A Study to Identify Local Alternatives to Shipping Non-Deposit Glass out of the State of Hawai‘i

A Report to the Governor and the Legislature of the State of Hawai‘i

Report No. 14-17
December 2014

THE AUDITOR
STATE OF HAWAI‘I

A Study to Identify Local Alternatives to Shipping Non-Deposit Glass out of the State of Hawai‘i

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Combination of alternatives are needed to down-cycle a significant volume of glass in Hawai‘i

Senate Concurrent Resolution No. 74 of the 2014 Legislature asked the Auditor to examine local alternatives to shipping non-deposit glass containers out of the State for recycling. We contracted with Oceanit Laboratories, Inc., to conduct the study. In this, the second of two reports, the study found there is no one single alternative option that would remove all or most non-deposit glass from the waste stream in Hawai‘i. The study emphasizes that glass is a low-value commodity which makes nearly every option—including recycling, down-cycling, or disposing glass in a landfill—costly to implement.

There are many local uses for glass, but all require varying levels of support

The report identifies several opportunities for large volume down-cycling uses in Hawai‘i. *Down-cycling* is the process of converting waste glass into new materials or products of lesser quality and reduced functionality. *Recycling* means to melt the glass containers and make them into another glass product. Using criteria such as cost, potential demand, health and safety, environmental impacts, and industry or public resistance, the study identified and assessed nearly a dozen alternative local uses of down-cycling glass. These options include using glass for non-structural backfill, agricultural soil amendment and ground cover, traction and mud abatement, and filtration media. The study also categorized alternatives by those that would be the simplest to implement; those that represent the highest value; and those that would produce the best long-term results. The report notes that a combination of these down-cycling alternatives is necessary to produce notable results due to industrial and market fluctuations.

Policies have created barriers to local uses for post-consumer glass

The study found the interaction between the advance disposal fee (ADF) and the deposit beverage container (DBC) programs creates inefficiencies in the recycling or down-cycling of glass. Both programs involve the same commodity but create two categories of glass that are subject to different rules and policies. This also increases costs as the glass must be separated manually to identify glass that falls under each program. Further, space is limited for recyclers, so it is more efficient for some counties and recyclers to treat both DBC and ADF glass the same and ship it all to the mainland for recycling.

The study also found that current laws are ambiguous on whether the State prefers to down-cycle or recycle. For example, the Department of Health promulgated a draft policy to help regulate the recycling of DBC and ADF glass. However, the department contends the policy does not necessarily apply to ADF glass which creates confusion for the counties and recyclers. Further, the study states while counties and recyclers believe they are not allowed to stockpile glass due to onerous regulatory restrictions, the department claims its glass policy does not restrict glass stockpiling.

In order to provide clarity to stakeholders regarding what is permissible regarding both DBC and ADF glass, the study suggests the department update and finalize its 2008 policy on glass recycling. The study recommends the policy, which currently encourages recycling over down-cycling, should equally emphasize both methods. Other areas the policy should be updated include glass stockpiling, listing approved down-cycling options, and increasing the recovery rate for ADF glass containers to roughly the same redemption rate achieved by the DBC program.

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Recyclable Materials Market Value in California

Material	Market Value
Glass	$2.76 ton
Aluminum	$1,720 per ton
#1 PET plastic	$395 per ton
#2 HDPE plastic	$464 per ton

Recommendations

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A Study to Identify Local Alternatives to Shipping Non-Deposit Glass out of the State of Hawai‘i

A Report to the Governor and the Legislature of the State of Hawai‘i

Conducted by

The Auditor
State of Hawai‘i
and
Oceanit
Laboratories, Inc.

Submitted by

THE AUDITOR
STATE OF HAWAI‘I

Report No. 14-17
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Foreword

This is a report on the study of local alternatives to shipping glass containers out of the State for recycling, and whether these alternatives would be environmentally and economically prudent. The study is in response to a request under Senate Concurrent Resolution No. 74, Senate Draft 1, House Draft 1, of the 2014 Legislature, which also asked the Auditor to perform an audit of the Department of Health's glass advance disposal fee program. Because our office does not have expertise in environmental issues, we contracted with Oceanit Laboratories, Inc., to conduct the study. The program audit report and the study were issued under separate covers.

Jan K. Yamane
Acting Auditor

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Chapter 1
Introduction

This report was written in response to Senate Concurrent Resolution No. 74 Senate Draft 1, House Draft 1 (SD 1, HD 1), of the 2014 legislative session. The Office of the Auditor was requested to examine local alternatives to shipping glass containers funded by the advance disposal fee (ADF) out of the state. Specifically, the resolution asked for a study on the use of glass as sand, landfill cover, and in roadway asphalt; and whether these alternatives would be environmentally and economically prudent alternatives.

The Office of the Auditor outsourced this study and contracted with Oceanit Laboratories, Inc., to prepare this report.

As part of our research we interviewed stakeholders from many aspects of the industry—counties, the State Department of Health (DOH), recycling companies, construction and manufacturing companies, environmental advocates, bottling interests, and others. We identified many significant issues affecting down-cycling or recycling in Hawai‘i that we feel should be addressed. Since there is a lack of current documentation on glass recycling and down-cycling in Hawai‘i, much of our information was derived from interviews with stakeholders.

ADF glass

ADF or advanced disposal fee glass (HRS Chapter 342G Part VII) is a broad category of glass containers comprised of food, non-food, and beverage containers not covered by the deposit beverage container (DBC) law. It includes food jars, wine and spirit bottles, and non-food jars. According to DOH, approximately 55 million items per year are imported into Hawai‘i under the ADF jurisdiction (Table 1.1).

Table 1.1 Bottles and Jars reported from Oct 2012 to Sept 2013.

Type	No. Items
Glass ADF Food (Food Jar)	19,305,557
Glass ADF Non-Food (Non-Food Jar)	6,330,201
Glass ADF W&S (Wine & Spirits)	29,943,561

Container data from DOH 2014

The statewide total weight of reported ADF glass is approximately 23,500 tons. Estimates may vary because this number was derived from assumptions regarding the average weight of container types. The individual county numbers were derived by prorating using the de facto population.

Table 1.2 ADF glass per county by tonnage.

County	De Facto Population (2010)	Tons of Glass
Honolulu	941,693	15,761
Hawai‘i County	196,251	3,285
Kaua‘i County	81,242	1,360
Maui County	186,515	3,122
TOTAL	1,405,701	23,527

(Population: DBEDT 2013; tonnages estimated from DOH 2014 data)

The funding for the recovery and handling of these containers is partially derived from the advance disposal fee of 1.5¢ per container (HRS Chapter 342G Part VII). This accounted for a total ADF revenue of about $833,690 for the period from October 2012 to September 2013 (calculated from DOH 2014 data).

However, there is no deposit on these containers, so there is no monetary incentive to return the glass for recycling or down-cycling. Approximately 46 percent of ADF glass that enters the state is recovered for recycling or down-cycling (based on county-reported recycling rates and calculations based on the tonnage of ADF glass containers. Table 1.1 and Table 1.3). To put this into perspective, the redemption and recycling rate for DBC containers in 2012 was 77 percent (DOH, 2013). It is clear that with an incentive the ADF container recovery rate could also be higher.

Table 1.3 Reported ADF glass tonnage and calculated recycling rate.

County	County-reported tonnage (2014)	Recycling Rate
Hawai‘i	1,246 (a)	38%
Maui	2,111 (b)	68%
Honolulu	6,954 (c)	44%
Kaua‘i	475 (d)	35%
Total	**10,786**	**46%**

(a) County of Hawai‘i, 2014
(b) County of Maui, 2014
(c) City and County of Honolulu, 2014
(d) County of Kaua‘i, 2014

The ADF glass program costs must be based on an estimated glass recovery rate. This is because the revenue for the ADF program is collected per container of ADF glass that enters the state. However, the ADF program costs are based on the amount of ADF glass that is recovered. This results in an inverse relationship between the costs of the program and the glass recovery rate. In other words, the higher the recovery rate, the more the ADF program will cost. As part of this study,

we have estimated the ADF program costs and glass recovery volumes in order to compare alternatives. Based on the reported numbers in Table 1.3, the ADF program recovery rate is 46 percent, or 10,786 tons for 2014. The program collected $833,690 for 2014. This is a very low recovery rate compared to the DBC program (77 percent) and other glass recycling programs throughout the country. For the purposes of developing comparative estimates in this study, it was assumed the ADF program would be modified and the recovery rate would be 75 percent (similar to the DBC program), equating to 17,625 tons of ADF glass per year.

ADF glass can only end up in a limited number of places: reuse by initial user, trash, litter, or recycle bin. Much of the glass placed in recycle bins is shipped to North America for remanufacturing into new containers. Kaua‘i and Hawai‘i County facilitate local down-cycling of ADF glass but Honolulu and Maui County ship most of their ADF glass to California for recycling.

What is recycling?

Recycling is the process of collecting and processing materials that would otherwise be thrown away as trash and turning them into new products. For the purposes of this report it is essential to have more precise terminology. There is a generally accepted hierarchy of terms in the environmental community. They include reuse, recycle, down-cycle, and garbage, as illustrated in Figure 1.1.

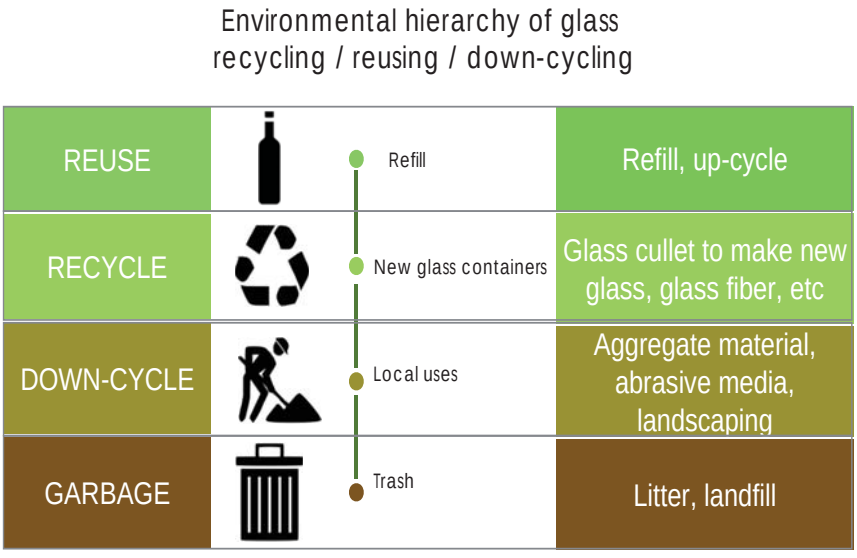

Figure 1.1 Environmental hierarchy of glass recycling (figure adapted from McDonough and Braungart, 2008).

Reuse includes conventional reuse, where the item is used again for the same function, and up-cycle reuse, where the item is used for a different,

higher value function. Reuse does not require material processing and saves time, money, energy, and resources. In broad economic terms, reuse offers quality products to people and organizations with limited means. Financial motivation is one of the main drivers of reuse. In the developing world, this driver can lead to very high levels of reuse. However, factors like rising wages and consequent consumer demand for the convenience of disposable products has made the reuse of low-value items such as packaging unprofitable, leading to the demise of many reuse programs. Current environmental awareness is gradually changing attitudes, and new packaging regulations are gradually beginning to reverse the situation. Reuse is very desirable but there are currently no opportunities for large-volume applications in Hawai‘i or in the mainland United States. The last glass bottle reuse facility in Hawai‘i closed down on Maui in 1988.

In the strictest sense, **recycle** means to melt containers and make another glass product. Most of the glass that is recycled is returned to its container form but some is made into fiberglass or other durable goods. There are no opportunities for large-volume recycling in Hawai‘i for several reasons, primarily because Hawai‘i does not have a large enough market or glass volume to justify the costs of a full-scale recycling facility. Therefore, Hawai‘i is unique because in order to recycle glass it must be transported a significant distance (typically to California). There are economic and environmental costs associated with this long transportation, making down-cycling uses potentially more viable in Hawai‘i than in other states. This study did not analyze the impacts of shipping glass to the mainland U.S.

Down-cycling is the process of converting waste glass into new materials or products of lesser quality and reduced functionality. Down-cycling aims to prevent wasting potentially useful materials; offset consumption of raw materials; and reduce energy usage, air pollution and water pollution. Examples include converting waste glass to sand, gravel, or blast media. There are several opportunities for large volume down-cycling uses in Hawai‘i. In this study, we identified and studied some of the most viable down-cycling options for glass in Hawai‘i.

The final level in the hierarchy is **garbage**. Material also be disposed of as garbage in a landfill or left as litter, which is not desirable. There is a significant cost to throwing glass in the garbage. Landfills are expensive to build, operate, and decommission. More glass garbage would further contribute to filling Hawai‘i’s landfills. In addition, landfills incur societal and environmental costs that are more difficult to quantify. On O‘ahu, glass also reduces the efficiency of the H-Power waste to energy plant.

Although landfilling of glass is not desirable, it does provide a baseline to begin to understand the costs of disposing of municipal solid waste, of which ADF glass is a component. Commercial tipping fees for each county give an indication of the cost of landfilling municipal solid waste. This fee is only the cost of dumping garbage; it does not include collection, sorting, or hauling.

Table 1.4 Tipping fee per ton for county landfills.

Commercial Tipping Fees (per ton)	
Hawai‘i County	$85 (a)
Maui County	$76 (b)
City and County of Honolulu	$91(c)
Kaua‘i County	$119 (d)

(a) County of Hawai‘i, 2014
(b) County of Maui, 2013
(c) City and County of Honolulu, 2014
(d) County of Kaua‘i, 2014

Choices between reuse, recycle, and down-cycle

In Hawai‘i there is no community consensus on whether to reuse, recycle, or down-cycle glass. All three options are beneficial uses of waste glass but the public, media, container importers, environmental groups, commercial recyclers, regulators and counties have different ideas on which should be implemented. Often the words *reuse, recycle,* and *down-cycle* have various and overlapping definitions, but it is important to understand the differences between the terms and craft laws, fee structures, and policies that would bring about the desired outcome(s).

Glass must be shipped to be recycled

Glass is heavy and expensive to ship. The cost of shipping 20 tons of containerized glass is approximately $2,400. Estimates for cost per ton vary from about $100/ton to $125/ton. A shipping company, Horizon Lines (2014), quoted $116 per ton for shipping glass from Hawai‘i to California. Much of Hawai‘i’s glass intended for recycling is shipped to Strategic Materials near Oakland, California. Strategic Materials, the recycler, pays about $5 to $9 per ton for the glass. Economically, this is not an attractive option. Despite the economic challenges, it is the preferred option for Honolulu and Maui counties. However, Hawai‘i and Kaua‘i counties do not export significant quantities of ADF glass. They have identified local down-cycling options.

The cost for each local down-cycling use can be compared to the cost of shipping glass to the mainland for recycling. However, it should be noted that the costs are estimates and can vary significantly depending

on the recycler, the island, and other factors. The freight charge to ship recycled materials to the mainland from Hawai‘i is approximately $120 per ton, and Hawai‘i recyclers receive $5 to $9 per ton for glass from mainland recyclers. These data can be used as a baseline or comparative value for cost and volume evaluation for each alternative local use.

Table 1.5 Baseline ADF glass volume and costs for shipping glass.

Item	Cost	Market Value	Net Cost
Freight charge to ship recycled materials from Hawai‘i to California (1)	$120/ton	$7/ton	$113/ton
Estimated volume of ADF glass			17,625 tons/year

(1) Shipping and commodity costs fluctuate. This is an average rate given by Counties and recyclers.

We found that Honolulu and Maui Counties feel they have tried and not succeeded on a variety of local glass down-cycling projects and reuse options. Very little documentation was located to verify the success or failure of these projects. Also, staff feel that state regulatory constraints push or require them to recycle in North America. In addition, it is more efficient for Maui and Honolulu to treat ADF glass in the same way as DBC glass. DBC glass is required by law to be recycled and, therefore, is shipped to the mainland United States. ADF and DBC glass is the same material, with the same array of possible uses. Due to facility and personnel limitations it is more efficient to treat the two “types” of glass the same. Note that although these types of glass have different regulatory and cost constraints, they are the same commodity—soda lime glass—and have the same potential for reuse, recycling, or down-cycling.

Methodology

We wish to extend our sincere thanks to all the many people in government and private industry who gave so freely of their time and mana‘o. Industry experts responded helpfully to numerous interview requests, telephone calls and emails. We could not have collected this information without their help.

A major source of information for this report was gathered from interviews and conversations with stakeholders in the recycling industry including private recycling companies, counties, the Department of Health, construction and manufacturing companies, environmental advocates, industry experts, regulatory agencies, bottling interests, potential users of down-cycled products, and others. A list of stakeholders is presented in Appendix C.

In addition, we researched available documentation on down-cycling in Hawai‘i and other areas. We reviewed numerous documents on recycling and down-cycling in order to further assess the feasibly of various options. Most of the available documentation on Hawai‘i down-cycling and recycling does not give details as to why a particular project did not continue. As a result, we were forced to rely on both informal verbal and written information sources.

Scope

The scope of work includes the following objectives:

1. To perform a study that identifies local alternatives to shipping non-deposit glass containers out of the state for recycling, including, but not limited to, the local conversion of glass to sand or the use of glass as landfill cover or in roadway asphalt.

2. The study includes analysis of whether these local alternative programs would be environmentally prudent and cost effective.

The study encompasses the following tasks and responsibilities:

1. Contractor is to identify local alternative programs in the collection, recycling, and re-use of non-deposit glass containers. Non-deposit glass containers include, but are not limited to, beverage items such as milk, wine, liquors, oils, and condiments; as well as non-food items such as perfumes, nail polishes, cleaning supplies, paints, and any other non-deposit glass containers as defined by the department.

2. The department will work collaboratively with the contractor to obtain any available data, including data from the counties, which the contractor deems necessary to perform the study.

3. Contractor must provide analysis of possible environmental impact for each local alternative it identifies regarding the collection, recycling, and re-use of recycled non-deposit glass. Contractor must provide analysis of economic impact for each local alternative it identifies regarding the collection, recycling, and re-use of recycled non-deposit glass.

