas were identified in this article.

If a company has capabilities to establish mass production at a lower cost, non-contact food plastic packaging and non-pressure pipes are recommended because of their large market sizes in Victoria of US$228 M and US$30 M p.a., respectively. Plastic packaging is a high contributor to landfill burden, with 452 Mt of plastic waste disposed at landfills every year. Since most of the packaging is used a few times, there is a stable demand for packaging products. On the other hand, HDPE pipes could have a stronger demand in the near future because of increasing housing demand resulting from migration and urbanisation trends in Australia.

If a stakeholder is pursuing a differentiator strategy and is eager to take up a niche market with a high premium on the products, shoes and 3D printing are promising markets with a strong customer preference. Although these markets are quite modest in Victoria (US$5.29M and US $2.73M p.a., respectively), they have a high growth potential because of a change in consumers' behaviours towards environmental awareness and care for the planet, as well as interest in customisation.

However, further research is needed on how these opportunities could be implemented. More studies should be conducted to identify the variability in the quality of the HDPE core from cladding because the quality of the feedstock would lead to the selection of the most suitable product to be manufactured. Further, since HDPE cannot be recycled an infinite number of times, there is a need to create a system for material tracking to create a truly circular economy.

CRediT authorship contribution statement

Olga Pilipenets: Formal analysis, Investigation, Data curation, Visualization, Software, Writing – original draft, Writing – review & editing. **Tharaka Gunawardena:** Validation, Supervision, Writing – review & editing. **Felix Kin Peng Hui:** Methodology, Supervision, Project administration, Writing – review & editing. **Kate Nguyen:** Writing – review & editing. **Priyan Mendis:** Conceptualization, Supervision, Funding acquisition. **Lu-Aye:** Validation, Resources, Visualization, Supervision, Project administration, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Acknowledgements

This work was supported by the Cooperative Research Centres Projects Round 8: CRCPEIGHT000084: Upcycling solutions for hazardous claddings and co-mingled waste, and the University of Melbourne Research Scholarship. The authors are also thankful to Mr Matt Marsh, Managing Director of Sebastian Property Services Pty Ltd, for his valuable suggestions.

