Industry Symbiosis and Waste Glass Upgrading: A Feasibility Study in Liverpool towards Circular Economy

Han-Mei Chen, Rongxin Zhou, Taige Wang

***Abstract*—**Glass is widely used in everyday life, from glass bottles for beverages, to architectural glass for various forms of glazing. Although the mainstream of used glass is recycled in the UK, the single-use and then recycling procedure results in a lot of waste as it incorporates intact glass with smashing, re-melting and remanufacturing. These processes bring massive energy consumption with a huge loss of high embodied energy and economic value, compared to re-use which's towards a 'zero carbon' target. As a tourism city, Liverpool has more glass bottle consumption than most less leisure focused cities. It is therefore vital for Liverpool to find an upgrading approach for the single-use glass bottles with a low carbon output. This project aims to assess the feasibility of an industrial symbiosis and upgrading framework of glass and to investigate the ways of achieving them. It is significant to Liverpool's future industry strategy since it provides an opportunity to target on economy recovery for post-COVID by industry symbiosis and an up-grading waste management in Liverpool to respond to the climate emergency. In addition, it will influence the local government policy for glass bottle reuse and recycling in North West England, and as a good practice to be further recommended to other areas of the UK. First, critical literature review of glass waste strategies has been conducted in the UK, and world-wide industrial symbiosis practices. Second, mapping, data collection and analysis have shown the current life cycle chain and the strong links of glass reuse and upgrading potentials via site visits to 16 local waste recycling centres. The results of this research have demonstrated the understanding the influence of key factors on the development of a circular industrial symbiosis business model for beverage glass bottles. The current waste management procedures of glass bottle industry, its business model, supply chain and the material flow have been reviewed. The various potential opportunities for glass bottle up-valuing have been investigated towards an industrial symbiosis in Liverpool. Finally, an up-valuing business model has been developed for an industrial symbiosis framework of glass in Liverpool. For glass bottles, there are two possibilities: 1) focus on upgrading processes towards re-use rather than single-use and recycling, 2) focus on 'smart' re-use and recycling leading to optimised values in other sectors to create a wider industry symbiosis for a multi-level and circular economy.

***Keywords*—**Glass bottles, industry symbiosis, smart reuse, waste upgrading.

I. Introduction

GLASS is a popular-used material all over the world with good reuse ability and high embodied carbon. Liverpool is a tourism city; it has more glass bottle consumption than most less leisure focused cities. The majority of glass bottles over 60,000 tonnes of used glass bottles and jars [1] including wine bottles, beer bottles and jars each day go directly to the commercial and business glass recycling centre. For each beer bottle of 500 ml, the estimated carbon footprint is equal to 503 g of carbon dioxide [2].

However, the reuse rate of the glass bottle is very poor in modern days compared to 1970's. Nowadays, only 5% is reused compared to 70% for recycling, 10% for disposing. In 1977 there was first bottle bank for glass bottle reuse scheme and successfully collected 500 tonnes of glass in the first six months [3]. The majority of glass bottles in Liverpool is recycled after one use for remanufacturing, rather than reuse. Environmentally speaking, it means the high embodied carbon in the glass bottle during manufacturing process has been lost, with accumulative carbon consumption in the remanufacturing states which creates large amount of carbon in the process and loss of the embodied carbon. Economically, there are only few single business models existing opening for recycling. It means less opportunities and limited time guarantee with certainty, rather than a spider net to bring more opportunities and sustainable businesses. The reasons behind the low reuse and higher recycling probability for glass bottle waste treatment is: 1) to make it faster process; 2) lack of economy motivation for each glass (currently low price of single bottle); 3) less labour cost for recycling comparing to reuse. As a result, the glass is much less valued currently regarding to its economic and environmental benefits. The social part – labour cost actually would not be equivalent to other current strategies.

The value of glass bottle regarding to its economic and environmental benefits can be upvalued after promoting strategies towards a circular economy via industry symbiosis. This research aims to: 1) environmentally, promote reuse by new handling solutions to challenge 'accumulative carbon in process and loss of embodied energy' 2) economically, build up a spider net to bring more opportunities and sustainable businesses, to overcome 'single line business models in the industry'.

This paper investigates the current business status of the glass bottles in Liverpool, Merseyside area. The current business models and supply chain have been analysed, with strengths, weakness, opportunities (and risks). The mapping exercise has demonstrated the areas with strong links and where can be more enhanced to promote local business with shorter, greener

Han-Mei Chen* and Taige Wang are with School of Architecture, University of Liverpool, 19-23 Abercromby Square, Liverpool L69 7ZN, UK (*e-mail: hanmei.chen@liverpool.ac.uk).

Rongxin Zhou is with School of Civil Engineering, Hefei University of Technology, Hefei 230009, China.

transport needs. Based on these investigations and assessments, the new business model and framework for the circular economy and industry symbiosis have been developed, which is a stepping stone and suitable for glass bottle case study towards circular economy in Liverpool.

The objectives of this research are to 1) investigate glass waste strategies in the UK, and world-wide industrial symbiosis practices, 2) conduct mapping exercise, collect data from 16 local waste recycling centres to analyse current life cycle chain and the strong links of glass reuse and upgrading potentials.

II. Glass Bottle Waste Strategies in Merseyside: Status of the Art

A. Current Waste Management Procedures

In Liverpool, the majority of the glass bottles is recycled after first-time use. The recyclable waste glass bottles include: 1) bottles of any colour (e.g. wine, beer), 2) jars (e.g. sauces, jam, baby food), and 3) non-food bottles (e.g. perfume, aftershave, face creams). Before recycling, the glass bottles need to be empty and rinsed as the residue can contaminate other materials leading to the failure of recycling [4].

