The Impact of Waste Plastic and the Role of Recycling Plastic in Reducing its Negative Impact towards Achieving a Net-Zero Society: A Case Study of Plastecowood

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ABSTRACT

The aim of this research is to improve the understanding on the role of recycling in achieving Net Zero goals pursued in the United Kingdom in the backdrop of the wider sustainability agenda. To achieve the aim of the study data was gathered on the company Plastecowood. Ten secondary internet sources and press releases about the company that discuss the dimensions covered by the research questions in regard to plastic recycling and other secondary data were utilized. A qualitative content analysis was conducted using NVivo software revealing important themes in the findings. Firstly, the analysis of this study found that Plastecowood contributed significantly towards Net Zero targets by trapping carbon emissions within their recycled products. Secondly Plastecowood reduced the health hazards associated with carbon emissions to the members of society. Thirdly there was a need to target certain elements when managing waste through recycling. A practical implication of this study is the averment that current recycling practices do not have the capacity to meet Net Zero goals and thus the need for stakeholders to find better efficient ways. Recycling of plastic should focus in producing high-quality recyclates and target strategic elements of the plastic value chain to achieve net zero goals.

Keywords: Plastecowood; Net Zero goals; Plastic waste management; Waste reduction; Recycling, Recycling Technology; Sustainable Development Goals

INTRODUCTION

The current trends in climate change have presented the need to adopt strategies tailored toward sustainable business. Population increase translates to an increase in waste output per capita, necessitating recycling as a mitigative measure [1]. Additionally, excessive lumbering presents a challenge in that deforestation threatens valuable tree species and decreases the percentage of forest cover per capita [2]. Plastecowood operates a business that recycles plastics into a sustainable alternative for timber, contributing to the realisation of an eco-friendly future in two simultaneous ways. The company is one of an emerging collective of enterprises trailblazing in sustainable profitability, which is the case where a business conducts profitable operations that are simultaneously eco-friendly.

Plastecowood is UK-based and specialises in producing Smartawood, a cost-effective wood-like product with the same desirable characteristics in wood, such as robustness and weather resistance [3]. Innovative processes have enabled the firm to price the product competitively. The firm had to differentiate itself to remain profitable in a highly competitive environment, focusing on sustainability and eco-friendliness as core attributes of its business strategy. Smartawood as a product is consistent with the United Nations NetZero goals: reduce greenhouse gas emissions to as close to zero as possible and allow natural processes to eliminate the remainder (UN, n.d.). Forests and oceans heavily facilitate these natural processes.

LPlastic waste is also a driver of the climate change crisis, with its proliferation in the last sixty years presenting an ecological challenge. Plastic is easily immobilised but not readily degraded, causing long-term odour emissions, deteriorating surface and groundwater quality, poisoning sites and adjacent land near landfills, and destabilising aquatic ecosystems ([4], [5]). The UK produces 4.9 million metric tonnes of waste annually, 75% of which ends as waste, while 92% of citizens are concerned about its management [6]. By simultaneously mitigating the impact of deforestation and the use of plastic waste, Plastecowood facilitates two pathways to NetZero's goals. The proposed study aims to understand the implications that Plastecowood has on the environment in terms of facilitating NetZero goals.

Plastic waste is a serious contributor to environmental pollution. The United Kingdom is one of the biggest contributors to global plastic waste. The average volume of plastic waste produced in the United Kingdom totals 3.7 million tonnes every year, which means that around 75% of the plastic consumed in the region is disposed of as waste [6]. The effects of poor plastic waste management on the region's systems are extensively negative. On average, 20% of plastic waste collected is managed, 50% is deposited in landfills, and 19% is incinerated, which is expensive and contributes to extensive carbon emissions [7]. Some of the mismanaged waste finds its way into waterways and, ultimately, into the ocean. Studies conducted on marine wildlife indicate that the waste is responsible for reducing reproducibility and the chances of survival, as well as leading to stunted growth and impaired development (Rist et al., 2016; [9] [10]. The environmental impact of plastic waste in landfills has been delineated in recent studies as the destabilization of ecosystems, reduced soil fertility, and aesthetic damage [11]. A recent report by Ballinger, Shanks, and Duffield [12]estimates that an energy generation project that utilizes plastic waste to generate energy will

produce more CO_2 emissions than landfills by 2035. This is in addition to the 232 million tonnes of CO_2 emissions attributed to plastic from the United States alone [13]. Therefore, proper plastic waste management is the key to alleviating the environmental threat posed by current waste management practices.

The role of recycling in plastic waste management is gaining increased attention. Idumah and Nwuzor [14] call attention to reducing available space for landfills and extensively discuss the role of various recycling methods as alternative municipal solid waste management methods. Present plastic waste production and management practices are forecasted to release2000 Mt of waste into ecosystems and landfills [15]. Faraca and Astrup [16] designate recycling as the preferred method of waste management and discuss plastic waste composition to aid recycling processes. In particular, Horvath, Mallinguh, and Fogarassy [17] recognise business solutions as the gateway to optimal plastic waste management. Milios, Davani, and Yu [17] consider high recycling targets and corollary recycling targets to be the future of waste management. Therefore, there is merit in understanding the role of recycling as a waste management strategy, especially in Plastecowood, a commercially viable solution with high recycling rates.

