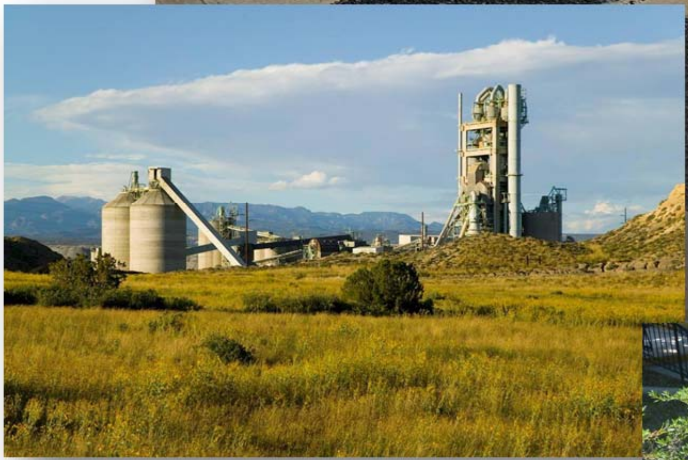
Colorado Waste Tire Market Development Plan

Colorado Department of Public Health and Environment



Prepared for:

The Waste Tire Advisory Committee

The Colorado Department of Public Health and Environment

Prepared by:

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May 9, 2013

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TETRA TECH

Colorado Waste Tire
Market Development Plan

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Acronyms

AASHTO – American Association of State Highway Transportation Officials
ADA – Americans With Disabilities Act
AGO – Attorney General's Office
ASTM – American Society for Testing and Material

Btu – British Thermal Unit

CDOT – Colorado Department of Transportation
CDPHE – Colorado Department of Public Health and Environment
CRS – Colorado Revised Statute

DOLA – Department of Local Affairs

GCC – Grupo Cementos de Chihuahua

NHSM – Non-Hazardous Secondary Materials
NOx – Nitrogen Oxide Compounds

OAG – Office of the Attorney General
OEM – Original Equipment Manufacturer
OTR – Off The Road

PTE – Passenger Tire Equivalents
PuPs – Public-Public Partnerships

RMA – Rubber Manufacturers Association
RTD – Regional Transportation District

SOx – Sulfur Oxide Compounds

TDA – Tire Derived Aggregate
TDF – Tire Derived Fuel
TSCA – Toxic Substances Control Act

USEPA – U.S. Environmental Protection Agency

WTMDF – Waste Tire Market Development Fund

Colorado Waste Tire Market Development Plan

1.0 Introduction

Consistent with Colorado Revised Statute (CRS) 25-17-202.9, the Colorado Waste Tire Advisory Committee and the Colorado Department of Public Health and Environment (CDPHE) engaged a team of waste tire experts led by Tetra Tech, Inc.'s (Tetra Tech) office in Denver, Colorado, to prepare this Waste Tire Market Development Plan. This Waste Tire Market Development Plan presents an analysis of the waste tire situation in Colorado and then outlines an approach for the state to realize the beneficial use of all waste tires in the state.

This project was funded by the State of Colorado Waste Tire Program.

1.1 Purpose, Goals, Plan Organization

Colorado's Waste Tire Management Program is managed jointly by the CDPHE Hazardous Materials and Waste Management Division and the Division of Environmental Health and Sustainability. In 2010, Colorado House Bill 10-1018 authorized formation of the Waste Tire Advisory Committee to provide technical advice on specific waste tire issues to these CDPHE divisions. The Waste Tire Committee also reviews changes in the regulations for waste tires proposed by the CDPHE and other stakeholders.

Colorado Revised Statute 25-17-208 defines the focus of the Waste Tire Advisory Committee:

a) Protect the safety and welfare of the citizens, wildlife, and environment adjacent to waste tire facilities;
b) Develop sound enforcement practices and risk mitigation practices to prevent the loss of life, property, and the environment caused by waste tires;
c) Prevent the illegal transportation and disposal of waste tires;
d) Develop markets for tire-derived products; and
e) Provide a long-term plan to reduce waste tire stockpiles and a waste tire market development plan.

Consistent with this focus, the purpose of this Waste Tire Market Development Plan is:

> ***To present a roadmap for identifying, expanding, and engaging waste tire reuse and recycling capacity in the state to achieve the goal of recycling or reusing 100 percent of newly generated and stockpiled waste tires in the state.***

To achieve this purpose, this Waste Tire Market Development Plan is organized around the following supporting goals:

- Section 2.0, Colorado's Waste Tire Situation, develops an understanding of:
  - The risks associated with waste tires.
  - A conceptual model of the sources, storage, movement, processing, and end uses of waste tires within the state.

    - Current and historical waste tire production.
    - Current and historical waste tire storage.
    - Current and historical waste tire end uses.

- Section 3.0, Influences on the Waste Tire System, assesses geographic, demographic, climactic, natural resource, infrastructure, regulatory (federal and state), and economic influences to identify drivers and impedance factors for waste tire reuse and recycling in the state.

- Section 4.0, Opportunities for Expanding Beneficial End Use, outlines the potential opportunities for creating additional end use capacity for waste tires, addressing increased capacity, associated capital investment requirements, and likelihood of success.

- Section 5.0 presents the steps necessary to develop and engage the additional beneficial end use capacity identified in Section 4.0. A monitoring program for promoting and assessing the effectiveness of the Waste Tire Market Development Plan implementation, and allowing for ongoing refinements, is also presented.

- Section 6.0 presents the references used in this plan.

The remainder of Section 1.0 presents the contributors to this plan.

1.2 Contributors

Table 1 lists the company or entity, role, and contact information for the people that authored and guided preparation of this plan.

Table 1. Authorship and Guidance Team for the Colorado Waste Tire Market Development Plan

Company/Entity	Role	Contact Information
CDPHE	Grant Administrator. Program direction, contract administration, information gathering and transfer.	Brian Gaboriau Waste Tire Grants Administrator CDPHE, Division of Environmental Health & Sustainability 4300 Cherry Creek Drive South DEHS-B2 Denver, CO 80246-1530 Phone: 303.692.2097 brian.gaboriau@state.co.us
Tetra Tech	Prime Contractor. Program management, research, planning, plan preparation, authorship, presentation development, economic analysis, and interview support.	Brian Myller Principal, Business Advancement Services Tetra Tech 518 17th Street, Suite 900 Denver, CO 80202 Phone: 303.312.8875 brian.myller@tetratech.com

Company/Entity	Role	Contact Information
TAG Resource Recovery	Technical guidance, research, expertise on end uses (particularly energy uses), economic analysis expertise on engagement scenarios, regulatory review, plan authorship, engagement interviews.	Terry Gray President 18038 Radworthy Drive, Suite 110 Houston, TX 77084 Phone: 713.463.7552 tagray@flash.net
Recycling Research Institute	Expertise on current state of the science for waste tire end uses, waste tire regulations, waste tire collectors, processors, and markets; regulatory review; plan authorship.	Mary Sikora Principal Founder and Editor of Scrap Tire News, Editor of Scrap Tire and Rubber Directory P.O. Box 2221 Merrifield, VA 22116 Phone: 571.258.0500 mary@scraptirenews.com
Dr. Dana Humphrey	Technical expertise on civil engineering end uses, technical guidance, economic analysis.	Dr. Dana Humphrey Dean, College of Engineering University of Maine 5711 Boardman Hall Orono, ME 04469-5711

Table 2 lists the people who are currently on the Waste Tire Advisory Committee. Members of this committee provided review and comments on the plan.

Table 2. Colorado Waste Tire Advisory Committee Members

Colorado Waste Tire Committee Member	Represented Entity
Charles Johnson	CDPHE
Joel Bolduc	End User
Christopher “Chris” Houtchens	Waste Tire Haulers
Larry Hudson	Tire Manufacturers
James Reid	Local Fire Authority
Michael “Scott” Skorka	Tire Retailer
Cyrus “Rusty” Hardy, Jr.	Law Enforcement
Trent Peterson	Tire Monofill
Richard “Rick” Welle	Processors

More than 65 people were contacted during preparation of this plan to obtain information about Colorado’s Waste Tire System and Program and ideas for possible improvements form a wide range of stakeholders. Further discussions with some of these stakeholders are included as a step in the Market Development Plan presented in Section 5.0.

Table 3. Individuals Contacted During the Preparation of the Waste Tire Market Development Plan

Name	Organization	Name	Organization
Christopher Houtchens	American Tire Exchange, Inc.	Justin Andrews	Holcim (US) Inc.
Lonnie Houtchens	American Tire Exchange, Inc.	Alan Greer	Geocycle (US)
Kevin Jacobs	Bridgestone Americas Tire Operations	Loren Snyder	Hudson Tireville
Robert deDios	CDOT	Dan Warta	Intrawest
Barbara Dallemand	CDPHE	Chris Barker	Jefferson County Open Space
Brian Gaboriau	CDPHE	Michael Irvin	Lake County Landfill
Charles Johnson	CDPHE	Randy Roth	Lakin Tire
David Snapp	CDPHE	William Spalding	Kersey Colorado
Karin McGowan	CDPHE	Randy Gorton	Kit Karson County Waste
Nick Boudreau	CDPHE	Steve Harem	Larimer County Solid Waste
Patrick Hamel	CDPHE	Debbie Martinez	Liberty Tire
Patti Klocker	CDPHE	Nicole Richins	Liberty Tire
Shana Baker	CDPHE	Rob Jahries	Liberty Tire
Bradley Wilson	CEMEX	Ryan Curtis	Liberty Tire
Denise T. Arthur, Ph.D	CEMEX	Mic Jaques	Lincoln County Landfill
Steve Goodrich	CEMEX	Dan Borgman	Logan County Landfill
Bradley Wilson	CEMEX	Todd Genovese	Martin Marietta
Jeff Lyng	Center for the New Energy Economy	Unnamed Representative	Morgan County Landfill
Shannon Wilcox	Chaffee County Waste Disposal	Kevin Walkowicz	National Renewable Energy
Francis Beland	CH2E	David Banas	Office of the Attorney General
Jeff Ackerman	Colorado Energy Office	Bill Andrews	Phillips County Landfill
Ken Kirkpatrick	Colorado Energy Recyclers	Unnamed Representative	Pitkin County Resource Recovery
Tom Binet	Colorado Office of Economic Development and International Trade	Alexandre Ivlev	Recycled Fuel
Dwain Immel	Colorado Tire Recycling LLC	Elizabeth Stengle	Republic Services
Teresa Immel	Colorado Tire Recycling LLC	Twylia Sekavec	Resource Management
Unnamed Representative	Custer County Landfill	Jim Clare	San Louis Valley Regional Solid Waste Authority
Kelly Berry	Eagle County Solid Waste and Recycling	Rustye Cole	Snowy River Enterprises
Brenda Zehr	EVRAZ Steel Mill	Larry Hudson	Tire Manufacturing
J.R. Gilles	EZ Play Surfaces	Robert Amme Ph.D	University of Denver
Rick Welle	Front Range Tire Recycle	Jason Chan	Waste Management
James Reid	El Paso County ESD	Lauren Light	Weld County

Name	Organization	Name	Organization
Verne Stuessy	Grupo Cementos de Chihuahua (GCC) (Midway Monofill)	Chris Peters	West Garfield County Landfill
Joe Collard	Geocycle (US)	Bradly Courtnage	WWF Incorporated
Bryan Sisson	Holcim (US) Inc.	Unnamed Representative	Yuma County Sanitary Landfill
Joel Bolduc	Holcim (US) Inc.		

2.0 Colorado's Waste Tire Situation

Colorado has the largest accumulation of unburied waste tires in the country. Estimates from 2011 indicated 60 million tires reside in monofills in the state, another 1 million tires are at temporary processor and collector facilities, and there are reportedly additional illegal waste tire accumulations requiring identification, quantification and abatement (CDPHE 2012a). Approximately 5 million additional waste tires are generated each year (CDPHE 2012a). According to the CDPHE, 93 percent of Colorado's waste tires generated annually were recycled or reused in 2010; this number increased to 100 percent in 2011 (CDPHE, 2012a). It is unknown how many waste tires are present in illegal stockpiles.

Unfortunately, stockpiled waste tires pose human health, environmental, and economic risks. These risks include:

- Substantial fire potential resulting from arson, lightning, and, when tire chips are present, possible auto ignition. Tire fires are extremely difficult to extinguish (some tire fires have lasted for years) and create air and water contamination that can require evacuation of nearby communities, and long-term, costly environmental remediation.
- Heightened disease vectors resulting from insects, particularly mosquitos, and rodents that hyper-populate in the tires and the water that is retained in the tires.
- Diminished value of land containing, and surrounding, waste tire stockpiles.
- Lost opportunity for agricultural, recreational, business, and residential use of property containing stockpiles.

In light of these risks, the state has enacted legislation intended to promote management practices for waste tires that protect and improve public health and environmental quality. This legislation includes House Bill 10-1018, which changed the authority for managing the waste tires and disbursement of the Colorado Waste Tire Budget, from multiple state agencies to the CDPHE. This bill also called for the establishment of the Colorado Waste Tire Advisory Committee, which is tasked to provide practical advice to the CDPHE regarding waste tire disposal, storage, transportation, regulations, and related funding.

The Waste Tire Advisory Committee consists of nine members, one from each of the major stakeholders in Colorado's Waste Tire Program:

(1) CDPHE
(2) End User
(3) Waste Tire Haulers
(4) Tire Manufacturer
(5) Local Fire Authority
(6) Tire Retailer
(7) Law Enforcement
(8) Monofill Operator
(9) Processor

With the exception of the CDPHE representative, all committee members are appointed by the Governor and are listed on Table 2. The Waste Tire Advisory Committee is required by CRS 25-17-202.9 (1) to develop a Waste Tire Market Development Plan that encourages complete beneficial use of the waste tires present in the state.

2.1 Colorado Waste Tire System

Figure 1 presents a conceptual diagram of Colorado's waste tire system, a complex network of generators, storage sites, processing facilities, and end users interconnected by a network of transporters. The information presented on Figure 1 reflects information collected by the CDPHE in 2011 (CDPHE 2012).

Hudson Tireville (Recently Purchased by CH2E)

Generators, represented by the orange box on the upper left side of Figure 1, input a near-continuous flow (or flux) of about 5 million waste tires into the system per year. This annual generation results from the discard of used or faulty tires at tire retailers, auto dealers, auto dismantlers, public and private vehicle maintenance shops, garages, service stations, car care centers, automotive fleet centers, local government fleet operators, and rental fleets. There are approximately 400 generators in the state.

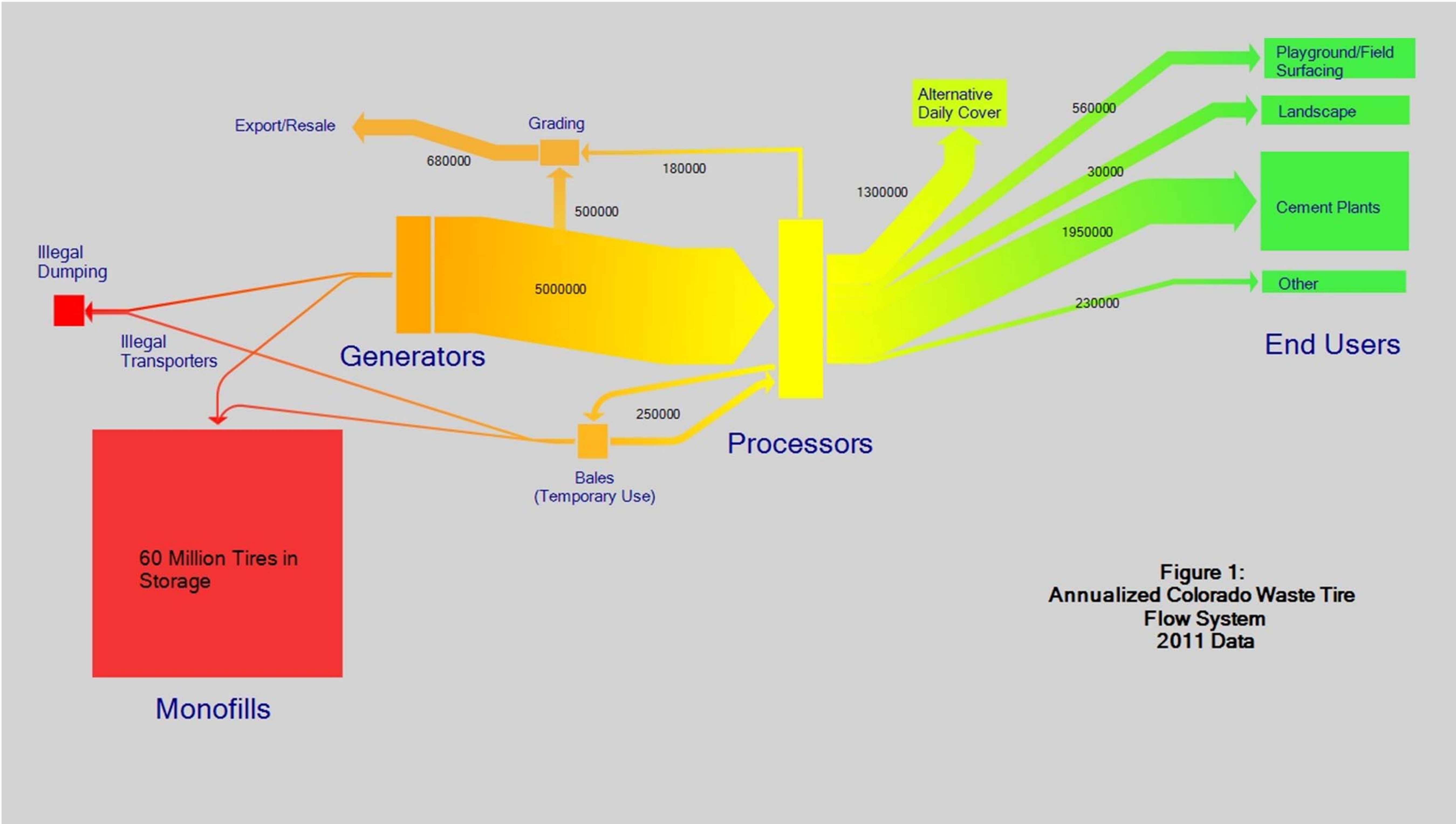


**Figure 1:
Annualized Colorado Waste Tire
Flow System
2011 Data**

Storage sites, shown in red on the left side of Figure 1, involve locations where waste tires collect over time and include:

- Legal monofills that contain only stored waste tires.
- Legal landfills that may contain tires and other waste.
- Illegal tire dumps that may contain only tires, or tires mixed with other waste.