Three major sources of waste glass bottles in Liverpool consist of 1) household waste, 2) commercial waste, and 3) waste from public places. For household waste, the waste management procedure starts from household; recyclable waste glass bottles are simply rinsed at home and kept in the blue bin, ready for collection by the recycling vans, which are then collected and transported to the Material Recovery Facilities (MRF). The other route of household waste is 16 Household Waste Recycling Centres, where residents drop waste glass bottles to the mixed glass, bottles & jars skip in recycling areas. These waste glass bottles are then being collected and transported to the MRF for recycling and material recovery purpose. There are two MRFs in Liverpool for recycling and material recovery, one sited in Bidston area and the other sited in Gillmoss area where 94% of the glass are sorted here, in colours, before send it to the St Helen's glass bottle colour sorting and manufacturing centre [5]. The process is shown in Fig. 1.

Fig. 1 The recycling route of household waste glass bottle [5]

Fig. 2 The recycling route of commercial waste glass bottle [6], [7]

For commercial waste, the waste management procedure starts from restaurants and bars, recyclable waste glass bottles are prepared and ready for collection by a registered waste carrier [6]. There are nearly 1000 eligible waste carriers in the Liverpool area. These waste carriers are owned by waste management and service companies and will deliver waste glass bottles to MRFs particularly dealing with commercial glass waste. There are two main MRFs for commercial glass waste near Liverpool, namely, Recresco Ellesmere Port and WSR Cheshire [7]. The process is shown in Fig. 2.

For glass bottle waste from public places, the recycling route is illustrated in Fig. 3. For glass bottle waste from public places, firstly they are gathered by collection vehicles, from mixed recycling bins to the waste site. The public spaces include streets and parks. Secondly in the waste site, the glass bottle waste will be transferred on to larger vehicles and then be delivered to MRF in Gillmoss for further deep recovery. Finally, the unsorted glass cullet from MRF will be sent to St Helen's for reprocessing.

Fig. 3 The recycling route of public waste glass bottles [11], [13]

The recycling process of glass bottles and jars in MRF is shown in Fig. 4. The waste delivered to MRF is mixed recyclable waste including glass bottles, cardboard and metals. From these mixed wastes, glass bottles need to be separated and crushed into cullet which are small pieces of glass. It includes three steps to process glass bottles to cullet: Step 1) Certain waste are picked out manually by workers which would damage the machines. Step 2) Glass Separation – Fig. 4 shows the separation of glass from other material apart from cardboard due to self-weight. Separation is done by gravity and fall into the lower box (shown in Number 4 in Fig. 5). Step 3) Glass Breaking - on the conveyor belt, mixed waste including glass bottles is sent ahead and fall through the gaps onto the glass breaker (Fig. 6). The breaker will crush mixed colour glass bottles into cullet. The cullet still contains some impurities and needs to be further purified.

B. A Case Study of Partnership

In 2018, A facility with cutting Edge technology for glass recycling was invested by Veolia Ltd. and soon build up a partnership with Knauf Insultation Ltd. in St Helens. Using this technology, the cullet sent from MRF was further purified under the decontamination process and can be used as raw materials in the glass insulation production [8]. In this case study, we can see that it greatly upcycled the waste and contaminated glass to a maximum use. Knauf insulation Ltd. produces the insulation with glass fibre material, as one of their major products in the UK market. In this partnership, 95% of glass is turned into 'cullet' and utilised in the production of glass fibre insulation in Knauf Insulation Ltd. [9]. The glass insulation factory is next door to the glass processing centre in St Helens which makes it a good match and sustainable in long term.

As stated in Fig. 7, thanks to the cutting-edge technology with high accuracy, the facility is able to sorting out and purifying the glass cullet at a micro-level. In order to collect ferrous materials, vibrating screens and magnets are employed while eddy current separators are used to pick up non-ferrous materials [8].

The cullet from the two waste recycling/recovery centres are still heavily contaminated as a result of different colours, brown, green, transparent and so on, some remaining packaging and glass dusts or various sizes of glass aggregates. Therefore, without proper further colouring and deep cleaning process, the recycled cullet is hardly be remanufactured to produce new glass bottles. Alternatively, the majority of these contaminated cullet has been transported to produce other glass-related products which does not require colour sorting and can utilize all the glass waste.