4. Contractor must provide analysis of whether each identified local alternative is self-sustaining, using current revenue from the ADF or whether additional funds or resources would be necessary and if so, how much.

5. Contractor must consult with stakeholders involved in the Glass Recovery Container program, including, but not limited, to the

counties, glass manufacturers, retailers, wholesalers, recycling entities, or any other parties engaged in the sale, collection, recycling, and reuse of recycled non-deposit glass for their input or suggestions regarding the identification of local alternatives and any concerns about cost and environmental impacts.

6. The final report must include a ranking of local alternatives based on cost, environmental viability, and availability of current department resources.

Criteria

We considered ten criteria when assessing the various local down-cycling uses. We analyzed a total of 11 local down-cycling uses of glass, which are described in more detail in Chapter 2 and Appendix B. The criteria were each assigned a number from 0 to 4 to provide an "index of down-cycling," where 0 is most favorable or least difficult, and 4 is least favorable or most difficult.

1. Cost analysis

We studied two different aspects in the cost analysis for each down-cycling option: processing costs to convert glass waste into a product that is usable in the industry, and market value for the existing product the glass cullet will be replacing.

For all the down-cycling applications studied, the post-consumer glass must be pulverized into a material with the required properties. Typically, the glass is pulverized into a 3/8"–0" glass cullet. This means that the size of the particles is less than 3/8 of an inch, commonly called *3/8" minus*. Then the glass cullet can be further pulverized into sand or other specified sizes. Costs were developed for processing the glass into 3/8" minus and into sand #30 sieve or smaller. Some uses required additional processing, such as cleaning or further size sorting and handling. Processing costs increases as glass is processed to a more refined product.

A scale from 0 to 4 was developed to rate the net cost for this criteria based on the range of highest net value use and lowest net value use. The following table shows the rating scale used for the cost criteria.

Table 1.6 Cost criteria rating scale.

Net Value/ton	Down-cycling Rating scale
$51 to $105	0
$1 to $50	1
$(50) to $0	2
$(105) to $(51)	3
$(145) to $(106)	4

2. Potential demand

A significant factor in determining the success of a down-cycling use is the compatibility of the supply of glass cullet versus the industry demand for the glass product. For example, a recycler is not going to invest money and time into marketing and developing an industry use if the industry demand is only a small percentage of the glass cullet supply the recycler is selling. Conversely, an industry is not going to be willing to adopt a replacement glass product if that product is unable to meet its current demands, unless the product is significantly less expensive or superior. Therefore, we created a rating scale based on the estimated state ADF glass supply of 17,625 tons per year. If an industry was able to consume a high percentage of the glass supply, then a lower "index of down-cycling" was given. Also, if the glass supply is unable to meet the industry demands, a higher "index of down-cycling" was given. The following table shows the rating scale.

Table 1.7 Potential demand criteria rating scale.

% of Glass	Down-cycling Rating scale
60%-100%	0
30%-60%	1
15%-30%	2
Well over 100% and difficult to meet demand	3
5%-15%	3
Less than 5%	4

3. Health and safety

The health and safety criterion of down-cycling glass concerns the potential impacts that each part of the process has on the safety and health of workers and other exposed persons throughout the lifecycle of the glass down-cycle option. These parts of the process include: pulverizing at the recycling plant, further processing (if necessary), stockpiling, installation or use, and disposal (if applicable). In addition, the criteria must address health and safety impacts of future unearthing if the down-cycle option is aggregate or sand.

Table 1.8 Health and safety criteria rating scale.

Description	Down-cycling Rating scale
No known health and safety effects with appropriate PPE	0
Minimal health effects	1
Administrative controls on uses	2
Engineered controls on uses	3
Unacceptable for use	4

4. Environmental impacts

There are only a few known significant environmental impacts for most of the down-cycling options. The primary environmental concern is aesthetic, since colored glass cullet may not look "natural" in many of the down-cycling options. Down-cycled glass generally replaces the use of a limited resource and provides a slight benefit to the environment. All of the down-cycling uses proposed in this study would replace materials that must be mined from either sources in Hawai‘i or on the mainland. Sources of mined gravel and sand are finite and should be conserved. The supply of natural sand and gravel in Hawai‘i's quarries is limited.

Table 1.9 Environmental impacts criteria rating scale.

Description	Down-cycling Rating scale
No known environmental impacts	0
Minimal impacts	1
Possible impacts that require more study	2
Significant impacts on the environment	3
Significant and possibly unacceptable impacts on the environment	4

5. Law, regulation and policy changes

This category describes changes that might be required in current state statutes, county ordinances, state regulations, or agency policies. Our intent for this criterion is to identify factors impeding local uses of glass. We found that the implementation of certain down-cycling options has been impeded by regulations, policies, or laws. It is possible that these laws, regulations, or policies, are in effect for other, overriding reasons and should remain in place.

Our conversations with the counties and recyclers identified a common perception that stockpiling of glass is prohibited by the Department of Health. The DOH regulates processed glass stockpiles in order to ensure that glass is either recycled or down-cycled in accordance with DOH policies. These policies have been identified as barriers to stockpiling.

It is important to understand that there are also state and county laws, rules, and policies in place to ensure that stockpiled materials do not pollute the environment. These rules apply to all stockpiled material and include appropriate provisions for testing as well as best management practices to contain or treat runoff water and control dust. These rules are necessary for environmental protection.

The index criterion for this category varies from 1 to 4. All of the local down-cycling uses for glass required some changes in laws, regulations, or policies.

Table 1.10 Law, regulation and policy changes criteria rating scale.

Description	Down-cycling Rating scale
No known changes to laws	0
Changes to stockpiling policy	1
Changes to regulations	2
Changes to multiple laws	3
Changes to long-standing policies, rules or laws.	4

6. Specification changes and testing

This category describes the extent of changes necessary in engineering specifications. Many of the down-cycling options of glass are primarily applied in the construction industry. This industry is often engaged in building public infrastructure and strictly follows approved specifications and standards. In order for these uses to be implemented, glass would have to be written into the applicable specifications or standards. In other cases, the specifications currently includes glass; however, it is written in a manner that effectively discourages the use of glass. This is a very important criterion for many large-volume uses of glass. It is intended to give an indication of the potential complexity of altering the engineering specifications.

Table 1.11 Specification changes and testing criteria rating scale.

Description	Down-cycling Rating scale
No changes to specifications necessary	0
Well-established non-structural use with simple changes anticipated	1
Well-established use with more complex changes to engineering specifications	2
Many complex changes anticipated	3
Not included in any known U.S. specifications (new specification)	4

7. Industry and public resistance

The resistance of the industry and public is a significant factor in implementing successful local down-cycling uses of glass. There can be resistance to glass down-cycling for a variety of subjective and objective reasons. Some examples include the belief that glass is hazardous, disagreements on what is a beneficial use, or simply a resistance to change. Resistance can necessitate more investment in public or industry education. A common stakeholder concern is that post-consumer glass is hazardous and continuing effort would be necessary to provide education on the properties of glass.

Table 1.12 Industry or public resistance criteria rating scale.

Description	Down-cycling Rating scale
No known resistance	0
Industry concerns on safety	1
Acceptance varies widely	2
Many concerns identified among the public and industry	3
Known high resistance from users, industry and public	4

8. Past and current applications

This criterion provides an indication of where and how the product was manufactured and used in the past. It has been reduced to a simple index. The index gives an idea of the ease of down-cycling, where 0 is the most established and tested option and 4 is given to options that are entirely new.

Table 1.13 Past and current application criteria rating scale.

Description	Down-cycling Rating scale
Used previously in Hawai‘i and U.S. mainland	0
Used on the U.S. mainland	1
Used internationally	2
Has been studied but no known use anywhere	3
No known uses or studies (a new use)	4

9. Market development

In some cases, a market for a product must be developed in Hawai‘i. Some of the down-cycling uses have been marketed and attempted on a large scale in Hawai‘i, such as glasphalt, and others have been used only on a small scale or individual basis. This category is intended to convey the degree of effort that might be needed to develop a particular market.

Table 1.14 Market development criteria rating scale.

Description	Down-cycling Rating scale
The market currently exists	0
Market developed in some counties	1
No known market in Hawai‘i	2
No known market in Hawai‘i but significant potential opportunity for growth	3
No known market in Hawai‘i but significant barriers to implementation.	4

10. Stakeholder complexity

This category is intended to give an indication of the number of entities and complexity of stakeholder involvement that might be necessary to implement a particular option. Stakeholders are listed in categories and are not necessarily individual entities. For example, there are multiple recycling firms in the state but they are listed as “recyclers.” The DOH, counties, and recyclers (recycling companies) are necessary stakeholders for every use. A list of stakeholders is included in Appendix C, and the complexity is presented as an index from 0 (simplest) to 4 (most complex).

Table 1.15 Stakeholder complexity criteria rating scale.

Stakeholder Complexity	Down-cycling Rating scale
DOH, counties, recyclers	0
Customers for product (+ those listed in 0)	1
Engineering & construction industry (+ those listed in 1)	2
Regulatory agencies	3
Public	4

Our work was performed from September 2014 to December 2014.

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Chapter 2
Local Uses for Glass Require Varying Levels of Support

Since glass is a relatively low-value commodity, recycling, down-cycling, or reusing large volumes of glass requires varying levels of government and industry support such as subsidies, incentives, and changes to the law, rules, and policies. In addition, support may also be required in other areas depending on the down-cycling use. For example:

- Some uses require industries to change their processing methods to utilize glass. This may necessitate additional space, equipment, time, and training.
- Public and industry education may be required to mitigate the perception that there are serious health and safety requirements pertaining to glass.
- Certain industries, agencies, and companies are resistant to the use of glass because of technical or environmental concerns. This may require education, pilot studies, or additional research and testing.
- Some uses require large, readily available volumes of glass; therefore, stockpile space would be necessary.
- Some uses require design specifications to be changed to allow for glass cullet.
- Lastly, all reuse options require brokerage. Many stakeholders in the recycling industry said that a major difficulty in local reuse of glass is the variability of the glass cullet demand and difficulty in finding steady customers.

Each down-cycling use in this study was rated based on the criteria discussed in Chapter 1. A brief description of each down-cycling use analyzed is found below. More information about each use, including past or current applications, potential demand, cost analysis, and other criteria, is available in the appropriate section in Appendix B. Other down-cycling or recycling options are possible in Hawai‘i, including but not limited to concrete, roof tiles, countertops, fiberglass, and new containers, but they were not analyzed in this study, since none of these products are currently manufactured in Hawai‘i.

Table 2.1 Criteria rating matrix for local uses of glass.

Glass Use		Cost	Potential Demand	Past or Current Applications	Health & Safety	Environ. Impacts	Law, Reg., Policy Changes	Spec. Changes	Industry or Public Resistance	Market Development	Stakeholder Complexity	Total Points
Agricultural Soil Amendment & Groundcover		4	0	0	0	0	1	1	0	0	1	**7**
Non-structural Backfill		4	0	0	0	0	1	2	1	0	2	**10**
Traction & Mud Abatement		4	1	0	0	0	1	1	0	1	2	**10**
Landfill Uses		4	0	2	1	0	3	0	3	0	1	**14**
Landscaping		2	2	0	0	0	1	2	0	2	2	**11**
Golf Courses	Maintenance	3	1	1	0	0	1	0	0	1	3	**10**
	Greens	3	0	3	0	0	1	0	0	4	3	**14**
Filtration Media		0	4	0	0	0	1	2	0	2	1	**10**
Beach Nourishment		4	0	3	0	2	4	0	3	3	4	**23**
Blast Media		2	4	0	1	0	1	0	2	2	3	**15**
Flowable Fill		4	1	3	0	0	1	4	0	3	2	**18**
Glasphalt		4	3	0	0	3	3	3	4	0	4	**24**

Local Uses for ADF Glass

Based on the data collected and the criteria evaluation, there are several local down-cycling options in Hawai‘i. Those with the lowest down-cycling rating scores are generally easier to develop and implement. The following section breaks the options into three categories: **Simplest-to-Implement**, **Highest Value**, **Long-Term Value,** and **Other Local Uses**. Optimally, these options should all be implemented. The first step is to implement the simplest-to-implement down-cycling options. This will open up the glass market and industry in Hawai‘i and provide more experience to bring about public and industry acceptance. Higher-value uses can be developed concurrently and then be implemented, which will help reduce the program’s overall cost in the long term. Lastly, the long-term value option should be researched and developed, since it has the potential to have added value beyond using the ADF glass.

Simplest-to-implement

Generally, the simplest down-cycling uses have flexible markets and few technical constraints. The following local uses have the lowest down-cycling rating scores and could be immediately implemented. They would likely utilize all the glass in the state. However, each county and recycler has different processes and procedures of running its glass

program and particular relationships with industry users, which will impact the use and demand for glass. Therefore, we recommend utilizing glass for all four of these applications. This will enable recyclers to withstand market fluctuations and sell glass to the industry with the most demand.

Based on the cost analysis performed in this study, ADF program costs were estimated for the simplest-to-implement option. The costs associated with all four simple-to-implement uses are similar and range from $120 per ton to $130 per ton. The amount of glass used for each of these four uses is unknown and would likely fluctuate as the market changes. An average cost of $125 per ton was used to estimate the ADF program costs. Assuming there would be approximately 17, 625 tons of ADF per year, this would result in a total ADF program cost of approximately $2.2 million per year. This does not include any deposit fee to incentivize container redemption.

Agricultural Soil Amendment and Groundcover

Use Rating: 7
Net Cost[1]: $120 per ton
Potential Market Demand:10,500 tons per year

Glass cullet can be used as a soil amendment to change the soil drainage properties and better facilitate plant growth. Processed glass can also be used as a groundcover either to control pests, weeds, dust, or mud. These applications are similar to applications used in landscaping, but the market and industries are significantly different. Agriculture would require low commodity prices. Agricultural uses would also generally elicit less public attention. Most uses in agriculture would have less stringent specifications and the glass aggregate would require little processing beyond 3/8" minus pulverizing. Glass is currently being used for agricultural soil amendments on Hawai‘i Island and has also been used on O‘ahu. For more information on Agricultural Soil Amendment and Groundcover, see Appendix B, page 48.

Requirements for implementation:

- Costs are supported.
- Allow practical stockpiling. This will require the counties, DOH, and recyclers to collaborate and develop regulations that accommodate their needs.

[1] Processing costs can greatly fluctuate with process volumes. These costs can significantly decrease as efficiency increases and processing equipment is paid off.

Non-Structural Backfill

Use Rating: 10
Net Cost: $120 per ton
Potential Market Demand: 270,000 tons per year

Processed glass can be used as general backfill, drainage backfill and utility line bedding, and drainage line backfill, either by itself or blended with soil or natural aggregate to provide non-structural and structural fills. Processed glass has been used for backfill, drainage and pipe bedding throughout North America and in Hawai‘i. Non-structural backfill requires minimal processing and there are few technical constraints, so glass cullet could be used for up to 100 percent aggregate replacement. There are no environmental or technical constraints on these uses, but changes in engineering specifications will be required. There is an incorrect perception that glass is hazardous, and the industry resists working with glass cullet. Although the cost of processed glass is higher than the cost of the equivalent natural aggregate, this option could be implemented immediately and could use large volumes of ADF material. For more information on Non-Structural Backfill, see Appendix B, page 36.

Requirements for implementation:

- Allow practical stockpiling
- Allow 100 percent glass in engineering specifications (including county water supply and wastewater specifications)
- Enforce state laws that require the use of glass (HRS 103D-407) or provide incentives for recycling

Traction and Mud Abatement

Use Rating: 10
Net Cost: $130 per ton
Potential Market Demand: 10,000 tons per year

Processed glass can be used to control mud and provide traction on dirt and gravel roads, trails, or baseyards. This use has been commonly applied throughout the nation and is a primary use for ADF glass on Kaua‘i. Generally, strict engineering specifications are not required for these applications. There may be aesthetic concerns with the use of glass on roads but there are no known environmental constraints. This use is a lower-value application of glass, but has little complexity and a high demand. For more information on Traction and Mud Abatement, see Appendix B, page 58.

Requirement for implementation:

- Allow practical stockpiling.

Landfill Uses

Use Rating: 14
Net Cost: $130 per ton
Potential Market Demand: 260,000 tons per year

Processed glass can be used in landfills as alternative daily cover, mud control, and drainage backfill. The application of recycled glass as a beneficial use in landfills has been applied in many areas of the country. Although it is one of the lowest value uses, it has no industry resistance and is completely within the control of the State to initiate. Landfills on Maui and Kaua‘i are ready and waiting to down-cycle glass for this purpose, and Hawai‘i County has also expressed interest. There is resistance from the DOH, primarily due to concerns about possible negative public sentiment regarding sending the material to a landfill. However, this application is replacing a local finite resource of either rock or soil and is not disposal in the landfill. Appendix B, page 53.

Requirements for implementation:

- The DOH must approve landfill uses as an appropriate down-cycling use.

- The DOH would need to review and approve applications showing the sanitary effectiveness of glass as landfill cover.

Highest value

The highest value use recommendations are based on the down-cycling rating criteria with an emphasis on the cost-analys score. These uses have the potential to provide a higher value; however, implementation may require significant stakeholder and industry involvement as well as market development.

The application of these higher value uses can help to reduce ADF program costs. Based on the cost analysis performed in this study, ADF program costs were estimated to include the “high value” local uses. The market demand for glass uses in landscaping (more than 4,000 ton/year) and golf course maintenance (about 7,700 tons/year) would likely not consume the entire supply of ADF glass in the state. To develop an approximate overall ADF program cost, we assumed that half of the ADF glass would continue to be used for the simplest-to-implement uses discussed above. However, the other half of the ADF glass supply could be used equally for landscaping and golf courses. This would result in a

total ADF program cost of about $1.65 million. Details of the calculation estimates are in Table 2.2 below.

Table 2.2 Highest value local uses of glass, cost calculations.