The role and efficiency of recycling in the achievement of Net Zero goals have not reached sustainable levels. Many of the best recycling practices are cost-intensive. Case in point, froth floatation is an effective but expensive means of recycling [18]. Current best plastic waste recycling practices are not efficient enough to meet Net Zero goals. The United Nations [19] estimates that GHG emissions will rise by 14% in 2030, which is against the Net Zero emission targets set in place. The United Kingdom has committed itself to reaching Net Zero emissions by 2050.

Additionally, it aims for a recycling rate of 65% under the Post-Brexit Resource and Waste Strategy [20]. Tallentire and Steubing (Tallentire & Steubing, 2020) recommend changes to the plastic value chaito improve recycling efficiency, such as providing financial incentives and consumer education to improve purchase intention. However, Plastecowood does not conduct consumer education, nor does it sell Smartawood at a price low enough to be considered a significant financial incentive; instead, it retails it at a competitive price. There is, therefore, a need to identify how Plastecowood contributes to meeting the UK's Net Zero goals. What is the importance of recycling promoted by Plastecowood? How significantly is recycling plastic waste reducing the negative impacts and playing a role in the UK's emission targets?

This case study aim to understand Smartawood's contribution to the United Kingdom's sustainability goals. The research uses Plastecowood as a case study to know how plastic recycling affects the environment. There is also the need to understand the role of Plastecowood in achieving NetZero goals. To this end, it will utilise qualitative content analysis.

MATERIALS AND METHODS

The goal of this research is to identify how plastic waste recycling is contributing to Net Zero goals. Specifically, this research aim to understand Plastecowood's role in attaining a Net Zero future. This paper uses Plastecowood as a case study from which recommendations and insights can be extrapolated to other similar players in the Net Zero agenda. The research includes a qualitative thematic analysis using NVivo software to extract insights from the data. The collection of relevant data for this research began in June 2022. The data collection is primarily based on the case study of Plastecowood and supported by ten secondary internet sources, i.e., press releases and journals related to the company's operations. The retrieval conditions: the theme is "recycling of plastic waste; the matching method is designated as accurate; check synonym expansion. Non-related journals, post-graduate theses, book reviews, and off-topic materials were eliminated to prevent the duplication of previous literature. The periodic parameters used for the case study data and journals were post-2016 and post-2018, respectively. NVivo 11 software was the main analytical tool in the coding process. The data from the case study is imported into the software alongside ten published internet sources and other online articles as raw material for analysis. The software is optimized for the analysis of qualitative data and processes qualitative input to give quantitative output.

The first step was importing data into NVivo's internal receptors. The software was then used to encode the contents of the case study and the ten internet sources in line with the program's rooted theory. Both automatic and manual coding are conducted primarily using descriptive language. In the first step of the initial generation of codes, there were the classification and summary of (1000) open codes, (15) spindle codes, and (3) selective codes based on Plastecowood's impact on the recycling of plastic waste. Based on those above, the three dimensions of this study are determined, for which the actual situation of each is analysed through the construction of the node matrix code. The composition and analysis of the first dimension – recycling as a form of waste management – is first conducted through literature research of the case study and the journals. The paper summed up the contents of the literature and analysed the research on the impact of plastic waste recycling as a form of waste management from the case study and the articles through coding analysis of the content. Second is the literature research on the Net Zero dimensions of Plastecowood. The research conducted on the impact of recycling plastic waste as a means of attaining Net Zero goals under the context of Plastecowood is the focus of this dimension. This research project studies the qualitative impact but considers the qualitative impact for a holistic analysis.

ANALYSIS AND RESULTS

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, and the experimental conclusion that can be drawn.

Analysis

Qualitative thematic analysis is the optimal methodology for this research. As a research methodology, it comprises identifying, analysing, and reporting patterns emergent from a set of data [22]. It involves intensive description and interpretation through coding and thematic construction. An added advantage of this method is its flexibility, as it is unbound by post-positivist, constructivist, or critical realist epistemological orientations [22]; [23]. Castleberry and Nolen [23] emphasize that using thematic analysis is contingent upon the study's goals. The method is optimal for investigating common or shared meanings, experiences, thoughts, or behaviours across a data set. Additionally, the method lies between the descriptive and interpretive poles of the continuum, suggesting that while it may not be suitable for theorising, it is well adapted to the understanding of perspectives and contextualisation of findings [23]. One drawback of the method is the untrustworthiness of data, stemming from the limited literature and the inconsistency and lack of coherence in producing themes due to flexibility [24]. To enhance the overall strength of the conclusion, this research will conduct thematic analysis using NVivo software, which facilitates and improves the research process [24]; [25]; [23]. The analysis was conducted using NVivo software. The advantages of the software have been expounded upon in earlier sections of this research as the convenience, ability to sift through large swaths of data akin to big data analysis, the systematic structuring and its role in maintaining researcher objectivity [26]. Furthermore, the software's capacity to handle a wide range of qualitative data and produce a reliable record makes it an appealing choice for this research. The secondary data used was from the case study supported by the ten secondary internet sources related to the operations at Plastecowood. The data was queried into the software's internal materials. The six steps of qualitative thematic analysis were strictly adhered to.