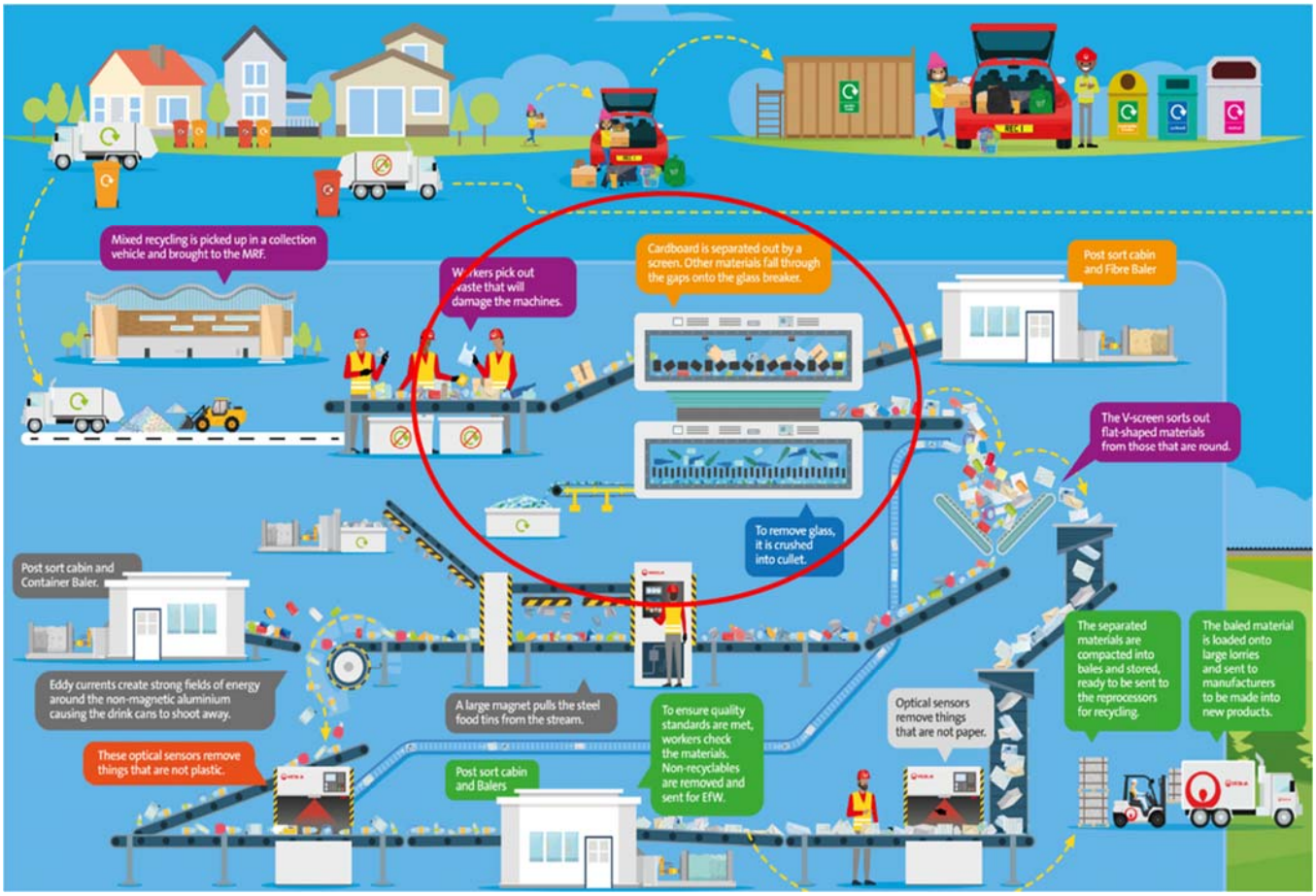

Fig. 4 Waste management processing in MRF [16]

Fig. 5 Step 2), number 4: the glass separation process

After collecting the cullet, Knauf factory will melt the glass cullet into the furnace, which is melted to convert into glass mineral wool. The mineral wool will be used for manufacturing of glass fibre insulation, also known as 'Glass Mineral Wool insulation'.

Fig. 6 Step 3) Cullet produced after glass breaking process in Gillmoss MRF

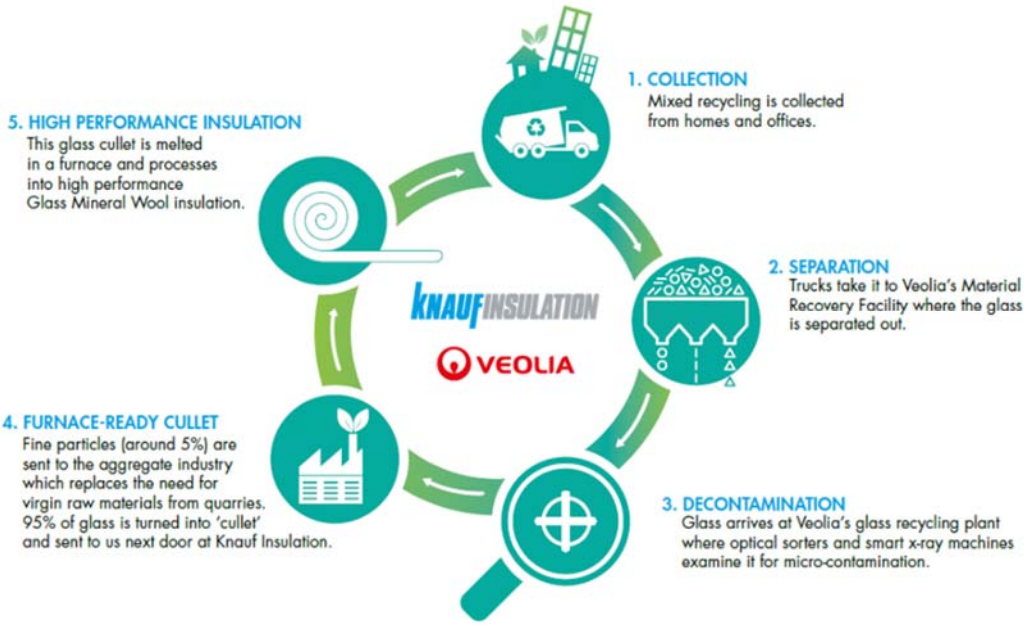

Fig. 7 Glass Recycling: A Cutting - Edge Partnership and the Business Model (Veolia Ltd. and Knauf Insultation Ltd. in St Helens) [1]

As shown in Fig. 8, in Liverpool, the current active business model includes to produce house insulation by transforming the recycled glass waste/cullet to glass fibres, then manufactured to be the glass fibre insulations. Fig. 8 (d) shows the glass insulation products in Knauf Insulation by using the recycled glass as raw material; Fig. 8 (b) shows the the highly purified glass cullet in Veolia Ltd.'s glass recycling plant ready to be delivered to Kanulf Insulation Ltd. to produce glass fibres [5].

In summary, the current material flow of the glass bottle in Liverpool is recycling only from glass to glass fibre insulation, there is no material flow from glass to glass, or from glass to other products at the moment. Therefore, the business status is a single line business model in the glass industry to the construction insulation industry.

This partnership brings many benefits to both companies and the society as an environmentally-friendly approach. Over 60,000 tonnes of used glass bottles have been recycled annually to minimise waste to the landfill [1].