References

[1] E. Potton, Grenfell Tower Fire: Background. https://researchbriefings.files.parliament.uk/documents/CBP-8305/CBP-8305.pdf, 2020 (accessed 22 October 2021).
[2] BBC News, Grenfell Tower: What happened. https://www.bbc.com/news/uk-40301289, 2019 (accessed 15 December 2021).
[3] E. Guillaume, T. Fateh, R. Schillinger, R. Chiva, S. Ukleja, Study of fire behaviour of facade mock-ups equipped with aluminium composite material-based claddings, using intermediate-scale test method, Fire and Materials 42 (2018) 561–577, https://doi.org/10.1002/fam.2635.
[4] M. Moore-Bick, The Grenfell Tower, Phase 1 Report -(accessed 20 November 2021, Inquiry Volume 1 (2019), https://assets.grenfelltowerinquiry.org.uk/GTI%20-%20Phase%201%20full%20report%20-%20volume%201.pdf,.
[5] A. Dow, L. Bourke, London fire: Grenfell Tower 'renovated with deadly cladding'. https://www.smh.com.au/world/london-fire-grenfell-tower-may-have-been-renovated-with-deadly-cladding-20170614-gwr9qf.html, 2017 (accessed 20 November 2021).
[6] S. Knapton, Grenfell Tower refurbishment used cheaper cladding and tenants accused builders of shoddy workmanship. https://www.telegraph.co.uk/news/2017/06/16/grenfell-tower-refurbishment-used-cheaper-cladding-tenants-accused/, 2017 (accessed 22 November 2021).
[7] G. Hammond, N. Brooker, England's cladding crisis creates 2m 'mortgage prisoners'. https://www.ft.com/content/913cc2ab-7fd5-4d41-a097-df408b4fa57d, 2020 (accessed 23 November 2021).
[8] P. Walker, R. Booth, Tests on 600 tower blocks find seven with Grenfell Tower-style cladding. https://www.theguardian.com/uk-news/2017/jun/22/flammable-cladding-found-on-other-flats-after-grenfell-fire-says-may, 2017 (accessed 20 November 2021).
[9] A. Welch, UK towers cladding test failures. https://www.e-architect.com/london/uk-tower-cladding-tests, 2017 (accessed 15 November 2021).
[10] J. Hackitt, Building a Safer Future (Final Report), accessed 22 November 2021, Independent Review of Building Regulations and Fire Safety. (2018), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/707792/Building_a_Safer_Future_-_foreword_and_summary.pdf,.
[11] India Block, UK government announces cladding ban following Grenfell Tower fire. https://www.dezeen.com/2018/10/01/grenfell-tower-fire-uk-government-announces-cladding-ban-news-architecture/, 2018 (accessed 20 November 2021).
[12] House of Commons, The cladding external wall system (EWS). https://commonslibrary.parliament.uk/the-external-wall-fire-review-process-ews/, 2021 (accessed 20 August 2021).
[13] DLUHC, Waking Watch Relief Fund. https://www.gov.uk/guidance/waking-watch-relief-fund, 2020 (accessed 16 November 2021).
[14] DLUHC, Remediation of non-ACM buildings. https://www.gov.uk/guidance/remediation-of-non-acm-buildings, 2020 (accessed 16 November 2021).
[15] FREP Committee, Cladding crisis and its impact on Londoners - Fire, Resilience and Emergency Planning Committee. https://www.london.gov.uk/sites/default/files/london_assembly_report_-_london_cladding_crisis_-_january_2021_002.pdf, 2021 (accessed 20 November 2021).
[16] DLUHC, Building Safety Programme. Monthly Data Release, England. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1025164/Building_Safety_Data_Release_September_2021.pdf, 2021 (accessed 16 November 2021).
[17] DELWP, Victorian Cladding Taskforce. Report from the Co-Chairs. https://www.planning.vic.gov.au/__data/assets/pdf_file/0019/426034/DELWP0124_Victorian_Cladding_Taskforce_Final_Report_July_2019_v9.pdf, 2019 (accessed 15 November 2021).
[18] VBA, Annual Report 2019/20. https://www.parliament.vic.gov.au/file_uploads/VBA_2019-20_Annual_Report__incorp_CSV__FINAL_KYPCgF7W.pdf, 2020 (accessed 15 November 2021).
[19] Cladding Safety Victoria, Act 2020. https://content.legislation.vic.gov.au/sites/default/files/2020-11/20-031aa%20authorised.pdf, 2020 (accessed 15 November 2021).
[20] W. Hosking, Flammable cladding: Crackdown on builders, surveyors and fire engineers linked to 790 properties statewide. https://www.heraldsun.com.au/news/victoria/flammable-cladding-crackdown-on-builders-surveyors-and-fire-engineers-linked-to-790-properties-statewide/news-story/61cc42738e011c23a62af3d6fe0cce28, 2021 (accessed 18 November 2021).
[21] P. Shergold, B. Weir, Building confidence – Improving the effectiveness of compliance and enforcement systems for the building and construction industry across Australia. https://www.industry.gov.au/sites/default/files/July%202018/document/pdf/building_ministers_forum_expert_assessment_-_building_confidence.pdf, 2018 (accessed 20 November 2021).
[22] Icon Plastics, About Icon. https://www.iconplastics.com.au/about/, 2010 (accessed 20 November 2021).
[23] B. Harrington, Non-conforming building products - Submission 149, RE: Inquiry into non-conforming building products – Implications of the use of noncompliant external cladding materials in Australia. https://www.aph.gov.au/DocumentStore.ashx?id=0fe8e04b-6098-4772-99b9-01bd4b19fd8f&subId=513034, 2017 (accessed 16 November 2021).
[24] DISER, Senate Economics References Committee's inquiry into non-conforming building products - The need for a coherent and robust regulatory regime. https://www.aph.gov.au/DocumentStore.ashx?id=13a783b3-00d0-4072-81c6-2c8d73d12023, 2020 (accessed 15 November 2021).
[25] D. Oswald, T. Moore, S. Lockrey, Combustible costs! financial implications of flammable cladding for homeowners, International Journal of Housing Policy (2021) 1–21, https://doi.org/10.1080/19491247.2021.1893119.
[26] V. Government, Cladding safety Victoria's projects. https://www.vic.gov.au/our-projects, 2021 (accessed 19 November 2021).
[27] CFMEU, Lockdown extended, capacity on sites to 25%. https://cfmeu-news.com.au/lockdown-extended-capacity-on-sites-to-25/, 2021 (accessed 20 November 2021).
[28] CFMEU, CFMEU Head Office declared a COVID-19 tier one exposure site. https://cfmeu-news.com.au/cfmeu-head-office-declared-a-covid-19-tier-one-exposure-site/, 2021 (accessed 20 November 2021).
[29] RE:AL, The UK's First ACM Recycling Company. https://www.linkedin.com/company/recycled-aluminium/, 2020 (accessed 15 October 2021).
[30] Facade Consultants Australia (FCA), The combustible cladding issue – What's it all about? https://facadeconsultants.com.au/the-combustible-cladding-issue-whats-it-all-about/, 2018 (accessed 10 November 2021).
[31] Facade Consultants Australia (FCA), A closer look at: Aluminum composite panel. https://facadeconsultants.com.au/a-closer-look-at-aluminium-composite-panel/, 2018 (accessed 10 November 2021).
[32] CSIRO, Fire Performance and Test Methods for ACP External Wall Cladding. Technical Report. https://www.planning.vic.gov.au/__data/assets/pdf_file/0028/505855/ACP-technical-report-by-CSIRO.pdf, 2020 (accessed 10 November 2021).
[33] VBA, Aluminium composite panels (ACP). https://www.vba.vic.gov.au/__data/assets/pdf_file/0010/97579/Aluminium-Composite-Panels.pdf, 2021 (accessed 15 October 2021).
[34] Alucoworld, Alucoworld | Aluminum composite panel production process. https://www.alucoworldpanel.com/alucoworld-%E2%96%8Ealuminum-composite-panel-production-process/, 2018 (accessed 15 October 2021).
[35] K. Nguyen, N.K. Kim, D. Bhattacharyya, A. Mouritz, Assessing the combustibility of claddings: A comparative study of the modified cone calorimeter method and cylindrical furnace test, Fire and Materials 46 (2) (2022) 450–462, https://doi.org/10.1002/fam.2981.
[36] T. Chen, A.C.Y. Yuen, G. Yeoh, W. Yang, Q. Chan, Fire risk assessment of combustible exterior cladding using a collective numerical database, Fire 2 (2019), Article 11. https://doi.org/10.3390/fire2010011.
[37] M.S. McLaggan, J.P. Hidalgo, J. Carrascal, M.T. Heitzmann, A.F. Osorio, J. L. Torero, Flammability trends for a comprehensive array of cladding materials, Fire Safety Journal 120 (2021), 103133, https://doi.org/10.1016/j.firesaf.2020.103133.
[38] D. Oswald, Homeowner vulnerability in residential buildings with flammable cladding, Safety Science 136 (2021), 105185, https://doi.org/10.1016/j.ssci.2021.105185.