Qualitative thematic analysis comprises 6 phases: familiarisation with data, generation of initial codes, searching for themes, reviewing themes, defining and naming themes, and discussion of findings [24]; [25]; [22]. The sequence of steps enables the researcher to engage with the data and identify themes arising critically. NVivo software is one of the most powerful computer-assisted software available for qualitative research and easily facilitates the six phases mentioned above. With NVivo software, the researcher is confident in their potential to produce a strong and trustworthy conclusion from the vigorous analysis. Another advantage of the software is the record production, which can be relied upon to provide a systematic breakdown of the study's thought process and logical progression.

The unit of analysis is Plastecowood. The primary data collection was collected from business reports, press releases, the official Plastecowood website, and social media mentions. The documents collected were dated from the year 2016 going forward to provide a panoramic view of Plastecowood across time. The selection of potentially relevant documents was based on the study's objectives. The first step of data collection was the extensive consultation of background material. This was carried out through an in-depth exploration of the Plastecowood website, focusing on press releases and reports. Plastecowood's press articles page largely facilitated this.

Additionally, the researcher engaged with Plastecowood's social media handles and analysed its online community engagement. Moreover, the researchers conducted Boolean searches about Plastecowood on the Google search engine, Google scholar and social media websites such as Twitter, Instagram and LinkedIn. The main words searched were "Plastecowood" and "Impact". After a preliminary analysis, the most relevant documents were duly identified. Most of the content included reports, press releases, the official Plastecowood website and social media mentions. These documents provided the data for the research. Sampling in document analysis involves the placement of limits regarding time and/or specific events. This study placed an inclusionary criterion of being published during and after 2016. The data was then subjected to a qualitative thematic analysis using NVivo software, recorded in the next section.

The researchers took specific steps to avoid researcher bias. In a documentary acnalysis of parliamentary documents using applied thematic analysis, Mackieson, Shlonsky and Connolly [27] recommend strict adherence to the phases detailed in thematic analysis to reduce bias. Their sentiments are echoed by Taylor et

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al. [28]and Castleberry and Nolen [23], who add that the explicit statement of possible bias should be stated in the manuscript. While the process of document analysis as a method of data collection has not been sufficiently alienated in the literature, this researcher has endeavoured to state all the steps taken in the data collection process. The researcher recognises the potential role of personal bias, as the researcher is an enthusiast of sustainable development and generally supports environmentally friendly initiatives to mitigate climate change. However, this disposition cannot significantly inflate the findings nor alter the data analysis process if the correct steps are taken.

Additionally, the researcher specifically combed the literature for the negative impact of Plastecowood in an attempt to present a dual-sided picture of the unit of analysis. All points of possible bias were expressly stated in the notes and manuscripts used in the data analysis process. The data analysis method employed was thematic analysis using NVivo software. The data were analysed until saturation was reached. The results of the analysis are presented in the following section.

Results

Results of Thematic Analysis

A total of 10 papers and the case study on plastic wood were attached as internal files in NVivo and used to facilitate the coding analysis process and identify related concepts and themes. The parent nodes can be an indicator of a possible theme emerging from the transcriptions. Another of the major features that designated NVivo software for use in this study is how it facilitates sub-group analysis. Each theme had a subgroup that facilitated an in-depth discussion of the results. Multiple child nodes under each parent code may represent the subthemes or a set of related concepts at a lower level of the analysis. The coding process commenced by identifying passages and quotes related to plastic recycling. The processing of passages generated three nodes, which represented the major themes. The parent nodes and child that were generated include.

- Plastic Recycling and Net Zero
- Recycling waste management and reduction of greenhouse emissions
- Waste management and greenhouse emissions
- Recycling and its Role in Reducing the Negative Social Impact of Plastic Waste
- Health Hazards
- Recycling as Waste Management
- Challenges with plastic recycling
- Rate of recycling of plastic
- Recycled plastic wood as an effective method of plastic waste management

The figure below shows the parent nodes and children nodes.