The secured glass supply chain brings mutual profits and achieve mutual goals. For Knauf, regarding resource maintenance, up to 80% of the raw glass fibre materials has been secured and will be maintained in a decade-long (around 10 years) commitment for Knauf Insulation to manufacture the glass insulation products. In the meanwhile, it brings more opportunity to increase the percentage of recycled glass cullet as the raw material into the glass insulation, thanks to the high quality of the processed glass cullet.

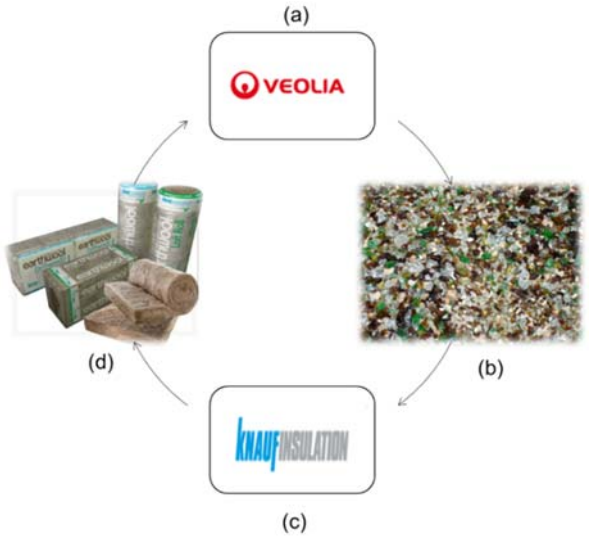

Fig. 8 A Circular Business Model for industry symbiosis (glass cullet after recycling to glass fibre insulation); Image courtesy of Knauf Insulation [10] and CC Rogers

For Veolia, it is a worth business. 5,000 tonnes of used glass bottles and jars can be processed per month (60,000 tonnes per year, 350 million bottles yearly) at the St Helen's recycling facility. 18 permanent jobs have been created during this investment of an innovative facility [8], [9]. This £10 million investment is believed to be good for jobs, the community and the planet [8], [9].

Regarding environmental benefits for both company's sustainable strategy and the society, this recycling and remanufacturing process means that 12,000 tonnes CO_2 equivalent is eliminated which equals to the elimination of CO_2 for 7000 cars per year. In addition, it can save 76,000 MWh energy (the energy needed to make 20 million wine bottles from scratch = 76,000 MWh energy). The eliminated carbon emissions bring up to 375,000 miles savings of road journeys [9].

This Partnership is a significant investment and contributed to circular economy by a closed-loop solution. It has been agreed that [8] this partnership has achieved the mutual goal as a huge boost for circular economy which also bring mutual benefits to both companies.

C. Mapping Exercise

This mapping exercise is only focusing on glass bottles from household and public places. Commercial glass bottles are excluded due to its complexity and uncertainty of collection patterns, varying from a bar to another bar. There's no regulation for collections, so it is hard to track the collections.

Household glass bottles can be recycled: 1) using the local council's kerbside recycling bin (in blue), bag or box and 2) at the local Household Waste Recycling Centre. The recyclable glass bottles include food jars, cosmetic bottles, drinks bottles (beer and wine), and medicine bottles. For recycling purpose, glass should not be smashed or broken in the blue bin. The metal lids and bottle tops are also recyclable in MRF [11].

1. The Local Council's Kerbside Recycling Bin (in Blue), Bag or Box

First, recyclable materials are collected by the local waste collection vehicles from individual households, usually twice a month. Then these vehicles will deliver all recyclable materials to transfer stations in Merseyside & Halton. After this, the gathered waste and recycling materials are transferred onto larger vehicles with the capacity of four collection vehicles used for kerbside waste collection. The destination of larger vehicles is MRFs for carrying out sorting and recycling process for various materials. The use of transfer stations reduces local traffic and the total vehicle miles with more positive environmental impact.

As can be seen in Fig. 9, four Transfer Stations are located at Bidston, Gillmoss, Huyton and Southport in the area of Merseyside and Halton [12], two MRFs in Bidston and Gillmoss and one reprocessing plant for glass cullet in St. Helen's. In Fig. 9, it is noted that Transfer Stations in Bidston and Gillmoss are the same locations as the MRF. Logistically it means that in Wirral council region and Knowsley council region, recycled materials are directed delivered from households to MRFs, without transfer stations; while in other regions, recycled materials are delivered to the nearest transfer stations first, before being moved to MRFs.

2. Local Household Waste Recycling Centres

Definition of Merseyside areas and Halton (Liverpool City Region Combined Authority): It covers the Liverpool City Region, which extends across much of Merseyside, including Sefton, Knowsley, St Helens and the Wirral, and Halton [13], [14].

As can been seen in Fig. 10, there are 16 Household Waste Recycling Centres in the Liverpool City Regions to dispose household recyclable goods [15]. More details of these centres are shown in Table II, Appendix A.

The recyclable glass bottles in these 16 household waste recycling centres are transported to two material recovery facilities in Bidston and Gillmoss. Afterwards, the mixed coloured glass cullet with contaminations is to be sent to St Helen's for further recovery processing especially decontamination and deep cleaning. In this pathway, the recycled glass bottles and jars are turned into glass cullet used in the production of glass insulation products [16].

Compared with household mapping, the pathway of public glass bottle waste (Fig. 11) is not complicated with one waste site, delivered to one MRF and then transferred to the reprocessing plant in St Helen's. The reason for that is because the quantity of glass bottle waste is much less compared to the household waste.