[39] D. Oswald, T. Moore, S. Lockrey, Flammable cladding and the effects on homeowner well-being, Housing Studies (2021) 1–20, https://doi.org/10.1080/02673037.2021.1887458.

[40] J. Reedie, Is this the solution to our cladding disposal woes? https://www.architectureanddesign.com.au/news/ecoloop-fairview-cladding-disposal, 2021 (accessed 26 October 2021).

[41] C. Wegener, M. Aakjær, Upcycling – a new perspective on waste in social innovation, Journal of Comparative Social Work 11 (2) (2016) 242–260. https://doi.org/10.31265/jcsw.v11i2.143.

[42] M. Dickinson, Constructing a Culture Cycle: an Upcycling Waste Centre in PTA CBD, Mini Dissertation, MInt(Prof), Department of Architecture, University of Pretoria, 2018, p. 198.

[43] X. Chen, Y. Wang, L. Zhang, Recent progress in the chemical upcycling of plastic wastes, ChemSusChem, Chemistry-Sustainability-Energy-Materials 14 (19) (2021) 4137–4151, https://doi.org/10.1002/cssc.202100868.

[44] J. Choi, I. Yang, S.S. Kim, S.Y. Cho, S. Lee, Upcycling plastic waste into high value-added carbonaceous materials, Macromolecular Rapid Communications 43 (1) (2022), https://doi.org/10.1002/marc.202100467.

[45] A. Pacheco-López, A. Somoza-Tornos, M. Graells, A. Espuña, Synthesis and assessment of waste-to-resource routes for circular economy, Computers & Chemical Engineering 153 (2021), 107439, https://doi.org/10.1016/j.compchemeng.2021.107439.

[46] D. Briassoulis A. Pikasi M. Hiskakis End-of-waste life: Inventory of alternative end-of-use recirculation routes of bio-based plastics in the European Union context Critical Reviews in Environmental Science and Technology 49 20 2019 1835 1892 https://doi.org/https://doi.org/10.1080/10643389.2019.1591867.

[47] K.Q. Nguyen, C. Mwiseneza, K. Mohamed, P. Cousin, M. Robert, B. Benmokrane, Long-term testing methods for HDPE pipe - advantages and disadvantages: A review, Engineering Fracture Mechanics 246 (2021), 107629, https://doi.org/10.1016/j.engfracmech.2021.107629.

[48] M.T. Rahman, A. Mohajerani, F. Giustozzi, Recycling of waste materials for asphalt concrete and bitumen: A review, Materials 13(7) (2020), Article 1495. https://doi.org/10.3390/ma13071495.

[49] M. Sofi, Y. Sabri, Z. Zhou, P. Mendis, Transforming municipal solid waste into construction materials, Sustainability 11(9) (2019), Article 2661. https://doi.org/10.3390/su11092661.

[50] W. Ferdous A. Manalo R. Siddique P. Mendis Y. Zhuge H.S. Wong W. Lokuge T. Aravinthan P. Schubel Recycling of landfill wastes (tyres, plastics and glass) in construction – A review on global waste generation, performance, application and future opportunities Resources, Conservation and Recycling 173 2021 105745 https://doi.org/https://doi.org/10.1016/j.resconrec.2021.105745.

[51] S. Abeysinghe, C. Gunasekara, C. Bandara, K. Nguyen, R. Dissanayake, P. Mendis, Engineering performance of concrete incorporated with recycled high-density polyethylene (HDPE)—A systematic review, Polymers 13(11) (2021), Article (1885), https://doi.org/10.3390/polym13111885.

[52] T.W. Loh, J. Stehle, K.T.Q. Nguyen, The thermal resistivity of concrete façade elements containing novel recycled plastic void formers: An experimental and numerical investigation, Journal of Building, Engineering (2022), 104101, https://doi.org/10.1016/j.jobe.2022.104101.

[53] M. Schlesinger, Aluminum Recycling, 1st ed., CRC Press, Taylor & Francis Group, Boca Rotan, 2006.

[54] Scraps Metal Prices, Scraps metal (copper, steel) prices in Australia 2021. https://www.scrapsmetalprices.com/, 2021 (accessed 15 November 2021).

[55] P. Kotler, K. Keller, Marketing Management eBook, 15th, global ed., Pearson Education Limited, Boston, 2016.

[56] ABS, Australia's population grew by .2 per cent. https://www.abs.gov.au/media-centre/media-releases/australias-population-grew-2-cent, 2021 (accessed 19 December 2021).

[57] M.J. Page, J.E. McKenzie, P.M. Bossuyt, I. Boutron, T.C. Hoffmann, C.D. Mulrow, L. Shamseer, J.M. Tetzlaff, E.A. Akl, S.E. Brennan, R. Chou, J. Glanville, J.M. Grimshaw, A. Hróbjartsson, M.M. Lalu, T. Li, E.W. Loder, E. Mayo-Wilson, S. McDonald, L.A. McGuinness, L.A. Stewart, J. Thomas, A.C. Tricco, V.A. Welch, P. Whiting, D. Moher, The PRISMA 2020 statement: An updated guideline for reporting systematic reviews, BMJ (2021), Article n71. https://doi.org/10.1136/bmj.n71.

[58] L. Alexandrescu, M. Georgescu, M. Sönmez, M. Nițuică, Biodegradable polymeric composite based on recycled polyurethane and rubber wastes: Material for green shoe manufacturing, Leather and Footwear Journal 20 (3) (2020) 323–331. https://doi.org/10.24264/lfj.20.3.10.