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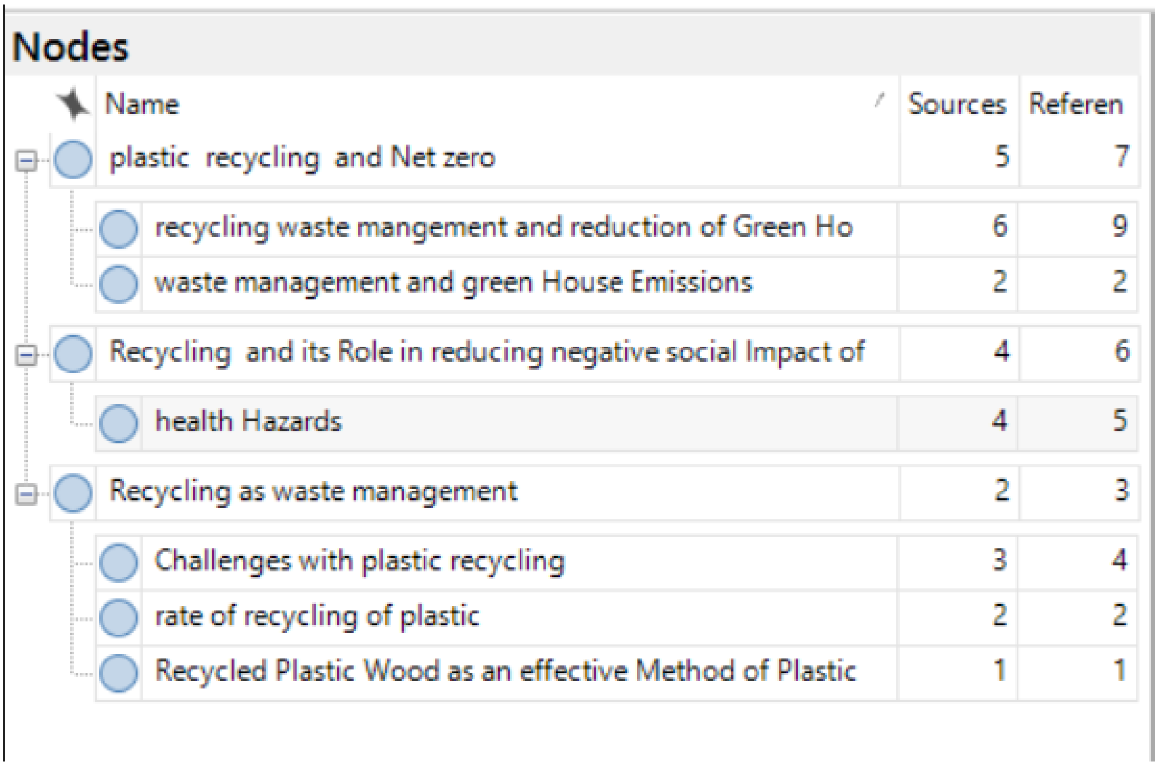
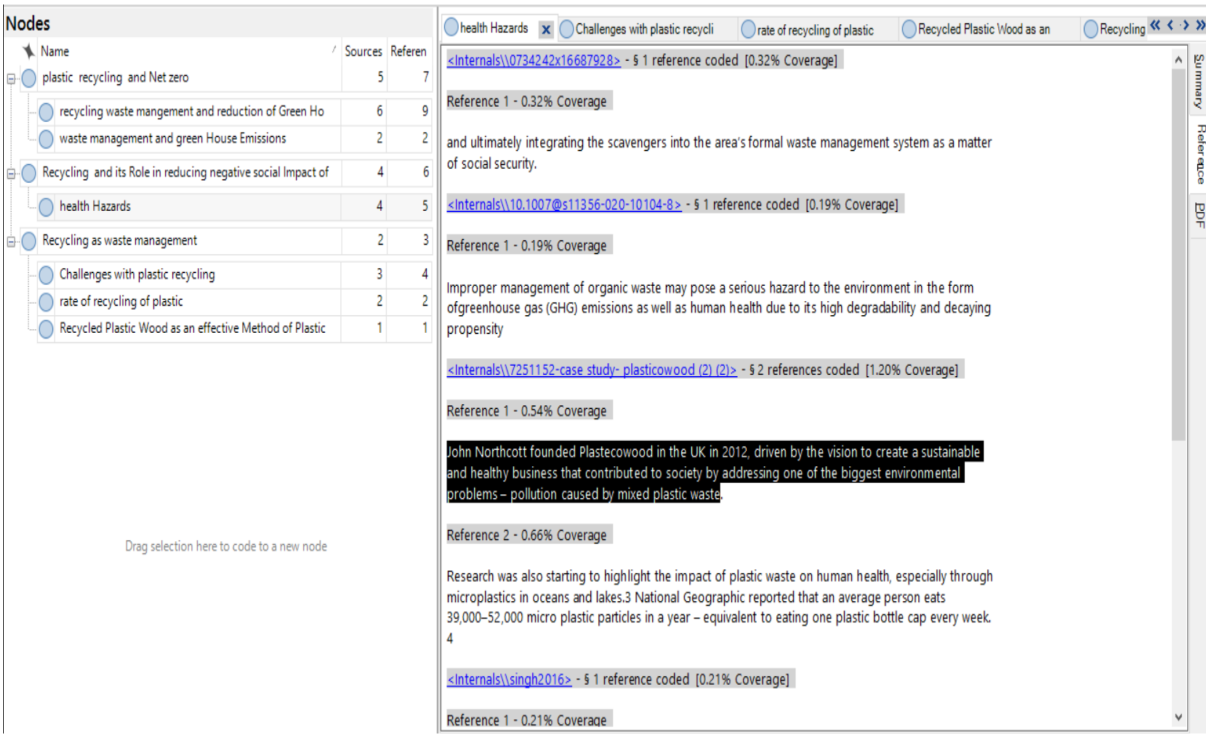


Figure 1. Parent nodes and children nodes

The coding process involved reading through each interview and coding the information related to the different Nodes. Each of the parent nodes is attached to the relevant passages from the transcribe, as shown in the example below;



Note: Example passages from the section of the transcription discussing recycling and its role in reducing negative social impacts such as health hazards