There are three legal monofills in the state: the Hudson Tireville (recently purchased by CH2E LLC and shown in the photo above), located north of Hudson, Colorado, contained an estimated 31.5 million waste tires in 2011; the Midway Monofill (recently purchased by Grupo Cementos de Chihuahua, SAB de CV [GCC] and shown in the photo below), located south of Colorado Springs, Colorado, contained an estimated 26.3 million waste tires in 2011; and the Resource Management Company facility in Julesburg, Colorado, had an estimated 2.5 million waste tires (CDPHE 2012) There are also numerous illegal tire dumps and inventory accumulations scattered throughout the state.

Midway Monofill

Processors, shown in yellow in the center of Figure 1, use specialized equipment to cut, slice, chip, shred, or grind whole waste tires into a size that is suitable for downstream recycling or end use. Processors also segregate reinforcing wire and fabric liberated from tires during processing. Processers are required by law to be registered annually.

Some companies construct tire *bales* (central portion of Figure 1), a method of volume reduction whereby whole or cut tires are compacted into a bundles and then banded together to form a bale measuring approximately 4 feet by 4 feet by 8 feet that weighs approximately 2,000 pounds. Tire bales are used as wind breaks, fences, sound barriers, and other applications. As shown on Figure 1, tire bales are considered temporary use, and not long-term beneficial use, because the bands holding the tires together ultimately break, leaving piles of waste tires that need to be re-managed.

End Users, shown in green on the right side of Figure 1, receive whole or portioned waste tires, chips, crumb rubber, or other waste tire-derived materials from processors and then use this material as a (1) source of energy, (2) feedstock for the manufacture of products, or (3) an actual product for use. The major types of end users known to be in operation in Colorado at the end of 2012 are shown on Figure 1.

End uses are considered "beneficial" when the end use technologies and practices employed improve (lessen) environmental and social impacts. Examples of beneficial end uses for waste tires can include heat generation and iron oxide input for cement plant kilns; heat generation and metal and carbon input for steel mills; ground rubber for applications and further processing into other products; civil engineering applications including landfill drainage aggregate and highway construction applications; and pyrolysis, which may be able to produce a type of fuel oil and other potentially sellable products if historical technical and economic obstacles can be overcome.

The U.S. Environmental Protection Agency (USEPA) considers using waste tires for fuel a beneficial use, and cites the following advantages (USEPA 2012):

- Tires have a similar energy content to oil and a significantly higher energy content per pound than coal;
- The ash residues from Tire Derived Fuel (TDF) may contain a lower heavy metals content than some coals;
- When substituted for coal (particularly high-sulfur coals) in cement kilns, waste tires can result in lower nitrogen oxide compound (NOx), sulfur oxide compound (SOx), and greenhouse gas emissions.

Waste tire end uses are further detailed in Section 4.2 of this plan.

Alternative Daily Cover, shown in the central portion of Figure 1, is a practice that involves spreading a layer of chipped tires on top of the daily-added waste at municipal landfills to prevent the wind-borne transport of the waste material. Alternative daily cover is generally considered a beneficial end use, but is not encouraged in some states because of its potential for abuse. When used properly, it is applied as a thin layer. When abused, it is applied in thick layers and becomes landfill disposal, and not end use. Other civil engineering applications for shredded tires (including others within landfills, such as leachate drainage layer, operations layer, gas collection) become an integral part of the engineering design and inspection, and are less vulnerable to abuse. No reports or indications of abuse were identified in Colorado during this study.

Transporters move the waste tires between the generators, monofills and landfills, processors and end users, and are represented by the arrows on Figure 1. The current annual transported waste tire flow volumes and directions are represented by the width of the arrows (wider arrows signify larger waste tire flow volumes) and the orientation of the arrow heads. The estimated flow volumes for the larger waste tire flows are also shown numerically on or near the arrows.

Transporters in the State of Colorado (as well as retailers, monofill operators, and processers) are required by law (statute and regulation) to register annually. Legally operating transporters properly load waste tires onto transport vehicles, drive the waste tires across the state's road system, drop the waste tires off at licensed processors or end users, and use manifests to document the origin, quantity, composition, routing, and destination of waste tires being transported. In some cases, trailers are parked at tire retailers or collection centers to facilitate accumulation of tires for optimal transportation efficiency.

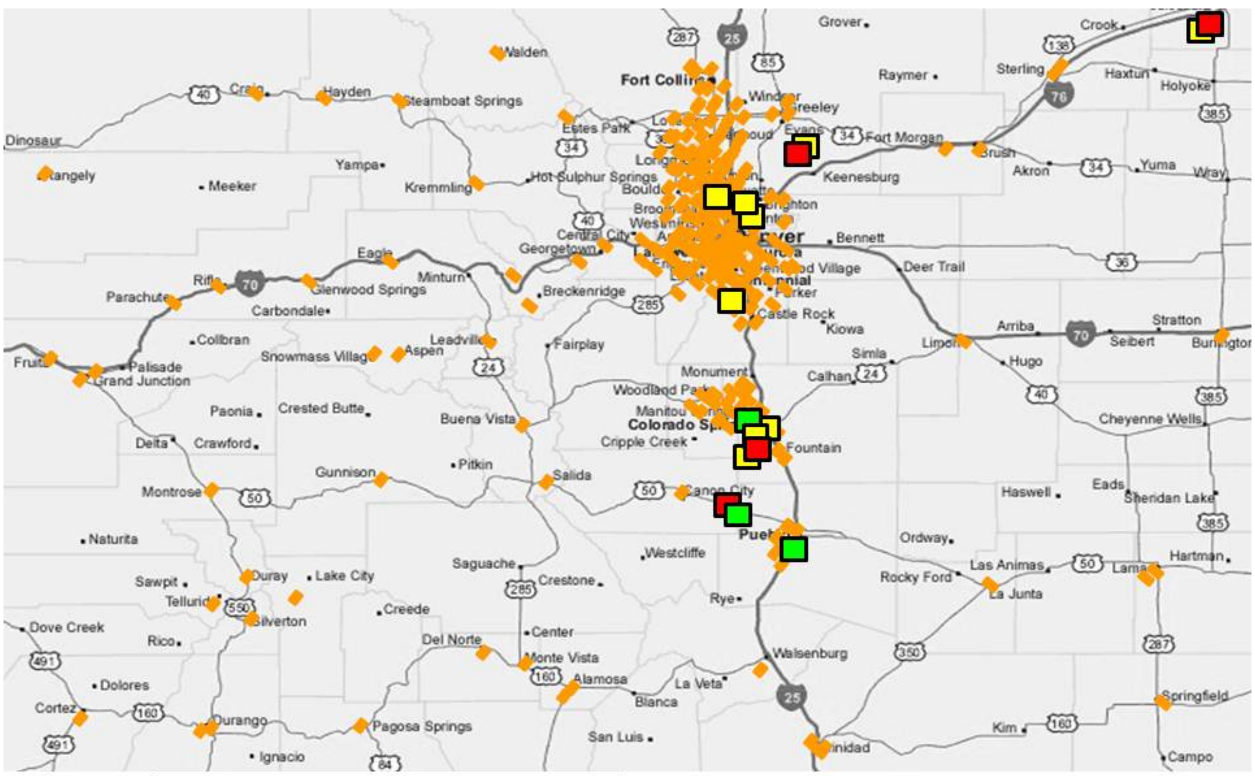
It is illegal to transport more than 9 waste tires per load without a current registration, and without following the required vehicle, safety, loading, weight, disposal, and manifesting requirements. Illegal transportation of waste tires by unregistered carriers is known to occur. Illegal transportation results not only in unsafe, undocumented transport of tires to processors and monofills, but also creates and expands illegal tire dumps (Figure 1) that are environmental and public liabilities. Illegal transporters have a negative impact on the economic structure of Colorado's waste tire industry and the people who follow the state's statutory and regulatory requirements. Consequently, consistent enforcement of waste tire transportation regulations across the state is critical to the success of Colorado's waste tire management program.

Some transporters include an intermediate step in their process of handling tires that is often referred to as *grading*. Grading involves assessing used tires for remaining tread life and carcass integrity. Tires are resold to dealers and agents for subsequent resale as used tires in the U.S. and other countries when tread thickness exceeds a minimum thickness requirement. This practice diverts a portion of the waste tires from downstream movement in the system, effectively increasing the residence time of tires within the system (Figure 1). This grading step is also practiced by some processors.

As shown on Figure 1, information available at the end of 2012 indicated that an annual generation of approximately 5 million waste tires was nearly completely delivered to end users. On the other hand, the estimated 60.2 million waste tires in monofills and 1 million waste tires in temporary storage at processors and collection facilities at the end of 2012 were not being substantively decreased (CDPHE 2012a). Current regulations require removal of 75 percent of waste tires received at monofill and storage sites (based on 3-year averages), but allow the remainder to be accumulated.

Based on these estimates, expansion of existing end users, or creation of new end users, will need to take place to consume the existing tires in monofills and stockpiles. The mandated date for abatement of monofills was recently extended from 2019 to 2024. To accomplish the goal of consuming the waste tires in monofills and stockpiles by 2024, end use capacity would need to increase by an average of approximately 6 million additional tires per year. This expansion in end use capacity is over and above the existing end use capacity that is currently consuming most of the annually generated waste tires. Without market expansion, tires from monofill abatement could flood existing markets and drive annual generation into other stockpiles. Future expansions in end use capacity and abatement of existing accumulations will need to be managed in a manner that does not negatively affect the end use of the annually generated waste tire stream.

Figure 3 shows the aerial distribution of monofills, generators, major processors, and major existing end users across the state. The representation of generators—primarily new and used tire retailers—on Figure 3 is notional. This figure shows that the vast majority of tire generation, processing, and end use occurs within the most populated metro areas along the Colorado Front Range, including the areas surrounding Ft. Collins, Boulder, Denver, Colorado Springs, and Pueblo. Waste tire generation also occurs in less populated towns throughout the state. While the volumes of waste tires in the less populated areas is relatively low, the challenges associated with moving waste tires from the less populated areas to the processors located along the Front Range can be significant.



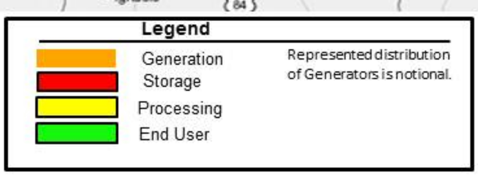


Figure 2: Distribution of Current Colorado Waste Tire Generators, Monofills, Processors, and Existing Major End Users

2.2 Current and Historical Waste Tire Generation

A cornerstone of an effective waste tire management program is defining the quantity of tires generated within the state. Waste tires primarily come from stores that install replacement tires and from vehicle salvage operations. It is difficult to estimate unit sales based on sales tax revenue because of the industry's complex product mix and price variations unless actual units are specifically identified on tax submittal forms. There are no publicly available industry statistics for replacement tire sales or salvaged vehicles within individual states. As a result, state generation is estimated based on proration of available nationwide data.

The Rubber Manufacturers Association (RMA) compiles national sales of original equipment and replacement tires annually, as shown on Table 4. Sales were compiled for 2011 and 2012 to examine recent variability. The data are provided in units and converted to Passenger Tire Equivalents (PTE) and to tons for subsequent use in the market analysis. The term "passenger tire equivalent" allows conversion of various tire sizes into a common weight basis. A PTE is an average passenger and light truck tire with a current weight of 22.5 pounds based on the most recent RMA data. A medium truck tire is equivalent to almost 5 PTE and has an average weight of about 110 pounds.

The PTE weight can change gradually over time, reflecting variations in the size of vehicles and associated tires. An average of 22.5 pounds has been used by the RMA for the past 4 to 5 years.

Table 4: 2011 and 2012 United States Replacement and Original Equipment Tire Sales

2011					2012				
REPLACEMENT TIRES (all units in thousands)					**REPLACEMENT TIRES (all units in thousands)**				
Type	Quantity	PTE/Unit	PTE	Tons	**Type**	Quantity	PTE/Unit	PTE	Tons
Passenger	194,395	1	194,395	2,187	**Passenger**	190,929	1	190,929	2,148
Light Truck	28,601	1	28,601	322	**Light Truck**	28,060	1	28,060	316
Subtotal	222,996		222,996	2,509	**Subtotal**	218,989		218,989	2,464
Medium Truck	16,508	5	82,540	929	**Medium Truck**	15,847	5	79,235	891
Total	239,504		305,536	3,437	**Total**	234,836		298,224	3,355
ORIGINAL EQUIPMENT TIRES					**ORIGINAL EQUIPMENT TIRES**				
Passenger	35,738	1	35,738	402	**Passenger**	40,048	1	40,048	451
Light Truck	4,181	1	4,181	47	**Light Truck**	4,245	1	4,245	48
Subtotal	39,919		39,919	449	**Subtotal**	44,293		44,293	498
Medium Truck	4,946	5	24,730	278	**Medium Truck**	5,074	5	25,370	285
Total	44,865		64,649	727	**Total**	49,367		69,663	784
TOTAL	284,369		370,185	4,165	**TOTAL**	284,203		367,887	4,139
Source: Rubber Manufacturers Association(1)					PTE is Passenger Tire Equivalent = 22.5 pounds				

Several correlations may be used to identify the proportion of national waste tires generated within Colorado. The most directly associated parameters are population, vehicle registrations, and gasoline consumption. The most recent available nationwide and Colorado statistics for each parameter are provided in Table 5. Although the most recent common basis for the data is 2010, the ratios do not generally change significantly over several years, as illustrated by the minor difference between the population ratios in 2010 and 2012 shown in Table 5. Colorado's percentage of each of these parameters ranges from 1.63 percent to 1.95 percent. Colorado's gasoline consumption (1.95 percent) may be influenced by its higher percentage of SUV and pickup trucks with poorer gas mileage, combined with a relatively high proportion of mountain driving. The arithmetic average of the three is 1.77 percent, with a projected maximum deviation of 10 percent.

Table 5: Waste Tire Generation Parameters

Parameter	Quantity		% Colorado
	US	Colorado	
POPULATION			
2010	308,745,538	5,029,196	1.63%
2012	313,914,040	5,187,582	1.65%
VEHICLE REGISTRATIONS (2010)			
AUTO	130,892,240	1,890,748	1.44%
BUS	846,051	9,343	1.10%
TRUCK	110,322,254	2,280,207	2.07%
SUBTOTAL	242,060,545	4,180,298	1.73%
GASOLINE CONSUMPTION (2010)			
2010	2,541,871,000	49,635,000	1.95%
AVERAGE			1.77%

National 2012 replacement tire sales were 234,836,000 units, representing 298,224,000 PTE and 3,355,000 tons. 2012 original equipment tire sales were 49,367,000 units representing 69,663,000 PTE and 784,000 tons. The total was 284,203,000 units, 367,887,000 PTE and 4,139,000 tons. The 2012 and 2011 totals differed by less than 1 percent.

The estimated waste tire generation in Colorado has been calculated in Table 6 based on national replacement tire sales and RMA's estimate of waste tires from salvage vehicles, as well as the proration percentage for Colorado of 1.77 percent of the U.S. total (multiplier of 0.0177). Based on these calculations, total 2012 waste tire generation in Colorado has been estimated to be 4,622,143 units representing 6,558,275 PTE and 73,780 tons.

Table 6: Estimated Waste Tire Generation in Colorado

	Replacement Tires			Salvage Vehicles			
Parameter	US Total	CO Multiplier	Colorado	US Total	CO Multiplier	Colorado	Total
Tires	234,838,000	0.0177	4,156,633	26,300,000	0.0177	465,510	4,622,143
PTE	298,224,000	0.0177	5,278,565	72,300,000	0.0177	1,279,710	6,558,275
Tons	3,355,000	0.0177	59,384	813,375	0.0177	14,397	73,780

The projected fees associated with the sale of new replacement tires and original equipment manufacturer (OEM) and replacement tires in Colorado is calculated in Table 7. Prorated tire units are multiplied by the appropriate fee for each type of tire. Based on this calculation, the total fee collections on replacement tire sales for 2012 should have been approximately $6,235,000. It should be noted that this amount represents fees over a calendar year, while the state collections are reported on a fiscal year basis. However, there was little variation in tire sales between the 2011 and 2012 calendar years, so this distinction is not anticipated to significantly affect this comparison.

Colorado collects the fee only on new replacement tire sales, while some states view the fee as advanced payment of tire management program costs and apply it to all new tire sales, including the tires on newly purchased (OEM) vehicles. Inclusion of OEM tires in Colorado would increase fee revenue by an estimated $1,311,000 annually and could help fund abatement of monofills and stockpiles in the future if needed.