[59] M. Alzerreca, M. Paris, O. Boyron, D. Orditz, G. Louarn, O. Correc, Mechanical properties and molecular structures of virgin and recycled HDPE polymers used in gravity sewer systems, Polymer Testing 46 (2015) 1–8, https://doi.org/10.1016/j.polymertesting.2015.06.012.

[60] I.R. Antypas, The influence of polyethylene processing on the plastic containers blowing, Journal of Physics: Conference Series 1515 (4) (2020), 042042, https://doi.org/10.1088/1742-6596/1515/4/042042.

[61] A. Arenas-Vivo, F.R. Beltrán, V. Alcázar, M.U. De La Orden, J. Martinez Urreaga, Fluorescence labeling of high density polyethylene for identification and separation of selected containers in plastics waste streams. Comparison of thermal and photochemical stability of different fluorescent tracers, Materials Today, Communications 12 (2017) 125–132, https://doi.org/10.1016/j.mtcomm.2017.07.008.

[62] G. Brown, G. McNally, J. Grabowska, P. Beaney, S. Cherry. (2010). Processing and performance of HDPE polymer blends including post consumer recycled HDPE. 68th Annual Technical Conference of the Society of Plastics Engineers, ANTEC 2010, Orlando, FL, 2010 https://www.scopus.com/inward/record.uri?eid=2-s2.0-77956690858&partnerID=40&md5=38c9cad86aed556c7ddb5fd1d0487eb3.

[63] V.S. Cecon, P.F. Da Silva, K.L. Vorst, G.W. Curtzwiler, The effect of post-consumer recycled polyethylene (PCRPE) on the properties of polyethylene blends of different densities, Polymer Degradation and Stability 190 (2021), 109627, https://doi.org/10.1016/j.polymdegradstab.2021.109627.

[64] S.P. Cestari, P.J. Martin, P.R. Hanna, M.P. Kearns, L.C. Mendes, B. Millar, Use of virgin/recycled polyethylene blends in rotational moulding, Journal of Polymer Engineering 41 (6) (2021) 509–516, https://doi.org/10.1515/polyeng-2021-0065.

[65] M.A. Md Ali, A. Abdullah, E. Mohamad, M.S. Salleh, N.I.S. Hussein, Z. Muhammad, S. Dahaman, Tensile properties of ternary blends for HDPE/PP/RECYCLE HDPE in blow moulding process, Journal of Advanced Manufacturing Technology 12(1 (2018) 31–42. Special Issue 2.

[66] N.C. Fei, S. Kamaruddin, A.N. Siddiquee, Z.A. Khan, Experimental investigation on the recycled HDPE and optimization of injection moulding process parameters via Taguchi method, International Journal of Mechanical and Materials Engineering (IJMME) 6 (1) (2011) 81–91.

[67] S.H. Rizvi, S.H. Masood, I. Sbarski, An investigation of mechanical, thermal and creep behaviour of recycled industrial polyolefins, Progress in Rubber, Plastics and Recycling Technology 23 (2) (2007) 97–110, https://doi.org/10.1177/147776060702300202.

[68] L. Coulier, H.G.M. Orbons, R. Rijk, Analytical protocol to study the food safety of (multiple-)recycled high-density polyethylene (HDPE) and polypropylene (PP) crates: Influence of recycling on the migration and formation of degradation products, Polymer Degradation and Stability 92 (11) (2007) 2016–2025, https://doi.org/10.1016/j.polymdegradstab.2007.07.022.

[69] V. Silano, C. Bolognesi, L. Castle, K. Chipman, J.P. Cravedi, K.H. Engel, P. Fowler, R. Franz, K. Grob, R. Gürtler, T. Husøy, S. Kärenlampi, W. Mennes, K. Pfaff, G. Riviere, J. Srinivasan, M.D.F. Tavares Poças, C. Tlustos, D. Wölfle, H. Zorn, V. Dudler, N. Gontard, E. Lampi, C. Nerin, C. Papaspyrides, A. Lioupis, M.R. Milana, Safety assessment of the process 'Morssinkhof Plastics', used to recycle high-density polyethylene and polypropylene crates for use as food contact materials, EFSA Journal 16(1) (2018), Article e05117. https://doi.org/10.2903/j.efsa.2018.5117.

[70] N. Hamidi, Upcycling postconsumer high-density polyethylene (PC-HDPE): Thermal stability and kinetics study of the filaments extruded from PC-HDPE, Journal of Macromolecular Science, Part B 61 (2021) 1–24, https://doi.org/10.1080/00222348.2021.1962571.

[71] S.H. Masood, S.K. Zanvar. (2005). Design and optimisation of a standard milk crate using FEM. Society of Plastics Engineers Annual Technical Conference ANTEC 2005 2005 Boston MA https://www.scopus.com/inward/record.uri?eid=2-s2.0-33644941070&partnerID=40&md5=a0df82b98e1dddb9fae78341d7c25b97.

[72] E.U. Thoden Van Velzen, S. Chu, F. Alvarado Chacon, M.T. Brouwer, K. Molenveld, The impact of impurities on the mechanical properties of recycled polyethylene, Packaging Technology and Science 34 (4) (2020) 219–228, https://doi.org/10.1002/pts.2551.

[73] F. Welle, Post-consumer contamination in high-density polyethylene (HDPE) milk bottles and the design of a bottle-to-bottle recycling process, Food Additives and Contaminants 22 (10) (2005) 999–1011, https://doi.org/10.1080/02652030500157742.

[74] H. Dany, W.W. Dhong, K.W. Jiat, T.K. Leong, N.Y. Yuhana, G. Tan, Deodorizing methods for recycled high-density polyethylene plastic wastes, Materiale Plastice 58 (3) (2021) 129–136. https://doi.org/10.37358/MP.21.3.5511.