Local Glass Use	Cost per ton	Estimated Volume for Use	Total Cost
Simple to Implement Glass Uses	$125	8,800 (50% of all ADF glass)	$1,100,000
Landscaping	$20	4,400 (25% of all ADF glass)	$88,000
Golf Course Maintenance	$105	4,400 (25% of all ADF glass)	$462,000
TOTAL			$1,650,000

Landscaping

Use Rating: 11
Processing Cost: $20 per ton
Potential Market Demand: 4,000 tons per year

Processed glass can be used as aesthetic or weed-control groundcover and as a landscaping soil amendment. It can also be used as a replacement for cinders, sand, or gravel. Landscaping soil mixtures typically include amendments such as sand and cinders to help improve drainage. In addition groundcovers are often used for landscape bedding for aesthetic appeal, to keep in moisture, control weeds, and protect plant beddings from pests and disturbances. Glass cullet can be used as a replacement for both of these uses in landscaping. Glass has been recently used for landscaping on Kaua‘i and Maui and is commonly used for this purpose throughout the country. Landscaping uses scored well in the criteria index because the industry demand is significant and processed glass has the potential to be a superior replacement product because of its environmental and aesthetic value. The landscaping industry is interested in the uses of processed post-consumer glass. This option is feasible to implement immediately, has a potentially higher value than other construction uses, and could use a large percentage of ADF glass. For more information on Landscaping, see Appendix B, page 51.

Implementation requirements:

Modification of DOH stockpiling policy.

- Adding glass cullet to specifications for landscape architects.
- Coordination with the landscaping industry.

Golf Courses

Use Rating (Maintenance): 10
Use Rating (Greens): 14
Net Cost (Maintenance): $105 per ton
Net Cost (Greens): $90 – 115 per ton
Potential Market Demand: 16,500 tons per year

Processed glass can be used on golf course greens and maintenance projects. Currently, golf courses use expensive imported silica sand or beach sand. Glass sand has been used at golf courses in other parts of the country and for a maintenance project on O‘ahu. It has been investigated on Maui. The application of glass cullet for maintenance projects can be implemented more easily than use for golf course greens, which has more stringent specifications. This option is feasible to implement in Hawai‘i but will require marketing, as golf course managers are accustomed to using expensive imported sand and are largely unaware that glass is a viable option. Glass as green sand would require more processing and effort, but could be a potentially higher value option in the longer term. For more details, see Appendix B, page 60.

Implementation requirements:

- Increase public awareness of this use.
- Encourage or require county golf courses to use processed glass for their maintenance projects and greens maintenance.

Filtration Media

Use Rating: 10
Net Profit: $57 – $162 per ton
Potential Market Demand: 4,000 tons per year

Filtration media is a small market but highly valuable and a fairly simple use of processed glass. Aloha Recycling on Maui sold glass media for filtration and this could be done by the other recyclers. The market demand for filtration media is less than 1 percent of the total state ADF glass supply. Therefore, it makes no impact in overall ADF program costs. However, it can be a valuable use for a small, individual recycler. Therefore, this use was not included in estimating overall ADF program costs. Appendix B, page 67

Long-Term Value

The long-term value use recommendations are not based on the scoring system. This use is appropriate for Hawai‘i because it may help with coastal erosion and in adapting to climate change; therefore, having the potential to provide long-term value. However, implementation may

require significant changes to laws, regulations, policies, and public sentiment.

The cost to fund the ADF program is not included for the beach nourishment option because there are too many unknowns about the environmental impacts and necessary degree of processing. Cost estimates used in this analysis assumed glass would have to be crushed to a sand-like material, which is costly. However, with further study less processing may be required, reducing costs. In addition, the cost of local beach sand is rising. Both of these factors can make this local use for glass more economically viable.

A pilot project is recommended. Estimated costs for a pilot project with the necessary design, permitting, and associated studies ranges from $1.3 to $1.5 million. Public input and participation should be solicited throughout the project. Environmental monitoring should extend for at least one year after glass material is in place. Regulatory agencies, including Department of Health (DOH) and Department of Land and Natural Resources (DLNR) would need to be closely involved in the formulation of the project.

Beach Nourishment

Use Rating: 23
Net Cost: $105 – $135 per ton
Potential Market Demand: More than 13,000 tons per year

Many beaches in Hawai‘i are eroding and the most appropriate method to counteract beach erosion is to replenish the eroding beaches with suitable sand from outside sources. The potential demand for beach nourishment sand is very high in Hawai‘i and the available local sand sources have significant environmental impacts. Using processed glass for beach nourishment has the potential to help with two environmental issues in Hawai‘i: glass waste and eroding shorelines. Beach nourishment scored high in the down-cycling criteria rating index; however, more research is required and a pilot project is recommended to assess the potential environmental impacts and to test degrees of glass processing necessary.

Florida has studied the use of glass as beach nourishment, but it did not implement the use because of the high cost. Possible aesthetic impacts and impacts to the marine environment must be studied. Although this option cannot be immediately implemented, it has the potential to be uniquely beneficial to Hawai‘i. A pilot study and more research would help understand the potential environmental impacts. For more information on Beach Nourishment, see Appendix B, page 63.

Implementation requirements:

- Regulatory approval from the departments of Health and Land and Natural Resources.
- Subject to significant public scrutiny.

Other local uses

We identified several other local uses that do not fit into the previous categories. Generally, these uses show potential for high value or high usage; however, they have significant constraints to implementation and may be among the most difficult to adopt.

Blast Media

Use Rating: 15
Net Cost: $10 – $115 per ton
Potential Market Demand: 25 tons per year

Post-consumer glass cullet has been shown to be an effective blast media and industrial abrasive. Glass cullet has benefits over other types of blast media. Typically, glass can replace natural silica sand, steel pellets, and in some cases, garnet. Processed glass has been used in Hawai‘i and on the U.S. mainland and is a commercially available blast media product. However, blast media applications are specialized in Hawai‘i. In addition, it is a low-volume niche market in Hawai‘i, with a very high value. Expansion of this market is mostly in the control of private-sector recyclers and the local blast media industry. The industry is mixed regarding its openness or resistance to using glass as a blast media. Large amounts of dust are produced in the blasting process and airborne dust creates the potential for respiratory effects on workers and bystanders. Despite these concerns, glass blast media has been determined to release less airborne concentrations of hazardous silica (NIOSH 1998) than silica sand. For more information on Blast Media, see Appendix B, page 66 .

Implementation constraints:

- Market demand likely to be low.
- Industry reluctance.
- High processing costs.

Flowable Fill

Use Rating: 18
Net Cost: $125 per ton
Potential Market Demand: More than 6,000 tons per year

Flowable fill (controlled low strength material) is the standard restoration requirement for all utility trenching in the Hawai‘i Department of Transportation (DOT) right-of-ways. It is a low-strength concrete material designed to fill trenches and cavities. The National Ready Mix Concrete Association (NRMCA, 2014) states in their guide specifications that crushed glass can be used in flowable fill. However, the size of glass cullet falls outside the American Society for Testing Materials standards, which is an overriding specification. Currently, glass cullet is not mentioned in Hawai‘i DOT flowable fill specifications and is not known to have been used in Hawai‘i. There are no regulatory or environmental concerns associated with glass cullet used as flowable fill. Studies have shown that glass cullet can be used in flowable fill and meet technical requirements. However, our research did not find any widespread use in the U.S.; this option will require further study and is not feasible for immediate implementation. For more information on Flowable Fill, see Appendix B, page 40.

Implementation constraints:

- Not known to have been used in Hawai‘i.
- Specifications changes could be complex.

Glasphalt

Use Rating: 24
Net Cost: $145 per ton
Potential Market Demand: 44,600 tons per year

Glasphalt refers to asphaltic concrete for transportation paving made with crushed glass as a partial substitute for the aggregate (sand or gravel) in the mix. The asphalt industry in Hawai‘i is generally opposed to using glass in asphalt because it is more expensive to process and is not a recyclable material. The counties and DOT are generally not in favor of the use of glasphalt because, in their experience, its impact on the quality of pavement is neutral at best and may be slightly negative. Despite this, it has been applied nationwide with varying degrees of success. This option is not feasible to implement immediately because of high industry and user resistance and cost and environmental concerns. For more information on Glasphalt, see Appendix B, page 43.

Implementation constraints:

- Limited supply of glass cullet.
- Glasphalt is not recyclable.
- Glass is not allowed in the surface course of DOT pavement.

Low Value and Department Policies Create Barriers to Down-Use

Glass is a relatively low-cost commodity, so its value does not cover the cost of recycling the product. For comparative purposes, Table 2.3 the scrap values per ton of commonly recycled materials in California as of September 2014 (Calrecycle 2014). Most of Hawai‘i’s recyclables are sent to California markets.

Table 2.3 Recyclable materials market value in California.

Material	Market Value
Glass	$2.76 per ton (1)
Aluminum	$1,720 per ton
#1 PET plastic	$395 per ton
#2 HDPE plastic	$464 per ton

(1) Anecdotal information indicates that Hawai‘i recyclers receive from $5 to $9 per ton for their glass in California. The reason for the higher value was not identified, but sorting, cleaning and crushing all add value to post-consumer glass.

These commodity values vary significantly on a monthly basis. For example, the monthly average scrap value of glass in California from October 2013 to September 2014 varied from $0.10 to $3.02 per ton (Calrecycle 2014).

Glass processing costs are volume dependent

The more glass, the lower the processing cost per ton to process. There are three primary reasons for this: (1) glass processing equipment is very expensive; therefore, processing large amounts of glass allows the cost to be more evenly distributed; (2) processing glass is more efficient when done in large quantities; and (3) the primary industries that utilize local glass cullet need large quantities of processed glass and often require it on short notice.

Local glass processing and down-cycling began to decline in 2005 when the DBC law went into effect. Recyclers say the decline is due to the decreased volume of available ADF glass. Deposit glass used to be included in the volume of ADF glass but is now excluded.

The reported recovery rate for ADF glass is low. Between September 2012 and October 2013, approximately 23,500 tons of ADF glass entered the state. However, approximately 11,000 tons of ADF glass was recovered as reported by the counties in 2014. This is between a 40 and 50 percent recovery rate. By comparison, the DBC program reported that about 20,000 tons of glass was redeemed in Hawai‘i in 2012, a 77 percent redemption rate calculated from data in the Report to the Legislature 2013).

In order for local glass down-cycling uses to be viable, there needs to be enough volume for recyclers to invest their time and money in pulverizing and processing glass. This requires prioritizing and maximizing recovery rates for ADF glass and/or allowing DBC glass to be used locally.

Glass value is dependent upon local supply and demand of other industries and the marketing and locations of recyclers

Many stakeholders in the recycling industry said that a major difficulty in local reuse of glass is the variability of glass cullet demand. Recycling companies and the counties have borne the task of brokering glass cullet through industry fluctuations. However, recycling companies prefer to have a steady, reliable end user such as a recycler on the mainland. Since glass value is dependent upon the supply and demands of other industries, it would be helpful if glass is used in multiple applications and industries. This allows recyclers to withstand market fluctuations.

Policies have created barriers to local uses for post-consumer glass

Deposit and non-deposit glass are the same commodity, yet the DBC and ADF laws treat them differently. For example, the DBC, or Hi5 law, provides for an incentive deposit and disposal fee for many types of beverage containers including glass beer and soft drink containers. When the DBC law went into effect, it created two “types” of glass that are subject to different rules and policies, even though they are the same commodity. However, the current policy is that DBC glass must be recycled (shipped to the mainland for recycling). ADF glass can be shipped or locally down-cycled. Some of the problems identified from the interaction between the ADF and DBC programs are:

- According to current interpretations of the law, DBC and ADF glass must be separated. This is a manual process and is costly to counties and their contracted recyclers.

- There is less glass available for local use because DBC glass must be sent to the mainland for recycling. Both large quantities and steady supply are important for local down-cycling options.

- Recyclers have limited space, so it is presently more efficient for some counties and their contracted recyclers to treat the two "types" of glass the same and ship all glass to North America for recycling.

The 2008 Department of Health draft policy on glass recycling encourages recycling over down-cycling and imposes limitations on glass down-cycling options

The DOH adopted a draft policy to help regulate the recycling of DBC and ADF glass. The draft policy is the active policy on glass recycling and the DOH, counties, and recyclers consider it to be in effect. It contains details of the DOH policy on applications, stockpiling, and remanufacturing. According to the introduction, the draft policy appears to apply to both the ADF and DBC programs, but the DOH says that it does not necessarily apply to ADF glass. The DOH draft policy:

- Encourages recycling over down-cycling. DOH is the agency tasked with regulating the recycling of glass so there is strong motivation for recyclers to conform to DOH policy and ship glass to the mainland for recycling. The draft policy states that "DOH would like to see more glass going to remanufacturing facilities." In other words, the policy favors recycling over down-cycling.

- Places limits on approved reuse, down-cycling, and recycling options. Approvals must be granted by DOH on a case-by-case basis after a written request.

- Lists landfill alternative cover as an "unapproved" glass recycling application.

- Makes it a priority to ensure that post-consumer glass is put to a meaningful use before payment is made for the glass, thus creating issues around stockpiling because the material is not yet put to use while it is being stockpiled. However, recyclers need to get paid for the material they process and store.

Counties and recyclers feel they cannot stockpile glass due to regulatory restrictions

According to recyclers and the counties, reporting, timeline, and rules regarding stockpiling are extremely strict and limiting; however, the Department of Health says that draft policy stockpiling requirements do not apply to ADF glass. Stockpiling is a standard procedure for aggregate producers and necessary to maintain supply for large-volume glass down-cycling options. There are state and county laws, rules,

and policies in place to ensure that stockpiled materials do not pollute the environment. These rules apply to all stockpiled material and include appropriate provisions for testing as well as best management practices to contain or treat runoff water and control dust. These rules are necessary for environmental protection. Clarifying which regulatory restrictions apply to ADF glass will enable recyclers and the counties to assess whether they can practically stockpile glass in amounts that would support down-cycling efforts.

Conclusion

We identified several options to shipping ADF glass out of state. However, to successfully implement local uses of ADF glass, we have some overall suggestions. These suggestions address significant obstacles to local down-cycling of ADF glass. Specific local uses of ADF glass are secondary.

Recommendations

The Department of Health should:

1. Consider combining the ADF and DBC glass processing streams. Doing so will increase efficiency and decrease costs while increasing the supply of glass available for down-cycling. Separating the glass was identified by the counties and recyclers as high cost item, but they were unable to give an exact cost. Details of this change were not evaluated in this study. However, other states, such as California, have combined glass streams.

2. Update and finalize the 2008 Department of Health Policy Glass Recycling Draft dated July 1, 2008. The policy should:

    a. Equally allow recycling or down-cycling;

    b. Clearly allow stockpiling of glass for the purposes of maintaining inventory;

    c. Include a complete list of approved down-cycling options. This will allow recyclers more flexibility in marketing their product; and

    d. Allow the use of glass as alternative daily cover in the down-cycling options.

3. Work with stakeholders to make practical policies and rules governing the stockpiling of processed glass.

4. Increase the recovery rate for ADF glass containers to 75 percent, which is approximately the same redemption rate that the DBC program has achieved. This could be done by increased funding of the "buy back" program and would require increasing the ADF rate. A higher recovery rate will slow the filling of landfills and increase the supply of glass available for down-cycling.

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Appendix A
Calculations

Glass Cullet Processing (3/8"-0"):

Item	$/ton
Pulverizing[1]	$ 90.27
Marketing/Brockerage[2]	$ 4.43
Stockpile/storage[3]	$ 5.56
Maintenace[4]	$ 5.56
Disposal of waste[5]	$ 14.25
15% profit[6]	$ 18.01
Subtotal	$ 138.07
TOTAL (rounded up)	**$ 140.00**

[1] Pulverizing costs were estimated based on rates given by Aloha Recyling Inc. from 2011. These rates were increased 3% per year for inflation

[2] Marketing and brockerage was assumed to be about 10 hours per week for all the ADF glass in the state.

[3] It was assumed that the cost of land for stockpiling is $5.00 sq. ft. For calculation purposes, it was assumed that at any given time there would be a 2000 cubic yard stockpile. This requires about 20,000 sq. ft. of space. The ADF annual tonage was assumed to be 17,625.

[4] Maintenance costs are based on Aloha Recycling estimates of $20,000-$30,000 per yr. Aloha Recycling estimated the monthly volumes of glass to be about 355 to 450 (This includes ADF and DBC, which prior to 2005, both were processed together). The annual volume was assumed to be 5,400 tons

[5] Solid waste disposal fees vary from $71/ton to $119/ton depending upon the county. For this calculation an average of $95/ton was assumed. Waste was assumed to be 15% of the total volume. This is based on information from Aloha Recycling, Honolulu Disposal, Andella and REMco.

[6] A 15% profit was assumed. According to Hawaii Recyclers profits typically profits range from 10%-20%. The U.S. Department of Defense profits for fixed fee projects was 12% for 2006 (Institute for Defense Analysis, 2009).

Glass Cullet Processing (sand, #30 sieve or smaller):

Item	Low end $/ton	High end $/ton
Pulverizing[1]	$ 112.82	$ 171.51
Marketing/Brockerage[2]	$ 8.85	$ 8.85
Stockpile/storage[3]	$ 11.12	$ 11.12
Maintenace[4]	$ 11.11	$ 22.22
15% profit[5]	$ 21.59	$ 32.06
Subtotal	$ 165.49	$ 245.76
TOTAL (rounded up)	**$ 170.00**	**$ 250.00**

[1] Pulverizing costs were estimated based on the following assumptions for the low end pulverizing cost estimate.
-ISC-55 VSI Screening & Crushing Plant: From USACE EP 1110-1-8 Vol. 10: Construction Equipment Ownership and Operating Expense Schedule, Region X, Hawaii: VSI screening/crushing plants with total estimated value around $400k (400 HP) are listed at $100-150/hr, used $150/hr (ISC-55 is 150 HP)
-5 day operation with 2 days of producing sand (Based on input from Kauai operation: 20 Tons per hour crushing, 5 da operation, 2 days crushing, 56% sand after running glass through 4 times)
-In a 5 day week, 2 days of crushing, 7 hours per day crushing, 20 Tons per hour, 8 cycles per day
-2 Man operation: 1 for feeding the screening/crushing plant, 1 for operating it
-State prevailing wage labor rates for equipment operators- about $80/hr
-Also added small forklift and backhoe for equipment
-The disposal of waste was added to the cost at $95/ton.
-56% of the pulverized material is aggregate (based on test data from Honolulu Disposal ISC equipment) and it was assumed to have a value of $20/ton. This was subtracted from the cost.
The following assumptions were made for the high end pulverizing cost estimate.
-Each re-run of the glass would cost an additional 30%. Aloha Recycling cost estimates for one run were applied.
All of the data was compared to the costs estimates from the Broward County, Florida 2013 study. Estimates for sand costs were $80-$260/ton.