Table 7: Projected Fee Collection in Colorado in 2012

	US	CO Multiplier	CO Quantity	Fee/ Tire	Fee
Replacement Tires					
Pass/LT	218,989,000	0.0177	3,876,105	$1.50	$5,814,158
Medium Truck	15,847,000	0.0177	280,492	$1.50	$420,738
Subtotal	234,836,000		4,156,597	$1.50	$6,234,896
New OEM Tires					
Pass/Lt Truck	44,293,000	0.0177	783,986	$1.50	$1,175,979
Med Truck	5,074,000	0.0177	89,810	$1.50	$134,715
Subtotal	49,367,000		873,796		$1,310,694
TOTAL	284,203,000		5,030,393	$1.50	$7,545,590

2.3 Current and Historical Waste Tire Storage

The Tetra Tech team used aerial photographs, brief on-site observations, and discussions with operators to approximate volumes of tires in the three largest existing monofills. The aerial photographs for the Hudson Tireville monofill (now owned by CH2E) in Weld County, the cited average cell size, and historical densities of similar piles approximate the state's estimate of 31.5 million waste tires (CDPHE 2012). At the Midway Monofill (now owned by GCC) in El Paso County and the Resource Management Company monofill in Sedgwick County, the uncertainty of underlying cell structures did not allow for meaningful approximation of the stored tire volumes. Estimates referenced in the CDPHE Status of Waste Tire Recycling in Colorado, 2011, report (CDPHE 2012) of 26.3 million tires at the Midway Monofill, and 2.5 million tires at the Resource Management company monofill are used in this plan.

3.0 Influences on the Waste Tire System

This section discusses physical, economic, and regulatory influences on Colorado's waste tire system.

3.1 Physical

The physical influences on Colorado's waste tire system stem primarily from the areal distribution of the major processors and end users along the Colorado Front Range, generators located throughout the state, and the mountainous setting of the western half of the state (Figure 3). The costs of transporting tires from less populated areas of the state to processors located along the Front Range are increased by travel distances and, in the western half of the state, the increased challenges of mountain driving. Some tires generated in western Colorado are transported to Utah processors based on these economics. Transportation costs can contribute to the presence of tire dumps in the less populated areas of the state.

Mountain driving by Colorado citizens may also increase the rate of waste tire generation through increased tire wear associated with twisty roads. Furthermore, the regular occurrence of snow in many parts of the state creates the need to use snow tires, which tend to wear more quickly than regular road tires.

Colorado is also located relatively close to coal, oil, and gas energy resources. This proximity can influence the cost of these energy sources relative to potential energy cost savings that can be gained from using waste tires as a fuel source. Colorado is distant from ocean shipping centers, which increases the cost associated with moving waste tires into overseas transport systems, effectively reducing opportunities for participation in export markets.

3.2 Regulatory

Many state waste tire management programs have been created with good intentions, but their success has suffered because they were (1) developed with inadequate practical knowledge and data regarding the local waste tire market, or (2) influenced by local political interests. Good programs recognize the need to evolve to meet changing market and program needs, correct loopholes/abuses, and to ultimately create a sound program with a predictable, level regulatory playing field that benefits all stakeholders. Colorado's program is evolving positively, but still has issues that can be improved as the program continues to evolve.

This regulatory analysis addresses seven key elements of the Colorado Waste Tire Program:

- Stockpile Abatement
- Processor/End User Reimbursement
- Market Development Fund
- Waste Tire Fire Prevention Fund
- Waste Tire Law Enforcement Grant Fund
- Department of Revenue Fee
- Regulatory Definitions

Current characteristics are discussed for each of these key elements, and then recommendations for improving the overall benefit to the program stakeholders are presented below.

3.2.1 Stockpile Abatement

Legal waste tire accumulations at registered monofills, collections sites and processors have been identified and are being monitored by CDPHE. The estimated 61.2 million waste tires at these sites at the end of 2011 represent a substantial, but known, abatement challenge. In addition, there are believed to be other unidentified illegal waste tire stockpiles and dumps located within the state. They are generally located in uncontrolled locations and can represent substantial public health and environmental hazards. Identification and abatement of these illegal stockpiles is a critical component of an effective state waste tire management program.

The State of Colorado's current program places responsibility on counties for illegal stockpile identification, project coordination, abatement contractor selection and management, and even contractor payment from local funds until reimbursement is received from the state program. As a result, there is no broad-based effort to identify and prioritize illegal stockpiles throughout the state. Few stockpiles are identified, and even fewer are abated, because counties are unwilling or unable to shoulder the burden of negative cash flow associated with contractor payments. Little to no accountability is placed on the stockpile creator or landowner for costs associated with abatement.

The following recommendations represent a combination of components with demonstrated results from states that have successfully completed abatement of existing piles. In all states with successful programs, the state waste tire management program is responsible for the following activities:

- Pile Identification—The state is responsible for working with counties and all other appropriate groups (such as game and fish, law enforcement, solid waste, illegal dumping, and citizens groups) to identify all significant illegal stockpiles in the state on a continuing basis.
- Prioritization—The state prioritizes the sites based on an assessment of tire quantity, fire hazard, safety, population density, and environmental characteristics of each site.
- Contractor Pre-qualification—The state uses a Request for Qualifications or similar process to select qualified contractors capable of abating identified stockpiles and constructively utilizing the tires without impairing markets for newly generated waste tires. This reduces the potential for cleaned up stockpiles to force newly generated tires into other stockpiles or landfills. Typically, 3 to 6 contractors are pre-qualified. For the following 2 to 4 years, the pre-qualified contractors are able to provide simple competitive bids quickly when stockpile sites are designated for abatement.
- Contractor Selection/Monitoring—A stockpile summary and a competitive bid response sheet is prepared and provided to each pre-qualified contractor when a site is designated for cleanup. The bids are made on a cost/ton basis for a uniform quantity estimate provided by the state. Contractors can typically respond promptly because of the site information provided by the state and specified response criteria. The process is efficient and cost-effective, and it may promote significant cost savings. The state is responsible for monitoring contractor performance but often draws on local officials to assist in this effort. Sometimes, the state pays a nominal stipend to the cooperating local agency to cover time and expenses associated with their assistance. The state reserves the right to reduce or refuse payment to contractors for loads that are heavily contaminated with dirt or debris.

- Continuity—Stockpile abatement is variable and therefore costs may vary between fiscal years. As a result, many states roll previously designated funds for this specific activity from budget year to budget year unless there is no foreseeable need for future abatement activity. This change could enhance operational flexibility and help funding and contractor activity become more predictable.
- Cost Recovery—The state places financial accountability for management of waste tires on the creator of the waste tire stockpile or the landowner that allowed the waste tires to be accumulated, or both. The initial stockpile assessment includes an investigation into responsible parties. If responsible parties with financial resources are identified, the state uses its enforcement options to have them abate the pile in a reasonable period of time. If prompt abatement is not possible, the state gains legal access to the site and abates the site with public tire fund resources.

  Some states seek to recover costs associated with stockpile abatement from the stockpile creators and landowners, especially in cases where the landowner was aware of the practice or received compensation. The threat of cost recovery clearly discourages landowners from allowing disposal or poorly conceived management applications on their property if they may ultimately be held responsible for paying for site abatement.

  In Florida, more than 65 percent of the tires in stockpiles were abated by the landowners to avoid cost recovery. The state placed liens on properties to protect its financial claims when it performed the abatement. Cost recovery can be waived if there is no reasonable chance of recovery or if the legal costs were likely to exceed any such recovery. The objective is accountability—forcing payment on those who profited instead of the public. The recovered funds are often used for other constructive purposes within the waste tire programs.

These regulatory approaches have proven effective and efficient in other state Waste Tire Programs.

3.2.2 Processor/End User Reimbursement

The current reimbursement program in Colorado disburses all funds each month at a variable rate ($/ton) based on dividing the available funds by the tonnage of requests received for reimbursement. To support in-state processors and markets, only processors and markets in Colorado are eligible for payment. Available funds change as a result of seasonal variations in tire sales and receipt of roll-over amounts from unused balances in other parts of the tire program. Reimbursement requests may vary through seasonality or variable product sales for large projects. The result is a variable and unpredictable reimbursement rate that can financially destabilize the very companies that it is intended to assist.

The current end user reimbursement also fails to reimburse end users of some important products that are sold through distribution channels. Examples include colored mulch, playground cover, and other crumb rubber products. The processor or end user payments get tangled in a web of definitions and practical obstacles that create an unlevel playing field and actually discourage development of some good products and markets. The variable reimbursement rate creates instability in an industry that already faces enough challenges.

The processor or end user reimbursement system should be changed and simplified to encourage all approved major market segments uniformly and enhance financial predictability, as recommended below.

Processor/End User Reimbursement

The processor and end user payments should be revised to allow processors to consolidate and receive the end user payment for products sold through distribution channels to individual customers using less than 50 tons. A consensus of stakeholders appears to favor a 1:1 split of the processor/end user payment. Separate processor and end user payments provide a cross-check on each other and allow processers and end users to negotiate and obtain equal incentive and reward. However, practical issues associated with end user payments to some end user markets (as noted above) have led most states to simplify the system by combining processor and end user payments into one payment to processors based on tonnage processed and sold to documented third party customers and distributors (with demonstrated distribution channels to end users).

Some early processor payment systems failed in other states because there was no requirement for third party sale of processed product. Texas, for example, spent $70 million converting piles of whole tires into piles of shredded tires with a substantial additional public liability for abatement of the resulting shredded tire piles because no markets were created by the processor payments. A processor must not receive payment unless the product is sold to approved markets with acceptable documentation. This provision forces the processor to establish product pricing that drives the market, in effect sharing the subsidy with the end user to create a viable market. Subsidy payments are used by a limited number of state programs, but most of those that are considered viable use this system, including Oklahoma and Louisiana.

Reimbursement Process

The entire financial system associated with Colorado's waste tire program is driven by good intentions to assure complete use of all funds every year. This approach avoids accumulations within the fund, but it removes the working capital required to allow stable, predictable operation within a longer-term framework. It is also structured to avoid overpayment issues. States that have committed to long-term fixed processor payments have often encountered short falls that have caused partial or delayed payments to processors or required use of supplemental general revenue funds for financial salvation. Historical examples include Oklahoma, Louisiana and Utah. Balancing payment stability and predictability with the absolute requirement of staying within fund financial limitations poses a practical challenge.

One possible solution would be to establish a conservative reimbursement calculation methodology that would allow a predictable reimbursement rate while allowing accumulation of a working capital cushion to minimize the impact of reasonable variations in fees and product sales. Projected available funding could be based on 90 percent of the average of the 2 preceding years. Projected tonnage eligible for processor payment could be based on 110 percent of Colorado's annual tire generation plus any anticipated monofill abatement quantities adjusted to reflect tonnage. Dividing this total would result in a conservative projected processor payment per ton produced and sold, paid on a uniform basis throughout the year. Tires collected from stockpile cleanups would have to be excluded from the reimbursement or the projected tonnage would have to be adjusted to reflect this volume if it is included in the reimbursement. Abatement of illegal stockpiles is generally considered separately funded and not eligible for additional reimbursement.

This conservative calculation basis should allow accumulation of a working capital cushion during the year. The calculation basis can be adjusted each year to reflect historical experience once a reasonable cushion has been established. Substantial adjustments in the reimbursement rates should be done gradually to allow processors and collectors to adjust alternative revenue sources. Increases in fees charged to pick up tires generally offset reimbursement decreases if companies have reasonable time to implement these changes. Contracts may limit the ability to change rapidly.

Once the processor reimbursement becomes predictable and significant, it may also have some negative impacts. The quantity of waste tires may expand as tires are drawn into Colorado from neighboring states or stockpiles as a result of the increased economic incentive. The manifest system and its enforcement will become critical factors in controlling abuses. This potential drawback has led to fraud, abuse and system failure in other states.

Two products should be excluded from the processor reimbursement. Used tires recovered from the waste tire flow reenter the usable tire market and should be considered waste tires only when they are no longer being used on vehicles as tires. In Colorado's system, the fee is not paid on sale of used tires, so the subsidy should not be paid. To do otherwise would allow for the possibility of subsidy payments being made two or more times on a tire when the fee is paid only once. In addition, baled tires compact the tires only until the bands break and then generally require further abatement or reprocessing. Including baled tires in the processor reimbursement system would open the door to multiple processor payments with only one fee payment. Baling is the least expensive tire volume reduction process and does not require a subsidy for appropriate applications. In addition, baled tires have historically failed in a high percentage of applications.

3.2.3 Market Development Grant Fund

Processor reimbursements can assist processors during initial program development and operation. However, they can also create false economics that lead to market and program failure when the reimbursement program sunsets. The potential for this outcome can be reduced by gradually decreasing reimbursements and shifting resources to the Market Development Grant Fund. The current Market Development Grant Fund and the Recycling Incentives Fund should be consolidated and a suitable scope of activities should be established to allow the range of activities necessary to be an effective market development tool.

To enhance the market development fund's effectiveness, it should be restructured to include competitive one-time grants designed to help with the following:

- Demonstrate and establish new markets through grants for initial applications or geographic diversification;
- Overcome initial capital obstacles for new markets by partially funding end user equipment required for initial use. In this case, capital can be provided as a loan that is converted to a grant based on subsequent actual tire usage.
- Partially fund product testing or engineering studies or other technical assistance required to support market development and acceptance.

These are just examples. This type of one-time support of end use markets can significantly accelerate market development without on-going subsidies, so these markets tend to survive in a free market system.

Some of the projected rollover and repayments at the end of this fiscal year could be diverted to this program to allow its rapid initiation. This diversion of funds would also prevent unsustainable spikes in processor reimbursements from these funding sources that impede future transition to a self-supporting free market system.

3.2.4 Waste Tire Fire Prevention Fund

The current Waste Tire Fire Prevention Fund allows funds to be used for training and equipment purchases for a variety of fire department and enforcement groups. It has been effectively utilized for these purposes, but could potentially provide additional value to the program if the money could also be used for other purposes.

For example, it may be appropriate to allow local and state fire officials to draw on supplemental funds or technical resources to assist in review, development, and implementation of fire control plans for major stockpiles identified within the state. Since future resource requirements will be less than historical equipment purchases, funding could be reduced and redeployed into the Market Development Fund.

3.2.5 Waste Tire Law Enforcement Grant Fund

The current Waste Tire Law Enforcement Grant Fund program provides primarily for training of law enforcement officers. This limited scope prevents use of grants or disbursements to encourage interagency coordination and cooperation in waste tire enforcement.

It may be appropriate to allow grants to state and local law enforcement agencies to provide supplemental funding for their assistance in coordinated enforcement efforts of waste tire hauling and dumping regulations with appropriate documentation of these efforts. Additional education and regular communications to law enforcement agencies in the state to increase and maintain attentiveness to waste tire hauling and storage enforcement may also be in order. Clarifying and possibly modifying penalties associated with violation of waste tire hauling, dumping and storage regulations deserves careful analysis. Other states have established penalties that command accountability, including felony penalties for some extreme violations.

3.2.6 Department of Revenue Fee

It is probable that a significant amount of projected fee revenue is not currently being collected. A total of $5,719,201 was collected in fiscal year 2012, while projections indicate that the total could have approached $6,235,000. In joint consultation between departments, methods may be identified that would enhance collection rates and decrease disparities that undermine the program and its enforcement. These methods may require resources beyond the current limitation of 1.667 percent of revenue specified in the act. It may be helpful to allow up to 2.5 to 3.0 percent for activities supported by both departments and with proper reporting as currently specified. The result could be a net increase in program revenue and credibility.

3.2.7 Regulatory Definitions

Definitions play a vital role in developing regulations and regulatory policy. Ensuring that the terms used throughout the regulatory framework refer to consistent definitions is critical to effectively and efficiently achieving program goals. This section presents definitions that can be used as the foundation for advancing Colorado's Waste Tire Management program to address both stockpiled tires and annually generated waste tires.

The definitions included here represent suggested changes to existing definitions in the current Colorado regulations found at SB09-289, HB10-1018, and HB12-1034. They also include new language to support proposed Waste Tire Program Statutory/Regulatory Alternatives. They are suggested for consideration, but should be carefully examined for compatibility with all applicable waste tire regulations and other underlying solid and hazardous waste statutes and regulations

These definitions are not comprehensive but offer a basis for clarifying implementation of current regulations and a pathway for enhancing Colorado's Waste Tire Program through new proposals for regulatory and market development alternatives designed to enhance and grow markets for waste tires and waste tire derived products in Colorado.

Baled tire—method of volume reduction of waste tires, whereby whole or cut tires are compacted into a bundle and then banded together to form a tire bale. Baled tires will not be considered for processor or end use subsidies.

End user—the last person or entity that uses the waste tires, chips, crumb rubber or similar materials to make a product with economic value or in the case of energy recovery, that utilizes the heat content or other forms of energy from the combustion or pyrolysis of whole waste tire, chips, shreds, or similar materials.

Manifest—a form or document used for identifying the quantity and composition and the origin, routing and destination of waste tires during transportation from point of generation, through any intermediate points to a processor, end user or disposer as approved by the regulating agency.

Retail tire dealer—a person or entity actively engaged in the business of selling new replacement tires. Retail tire dealers may also be, but are not limited to, manufacturers, wholesalers and others who sell new replacement tires.

Retreadable casing—a tire that has the quality and soundness of the tire structure to accept a retread or repair and provide additional service and is destined for retreading.

Retreaded tire—a casing to which a new tread has been affixed to extend the useable life of the tire. "Recap" is another term for a retreaded tire.

Tire—a tire for any passenger vehicle, including any truck, weighing less than 15,000 pounds, and for any truck, including any truck tractor, trailer, or semi-trailer, weighing more than 15,000 pounds, but not more than 50,000 pounds.

Tire derived material (product)—material derived from waste tires after processing such as, but not limited to, chipped, shredded, cut or sliced tires, crumb rubber, steel cord, cord material, oil or carbon black and has been sold and removed from the facility of a waste tire processor. This definition does not include a tire bale composed of whole tires or any components of waste tires.

Used tire—a tire that previously has been on a vehicle but that retains suitable tread depth (a minimum 2/32-inch of road tread) and is free of damage or defects so that it may safely be returned to its original purpose. It must be inventoried and marketed in substantially the same fashion as a new tire, the dealer must be able to provide satisfactory evidence to the regulating agency that a market exists and that the used tires, are in fact, being marketed.

