Recycling and Reuse of Crumb Rubber Infill Used in Synthetic Turf Athletic Fields

March 31, 2016

Louis Berger

TABLE OF CONTENTS

Executive Summary

This report provides a high level overview of trends, barriers and issues related to recycling crumb rubber infill used in synthetic turf athletic fields, and identifies options to boost recycling. The Louis Berger Group (Louis Berger) prepared the report under contract to CalRecycle, with support by DK Enterprises and Boisson Consulting. Following is a synopsis of key findings, along with some related issues and recommendations for CalRecycle consideration.

Trends

Synthetic turf infill is an important market for crumb rubber made from scrap tires. Since 2008 four-to-six percent of California generated scrap tires has flowed to this market (20-to-25 percent of all California-produced crumb rubber).

Most synthetic turf athletic fields continue to use infill comprised of crumb rubber and sand; however, alternative infill materials have gained market share recently.

The number of synthetic turf fields reaching the end of their useful life and in need of replacement is growing. The Synthetic Turf Council estimates that up to 1,000 fields per year nationally may be removed by 2017, with roughly 10 percent (about 100) of these in California.[1] However, some field owners have reportedly delayed replacement which may reduce these projections somewhat.

Interest in recycling synthetic turf athletic field components (i.e., infill, turf, etc.) has grown in recent years. Several firms offer removal, reuse and/or recycling services, recycling services and/or equipment. However, recycling levels remain low due to poor economics and other market constraints. One knowledgeable source estimates that, nationally, 15 percent of field removals reuse a portion of infill in the replacement field, and about five percent recycle some "carpet" components (that is, the backing layer and synthetic grass material).[2] In 2014, approximately 22.4 million pounds of California-produced crumb rubber was used in synthetic turf fields. Assuming 85 percent of this were to be ultimately disposed as these fields reach the end of their useful life over the coming decade that would equate to just over 19 million pounds, or 9,500 tons. The Synthetic Turf Council has established a Reuse and Recycling Committee to help strengthen current practices.

The situation for recycling synthetic turf athletic fields is similar to some other types of recycled-content products that do not have closed-loop markets, such as molded rubber products, plastic lumber and other rigid plastic products that are currently not typically recycled back into the same type of product.

Barriers

The multi-material nature of synthetic turf fields complicates recycling of individual components. Technologies to remove, separate and clean various turf components are available, though still evolving.

[1] As reported in "Trends in End-of-Life Management for Synthetic Turf Products." Presentation by Adam Coleman, Turf Reclamation Systems, at the 2015 CalRecycle Tire Conference.
[2] Mark Heinlein, President, Turf Reclamation Solutions.

Recycling crumb rubber infill is usually much more costly than disposal due to the comparatively high cost of separating and cleaning infill and turf materials, and transportation to processors and end-users.

Certain characteristics of recovered crumb rubber infill may be degraded compared to new crumb rubber, but it still performs well in new/replacement infill installations. Reuse is greatly facilitated when the same firm that originally installed the field is replacing it, so that material specifications are the same or similar.

Markets for recycled crumb rubber infill are extremely limited. The market that appears to have success is reusing a portion of the material in new/replacement synthetic turf athletic field installations. Other uses may have potential but would require additional material processing and market development efforts.

Field owners and developers lack information on synthetic turf athletic field recycling options and processes.

CalRecycle Options to Promote Recycling of Crumb Rubber Infill Recycling

Identified options include:

- Provide funding through grants, loans and/or incentives.
- Research the potential to establish a fixed facility to clean and process recovered crumb rubber infill.
- Research and provide information on potential markets and end-users, especially those with relatively forgiving specifications that may allow a degree of sand and/or other components with crumb rubber (e.g., use in kilns, rubberized asphalt, etc.).
- Fund technical assistance and demonstration projects involving the identified markets and end-users.
- Research issues related to recycling all end-of-life tire-derived products (e.g., molded rubber products).

Issues and Recommendations

Following are key issues and recommendations for CalRecycle's consideration:

Issue: What should be CalRecycle's top priorities to promote crumb rubber infill recycling?
Recommendation: For now, seek to prove the concept by researching potential markets and end-users, evaluating the feasibility of establishing a fixed processing facility for recovered crumb rubber infill, and funding a few technical assistance and demonstration projects to prove their viability.

Issue: Will increased crumb infill recycling reduce demand for newly-produced crumb rubber and what are the implications for CalRecycle programs?
Recommendation: Anecdotally, very little of the crumb rubber from synthetic turf fields being replaced is being reused in new/replacement fields. However, there is some potential for this amount to increase over time. True to its recycling mission, CalRecycle should seek to maximize the value of recycled crumb rubber (and other recycled materials) through prolonged and varied recycling uses.

Issue: Should CalRecycle shift a portion of waste tire market development resources away from new crumb rubber to focus on recycled crumb rubber infill material?
Recommendation: Yes, but not so much that it severely impacts other goals. For example, over one or more years CalRecycle could allocate $300,000 to $500,000 to cover an evaluation of potential markets, a

feasibility study on establishing capacity to process recovered crumb rubber infill, and a few California-based demonstration projects.

Issue: Should CalRecycle resources be used to help recycle EOL crumb rubber infill that originally was sourced from outside the state?
Recommendation: Yes. Some California crumb rubber producers report that crumb rubber from outside the state is sometimes in California synthetic turf field construction (an estimate of the amount is not available). Regardless of the original source of crumb rubber infill, when recycled from a California synthetic turf athletic field it is now a California waste product. Given that tire funds are required to be spent on tires originating in California, however, this approach may require concurrence by CalRecycle's legal department.

Issue: How can CalRecycle broadly promote recycling of other tire-derived products and recycled content products made from other materials that are not recycled in closed loop?
Recommendation: The market research mentioned above should also cover other non-closed-loop tire-derived products (e.g., molded rubber products or playgrounds) to identify opportunities to maximize the useful life of the materials used.

Conclusions

This brief, high-level report identifies several specific opportunities for CalRecycle to promote synthetic turf sport field crumb rubber infill recycling in a way that advances these other goals at the same time. As with other market development efforts, CalRecycle should view such activities as long-term investments that may pay dividends over time as the current trends play out and recycling infrastructure and markets continue to evolve.