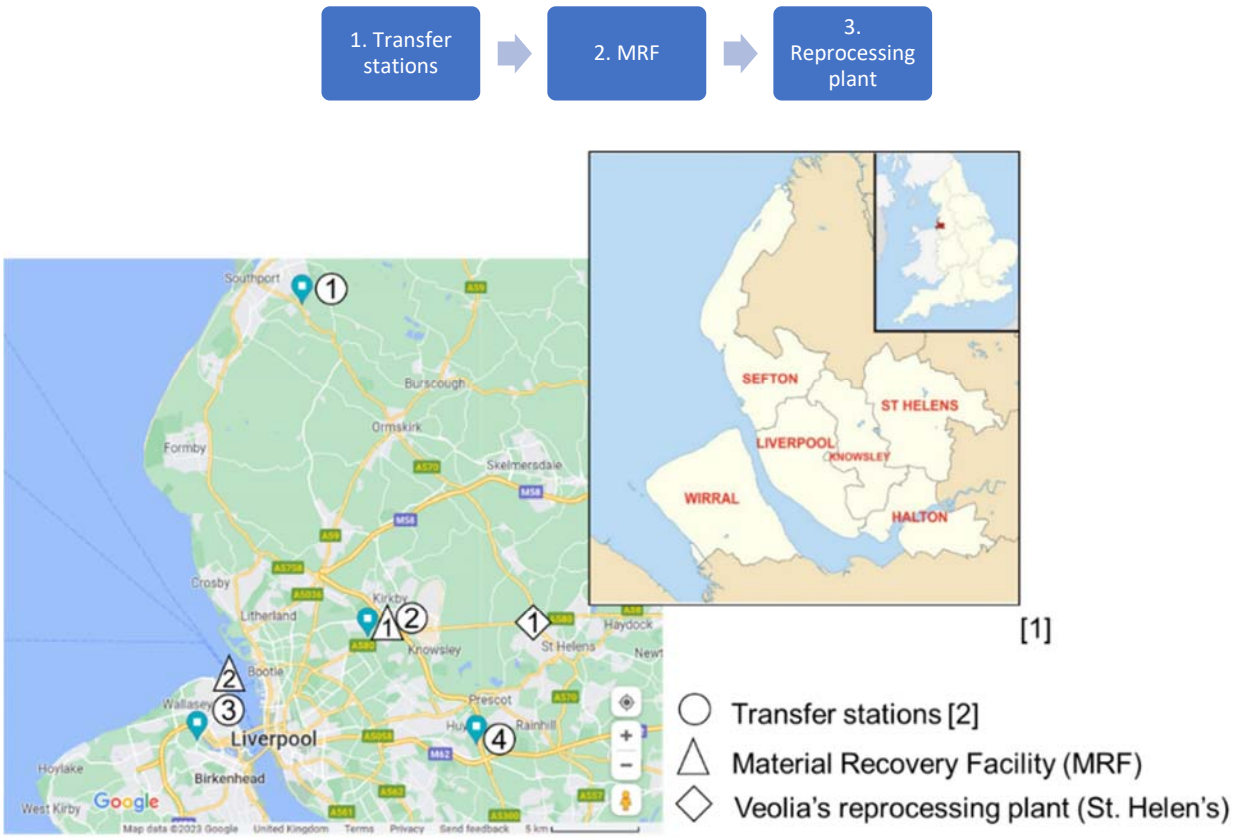

Fig. 9 Route mapping for the local council's kerbside recycling

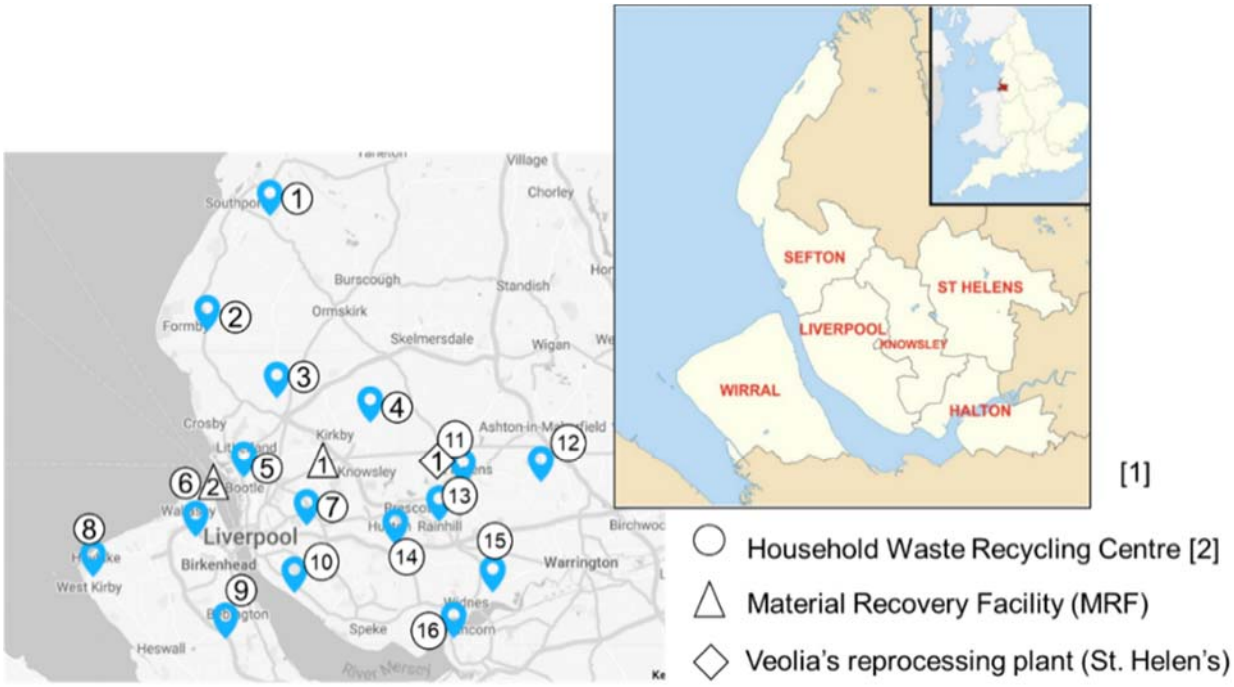

Fig. 10 Route mapping for the 16 local Household Waste Recycling Centres in Merseyside, to St Helen's recycling centre and another centres