[2] Marketing and brockerage was assumed to be about 20 hours per week for all the ADF glass in the state. This is doul the marketing costs for 3/8 minus cullet because sand is a less marketed industry and recyclers would be required to market multiple products, sand and aggregate.

[3] The same caclulations were used as for 3/8" minus cullet. However, the stockpile costs were assumed to be double t 3/8 minus costs because two or more stockpiles would be necessary. Although it is the same volume of material, there would need to be space between stockpiles and possibly spaced for bagged sand as well.

[4] Maintenance costs were based on the same assumptions and calculations as 3/8" minus cullet. However, costs were multiplied by 2 to 4 times, because the equipment would undergo more wear due to multiple runs. It is likely this cost could vary significantly and is particularly dependent upon they type of equipment the recycler owns.

[5] A 15% profit was assumed. According to Hawaii Recyclers profits typically profits range from 10%-20%. The U.S. Department of Defense profits for fixed fee projects was 12% for 2006 (Institute for Defense Analysis, 2009).

Use	Processing Cost	Additional Costs	Total Cost	Market Value	Net Value
Non-structural Backfill	$140	-	$140	$20 [5]	(-) $120
Flowable Fill (CLSM)	$140	$20 [1]	$160	$35 [6]	(-) $125
Glasphalt	$140	$40 [2]	$180	$35 [6]	(-) $145
Agricultural Soil Amendment & Groundcover	$140	-	$140	$20 [5]	(-) $120
Landscaping	$140	$15 [3]	$155	$135 [7]	(-) $20
Landfill Uses	$140	-	$140	$10 [8]	(-) $130
Traction & Mud Abatement	$140	-	$140	$10 [8]	(-) $130
Golf Course Uses: Maintenance	$140	-	$140	$35 [6]	(-) $105
Golf Course Uses: Greens	$170 - $250	$15 [3]	$185 - $265	$95 - $150 [9]	(-)$90 - (-)$115
Beach Nourishment	$170 - $250	$15 [3]	$185 - $265	$80 - $130 [10]	(-)$105 - (-)$135
Blast Media	$170 - $250	$240 - $265 [3,4]	$410 - $515	$400 [11]	(-)$10 - (-)$115
Filtration Media	$170 - $250	$240 - $265 [3,4]	$410 - $515	$572 [12]	$57 - $162

*All costs are per ton of glass cullet

[1] It was assumed that there would be some additional processing costs similar to glass cullet used in glasphalt. These may include testing, sieving, developing mix designs, additional loader and handling. It was assumed the additional costs would be about 50% of those of asphalt since one of tha major additional asphalt costs is the loss in RAP and that does not pertain to flowable fill.

[2] Additional costs include developing mix designs for glasphalt, testing and sieving to gradation, changes to processing, additional loader, handling, and loss in RAP. These costs were unable to be itemized, but the recyclers on Maui (Aloha recycling) and Oahu (Honolulu Recovery, Reynolds) all claimed that asphalt mixing companies would only use the glass if it was free. According to Grace Pacific the glass cullet typically replaced a #4 rock aggregate. Therefore, it was assumed that the additional costs added up to the costs of a #4 aggregate, which was $38/ton from Grace Pacific 2011 price list and $41.65/ton from Ameron Hawaii 2013 price list. For the cost estimate, it was assummed the additional costs were $40/ton.

[3] It is assumed that the glass must be cleaned. Based on anecdotal informaiton from recyclers it costs about an $15/ton to wash the glass. This does not include drying.

[4] Based on estimates from Aloha Recycling Inc. and equipment cost estimates. It is appoximately $225 - $250 per ton to bag into 60 lb bags. A conservative estimate was used, $250/ton. On a small batch basis it is very expensive to bag. There are ways to make this more cost effective in large quantities.

[5] Business Services Hawaii in Hawaii County typically charges $20/ton for glass cullet. Other recyclers on Oahu and Maui charged between $20-$30/ton for glass cullet. This is lower than comparable rock aggregate, but due to industry resistance, the price needs to be lower.

[6] Cost based on S4C (3/8”-0”) aggregate from Ameron Hawaii 2013 price list, $34.95/ton.

[7] Based on an average between Hawaiian Earth Product Price for Black Cinder 5/8” ($140/cu.yrd.) and Hawaiian cement cinder cost from 2014 price list ($105/ton).

[8] Information from recyclers and landfill managers on Maui say prices for glass cullet used for landfills or general aggregate can range from $8-$12/ton.

[9] Waialae Country Club said they pay $95/ton for local beach sand, and $130-$150/ton for imported sand.

[10] Average cost of beach sand from Maui, Molokai or North Shore Oahu

[11] Aloha Recycling previously sold blast media for $10-$12 per 50-60 lb bag.

[12] Island Pool & Spa, main supplier of filter media in Hawaii, charges $25.74/100 lb bag. Assume value is 10% less.

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Appendix B

Down-Cycling Uses

Non-Structural Backfill

Backfill, Utility Bedding, Drainage Media

Introduction

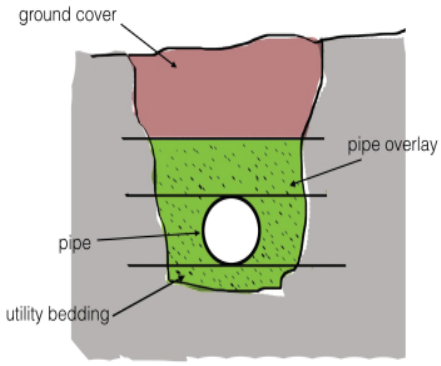
Processed glass can be used as general backfill, drainage media and pipe conduit bedding, either by itself, or blended with soil or natural aggregate to provide nonstructural and structural fills.

Use Description

Processed glass is viable material to use for non-structural backfill. Non-structural backfill uses include backfill, utility bedding and drainage media. Pulverized glass can either be used by itself, or more often, blended with soil or natural aggregates. Reddy (1999) determined that glass is a feasible alternative to natural gravels for backfill material for retaining structures. Glass backfill can also be placed under foundations, sidewalks, and behind retaining walls. Glass has the additional advantage of improving drainage properties of the backfill material.

A viable application for glass cullet is utility pipe bedding. Pipe trench bedding is required for most utility line installations. Water pipelines in Hawai‘i are required to have bedding to a minimum thickness of 6 inches below the pipe and 12 inches above the pipeline. Currently natural gravel is used.
Glass has been found to be useful in the construction of drainage blankets, French drains as well as other water drainage functions. The high permeability and inert properties of glass cullet contribute to its functionality. There are no environmental constraints on this use but changes in engineering specifications would be required.

Presently, Hawai‘i State law requires, “All state and county construction projects calling for nonstructural backfill shall utilize one hundred per cent crushed glass when available at a cost equal to or lower than the equivalent aggregate”. (§103D-407). Nonstructural backfill is defined as, “fill in areas not subject to structural loading, including but not limited to utility line bedding, drainage backfill behind retaining walls, drainage line backfill in leach fields or french drains, and similar uses”. All specifications are required to include these provisions. In addition §103D-1005 requires preference be given to contractors using products containing recycled materials.



Past or Current Applications

The use of processed glass as a backfill has been applied nationwide, including Hawai‘i. Recently, glass cullet was used as drainage backfill in the underdrains for a landfill located on the Island of Maui. Anecdotal information collected during this research effort also identified the use of glass cullet as s backfill on the Islands of O‘ahu, Maui and Kaua‘i.

Processed glass has been used for backfill, drainage and pipe bedding throughout North America. Some examples include backfill uses in New Hampshire, Florida, Idaho, Alberta (Canada), Ontario (Canada), New York, Texas, Colorado, Wisconsin, Arkansas, Arizona, Iowa, California, Michigan and Wyoming. The States of Washington, Florida and Indiana have also included glass into their specifications.

A test was conducted in Australia to analyze the performance of crushed glass as pipe bedding for the Sydney Water Department in New South Wales (Department of Environment and Climate Change NSW 2007). Chemical analysis of the glass aggregate indicated that metals, persistent organic compounds and other organic pollutants were all well below acceptable limits. Workers considered the glass easier to handle and spread than natural sand. In addition, the workers experienced no greater problems with odor, skin irritation or dust than they would with natural sand.

Potential Demand

The potential demand for glass is judged to be high compared to the supply of glass. It was not feasible to calculate the entire demand for backfill, drainage media and pipe bedding in Hawai‘i. The USGS reported 105,000 tons/year of aggregate is used for drainage. However, it was estimated, based on the Honolulu Board of Water Supply Capital Improvement Plan (2013 to 2019), that approximately 3,500 tons per year of pipe bedding will be required over a six year period. In addition, the Honolulu Department of Environmental Services plans to install about 2-miles of new pipeline per year, requiring approximately 4,500 tons of pipe bedding per year. Overall, it was estimated that the potential demand was well over 275,000 tons per year. However, it is not necessary or likely that all of these projects will demand glass cullet. Therefore, the demand can be closely matched to the supply.

Cost Analysis

The actual cost of processed post-consumer glass is greater than the cost of the comparable aggregate. The costs must be subsidized in order for the product to be successfully down-cycled. Glass cullet used in nonstructural backfill is processed to a 3/8-inch minus aggregate size. There are no anticipated additional

costs. The cost estimate for this processing is approximately $140 per ton. The comparable material is rock aggregate which costs about $35 per ton (Ameron 2013). However, based on information from Business Services Hawai‘i, Aloha Recycling and Honolulu Recovery, the glass cullet can be sold at $20-$30 per ton. To be conservative, it was assumed to be valued at $20 per ton. Therefore, the net value is about (-)$120 per ton.

Criteria Rating:

Criteria	Description	Score (0-least concerns and 4-most concerns)
Cost	The net value of for is found to be about (-)$120/ton of glass cullet.	4
Potential Demand	The potential demand was over 275,000 tons per year. This well exceeds the supply of glass. However, there are several different industry users of for this application, so there is flexibility in demand and it can be matched to the current supply of glass.	0
Past or Current Applications	This material has been studied and applied on the Continental United States, Australia and Hawai‘i.	0
Health & Safety	There are no known impacts to Health and Safety.	0
Environ. Impacts	There are no known adverse impacts to the environment. The use of post-consumer glass will result in a slight decrease in the use of finite mined aggregate resources.	0
Law, Reg, Policies Changes	There are no known laws, regulations or policies prohibiting this use. The DRAFT DOH Glass Recycling Policy dated 7/1/08 allows the use of glass for fill and pipe bedding. Drainage applications are not mentioned. This use will require stockpiling. The Hawai‘i DOH discourages stockpiling ADF glass.	1
Spec Changes	The law (§103D-407) requires that glass be included in specifications for nonstructural backfill in government projects. It appears that it is not included in all specifications. If the law were enforced then there would be more opportunities for use as backfill. Standards and specifications would require changes.	2
Industry or Public Resistance	The construction industry has concerns about the safety of glass and of glass dust in particular.	1
Market Development	The market for this product already exists.	0
Stakeholder Complexity (count of stakeholders)	County Governments Hawai‘i Department of Health Recyclers HDOT Engineering and construction	2
	Total	10

Flowable Fill (CLSM)

Introduction

The National Ready Mix Concrete Association (NRMCA, 2014) states in their guide specifications that crushed glass can be used in Controlled Low Strength Materials (CLSM), commonly called flowable fill. Flowable fill is the standard restoration requirement for all utility trenching in Hawai‘i DOT right-of-ways. Glass cullet is not mentioned in Hawai‘i flowable fill specifications and is not known to have been used in Hawai‘i. However, it is feasible to apply this material in Hawai‘i. Trenching commonly occurs in county and state road right-of-ways. In order to allow the use of crushed glass in flowable fill, changes would have to be made to specifications and would be required but there are no regulatory or environmental concerns.

Use Description

Flowable fill is a low strength concrete material used in construction to quickly fill trenches and underground cavities. It is not intended be strong and in fact must be weak enough to be easily removed with heavy hand tools or light construction equipment. The reason it is in wide use is that it requires less time to emplace than more traditional compacted soil. Quick emplacement is very important on roads and other areas where reducing closure time is an important consideration. Another major benefit is safety because workers spend less time in hazardous confined trenches.

When used as a construction fill material, flowable fill pours easily and supports loads after setting. Additionally, it does not require any compaction and reduces the amount of time and labor required for placement. CLSM is often used for filling underground utilities, backfill, void filling, pavement bases and various other construction uses. It is a low strength concrete mix, typically consisting of sand or fine aggregate and cement. The maximum strength is 150 psi, but generally has a compressive strength of 50-100 psi, so that it can be easily removed.

Past or Current Applications

The National Ready Mix Concrete Association (NRMCA, 2014) states in their guide specifications that processed glass along with several other non-standard materials can be used in CLSM. They caution that the engineer should review the performance characteristics of the CLSM mixture to ensure compliance with the required specifications. The Clean Washington Center reviewed the use of flowable fill in 1993 (CWC 1993). At the time it was unclear whether or not glass cullet was technically or economically feasible for use in flowable fill.

A study was conducted in 2001 in Wisconsin to determine the effects of glass in CLSM. When glass is used in normal high-strength concrete mixes the alkali-silica reaction causes cracking in the concrete. This reaction is not an issue with CLSM. The study (Tarun and others, 2001) indicated that post-consumer glass cullet can be a replacement for sand up to 70% and yield a material with equivalent properties to traditional CLSM. The CLSM mixture with glass achieved the required design strength. The glass used was obtained from a recycling company in Wisconsin. The glass used was courser than the regular concrete sand and is outside the current ASTM limits.

Flowable fill is the standard restoration requirement for all utility trenching in Hawai‘i DOT right-of-ways (HDOT, 2001). Currently, glass cullet is not mentioned in the flowable fill specifications and is not known to have been used in Hawai‘i. However, it is feasible to apply this material in Hawai‘i.

Potential Demand

Estimates for potential demand were not found from research and stakeholder contact during this study. However, the application for flowable fill is similar to that of pipe cushioning, so a comparable potential demand could be estimated. Trenching commonly occurs on county and state road right-of-ways. A recent small utility project involving the emplacement of a fiber optic cable along a state highway used about 50 cubic yards of flowable fill. If 70% of the sand were replaced with glass sand this would equate to about 43 tons of glass sand (Concrete Promotion Group, 2014; assuming 2500 pounds of sand per cubic yard). Particularly on O‘ahu, this is a high volume market. The construction of the Honolulu Rail Transit Project would require large scale trenching and utility relocation in County and State right of ways. Flowable fill would likely be used in most of these projects. It is estimated that the demand for flowable fill is over 6,000 tons per year.

Cost Analysis

The actual cost of processed post-consumer glass is greater than the cost of the comparable aggregate. The costs must be subsidized in order for the product to be successfully down-cycled. Glass cullet used in flowable fill should be processed to a 3/8-inch minus aggregate size. Due to the lack of feedback from stakeholders or applications in other areas, additional costs are estimated based on the additional costs associated with asphalt. The cost estimate for this processing is approximately $160 per ton. The comparable material is rock aggregate which costs about $35 ton based on Ameron Hawai‘i’s 2013 price list. Therefore, the net value is about (-)$125 per ton.

Criteria Rating:

Criteria	Description	Score (0-least concerns and 4-most concerns)
Cost	The net value of the glass for flowable fill is about (-)$125 per ton.	4
Potential Demand	The potential demand is estimated to be over 6,000 tons per year. There is no documentation or stakeholder feedback to support this. It is based on similar construction materials and current projects.	1
Past or Current Applications	Although the material has been studied there are no known applications in Hawai‘i or the continental United States.	3
Health & Safety	There are no known impacts to Health and Safety.	0
Environ. Impacts	There are no known adverse impacts to the environment. The use of post-consumer glass would result in a slight decrease in the use of finite mined sand resources.	0
Law, Reg, Policies Changes	There are no known laws, regulations or policies prohibiting this use. The DRAFT DOH Glass Recycling Policy dated 7/1/08 does not mention this application. This use would require stockpiling. The Hawai‘i DOH discourages stockpiling ADF glass.	1
Spec Changes	The most cost effective glass cullet to produce is 3/8”-0”. This size aggregate falls outside of the ASTM standards, which is an overriding specification for CLSM. It would take significant effort to make an exception to this standard. In addition, State and County specifications must be changed to include glass cullet for flowable fill or CLSM.	4
Industry or Public Resistance	There is no known industry resistance to this use of glass. However, most stakeholders did not respond to inquiries, so in depth feedback was not gathered.	0
Market Development	Glass has never been used in flowable fill, therefore significant market development would be required.	3
Stakeholder Complexity	Hawai‘i Department of Transportation Hawai‘i Department of Health Recyclers Engineering & Construction Community	2
	Total	18

Asphalt (Glasphalt)

Introduction

The legislature requested an examination of the possibility of using crushed glass as a full or part substitute for gravel aggregate in asphalt used for road construction. It is often called glassphalt and glasphalt. Application of recycled glass as glasphalt is not a new concept and has been applied in Hawai‘i and many other States.

Use Description

Glasphalt is asphaltic concrete used for paving and is produced by using crushed glass as a partial substitute for the aggregate (sand or gravel) in the mix. Asphaltic concrete pavements typically consist of three layers: surface pavement, basecourse, and subbase. Typically in Hawai‘i pavements, the basecourse is an asphaltic mixture with aggregate and bituminous compounds and the subbase is aggregate. The surface pavement is the smooth riding surface with a finer gradation of aggregate and more bitumen as compared to the basecourse. Over half of the asphaltic concrete is used for resurfacing or replacing the surface course on existing roads.