[75] M. Salehi Morgani, E. Jalali Dil, A. Ajji, Effect of processing condition and antioxidants on visual properties of multilayer post-consumer recycled high density polyethylene films, Waste Management 126 (2021) 239–246, https://doi.org/10.1016/j.wasman.2021.03.005.

[76] A. Badache, A.S. Benosman, Y. Senhadji, M. Mouli, Thermo-physical and mechanical characteristics of sand-based lightweight composite mortars with recycled high-density polyethylene (HDPE), Construction and Building Materials 163 (2018) 40–52, https://doi.org/10.1016/j.conbuildmat.2017.12.069.

[77] V. Ranta, L. Aarikka-Stenroos, P. Ritala, S.J. Mäkinen, Exploring institutional drivers and barriers of the circular economy: A cross-regional comparison of China, the US, and Europe, Resources, Conservation and Recycling 135 (2018) 70–82, https://doi.org/10.1016/j.resconrec.2017.08.017.

[78] P.P. Prasoon, M.S.R. Kumar, G. Vaisakh, Experimental investigation on effect of partial replacement of coarse aggregate by plastic aggregate on M 40 grade self compacting concrete, International Journal of Civil Engineering and Technology 9 (6) (2018) 964–970.

[79] R. Juan, C. Domínguez, N. Robledo, B. Paredes, S. Galera, R.A. García-Muñoz, Challenges and opportunities for recycled polyethylene fishing nets: Towards a circular economy, Polymers 13(18) (2021), Article 3155. https://doi.org/10.3390/polym13183155.

[80] A. Abkowitz, RJ Models's flashy replicas of luxury homes; The model-maker creates intricate designs from its workshop in Shenzhen, China, Wall Street Journal. https://www.proquest.com/newspapers/rj-modelss-flashy-replicas-luxury-homes-model/docview/1683602754/se-2?accountid=12372, 2015 (accessed 15 December 2021).

[81] P. Ahmedzade, T. Günay, O. Grigoryeva, O. Starostenko, Irradiated recycled high density polyethylene usage as a modifier for bitumen, Journal of Materials in Civil Engineering 29(3) (2017), Article 04016233. https://doi.org/10.1061/(ASCE)MT.1943-5533.0001757.

[82] C. Angulo, S. Brahma, A. Espinosa-Dzib, R. Peters, K.M.E. Stewart, S. Pillay, H. Ning, Development of hemp fiber composites with recycled high density