1. Introduction

Over the past decade use of crumb rubber as infill in synthetic turf fields has become an important scrap tire recycling market. With a useful life-expectancy of 8 to 10 years, a growing number of fields are reaching the end of their useful life and require replacement, and this is driving increased interest in whether and how the materials used in synthetic fields can be reused or recycled.[3]

The purpose of this brief report is to provide CalRecycle staff and management with a high level overview of key trends, barriers and issues related to recycling the crumb rubber infill used in synthetic turf fields, and to identify options to boost recycling levels. Louis Berger prepared the report under contract to CalRecycle, with support by DK Enterprises and Boisson Consulting. Research was conducted in summer and fall, 2015, including a review of information available on the Internet, along with interviews with select industry stakeholders.

While CalRecycle is interested in promoting recycling of all products, including all materials used in synthetic turf fields, the focus of this particular report is on crumb rubber infill only. CalRecycle also initially asked that this report address the recycling of playground surfaces made with crumb rubber at the end of their useful life; however, no information sources on this topic were identified and the team is not aware of any specific examples of rubberized playground surfaces being recycled.

After this introduction, Section 2 presents key findings on related trends and barriers. Section 3 then identifies alternative policies and programs to boost crumb rubber infill recycling, and also presents recommendations on how CalRecycle can address several related issues. Section 4 provides broad conclusions regarding next steps. Finally, Appendix A provides information on several firms researched for the report, and Appendix B provides a bibliography of identified information sources.

[3] Except where noted, the term "recycled" is being used in this report to broadly refer to reuse and recycling.

2. Trends and Barriers

Following is a synopsis of key trends, barriers and issues related to recycling of crumb rubber infill derived from deconstructed synthetic turf fields, based on research conducted for this report.

Trends

Synthetic turf infill has become an important market for crumb rubber made from scrap tires.

Use of synthetic turf in soccer, football, rugby and other types of athletic fields has been growing for several years, driven by its durability, shock-absorbing qualities, substantially lower water use and lower maintenance costs.[4]

Synthetic turf athletic fields usually employ loose filled 10-20 mesh crumb rubber granules interspersed between the grass blades.[5] According to several sources, a typical 80,000 square-foot synthetic turf athletic field may contain approximately 200,000 to 225,000 pounds of crumb rubber, and the same amount or more of sand may be combined with the crumb rubber.[6]

The number of synthetic turf fields has been growing steadily for over a decade. Estimates vary somewhat, but according to one source, in 2014 there were more than 8,500 fields nationally, with more than 900 in California, and in 2013, 1,300 new fields were installed nationally, with 85 of these in California.[7] As shown in Figure 1, use of California-sourced crumb rubber as infill in synthetic turf fields uses about four to six percent of all California-generated scrap tires. In 2014, for example, synthetic turf athletic fields consumed 1.7 million passenger tire equivalent (PTE) of the total 44 Million waste tires generated in the state, accounting for 3.8 percent of all California waste tires in that year. While five percent may seem like a small portion, it is a vital component of California's diversified scrap tire market. And, the California-sourced crumb rubber flowing to infill markets has represented between 20 and 25 percent of all California-produced crumb rubber in recent years.[8] Also, a portion of crumb rubber used in California synthetic turf fields is sourced out-of-state, so the potential market for California crumb is larger than that shown in Figure 1.

Most synthetic turf athletic fields continue to use infill comprised of crumb rubber and sand; however, alternative infill materials have gained market share recently.

Some organizations have raised concerns regarding the environmental health and safety of crumb rubber infill, and beginning with a news story in October 2014, this topic has received national attention on numerous networks and major print publications. Numerous studies have failed to support these concerns, including a 2010 CalRecycle sponsored study on crumb rubber use in synthetic turf by the Office of

[4] Synthetic Turf is also used in many other applications, such as landfill closures, public green spaces, pet parks, golf courses, playgrounds, open-air malls and residential lawns. In contrast to athletic fields, however, these applications typically do not require the cushioning properties provided by crumb rubber infill.

[5] Crumb rubber may sometimes also be used in an underlayment pad or elastic layer beneath the turf. However, the project team is not aware of specific examples of such use in California.

[6] See, for example: "Removal, Recovery, Reuse and Recycling of Synthetic Turf and Its System Components." Synthetic Turf Council. January 2013.

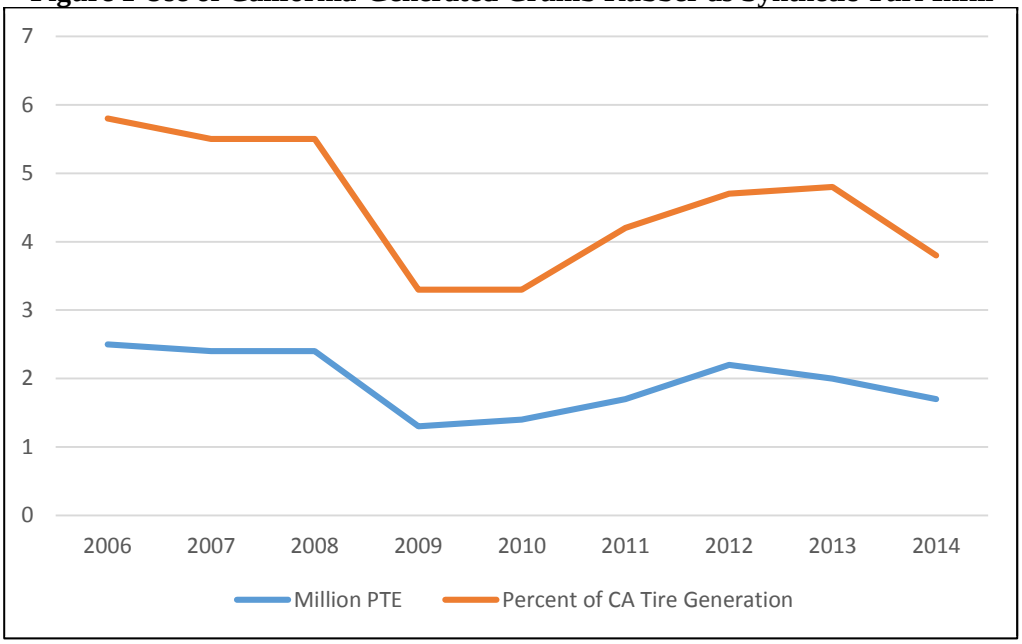
[7] Opportunities for Recycling End-of-Life Turf Fields." Presentation by Mark Heinlein, President, Turf Reclamation Systems, at the 2014 CalRecycle Tire Conference.