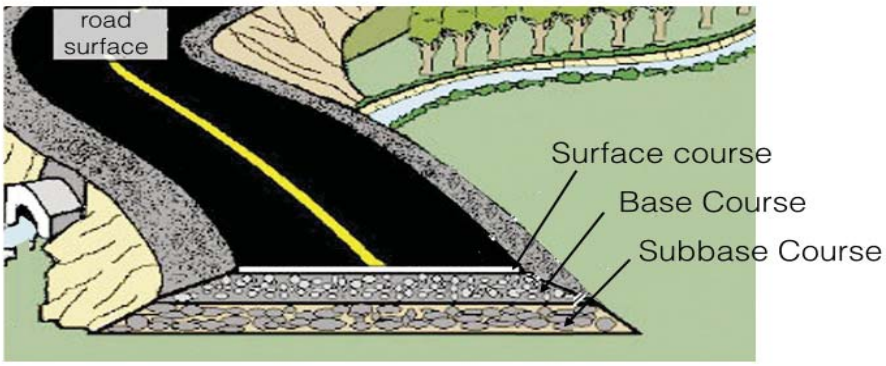


Figure B-2 Asphalt road structure

The application of glass cullet in asphaltic concrete has been researched since the late 1960's. It was found that glass cullet can replace aggregate up to 25% in basecourse and 10-15% in surface course pavements with satisfactory performance (**FHWA 1998).** Hawai'i law allows up to 10% glass cullet replacement of rock aggregate in the basecourse layer and no glass in the surface layer. The asphalt industry and major users such as the Counties and State DOT are generally not in favor of the use of glasphalt for several reasons, including:

- Difficulty or inability to recycle glasphalt pavement. Once glass is added to asphalt it is no longer "grade A" asphalt mix cannot be used as a recycled asphalt pavement (RAP) (Nakamura 2014). According to the State DOT and Grace Pacific, the largest asphalt producer in the Hawai'i, most asphalt is recycled. Approximately 100,000 tons of recycled asphalt pavement is used per year (Muench and Muramoto, 2011).

- Higher production costs.

    - During the mixing process an additional loader is required to add the glass cullet at the appropriate rate while the heated rock aggregate and bitumen are being mixed. This can be cumbersome on a batch by batch basis. Some facilities have physically modified their plant to incorporate a built in automatic loader (Harder 2014).

    - Since glass cullet cannot be used in the State DOT pavement surface course this causes production of glasphalt to be very costly or impractical. The equipment has to be cleaned after a glasphalt mix, prior to mixing a State DOT surface pavement mix. According to Grace Pacific, this extra step makes producing glasphalt impractical for their business to operate.

    - Another cost associated with production costs, is the need for asphalt producers to locate additional stockpile space to store the glass (Telver 2014; Castro 2014).

- Inadequate supply of glass cullet to meet the volume demands of the industry.

- There is conflicting information on the performance of glass cullet in pavement structures.

    - Several performance concerns are related to glass in the surface layer (pavement raveling, stripping, poor skid resistance, abnormally high tire wear, and excessive glare). (FHWA 1998) Therefore, no glass is allowed to be used in the top layer of HDOT pavement.

    - Several studies have shown that glass meets the physical property tests for subbase aggregate (PENNDOT 2014; HDR 1997). However, the State DOT has concerns that the glass cullet is not strong enough for a subbase course and cannot be compacted (Herbert Chu). Anecdotal information alludes to nationwide resistance to the application of glass cullet (Harder, 2014).

There are also benefits to using glass cullet as an aggregate replacement in asphalt concrete mixes: low absorption, which reduces the amount of bituminous compounds required in the mix. This can create savings up to $100 per ton of asphaltic concrete (Grace Pacific conversation).

Applications

The use of glass in asphalt has been advocated by legislative bodies in Hawai'i. Both the legislature and the Honolulu City Council have passed laws encouraging the use of glass cullet in asphalt and construction. Glasphalt has been used in Hawai'i. In the past, glasphalt was included in standard pavement plan details

(Young 2014). However, the actual extent glasphalt was used on State DOT or C&C of Honolulu roads is unknown. Based on the anecdotal evidence collected in this project, glass cullet has been used in parking lots, walkways and access roads. Glasphalt was used in City and County of Honolulu and Maui County recycling facilities, Hawai‘i Island Recycling facilities, and the Halawa Coca Cola facility. Glasphalt was used on Keapana Road on the Island of Kaua‘i. Most recently, glasphalt was used on the walkways at the Honolulu Zoo Finally, glasphalt was used in the access road to the Central Maui Landfill with no reported adverse effects. This is significant because the landfill access road is subject to heavy vehicles.

In a majority of areas, the amount of glass available does not meet the continuous demand for road construction. New York City is one city that produces enough crushed glass to provide enough glass to the point where it becomes a feasible option to use it in asphalt pavement (FHWA 1998). New York State Department of Transportation specifications allow for up to 30% of glass in subbase course. (NYSDOT 2013). However, glasphalt has been used in many areas of the country. The transportation departments of Minnesota, Kentucky, Oregon, Alaska, Washington, Wisconsin, Connecticut, California, New Hampshire and New York encourage contractors to use glass cullet in road sub-bases, as long as an adequate supply of glass is available that meets the state specifications (Andela undated). For example, the City of Baltimore uses glasphalt in the surface layer of their highways.

Potential Demand

The demand for asphalt concrete varies from year to year and is primarily based upon government funding and contracting. However, there was approximately 750,000 tons of hot mix asphalt (HMA) used in 2010 on the Island of O‘ahu (Muench and Muramoto, 2011). Approximately 60% of the hot mix asphalt on O‘ahu is by City and County (C&C) of Honolulu, 15% by StateDOT, 15% by military and 10% for others (Muench and Muramoto, 2011). The C&C of Honolulu, and HDOT have included glass cullet in their specifications.

The Hawai‘i Revised Statutes (HRS) 103D-407 mandates using a minimum of 10% recycled glass content in basecourse and subbase paving materials with the caveat that the quality standards are not reduced and the materials are available. According to the State DOT and C&C of Honolulu specifications, a maximum of 10% glass cullet may be used in basecourse. StateDOT specifications allow for 10%-25% glass cullet in subbase or embankments. C&C of Honolulu allows for a maximum of 10% glass cullet in surface course mixes for roads with 40 mph speed limit or less.

Based on the data presented in Muench and Muramoto, 2011, and the C&C of Honolulu and State DOT specifications, the estimated potential annual amount of glass cullet in glasphalt is over 44,600 tons. **Table B-1** below shows the breakdown of this estimate based on the pavement layer. This estimate is derived from the O‘ahu asphalt use in 2010. These are likely conservative estimates and would be larger if neighbor islands were also included. The purpose is to show that there is a significant market relative the volumes of ADF glass recovered.

Table B-1 Glass tonnages in glasphalt

Pavement Layer	Tons
Mill & Fill Surface Coat (Counties only)	34,000
Surface Course (Counties only)	1,700
Base Course (Counties & DOT)	5,700
Subbase Course (DOT only)	3,200
TOTAL	44,600

Cost Analysis

Glass cullet used in pavement structures should be processed to a 3/8-inch minus aggregate size. However, there are additional costs such as testing, grading, handling, additional mixing equipment and loss in RAP. The cost estimate for this processing is approximately $180 per ton. The comparable material is rock aggregate which costs about $35 ton based on Ameron Hawai‘i’s 2013 price list. Therefore, the net value is about (-)$145 per ton.

Criteria Rating

Criteria	Description	Score (0-least concerns and 4-most concerns)
Cost	The net value was found to be about (-)$145 per ton of glass cullet.	4
Potential Demand	The potential demand was over 44,600 tons per year. This is significantly higher than the glass supply and information gather from the industry and recyclers indicate that the glass recyclers were unable to meet the asphalt manufacturer’s demands.	3
Past or Current Applications	Glasphalt has been used in many states. It also has been used in Hawai‘i.	0
Health & Safety	This use has been accepted in other states for the function of daily cover. There are no known impacts to health and safety.	0
Environ. Impacts	There are no known direct adverse environmental impacts of using glasphalt. But under the current rules governing roadway pavements, glasphalt cannot be recycled. Most old pavement is recycled into new pavement, thus reusing the bitumen and aggregate. This is a significant adverse environmental impact from.	3

Criteria Rating		
Criteria	**Description**	**Score (0-least concerns and 4-most concerns)**
Law, Reg, Policies Changes	The use of glass in asphalt has been approved by legislative bodies in the State of Hawai‘i. Both the State Legislature and the Honolulu City Council have passed laws encouraging the use of glass cullet in asphalt, basecourse and other non-structural applications. For example, HRS 103D-407 allows the use of glass in State and County roadway materials and other public projects. It is important to note that it must be available at a cost comparable with the equivalent aggregate product. The cost of producing aggregate from post-consumer glass is higher that the equivalent aggregate product. As of 2011 State DOT no longer mandated the use of glass in asphalt (Shishito 2014). It is no longer required if a contactor had to pay any additional costs. No one on O‘ahu produces glass cullet although two facilities have the capability. City and County of Honolulu ordinance (ROH 9-8) also strongly encourages the use of glass in both surface and subbase layers. It specifically states that “glasphalt, if available, shall be used in city road constriction and paving projects….”. It is important to note that the glass must be available in sufficient quantities Although glass cullet in roadway pavement is allowed by law, it appears that the general policy is not to use glass because concerns about quality. In order for glasphalt to come into general use there would need to be a change in policy.	3
Spec Changes	Current specifications do not allow any glass in the surface course layer of asphalt and up to 10% in the base course and subbase layers. In order for there to be economical production of glasphalt, specification would need to be changed to allow some glass in the upper layer.	3
Industry or Public Resistance	The industry, including asphalt producers, HDOT and Counties do not want to use glasphalt. The public has some concerns with its use.	4
Market Development	There is a market for glasphalt, particularly, in the basecourse and subbase layers of pavement.	0
Stakeholder Complexity (no. of stakeholders involved)	Counties, Recyclers, State DOH, State DOT, several asphalt producers, engineering community, and the public	4
	Total	24

Agricultural Soil Amendment and Groundcover

Introduction

Processed glass has agricultural applications. There are two general categories for this use. Glass cullet can be used as a soil amendment to change the soil drainage properties to better facilitate plant growth. Secondly, glass cullet has been used as a groundcover either to control weeds, dust or mud. These applications are similar to applications used in landscaping, but the market and industries are significantly different. Agriculture would require low commodity prices. This application would generally elicit less public notice. Most uses in agriculture would have less stringent specifications and the glass aggregate would require little processing beyond general aggregate pulverizing. Glass is currently being used for agricultural soil amendments on Hawai‘i Island and has also been used on the Island of O‘ahu. This application has the potential to use large volumes of glass. Skumatz and Freeman (2007) report indicated mixed success when mixing crushed glass with compost. Some reports indicate that glass sinks to the bottom of the compost and that it imparts a “sparkly” look to the soil product. Despite this, it can improve the drainage properties of compost soil.

Past or Current Applications

Glass is currently being used for agricultural applications in Hawai‘i County. A Hawai‘i County recycler, Business Services, encourages this reuse option. Farmers have used glass cullet as drainage and as a media to cover the soil. The soil cover discourages weeds. According to anecdotal evidence, glass has also been use to control pests such as ants, centipedes, slugs and snails. This has been a viable option for glass cullet down-cycling in Hawai‘i. Business Services sells the glass cullet, including delivery, for $20 per ton. There are several possible reasons for this successful implantation. One reason for their success is that Business Services has a 23 acre facility for all their recycling operations. This provides them enough space to house their Andela glass crusher and create glass stockpile areas for. Efficient operation and stockpiling are essential components of a local glass any down-cycling business.

Daysog (2014) highlights a beneficial use in the town of Mililani on the Island of O‘ahu where glass was used as a soil amendment. They used 14,000 tons of crushed ADF glass at the Sandwich Islands Communications facility from 2005 to 2008 to improve soil drainage for a citron orchard. Additionally, Reindl (2003) reports that glass has been used for landscaping purposes in other areas as well including, New Mexico (2002), Maui (2002), and Arizona (1998).

The company Hawai‘ian Earth Products of Honolulu is open to incorporating glass cullet into their products, but studies first have to show that it has benefits. They currently use Hawai‘i carbonate sand, which adds lime and helps with drainage and balances the pH levels. Cinders (from Hawai‘i Island) help with drainage and add nutrients. The cinders that they use in their current soil mixes are currently 3/8” in diameter. It should be noted that if necessary, Hawai‘ian Earth Products has the room to stockpile.

Potential Demand

The potential demand is large. As mentioned above, Sandwich Isles Communications Facility used 14,000 tons from 2005 to 2008 to treat five acres of agricultural land. This equates to about 3,500 tons per year. This is only one relatively small agricultural use. Most of the ADF glass in Hawai‘i County (1,054 tons per year) is used for agricultural purposes. Hawai‘ian Earth Products of O‘ahu estimated they use about 6,000 to 7,000 tons of sand for agricultural soil amendments. Based on all this information, it is estimated that the potential demand is over 10,500 tons per year and it may be significantly more.

Cost Analysis

The actual cost of processed post-consumer glass is greater than the cost of the comparable of landscaping uses. The costs must be subsidized in order for the product to be successfully down-cycled. Glass used for agricultural soil amendments and groundcover must be pulverized to a 3/8" minus aggregate size. The processing costs for 3/8" minus aggregate and cleaning is about $140 per ton. The material to be replaced is most likely cinders and sand. Although the cost for 5/8" cinders is $105 per ton on Hawai'ian Cement 2014 price list and $140 per cubic yard based on Hawai'ian Earth Product price list, processed glass has been sold for agricultural uses for significantly less. This is to encourage the industry to use this alternative product. Business Services in Hawai'i County sell glass cullet for $20 per ton. This value was used for agriculture purposes since this has was proven to be successful. It is possible that processed glass could become more valuable as the industry becomes more familiar with using it. The resulting net value is (-)$120 per ton.

Criteria Rating

Criteria	Description	Score (0-least concerns and 4-most concerns)
Cost	The net value of glass cullet for agricultural soil amendments and groundcover is about (-)$120 per ton.	4
Potential Demand	The market demand was estimated to be about 10,500 tons per year based on previous and current local uses for agricultural soil amendments and groundcover.	0
Past or Current Applications	Glass has been used for agricultural and landscaping purposed in Hawai'i and the Continental United States.	0
Health & Safety	There are no known impacts to Health and Safety.	0
Environ. Impacts	There are no known adverse impacts to the environment. The use of post-consumer glass would result in a slight decrease in the use of finite mined aggregate resources.	0
Law, Reg, Policies Changes	There are no known laws, regulations or policies prohibiting this use. The DRAFT DOH Glass Recycling Policy dated 7/1/08 indicates that agricultural uses are allowed. This use would require stockpiling. The Hawai'i DOH discourages the stockpiling of ADF glass.	1
Spec Changes	Typically agriculture uses do not require specifications.	1
Industry or Public Resistance	There is no known industry resistance to this use of glass.	0
Market Development	There is a market for this use in Hawai'i.	0

Criteria Rating		
Criteria	**Description**	**Score (0-least concerns and 4-most concerns)**
Stakeholder Complexity	Hawai‘i Department of Health Recyclers Honolulu, Kaua‘i, Maui, Hawai‘i Counties Farmers	1
	Total	7

Landscaping

Introduction

Processed glass can be used as an aesthetic enhancer, weed-control groundcover and as a landscaping soil amendment. It can be used as a replacement for cinders, sand or gravel. Processed glass is used in several places throughout the United States as a decorative landscaping aggregate.

Use Description

Landscaping soil mixtures typically include amendments such as sand and cinders to help improve its drainage property. Glass cullet can be used as both an agricultural soil amendment and groundcover. Glass cullet used in groundcovers is beneficial because of its aesthetic appeal, to retain moisture, control weeds and protect the plant beddings from pests and disturbances. Using glass cullet in the landscaping market would require adherence to the stringent specifications followed by landscape architects and additional processing. Large scale use of glass by the landscaping industry would also require a consensus from business, land owners and landscape architects. However, it may be worth navigating through the stringent specifications, processing costs, and need for consensus from the industry because with respect to groundcover, its aesthetic appeal may warrant a higher value to be placed on the product.

Past or Current Applications

Skumatz and Freeman (2007) report mixed success when mixing crushed glass with compost. Some reports indicate that glass sinks to the bottom of the compost and that it imparts a "sparkly" look to the soil product. However, despite these concerns, it can improve the drainage properties of compost soil.

Glass cullet has been used in various specialty landscaping applications in the State of Hawai‘i. On the Island of Kaua‘i the application of using glass cullet in landscaping has been implemented in a few public area projects as well as private residential projects. For example, Café Coco Restaurant used glass cullet for a groundcover in their outdoor dining area and a roundabout in Kapa‘a is landscaped with glass cullet and the (The Garden Island, 2013). The Tip Top Hotel used glass for landscaping purposes (The Garden Island 2013a). A contractor on the island of Kaua‘i claims the use of glass is a good insect repellent; particularly for ants and centipedes. The recycler, Business Services Hawai‘i on Hawai‘i Island substantiated the claim by also stating glass is a good pest deterrent.

There is also the possibility of using glass as a landscaping soil amendment. Hawai‘ian Earth Products of Honolulu is open to using processed glass in their products, if studies can indicate that it is beneficial. It should be noted that if necessary, Hawai‘ian Earth Products has the room to stockpile. They stressed that it would only be used for landscaping if glass cullet is included in the official list of specifications used by landscape architects.

Potential Demand

The landscaping demand is dependent upon the use. Glass cullet used in landscaping would most often replace cinders. The volume is difficult to estimate because many of landscaping uses are private and small scale projects. The 2008 U.S. Geological Survey (USGS) minerals report estimated that approximately 400,000 tons of cinders were used in the state of Hawai‘i. For the purposes of this study we estimated that 1% of the total cinders used could be replaced with glass cullet for landscaping uses either as a soil amendment or groundcover. Hence, the potential market demand was estimated at 4,000 tons per year.