polyethylene grocery bags, Environmental Progress & Sustainable Energy 40(4) (2021), Article e13617. https://doi.org/10.1002/ep.13617.
[83] M. Arabani, M. Pedram, Laboratory investigation of rutting and fatigue in glassphalt containing waste plastic bottles, Construction and Building Materials 116 (2016) 378–383, https://doi.org/10.1016/j.conbuildmat.2016.04.105.
[84] A. Arulrajah, E. Yaghoubi, Y.C. Wong, S. Horpibulsuk, Recycled plastic granules and demolition wastes as construction materials: Resilient moduli and strength characteristics, Construction and Building Materials 147 (2017) 639–647, https://doi.org/10.1016/j.conbuildmat.2017.04.178.
[85] M. Avella, R. Avolio, I. Bonadies, C. Carfagna, M.E. Errico, G. Gentile, Recycled multilayer cartons as cellulose source in HDPE-based composites: Compatibilization and structure-properties relationships, Journal of Applied Polymer Science 114 (5) (2009) 2978–2985, https://doi.org/10.1002/app.30913.
[86] X. Colom, J. Cañavate, F. Carrillo, J.J. Suñol, Effect of the particle size and acid pretreatments on compatibility and properties of recycled HDPE plastic bottles filled with ground tyre powder, Journal of Applied Polymer Science 112 (4) (2009) 1882–1890, https://doi.org/10.1002/app.29611.
[87] B. Haworth, D. Chadwick, L. Chen, Y.J. Ang, Thermoplastic composite beam structures from mixtures of recycled HDPE and rubber crumb for acoustic energy absorption, Journal of Thermoplastic Composite Materials 31 (1) (2018) 119–142, https://doi.org/10.1177/0892705716681836.
[88] A.C. Kılınc, M. Atagur, O. Ozdemir, I. Sen, N. Kucukdogan, K. Sever, O. Seydibeyoglu, M. Sarikanat, Y. Seki, Manufacturing and characterization of vine stem reinforced high density polyethylene composites, Composites Part B: Engineering 91 (2016) 267–274, https://doi.org/10.1016/j.compositesb.2016.01.033.
[89] S. Lim, J. Liu, K. Jayaraman, Extrusion and evaluation of saw dust-recovered HDPE composite bars, Advanced Materials Research 79–82 (2009) 299–302, https://doi.org/10.4028/www.scientific.net/AMR.79-82.299.
[90] E.C.D.B. Lustosa, C.H.S. Del Menezzi, R.R.D. Melo, Production and properties of a new wood laminated veneer/high-density polyethylene composite board, Materials Research 18 (5) (2015) 994–999, https://doi.org/10.1590/1516-1439.010615.
[91] C. Sica, A. Dimitrijević, G. Scarascia-Mugnozza, P. Picuno, Technical properties of regenerated plastic material bars produced from recycled agricultural plastic film, Polymer-Plastics Technology and Engineering 54 (12) (2015) 1207–1214, https://doi.org/10.1080/03602559.2014.1003228.
[92] P. Sormunen, T. Kärki, Compression molded thermoplastic composites entirely made of recycled materials, Sustainability 11(3) (2019), Article 631. https://doi.org/10.3390/su11030631.
[93] C. Xu, W. Jian, C. Xing, H. Zhou, Y. Zhao, H. Pan, X. Xiong, Flame retardancy and mechanical properties of thermal plastic composite panels made from Tetra Pak waste and high-density polyethylene, Polymer Composites 37 (6) (2016) 1797–1804, https://doi.org/10.1002/pc.23352.
[94] R. Chianelli-Junior, J.M.L. Reis, J.L. Cardoso, P.F. Castro, Mechanical characterization of sisal fiber-reinforced recycled HDPE composites, Materials Research 16 (6) (2013) 1393–1397, https://doi.org/10.1590/S1516-14392013005000128.
[95] A. Collet, M.V. Flach, P.A. Da Silva, A.L. Catto, C.R. Klauck, M.A.S. Rodrigues, V. D. Jahno, Recycling of post-consumer HDPE drug packaging with banana pseudostem fiber, Macromolecular Symposia 367 (1) (2016) 119–125, https://doi.org/10.1002/masy.201500161.
[96] J.L. Toupe, A. Trokourey, D. Rodrigue, Simultaneous optimization of the mechanical properties of postconsumer natural fiber/plastic composites: Phase compatibilization and quality/cost ratio, Polymer Composites 35 (4) (2014) 730–746, https://doi.org/10.1002/pc.22716.
[97] S. Charoenvai, Durian peels fiber and recycled HDPE composites obtained by extrusion, Energy Procedia 56 (2014) 539–546, https://doi.org/10.1016/j.egypro.2014.07.190.
[98] J. Martínez Urreaga, C. González-Sánchez, A. Martínez-Aguirre, C. Fonseca-Valero, J. Acosta, M.U. De La Orden, Sustainable eco-composites obtained from agricultural and urban waste plastic blends and residual cellulose fibers, Journal of Cleaner Production 108 (2015) 377–384, https://doi.org/10.1016/j.jclepro.2015.06.001.
[99] F. Mengeloglu, K. Karakus, Polymer-composites from recycled high density polyethylene and waste lignocellulosic materials, Fresenius Environmental Bulletin 17 (2) (2008) 211–217.
[100] Y. Yang, N. Reddy, Utilizing discarded plastic bags as matrix material for composites reinforced with chicken feathers, Journal of Applied Polymer Science 130 (1) (2013) 307–312, https://doi.org/10.1002/app.39173.
[101] A. Samariha, B. Bazyar, Effect of nanosilica and aluminum hydroxide on thermal, flammability, and morphology properties of nanocomposite made of recycled high-density polyethylene and OCC flour, BioResources 15 (2) (2020) 3382–3393. https://doi.org/10.15376/biores.15.2.3382-3393.
[102] S. Sánchez-Valdes, High-density polyethylene/recycled HDPE/nanoclay composites using an amine-alcohol modified polyethylene as a compatibilizer, Iranian Polymer Journal 30 (3) (2021) 297–305, https://doi.org/10.1007/s13726-020-00889-3.
[103] M.A. Dalhat, H.I. Al-Abdul Wahhab, Performance of recycled plastic waste modified asphalt binder in Saudi Arabia, International Journal of Pavement Engineering 18 (4) (2017) 349–357, https://doi.org/10.1080/10298436.2015.1088150.
[104] C.L. Simões, S.M. Xará, C.A. Bernardo, Life cycle assessment of a road safety product made with virgin and recycled HDPE, Waste Management and Research 29 (4) (2011) 414–422, https://doi.org/10.1177/0734242X10379146.
[105] Y.-M. Lian, W. Utetiwabo, Y. Zhou, Z.-H. Huang, L. Zhou, M. Faheem, R.-J. Chen, W. Yang, From upcycled waste polyethylene plastic to graphene/mesoporous carbon for high-voltage supercapacitors, Journal of Colloid and Interface Science 557 (2019) 55–64, https://doi.org/10.1016/j.jcis.2019.09.003.