[8] "California Waste Tire Market Report: 2014." Prepared by Louis Berger Group with support by Boisson Consulting and DK Enterprises, for CalRecycle. July 2015.

Environmental Health Hazard Assessment (OEHHA). CalRecycle is currently engaged in a new, broad study in partnership with OEHHA in an effort to comprehensively address these concerns.

Through spring 2015, industry perspectives on how this issue is impacting demand for crumb rubber were mixed. While bids for new turf fields increasingly required the inclusion of alternative infill materials, crumb rubber had held market share due to its superior price point and performance qualities. The issue continues to garner the attention of news media and, recently, industry representatives have indicated that some field developers and installers are choosing alternatives to crumb rubber. One national firm that markets and installs synthetic turf fields recently made the decision to completely stop using crumb rubber infill, citing concern over potential liability and law suits. While data on the extent of the shift are currently available, one well-informed industry representative estimated that crumb rubber's share of the infill market may have slipped from approximately 95 percent to perhaps 90 percent.

Figure 1 Use of California-Generated Crumb Rubber as Synthetic Turf Infill



Source: CalRecycle Annual Waste Tire Market Reports, 2008 – 2014.

The number of synthetic turf fields reaching the end of their useful life and in need of replacement is growing.

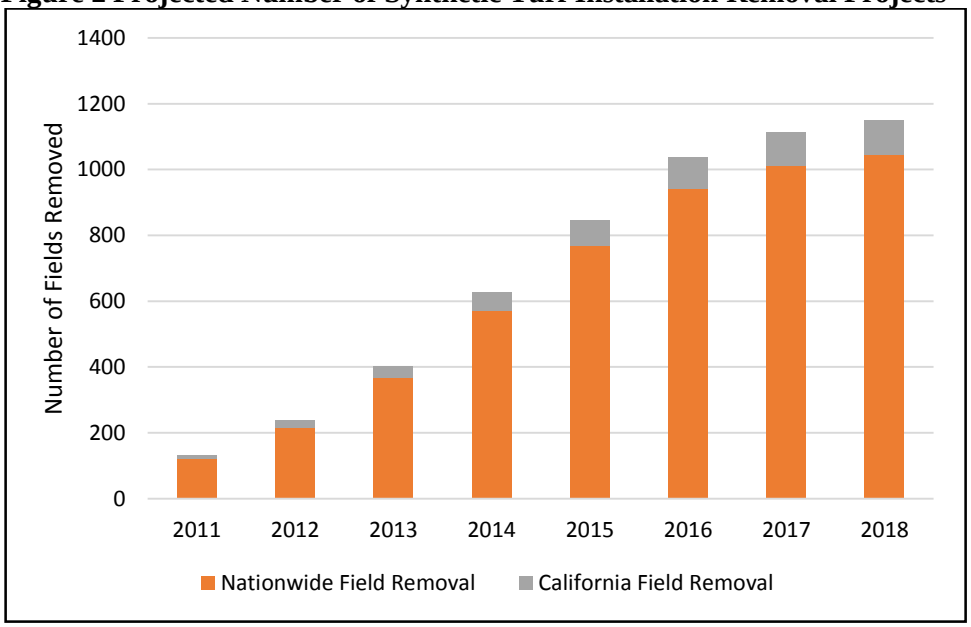
In replacement projects, the foundation and base layers often remain for direct reuse while the turf and infill material are replaced. Many industry sources say that a typical synthetic turf athletic field lasts about eight-to-ten years before reaching the end of its useful life and requiring replacement. The lifetime of any particular field may vary with its usage, exposure to intense sunlight, maintenance, and other factors, but eventually the need for replacement may be indicated by torn or trampled turf and disintegrated infill. As shown in Figure 2, often-cited industry projections indicate that by 2017, more than 1,000 synthetic turf athletic fields could be deconstructed annually nationwide, with approximately 10 percent of these in California. One source estimated that about 1,500 fields are being installed across the U.S. during 2015, with replacement projects accounting for 750 of these.[9] According to another source, in 2013 about 22

[9] "Trends in End-of-Life Management for Synthetic Turf Products." Presentation by Adam Coleman, Turf Reclamation Systems, at the 2015 CalRecycle Tire Conference.

percent of the 1,200 to 1,300 synthetic fields installed nationally were replacement fields.[10] Due to the high cost, some field owners may be choosing to prolong replacement as long as possible. However, industry representatives indicate that, even if some projects are prolonged, the projections in Figure 2 accurately describe the trend.

Assuming the figures above, a plausible scenario would be that 150 fields are installed in California in 2015 (10 percent of the projected national number), using a total of about 29.7 million pounds of crumb rubber infill (assuming 90 percent of the fields use an average of 200,000 pounds per field). Assuming 22 percent of these are replacement fields in which 100 percent of the recovered infill is reused (an upper maximum amount that is not realistic in practice), then a maximum of 6.5 million pounds of crumb rubber could be sourced from the deconstructed fields themselves. This would reduce demand for new crumb rubber in these installations from about 29.7 million pounds to 23.1 million pounds. (For comparison, as shown in Figure 1, use of California-sourced crumb rubber in synthetic turf athletic fields has averaged about 2 million PTE, or 24 million pounds of crumb rubber, over the past nine years. A portion of demand in California is filled by out-of-state suppliers.)

Figure 2 Projected Number of Synthetic Turf Installation Removal Projects[11]



Interest in recycling synthetic turf athletic field components has grown in recent years, but recycling levels remain very low.

As more and more synthetic turf fields reach their end-of-life, there has been growing interest in recycling rather than disposing their components. Many field owners have explored recycling projects, and some have chosen to pursue the option. A number of U.S. companies advertise the ability to provide synthetic turf field removal services, and a growing number offer maintenance, recycling services and/or offer recycling equipment. (Appendix A identifies several firms that were researched for this report.) At least one

[10] "Synthetic Turf Market Update and End-Of-Life Recycling." Presentation by John Baize, President, Act Global, at the 2014 CalRecycle Tire Conference.