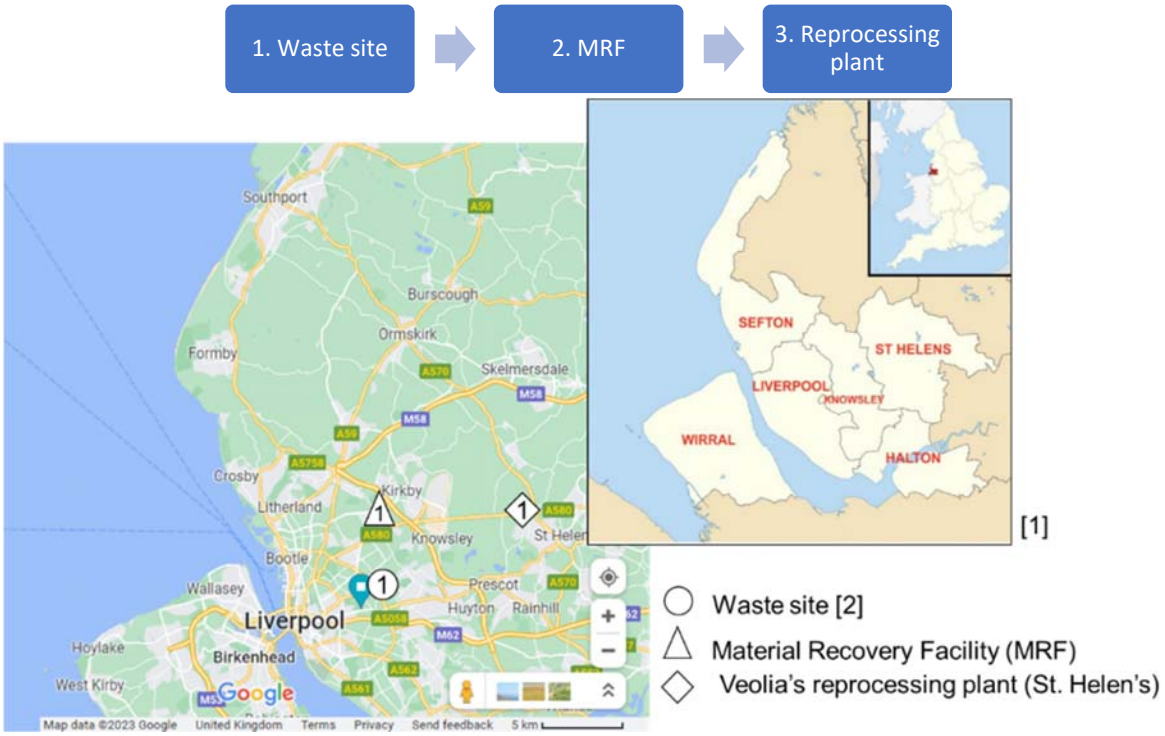

Fig. 11 Route mapping for public glass bottle waste recycling

Fig. 12 'WOBO' prototype for a garden house [19]

III. Framework of Industry Symbiosis

A. Existing Business Models for Industry Symbiosis

For glass bottle waste management, there are some business models for industry symbiosis around the world. In 1964, Heineken Ltd. in Netherland has produced 100,000 beer bottles called 'WOBO'. It gave a new concept of design for reuse. After sanitated, it could be reused as construction block in buildings, non-load bearing walls or partition walls. The designer was the architect John Habraken. The volume of these bottles is 35 cl. and 50 cl. [17], [18]. Although it had not been produced further to be applied to a real WOBO building, it inspired and motivated the reuse and repurpose of glass bottles [17]. Heineken managed to build a garden house by using 'WOBO' as a prototype (Fig. 12).

A successful and ongoing business model is used by an art workshop in Taiwan. It has opened its production line towards art work and domestic products including decorations by using the recycled glass. The glass material originally was glass bottles comes from all over Taiwan and has been put into new and innovative glass products. It has been divided by colours and original use. For this company, the change of raw materials has saved the price by 30%, and the environmental impact of carbon footprint is reduced by 20%. In addition, it creates 5 jobs of innovative design and manufacturing the glass products. For the recycling company, the collection process, the recycling process, the sale price of recycled materials to this company is a good business. Environmentally speaking, it saved the valuable glass from salvage to the landfilled. As a result, the price has been upvalued compared to recycling to glass bottles. It motivates the recycling of glass bottles and has strong potential to be adapted to Liverpool.

The Reverse Vending Machines (RVMs) (Fig. 13) are a business model for glass reuse scheme. These machines are going to be displayed in London. It means that there will be more public glass bottles being collected and send to the recycling centre – for most of the glass bottles which are intact, it can be simply sanitated and reused according to food package standardisation; for some damaged ones, it can be put into the recycling lane, either colour sorted to make into new glass bottles, or other glass products, or non-colour sorted to make into glass fibre insulation projects and so on. In general, it will motivate the reclaiming and reuse of glass bottles, rather than single recycling.

Fig. 13 The Reverse Vending Machines in London [20]

B. A Framework for Glass Bottle Industry Symbiosis in Merseyside

To develop the framework, not only the potential advanced technologies are investigated, but also the companies who are having partnership in glass bottles, namely Veolia Ltd. and Knaulf Insulation Ltd., to understand their value and future vision in sustainability. Veolia delivers Ecological Transformation [21] for its customers through decarbonisation, treating pollution and depollution, and resource generation and optimisation, aiming at resourcing the world for future generations. On the other hand, Knauf Insulation Ltd. [22] provides a good example to enhance the utilisation of the recycled materials from another sector. It is commented by Knauf that more industry partners are encouraged to put circular economy strategy into their own practice to expand it further and create more closed-loop solutions [8].