Waste tire—a tire that is no longer mounted on a motor vehicle and is no longer suitable for use as a tire as a result of wear, damage, or deviation from the manufacturer's original specifications.

Waste tire facility—a processing site that is used for the processing of waste tires and that is owned or operated by a processor who has the required registration for the site, a waste tire monofill, a collection facility as defined by the commission, and any other facility at which a quantity of waste tires in excess of a limit established by rule by the commission are stored for at least 90 days, processed or disposed of. Locations and operations associated with activities funded by the waste tire cleanup fund are excluded.

Waste tire generator—any person who generates waste tires. Generators may include, but are not limited to retail tire dealers, auto dealers, auto dismantlers, public and private vehicle maintenance shops, garages, service stations, car care centers, automotive fleet centers, local government fleet operators, and rental fleets.

Waste tire hauler—any person, business, or other entity engaged in the business of picking up and transporting waste tires for processing, recycling, approved storage or shipment out of state. Waste tire hauler does not include a solid waste collector operating under a license or franchise from any local government unit, a private individual or private carrier who transports the person's own waste tires to a processor or for proper disposal, a person who transports fewer than five tires for disposal, or any county, city, town or municipality in this state.

Waste tire processing—any method, system or other treatment that changes the physical form, size or chemical content of waste tires so that they are no longer whole, such as cutting, slicing, chipping, shredding, distilling, freezing, or other processes that are approved by the regulating agency and produce tire derived material that is readily suitable for downstream recycling, beneficial re-use, or sale to an end user.

Waste tire processor—any person or entity that is approved by the regulating agency to receive tires from waste tire generators or waste tire haulers for waste tire processing.

These definitions are believed to be consistent within themselves, but careful review will be required to assure broader consistency when they are incorporated into current or modified Colorado legislation or regulations.

3.3 Economic

Several economic factors influence the movement and storage waste tires in Colorado. These factors include energy costs, regulatory costs, subsidies, and market trends at the national and state levels.

Coal, oil and gas, are relatively inexpensive in Colorado. Their relatively low cost makes tire-derived-fuel less attractive as an alternative energy resource in Colorado compared with many other states. Nevertheless, waste tires are still able to offset energy costs in many circumstances in Colorado. Additionally, improvements in corporate branding, community acceptance (license to operate), and regulatory compliance can be positive economic outcomes associated with the use of waste tires as fuel.

National Trends

Several key trends that are influencing market conditions at the national level are described below (RMA, 2012).

- Competition for waste tires is increasing. This increased competition is largely the result of strong demand for waste tires in Asia and other countries that has led to the rise of "unpermitted and non-compliant operations" competing for tires. For the most part, activity has been concentrated in regional areas in California, Washington, Florida, and the Mid-Atlantic states but has caused a shift in supply lines for processors, including ground rubber producers, and temporarily pushed tip fee revenues down in these geographic areas.
- Tire reuse and retreading is up. Domestic used passenger vehicle tire sales increased by 35 percent over 2010 and truck tire retreading increased by 13 percent, according to industry statistics. Consumers seeking cost savings in a slow economy are driving demand.
- Truck tire supply is down. Truck tires have long been the desired feedstock for crumb rubber producers. The relatively high natural rubber content in truck tires, as well as the low metal and fiber content, allows crumb rubber producers to meet market and customer specifications for certain products and applications. Truck tire supplies are challenged by several factors, including relatively stable generation rates for truck tires, the increased number of truck tires compromised by export and baling operations, and strong demand for reuse of truck tires domestically and in Mexico and South and Central America.

- Crumb rubber markets have grown slightly. Overall U.S. crumb rubber market demand grew by slightly more than 3 percent over 2010, although certain market sectors challenged by the economic uncertainties and other factors remained flat.
- Rubberized asphalt grew significantly in some markets (California, Georgia, and Massachusetts) but overall ground rubber consumption in this market held steady at the 2010 level of 185 million pounds. Several recent developments in this market sector could have positive impacts on the future demand for ground rubber in asphalt applications. These developments include:

  - In 2012, the industry formed the Rubber Asphalt Foundation to expand the rubberized asphalt market through coordinated informational and educational campaigns.
  - The American Association of State Highway Transportation Officials (AASHTO) approved several changes for testing standards that will allow recycled tire rubber into the widely used performance grade asphalt standards used by state Departments of Transportation.
  - A new study by the National Center for Asphalt Technology concluded that the method of manufacturing crumb rubber, whether cryogenic or ambient, does not impair the performance or quality of rubber asphalt pavements.
  - The Georgia Department of Transportation amended the state's road construction specifications to include recycled tire rubber as an alternative to conventional polymers in asphalt production.
  - Several Canadian provinces are conducting programs to research and use rubberized asphalt. This development is important because successful use in Canada, together with cold weather performance data in New England and Sweden, further dispels the misperception that rubberized asphalt is only a warm weather technology.
  - Laboratory and field tests show that rubberized asphalt saves $2 to $5 per ton and performs better than conventional polymer-based asphalt.
  - Other growing opportunities for ground tire rubber include increased use with warm mix asphalt, recycled asphalt pavement, thin pavement overlays on concrete pavement, and development of terminal blend technology and a new plant mix technology (Recycling Research Institute, 2012-13).

- Crumb rubber going into turf and athletic and recreational fields increased by 31 percent in 2011 continuing the growth trend in this market from 2010. For this application, crumb rubber typically in the 10 to 30 mesh range is used as infill between the blades of "grass" in synthetic sports fields. A promising area of expansion in this market sector is crumb rubber infill for natural grass fields, lawns, and other grassy areas. Renewed interest in the benefits of crumb rubber in protecting grass root systems, and improving drainage and lawn health are driving demand.

  - On the downside, most installations in the athletic and recreational field market are for municipal recreational facilities and school districts making this market segment vulnerable to government budget shortfalls. In addition, although concerns over health and safety risks have largely been mitigated, projects–especially those where children will be using the field–are still vulnerable to questions about potential health impacts.

- The pour-in-place playground market used slightly more crumb rubber in 2011 (about 2 percent). The majority of pour-in-place products use buffings as their main ingredient and only a small percentage of ground rubber. For most pour-in-place products, crumb rubber is used in the base layer, while tire buffings are used in the surface layer. Pour-in-place surfacing generally meets Americans with Disabilities Act (ADA) requirements for wheelchair accessibility and is less susceptible to concerns about fire and other health and safety factors. As a result, some industry stakeholders predict this application could surpass loose-fill playground surfacing.
- The molded and extruded product market increased by 29 percent in 2011 with opportunities for expansion in this market in the feedstock conversion and new product development categories. Market drivers in this category include potentially lower raw material costs, enhanced product performance and new marketing opportunities in the green build sector.
- Market demand for ground rubber playground mulch and landscape mulch was flat overall in 2011. The playground rubber mulch market largely depends on grant funding in most states and its use is often limited or cancelled by budget constraints. The higher up-front cost of rubber playground mulch and the potential for renewed health and safety concerns further constrain this market. On the upside, playground rubber mulch typically outsells competing materials based on its enhanced fall safety, longer life and lower maintenance costs benefits.
- Landscape rubber mulch demand slowed in 2011 as municipal parks and recreation divisions dealt with reduced budgets and retail sales saw less rapid turnover of rubber mulch compared with other products. Industry stakeholders predict substantial room for growth in this market as the economy improves and consumers take advantage of rubber landscape mulch's lower maintenance costs, longer use life (it does not deteriorate or need to be replaced yearly) and its resistance to bugs and insects.

Colorado Trends

- Market conditions that influence the movement of waste tires at the state level are described below.
- Colorado's waste tire collection and processing industry is experienced, but is continuing to evolve to meet changing needs. The majority of Colorado's waste tire businesses have been in operation for more than 15 years. Ten waste tire companies operate in the state currently. Other than the first years of Colorado's Waste Tire Management Program when only one or two businesses were involved in collection of tires, the number of companies that manage Colorado's annual waste tire generation has been consistent at eight to 10 companies. The services these companies provide have continued to evolve within basic parameters of collecting, hauling, sorting, processing, and baling.

- Crumb rubber ranks fourth on Colorado's 2011 Top Ten Recycled Waste Tire End Use Markets list. According to the ranking, 468,786 tires were consumed in the production of crumb rubber. However, these tires went out of state to a Utah-based processor where the crumb rubber was produced. Of these, the report indicated that 63,280 waste tires were used to produce crumb rubber for recreational and playground surfacing and 28,879 waste tires were used to produce ground rubber landscape mulch (CDPHE 2012).

- Of the 10 waste tire processing facilities registered to process tires in Colorado in 2011, two companies added or configured their processing capability to manufacture crumb rubber for mulch, playground surfacing and equine footing. Front Range Tire Recycle, Inc. manufactures ¾ inch, ½ inch and ¼ inch ground rubber. Another Colorado waste tire processor, Snowy River Enterprises, makes ¾ inch ground rubber for landscape mulch. In addition, Colorado waste tires supply a Utah waste tire processor that manufactures ground rubber in sizes ranging from ¼ inch to 20 mesh. Together, these ground rubber producers consumed 560,945 Colorado waste tires to produce ground rubber (CDPHE 2012).
    - Colorado's only dedicated crumb rubber processor closed in 2006. The company began operations in 1992 and built a crumb rubber market for playground and recreational field surfacing, infill for natural grass and synthetic turf, landscape mulch, and equine arena footing. Another firm acquired the company's assets in 2007. That company went out of business in 2011.
- New business entities have continued to show interest in participation in Colorado's waste tire industry. CH2E recently purchased the Hudson Tireville Monofill and has expressed interest in developing and implementing a business strategy capable of constructively using the monofill's waste tire resources. Likewise, GCC of America has purchased the Midway Monofill and stated its intention to use waste tires as a supplemental energy resource in its cement manufacturing facility. Other companies continue to explore opportunities to participate in the industry.

Evaluation of Incentives

Colorado's tire recycling infrastructure is driven largely by the makeup of the Colorado waste tire market (such as TDF, tire derived aggregate [TDA] applications and monofills), and by the state's legislative and regulatory framework that includes incentives for both processors and end-users. Colorado incentivizes the use of Colorado waste tires in public projects involving, for example, playground surfacing, athletic fields, and infill for existing turf surfaces, through the Public Projects grant program.

During 2011, 11 recycling incentive grants in seven counties were completed. The total amount awarded was $612,044 to fund the use of crumb rubber from 112,301 tires for two athletic field installations and 10 playground safety surfacing installations. In 2012, 12 communities received incentive grants totaling $502,764 to fund the use of crumb rubber from 86,008 tires for four athletic fields and eight playground surfacing projects. Incentive grants for 2013 total $507,540 for 13 projects in three cities and two school districts that will use ground rubber from 81,278 tires for athletic field and playground surfacing and playground mulch.

Colorado waste tire industry stakeholder and waste tire program managers cite the education and community outreach the projects provide as one of the program's main benefits. The program has made tire recycling visible in communities throughout the state with products and uses that improve safety and lower maintenance and costs. Officials believe these benefits will eventually allow these end-uses to stand on their own without incentives and attract non-government incentives (private sponsorship of projects and fund-raising).

While there are some retail sales of mulch to homeowners, and private purchases involving athletic fields and molded and extruded products, the majority of ground rubber used in Colorado is purchased by state and local government entities.

The slow economic recovery continues to have a negative impact on state and local government purchasing nationwide and, with housing sales still lagging, local government budgets will likely be challenged for several more years. As a result, in Colorado and nationally, ground rubber markets for playground and athletic surfacing remain flat.

End User and Processor Partial Reimbursement Program

The End User Program was created by law (HB 98-1176) in 1998 and amended in 2001, 2003, and 2007 to include additional funds for end user and processor reimbursements. Initially, this program was managed by the Department of Local Affairs (DOLA) and provided up to $20.00 per ton of waste tires in partial reimbursements. The reimbursement payment was increased several times reaching $50.00 per ton before the program was moved to CDPHE in 2010. The 2010 legislation raised the maximum reimbursement to $65.00 per ton. From 1998 through 2007, more than 26 million tires were reused or recycled through the End User and Processor Partial Reimbursement Program.

Evaluation of Historical Market Development Strategies

As noted earlier, quantifying ground rubber markets for waste tires is difficult, mainly because most processors do not track the entire market or define ground tire applications the same way. In Colorado, tracking ground rubber markets is particularly difficult because a significant, but not consistently tracked, portion of the state's ground rubber is brought in from out of state. This makes it difficult to quantify the state's ground rubber markets and end uses, and also to plan for growth.

Despite the inconsistent reporting, it is apparent from discussions with processors that Colorado lacks ground rubber markets and has limited ground rubber processing capacity. Several years ago, the state commissioned a study to address the lack of ground rubber markets, and specifically rubberized asphalt. Led by Dr. Bob Amme, the study, "Promoting Rubberized Asphalt and Other Waste Tire Products in Colorado" (Amme, 2008) aimed to increase the beneficial use of Colorado's waste tire rubber by raising the awareness of agencies and contractors regarding the use of ground tire rubber as an asphalt modifier. It was launched in response to the essentially non-existent market in Colorado for rubberized asphalt paving, crack sealing and related road surface treatments.

The study was aimed at demonstrating that rubberized asphalt provides a quieter, safer roadway surface along with longer pavement life and can be more economical than the types of paving currently used in Colorado. It also looked at demonstrating the use of rubberized asphalt mix in designing pedestrian trails with the goal of opening up a potential new market for ground rubber that, if successful, could consume significant quantities of ground rubber.

The study is important because it identified weaknesses in the ground rubber market and potential needs in Colorado and laid out marketing and promotion strategies to grow the use of rubberized asphalt on Colorado roads and trails. These strategies are valid recommendations for building ground rubber markets and mirror similar efforts that are being successfully employed today in other states and nationally to expand the use of rubberized asphalt.

For example, during the Colorado study, efforts were taken to engage stakeholders, including rubberized asphalt experts, paving professionals, transportation and environment agency representatives, road contractors, and equipment and technology representatives in educational workshops and meetings designed to raise awareness of the benefits of both ground rubber and rubberized asphalt for Colorado communities.

In Georgia, a similarly designed program was the impetus for bringing attention to the use of rubberized asphalt on Georgia roads and encouraging the Georgia Department of Transportation to amend the state's construction specifications to include recycled tire rubber as an alternative to conventional polymers in asphalt production. As a result, Georgia will use millions of pounds of ground rubber derived from Georgia waste tires during the 2013 paving season.

Most significantly, the "Georgia model" for a rubberized asphalt campaign is being rolled out in other states to promote the use and benefits of rubberized asphalt. Wisconsin and Tennessee—states that, like Colorado, have virtually non-existent markets for rubberized asphalt—held informational meetings between November 2012 and May 2013 and are now moving forward with trials and demonstration projects.

The Colorado study's goal to promote and expand a rubberized asphalt industry in the state parallels another industry trend initiated on a national level in 2012. The Rubber Asphalt Foundation is a newly expanded group that offers an opportunity to address lingering questions on all rubber-modified asphalt. It is designed to work with Departments of Transportation and other stakeholders and could centralize information on all modified asphalts and help streamline and shorten the research phase of future projects. Among its goals, the foundation seeks to be a resource and catalyst for moving rubberized asphalt out of the "research/experimental" category to a paving product readily available to highway engineers and contractors.

The Colorado study also identified terminal blend paving as an opportunity for expanding rubberized asphalt. Terminal blend is one of the national trends identified to expand rubberized asphalt use. This technology is appealing to the asphalt industry because it blends rubber and asphalt at the asphalt production terminal, eliminating the need (and equipment) to blend and mix crumb rubber in the field. Terminal blend also has the potential to expand the use of crumb rubber in other non-paving asphalt products such as coatings, sealants, and asphalt shingle manufacturing.

Terminology

How incentive recipients are defined has been a source of confusion, wrongful payments, and even fraud in some programs. Most U.S. incentive programs make no clear distinction in terms commonly defining ground rubber producers as end users. These programs also do not include tire-derived rubber product manufacturers or other firms purchasing ground rubber to make new products in their definitions.

Summary

Ground rubber production is both capital and equipment intensive. Finer rubber is more costly to produce than coarse ground rubber both from an operational cost (energy-intensive) and from a capital equipment cost. Currently two Colorado processors have limited capability to produce volume quantities of ground rubber in a range of sizes. Although Colorado has a well-developed waste tire collection, hauling and processing infrastructure, it is still developing the capacity and capability to produce a range of rubber feedstock sizes (crumb rubber, ground rubber, or mulch size rubber). In addition, the majority of processors in the state have not advanced their processing systems to include quality measurement, product controls or production efficiency. Most operate at primary and secondary processing levels.

New ground rubber markets have not developed or have been discouraged in Colorado because the processing capacity for the material is not available. This statement is borne out in the "Promoting Rubberized Asphalt and Other Waste Tire Products in Colorado" study (Amme, 2008). In addition, no markets in the molded and extruded market sector have developed in the state.

Experience in the nine states with incentive programs has shown that when processors become dependent on incentives, it limits creativity in seeking new markets, stifles improvements in the current infrastructure, and reduces the "incentive" to produce higher-value products. Processor incentives in Colorado should be evaluated to find new ways of assisting and encouraging processors to make improvements in processing to lower costs and produce end products that can compete in the marketplace. Industry stakeholders report that incentives directly benefit processors and end users by enhancing cash flow and thereby strengthening the overall profitability, competiveness and vitality of their operations.