[11] "Trends in End-of-Life Management for Synthetic Turf Products." Presentation by Adam Coleman, Turf Reclamation Systems, at the 2015 CalRecycle Tire Conference. The figure assumes that approximately 10 percent of national removal projects occur in California. It is not clear which estimates are actual removal projects and which are projections.

turf installation firm in California has purchased turf removal equipment. One California processor reported they were approached regarding their ability to process or market recovered crumb rubber infill, but they were unable to identify a viable use. Nationally, at least one firm (Turf Reclamation Systems) has focused its business model exclusively on turf field end-of-life management and recycling, both selling equipment and providing services. Where possible, the firm reuses a portion of crumb rubber from fields being dismantled in the replacement field; however, they have not identified other viable markets for the crumb rubber that would not require extensive processing, which is currently not available. Another firm (Everwood Recycling International) had been exporting carpet-related recovered field components from Washington State and the East Coast to facilities in Hong Kong and mainland China has reportedly stopped this practice due to the high cost of shipment. There are numerous companies that may extract the crumb rubber and sand and clean by shaking out the sand through a sieve shaker process. However, industry reported that there is not anyone commercially separating the sand and crumb rubber so that that crumb rubber could be used in other molded and tire-derived products. And, a small number of firms focus on attempting to "repurpose" (i.e., reuse) the carpet portion of dismantled fields in applications such as dog parks. Reportedly, one of these firms often warehouses material near deconstruction sites while they research such repurposing opportunities.

Anecdotally, it appears that in practice landfill disposal is by far the most common method for managing field components after removal, and no complete examples of an actual recycling project for the components of a removed field in California were identified. The reports and presentations listed in Appendix B: Bibliography identify several case studies of synthetic turf field recycling projects. Although it is not very common, there are reportedly opportunities for recycling the carpet-related plastic components of deconstructed fields in the established polyethylene and polypropylene plastics reclamation industry. However, the only use for recovered crumb rubber infill that the project team is aware of is to reuse a portion of the material in construction of new/replacement fields.

Overall, while we could not obtain statistics on the percentage of removed synthetic turf fields that were recycled, anecdotally it appears to be a very small portion. According to one knowledgeable source, of all field removal projects, perhaps 15 percent involve reuse of a portion of the infill in the replacement field, and only about five percent involve recycling "carpet" components. The Synthetic Turf Council has recently established a Reuse and Recycling Task Force which will begin operation in January 2016 to further advance recycling efforts.

The synthetic turf field recycling situation is similar to some other types of recycled content products that are not closed-loop markets.

While not researched for this report, generally the situation with synthetic turf is similar to that of other tire-derived products and other recycled-content products that are not recycled in a closed loop. That is, they are often used to produce durable recycled content products that may or may not themselves be recyclable. Examples of tire-derived products in this situation include molded products like pavers or mats. Similar recycled-content products made from other materials include lumber, nursery pots and other rigid plastic products made with recycled plastic, fiberglass and pressed glass products made from recycled glass and wallboard or cellulose insulation made from recycled paper. Government recycling agencies like CalRecycle and recycling advocacy organizations often call for closed-loop recycling in which a product is recycled and used to produce the same product, because this directly reduces natural resource use and the associated energy and emissions. Short of closed-loop recycling, there may be other alternatives to maximize the useful life of all recycled materials. However, the project team is not aware of any studies comprehensively analyzing this issue and providing a framework for decision making, whether for tire-derived products or other types of recycled content products.

Barriers

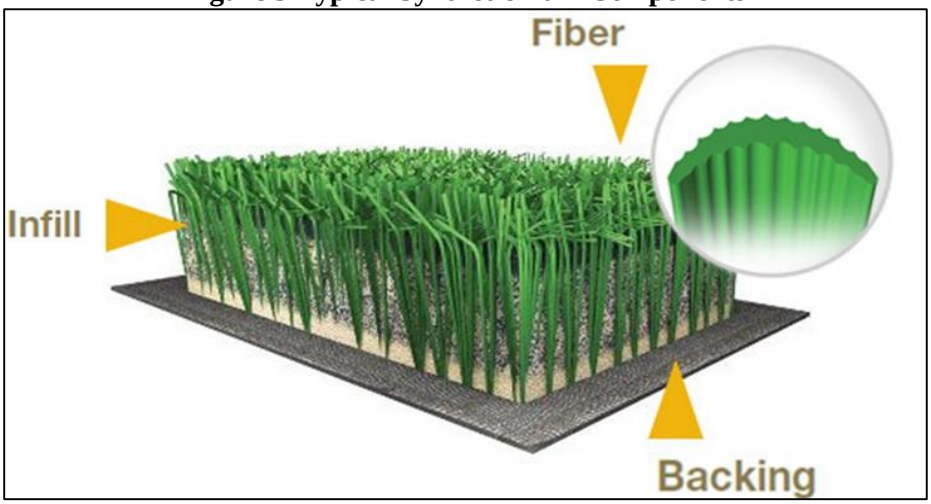
The multi-material nature of synthetic turf fields complicates recycling of individual components.
Although this report focuses on crumb rubber infill, it is useful to consider the broader context. Synthetic turf athletic fields are assembled in layers using many different material types. The mixture of material types increases the difficulty to remove and recycle the components because the layers of the system require separation.

According to the Synthetic Turf Council,[12] and as illustrated in Figure 3, a typical synthetic turf athletic field system consist of:

- Geotextile (polypropylene plastic film);
- Drainage pipes (polyvinylchloride);
- Drainage layer (stone aggregate or Expanded Polypropylene or Polystyrene);
- Underlayment (shock pad or elastic layer, which may not be removed in deconstruction);
- Turf backing (plastic film, which also may not be removed in deconstruction);
- Infill (crumb rubber, sand and/or various other materials); and
- Turf blades (plastic fiber).

This report sometimes makes a distinction between "carpet components" of turf fields (i.e., the backing and fibrous artificial glass blades) and the sand/crumb rubber misused as infill.

Figure 3 Typical Synthetic Turf Components



Source: Synthetic Turf Council

Infill is interspersed between the synthetic turf to provide the necessary stability, uniformity, and resiliency. Each blade customarily stands above the infill material. There are various types of infill materials including:

[12] "Removal, Recovery, Reuse and Recycling of Synthetic Turf and Its System Components." Synthetic Turf Council. January 2013.

- Crumb rubber[13] (post-consumer tire rubber, which may be coated with colorant, sealant or anti-bacterial substances);
- EPDM (ethylene propylene diene monomer);
- TPE (thermos-plastic elastomer);
- Cork (organic);
- Coconut husk (organic);
- Sand (silica); and
- Coated silica sand (elastomeric or acrylic coating).