1. Reuse

Reverse Vending Machines (RVMs) in London have shown a proactive and forward step and rewarded strategy to encourage recycling. Above the level of recycling in the waste hierarchy is reuse. The current RVMs are for recycling only, by further developing the RVMs techniques for reuse purposes, the reuse rate can be much higher to save carbon footprint and energy. There are some glass bottles using the automotive or semi-automotive techniques e.g. Aquatech-BM Bottle Washing Equipment, Dairy Milk Half Gallon Bottle Cleaning Machine. The techniques have hight potential to be implemented in RVMs thus the machines will be able to either produce sanitated glass bottles, or be able to stacked intactly inside the machine and transferred to a washing and sanitated station for deep processing and come out as sanitated glass bottles. It needs to be mentioned that the machine may need to identify certain bottles to be reused, and recycled separately. Ideally, only certain brand of bottles will be reused to produce new beers and wines whose factory is close with Liverpool area to have a good saving on the transport and the associated carbon footprint compared to the raw materials resources to beer factory.

2. Recycling

The current glass cullet after recycling is unsorted by colours. The glass processing centre own by Veolia Ltd. [21] has the ability of colour sorting glass, which gives it another strategy and potential to sort out the glass cullet into different colours as brown, green and transparent. It means that the sorted coloured cullet can be sold to the glass bottle manufacturing company with a potential of higher price compared to the unsorted one. It will stimulate the company's development and provide more opportunity to the company, also cross one more step and promote a new business model towards circular economy. The company is looking forward to find a more mutual beneficial way of doing it, without increasing a large amount of the labour cost, with a sustainable business model, with more industry demands and connections with other industry to create an industry symbiosis towards circular economy and circular supply chain, sustainable and circular manufacturing.

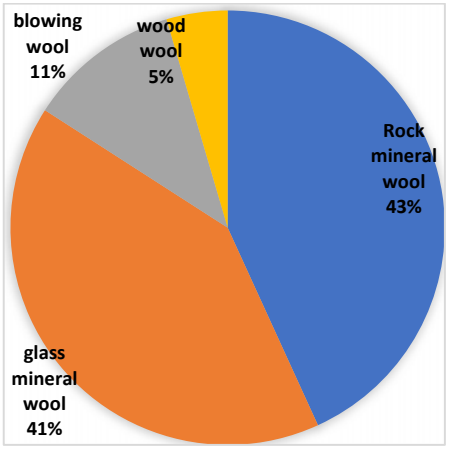

Fig. 14 The proportion of products using different materials in Knauf Ltd.

TABLE I
THE PROPORTION FOR PRODUCT NUMBERS

Material Type	Rock mineral wool	Glass mineral wool	Blowing wool	Wood wool	Total
Product No.	19	18	5	2	44
Percentage	43%	41%	11%	5%	100%

Knauf Ltd. is the only manufacturer of both Glass and Rock Mineral Wool. The material of its insulation products varies from rock mineral wool, glass mineral wool, blowing wool and wood wool. The proportion of products according to the material type can be illustrated in Fig. 14 and Table I.

Fig. 15 Sustainability through the supply chain [22]

In terms of sustainability within the supply chain (Fig. 15), the choice of raw materials puts recycled materials as a primary source. In Knaulf, up to 80% of raw materials to produce mineral wool insulation are recycled glass from Veolia's recycling plant next door [1]. Therefore, the need for mineral raw materials is heavily reduced [22]. In addition, Knaulf maximises the used of its own factory waste into the manufacturing process to achieve the zero-landfill goal in the UK plants [22].

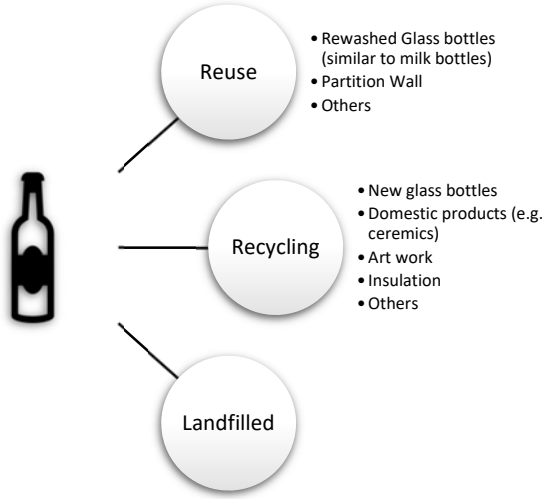

Fig. 16 A framework for glass bottle industry symbiosis in Merseyside

As can be seen from Fig. 16, apart from other inspired business models of industry symbiosis, more opportunities can be developed in the new industrial symbiosis framework of glass bottle in Merseyside.

IV. Conclusion

In this paper, current recycling strategies of glass bottle have been demonstrated. It has also introduced a case study of industry symbiosis and the associated partnership. The business model has shown a single recycling waste management of glass bottles, from cullet to glass fibre insulation. The mapping exercise for glass bottle recycling in house waste and public waste has shown a clear vision of various pathways to the recycling plant in stages. It would help to identify the transportation distance and logistic optimisation if considering any alternative route for upvaluing in the next stage.

In Section II, the investigation on the glass bottle waste management demonstrated the current status of the glass bottle pathways and the business involved with. There is only recycling for glass bottles, from glass bottle after single use to anther insulation products enriching in glass fibres. It opens other sustainable possibilities and new business models for 1) reuse glass bottles, either to new glass bottles or to other functions like decoration wall, 2) recycling glass bottles, to other industry products using the processed cullet.