[106] R. Mujal-Rosas, M. Marin-Genesca, J. Ballart-Prunell, Dielectric properties of various polymers (PVC, EVA, HDPE, and PP) reinforced with ground tire rubber (GTR), Science and Engineering of Composite Materials 22 (3) (2015) 231–243, https://doi.org/10.1515/secm-2013-0233.
[107] H. Xu, Y. Li, X. Han, H. Cai, F. Gao, Carbon black enhanced wood-plastic composites for high-performance electromagnetic interference shielding, Materials Letters 285 (2021), 129077, https://doi.org/10.1016/j.matlet.2020.129077.
[108] A. Naranjo, A. Colonia, J. Mesa, A. Maury-Ramírez, Evaluation of semi-intensive green roofs with drainage layers made out of recycled and reused materials, Coatings 10(6) (2020), Article 525. https://doi.org/10.3390/coatings10060525.
[109] I.-R. Istrate, R. Juan, M. Martin-Gamboa, C. Domínguez, R.A. García-Muñoz, J. Dufour, Environmental life cycle assessment of the incorporation of recycled high-density polyethylene to polyethylene pipe grade resins, Journal of Cleaner Production 319 (2021), 128580, https://doi.org/10.1016/j.jclepro.2021.128580.
[110] Y. Li, H. Xu, C. Wu, The effect of using the two-step extrusion method on the oxidation induction time value of recycled high density polyethylene, Polymer Journal 44 (5) (2012) 421–426, https://doi.org/10.1038/pj.2012.9.
[111] R. Schouwenaars, V.H. Jacobo, E. Ramos, A. Ortiz, Slow crack growth and failure induced by manufacturing defects in HDPE-tubes, Engineering Failure Analysis 14 (6) (2007) 1124–1134, https://doi.org/10.1016/j.engfailanal.2006.11.066.
[112] M.B. Ardakani, T. Ebadi, S.M.M.M. Hosseini, Effect of using postmanufacturer HDPE compounds on the behavior of landfill leachate collection pipes, Journal of Pipeline Systems Engineering and Practice 9(3) (2018), Article 04018007. https://doi.org/10.1061/(ASCE)PS.1949-1204.0000325.
[113] M.M.B. De Oliveira Sampaio, L.E. Pimentel Real, Polyethylene blends: Better formulations for recycled polyethylene, Macromolecular Symposia 321–322 (1) (2012) 208–211, https://doi.org/10.1002/masy.201251137.
[114] L. Nguyen, G.Y. Hsuan, S. Spatari, Life cycle economic and environmental implications of pristine high density polyethylene and alternative materials in drainage pipe applications, Journal of Polymers and the Environment 25 (3) (2017) 925–947, https://doi.org/10.1007/s10924-016-0843-y.
[115] L.K. Nguyen, S. Na, Y.G. Hsuan, S. Spatari, Uncertainty in the life cycle greenhouse gas emissions and costs of HDPE pipe alternatives, Resources, Conservation and Recycling 154 (2020), 104602, https://doi.org/10.1016/j.resconrec.2019.104602.
[116] G. Palermo, P. Vibien, K. Oliphant, T. Kosari, New test method to determine effect of recycled materials on corrugated HDPE pipe performance as projected by rate process method, Plastics, Rubber and Composites 36 (5) (2007) 213–218, https://doi.org/10.1179/174328907x191305.
[117] M. Pluimer L. McCarthy A. Welker E. Musselman Evaluation of corrugated HDPE pipes manufactured with recycled content underneath railroads Pipelines 2015 Conference: Recent Advances in Underground Pipeline Engineering and Construction 2015 Baltimore 10.1061/9780784479360.051.
[118] Y. Wang, L. Lu, Y. Hao, Y. Wu, Y. Li, Mechanical and processing enhancement of a recycled HDPE/PPR-based double-wall corrugated pipe via a POE-g-MAH/CaCO3/HDPE polymer composite, ACS Omega 6 (30) (2021) 19705–19716, https://doi.org/10.1021/acsomega.1c02354.
[119] S. Chong, G.-T. Pan, M. Khalid, T.-C.-K. Yang, S.-T. Hung, C.-M. Huang, Physical characterization and pre-assessment of recycled high-density polyethylene as 3D printing material, Journal of Polymers and the Environment 25 (2) (2017) 136–145, https://doi.org/10.1007/s10924-016-0793-4.
[120] J.F. Horta, F.J.P. Simões, A. Mateus, Large scale additive manufacturing of eco-composites, International Journal of Material Forming 11 (3) (2018) 375–380, https://doi.org/10.1007/s12289-017-1364-5.
[121] M.A. Kreiger, M.L. Mulder, A.G. Glover, J.M. Pearce, Life cycle analysis of distributed recycling of post-consumer high density polyethylene for 3-D printing filament, Journal of Cleaner Production 70 (2014) 90–96, https://doi.org/10.1016/j.jclepro.2014.02.009.
[122] G.-T. Pan, S. Chong, H.-J. Tsai, W.-H. Lu, T.-C.-K. Yang, The effects of iron, silicon, chromium, and aluminum additions on the physical and mechanical properties of recycled 3D printing filaments, Advances in Polymer Technology 37 (4) (2018) 1176–1184, https://doi.org/10.1002/adv.21777.
[123] C.G. Schirmeister, T. Hees, E.H. Licht, R. Mülhaupt, 3D printing of high density polyethylene by fused filament fabrication, Additive Manufacturing 28 (2019) 152–159, https://doi.org/10.1016/j.addma.2019.05.003.
[124] N. Singh, R. Singh, I.P.S. Ahuja, Recycling of polymer waste with SiC/Al2O3 reinforcement for rapid tooling applications, Materials Today, Communications 15 (2018) 124–127, https://doi.org/10.1016/j.mtcomm.2018.02.008.
[125] N. Singh, R. Singh, I.P.S. Ahuja, Thermomechanical investigations of SiC and Al2O3–reinforced HDPE, Journal of Thermoplastic Composite Materials 32 (10) (2019) 1347–1360, https://doi.org/10.1177/0892705718796544.
[126] F. Tahmasebinia, S.M.E. Sepasgozar, S. Shirowzhan, M. Niemela, A. Tripp, S. Nagabhyrava, K.K. Mansuri, F.-M. Zuheen, Criteria development for sustainable construction manufacturing in Construction Industry 4.0, Construction Innovation 20 (3) (2020) 379–400, https://doi.org/10.1108/ci-10-2019-0103.
[127] O. Uslu, Y. Aykut, Bicomponent and blended HDPE/LDPE filament porduction and usage in 3D printers, Tekstil ve Muhendis 28 (121) (2021) 1–15, https://doi.org/10.7216/1300759920212812101.
[128] P. Bucki, P. Siwek, A.L.M. Ojeda, Characterisation of two direct covers made of PP and HDPE in the organic production of zucchini, Fibres & Textiles in Eastern Europe 29 (3) (2021) 60–66, https://doi.org/10.5604/01.3001.0014.7788.