Unlike residential or municipal park synthetic turf fields, athletic systems sometimes include a shock pad or elastic layer beneath the turf. When used, these underlayment layers provide additional protection by contributing to G-max[14] levels for impact attenuation, and include:

- Shock pad (PVC/NBR, polypropylene or crumb rubber/polyurethane); and/or
- Elastic layer (crumb rubber/polyurethane).

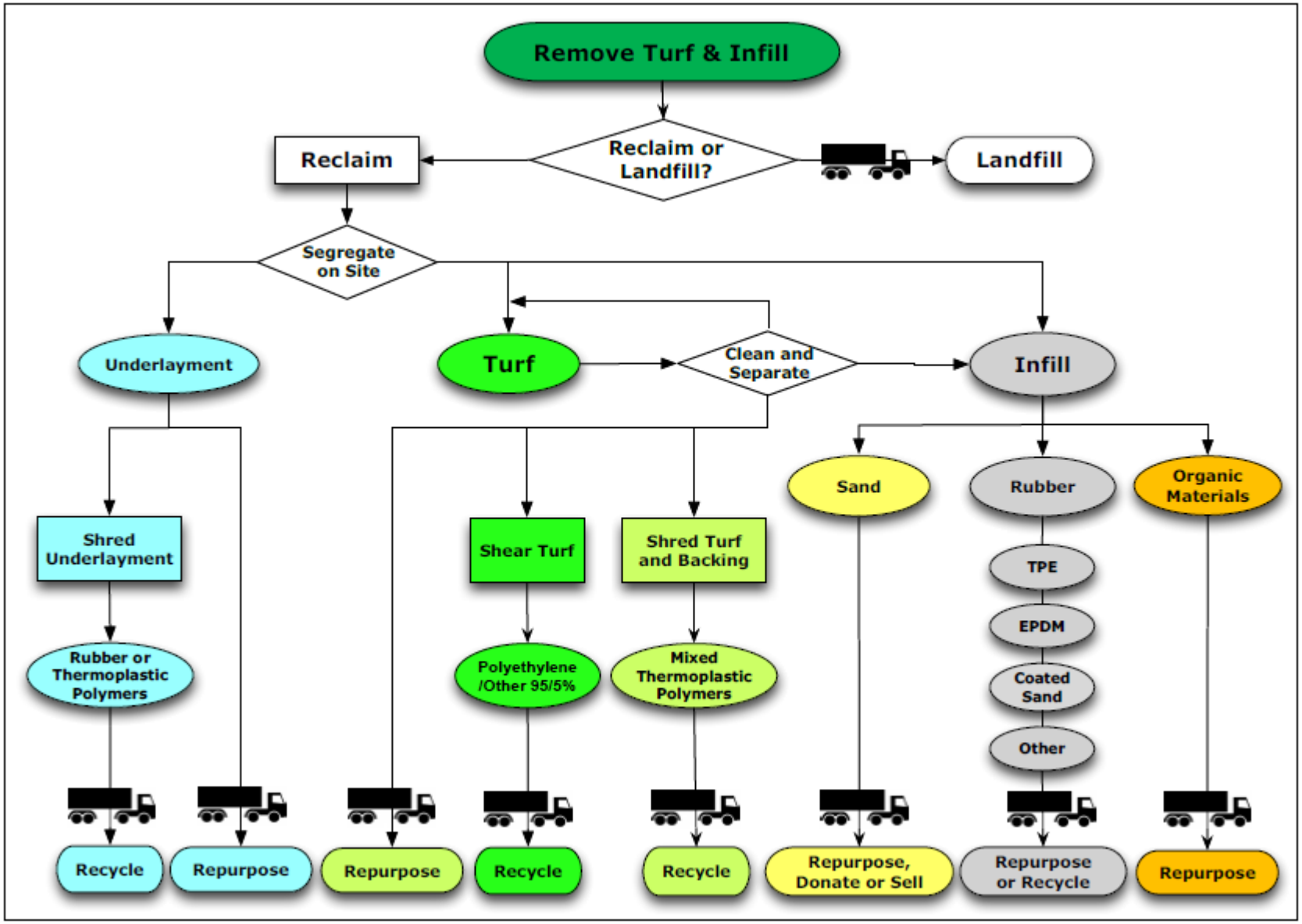
Technologies to remove, separate and clean various turf components are available, though still evolving.

As noted above, the multiple materials used in synthetic turf athletic fields are challenging to separate for recycling. However, technologies to remove turf materials and to separate and clean components are available, and are reportedly improving steadily. Figure 4 on the next page illustrates the processes and flows for different turf components. Equipment manufacturers have helped general contractors overcome the challenges by developing specialty equipment tailored to the task. Processes vary, but in recycling projects infill materials may be first removed via vacuum, and then the carpet portion is removed and rolled into compact bundles. In an alternative, reportedly less efficient approach, the carpet may be cut and then pounded from behind to remove infill. If destined for reuse on-site in a replacement field, a portion of the infill material may be stored on-site and then placed, often in the base layers of the new field, with additional, new crumb rubber infill placed on top of this. Carpet components must be shipped to processors for recycling. And, to be used in applications other than reuse as infill, the crumb rubber infill would need to be shipped to a processor for further processing to clean the crumb rubber of sand and other contaminants. No established facilities actively providing this service were identified, although the Pennsylvania facility noted above has recently begun such activities.

[13] In most field applications using crumb rubber for infill, it's common practice to mix it with sand at a 2:1 crumb rubber to sand ratio. Other mixture ratios and types are also used.

[14] G-max is a measure of a surface's maximum fall-height that satisfies safety criteria, as determined in product tests.

Figure 4 End-of-Life Management Flow Chart for Synthetic Turf Athletic Fields[15]



[15] "Removal, Recovery, Reuse and Recycling of Synthetic Turf and Its System Components." Synthetic Turf Council. January 2013.

Recycling crumb rubber infill is usually much more costly than disposal.