As can be seen in Section III, there are still high potential of reuse and other recycling routes to be developed aiming to upvalue and provide more opportunities for other industries to be involved to create more values from each side. Therefore, a new framework has been developed to oversee the future trend. More business models can be created with details in the future after thorough investigations in this region, with targeting industries and companies. It is concluded that the new business model and framework for the circular economy and industry symbiosis have been developed and has high potential to be a suitable for glass bottle case study towards circular economy in Liverpool.

The limitation of this research is only focusing on house waste and public waste of the glass bottles. The glass bottle consumption and waste management strategy need to be further explored to understand the current status for an upgrading towards circular economy.

The following research at the next stage would be conducting focus groups to validate, revise or extend the new framework.

Five focus groups within glass bottle industry and construction industry would be carried out to investigate the mutual values of industries. In addition, economically, the whole life cycle cost will be carried out to analyse and compare costs of single-use glass bottles with multi-use glass bottles after reuse or recycling. Environmentally, for reuse using adapted Reverse Vending Machines (RVMs), the energy consumption during the whole waste upvaluing process will be calculated and compared with the recycling path route.

APPENDIX A

TABLE II
16 HOUSEHOLD WASTE RECYCLING CENTRES IN THE LIVERPOOL CITY REGIONS

Council No.	Council name	Name	Address	No. in the map (Fig. 10)
1	Sefton Recycling Centre	Southport Household Waste Recycling Centre	Foul Lane, Southport PR9 7RG	1
1	Sefton Recycling Centre	Formby Household Waste Recycling Centre	Altcar Road, Formby L37 8DL	2
1	Sefton Recycling Centre	Sefton Meadows Household Waste Recycling Centre	Sefton Lane, Maghull L31 8BX	3
2	Knowsley Recycling Centre	Kirkby Household Waste Recycling Centre	Depot Road, Kirkby L33 7UZ	4
1	Sefton Recycling Centre	South Sefton Household Waste Recycling Centre	Irlam Road, Bootle L20 4AE	5
3	Wirral Recycling Centre	Bidston Household Waste Recycling Centre	Wallasey Bridge Road, Wirral CH41 1EB	6
4	Liverpool Recycling Centre	Old Swan Household Waste Recycling Centre	Cheadle Avenue, Liverpool L13 3AF	7
3	Wirral Recycling Centre	West Kirby Household Waste Recycling Centre	Greenbank Road, Wirral CH48 5HR	8
3	Wirral Recycling Centre	Clatterbridge Household Waste Recycling Centre	Mount Road, Bebington, Wirral CH63 4JZ	9
4	Liverpool Recycling Centre	Otterspool Household Waste Recycling Centre	Jericho Lane, Aigburth, Liverpool L17 5AR	10
5	St Helens Recycling Centre	Ravenhead Household Waste Recycling Centre	Burtonhead Road, St Helens WA9 5EA	11
5	St Helens Recycling Centre	Newton-le-Willows Household Waste Recycling Centre	Junction Lane, Newton-le-Willows, St Helens WA12 8DN	12
5	St Helens Recycling Centre	Rainhill Household Waste Recycling Centre	Tasker Terrace, Rainhill L35 4NX	13
2	Knowsley Recycling Centre	Huyton Household Waste Recycling Centre	Wilson Road, Huyton L36 6AD	14
6	Halton Recycling Centre	Johnsons Lane Household Waste Recycling Centre	Johnson's Lane, Widnes, WA8 0SJ	15
6	Halton Recycling Centre	Picow Farm Household Waste Recycling Centre	Picow Farm Road, Runcorn, WA7 4UD	16

REFERENCES

[1] https://www.knaufinsulation.co.uk/veolia-partnership-knauf-insulation
[2] https://haymax.biz/blog/plastic-vs-glass/
[3] https://www.fswaste.co.uk/history-of-glass-recycling/
[4] Merseyside & Halton Recycling Guidelines, 2017, https://www.merseysidewda.gov.uk/wp-content/uploads/2011/12/Merseyside-Recycling-Guidelines-2017-August.pdf
[5] https://www.packaging-gateway.com/projects/veolia-closed-loop-glass-recycling-facility-st-helens-merseyside/
[6] https://www.gov.uk/managind-your-waste-an-overview
[7] https://www.veolia.co.uk/services/commercial-glass-collection
[8] https://www.veolia.co.uk/press-releases/new-multi-million-ps-facility-opens-using-cutting-edge-technology-turn-glass
[9] https://www.veolia.co.uk/sites/g/files/dvc1681/files/document/2018/03/8661_KNAUF_INFOGRAPHIC3.pdf
[10] https://www.knaufinsulation.co.uk/
[11] Recycling in Liverpool https://recycleright.org.uk/do-it-right/liverpool-city-council/
[12] https://www.merseyside-and-halton.veolia.co.uk/facilities-services/transfer-stations
[13] https://www.liverpoolcityregion-ca.gov.uk/corporate-plan/
[14] https://tonyrobertson.mycouncillor.org.uk/2020/10/02/merseyside-or-liverpool-city-region/
[15] https://www.merseysidewda.gov.uk/find-a-local-recycling-centre/
[16] https://www.merseysidewda.gov.uk/where-do-the-sorted-materials-go/
[17] https://www.heinekencollection.com/en/stories/the-story-behind-the-wobo
[18] https://inhabitat.com/heineken-wobo-the-brick-that-holds-beer/
[19] https://www.heinekencollection.com/application/files/8215/4309/4915/072.jpg
[20] https://www.veolia.co.uk/reverse-vending-machines-rvms
[21] https://www.veolia.co.uk/
[22] https://www.knaufinsulation.co.uk/why-knauf-insulation/sustainability