Cost Analysis

The actual cost of using processed post-consumer glass is greater than the cost of the comparable materials for landscaping uses. The costs must be subsidized in order for the product to be successfully down-cycled. Glass used for landscaping must be cleaned and pulverized to a 3/8" minus aggregate size. It is also possible for the glass to be sold in higher cost, retail quantities, but this would require bagging. For this study bagging of the product and higher value option was not estimated. The processing costs for 3/8" minus aggregate and cleaning is about $155 per ton. The replacement material would most likely be cinders and sand. The cost for 5/8" cinders is $105 per ton on the Hawai'ian Cement 2014 price list and is $140 per cubic yard based on the Hawai'ian Earth Product price list. The average value is about $135 per ton. The resulting net value is (-)$20 per ton.

Criteria Rating

Criteria	Description	Score (0-least concerns and 4-most concerns)
Cost	The net value of glass cullet for landscaping is about (-)$20 per ton.	2
Potential Demand	The market demand was estimated with the assumption that 10% of all cinders could be replaced with glass cullet for landscaping. This is about 4,000 tons per year.	2
Past or Current Applications	Glass has been used for landscaping purposes in the state of Hawai'i and the continental U.S.	0
Health & Safety	There are no known impacts to Health and Safety.	0
Environ. Impacts	There are no known adverse impacts to the environment. The use of post-consumer glass would result in a slight decrease in the use of finite mined sand resources.	0
Law, Reg, Policies Changes	There are no known laws, regulations or policies prohibiting this use. The DRAFT DOH Glass Recycling Policy dated 7/1/08 indicates that agricultural uses are allowed. This use would require stockpiling. The Hawai'i State DOH discourages the stockpiling of ADF glass.	1
Spec Changes	Specifications must be changed to include glass cullet in soil and groundcover applications in architecture and landscaping.	2
Industry or Public Resistance	There is no known industry resistance to this use of glass in landscaping.	0
Market Development	There is a market for this use in the state of Hawai'i. However, to make this a viable use, the market would have to be expanded and developed.	2
Stakeholder Complexity	Hawai'i Department of Health Recyclers Counties of Honolulu, Hawai'i, Maui, Kaua'i Customers Landscape architects	2
	Total	11

Landfill Uses

Introduction

The Hawai‘i State Legislature requested an examination of the possibility of using processed glass as landfill cover. The application of using recycled glass as a beneficial use in landfills is not a new concept and has been applied by various states nationwide. While conducting our interviews and research we discovered there are various ways in which processed glass may be utilized in a landfill, beyond just as a landfill cover. In short, four major uses for processed glass in landfills were identified; these uses are either currently implemented in Hawai‘i or have been recently proposed for implementation in Hawai‘i. These four major uses include:

1. Alternative daily cover (levelling cover)

2. Daily cover when mixed with earthen material

3. Operational uses such as traction control

4. Landfill leach field drainage media

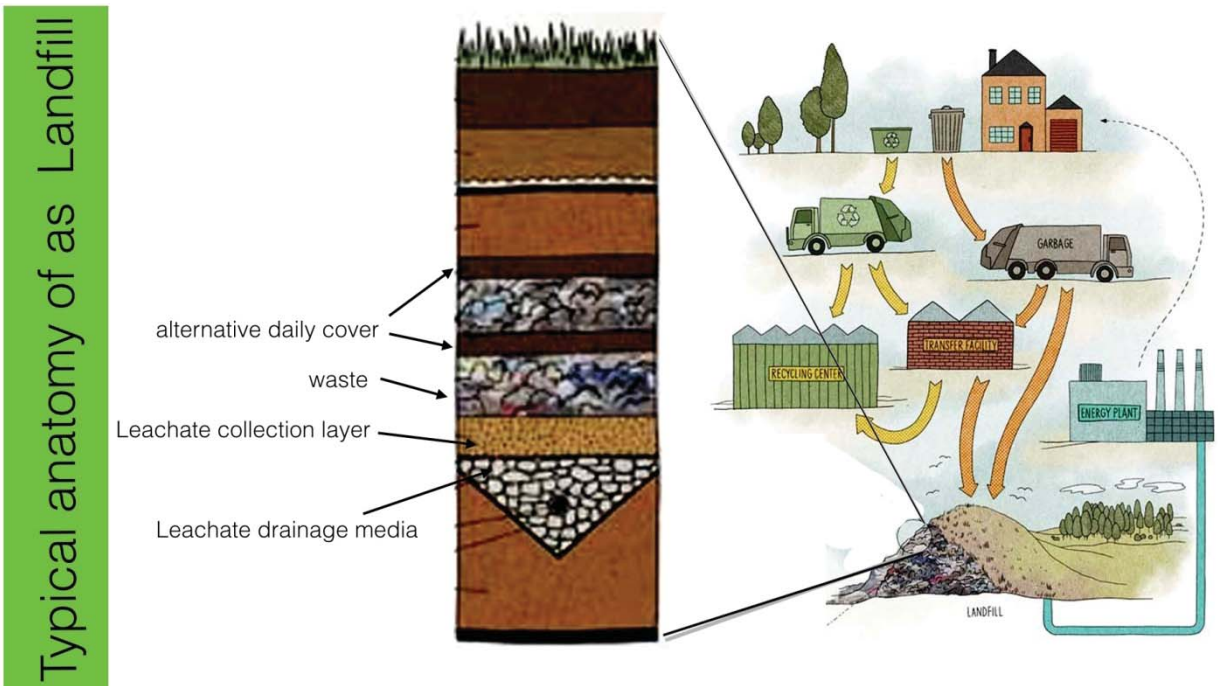
Use Description

At the end of each day, landfill operators must cover the waste placed in a municipal solid waste landfill with either 6 inches of soil (“earthen material”) or an approved alternative daily cover. This daily cover is intended to reduce odor, pests, fire hazard and to prevent blowing litter and dust. Federal and State regulations require the use of six inches of soil or earthen material as daily cover. Landfill operators are also allowed to use alternative materials to cover solid waste in landfills and these diverse materials are commonly referred to as “Alternative Daily Cover”. Many materials have been used as alternative daily cover nationwide. Some examples include geo-fabrics (tarps), foam, processed green waste, sludge, ash and kiln dust, processed construction materials, shredded tires and processed glass. Currently, the use of alternative daily cover is allowed in Hawai‘i upon approval on a case-by-case basis by the Director for Hawai‘i State Department of Health (DOH) (§11-58.1-15). The use of glass when mixed with earthen material (soil) and as levelling cover also must be approved by the Director of Hawai‘i’s DOH.

(2) Alternative materials of an alternative thickness (other than at least six inches of earthen material) may be approved by the director if the owner or operator demonstrates that the alternative material and thickness control disease vectors, fires, odors, blowing litter, and scavenging without presenting a threat to human health and the environment.”

The higher permeability of processed pure post-consumer glass may limit its effectiveness as daily cover. Higher permeability materials may not be as effective in controlling odors and disease vectors. It is recommended that glass should be used in combination with traditional earthen daily cover.

Figure B-3. Typical anatomy of a landfill



Glass aggregate can be used in landfills as traction control for temporary access roads. The development of a landfill requires the construction of many temporary access roads leading to the landfill face. Typically temporary access road are covered with gravel for traction control.

Landfills often require drains and pipes to safely remove water from the landfill (leachate). The drain pipes are generally surrounded by a permeable media such as gravel. Processed post-consumer glass is also a good material to utilize as a leach field drainage media.

Past or Current Applications

Glass has been used as a landfill cover in various other states. The Clean Washington Center in the state of Washington assessed the use of glass as a landfill cover. They determined that it is a potentially high volume market with low processing costs. This use has lower processing costs than most other glass aggregate applications because of less stringent specifications on gradation. The cost increases as the glass is processed into smaller particles. Glass was tested for harmful contaminants and leaching potential and it was found to have no appreciable environmental impact (CWC 1993).

Most states have procedures in place for assessing and approving alternative daily cover materials and methods and some states have approved recycled glass for this purpose. For example, the states of Massachusetts and New York have approved processed glass as an alternative daily cover (California 2009). Landfills in Palm Beach, Florida; Madison County and Oneida/Herkimer Counties, NY; Seattle, Washington, and Gillete, Wyoming have used glass cullet as daily fill (HDR Engineering 1997).

Broome County, New York (near Syracuse, NY) has approval from the State of New York to use glass aggregate mixed with soil or tire chips as an alternative daily fill. The Broome County Landfill currently receives approximately 11,000 tons of glass aggregate per year from the Syracuse Recycling Facility and most

of that processed aggregate glass is used for traction control on access roads leading to the working face of the landfill. (Broome County 2014)

Hawai‘i’s Island of Maui County Department of Environmental Management has recently used construction grade 3/8” minus glass cullet on a leachate recirculation project for the Central Maui Landfill. The contractor was given the option of using 1 ½” minus gravel or 3/8” minus crushed glass and they chose to use crushed glass. Approximately 1000 cubic yards (780 tons) of glass were used in the infiltration lateral drains for the project.

Potential Demand

Maui County is actively considering the possibility of using construction grade glass cullet as leveling cover or mixed soil and crushed glass as alternative daily cover at the Central Maui Landfill. The landfill requires approximately 500 tons of soil per day for cover. In addition, they use soil and aggregate for road maintenance and subsidence fill purposes. Presently, the County pays $8/ton for soil cover. They are also considering the possibility of using crushed glass as an aggregate on landfill roads. Hawai‘i County is not opposed to using glass as a daily landfill cover although they are concerned about regulatory approval.

Kaua‘i County is also considering the possibility of using glass cullet at their Kekaha Landfill for traction control purposes on temporary access roads. The County has not proposed a tonnage figure for this amount but it was estimated at 4000 tons per year based on data from a similar landfill. In addition, Kaua‘i County would consider the possibility of using glass as an alternative daily cover but they are also concerned about regulatory approval. Although the County has not presented their estimates for total demand daily cover we determined that approximately 51,000 tons would be required based on the demand for daily cover at the Central Maui Landfill. Hawai‘i County would also consider the use of processed glass in their landfills. Presently, Honolulu County is not considering the possibility of using crushed glass in landfills.

Table B-2. Potential landfill processed glass demand

Use	County	Location	Description of Material Replaced	Demand
Landfill Alternative Daily Cover	Maui	Central Maui Landfill	Soil from off-site @ $8 per ton	141,000 ton/year
	Hawai‘i	Hilo Landfill	Earthen material from off-site	51,000 ton/year
	Kaua‘i	Kekaha Landfill	Earthern material from off-site	52,000 ton/year
Landfill Drainage	Maui	Central Maui Landfill	1 ½ “ gravel from off-site	780 tons (one job)
Landfill Road Traction Control (Temporary Access Roads)	Maui	Central Maui Landfill	Gravel from off-site	11,000 ton/ year
	Kaua‘i	Kekaha Landfill	Gravel from off-site	4,000 ton/year

Cost Analysis

The actual cost of processed post-consumer glass is greater than the cost of the comparable soil or aggregate. The costs must be subsidized in order for the product to be successfully down-cycled. Glass cullet used in landfills is processed to a 3/8-inch minus aggregate size. There are no anticipated additional costs. The cost

estimate for this processing is approximately $140 per ton. The comparable material is rock aggregate and soil. These material costs can vary from $8/ton to $35/ton. It was estimated the glass cullet value for landfill uses would be $10/ton. Therefore, the net value is about (-)$130 per ton.

Criteria Rating

Criteria	Description	Score (0-least concerns and 4-most concerns)
Cost	The net value for landfill uses is about (-)$130 per ton of glass cullet.	4
Potential Demand	The potential demand was about 260,000 tons per year. This well exceeds the supply of glass. However, there are several different uses for glass cullet in landfills so there is flexibility in the demand and it can be matched to the current supply of glass.	0
Past or Current Applications	Glass has been studied, approved and used as alternative daily cover on the Mainland but not Hawai‘i.	2
Health & Safety	Landfill cover: Various states have approved the use of processed glass in landfills as a daily cover. There are no known impacts to health and safety but the landfill operator would be required to demonstrate that the particular cover application will, “*control disease vectors, fires, odors, blowing litter, and scavenging without presenting a threat to human health and the environment.”* Traction control: Various states across the United States have approved the use of processed glass in landfills as a means of traction control. There are no known impacts to health and safety. Landfill drainage: There are no known impacts to health and safety.	1
Environ. Impacts	There are no known adverse environmental impacts. The use of down-cycled glass will displace the use of mined earthen materials. This is a benefit to the environment because mining of soil or earthen materials impacts the environment.	0
Law, Reg, Policies Changes	Landfills are regulated by the Hawai‘i State Department of Health. DOH also regulates the types of alternative daily cover. Currently the use of alternative daily cover is allowed in Hawai‘i upon approval on a case-by-case basis from the Director of Health (§11-58.1-15). The use of glass when mixed with earthen material (soil) and as levelling cover also must be approved by the Director of Health. The use of glass in landfills as alternative daily cover is “unapproved” according to the DOH DRAFT Glass Policy dated July 1, 2008. The DOH and the Counties consider the draft policy to be in effect and this would need to be revised to allow post-consumer glass to be used beneficially in landfills.	3
Spec Changes	There are no known specifications to change in order to implement these down-cycling options	0

Industry or Public Resistance	There may be public resistance to the use of glass in landfills. There is a common perception that landfill use constitutes "throwing away" when we should be recycling the glass.	3
Market Development	This use of post-consumer glass is controlled directly by the Counties. Market development is not necessary.	0
Criteria Rating		
Criteria	**Description**	**Score (0-least concerns and 4-most concerns)**
Stakeholder Complexity	Counties Hawai'i State Department of Health Environmental Groups Public	1
	Total	14

Traction and Mud Abatement

Introduction

Glass cullet can be used as an aggregate for gravel roads. It can be used on private or agricultural dirt or gravel roads. Gravel is used for paving of temporary or permanent roads, walking trails, base yards and parking lots. It is used in agricultural areas, construction, and rural roads. Gravel is also used for traction control and mud abatement at landfills. Glass cullet aggregate can be used as a replacement for rock aggregate to add traction or aid in mud abatement on dirt or gravel roads. This use of glass cullet has been commonly applied throughout the Nation (Reindl 2003; HDR 1997). Generally, strict engineering specifications are not required for these applications. There may be aesthetic concerns with the use of glass on roads but there are no known environmental constraints.

Past or Current Applications

Post-consumer glass has been used for traction and mud abatement in many States throughout the country (Reindl 2003). For example, crushed wine bottles were used on park trails in Sun Valley Idaho and Boulder, Colorado. Glass cullet was also used for road construction at a landfill in Bismarck, North Dakota. Other applications have been documented in various states, including: California, South Carolina, Maryland, Texas, New Hampshire, New York, Minnesota and Wisconsin.

The primary use for ADF glass in Kaua‘i County is for traction and mud abatement at a construction base yard. It appears that glass has been used for similar purposes on Hawai‘i Island as well.

Potential Demand

The total potential demand for this use category is difficult to estimate because the market is made up of private contractors and agriculture land managers. The demand for traction and mud abatement in landfills is approximately 15,000 tons per year. Based on this information, it is estimated that the potential demand for traction and mud abatement (not including landfill uses) could be approximately 10,000 tons per year.

Cost Analysis

The actual cost of processed post-consumer glass is greater than the cost of the comparable gravel. The glass processing costs must be subsidized in order for the product to be successfully down-cycled. Glass cullet used for traction and mud abatement s is processed to a 3/8-inch minus aggregate size. There are no anticipated additional costs. The cost estimate for this processing is approximately $140 per ton. The comparable material is gravel and gravel costs can vary from $8/ton to $33/ton. In comparison, the estimated value for glass cullet used as traction and mud abatement would be $10/ton. Therefore the net value is about (-)$130 per ton.

Criteria Rating

Criteria	Description	Score (0-least concerns and 4-most concerns)
Cost	The net value for these uses is about (-)$130 per ton of glass cullet.	4
Potential Demand	Data to accurately estimate the demand from traction and mud abatement is not available. Based on landfill traction and mud abatement demands, the demand was estimated to be about 10,000 tons/year	1
Past or Current Applications	Glass has been used as traction control or mud abatement in Hawai‘i Island and in the Continental U.S. This is a tested application.	0
Health & Safety	There are no known impacts to Health and Safety.	0
Environ. Impacts	There are no known adverse impacts to the environment. The use of post-consumer glass will result in a slight decrease in the use of finite mined gravel resources.	0
Law, Reg, Policies Changes	There are no known laws, regulations or policies prohibiting this use. The DRAFT DOH Glass Recycling Policy dated 7/1/08 allows the use of cullet for road-base. This use will require stockpiling. The Hawai‘i DOH discourages the stockpiling of ADF glass.	1
Spec Changes	Specifications must be changed, if processed glass is to be used on the road-base of State or County roads. Otherwise no changes to specifications will be required.	1
Industry or Public Resistance	There is no known industry resistance to this use of glass.	0
Market Development	The market is more developed on the Islands of Kaua‘i and Hawai‘i. The Islands of O‘ahu and possibly Maui would require some market development.	1
Stakeholder Complexity	Hawai‘i Department of Health, Recyclers Honolulu, Hawai‘i, Maui and Kaua‘i Counties Construction Companies Agricultural Groups (farmers) and other private landowners	2
	Total	10

Golf Course

Introduction

Green sands and bunker sands are extremely important features of golf courses (USGA, 2014). Golf courses typically purchase large amounts of sand to maintain these features. Glass cullet can be processed into sand and used in golf courses in the state of Hawai‘i. Currently, golf courses in Hawai‘i use primarily silica sand which is imported from Vietnam, China, Australia or Idaho. For some landscaping projects they use local sand from the Islands of O‘ahu, Maui or Molokai. The use of glass sand in golf courses is a potentially a viable option in the state of Hawai‘i. The sand used on greens must meet stringent requirements set by the U. S. Golf Association (USGA). The stringent requirements of sand include: particle size, particle shape and penetrometer value, crusting potential, chemical reaction (pH) level and hardness, and infiltration rate. With the use of processing, glass cullet could meet many of the specifications and the darker color of green sand could be valuable because it keeps the ground warmer. There are even more stringent specifications placed on bunker sand regarded color and overall playing quality. Creating sand that could be used in bunkers would require significant processing beyond the capabilities of the current recyclers in the state of Hawai‘i. Typically, golf courses also use sand for large maintenance projects every 5-20 years. The sand required for these projects usually must meet less stringent specifications, meaning glass cullet could be a viable alternative. The primary areas where glass cullet sand may be used on golf courses would be for maintenance projects and to maintain the sand on the greens.