For several reasons, recycling crumb rubber infill derived from deconstructed synthetic turf athletic fields is usually much more costly than disposal, resulting in a key barrier to increased recycling. First, the cost of renting specialty equipment to separate field components and clean crumb rubber infill of sand and other materials is much more costly than the equipment needed to ship the materials to landfill. Second, the different material components will usually need to be shipped to distinct processing or end-use facilities, and, given that landfills are far more ubiquitous than the needed recycling facilities, the shipping distance and cost for recycling usually is much higher than for disposal. According to the Synthetic Turf Council, when compared to the $30,000 to $60,000 cost of landfilling an 80,000 square-foot sports field, it is unlikely that the cost of transporting the synthetic turf and/or infill farther than 200 miles could be considered feasible.[16] Finally, as discussed further below reusing crumb rubber infill in new/replacement fields is one of the only viable markets currently. However, while this is often feasible, it is usually uneconomical compared to purchasing new crumb rubber at a price of perhaps 15 to 20 cents per pound.

Recovered crumb rubber infill may have reduced performance characteristics compared to new crumb rubber, but is still often suitable for reuse in new/replacement installations.

According to tests conducted by Turf Reclamation Systems, recovered crumb rubber infill does show reduced performance characteristics but may still be suitable for certain applications.[17] According to this source, changes and/or degradation to crumb rubber infill in turf applications over time may include:

- Distribution of particle sizes based on sieves analysis;
- Increased specific gravity;
- Increased bulk density; and
- Reduced compression and recovery.

However, the net impact of these changes may have little impact on G-max fall safety test performance. In one reported test the recycled crumb rubber infill when used in a 50/50 mix with sand and no pad had a reduction in G-max score of less than 10 percent, and in another test a 2:1 crumb rubber/sand ration actually showed improved G-max scores.

Markets for recycled crumb rubber infill are extremely limited.

By definition any product is recyclable if there is a post-consumer market available and it is technically and economically viable to separate and ship the product to that market. The grass portion of synthetic fields can be repurposed (i.e., reused) in applications such as dog parks, landfill caps or other areas where a relatively low quality turf product is suitable. And, the plastic grass blades used in artificial turf may have a comparatively viable market in the established post-consumer polyurethane and polypropylene industry, or could be used to produce such products as synthetic lumber or molded parts used in the automotive, flooring and other industries. No specific examples of this being done in practice were identified.

While the Synthetic Turf Council cites a long list of potential markets for recycled crumb rubber infill, as shown in Table 1 on the following page, research for this report suggests that in practice, the actual market for recovered crumb rubber infill beyond reuse is virtually non-existent. One leading company involved in synthetic turf athletic field deconstruction indicates that they currently dispose 75 percent of the material in

[16] "Removal, Recovery, Reuse and Recycling of Synthetic Turf and Its System Components." Synthetic Turf Council. January 2013.

[17] Opportunities for Recycling End-of-Life Turf Fields." Presentation by Mark Heinlein, President, Turf Reclamation Systems, at the 2014 CalRecycle Tire Conference.

landfill, and are able to reuse 25 to 50 percent of crumb rubber infill in new/replacement fields. Reuse is limited to select projects where economics are relatively attractive (especially where landfill costs are high) or in which the field owner specifically elects to pay more to cover higher recycling/reuse costs. One company that had reportedly warehoused recovered turf materials for a time was said to have found a use in Mexico, but the project team was not able to verify this. One company had been shipping recovered field materials to facilities in Hong Kong and mainland China, but has since stopped due to prohibitively high transportation costs. It is unclear what type of market, if any, the crumb rubber infill portion of these materials found there. In California, a sample of recycled crumb rubber infill was reportedly tested for use as fuel by one of the state's cement kilns, but was rejected. And, one processor said recovered infill is undesirable for use in rubberized asphalt applications because of the costly and uncertain processing required to remove contaminants such as sand, dirt and turf fiber. No specific examples of recycled crumb rubber infill being used in the manufacture of a new product, other than reuse in new/replaced synthetic fields as infill, was identified. Because different turf installers use different crumb rubber specifications (which sometimes include coatings) and different mixtures of rubber and sand, reuse is usually feasible only when the same firm that originally installed the field is replacing it, so that material specifications are the same or similar.

Table 1 Potential Markets for Recovered Crumb Rubber Infill as Identified by the Synthetic Turf Council

Category	Examples[18]
Field/landscape Applications	▪ Reuse as infill on new synthetic turf sports field or landscape installations (AI) (CS) ▪ Natural turf soil amendments to improve wear tolerance and prolong playability of natural turf sports fields (AI) ▪ ADA-compliant playground surfacing (AI) (CS)
Road and Rail Applications	▪ Acoustic barriers (CS) (AI) ▪ Road base (CS) ▪ Portable traffic control devices (CS) ▪ Ripple strips and speed bumps (CS) ▪ Rail crossings, sleepers and buffers (CS) ▪ Asphalt (CS)
Construction & Industrial	▪ Industrial flooring (CS) ▪ Acoustic barriers (CS) (AI) ▪ Sprayed up roofing, insulation and Adhesive sealants (CS) ▪ Mounting pads and shock Absorbers (CS) ▪ Airfield runways (CS) ▪ Carpet underlay (CS) ▪ Children's playground surfacing (CS) (AI) (AIWP)
Marine	▪ Wharf buffers (CS) (AI) ▪ Floating docks (CS) (AI) ▪ Non slip flooring (CS) (AI)
Sporting	▪ Equestrian surfaces and workout areas (CS) (AI)
Landscaping	▪ Watering systems, rubber hosing & low pressure irrigation drip hoses (CS) ▪ Infill for Synthetic/Artificial Landscape Turf (CS) (AI)
Natural Turf Soil Amendment (to improve wear tolerance and prolong playability)	▪ Athletic Fields (AI) (CS) ▪ School Campus Areas (AI) ▪ Soil Compacted Walkway or Pathway Areas (AI)
Energy Recovery	▪ Energy can be recovered from crumb rubber infill by incineration, pyrolysis or gasification. ▪ The calorific value (CV) of tire rubber is 27.5 MJ/kg (14,000-16,000 BTU).

Source: "Removal, Recovery, Reuse and Recycling of Synthetic Turf and Its System Components." Synthetic Turf Council. January 2013.

[18] AI indicates the extracted infill may be used As Is with minimal cleaning. CS indicates Cleaning and Separating the sand and crumb rubber may be required.

Field owners and developers lack information on synthetic turf athletic field recycling options and processes.