Figure 2: Example of Coding the Transcripts

Table 1. Summary of themes and subthemes from Qualitative Analysis

Parent Nodes (Themes)	Child Nodes (Subthemes)	Examples of quotes from Papers and Case study
Plastic Recycling and Net Zero	• Recycling waste management and reduction of greenhouse emissions	"Reducing emissions is possible if the use of plastics is decreased through either a reduced need for products or services fulfilled by plastics, reduced use of plastic materials to fulfill specific functions, or reuse of plastic products for the same function." "It also allowed me to tell an optimistic story – one where humanity makes a positive intervention to repurpose the unwanted and toxic into something sustainable, useful…. and hopefully carbon-neutral! This carbon-negative sculpture can be easily recycled into fresh construction materials when no longer required in its current form." ''Plastecowood is not only removing difficult-to-recycle plastic from the UK's waste stream but is also putting it to great use in the manufacture of a carbon-negative alternative to timber, steel, and concrete products.''
	• Waste management and greenhouse emissions	Smartawood ® (which comes with a minimum ten-year manufacturer's warranty) lasts many times longer than timber and never releases its captured carbon into the atmosphere. At the end of its long use time, it can even be fully recycled by the manufacturer into further Smartawood ® products. In contrast, wood rots over relatively short time periods and releases all the CO_2 captured as a growing tree straight back into the atmosphere.
		Plastecowood creates Smartawood from mixed recycled plastic packaging waste at its manufacturing facility in Bodelwyddan. The business estimates that each tonne of Smartawood manufactured uses more than 25,000 pieces of plastic packaging waste, saves 700kg of carbon from landfill or incineration, and prevents, on average, two and a half trees from falling. '' The production of plastics, as well as many other industries and value chains, are all connected to various sources of carbon lock-in,32 which create barriers to mitigating their climate impact. The business estimates that each tonne of Smartawood manufactured uses more than 25,000 pieces of plastic packaging waste, saves 700kg of carbon from landfill or incineration, and prevents, on average, two and a half trees from falling.

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Recycling and its Role in Reducing the Negative Social Impact of Plastic Waste	• Health Hazards	"The funding supports the business' purchase of two additional processing lines, which will triple its output of Smartawood – a carbon-negative alternative to timber – lumber and assembled products from 2,000 tonnes annually to 6,000 tonnes." ''Improper management of organic waste may pose a serious hazard to the environment in the form of greenhouse gas (GHG) emissions as well as human health due to its high degradability and decaying propensity.'' ''John Northcott founded Plastecowood in the UK in 2012, driven by the vision to create a sustainable and healthy business that contributed to society by addressing one of the biggest environmental problems – pollution caused by mixed plastic waste.'' "Plastecowood creates Smartawood at its manufacturing facility in Bodelwyddan from mixed recycled plastic packaging waste that is often rejected by other businesses because it is contaminated, or they cannot recycle it." "The firm on the Express Business Park was found guilty of breaching health and safety regulations after the Health and Safety Executive brought prosecutions."
Recycling as Waste Management	• Challenges with plastic recycling	"Although many plastic types are mechanically recyclable in theory, there are challenges linked to the complexity of collecting, sorting, and pre-treating plastic waste before the actual recycling process; these processes also degrade the polymers.'' " Management of waste is a complex process because of the requirement of various information from different sources such as influencing factors in waste generation, forecasts of vast quantities and reliable data."
	• Rate of recycling of plastic	" The recycling rates and the value of recycled plastic could increase and lead to a more economically viable mechanical recycling industry." '' The recycling rate of post-consumer plastic waste is high compared to other EU MS, at about 40% in 2016, and can be matched only with Germany and Czechia at about 38% recycling rate, respectively, in the same year [2]. This rate could be described as remarkable—despite being quite modest compared to other waste materials, e.g., paper—taking into account the fact that Sweden has significant overcapacity and reliance on waste incineration [23,24].''

	• Recycled plastic wood as an effective method of plastic waste management	”We receive plastic waste packaging, mainly from household collections, and convert it into recycled plastic lumber – planks, boards, posts, and profiles – in our UK factory based in Bodelwyddan, North Wales. This range of high-endurance, long-life products is called Smartawood™.”

DISCUSSION

Authors should discuss the results and how they can be interpreted from the perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted. The first theme emanating from the data was the relationship between recycling and the achievement of Net Zero goals. This theme presents the more technical side of this discussion. Data from the case study shows the increasing concern about the production of plastic waste in the United Kingdom. The concern over the environmental impact of plastic waste was a chief motivation in developing the manufacturing process for producing Smartawood by John Northcott. Plastecowood represents the emerging class of sustainable entrepreneurship that identifies the potential benefits for stakeholders by engaging in the circular economy [29]. The case study mentions how, in 2018, the United Kingdom “generated 5.8 million tonnes of plastic waste – enough to fill Wembley Stadium six times over” [3]. Plastecowood’s innovation inspires people across the divide to propagate its efforts and embody its qualities. A sculpture by UK artist Mark Weighton utilized Smartwood to inject optimism into the world through art that told the story of rebirth. “To reach net-zero emission targets by 2050, GHG emissions from the value chains and life cycles of plastics must be rapidly reduced…” [30]. The data further asserts that the only effective means of achieving Net Zero emissions is the replacement of virgin plastic with recycled plastic [31]. Net Zero goals necessitate high-end conversion procedures, reducing pollution, and eco-friendly materials [6]. The findings show that Plastecowood harnesses the insights from the literature and plays a significant role in achieving Net Zero goals.

This sub-theme in the literature expounds specifically upon the role of recycling plastic in reducing carbon emissions. The data indicate that Plastecowood significantly contributes to the reduction of carbon emissions. In a more detailed breakdown of the data from the case study, it is apparent that using plastic waste as the raw material for Smartawood directly contributes to the plastic value chain by directing plastic away from landfills and incineration [3]. Data from internet sources show that Plastecowood is filling a useful niche by using hard-to-recycle plastic as its raw material. Data from the case study shows that the main type of plastic used is packaging waste, pointing to the strategic placement of the company in the plastic value chain.