[129] B. Li, Y. Zheng, Z. Pan, B. Hartsough, Improved properties of medium-density particleboard manufactured from saline Creeping Wild Rye and HDPE plastic, Industrial Crops and Products 30 (1) (2009) 65–71, https://doi.org/10.1016/j.indcrop.2009.01.006.

[130] N. Soponpongpipat, K. Kositchaimongkol, Recycled high-density polyethylene and rice husk as a wetted pad in evaporative cooling system, American Journal of Applied Sciences 8 (2) (2011) 186–191, https://doi.org/10.3844/ajassp.2011.186.191.

[131] R. Juan, C. Domínguez, N. Robledo, B. Paredes, R.A. García-Muñoz, Incorporation of recycled high-density polyethylene to polyethylene pipe grade resins to increase close-loop recycling and Underpin the circular economy, Journal of Cleaner Production 276 (2020), 124081, https://doi.org/10.1016/j.jclepro.2020.124081.

[132] V.C. Costa, F.M.V. Pereira, Laser-induced breakdown spectroscopy applied to the rapid identification of different types of polyethylene used for toy manufacturing, Journal of Chemometrics 34(12) (2020), Article e3248. https://doi.org/10.1002/cem.3248.

[133] A. Fazli, D. Rodrigue, Phase morphology, mechanical, and thermal properties of fiber-reinforced thermoplastic elastomer: Effects of blend composition and compatibilization, Journal of Reinforced Plastics and Composites 41 (7–8) (2021) 267–283, https://doi.org/10.1177/07316844211051749.

[134] Q. Xu, H. Yi, X. Gao, J. Shi, D. Yao, Recycling of polyethylene bags into high-strength yarns without using melt processing, Polymer Engineering and Science 60 (2) (2020) 281–287, https://doi.org/10.1002/pen.25281.

[135] Mintel, The post-consumer recycled plastic quandary. https://clients-mintel-com.eu1.proxy.openathens.net/insight/the-post-consumer-recycled-plastic-quandary, 2020 (accessed 10 November 20021).

[136] Ernst & Young, Can repurposing drive your purpose? How chemical companies can leverage circular economy to create long-term value. https://www.ey.com/en_gl/chemicals/can-repurposing-drive-your-purpose-in-a-circular-economy, 2020 (accessed 12 November 2021).

[137] The Guardian, Waitrose to stop selling plastic toys in Christmas crackers from 2020. https://www.theguardian.com/environment/2019/oct/21/waitrose-to-stop-selling-plastic-toys-in-christmas-crackers-from-2020, 2019 (accessed 10 November 2021).

[138] The City of Melbourne, City of Melbourne Population and Jobs Forecasts 2020-2040. Summary Report 2021. https://www.melbourne.vic.gov.au/about-melbourne/research-and-statistics/Pages/city-forecasts.aspx, 2021 (accessed 18 November 2021).

[139] Barwon Water, Sewer mains replacement and rehabilitation. https://www.barwonwater.vic.gov.au/about-us/major-projects/sewer-mains-replacement-and-rehabilitation, 2021 (accessed 15 December 2021).

[140] IBISWorld, Footwear Retailing in Australia - Market Research Report. https://www.ibisworld.com/au/industry/footwear-retailing/408/, 2021 (accessed 11 November 2021).

[141] N. Johns, 2020's biggest footwear industry predictions: A Gen Z takeover, breaking with gender norms & more. https://footwearnews.com/2020/business/retail/gen-z-footwear-industry-consumer-habits-1202917310/, 2020 (accessed 26 November 2021).

[142] Goldstein Market Intelligence, Global customized footwear industry analysis: By product type, by distribution channel, by end user & by geography with COVID-19 impact | Forecast period 2017-2030. https://www.goldsteinresearch.com/report/customized-footwear-market-outlook-2024-globalopportunity-and-demand-analysis-market-forecast-2016-2024, 2020 (accessed 11 November 2021).

[143] D. Burrus, 3D printed shoes: A step in the right direction | WIRED. https://www.wired.com/insights/2014/09/3d-printed-shoes/, 2021 (accessed 24 November 2021).

[144] McKinsey & Co, The state of fashion 2019. https://www.mckinsey.com/~/media/mckinsey/industries/retail/our%20insights/the%20state%20of%20fashion%202019%20a%20year%20of%20awakening/the-state-of-fashion-2019-final.ashx, 2019 (accessed 10 November 2021).

[145] MarketsandMarkets, 3D printing filament market by type (plastics, metals, ceramics), end-use industry (aerospace & defense, medical & dental, automotive, electronics), region (North America, Europe, Asia Pacific, MEA, South America) - Global forecast to 2025. https://www.marketsandmarkets.com/Market-Reports/3d-printing-filament-market-267169690.html, 2020 (accessed 20 October 2021).

[146] Mordor Intelligence, 3D printing filament market - Growth, trends, COVID-19 impact, and forecasts (2022 - 2027). https://www.mordorintelligence.com/industry-reports/3d-printing-filament-market, 2021 (accessed 10 November 2021).

[147] J. Johnston, Early Explorations in Science, 2nd ed., Open University Press, Maidenhead, England, 2005.

[148] J. Hopewell, R. Dvorak, E. Kosior, Plastics recycling: challenges and opportunities, Philosophical Transactions of the Royal Society B: Biological Sciences 364 (1526) (2009) 2115–2126, https://doi.org/10.1098/rstb.2008.0311.

[149] A. Chamas, H. Moon, J. Zheng, Y. Qiu, T. Tabassum, J.H. Jang, M. Abu-Omar, S. L. Scott, S. Suh, Degradation rates of plastics in the environment, ACS Sustainable Chemistry & Engineering 8 (9) (2020) 3494–3511, https://doi.org/10.1021/acssuschemeng.9b06635.

[150] HM Treasury, The Green Book: Central Government Guidance on Appraisal and Evaluation. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1063330/Green_Book_2022.pdf, 2020 (accessed 20 April 2022).

[151] EPA Victoria, Waste levy | Environment Protection Authority Victoria. https://www.epa.vic.gov.au/waste-levy, 2021 (accessed 24 November 2021).