Between 1988 and 1998, nine U.S. states (including Colorado) implemented tire incentive programs mainly with a goal of cleaning up illegal tire stockpiles and developing in-state processing capacity to manage annual waste tire generation and creating end-uses. Four of these programs sunset by law after they achieved various levels of progress (Idaho, Oregon, Texas and Wisconsin), while five are ongoing (Colorado, Louisiana, Oklahoma, Utah and Virginia). Each program had some success in developing in-state markets and infrastructure and in launching TDF as a viable end use that is now a well-established market. Only two—Utah and Oklahoma—specifically promote crumb rubber in their programs.

The lesson emerging from these programs suggests that lower-value, high-volume end uses rise to the top and dominate the market, not allowing a diverse waste tire market to emerge. However, some states—Texas and Wisconsin, for example—have well-established tire management infrastructure with growing crumb rubber capacity that developed after their incentive programs sunset. Markets in Texas are especially strong, with eight TDF users, an established rubberized asphalt market, three existing crumb rubber producers, and one large new crumb rubber producer planning to startup in 2013.

It is important to note that of these nine incentive programs, no two are defined exactly alike and each one has singular characteristics that complicate making broad generalizations. Key differences include the types of eligible firms and market segments, incentive payment amounts, whether out-of-state firms are eligible, terminology, and the nuances of each program's rules.

In contrast to these state programs, Colorado is an anomaly. On a national basis, Colorado is identified by its monofills. As of 2011, more than 60 million waste tires were stored in tire monofills and legal stockpiles. In Colorado, placing tires in monofills for storage does not constitute final waste disposal. The state anticipates that tires stored in monofills will be reused later for tire-derived fuel; rubber crumb for roadways and molded rubber products, playgrounds, sports fields, or for other uses. This conclusion is supported by the recent change in ownership of the state's two largest monofills. One was purchased by a cement company that will process the tires for use as a supplemental fuel at its in-state kiln. Similarly, the new owners of the largest monofill have indicated that they are developing strategic alternatives for consuming all tires in the monofill.

Colorado already has an established infrastructure and end uses sufficient to handle tires generated annually. Going forward, the state will need to re-focus and re-align the goals of its waste tire program to increase diversion, strengthen crumb rubber production, diversify demand for recycled tires, and reduce storage of waste tires. Other related goals might focus on promoting the highest and best uses for tires and ensuring equity across the industry.

Markets remain an issue in all the states with incentive programs. TDF and TDA in landfill applications emerged as the strongest end uses for tires in all nine state programs. TDF continues as the strongest market in the five active state programs. Only Utah has significant crumb rubber processing capacity, but most of the crumb rubber produced in the state is sold out of state. Even under Ontario, Canada's highly subsidized incentive payment system, end use demand has lagged behind crumb rubber production and large quantities of crumb rubber are exported to U.S. markets.

None of the states has a strong diversity of end uses. In Louisiana, processors are taking the lead in developing a rubberized asphalt market. In Virginia, a new crumb rubber facility opened in 2011. It is only the second facility dedicated to producing crumb rubber to open in the state in more than 20 years. The company hopes to take advantage of recent state efforts to encourage rubberized asphalt. Several rubber-modified asphalt-modified demonstration pavements were laid in 2011 and 2012 as a result of a legislative push to consider the use of rubber-modified pavement as part of the state's quiet pavement program. Texas developed a rubberized asphalt market and crumb rubber processing capacity in the state after its incentive program ended.

Colorado's incentive program needs to be balanced and have oversight and review mechanisms to assure the best use of incentives in each market. One option is to target end user incentives to promote expansion in new market segments such as rubber-plastic molded products. Industry stakeholders and incentive program managers need to work together and look for creative ways to use incentives, including targeting incentives to specific market needs (quality assurance, education, and technical expertise) and finding partners to share or match incentives.

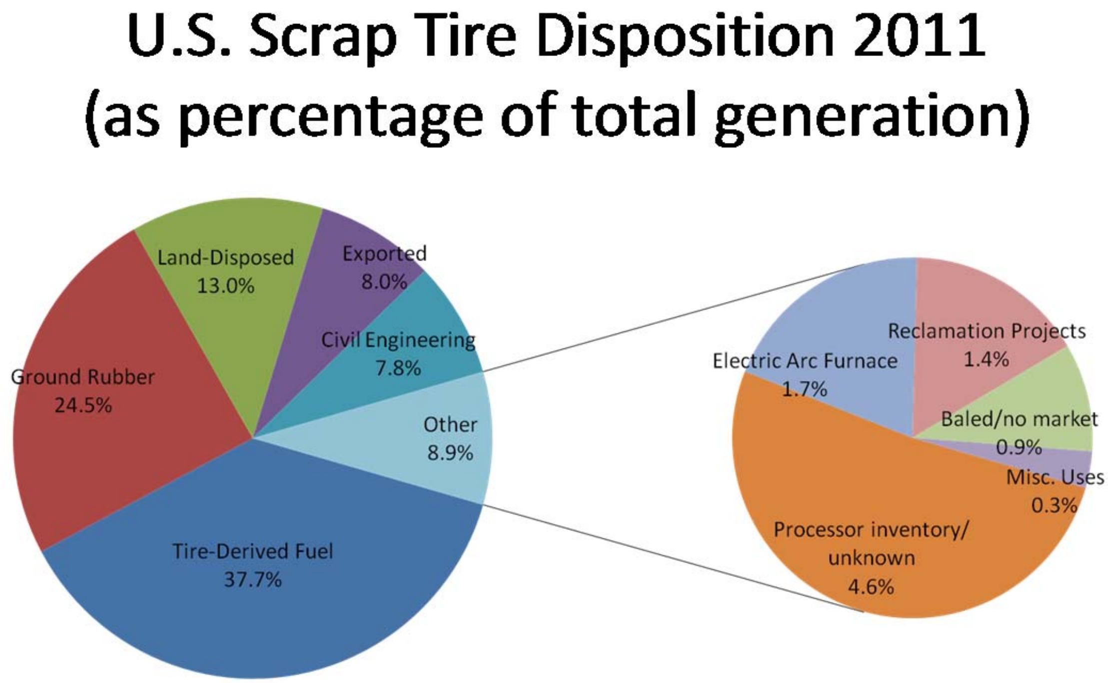
4.0 Opportunities for Expanding Beneficial End Use

Waste tires began to be recognized as a resource in the 1990s. In addition to basic recycling objectives, a series of major stockpile fires encouraged states to initiate waste tire management programs to stop illegal disposal and create markets. Many tire processing methods and equipment components were tried, with mixed results. Market development efforts tested the limits of creativity and “credibility.” The long-term result has been development of diverse products and a tire processing industry capable of making these products. In a relatively short period of 15 to 20 years, waste tires have progressed from a disposal liability to a valuable resource with broad market penetration.

Figure 4 summarizes the U.S. markets for products derived from waste tires based on the most recent data compiled by the Rubber Manufacturers Association (RMA) in the U.S. (2011). RMA revised its reporting methodology by deducting used tires recovered from tire collections before waste tire generation and disposition would be defined. According to RMA, 265.8 million waste scrap tires were collected in 2011, representing 4.356 million tons. In total, 35.1 million tires (575,000 tons) were culled for resale. As a result, RMA considers actual waste tire generation to be the net difference, or 230.7 million tires (3.781 million tons). The following RMA charts and data are based on this net national waste tire generation in 2011.

TDF is recognized as a viable energy resource in the U.S. and consumes 37.7 percent of annual generation in about 100 facilities across the country. Approximately 24.5 percent of the tire-derived material was converted into ground rubber, ranging from large particles for mulch and playground fall protection to fine mesh crumb rubber for extrusion molded products and rubber modified asphalt. Civil engineering applications using TDA represented 7.8 percent of the material used.

Figure 3: U.S. Waste Tire Disposition 2011



In addition to these major markets, 8 percent of the material was exported in 2011, mostly as bales to China through Vietnam in a practice that has diminished dramatically since mid-2012. Thirteen percent of the material was land-disposed and 8.9 percent was used in other smaller categories including electric arc furnaces (1.7 percent), reclamation projects (1.4 percent), baled tires with no markets (0.9 percent), miscellaneous uses (0.3 percent) and processor inventory/unknown 4.6 percent. In total, about 82 percent of the net waste tire generation was constructively utilized and most of the remainder of the material was properly disposed of or managed. In addition, 13.2 percent of gross waste tire collections were sorted for resale and deducted from generation before calculation of the other market percentages as previously noted.

The following sections summarize the characteristics, volumes, benefits, and issues associated with each of these major market segments. Historical development, current status, market potential and accelerators that deserve consideration for increasing each market in Colorado are discussed.

4.1 Current Market Perspective

This section discusses the top eight opportunities for increasing beneficial end use capacity of waste tires in Colorado.

4.1.1 Alternative Energy Resource (TDF)

Waste tires have been used as a supplemental energy resource in Japan, Europe, and the U.S. since the 1970s, and it is the largest end use application for waste tires in most of these countries. TDF was the cornerstone of initial market development in many waste tire management programs and remains an important component even as efforts have continued to develop applications that use the materials value of the rubber. The sheer volume of waste tires generated annually in the U.S. forces broad market diversification to maximize constructive utilization that could not be achieved without substantial TDF markets.

The chemical characteristics of any energy resource affect its technical and environmental performance. Tires are a hydrocarbon-based material derived from oil and natural gas. Some inorganic materials are added to enhance vulcanization reactions or performance properties such as flexibility and resistance to ultraviolet light. Tires have a heat content of 14,000 to 15,500 British thermal unit (Btu)/pound, depending on the type of tire and degree of reinforcing wire removal. By comparison, coal that may be displaced by use of tires typically contains 8,000 to 12,500 Btu/pound.

The composition of tires and coal varies depending on type and source. However, Table 8 provides representative proximate and ultimate analyses of TDF with about 90 percent of the reinforcing wire removed, a northeastern bituminous coal, and a western sub bituminous coal used to generate steam. Proximate analysis defines basic combustion characteristics. Ultimate analysis defines elemental composition.

Table 8: Comparative Chemical Characteristics of Tire Derived Fuel to Coal

Characteristic	Bituminous Coal-Northeastern US	TDF (90+% Wire Removed)	Subbituminous Coal-Western US
Moisture (% As Received)	10.43	0.62	24.68
Heating Value (BTU/Pound, as Received)	10,641	15,404	9,287
Proximate Analysis (%, Dry Basis)			
Ash	16.16	4.81	6.37
Volatile Carbon	38.14	67.06	44.43
Fixed Carbon	45.70	28.13	49.20
TOTAL	100.00	100.00	100.00
Ultimate Analysis (%, Dry Basis)			
Carbon	65.49	83.79	70.73
Hydrogen	4.56	7.13	4.85
Nitrogen	1.11	0.24	0.84
Sulfur	4.52	1.84	0.41
Ash	16.16	4.81	6.37
Oxygen (by difference)	8.16	2.18	16.80
TOTAL	100.00	100.00	100.00
Ultimate Analysis Expressed as Pounds/Million Btu			
Carbon	55.13	54.05	57.36
Hydrogen	3.84	4.60	3.93
Nitrogen	0.93	0.16	0.68
Sulfur	3.81	1.19	0.33
Ash	13.61	3.12	5.17
Oxygen (by difference)	6.87	1.42	13.62
SUBTOTAL	84.19	64.54	81.09
Moisture	9.80	0.40	24.68
TOTAL	93.99	64.94	105.77

A comparison of the proximate analysis indicates that tires offer efficiency advantages versus coal. For instance, tires generally have lower moisture content than coal. Since the energy required to heat and vaporize water is often non-recoverable in the energy conversion process, lower moisture content can translate into higher combustion efficiency. Lower ash content of TDF (without wire) offers another advantage versus coal and can decrease ash disposal costs. A tire's higher volatile-to-fixed carbon ratio enhances its ability to combust rapidly and completely. TDF's advantages become commanding when compared with some high-ash, low-Btu coals and lignite. This advantage is particularly true in cement plants, where the waste tire ash constituents are incorporated into the cement product. Based on proximate analysis, tires compare favorably with coal as an energy source.

Based on ultimate analysis, tires offer some additional advantages and disadvantages. When compared with many eastern coals, TDF's lower sulfur content (especially in terms of pounds/million Btu) offers the potential advantage of decreasing emissions of sulfur oxide compounds referred to as SOx. However, many western coals have lower sulfur content, so SOx must be controlled within these systems to prevent an increase with TDF.

Combustion systems burn less of a high-energy fuel to obtain the same amount of energy, so expressing the ultimate analysis as pounds per unit of energy (Btu) identifies some other important environmental factors. Combustion of TDF generates less carbon per Btu than either coal summarized in Table 8. Since carbon converts to the greenhouse gas carbon dioxide during combustion, TDF reduces emissions of carbon dioxide compared with these coals. TDF also has higher hydrogen content. When hydrogen combines with oxygen during combustion, it releases energy and forms water with no greenhouse gas. Therefore, TDF’s lower carbon and higher hydrogen content on an energy basis results in lower greenhouse gas generation. In addition, TDF’s lower nitrogen content can decrease emissions of nitrogen oxide compounds called NOx.

Tires generally contain metals at concentrations comparable to, or lower than, coal, with one notable exception. Zinc is added to tires as part of the rubber vulcanization process at levels approaching 1.0 to 1.5 percent by weight. Therefore, zinc levels in tires are higher than coal. Applications using tires as an energy resource must be able to control zinc emissions to avoid a negative environmental impact. Common air pollution control equipment such as electrostatic precipitators and baghouses effectively control zinc oxide emissions from TDF combustion.

From a chemical standpoint, tires offer both environmental advantages and disadvantages versus coal. Therefore, tires can provide a valuable and environmentally friendly energy resource when used in applications that draw on their advantages and properly control their disadvantages.

All suitable facilities have the following characteristics:

Solid Fuel – Tires can be used whole in some applications such as cement kilns. Others require tires to be shredded into TDF, with reinforcing bead and cord wire removed if necessary. Regardless of particle size, tires remain a solid fuel, so applicable systems must be able to receive and combust solid fuel to be a candidate for TDF use. However, the energy from TDF can replace higher-cost oil and gas in some cases where oil, gas, and solid fuels are co-fired in the same furnace.

Complete Combustion – Appropriate applications must have a combination of air/fuel residence time, combustion temperature profile, and air turbulence to assure complete combustion.

Emissions Control – Appropriate facilities must have emissions systems capable of controlling any changes in SOx and particulate within environmentally sound permit limits.

Perceptions and Issues

Evaluation of TDF for specific applications involves consideration of the following technical, operational, environmental, regulatory, economic, perception, policy, and market issues:

Technical Issues – Many technical issues must be evaluated to assess the suitability of using TDF in specific applications, including fuel handling, combustion conditions, ash handling and disposal, and emissions control capabilities. In general, most cement manufacturing facilities, some specific types of power plants (most circulating fluidized bed boilers, and some cyclone-fired power boilers), and some wood burning stoker-fired boilers are worthy of consideration.

Operational Consistency – Operational consistency is a critical parameter in controlled combustion, so TDF is normally metered into the combustion unit by a suitably designed and demonstrated metering unit. The unit is electronically tied to the control room and control system to assure proper operation.

Environmental Factors – In appropriate applications, many emissions parameters are monitored and tested. Some decrease or increase marginally with TDF usage, but the overall impact is not significant and remains within established permit limits. This performance has been demonstrated by more than 20 years of usage involving at least 100 facilities in the U.S. Any new applications must be confirmed by performance testing and continuous monitoring of major environmental parameters. TDF should be used only in facilities capable of maintaining environmental performance in compliance with all applicable regulations and permits. As previously discussed, TDF can actually result in reduced greenhouse gas emissions versus displaced coal.

Regulatory Considerations –The US EPA has recently promulgated a Non-Hazardous Secondary Materials (NHSM) rule (40 CFR 241) providing the standards and procedures for identifying whether NHSM are solid waste under the Resource Conservation and Recovery Act when used as fuels or ingredients in combustion units. Under this rule, waste tires that are managed under the oversight of established tire collection programs, including tires removed from vehicles and off specifications tires, were given a non-waste determination for specific Non-Hazardous Secondary Materials when used as fuel. As a result, use of these waste tires as a fuel has not been impacted and they can continue to be combusted in appropriate applications either in whole or shredded form under Section 112 provisions of the Clean Air Act.

However, tires retrieved from stockpiles are considered to be solid waste and must be shredded with removal of loose wire liberated during processing to continue to fall under Section 112 provisions. Use of whole tires retrieved from stockpiles will fall under the more stringent provisions of Section 129 of the Clean Air Act governing solid waste combustors. Some cement kilns are the only major energy users consuming whole tires. They may continue to use whole or shredded waste tires managed under an established tire collection program and remain under Section 112. However, use of whole tires from stockpiles will require compliance with Section 129 provisions of the Clean Air Act unless the company successfully petitions EPA for designation of these tires as non-waste. The overall conclusion is that the NHSW rule will have no impact on the use of tires as an energy resource as long as they use shredded tires with free wire removed or whole tires managed under an established tire collection program.

Economic Considerations – TDF substitution for traditional fossil fuels is generally driven by energy savings, enhancing the economic viability of some facilities in today's globally competitive market and contributing to job preservation at these facilities.

Public Perception – Tire stockpile fires generate massive amounts of dense black smoke and noxious fumes from incomplete combustion as a result of oxygen starvation at the surface of the fire. This uncontrolled combustion is totally different from carefully controlled combustion in industrial applications. Industrial applications are designed, controlled, and monitored to achieve complete combustion and to control emissions. In the absence of technical understanding, some people maintain the perception that TDF use will result in black smoke and dangerous emissions.

Policy – Some states have chosen to evaluate potential markets based on program needs, allowing TDF to absorb stockpile abatement tires or incremental generation while markets utilizing the materials value of rubber are developed. TDF decreases low-value uses such as daily cover or soil substitution where TDA offers no technical advantage.

High Value Market Transition – One concern about TDF use is the perception that other markets will not be developed if TDF is allowed. However, economics dictate that waste tires flow from TDF to civil engineering markets as applications using rubber's materials value are developed. Higher revenue draws tires to higher value products naturally, as has been proven repeatedly in practice.