Additionally, each tonne of Smartawood comprises 70% carbon by weight, translating into 700 kilos of carbon withheld from the atmosphere. This represents a significant reduction of carbon emissions as rotting wood would otherwise release all the carbon absorbed back into the atmosphere during its lifespan. In contrast, Smartawood does not rot and can again be recycled after ten years. Moreover, it diverts waste from incineration under the attempt by the UK to generate cleaner energy from incinerating plastic waste. Around 44.8% – 45.5% of waste collected by local authorities is incinerated, producing more carbon emissions per kilowatt hour (504 gCO_2e/kWh) than the newer, cleaner sources of electricity coming onto the national grid (270 gCO_2e/kWh) [12]. Therefore, Plastecowood offers an optimal alternative for reaching Net Zero goals.

Recycling plastic plays a major role in solid waste management. In the literature, solid waste management is primarily a concern of the relevant municipal authorities. However, 70% of the solid waste collected goes into landfills or incineration [31]. In the United Kingdom, plastic waste management is often directed to incinerators. While the incineration rate has been increasing and the energy is being converted into electricity, the analysis reveals a general mismatch between government sentiment and quantified effect. Incineration is less effective at solid waste management, be it in the presence or absence of energy recovery, as it releases 50% – 80% of its weight in carbon content into the atmosphere [30]. The value chain of waste management further contributes to GHG emissions. "The production of plastics, as well as many other industries and value chains, are all connected to various sources of carbon lock-in,32 which create barriers to the mitigation of their climate impact" [30]. Infrastructural lock-in by incinerators further exists via the continuous input of fuel over their 25-year life spans exacerbated by residues such as bottom and fly ash. Lock-in in waste management presents a significant problem in moving toward a Net Zero future. Milios, Davani, and Yu [31] assert that the optimal waste management system "… must be organised with high-quality output and high reuse potential in mind." Data from the case study illustrates that Smartawood comes with a ten-year warranty, after which it can be reused to make other Smartawood products. Additionally, Smartawood saves 2.5 trees from the feller's blade, allowing natural processes of carbon absorption to happen. Therefore, Smartawood exploits several points of the value chain, designating recycling as the optimal means of waste management.

However, the success of waste management is contextual. Using the wrong approach for waste management potentially regresses the advance to a Net Zero future. In a study aimed at evaluating waste management in Iran, Kamarehie et al. [32] conclude that "incineration (50%), landfilling (30%), and MRF (material recovery facility) (20%) are best fitted to the waste management in Iran." While this may seem like a mismatch between the recommendations of these two studies, the nature of the waste in Iran is worth noting. Of the waste produced in the country, only 8.39% is plastic, while 65.85% is organic matter [32]. Therefore, investing in a more sophisticated composting scheme in Iran is necessary instead of a recycling project. Ragossnig and Schneider [33] reiterate that recycling measures will likely vary depending on the location. In Middle Europe, extended producer responsibility schemes have been implemented with success. They have diverted the burden of waste management from the consumer to the commodifier. The expansion of such schemes, while technically appealing and theoretically fit, cannot be realistically implemented. Barriers such as financial structure limit the practicality of extended producer responsibility schemes, including non-packaging waste. A cost-benefit comparison of licensing of packaging waste against a waste fee for citizens for residual waste shows that the individual interests of stakeholders limit the progress achievable in waste management despite being revolutionary two decades ago [33]. Recycling strategies must be responsive to context.

This theme represents the social aspect of the operations at Plastecowood. Data from the case study shows that the founder and managing director of Plastecowood, John Northcott, "driven by the vision to create a sustainable and healthy business that contributed to society by addressing one of the biggest environmental problems…" founded the company to deal with plastic waste. The health impact of plastic waste is a significant driver of sustainable entrepreneurship. Data from the case study shows how health statistics impact the perception of plastic waste and accompanying actions. Luleux et al. [3] refer to reports from National Geographic, which showed " an average person eats 39,000–52,000 microplastic particles in a year – equivalent to eating one plastic bottle cap every week." The discourse on the effects of plastic waste on human health is extensive, with Singh et al. [18] relating how plastic causes skin corrosion/irritation, aspiration hazard, and serious eye damage/eye irritation, among others. Therefore, the health effects of plastic waste are extensively recognised in the literature and offer an adequate incentive for producing sustainable alternatives to counter plastic overreliance.

Recycling plastic waste and the promotion of alternatives to virgin plastic significantly counter the health hazards of plastic waste. The government of the United Kingdom quantified the health cost of $PM_{2.5}$, particulate matter that emanates from incineration, as ₤216443 per tonne of pollutant [12]. In addition to the individual physical threat posed by plastic and poorly managed waste, the human species faces other threats in the form, such as the melting of glaciers, extreme weather, unpredictable rainfall, extinction of species, low agricultural productivity, food shortages, and water scarcity [18]. Sustainable entrepreneurship and corporate social responsibility are important aspects of the effort to promote sustainable development, which entails a comprehensive improvement in standards across healthcare and education [29]. A report by Eunomia Research and Consulting asserts that for the lowest health air quality impact, the optimal method of waste management should be a landfill with bio-stabilisation compared to various incineration modes, even with the most advanced incineration technology [12]. However, in the absence of a comparison with recycling, it is difficult to provide an outright winner for the best method of recycling. This study contends that the interlinkage of the United Nation's sustainable development goals requires the actualisation of a circular economy, necessitating recycling as the optimal means of improving waste collection systems ([29]; [21]. Milios, Davani, and Yu [31] report that a ban on incineration coupled with explicit Net Zero emission targets would translate into 544.6 $ktCO_{2e}$ of savings. Therefore, recycling is an important means of averting the health hazards of inefficient waste disposal.