Given the rapidly changing synthetic turf market place, evolving recycling technologies and the attention given to environmental health and safety issues, there may be a general lack of understanding about deconstruction and recycling options among public schools, local agencies and other organizations that own and manage synthetic turf athletic fields. As the turf recycling infrastructure continues to evolve, there is a need for consolidated information on: the firms available to do the work; typical costs; best management practices regarding contracting, oversight and regulatory/environmental issues; and generally expectations for how the process may play out. Most importantly, field owners need to understand their options for managing fields at the end of their useful life, and how they can most efficiently consider recycling options.

3. CalRecycle Options, Key Issues and Recommendations

Following are some options CalRecycle may wish to consider to help promote increased recycling of crumb rubber infill recovered from end-of-life synthetic turf athletic fields.

Provide funding through grants, loans and/or incentives.

CalRecycle's Tire-Derived Product grants have supported many synthetic turf installations in the past, and CalRecycle continues to consider them eligible for such funding. CalRecycle could explicitly adjust program rules to provide grants to cover all or a portion of the cost to deconstruct and recycle the rubber portion of existing fields at the end of their useful life. Such funding could be limited to the cost of recovering, processing the recycled crumb rubber (similar to current grants covering the cost of new crumb rubber). Or, CalRecycle could choose to support the process further by covering costs related to recycling other components of the field, if deemed allowable under current statutory authority for the tire fund. Similarly, loans could be provided to firms offering turf/infill recycling services to help cover the cost of new equipment and other fund uses as allowed under current loan program rules. Finally, recognizing the high cost and need for innovation related to recycling crumb rubber infill from turf installations, CalRecycle could create a special category within the relatively new Tire Incentive Program to provide a per pound payment for recovering and processing the infill rubber, or fund testing of recovered crumb rubber infill through the Feedstock Conversion Technical Assistance and Material Testing Program.

Research the potential to establish a facility to process recovered crumb rubber infill.

Another option would be to offer funding through one or more of these programs to help establish and/or support ongoing operations of a fixed facility capable of secondary processing and cleaning of recovered crumb rubber infill material. According to one industry source, such an operation might have capital costs (for needed processing equipment only) of about $500,000 or less, but would need a steady supply of recovered crumb rubber infill from 50 to 100 deconstructed fields per year to be viable. While California has apparently already reached this number of annual field deconstruction projects, it may be challenging to recover crumb rubber infill from a sizable number of the projects without CalRecycle support. Moreover, given the size of California, significant transportation would be required to ship materials to a centralized facility, which may be prohibitive. One option would be to support establishing two facilities (one north and one south), but this would reduce the volumes available to either facility.

Research potential markets and end-users.

As described above, a large number of potential markets for recycled crumb rubber infill have been identified, while the only viable market used in practice appears to be reuse, and only in certain situations. CalRecycle could sponsor or conduct research in-house to evaluate potential markets and to identify specific potential end-users. Such research could involve universities and/or companies involved in products that have relatively forgiving performance specifications and that can potentially benefit from the properties of crumb rubber combined with sand particles. Such markets may include, for example, certain applications for cement or certain asphalt paving applications. An application that allowed low-specification standards including some level of contamination with silica sand and requiring little to no pre-processing of reclaimed infill would be ideal.

Fund technical assistance and demonstration projects involving the identified markets and end-users.

CalRecycle could proactively reach out to partners and offer technical assistance and funding to execute a variety of demonstration projects, much like it has done with rubberized asphalt and tire-derived aggregate

used in civil engineering applications. Given the early stage of synthetic turf field recycling, this would appear to be an effective approach that could address many of the barriers identified above. One option would be to focus on testing recovered crumb rubber infill material processed through various systems to compare the costs and performance characteristics.

Research issues related to recycling all end-of-life tire-derived products.

As discussed above, the issues related to recycling end-of-life synthetic turf sports field components are similar to those of other tire-derived products and recycled content products made with other materials that do not have closed-loop markets. CalRecycle could consider a focus on recycling synthetic turf components as an initial effort to demonstrate opportunities to prolong the useful life of such recycled material applications, and/or to demonstrate the potential for continuous recycling that approximates the benefits of closed-loop systems. CalRecycle could sponsor a study to evaluate the need and options for promoting closed-loop recycling for a variety of products. In particular, given the special programs in place and the relationship of the carpet recovery industry to the synthetic turf industry, such a study could potentially start by focusing on those two product groups.

Issues and Recommendations

Following are some issues that CalRecycle Staff and Management should consider when determining whether and how to promote crumb rubber infill recycling.

What should be CalRecycle's top priorities to promote crumb rubber infill recycling?

Recommendation: For now, seek to prove the concept by researching potential markets and end-users, and funding a few technical assistance and demonstration projects. This could include sponsoring a feasibility study to explore the potential for establishing a fixed facility to process recovered crumb rubber infill. This report indicates the turf recycling infrastructure is still evolving and there is a need for enhanced markets. The good news is that reuse in new/replacement fields may hold the greatest potential. However, work is still needed to improve the economic, technical and market viability of this option.

Will increased crumb infill recycling reduce demand for newly-produced crumb rubber and what are the implications for CalRecycle programs?

Recommendation: Increased crumb rubber infill recycling does have the potential to reduce demand for new crumb rubber in new/replacement synthetic turf athletic fields. As noted in Section 2, based on several assumptions, initially maximizing reuse of recovered crumb rubber infill in new/replacement fields might reduce demand for new crumb rubber in such applications from about 29.7 Million pounds to 23.1 Million pounds. However, true to its recycling mission, CalRecycle should seek to maximize the value of recycled crumb rubber (and other recycled materials) through prolonged and varied recycling uses.

Should CalRecycle shift a portion of waste tire market development resources away from new crumb rubber to focus on recycled crumb rubber infill material?

Recommendation: Yes, but for now not so much that it severely impacts other goals. For example, over one or more years CalRecycle could allocate perhaps $300,000 to $500,000 to cover an initial evaluation of potential markets, a feasibility study on establishing a fixed processor for recovered crumb rubber infill, and a small number of California-based demonstration projects.

Should CalRecycle resources be used to help recycle EOL crumb rubber infill that originally was sourced from outside the state?

Recommendation: Yes. Regardless of the original source of crumb rubber infill, when recycled from a California synthetic turf athletic field it is now a California waste product. Given that tire funds are required to be spent on tires originating in California, however, this approach may require concurrence by CalRecycle's legal department.