Applicability

Whole or shredded tires can be used as an energy resource. Examples of facilities that have demonstrated their ability to use TDF in compliance with all applicable regulations are discussed in the following sections.

4.1.1.1 Cement Manufacturing Kilns

Conceptual Usage – Cement manufacturing consumes massive amounts of energy to heat a complex mixture of raw materials to more than 1400 degrees Centigrade. Whole or shredded tires can be injected into the cement process at several points to increase energy efficiency and decrease NOx generation. TDF usage is one of the approved technologies for NOx reduction in California cement plants and by the USEPA (USEPA, 2012). Tires have been used successfully in all major variations of cement manufacturing processes. Reinforcing wire in tires provides a raw material required in cement, thereby reducing iron purchases.

Current Market Position – The use of TDF as a supplemental energy resource in cement production is the largest current application in Colorado. There are three major cement manufacturing facilities in Colorado.

- Holcim (US) Inc. – Tires are currently processed at the Geocycle facility in Colorado Springs and then used at the Holcim cement plant in Florence, Colorado. Holcim has demonstrated a commitment to creating a consistent market for waste tires and exploring opportunities to expand usage as its production volumes rebound from the negative impact of the recession and associated housing slowdown. The company may also examine other opportunities to increase usage at existing production rates by displacing additional coal.

- GCC – GCC has been permitted to use shredded tire chips in its kiln in Pueblo, Colorado. It has purchased the nearby Midway Monofill and is exploring options for retrieving and processing tires from the monofill for use in its kiln. If tires are available from ongoing generation, GCC may also use them to supplement monofill tires to optimize its utilization of this resource. GCC's usage could substantially abate the monofill within 7 to 10 years. By initially removing tires from appropriate areas, the monofill's environmental risk could be significantly reduced within several years. The GCC plant plans to begin using tire chips as a fuel in 2013.
- CEMEX – The CEMEX plant in Lyons, Colorado conducted TDF trial usage in 2002 and 2003, developing an environmental performance data base and a detailed analysis of the environmental and health impact associated with TDF usage. The facility has made additional capital and operational changes since then that may further enhance environmental performance. Use of TDF could offer substantial economic benefit to the plant and could improve its financial viability in today's challenging business climate. The CEMEX plant is located within 35 miles of the large monofill north of Hudson, Colorado, and could offer a logistically and environmentally sound application for some monofill tires if the current monofill owner (CH2E), CEMEX, local and state regulatory agencies and residents recognize that it would be beneficial to all parties to re-evaluate possible use of TDF at the facility.

Potential Usage – Use of TDF in cement kilns is a cornerstone of Colorado's waste tire management program and may be able to further improve utilization of ongoing generation tires. In addition, GCC intends to abate the Midway monofill by producing and using TDF from monofill tires. CEMEX could play a role in constructively utilizing on-going generation tires and abating the Hudson monofill if its participation is warranted and acceptable to involved stakeholders.

4.1.1.2 Power Generation Facilities

Conceptual Usage — TDF has demonstrated its environmental and technical performance when it has displaced coal in certain types of power boilers, such as fluidized bed, cyclone, and some stoker-fired power boilers. These boilers have combustion conditions conducive to complete combustion of economically-produced TDF particle sizes. Large wall-fired and tangentially-fired units require smaller TDF particles that currently cannot be produced at costs competitive with coal in Colorado. Smaller biomass-fired facilities can be candidates to use TDF if they require supplemental fossil fuel to maintain optimal combustion conditions and efficiency.

Large Power Boilers – Nineteen large coal fired power boilers were identified in Colorado, but all are wall-fired or tangentially fired. These units do not have sufficient particle residence time to allow complete combustion of nominal 1-inch-sized TDF. Since the cost to produce smaller TDF escalates dramatically, TDF currently cannot compete economically with coal in these boilers. Based on available references, no large utility boilers appear to be candidates for TDF usage in Colorado at this time.

Fluidized-bed Boilers – Fluidized bed boilers have an excellent combination of temperature, turbulence, and residence time to assure optimal combustion conditions. The limestone fluidizing medium enhances temperature uniformity within the bed and scrubs sulfur by contact with combustion gases.

These units are environmental leaders, but only three comparatively small units were identified in Colorado. Based on initial exploratory discussions, each of the units has technical or economic issues (or both) that will probably preclude use of TDF at this time. However, future market development efforts should include more detailed discussions and possible site visits to fully explore possible use.

Biomass Boilers – Some boilers combust bark, wood waste, or other biomass materials to generate steam and power. Paper mill power boilers commonly use TDF as a supplemental energy resource. Wood absorbs moisture during rainy periods and can be difficult to combust fully. The high energy content of TDF serves as an octane booster to enhance boiler performance and complete combustion. TDF generally displaces supplemental fossil fuel usage, often oil, coal, or natural gas. There are currently no paper mill power boilers in Colorado or nearby states. However, there are some smaller biomass units that should be explored in more detail during future market development efforts. These units derive economic and tax benefits from using renewable energy resources, and TDF is not currently recognized as a renewable energy resource in Colorado. Tires contain an average of 28 percent natural rubber that is considered a renewable material. As a result, the federal government has recently recognized TDF as 28 percent renewable, a factor that could be important if TDF displaces fossil fuels as a supplemental energy resource in these facilities.

4.1.1.3 Steel Production (Electric Arc Furnaces)

Some U.S. and foreign steel production facilities have used cut tires as a source of carbon in steel manufacturing. Tires contain about 30 percent carbon black (elemental carbon), and the remaining energy content is beneficial in this energy-intensive production process. A large steel production facility was identified in Colorado, and a preliminary discussion indicated that there may be an interest in continuing to explore the technical and economic feasibility of using TDF to displace some coke purchases. Use of waste tires in steel production is generally considered a higher-value use than traditional TDF because the elemental carbon in tires is effectively reused to enhance performance properties of the steel. Facilities have typically used 250,000 tires or more annually.

Market Development Plans and Accelerators

TDF is the largest existing application for waste tires in Colorado and offers potential for significant expansion. It is important for Colorado to have diverse markets and not totally depend on one use, but energy utilization will be required to play a major role in abatement of Colorado's monofills and other stockpiles. TDF is one of the few markets that can be developed relatively quickly and can continuously consume large quantities. Within the framework of annual generation, additional TDF usage would displace baling and reduce pressure for excessive daily cover usage and accumulation. It may be enhanced by its role in abating major identified monofills and any stockpiles identified in the future.

Future TDF market development efforts should focus on the specific market segments offering identified potential.

1. The cement industry is experienced and knowledgeable in TDF usage, but best practices can still be implemented on a wider basis across the industry to maximize the use and benefit of TDF.
2. The prospect of TDF usage can provoke public reaction. Providing data and an unbiased perspective to interested groups has provided a forum for discussion based on fact. Candid discussion of positive and negative factors can provide a sound foundation for constructive plans reflecting the concerns of stakeholders.
3. Fluidized bed boilers should be fully explored. Operational limitations, rigorous TDF specifications, and low coal competitive prices decrease the probability of usage in Colorado, but there have been good technical, economic, and environmental applications for TDF in other areas of the country.
4. Existing and planned biomass boilers should also be fully explored. If appropriate based on this evaluation, official recognition of TDF's renewable energy component in Colorado may help accelerate use of TDF as a supplemental energy resource in these facilities.
5. Additional on-site discussion should be conducted with the Colorado steel manufacturing industry to assess the technical, environmental, and economic viability of using TDF as a carbon and energy resource.
6. If Colorado's waste tire management program is modified to create a larger Market Development Fund, competitive grants could be used to reduce barriers to additional TDF market development. Examples could include:
    - Sharing the cost of environmental trials to assure the performance of new or modified applications.
    - Sharing the cost of metering systems or necessary end user facility modifications to reduce economic hurdles during initial or increased implementation. In general, this assistance is granted initially as a loan and is converted into a grant based on actual tire usage. These grants have proven effective in accelerating development of sustainable markets that continue without on-going subsidies.
7. Providing technical assistance has historically allowed potential end users to gain an understanding of and evaluate potential TDF usage. The Tetra Tech team has successfully served this function in support of other state and federal market development programs. Actual time expended in support of each potential end user is normally limited, but it can accelerate their learning curve.

4.1.2 Pyrolysis

Pyrolysis is, by definition, thermal decomposition of organic compounds in an oxygen-limited environment. Promoters have called their pyrolysis processes thermal distillation, destructive distillation, and many other names to avoid identification with pyrolysis.

Pyrolysis of waste tires typically generates gas, oil, and char products. The quantity and quality of each product depend on many process variables, including temperature, pressure, and residence time. Twenty to 35 percent of a tire's energy content is typically converted into a combustible gas that is used to fuel the pyrolysis process or is combusted in a flare prior to release. Thirty-five to 50 percent of the output from the process is transformed into an oil product that varies in quality from saleable fuel oil to lower-value oil blend stock. The residual solid product (referred to as char) constitutes 25 to 40 percent of the output and contains a mixture of the following materials:

- Multiple types of carbon black used in various sections of a tire for strength, wear, or other critical performance properties;
- Titanium dioxide from white sidewalls and lettering in older waste tires;
- Zinc dispersed uniformly within tires as a vulcanization accelerator;
- Steel from bead and radial reinforcement wire;
- Other inorganic chemicals.

Pyrolysis is not a new process. It was developed in Europe more than 60 years ago to transform coal into gas for street lamps. Over the past 25 years, many processes, equipment, and operating variations have been applied to waste tires. A U.S. Department of Energy publication titled "Scrap Tires: A Resource and Technology Evaluation of Tire Pyrolysis and Other Selected Alternate Technologies" identified 31 pyrolysis projects in 1991 that used fluidized beds, traveling grate chambers, rotary kilns, retorts, molten salt and hot oil baths, plasma arc units, and microwave chambers as reactors. Various operating conditions have been extensively explored to optimize production and quality of product streams. In spite of this extensive developmental effort, no commercial-scale pyrolysis systems currently operate continuously in North America. For this reason, any grant requests for pyrolysis projects should be thoroughly vetted.

Extensive technical and economic resources (an estimated $300 million) have been invested in projects developed by major companies such as Goodyear/Tosco (The Oil Shale Co.), Firestone, Occidental, Uniroyal, Nippon, and Foster-Wheeler. In addition, many pilot or "demonstration" projects have been developed by smaller companies and entrepreneurs. One major project developed by Foster-Wheeler in England (called Tyrolysis) failed technically and economically after expenditures exceeding $30 million.

Major reasons for failure of pyrolysis projects have included the following:

- Operating Problems: Utilizing complex equipment at high temperatures with an abrasive feedstock such as waste tires is generally maintenance-intensive. Downtime and maintenance expenses have often been underestimated in projections of total project costs.
- Safety: Operating in an oxygen-limited, high-temperature environment creates the possibility of fires or explosions if air enters the system accidentally. These accidents have destroyed or damaged numerous pyrolysis facilities, including complete destruction of the $6 million Intenco operation in Texas.
- Feed Availability and Processing: The scale required for economic feasibility can require more tires than are available within an economical delivery area at projected net tipping fees. In addition, capital and operating costs associated with shredding or feed preparation have often been underestimated.
- Product Quality: It is difficult to optimize quality and yields of three inter-related product streams (gas, oil, and char) since conditions favoring one often have a negative impact on

another. Because of the mixture of carbon blacks and other constituents, the char has historically been suitable for only low-value applications with limited market volumes, even when the char is further processed to control size uniformity and iron content.

- Environmental Impact: Tires contain about 1.8 percent sulfur and 1.0 to 1.5 percent zinc, by weight. These inorganic materials are not destroyed or decomposed thermally, so they remain in one or more of the pyrolysis products as defined by an elemental mass balance for specific operating conditions. In addition, partially decomposed hydrocarbons may not be fully removed from the exhaust gas stream by condensation or combustion. As a result, pyrolysis units must have air pollution control systems to prevent discharges to the environment. Pyrolysis promoters often claim that their process has no emissions because all materials are captured as products. However, the gas product is generally combusted to fuel the process or flared on site because it cannot be transferred in normal gas transmission lines. In either case, combustion creates emissions that require controls to comply with clean air standards in the U.S. In addition, the char product may require disposal as a hazardous waste if it is not marketable. These practical realities should be reflected in capital and operating cost projections, but rarely are.
- Economics: The economic feasibility of pyrolysis depends on many operating factors such as system reliability, capital and labor costs, process, feedstock preparation expense, environmental control requirements, and product revenue. Past operations have not been economically sustainable at reasonable tipping fees because they have not been able to develop high-value (greater than $0.20 per pound) markets for all of the char generated. The materials recovery appeal and economic viability of this process are dependent on high-value application of the carbon black content of the char stream. Unless this objective is achieved, pyrolysis simply becomes a capital-intensive process for conversion of a viable solid fuel into a low-grade liquid fuel, while wasting up to 70 percent of its initial energy content.

There are many companies promoting pyrolysis systems within North America. None of these technologies has been practiced on a continuous commercial scale for an adequate period of time to fully demonstrate long-term operating economics and char marketability. Most of these companies, like the many failures before them, claim technical improvements that overcome historical failures.

Some proponents identify multiple processing steps intended to improve particle size uniformity of the char product. However, the pyrolytic char does not retain the structural reinforcing properties of virgin carbon blacks used in tires and other performance applications. Size reduction and particle size classification will not restore these critical properties. High metals content and residual organics from decomposition of rubber polymers further limit potential markets for the char product. Historical experience dictates that actual markets should be specifically defined and supported by verifiable contractual commitments before any future investment in "commercial" pyrolysis technologies.

The USEPA has recently required pyrolysis producers to classify and register its products under Toxic Substances Control Act (TSCA) provisions. Only one pyrolysis facility has complied with TSCA requirements so far. Demonstrating compliance can be a costly and time-consuming challenge.

Without proper compliance, the pyrolysis facility and its customers are subject to substantial fines and penalties.

A waste tire pyrolysis facility has been constructed in Colorado Springs by Recycledfuel Company. The equipment was purchased from China and installed in a commercial/industrial warehouse area. The company has not yet obtained all of the permits required to initiate operation. The facility is reportedly able to process more than 1 million tires/year, but no actual projection can be made until all permits have been obtained and performance has been demonstrated. This small facility faces limited resources and substantial hurdles to overcome before it is demonstrated as a viable long term business.

Hudson Tireville has recently been purchased by CH2E, a relatively new company that has announced planned construction of a pyrolysis facility in Las Vegas. The facility reportedly is designed to process up to 20 million tires/year, as well as other organic materials, at a construction cost of about $25 million. CH2E was contacted during this study. Company representatives indicated that they have not yet fully developed their strategy for the Hudson site, but they have several technologies available and their goal is to use the tires in the monofill within a reasonable period of time. Their plans should become more apparent with time and have a significant impact on long-term development of the waste tire market and the use of pyrolysis in Colorado.

4.1.3 Tire Derived Aggregate

A broad range of civil engineering applications use substantial quantities of TDA in the U.S. It is the third largest market (behind TDF and crumb rubber), using 7.8 percent of generation in 2011, according to the RMA.

TDA is a term coined by Dr. Dana Humphrey, Dean of the School of Engineering at the University of Maine and a major contributor to development of TDA applications and data. His objective was appropriate recognition of shredded tires as an engineered product made by cutting waste tires into 1- to 12-inch pieces. TDA has unique properties that make it suitable for use in a wide range of geotechnical challenges, including:

- Light Weight: Approximately 50 pounds per cubic foot, a fraction of the weight of traditional aggregate materials. TDA has been used as an economical lightweight fill in highway embankments in 13 states and most recently in New Brunswick, Canada.
- Compressibility: Produces low lateral pressures on walls (as little as one-half that of soil) and has demonstrated vibration absorption properties for use under urban rail tracks and new light rail systems.
- Low Thermal Conductivity: TDA transmits heat or cold poorly, making it a good thermal insulator (up to eight times better than soil), and allowing it to retard frost penetration in road bases or around home foundations.
- High Permeability: Permeability of more than 1 foot per minute allows liquids and gases to pass through TDA rapidly, making it an effective drainage medium under roadways, along highway edge drains, around house foundations, in French drains, in septic system drain fields, and in landfill drainage and gas collection systems.

- Good Shear Strength: Enhances strength and stability when placed in large applications such as roadway embankments, and absorbs vibrations.

When used in appropriate applications, TDA's properties can greatly reduce construction costs. Guidelines and construction specifications are available to help engineers take advantage of the special engineering properties of TDA. Most important of these is ASTM International Standard D6270-98 (Ref. 3), Standard Practice for Civil Engineering Applications of Scrap Tires (http://www.astm.org/Standards/D6270.htm). This document lists the typical geotechnical properties of TDA, applicable test methods, and construction guidelines.

TDA can be used as a substitute for conventional drainage aggregate for a wide range of applications. This material is advantageous when conventional aggregate is more expensive or is unavailable. Potential drainage applications include:

- Drainage layers within landfill leachate collection and removal systems
- Permeable aggregate for landfill gas collection layers and trenches
- Free draining aggregate for edge drains for roadways
- Permeable backfill for below-grade exterior walls
- Septic system drain fields

In addition, TDA is used in lightweight fill applications where its low density offers significant economic advantage, such as:

- Lightweight fill over unstable underlying soils, particularly in coastal and basin areas
- Stabilization of landslide areas
- Retaining wall backfill where TDA offers light weight, good drainage, and low lateral pressure.