However, Plastecowood has been faulted in the past for not taking enough measures to protect the health of its workers. In 2016, the company was fined £20000 after a worker had portions of two fingers amputated after attempting to remove red-hot plastic from machinery. The action was brought against the company's Health and Safety Executive, and the company was found guilty of breaching health and safety standards. Additionally, the company was ordered to remit an additional £14000 for failing to comply with an abatement notice to cease the emission of odours amounting to a nuisance.

Under this theme, it emerges that waste management can be optimised through the strategic adoption of plastic recycling. Data from the case study shows that manufacturing a single tonne of Smartawood material is equivalent to recycling at least 25000 milk pint bottles. The statistics mentioned above highlight the potential of recycling as an optimal method of waste management. In fact, the goal of having a Smartawood factory outside every major city in the world to improve waste management across the world's most important urban areas has been established. Towards this goal, Santander UK has awarded Plastecowood £1.3 million in funding to support its purchase of two more processing lines and support its short-term goals of increasing turnover to £10m [34]. Global estimates state that 58% of waste is sent to landfills, 24% is incinerated, and 18% is recycled [30]. More specifically, of global plastic waste produced in 2015, 31% was landfilled, 13% incinerated, 14% recycled, 19% leaked into the environment, and 22% openly burnt [30]. Currently, 70% of the waste produced in the European Union is sent to landfills or incinerated [31]. The situation is worse in India, as 80% of solid plastic waste is landfilled, 8% is incinerated, and 7% is recycled [18]. However, very little of what is sent to landfills is bio-stabilised, portending extensive emissions. Additionally, incineration is ineffective, with a total ban forecast to save 544 kt of carbon emissions [31]. In light of the inefficiency of landfilling and incineration as strategies for handling plastic waste, recycling waste emerges as the optimal method.

Worth noting is that recycled plastic must replace the demand for virgin plastic to be genuinely effective ([33]; [31]). To further support plastic recycling, plastic waste revenues, government subsidies, and the quantity, marketability, and quality of recyclables must support the financial viability of a recycling operation [33]. In that respect, Smartawood has performed well. Data from the case study shows that Plastecowood produced 100 tonnes of durable output weekly in 2021, affording a ten-year warranty.

Therefore, other recyclate manufacturers must learn from Plastecowood's strategies and adopt the quality of manufacturing used at the company.

The main challenges with plastic recycling under this sub-theme are the cost of recycling and the dissemination of information. Per the case study, an inefficient manufacturing process leads to financial losses. Plastecowood lost €30000 monthly by the end of 2014 due to the manufacturing process in place at the time, characterised by labour-intensive but low-value activities. The situation is the same in the literature about large-scale recycling initiatives. Under the current conditions, the cost of recycling outweighs the revenues. The economic cost of increased plastic recycling across the value chain under current conditions amounts to 9.1 million euros, even in advanced waste management systems such as Sweden's [31].

Statistics from the case study show that 70% of the machinery involved and steps in the manufacturing process are related entirely to sorting plastic waste [3]. Bauer et al.[30] affirm the complexity of collecting and sorting as significant barriers to cost-effective recycling. Information also plays an important role in the appreciation of sustainable products. It emerges that John Henning, from the case study, had to gather senior management experience in the plastics, packaging, and chemical industries as a prerequisite for making Plastecowood profitable. Information is a key factor for success. Kamerehie et al. [32] state that the failure of plastic waste management in Iran was caused partially by constraints on the information. The uptake of sustainable products is also limited by ignorance of their existence. Mitra and Ghosh [35] find that 16% of people have no knowledge of the nature of a green product. Effectively, their potential purchase intention cannot be harnessed. The lack of plastic waste management data in some municipalities also complicates efforts to conduct quality waste management studies (Tallentire & Steubing, 2020). The difficulty of building the necessary chemical expertise to handle chemical recycling further places recycling efforts on a precarious footing [33]. Therefore, information is a critical enabler in recycling efforts.

Under this sub-theme, the structures supporting plastic waste recycling are interrogated. The European Union has set ambitious targets for recycling rates in place. The target recycling rate for plastic is 55%[21]. As of 2018, Sweden had the highest recycling rate of any country in the EU, clocking an impressive 40% even in the presence of incineration overcapacity [31]. The highest recycling rates of 49% witnessed in 2016 are attributed to an effective Extended Producer Responsibility scheme [31]. The literature identifies two scenarios where plastic recycling rates are high: in the presence of landfill restrictions or in the context of limited incineration capacity even without landfill bans [31]. The literature further identifies how to optimise recycling efforts. While quotas are considered an effective means of pushing recycling, the production of recyclables of high quality for a wide variety of applications will naturally create the pull effect, ushing recycling rates upward [33].

Furthermore, optimal recycling processes are advisable for reaching recycling targets. Tallentire and Steubing [21] assert that best recycling practices can improve recycling rates by 50% and reduce GHG emissions by 0.47%. Moreover, they recommend the collection of municipal plastic waste through plastic and metal commingling (PMC). With a further 5% of generated plastic recovered from residual waste collection, the 2030 targets are forecast to be met.