How can CalRecycle leverage new experience with recycling end-of-life synthetic turf fields to more broadly promote recycling of other tire-derived products and recycled content products made from other materials that are not recycled in closed loop?

Recommendation: The market study mentioned above could include a scan of potential markets for other non-closed loop tire-derived products to identify opportunities to maximize the useful life of the materials used. Given the potential synergies with the carpet recovery industry, a focus on tires and carpet may be particularly appropriate.

4. Conclusions

The synthetic turf industry is going through a period of rapid change. A growing number of installed fields are reaching the end of their useful life, driving interest in recycling opportunities. The number of fields being installed continues to grow, in part due to demand for replacement fields. And a new infrastructure and market place for deconstructing and managing end-of-life fields, including recycling, is beginning to evolve. All of this is occurring with the backdrop of continuing concern over environmental health and safety issues and the potential for legislation making new field installation more difficult. The other important backdrop is CalRecycle's new focus on recycling, and the associated need to maximize the useful life and environmental benefits of all recycled materials through closed-loop recycling systems.

This brief, high-level report has identified several specific opportunities for CalRecycle to promote synthetic turf recycling in a way that advances these other goals at the same time. As with other market development efforts, CalRecycle should view such activities as long-term investments that may pay dividends over time as the current trends play out and recycling infrastructure and markets continue to evolve.

Appendix A: Description of Select Companies Researched for this Report

Company	Services Provided							
	Installation of Synthetic Turf Athletic Fields	Installation of Playground, Dog Parks, Other Turf Applications	Manufacturer Equipment for Turf Reclamation	Supplier of Equipment for Turf and/or Infill Removal	Turf Removal	Turf and Infill Removal	Reuse Infill at Same Field	Recycle / Reuse Turf
Act Global International Austin, TX http://www.actglobal.com/	X	X					X	
Artificial Grass Recyclers Termecula, CA http://www.artificialgrassrecyclers.com					X	X		
AstroTurf Dalton, GA http://www.astroturf.com/	X	X					X	
Colony Landscape and Maintenance, Inc. Alviso, CA http://www.colonylandscape.com	X	X		X	X	X	X	
Everwood Recycling International, Inc. Lantzville, BC http://www.polypacificposts.com				X	X			X
Field Turf Montreal-Quebec http://www.fieldturf.com	X	X					X	
FieldAway USA, Inc. Dalton, GA http://www.fieldaway.com/			X					
FIELDS Canton, GA http://fields-inc.com/	X	X						
G9Turf Hauppauge, NY http://www.g9turf.com	X							
Playing Surface Solutions, Inc. Saegertown, PA http://www.pssfields.com	X		X		X	X		

Company	Services Provided							
	Installation of Synthetic Turf Athletic Fields	Installation of Playground, Dog Parks, Other Turf Applications	Manufacturer Equipment for Turf Reclamation	Supplier of Equipment for Turf and/or Infill Removal	Turf Removal	Turf and Infill Removal	Reuse Infill at Same Field	Recycle / Reuse Turf
Shaw Sports Turf Calhoun, GA http://www.shawsportsturf.com/	X	X					X	
SMG Equipment LLC / SMG Sportplatzmaschinenbau GmbH Auburn, Washington http://www.smg-gmbh.de			X	X				
Sports Facility / Used Artificial Turf Cartersville, GA http://www.usedartificialturf.com		X						X
Sports Field Removal Tonkawa, OK http://www.sportsfieldremoval.com				X	X			
Synthetic Sports Turf Recyclers Menifee, CA http://www.syntheticsportsturfrecyclers.com/	X	X			X	X	X	X
The Motz Group Cincinnati, OH http://themotzgroup.com	X	X						
Turf Reclamation Solutions, Inc. Cincinnatti, OH http://www.recyclingartificialturf.com/			X	X	X	X		X
United Sport Surfacing of America Irvine, CA http://www.sustainablesurfacing.com		X						

Appendix B: Bibliography

"A Guide to Synthetic and Natural Turfgrass for Sports Fields: Selection, Construction and Maintenance Considerations." Sports Turf Managers Association. 2008.
http://www.stma.org/sites/stma/files/STMA_Synthetic_Guide_2nd_Edition.pdf

"Companies Team Up to Recycle Synthetic Turf Fields." Jennifer Kalish. Plastics News, August 13, 2014.
http://www.plasticsnews.com/article/20130814/NEWS/130819958&template=printthis

Opportunities for Recycling End-of-Life Turf Fields." Presentation by Mark Heinlein, President, Turf Reclamation Systems, at the 2014 CalRecycle Tire Conference.
http://www.cce.csus.edu/conferences/CalRecycle/tw14/docs/TC_Sess5_HeinleinBaize_RecECOturfF_SWAP042514.pdf

"Qualifying Reclaimed Rubber for Re-use in Sports Fields." Presentation by Mark Heinlein, Turf Reclamation Systems, at the 2012 CalRecycle Tire Conference. August 29, 2012.

"Removal, Recovery, Reuse and Recycling of Synthetic Turf and Its System Components." Synthetic Turf Council. January 2013.

"Synthetic Turf 360: A Guide to Today's Synthetic Turf." Synthetic Turf Council. 2011.
http://c.ymcdn.com/sites/www.syntheticturfcouncil.org/resource/resmgr/files/synthetic_turf_360.pdf

"Synthetic Turf Market Update and End-f Life Recycling." Presentation by John Baize, President, Act Global, at the 2014 CalRecycle Tire Conference.
http://www.cce.csus.edu/conferences/CalRecycle/tw14/docs/TC_Sess5_Baize_OverviewSynTurfUp_042314.pdf

"Synthetic Turf Removal Equipment by TRS." A You Tube video available at:
https://www.youtube.com/watch?v=9eWlf9Kc3Gc

"Synthetic Turf Systems Removal and Replacement Technologies." Mark Mitchell, FieldAway USA, Inc. CalRecycle 2012 Tire Conference. August 29, 2012.

"Trends in End-of-Life Management for Synthetic Turf Products." Presentation by Adam Coleman, Turf Reclamation Systems, at the 2015 CalRecycle Tire Conference. August 19, 2015.

"Trends in Sales of new Synthetic Turf Sports Fields." Presentation by Jeremy Gauche, Act Global International, at the 2015 CalRecycle Tire Conference. August 19, 2015.