Past or Current Applications

Sand is used in golf courses for bunkers, greens and other maintenance projects. The use of glass sand for golf courses has been investigated in various states including: Hawai‘i, Florida and Texas (Reindl 2003) but it is not known if it has been used routinely. A two year study conducted in the United Kingdom (Owen & Baker 2003) indicated that glass sand met their requirements for greens and bunker sands.

Aloha Recycling on the Island of Maui worked with a local golf course to utilize post-consumer glass as sand on their golf course facilities. There were a few constraints that prevented this use of glass; the requirements for golf course sand are stringent and the Aloha Recycling equipment could not produce the required fine grain size required for distribution. Also Aloha Recycling could not provide enough glass sand to meet the volume needs at the golf courses. Wai‘alae County Club, on O‘ahu has used glass cullet aggregate for drainage in their maintenance projects. They were open to using glass sand for further maintenance projects and possibly greens maintenance.

Potential Demand

The potential demand for glass sand in golf courses is very large. Based upon information provided by the Wai‘alae Country Club, maintenance projects occur once every 5-20 years. An upcoming project at Wai‘alae Country Club will use about 700 tons of silica sand. There are around 64 golf course in the state of Hawai‘i. Based upon this information, maintenance projects can use 1,700 to 13,600 tons of glass per year. Wai‘alae Country Club estimates that greens maintenance requires about 250 to 300 tons of silica sand per year. Therefore it is estimated that golf course green sand demand could be 12,500 to 20,400 tons per year.

Cost Analysis

The actual cost of processed post-consumer glass is greater than the cost of the comparable beach or silica sand. The costs must be subsidized in order for the product to be successfully down-cycled.

Glass cullet used in maintenance projects is assumed to be processed to a 3/8-inch minus aggregate size. There are no anticipated additional costs. The cost estimate for this processing is approximately $140 per ton. The comparable material is rock aggregate or silica sand. These material costs can vary from $20/ton for basic rock to $130/ton for imported silica sand. It was assumed that the value would be about $35/ton. Therefore the net value is about (-)$105 per ton. This could potentially become higher if the glass is used as a replacement for silica sand.

Glass cullet used for golf course green maintenance needs to be processed to sand (#30 sieve and smaller). The processing costs were calculated to be $185 to $265 per ton. The comparable material is silica sand, which ranges in value from $80 to $130 per ton. Therefore the net value is about (-)$90 to (-)$115 per ton.

Criteria Rating

Criteria	Description	Score (0-4)	
		Maint.	Greens
Cost	The net value for golf course maintenance use is about (-)$105 per ton. The net value for golf course green sand maintenance use is about (-)$90 to (-)$115 per ton.	3	3
Potential Demand	The potential demand for maintenance projects is about 1,700-13,600 tons/ year. Green maintenance sand demand is estimated to be 12,500-20,400 tons / year. Both of these uses closely match the supply of glass cullet.	1	0
Past or Current Applications	Golf course maintenance uses have been investigated and used for maintenance projects at Wai‘alae Country Club and possibly other golf courses within the state of Hawai‘i. Green sand use has been investigated, but it is not known if it has been routinely used in the mainland U.S.	1	3
Health & Safety	There are no known impacts to Health and Safety.	0	0
Environ. Impacts	There are no known adverse impacts to the environment. The use of post-consumer glass will result in a slight decrease in the use of finite mined sand resources and will benefit the environment by reducing an imported material or sources of local sand.	0	0
Law, Reg, Policies Changes	There are no known laws, regulations or policies prohibiting this use. The DRAFT DOH Glass Recycling Policy dated 7/1/08 does not mention golf course use. This use will require stockpiling. The Hawai‘i DOH discourages the stockpiling of ADF glass.	1	1
Spec Changes	The USGA publishes specifications for golf course sand. However, materials used for maintenance drainage projects do not have to follow stringent specifications and little additional processing may be necessary.	0	0
Industry or Public Resistance	Resistance for maintenance has been low from consulted stakeholders. Their primary concern is that the material meets the specified needs and is cost effective.	0	0

Market Development	The market for maintenance use would require a small amount of development. Use in greens would require significant market development and possibly pilot studies.	1	4

Criteria Rating

Criteria	Description	Score (0-4)	
		Maint.	**Greens**
Cost	The net value for golf course maintenance use is about (-)$105 per ton. The net value for golf course green sand maintenance use is about (-)$90 to (-)$115 per ton.	3	3
Stakeholder Complexity	Hawai‘i Department of Health Recyclers USGA Golf Courses (Many are privately owned)	3	3
	Total	10	14

Beach Nourishment

Introduction

Clean and healthy recreational beaches are an important economic benefit to visitors and residents. However, past studies conducted by the University of Hawai‘i and other government agencies concludes that the beaches in Hawai‘i are gradually being depleted by shoreline erosion. The most appropriate method to counteract beach erosion is to replenish the eroding beaches or their sand sources with suitable sand from outside sources. Glass cullet could be used as a beach nourishment material. It can be processed to a similar grain size as beach sand. Currently, sand for beach replenishment can be obtained from dredged material or sand mined form terrestrial sources. Both of these sources are limited and have some adverse impacts on the environment. There are limited resources for clean beach sand in Hawai‘i and this resource is declining (Hanazawa 2006). The use of glass could help supplement the available material for beach nourishment and offset the use of natural sands.

Use Description

This use of glass has been studied, but would require further study because of the wide range of potential impacts. Using processed glass as beach sand may result in adverse impacts to the environment. These adverse impacts include a change to the aesthetics of beach sand, and impacts marine biota and reefs. It would be necessary to conduct additional studies to assess the possible impacts. A pilot study should be conducted. Using glass in beach nourishment would require regulatory approval from the State DOH and State Department of Land and Natural Resources (DLNR) and could also be subject to significant public scrutiny.

Past or Current Applications

There has been limited investigation and implementation of glass as source material for beach nourishment projects. Glass sand does not appear to have been used for beach nourishment on beaches in the United States although it may have been used in the Caribbean and New Zealand (These uses are unconfirmed; Broward County 2013).

Florida has studied the possibility of using glass sand for beach nourishment. Santa Rosa County (Jacksonville) lists beach nourishment as one of the possible glass uses. Broward County (Fort Lauderdale) has studied and performed a cost analysis of glass cullet as a sand source (Broward County 2013). County officials concluded that although glass is suitable for beach nourishment, the costs to process the glass cullet into suitable sand were greater than the costs of sourcing other inland and offshore sand. Collier County, Florida also studied the use of glass cullet as beach nourishment material. Makowski and others (2013) studied the suitability of glass cullet as artificial dune fill and concluded that glass is a safe, inert fill material for use as dune nourishment. The study showed dune vegetation grew at a quicker rate and in some cases more densely in sand dunes augmented with glass cullet.

There is a well-known beach in Hanapepe, Kaua‘i, Hawai‘i popularly known as “glass beach.” It was once a dumping area for old bottles and now the glass has been pulverized by the ocean into a smooth, glass sand beach. Glass was not intentionally placed here to nourish the beach but it does provide a good example of beach nourishment and the potential environmental impacts. At this time there are no known environmental impacts, but this is an area that requires more study.

Potential Demand

A large number of Hawai‘i’s beaches are eroding, so the need for beach nourishment projects (potential demand) is much larger than the number of beach nourishment projects completed each year (actual demand). It is costly to perform beach nourishment projects. It is the job of private and government entities to prioritize the needs of various projects therefore beach nourishment would have to be seen as a priority to attract funding for study and possible implementation.

Waikīkī is a high-priority beach where h nourishment projects are routinely implemented. Beach nourishment projects conducted in Waikīkī used an average of 5300 tons of sand per year between 2000 and 2012 to complete three projects. One study by Miller and Fletcher (2003) concluded that Waikīkī has lost at least 77,000 cubic meters of sand to permanent offshore losses between the years of 1951 and 2001. The demand for sand to be used for beach nourishment projects on the Islands of O‘ahu, Maui, and Kaua‘i was established by gathering by information from known completed beach nourishment projects completed by government and private entities. The following estimates were made: 9,900 tons per year for O‘ahu, 2,300 tons per year for Maui and 1,100 tons per year for Kaua‘i.

Cost Analysis

On the Island of O‘ahu, sources of natural sand has gradually depleted, causing the cost of natural sand to increase from $80 per ton in 2000 to about $130 per ton in 2013. Costs to create a beach sand material free of contaminants includes additional processing to reach the proper gradation size and cleaning. The estimated processing costs range from $185/ton to $265/ton. Since the processing costs are higher than the current value of beach sand the net value is negative, from (-)$105 to (-)$135 per ton. However, as the local sources of beach sand become depleted this value could increase. In addition, as more research is conducted, the cost of processing glass may decrease. Previous studies have shown that using large grain size material for beach nourishment gives more erosion protection. This could significantly reduce the processing costs. Hence, in the long term the net value of this down-cycling use could change significantly and may even be positive.

Criteria Rating

Criteria	Description	Score (0-least concerns and 4-most concerns)
Cost	The net value was found to be from (-)$105 to (-)$135 per ton.	4
Potential Demand	The potential demand was about 13,300 tons per year. This matches the supply of glass cullet (17,625 tons/yr) closely.	0
Past or Current Applications	Glass has not been used for beach nourishment in the state of Hawai‘i. It does not appear to have been used anywhere in the United States although it may have been used in the Caribbean and New Zealand. Studies on using glass for beach nourishment have been conducted.	3
Health & Safety	There are no known effects on health and safety.	0
Environ. Impacts	Current studies do not show any negative impacts on the environment, however, further studies are required because there could be impacts on the ocean, reefs and the aesthetics of beaches. This alternative use has the potential to be very positive for the environment because it can help replace the sourcing of local sand which is a finite resource.	2

Critera Rating		
Criteria	**Description**	**Score (0-least concerns and 4-most concerns)**
Law, Reg, Policies Changes	The DLNR has a policy prohibiting debris, rubble and other non-beach material. The State DOH Clean Water Branch and the U.S. Army Corps of Engineers (ACOE) have jurisdiction over the placement of sand on beaches.	4
Spec Changes	There are no known specifications to change in order to implement glass cullet for beach nourishment.	0
Industry or Public Resistance	There may be substantial public and agency resistance to the use of glass sand to augment beaches. Significant efforts would have to be made to incorporate stakeholders, including the public and regulatory agencies, early on in the process.	3
Market Development	A market does not currently exist for glass beach sand. It would need to be developed for government and private customers.	3
Stakeholder Complexity	• Hawai‘i State Department of Health • Department of Land and Natural Resources • U.S. Army Corps of Engineers • Counties • Environmental Groups and Public	4
	Total	**23**

Blast Media

Introduction

Post-consumer glass cullet has been shown to be an effective blast media and industrial abrasive (Skumatz, 2007). Glass cullet can be used to clean, scour and blast various surface types. Glass cullet has benefits over other types of blast media. For example, glass is safer than silica sand as a media because it will not cause silicosis (a lung disease). It has a low heavy metal content as compared to smelter-derived abrasives. Glass cullet blast media usually generates less dust particles than other media types. However, the use of glass cullet requires more processing such as cleaning; drying; crushing to a fine, specific grade; and bagging. The sandblasting industry in Hawai‘i is mixed regarding their position on using glass as a blast media.

Use Description

Most of our blast media is shipped into the Hawai‘ian Islands. Using glass cullet could potentially replace a material that is currently imported. The current media used varies extensively from soft organic media to very hard garnet. Typically glass can replace silica sand, steel shot/grit, copper slag and in some applications garnet. Glass media can be reused. Sandblasters often select media that can be reused several times. Crushed glass has been shown to exhibit abrasive performance characteristics similar to silica sand with a few exceptions. It is a slightly softer material than silica sand (NIOSH 1998).

Past or Current Applications

Glass is available commercially as a blast media but it is not available locally therefore it must be imported. It is currently used as a sandblasting media in many states throughout the country (Reindl, 2003).

Maui Monument and Granite used glass cullet for blast media about 10 years ago. They preferred glass because it does not have significant amounts harmful crystalline silica and metal contaminants. It produces less dust and is easy to clean up. The glass blast media was supplied by Aloha Recycling. The primary reason they did not continue to use the glass cullet media was because Aloha Recycling was unable to produce enough of the size they needed. Labor and processing costs to make the glass into a blast media were very high. The glass pulverizing equipment they were using produced less than 1% glass in the gradation size required for blast media. According to Aloha Recycling, the blast media was a small by-product of the pulverizing process. In addition the material had to be dried and bagged.

JC Sandblasting, of Kaua‘i, has been using glass for blast media since the 1990’s and still uses a small amount, which they process on their own to make a product to fit their needs. A primary hurdle in this application of glass cullet is resistance from the industry. The largest distributor of blast media in Hawai‘i is Mr. Sandman Inc. They are opposed to the use of post-consumer glass cullet for blast media. They do not trust the material safety data sheets (MSDS) and believe the product may have contaminants. According to them, glass cullet can also get stuck into paint.

Pearl Harbor ship yard has the single largest demand for blast media in Hawai‘i. They currently used steel shot. They prioritize using media that can be reused several times because their used media is considered hazardous waste. An O‘ahu based company Sunset Powder Coatings is interested in the opportunity to use a recycled material, but also puts a priority on materials that can be reused to reduce waste. Despite this blasting media is a viable use for some applications with no environmental constraints.

Potential Demand

The market demand was unable to be estimated during this study. However, based on anecdotal information and comparable markets, the blast media market demand is likely to be small compared to the volume of glass cullet available in Hawai‘i. However, blast media has a high value and there are benefits of glass over some of the existing materials.

Cost Analysis

The actual cost of processed post-consumer glass is greater than the cost of the comparable of blast media. The costs must be subsidized in order for the product to be successfully down-cycled. Glass used for blast media must be pulverized to a sand grain size (#30 sieve and smaller), cleaned, dried and bagged to be sold for blast media. The processing costs total to $410 to $515 per ton. According to Aloha Recycling they were able to sell bagged, glass cullet media for sandblasting for $20-$30 per 50-60lb bag. This is estimated to be approximately $400 per ton. The resulting net value is (-)$10 to (-)$115 per ton. It should be noted, that the processing costs have the potential to be significantly reduced if the market was expanded and the processing is done in bulk. This is a smaller market, but has the potential of offset low net values of other markets.

Criteria Rating

Criteria	Description	Score (0-least concerns and 4-most concerns)
Cost	The net value of glass for blast media is (-)$10 to (-)$115 per ton.	2
Potential Demand	The market demand information was unable to be found during this study. It is estimated to be relatively small compared to the glass cullet supply.	4
Past or Current Applications	Glass has successfully been used as blast media in Hawai‘i and the Continental U.S.	0
Health & Safety	There are no known additional impacts to Health and Safety. Glass is actually a safer product for workers to handle and the public to be exposed to because it does not cause silicosis. Despite this, all blast media should be carefully monitored to ensure worker and public health and safety.	1
Environ. Impacts	There are no known adverse impacts to the environment. The use of post-consumer glass would result in a slight decrease in the use of finite mined sand resources.	0
Law, Reg, Policies Changes	There are no known laws, regulations or policies prohibiting this use. The DRAFT DOH Glass Recycling Policy dated 7/1/08 does not mention blast media use. This use would require stockpiling. The Hawai‘i DOH discourages the stockpiling of ADF glass.	1

Critera Rating		
Criteria	**Description**	**Score (0-least concerns and 4-most concerns)**
Spec Changes	There do not appear to be any specifications regarding using glass as blast media.	0
Industry or Public Resistance	Industry resistance appears to be significant. User acceptance varies widely.	2
Market Development	The market would need to be developed.	2
Stakeholder Complexity	Hawai‘i Department of Health Recyclers Counties Health and Safety Regulators Blast media distributors Blast media users (sand blasters) Pearl Harbor Naval Shipyard	3
	Total	15

Filtration Media

Introduction

Glass cullet can be used as a water filtration media. It has been determined to be an effective alternative to natural silica sand or cinders. It has been used for drinking water filter systems, swimming pool filter systems, fish tanks and aquaponics systems.

Use Description

Water filtration media is composed of a granular material such as sand or gravel and it is used to remove impurities from water. Filter media is used in filter systems for swimming pools, aquaponic systems, koi ponds and water treatment facilities. It is possible to use glass cullet for drinking water filtration.

Past or Current Applications

Glass cullet has been used as filter media on the Island of Maui as well as in the states of New York, Texas and North Carolina (Reindl 2003). Glass recyclers around the county advertise using glass as filter media. The primary distributors of filtration media in Hawai‘i, Island Pool and Spa and The Aquaponics Place were consulted and both were not resistant to using glass cullet, if it met their specifications at an equal or lower cost.

There are no known environmental constraints placed on using glass as a filtration media. The market could be significantly larger if used for drinking water filtration, but this would require further study and stakeholder consultation. This may require the DOH and county water suppliers to modify standards. Processed glass would be used instead of sand filtration media. Most drinking water systems in Hawai‘i would not require this type of media, making the demand relatively low. This potential use was not further investigated in this study.

Potential Demand

The potential demand for using glass as a filtration media in was estimated based on anecdotal information derived from Island Pool and Spa and The Aquaponics Place. Island Pool and Spa estimated they use about 15 to 20 tons per year of silica sand. The Aquaponics Place estimated that they use over 100 tons per year of cinders. The potential demand is estimated to be 20 to over 100 tons per year. This is small market, but is the highest value local use that could potentially offset lower value, large volume uses.