Perspective and Issues

Multiple factors influence the use of and market for TDA, including:

- Economic Applicability TDA has been economically used for a wide range of applications in the U.S. The economics of using TDA depend on the local cost of TDA and competing alternative construction materials. TDA is generally cost competitive for projects that require use of lightweight fill material for embankment construction. It can offer economic advantages in applications using its thermal insulating and vibration dampening properties. TDA can also be cost-effective in drainage applications where the supply of conventional drainage aggregate is limited. TDA is not, however, generally a cost-effective substitute for conventional earth fill. This usage is sometimes represented as a constructive use, but is more accurately just lineal landfill disposal.
- Stockpile Requirements: Many civil engineering projects require large quantities of TDA for placement in a short period of time, so the material has to be stockpiled at the processor or construction site for use. Since TDA can be ignited, storage should follow International Fire Code and local Fire Marshall requirements to minimize the probability and environmental

consequences of any such event. Since most construction is seasonal, storage can be for extended periods. Project delays and cancellations can further compound storage concerns. Firm project commitments prior to TDA production and proper storage design can minimize these concerns.

- Leaching of Metals and Organic Materials Contained in TDA: TDA contains metals such as iron and manganese in reinforcing wire and zinc within the polymer rubber matrix. All of these metals occur naturally in soil, often at levels greater than in tires. Exposed wire can dissolve in time, gradually introducing these materials into the surrounding soil. Zinc and organics are less prone to leaching in large TDA particles because they are contained within the rubber itself and do not readily migrate to the surface under normal environmental conditions. Several studies have also shown that TDA has negligible impact on groundwater. A statistical analysis of the effect of TDA on groundwater is presented in "Literature Review of the Water Quality Effects of Tire Derived Aggregate and Rubber Modified Asphalt Pavement" Humphrey and Swett, 2006). Many states limit TDA applications to above the mean water table to further control leaching potential. Florida also limits septic drain field applications to residential systems to avoid extreme pH conditions that could increase leaching in some commercial systems.
- Auto-ignition: Deep piles of compacted tire shreds have auto-ignited during storage and use in some roadway construction. The mechanism is not fully identified, but most examples have had the following common characteristics: (1) deep piles in excess of 12 feet, (2) compaction by movement of heavy equipment on top of the pile, (3) exposure to wet conditions, (4) the presence of contamination or fines within some piles, and (5) concentrated areas containing wire or fluff in some piles. As a result, proper storage and use of TDF avoid these common characteristics by limiting depth to 12 feet or less, avoiding compaction in storage piles, assuring water drainage from pile areas, and preventing contamination with wire, fluff, fuel, or fines. Design criteria are discussed in more detail in the previously referenced ASTM Standard for Civil Engineering Applications.
- Cash flow: Year-round production and seasonal sales of TDA products require substantial inventory accumulation that can increase working capital requirements. Variations in cash flow can alter business plans.

TDA has a well-developed design data base and broad proven applicability in civil engineering applications in the U.S., but Colorado's experience has been limited. TDA has been used as a vibration dampening sub-base under Denver's Regional Transportation District (RTD) light rail lines. Highway cone support rings cut from passenger and truck tire side-walls are made and used in Colorado.

The biggest challenge to TDA use is educating highway engineers about its design characteristics and demonstrating its performance in actual long-term installations. Gaining acceptance for new materials is a challenge. There is a natural reliance on proven materials and design practices, and an even more natural reluctance to try new ones.

Colorado has limited experience with civil engineering applications for tire-derived aggregate. Discussions were conducted with the Colorado Department of Transportation (CDOT), CDPHE, and representatives of major landfill companies to define existing applications and opportunities for market development. Based on these discussions, the following is a brief summary of findings and suggested steps regarding highway applications and developing major TDA market segments:

4.1.3.1 Highway Applications

There are a broad range of appropriate uses for TDA in highway construction that takes advantage of its unique design characteristics. Some roadway embankment projects in California, Maine, Virginia, and New Brunswick, Canada, have used more than 500,000 waste tires and have saved hundreds of thousands of dollars versus other lightweight fill alternatives. Use of TDA in retaining wall backfill, edge drains, and frost heave prevention are gaining acceptance because of savings. CDOT has expressed interest in increasing its understanding of TDA, its applications, and its potential savings.

Market Development Plans and Accelerators

1. Since education is a critical first step in defining and developing applications for TDA, CDOT and CDPHE have discussed initiating a cooperative effort to offer one or more educational seminars covering TDA design characteristics, practical examples, and long-term results. Sessions could range from a 1 to 2 hour broad overview for management personnel to a 6 to 8 hour short course for design engineers. Value may be maximized by including CDOT central and regional engineers as well as appropriate county engineers. Multiple sessions could be conducted as warranted.
2. The second step is identification of specific projects that could use TDA on state, county, or city projects. Once identified, a recognized expert could be engaged to assist the design team in evaluating the applicability of TDA and incorporating TDA into the design as appropriate.
3. Continuing assistance could be provided TDA specifications, procurement, staging, and installation as appropriate to make initial experiences comfortable and successful.
4. If a larger grant program is initiated, competitive grants could be requested to support demonstration projects and document actual installation under Colorado conditions. If possible, it can be desirable to encourage design engineers to visit these projects during construction.

4.1.3.2 Landfill Applications

There are also a broad range of applications for TDA in modern landfill design and operations. TDA's high permeability makes it suitable for leachate drainage layers and gas collection channels (both lateral, vertical and top). It can also be used to contour the top slope of old landfills prior to final closure. Although Colorado's landfill management companies have extensive corporate experience with TDA use in a variety of applications, its primary use in Colorado has been daily cover.

Market Development Plans and Accelerators

The market development plans for landfill TDA applications are similar to the previously discussed highway steps and could involve the same experts. The main difference is that this is a smaller design and operations group, so the initial educational sessions may best be structured to provide TDA design characteristics, practical examples and long term results, followed by discussion among private sector, public sector and CDPHE engineers about the viability of alternatives in Colorado. A foundation for future use could be developed by discussing appropriate steps in permit modification and required demonstration.

The remaining steps would be similar to highway applications steps 2 through 4. Some grant requests may involve relatively small amounts to support preparation of required permit modification documentation by landfill design consultants. Operators have limited manpower and financial resources for preparation of such documentation, so assistance could significantly accelerate TDA usage in applications other than daily cover.

On-site Waste Water Treatment Systems

TDA has been used extensively as an alternative aggregate in on-site septic system drain fields and channels. The science was pioneered at North Carolina State University and has been used extensively in many states including South Carolina, Vermont, and Florida. Its light weight offers economic and practical advantages in transportation and labor efficiency versus natural aggregate. Its greatest use is in areas with limited availability of aggregate. On a national basis, alternative technologies appear to be displacing aggregate of any type. Infiltrators have become the prevalent technology used in Colorado and reportedly offer installation advantages. Although this application does not appear to offer significant potential, several additional discussions should be conducted with installers, including areas with limited aggregate availability. These discussions will dictate any subsequent market development.

4.1.4 Ground Rubber

Nationally, ground rubber (or crumb rubber) applications consumed 764 million pounds of rubber derived from 56.6 million waste tires in 2011. This amount represents a 38.2 percent increase in the ground rubber market segment since 2005, according to the RMA's 2011 Scrap Tire Market Report (RMA 2011). In 2005, ground rubber markets consumed 553 million pounds of ground rubber. The major increases for the ground rubber were in for use in sports surfacing, landscape mulch, and molded and extruded products.

Ground rubber is derived from two major sources: tire buffings and processed whole waste tires. Tire buffings, a byproduct of the retreading process, are credited with being the inspiration for many of today's recycled rubber products and applications. Molded rubber products have been made from tire buffings for more than 20 years. Once the primary feedstock for manufacturing ground rubber, tire buffings continue to be used in molded and bound rubber products, pour-in-place surfaces, landscape mulch mixes, and more.

An estimated 250 million pounds of buffings are generated annually in the U.S, according to the RMA. This estimate has held steady since 2007. In 2011, the U.S. tire retread industry reported truck tire retreading increasing by 13 percent over 2010 (TRIB 2013). This trend has continued and truck tire retreaders expect increases in 2013 as consumers seek cost savings in challenging economic times. About 150 million pounds of tire buffings are also imported from Canada each year, for a total U.S. supply of 400 million pounds annually (RMA 2011).

Processing whole waste tires into ground rubber involves size-reducing the tires in a multi-stage process using shredders, granulators, and sophisticated separation machinery and systems for removing fiber, steel, and other contaminants. Generally, crumb rubber produced by reducing waste tires falls into sizes ranging from 3/8 inch to 40 mesh particles. Finer grades of ground rubber, from 40 to 200 mesh, typically require secondary and tertiary processing.

Identifying the ground rubber market for waste tires poses particular challenges that make it difficult to provide accurate estimates for the sources of ground rubber and the products and applications that consume ground rubber. Most state agencies do not track this information. Moreover, the major ground rubber processors do not all track the entire market or define ground rubber applications the same way. For example, some sources may include tire buffings in market numbers, while others do not. Additionally, some define ground rubber as coarse material generally ¼ inch or greater in size, and some define crumb rubber as fine material generally of 4 mesh or smaller (Scrap Tire & Rubber Directory, 2013).

Ground rubber is used in a wide variety of applications and products, from flooring and roofing to athletic surfaces and landscape mulch and as an ingredient in asphalt pavement. Overall, applications for ground rubber fall into six major market segments: athletic/recreational surfaces; molded and extruded products; rubber modified asphalt and sealants; tires and automotive; landscape mulch; and export (USEPA 2010). These applications are discussed in the following sections.

Athletic/Recreational Surfaces

Athletic and recreational field applications have emerged as one of the largest and most rapidly growing markets for ground rubber in the U.S. This market segment encompasses the use of ground rubber in synthetic sports turf, natural grass turf, playground cushioning, and playground turf. The Synthetic Turf Council and other industry sources estimate that ground rubber-based sport surfacing has grown to more than 1,000 field installations in the U.S. as of 2012.

This market segment also encompasses ground rubber used as a loose fill (bark and mulch) cushioning under and around play equipment. Ground rubber is also incorporated in pour-in-place protective surfaces and is the main ingredient in molded rubber playground mats and tiles installed in play areas for fall protection and ADA accessibility. Industry reports indicate that there was a slight decrease in ground rubber use in this market in 2011. This estimation is mostly drawn from a few states that report ground rubber use as part of grant program project awards and anecdotally from industry stakeholders. However, no published data on a national scale provide specific quantities of ground rubber used annually for playground installations.

Molded and Extruded Products

Molded and extruded products are one of the oldest uses for ground tire rubber. Molded products have been made from tire buffings for many years but ground tire rubber has replaced tire buffings in many products as the volume and quality of ground rubber produced in the U.S. grew and the range of products and the size of the market expanded. For molded products, ground tire rubber, typically 10 to

30 mesh, is combined with urethane and other additives including plastics, depending on the application.

Molded rubber products are found in diverse applications across many commercial and industrial markets. These markets include but are not limited to flooring, mats, carpet underlay, wheelchair accessibility ramps, roof walkway pads, garden pavers and tiles, wheel stops, traffic control devices, and more. According to the RMA's latest waste tire market data, molded and extruded products are the second largest application for ground rubber from waste tires. These products represented about 32 percent of ground rubber usage in the U. S. in 2011.

A new growth area in the molded and extruded products market is in the use of ground rubber with other rubber or plastic polymers to enhance or modify thermoplastic properties. This application opens up opportunities for using ground rubber in injection molded products and extruded goods. Continuing research and development of products using surface modified and surface treated rubber is expected to further build market potential in this sector.

Tires and Automotive

Ground rubber from waste tires is used in manufacturing new tires, in rubber compounds used to retread worn tires, and in molded and extruded automobile parts. Tire manufacturers report that limited quantities of finely ground waste tire rubber (5 to 15 percent by rubber weight) can be used in some components of the tires. Development of new rubber compounds using tire-derived ground rubber is creating new market opportunities for ground rubber in off the road (OTR) tread rubber compounds and in solid rubber tire retread rubber. Use of ground rubber in automotive and vehicle parts and accessories was up in 2011 and continues today as vehicle manufacturers promote sustainability, environmental responsibility, and use of recycled materials in their products.

Landscape Mulch

Landscape mulch rubber, generally the same material used in loose-fill playground surfacing, is sold to landscape designers and installers, architects, building managers, contractors, and others for use in a wide variety of landscaping and mulch applications. Growth in this market has taken ground rubber directly to consumers through sales in national big box retail outlets such as Home Depot, Costco, Walmart, Lowe's, and others. As a result, a national market and national marketplace presence for ground tire rubber is developing.

Rubber Modified Asphalt

Rubber modified asphalt is a pavement mix that blends ground tire rubber with asphalt to modify the properties of the asphalt in highway construction. Ground tire rubber can be incorporated either as an asphalt binder or as an aggregate. Rubber modified asphalt technology was first introduced more than 30 years ago and has been actively promoted over the past 20 years. Rubber modified asphalt is the third-largest application for ground rubber in the United States, accounting for 11 percent of the ground rubber market in 2011. Until recently, more than 90 percent of the rubber modified asphalt produced has been used in Arizona, California, Florida, South Carolina, and Texas. Many other states, including Nevada, Rhode Island, Washington, Missouri, and New Jersey, have conducted trials and paved test sections of roadway with rubberized asphalt but overall the market for ground rubber in asphalt applications has not expanded significantly.

4.2 Summary of Expansion Opportunities for Beneficial End Uses of Waste Tires in Colorado

Considering the information presented above, the main opportunities for expanding the end use capacity for waste tires in Colorado are:

- Increase consumption of existing cement plants, including using waste tires in heretofore unused places in kilns.
- Bring additional cement plants on line (CEMEX in Lyons and GCC in Pueblo).
- Establish consumption at EVRAZ Steel Mill.
- Increase design applications for TDA in highway and landfill applications.
- Monitor efforts to develop new pyrolysis technologies capable of achieving technical and economic success that has been so elusive historically.
- Begin using crumb rubber in asphalt.
- Increase other ground rubber markets.

4.3 Investment Strategies

In a well-functioning market for private goods, suppliers provide goods and services to consumers at a price that meets the needs of both supplier and consumer. Government intervention in the marketplace can be used when a negative externality exists that needs to be addressed—in this case, stockpiling waste tires. Intervention can be in the form of regulation, but it can also be financial in nature, such as a tax, tax credit, fee, or subsidy to stimulate a desired market.

With that in mind, this section discusses how government activities and funds channeled through the Waste Tire Market Development Fund may be most effective as a complement to the private sector to stimulate both the demand side and the supply side of the waste tire market. This section also outlines public- and private-sector government partnerships opportunities that may serve the overall goal of market development. Finally, this section includes commercial financing options for waste tire enterprises and presents a table that summarizes investment options.

Demand Generation

Sufficient demand is necessary to stimulate development and expansion of private-sector enterprises for retrieving, hauling, and processing waste tires. A key determinant of the ability for newly developed and established enterprises to qualify for commercial financing will be the anticipated product demand, both in terms of reliability of demand and volume demanded. Demand reliability is important for demonstrating a predictable revenue stream over time to potential lenders for private-sector companies seeking finance. The overall volume demanded is especially important for profitability when a large initial capital investment is required. As a portion of the fixed cost of equipment must be recovered from each unit's selling price, and the more units sold, the greater the possibilities to recover initial capital investment costs and remain profitable.

A valuable role for Waste Tire Market Development Fund (WTMDF) would be to fund a marketing campaign to generate demand in the marketplace for Colorado-produced waste tire material, secondary products made from shredded tires, and waste tires to be used directly as fuel. Demand can be from private-sector companies or public-sector agencies, as discussed below.

*Private Sector Demand***:** As is already planned, display and demonstration projects can be effective in promoting the use of waste tire material and waste tires by industry, particularly if coordinated with industry associations.

The WTMDF may consider offering incentives to companies to use these materials, but it would need to consider the cost and complexities of establishing such a program, particularly if there are a large number of buyers. The WTMDF may further consider whether market momentum would be maintained after phase-out of the program.

Public Sector Demand: Government entities, such as the Department of Transportation, public works departments, or recreation departments, can influence the use of tire-derived products through procurement rules and procedures. Departments can purchase waste tire materials through their department budgets, as they would with any other purchase of materials. As interest in the use of waste tire materials develops among government agencies, they may face the issue that it costs more than alternative materials. The CDPHE may want to consider funding a state or municipal grant program to make it financially feasible for agencies to incorporate waste tire materials into demonstration projects within their budget constraints. This support can help to generate a large volume of demand by stimulating public-sector purchases. In some cases, blanket negotiated purchase agreements have been developed to facilitate purchases by multiple agencies. It would be important to have well-defined criteria for grant qualification and awards.

Supply Generation

Supply-side enterprises include companies to retrieve, haul, and process waste tires, assuming that companies interested in using waste tires as fuel already exist and would just be making the decision to purchase raw tires or processed tires as a fuel source. The private sector will be motivated to meet any unfulfilled demand in the marketplace, as long as it is profitable to do so. If a sufficient and reliable demand is created, it will serve as the impetus to initiate or expand businesses, and those that are well managed will survive. Past experience with waste tire product companies in the U.S. has shown that generating supply without sufficient demand or an adequate understanding of the market dynamics can lead to business failures.

Waste Tire Market Development Fund

There are two ways that government finance channeled through the WTMDF may be applied to help develop the waste tire market. One would be to stimulate the demand for TDF and waste tire materials, and the other would be to assist in business development to grow their supply.

To stimulate demand, the WTMDF could issue grants for select activities, such as marketing and training programs or technical and financial feasibility studies regarding use of TDF and waste tire material. As discussed above, grants could be provided to public-sector agencies to help them incorporate waste tire material into their projects. In addition, and as mentioned above, purchase incentives could be provided by buyers, but there is a concern of maintaining a robust market after phase-out of the incentive.

Grants issued to suppliers would potentially introduce distortions to established market by creating an unfair competitive advantage for some suppliers over others who may have already purchased equipment with private funding. The same would be true for tax incentives for equipment purchases. This type of concessionary finance may be best-suited for the demand-generation activates noted above.