The efficacy of recycling plastic as a wood alternative is apparent in the literature. Data from the case study highlights the triple supremacy of recycling plastic as an alternative to wood: one tonne of Smartawood recycles around 25000 plastic containers, recovers 700kg in carbon emissions, and saves 2.5 trees from being chopped down. According to Bauer et al. [30], recycling reduces GHG emissions by 1.1–3.0 kg CO_2 per kilo of plastic vis a vis incineration. Therefore, more consideration should go towards recycling plastic into alternatives for wood because of the immense carbon capture rates and recycling capacity. In the instance that a perfect recyclable cannot be produced from plastic waste, there is merit in channelling polymers into bulk application areas such as the manufacture of crates and pallets, as well as products that can be manufactured using Smartawood [30]. The case study further states that using plastic instead of wood ensures that rotting wood does not release all the carbon it has captured in its lifetime into the atmosphere. The literature stands firmly in favour of recoursing to wood alternatives as a source for recycled plastic.

CONCLUSION

This study concludes that recycled plastic is essential for achieving environmental goals. As highlighted in the case study, savings amounting to 2.5 trees, 25000 bottles, and 700kg in carbon emissions peptone of Smartawood are significant and worth building upon. Recycling plastic waste ensures less plastic matter in the environment, effectively optimising the plastic value chain and reducing the risk of ecological instability in marine environments. Depending on the use of recycling, recycled products can contribute to saving trees. In the case of Smartawood, a multi-faceted solution to carbon lock-in is reached. In addition to the plastic deviated from landfills, incineration, and leakage, the product saves 2.5 trees per tonne, protecting the supply of trees that contribute to environmental integrity and aesthetics in many ways. Additionally, the product's lifespan and use as an alternative to wood means that the lifetime carbon uptake that rotting wood would have released is avoided. Moreover, reducing carbon emissions from plastic waste management means recycling plastic reduces health hazards.

Recycling is central to plastic waste management. As the discussion shows, plastic recycling is the most effective way to deal with plastic waste. Incineration produces up to 3kg more carbon emissions per kilo, or 50%-80% of carbon content per kilo, compared to recycling [30]. Landfilling with bio-stabilisation still falls short of the emission savings of recycling [12]. Therefore, recycling plastic emerges as the best method of plastic waste management. However, recycling efforts are contingent on several factors, including the dominant type of waste in the area, available resources, and its application. Recycled plastic must be of satisfactory quality to push virgin plastic off the plastic value chain for true emission savings and environmental gains ([33]; [31]. However, Smartawood performs extraordinarily in replacing timber products, saving trees in the process. Recycling ought to be strategic and have a multi-faceted contribution to the environment rather than simply direct plastic waste into other areas of the plastic value chain.

There are several challenges faced with adopting recycling to manage waste. The challenges identified relate to technicality, cost, and the spread of information. In the first part, too much of the machinery and recycling procedure is involved with separating plastic from the rest of the waste. The need to hire skilled chemical experts to operate the most effective chemical recycling plants also pushes the cost of recycling upwards [33]. The cost of establishing effective recycling schemes is also high. Information is identified as a significant barrier to commercializing recycled products. 16% of people do not know what a green product is, which significantly lowers the possible purchase intention and consequent purchases that would have been made in the presence of that knowledge [35]. Additionally, the lack of standardized statistics on waste in municipalities hinders research and makes comparative studies difficult, limiting the generalizability of recycling schemes and strategies [21]. The challenges hinder what is otherwise the most effective strategy of waste management. Recycling effectively lowers carbon emissions. In the context of explicit emission reduction targets and a ban on incineration, Smartwood reduces carbon emissions by 700 kilograms per tonne, totalling 544 kilotons. [31]. Recycling also offers a strategic inlet for the private sector to contribute to Net Zero goals by commercialising the resulting product.

The findings inform several recommendations of this study. The first is an increase in plastic recycling through public-private partnerships. On the one hand, municipal governments could be tasked with implementing best-scenario recycling methods. Tallentire and Steubing [21] recommend using the PMC commingling method in plastic waste collection. Additionally, they present a recycling scenario where 50% of the plastic waste is recycled, leading to a 0.47% reduction in GHG emissions. Municipalities must also address the challenge of landfilling to increase the recycling rate and overall outcomes. As a complete and immediate ban on landfilling would be impossible, introducing bio-stabilisation into landfilling processes would optimise the landfilling process. With a progressive ban on landfilling via a quota system limiting the amount of waste sent to landfills, the recycling rate will gradually increase. However, a compromise on incineration is not as viable. All incineration must use the most advanced technology or cease operation to boost recycling rates. Authorities must also set explicit emission targets to provide a framework for success and failure.

On the other hand, the private sector has a massive role in promoting recycling rates. By facilitating research into sorting plastic waste, the private sector can significantly ease the burden of recycling. The process employed in producing Smartawood is especially efficient and can be taken up by other recyclers to streamline the production process. Further research can also be facilitated by collecting local authorities' standardised information on waste management. The information from such programs would significantly empower the entire recycling industry.

Additionally, producing high-quality recyclates with various uses will feed the demand for recycled plastic material. More research should be carried out into the applications of recycled polymers. Lastly, information should be made clearer to consumers. Simple information may improve consumer uptake and intention to use, such as the material that comprises the recycled product and the environmental effects of such composition.

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