Cost Analysis

The cost of processed post-consumer glass is less than the cost of comparable materials used as filtration media. This is the only local use for glass cullet which currently has a positive net value. Although, some of the uses could become more valuable as the industry demand increases and production becomes more efficient over time.

Glass used for filtration media must be pulverized to a 3/8” minus aggregate size or sand size, cleaned and bagged. It is assumed that the filtration media would be crushed into sand particle size. The total processing costs are $410 to $515 per ton. Island Pool and Spa currently sells 100 lbs. bags of silica sand filtration media for $25.74 per bag. In order to place the glass at a competitive price point, the estimated value was marked 10% less than the current cost of silica sand filtration media. Hence, the assumed market value of glass for filtration media is $572 per ton. The resulting net value is $57 to $162 per ton.

Criteria Rating

Criteria	Description	Score (0-least concerns and 4-most concerns)
Cost	The net value of glass cullet for filtration media is $57-$162/ton.	0
Potential Demand	The market demand was estimated to be about 20-100 tons per year. This is very low compared to the 17,625 tons of ADF glass per year.	4
Past or Current Applications	This application has been studied and applied in Hawai‘i and the continental U.S.	0
Health & Safety	There are no known impacts to Health and Safety. If the media is intended for use in drinking water treatment plants, further study would be necessary.	0
Environ. Impacts	There are no known adverse impacts to the environment. The use of post-consumer glass would result in a slight decrease in the use of finite mined aggregate resources.	0
Law, Reg, Policies Changes	There are no known laws, regulations or policies prohibiting this use. The DRAFT DOH Glass Recycling Policy dated 7/1/08 allows the use of glass for water filters. Stockpiling requirements are minimal for this use.	0
Spec Changes	It is probable that specification changes would be required to fully implement the use of processed glass in filtration media.	2
Industry or Public Resistance	There does not appear to be any resistance.	0
Market Development	The market for this product already exists. There would need to be marketing to encourage people to use the product.	2
Stakeholder Complexity (count of stakeholders)	Swimming pool owners Hotels County Governments Hawai‘i Department of Health Recyclers	1
	Total	9

Appendix C

Stakeholders

Appendix C
Stakeholder List

Stakeholder (name, contact)	Date(s)	Notes
Interested Groups		
Jeffrey Mikulina, Director Blue Planet Foundation 55 Merchant Street, 17th Flr Honolulu, Hawaii 96813 (808) 954-6161	10/23/14 - visited office 10/28/2014, call	
John Harder Kauai	10/9/2014, meeting 11/6/2014, call	Provided valuable information.
Hawaii Chapter, Sierra Club	9/26/14 -spoke with Albert Perez, Political Chair 9/30/14 - emailed Leilei and Matt (former committee chairs) 11/1 to 11/3/2014 -emails with Anthony Aalto (Capitol Watch)	Discussed Sierra Club viewpoint
Ashford + Wriston, LLWP Representing The Wine Institute First Hawaiian Center, Suite 1400 999 Bishop Street Honolulu, Hawaii 96813 tel: (808) 539-0842 fax: (808) 533-4945	10/23/14 - Met with Mihoko Ito and Gary Slovin	The Wine Institute represents wine importers.

Stakeholder (name, contact)	Date(s)	Notes
Government		
Steven Chang, Darren Park, Wendy Okazaki, Thomas Miyashiro Hawaii Department of Health Solid and Hazardous Waste Branch Office of Solid Waste Management 919 Ala Moana Blvd., Room 212 Honolulu, Hawaii 96814 Ph: (808) 586-4226	9/18/2014 - meeting 10/1/2014 - meeting Oct to Dec-numerous emails Wendy Okazaki	Met to discuss the ADF program and the viewpoint of the Dept of Health. Many helpful conversations and emails.
Allison Fraley Solid Waste Program Coordinator County of Kaua'i Solid Waste Division 4444 Rice Street, Suite 295 Lihue, HI 96766 Phone: (808) 241-4837	9/24/2014, 9/26/2014 - call 10/9/2014, meeting; 11/20/14 - emails	Meeting and numerous emails.
Irene Cordell Recycling Coordinator Dept of Env. Managment County of Maui (808) 270-7269	9/29/14 - telephone 11/19/14 - telephone 11/20/14 - emails	Discussed the ADF glass program for Maui County
Sage Kiyonaga & Mike Kehano Engineers Dept of Env. Management County of Maui	10/13 to 10/15/14-emails	Discussed use of glass as landfill levelling cover
Linda Peters (Recycling Coordinator) Chris Chin Chance (Recycling Specialist) Mike Kaha (Deputy Solid Waste Chief) Shon Pahio (Business Services Hawaii) Jeri Pankey (Business Services Hawaii) Darren Park (DOH) Wendy Okazaki (DOH) County of Hawaii Recycling Coordinator	10/6/2014 - Meeting in Hilo Numerous helpful emails Oct to Dec	Discussed the County ADF glass program with County officials, contractor (Business Services) and DOH
Linda Peters (Recycling Coordinator) Chris Chin Chance (Recycling Specialist)	11/18/14 -emails 11/17/14 -telephone (Chris) 11/14/14-emails 11/9/14-emails	Provided information on costs, operations, amounts of glass

Stakeholder (name, contact)	Date(s)	Notes
Suzanne Jones,, Irobella Wreagh - City and County of Honolulu, Refuse Division Wendy Okazaki (DOH)	9/26/14 - meeting	Discussed the C&C program and the history of ADF glass
Michael O'Keefe Recycling Program Branch Chief City & County of Honolulu ENV - Refuse Division 1000 Uluohia St, Ste 201 Kapolei, HI 96707 Office: (808) 768-3427	11/13/14, 10/3/14, 10/2/14, 9/30/14 - emails 11/19/14 -telephone	Informaton on City ADF glass recycling program.
Gail Suzuki-Jones Energy Analyst / LEED-AP EBOM State of Hawaii - Energy Office Department of Business, Economic Development and Tourism P.O. Box 2359, Honolulu, HI 96804 808-587-3802 ph/586-2536 fx	10/7/2014 -emails and telephone	Provided documents and information on the former DEBDT program (Clean Hawaii Center)
Shirley Yeung Accountant/Hawaii Deposit Beverage Container Program Solid and Hazardous Waste Branch/Environmental Management Division Hawaii State Department of Health Phone: (808) 586-4226 Fax: (808) 586-4043	11/13/14 - email	confirmed number of 2013 ADF bottles

Stakeholder (name, contact)	Date(s)	Notes
Recyclers		
Todd Reed Aloha Recycling 75 Amala Place, Kahului, HI 96732 Phone (808) 871-8544	10/9/14 call, 10/16/2014, call 11/13/2014, call	
Kevin Cadwalder, Damian Rodriquez REMCo Livermore, CA 94551 Phone: (925) 447-0805	11/14/2014, 11/17/2014 - email	
Greg Apa, Senior VP Honolulu Disposal 1169 Mikole St, Honolulu, HI 96819 Phone: (808) 792-0126	11/18/2014, call	
RRR Recycling Services Hawaii 91-165 Kalaeloa Blvd, Kapolei, HI 96707 Phone:(808) 682-5600	9/21/2014, call	
Karen, Business Manager Island Recycling Campbell Industrial Park 91-140 Kaomi Loop, Kapolei, Hawaii 96707 Phone: (808) 682-9200	9/21/2014, call 10/15/2014, call (Karen)	
Terry Telfer, President Bruce Iverson, Director of Marketing & Development Reynold's Recycling	9/25/2014, call (Bruce) 10/28/2014, call (Terry)	
Craig Matsuo Honolulu Recovery Systems 358 Hookela Place, Honolulu, HI 96819 Direct: (808) 792-0159	9/29/2014, call 10/2/14 - visit/meeting	ISC Glass Crusher, met with Mr Matsuo
Joanne Carvalho JC Sandblasting & Recycle 3133 Oihana St, Lihue, HI 96766 (808) 245-2600	2014, call 10/8/2014, meeting	
Alvin, Operations Manager Garden Isle Disposal 2666 Niumalu Rd, Lihue, HI 96766 (808) 245-2372	10/9/2014 - visit	

Stakeholder (name, contact)	Date(s)	Notes
Shon Pahio (Business Services Hawaii) Jeri Pankey (Business Services Hawaii) 808-966-7489 16-630 Kipimana St, Keaau, HI 96749	11/18/14 -phone (Jeri) 11/18/14-email to Shon 11/24/14 -email Shon	Hawaii County ADF glass contractor. Spoke with Jeri. She recommended that I email Shon Pahio. Asked questions about the uses of glass (no response).
Maui Disposal Company 280 Imi Kala St, Wailuku, HI 96793 (808) 242-7999	11/18/14 - phone	Spoke with a salesperson, discussed rates, recycling program
Craig Hysack Equipment Sales Engineer Andela Products ph: (315) 858-0055 ext. 224 fax: (315) 858-2669	11/5 to 11/20/14 - emails and telephone	Provided information on the Andela Glass Pulverizer (a machine used in Hawaii)
Traction/Mud Abatement		
Troy Tanigawa, Environmental Services Management Engineer Division of Solid Waste Management Department of Public Works, County of Kauai 4444 Rice Street, Suite 295 Lihue, HI 96766 Phone: (808) 241-4838	10/9/2014 - visit	
Non-Structural Backfill		
Henkels & McCoy Lee Zubrod, Project Manager; Joe Morris, Superintendent	12/2/2014, email	no response
Stakeholder (name, contact)	**Date(s)**	**Notes**
Landscaping/Groundcover		
American Society of Landscape Architects - Hawaii Chapter Allan Schildknecht, President	11/25/2014, email	Familiar with glass as landscaping material, a national ASLA meeting is presenting on this topic. Recommended experiments for golf courses
Soil Amendment		
James Abreu, Sales & Marketing Manager Hawaiian Earth Products 91-400 Malakole St, Kapolei, HI 96707 (808) 682-5895	9/26/2014, call	

Stakeholder (name, contact)	Date(s)	Notes
Sandblasting		
Matt Otterson Maui Monument & Granite 75 Amala Pl, Kahului, HI 96732 Phone: (808) 877-4609	11/3/2014 - telephone	Used glass from Aloha recycling for blast media. Provided anecdotal information.
Scott Roworth, VP Sunset Refinishersd and Sunset Powder Coating 96-1276 Waihona St Pearl City HI 96782 (808) 454-2500	11/13/2014, call	
Mr. Sandman Inc. 697 Ahua St, Honolulu, HI 96819 (808) 833-2500		
Joanne Carvalho JC Sandblasting & Recycle 3133 Oihana St, Lihue, HI 96766 (808) 245-2600	2014, call 10/8/2014, meeting	
Stakeholder (name, contact)	**Date(s)**	**Notes**
Golf Course		
Dave Nakamura, Golf Course Superintendent Waialae Country Club 4997 Kahala Avenue, Honolulu, HI 96816 Main Number (808) 734-2151 Direct: (808) 748-4262	10/23/2014, call	
Hawaii Kai Golf Course Maintance Manager	10/9/14-telephone	Helpful information on cost, source and amount of sand used.
Wailea Golf Club	10/9/2014	Called twice and left message but no response.
Ewa Beach Golf Club	10/9/2014	Called and left message but no response.
Ala Wai Golf Course	10/9/2014	Called and left message but no response.
Turtle Bay Golf Course	10/16/2014	Called and left message but no response.
Stakeholder (name, contact)	**Date(s)**	**Notes**
Filtration Media		
Island Pool and Spa Supply 1169 Kona St, Honolulu, HI 96814 (808) 593-8448	10/27/2014, call	
The Aquaponics Place LLC 41-1515 Lukanela St. Waimanalo, HI 96795 Ph: (808) 259-5797	10/27/2014, call	

Stakeholder (name, contact)	Date(s)	Notes
Flowable Fill		
Ameron Hawaii 2344 Pahounui Dr, Honolulu, HI 96819 (808) 832-9200	10/15/2014, call	no response
Hawaiian Cement Gavin J. Shiraki, Manager of Sales Oahu Concrete and Aggregate 99-1300 Halawa Valley Street Aiea, Hawaii 96701-3289 Ph# 808-483-3378	email 12/2/2014	responded briefly with cost sheet. No experience with glass or flowable fill.
Tarun R. Naik, Ph. D., P. E. University of Wisconsin Milwaukee, Wisconsin 53211 Phone: 414-395-6191 email: tarun@uwm.edu	10/20/2014 - email	no further details beyond study conducted
Stakeholder (name, contact)	**Date(s)**	**Notes**
Glasphalt		
Jeremy Castro, Quality Control Manager Grace Pacific LLC, Asphalt Division Kalaeloa AC Plant Kapolei, HI 96707 (808) 479-5290	9/29/2014, call 10/23/2014, call	
Jon Young, Executive Director Hawaii Asphalt Paving Industry 1287 Kalani Street, Suite 202 Honolulu, HI 96817 Tel: 808.847.HAPI (4274) Email: jon@hawaiiasphalt.org	9/29/2014, call	
Joanne Nakamura State of Hawaii, Department of Transportation, Highways Division (808) 832-3405 ext. 132	9/30/2014, call	
Herbert Chu, HWY-L, HDOT, 2530 Likelike Highway, Honolulu, HI 96819 Phone (808) 832-3405 x 232, E-mail herbert.chu@hawaii.gov	9/30/2014, call	
DOT, Soils	Eric Shishito	10/15/2014
Rons Construction		10/23/2014
Road Builders	eric Rylander	10/23/2014

Stakeholder (name, contact)	Date(s)	Notes
Beach Nourishment		
University of Hawaii	Mike Foley	9/26/2014 - coversation, 9/29/2014 - email
University of Hawaii Dolores Foley College of Social Sciences	11/13/2014 - email	May have studied glass as beach nourishment, no response
Collier County, Florida	emailed & called several times 11/19/2014	Unable to respond because very busy with current project.
Broward County, Florida	called	Responded with 2013 study.
Legislators		
Representative Chris Lee	10/3/2014 - Meeting	Met with Representative Lee
Senator Mike Gabbard Rock Riggs (Senators Aid)	9/23/2014 -telephone	Spoke with Rock Riggs
Additional Uses		
OCCL		9/26/2014
TileCo	Dennis	9/26/2014 (No contact), emailed -
University of Hawaii	Dr. Lin Shen	9/29/2014 - email
White Lava		9/30/2014
Other		
Horizon Lines Horizon Lines Hawaii Customer Service PH: 808-842-5349 l Fax: 808-842-5395	11/17/2014 - email and telephone	confirmed shipping rates
PVT Land Company 87-2020 Farrington Hwy, Waianae, HI 96792 (808) 668-4561	10/6/14 -email Steve Joseph (General Manager) 10/7/14- Called Ben Yamamoto	Mr. Yamamoto said that Steve Joseph would call back. No response.

Appendix D

Abbreviations

ADC Alternative Daily Cover

ADF Advanced Disposal Fee

ASTM American Society for Testing and Materials

CLSM Controlled Low Strength Material (Flowable Fill)

DBC Deposit Beverage Container

DBEDT Department of Business, Economic Development, and Tourism

DOH Department of Health

DOT Department of Transportation

GID Garden Island Disposal

MSW Municipal Solid Waste

NRMCA National Ready Mix Concrete Association

RAP Recycled Asphalt Pavement

RCRA Resource Conservation and Recovery Act

Definitions

Advanced Disposal Fee: A statewide glass recovery program started by the Department of Health. A 1.5 cent fee is charged per non-deposit glass container unless exempted by state law. This fee is used to encourage recycling and divert glass from the waste stream and provide relief to rapidly-filling landfills.

Aggregate: In this report, aggregate is used to refer to construction aggregate. This describes a broad category of coarse particulate material used as base course, subbase material, back fill, or as an addition to a concrete mixture.

Alternative Daily Cover: Material used to cover the waste placed in a municipal landfill at the end of each working day. Soil is typically used; other materials constitute alternative daily cover.

Cullet: The product created by the crushing or pulverizing of glass products. It comprises a form of aggregate or the precursor to recycled glass products.

Deposit Beverage Container: A statewide glass recovery program that incentivizes recycling by placing a 5 cent redeemable deposit on each applicable beverage container. The deposit is collected by consumers when they return the container to a redemption center.

Down-cycling: The process of converting waste material or product into new material or product that is of a lesser quality and/or value than the original.

Flowable Fill: Also known as CLSM, a low strength (less than 1,200 psi) concrete mixture that is used for non-structural fill or easily removable backfill.

Glassphalt: Asphaltic concrete mixtures that use cullet as a partial substitute for typical rock or sand aggregate to make an asphaltic concrete mixture.

Glass Recovery Container Program: Any program to divert used glass containers from waste streams. In Hawai‘i there are the ADF and DBC programs. (This definition is used throughout this report. HRS Part VII of Chapter 342G-81 has a more specific definition.)

H Power: A waste to energy facility owned by the City and County of Honolulu. The facility in Kapolei processes 3,000 tons of waste per day, generating up to 90 MW. The facility does not burn waste at a high enough temperature to burn glass therefore it melts and then is taken to the landfill.

Pipe Bedding: A granular backfill that is placed underneath new pipe installations to support the pipe weight.

Post-Consumer: Discarded by an end user. A material or finished product that has served its intended use and has been diverted or recovered from waste destined for disposal, having completed its life as a consumer item.

Up-cycling: The process of converting waste material or product into new material or product that is of a higher quality and/or value than the original.

Recovery: Waste materials and byproducts that have been diverted from solid waste disposal.

Recycling: The process of converting waste material or product into new material or product that is the same or similar than the original.

Silicosis: A form of occupational lung disease caused by inhalation of crystalline silica dust. It causes inflammation and scarring in the upper lobes of the lungs. Crushed glass contains less than 1% free crystalline silica and therefore does not cause silicosis.

Soda Lime: A type of glass consisting of soda, silica, alumina, and small quantities of fining agents. Soda lime glass accounts for approximately 90% of manufactured glass.

Sphericity: A measure of how round an object or particle is.