The State of California operates a tire grant program through CalRecycle to support activities that help reduce the volume of waste tires. Activities supported include cleanup of tire waste piles, enforcement activities, market development, and demonstration projects. These grants are funded by fees charged for new tires sold in California. Previously, they have funded research, business assistance, product procurement, and amnesty events. The grants are issued to individuals, businesses, local governments, universities, school districts, park districts, and qualified California Indian tribes.

Another type of concessionary finance is soft loans (issued with less stringent terms than commercial finance) for equipment purchases and other capital investments for new and expanding businesses serving the waste tire market. With scheduled payback over time, the WTMDF could operate as a revolving fund that continuously issues new loans as funds are repaid by borrowers. While the advantageous lending terms introduces some distortion to the market, it is much less than with grants. The loans would boost businesses that may otherwise have a difficult time qualifying for loans on the commercial market because of relatively unknown technologies or an undeveloped market sector. This type of loan program would require well-defined application qualification and screening procedures, award criteria, and repayment terms.

Public-Sector Partnerships

Public-sector partnerships include public-public partnerships (PuPs) between two government entities and partnerships between a government organization and a non-profit organization, where neither partner is seeking to gain a profit, but to better serve the public good.

This type of arrangement is frequently seen in the water sector among utilities, where more established utilities help to develop the capacity and effectiveness of partner utilities. However, PuPs are flexible and can be adapted to many situations where there are compatible expertise and a shared vision among two partners to reach a socially desirable goal. There may be modest administrative costs associated with partnership activities, which would potentially come from the WTMDF. It is important to have the following in place when a PuP is developed:

- Shared vision of goals, timeline, and what constitutes effective outcomes
- Memorandum of Understanding or other type of agreement that details each partner's responsibilities and funding commitments
- Common understanding of the ongoing coordination and decision making processes that would be needed to adapt to changing situations
- Clear understanding of the mutual reporting requirements among the partners
- Agreement on which partners may claim credit for program successes for internal organizational and promotional purposes

Some potential partnerships that the CDPHE might consider are:

- Industry Associations: to develop display and demonstration projects, disseminate information on technical and financial feasibility, and to survey members on potential interest in TDF and waste tires material.
- University of Colorado Denver Bard Center for Entrepreneurship: to work with students, faculty, and entrepreneurs to promote potential business opportunities in tire recycling
- State and Local Government Agencies: to implement training programs on use of waste tire material for road projects, civil engineering projects, playground and athletic fields, and other.

Public-Private Partnerships

A public-private partnership is a contractual agreement between a public entity and a private-sector organization, whereby the private-sector partner produces the good or service, with the public-sector retaining large responsibility for the objectives and oversight of the activity. Public-private partnerships can take the form of contracting out, franchising, joint ventures, and strategic partnering.

Public-private partnerships are commonly used when government has assumed responsibility for the provision of a public good or service because an inadequate supply is provided by the market or it is distributed unequally among the population, because of pricing and other reasons. However, the government may not be well suited to efficiently produce the good or service as a result of a variety of considerations that include technological expertise, capital investment requirements, and economies of scale.

By taking advantage of the skills and assets of each partner, a project can be developed to benefit the public in greater terms than if undertaken by one of these partners alone. Each partner contributes in an agreed-on way and shares in the potential risks and rewards. The private-sector partner will be seeking to gain a profit from the partnership, so this type of arrangement is best suited for activities that can be expected to generate relatively predictable income over time to the private-sector partner.

When used for utility operation, there is usually a predictable revenue stream from user fees or other similar payments.

CDPHE should consider whether any of the demand-side or supply-side waste tire market needs are most effectively met by a public-private partnership. Examples would be contracting to marketing for in-state and out-of-state demand generation and training of government entities on uses for waste tire materials in government projects.

Commercial Financing

Loans and lines of credit from a commercial lending institution, issued at a commercial lending rate, would be best suited to well-established enterprises that are expanding their operations to include tire recycling. These enterprises would have established relationships with creditors and proven management capacity that would help to qualify for this type of financing—for example, a successful general hauling company that is purchasing appropriate retrieval equipment or additional trucks to expand into tire hauling, or a recycling facility that purchases equipment and expanded storage facilities to shred waste tires for resale to the secondary market. In the case of the haulers, they would need to demonstrate the anticipated revenue stream from tipping fees and possible purchase fees paid by the tire processor. For the recycling facilities, they would need to demonstrate anticipated revenue from waste tire material sales.

For facilities that would use waste tires as a fuel product, presumably they are doing so because of cost savings over alternative fuels. Should they incur additional up-front costs in equipment needed to adapt to the new fuel, a well-established business would be in a position to quality for commercial financing, particularly by demonstrating the operating cost savings over time by using this fuel over more expensive alternative fuels. Table 9 presents a summary of potential enterprise capital funding needs, financing options, and risk factors, among other considerations.

Table 9: Summary of Investment Options

Activity	Potential Market for Product/Service	Major Investment Requirements	Financing Options	Revenue Source	Key Risk Factors for Profitability
Tire retrieving and hauling	Fairly developed	- Retrieval equipment - Trucks - Worker training	Commercial finance for established enterprises	- Tipping fees - Possible purchase fees from processing facility	Reliable stream of waste tires
Tire processing and delivery for secondary product or fuel use	Somewhat developed	- Storage facility - Processing equipment - Worker training - Trucks	Commercial finance for established enterprises	Sales of processed tire material	- Reliable stream of waste tires - Sufficient demand - Changes in fuel costs
Pyrolysis plant	Variable	- Processing equipment - Storage facility - Safety equipment - Work training	Commercial finance difficult because of the history of failures among pyrolysis plants	- Tipping fees - Sale of primary and secondary value-added products	- Operating problems - Fluctuating market prices -Uncertain product demand - Changes in fuels costs - Changes in environmental disposal fees - General economic fluctuations (impacting labor and general operating costs)
Molded Products	- Second largest application for ground rubber - Versatile, variety of products	- Processing equipment - Product testing (for new products) - Distribution and marketing	Start-up finance Assistance from WTMDF	New product sales	- Changes in market demand for certain products - General economic fluctuations (impacting labor and general operating costs)

Activity	Potential Market for Product/Service	Major Investment Requirements	Financing Options	Revenue Source	Key Risk Factors for Profitability
Playgrounds/Athletic Field Construction	Large market and rapidly growing	- Equipment (minimal) - Work training	Start-up finance Assistance from WTMDF	New product sales	- Changes in market demand - General economic fluctuations (impacting labor and general operating costs)
Existing businesses incorporating waste tire materials into existing projects or as fuel					
Landscaping Use **Road Paving** **Civil Engineering Projects** **Electric Power Plants** **Cement Plants** **Steel Plants**	NA	Adaptation to new raw material or fuel	- Existing lines of commercial credit or internal funds - WTMDF assistance, especially for public sector entities	Existing product sales	Problems adapting to new raw material or fuel resulting in unanticipated costs

5.0 Market Development Plan

This section builds off of the previous sections of this report to outline the recommended plan for developing and engaging waste tire reuse and recycling capacity necessary to consume 100 percent of newly generated and stockpiled waste tires in the state. For this plan, the date for achieving this goal is December 31, 2024; the number of tires in monofill storage and legal stockpiles is estimated to be 61.2 million; and there are an unknown quantity in illegal stockpiles and dumps within the state. The number of waste tires annually generated is estimated to be an average of 6 million tires per year, reflecting growth in Colorado's population and economy. This section presents a conceptual model of the sources, processors, end uses, transport pathways, and tire flow volumes that are relevant to achieving this goal. This section also presents a Gantt chart that shows the chronology of the main steps recommended to achieve this goal and a monitoring plan that assesses and promotes the effectiveness of the recommended steps.

5.1 Conceptual Model of the Goal State

Whereas Figure 1, introduced in Section 2, diagrams the waste tire flow system in Colorado based on 2011 information, Figure 5 represents the state's waste tire flow system based on the updated information presented in this plan. This figure also presents the end use alternatives that are judged most likely to succeed in achieving the goal of 100 percent recycling or beneficial use of the state's stored and monofill storage and annually generated waste tires. The white arrows on Figure 5 represent the "goal state" -- the average annual waste tire flows and consumption rates that will need to be maintained in the system over a 10-year period to achieve 100 percent beneficial consumption by 2024.

It is important to understand that this system is highly dynamic: during early years, end use capacity will likely be building up, while during middle years, end use consumption will likely be at is highest, and during the later years, end use consumption rates will taper down as the monofill waste tires are depleted.

Furthermore, as efforts to build end use capacity progress, it may turn out that some end uses expand more rapidly than others, so the flow and consumption rates shown on Figure 5 could alter significantly. Nevertheless, Figure 5 reflects the end uses that are believed to be most capable of success, and hence, are worthy of pursuit at this point. Figure 5 also illustrates relative flow and consumption rates that are reasonable for these alternatives.

In comparison to the 2011 waste tire flow system, the goal state system exhibits the following similarities and differences; significant assumptions are also listed:

1) Annual generation increases to 6.5 million waste tires per year, reflecting the updated values presented earlier in this plan.
2) Grading flows remain the same as in 2011.
3) Illegal transportation and dumping are assumed to have essentially ceased (the flow arrows for these are no longer represented on the figure) as a result of increased enforcement, tracking, and more strategic financial incentives.

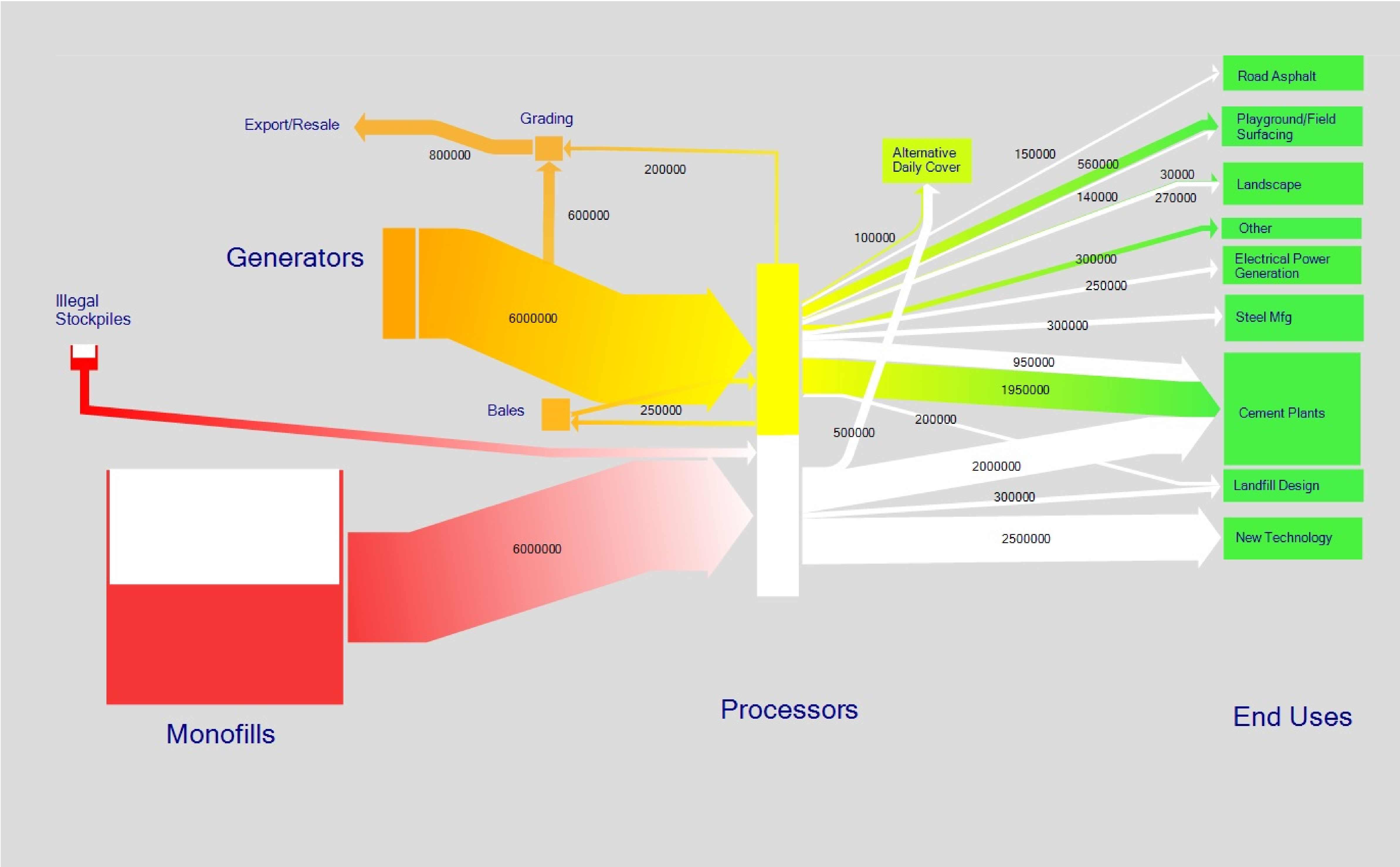


Figure 4
Goal State for Average Annualized Waste Tire Flow System

4) Monofills and illegal dumps are being depleted of their waste tires. At the end of the 10-year period, the monofills should be completely depleted.
5) The additional waste tire flows that are needed (white arrows), and the flows already being realized (colored arrows) are shown via arrow widths and directions. The larger of the additional waste tire flows are also shown numerically.
6) Alternative Daily Cover and Baling decrease to minimal usage for specific needs where tire-derived products are uniquely suitable and monitored.
7) Additional annual flow rates of waste tires from monofills equates to 6 million tires per year (average), plus a quantity from illegal stockpiles estimated to be 500,000 tires per year. Note that current owners of the two largest monofills have indicated that they will increase market capacity to a level that could consume the majority of the monofill tires. Based on current information, these markets are included within energy market development that will be driven by the monofill owners. If these plans fail to be implemented, the State would then need to choose whether to accelerate its market development plans to utilize as many monofilled tires as possible, or to close the sites using financial resources from the owners. Nevertheless, this figure presents other beneficial use markets that may be extended if current monofill owners are unsuccessful in fulfilling current intentions.
8) Additional processing is developed in order to handle the additional flow from the monofills.
9) Additional end use capacity is developed for the existing end uses of playground/field surfacing, landscaping, TDA, and cement plants.
10) Pyrolysis, or an alternative technology at the Hudson Tireville (CH2E) is effective and depletes the Hudson monofill of 2.5 million waste tires per year over the entire 10-year period.
11) CDOT begins to use crumb rubber in road asphalt and increases in other ground rubber markets consume 200,000 waste tires per year; the ability to generate this much crumb rubber is developed through increased processing capacity.
12) The steel plant builds an average waste tire consumption capacity of 300,000 tires per year.

5.2 Action Sequence

Figure 6 is a Gantt Chart that presents the schedule (sequence) of actions that need to be taken to engage the opportunities identified in Section 4.0 so that the goal state represented on Figure 5 can be realized.

The steps presented on the Gantt chart are necessary to connect the organizations, people, information, and funding needed to capitalize the opportunities presented in this Waste Tire Market Development Plan.

5.3 Monitoring Plan

This Waste Tire Market Development Plan lays out steps leading to the beneficial use of all waste tires produced and stored in the State of Colorado. Some of these steps can lead to new technologies; others to expanded end uses with existing entities. Many of these steps need to be advanced iteratively while monitoring the resulting change in beneficial use capacity. Some steps may lead to more beneficial use than predicted, other steps may consume less than intended. As the program advances through these steps, it will be important to regularly monitor the results that are being gained, the overall status of the system, existing and perhaps new influences, and then to adjust activities accordingly to garner the most valuable increases in beneficial use for the state and its citizens. Waste tire market development is a marathon, not a sprint, and requires a thoughtful plan, experience and perseverance.

To this end, a Monitoring Plan should be implemented that involves a combination of quarterly status reports delivered to the Waste Tire Committee, and collaborative meetings with the Waste Tire Committee to discuss these reports and refine next steps. The quarterly report should center on these three components of this Marketing Plan:

1) Gantt chart. The Gantt chart should be updated and presented to the Waste Tire Advisory Committee on a quarterly basis, with percent complete represented for each task, and a discussion of progress made, factors concerning task success, hurdles, recommended course corrections, and lessons learned.

2) Goal State Figure (Figure 5 in this plan). This figure should be updated periodically using currently available information and then used to monitor the status of monofills (how many tires remain), processors (how many tires are being processed), end users (how many tires are being beneficially used), flow paths, and haulers, and to maintain a flow balance that does not allow tires to be untracked within the system. The updated goal state figures can be compared with the earlier versions, including Figure 5 in this plan, to assess the actual performance being obtained by the market development efforts.

3) The Distribution of Current Colorado Waste Tire generators, Monofills, Processors, and Existing Major end users (Figure 2 in this plan) should be updated periodically and used to track the location and status of illegal dumps, progress of remediation, and other project elements including contractor activity and progress. Opportunities for local beneficial consumption of illegally dumped waste tires could also be evaluated from this figure.

Based on review of these elements of the Monitoring Plan, the Waste Tire Advisory Committee can identify steering actions designed to best advance the progress of the Waste Tire Market Development for the subsequent quarter. These actions will address the previous results and circumstances, and new developments, to best advance Colorado's waste tire system toward the beneficial use of all of the state's stored and annually generated waste tires.

Colorado Waste Tire Market Development Plan
Schedule
CDPHE and Waste Tire Advisory Committee

ID	Task Name
1	QUARTERLY MONITORING REPORTS AND MEETINGS
2	REGULATORY DEVELOPMENT
3	MODIFICATIONS
4	Identification of Conceptual Alternatives
5	Conceptual Agreement
6	Legislative and Regulatory Development
7	Legislative Interaction
8	Legislative Introduction
9	Legislative Support
10	
11	STOCKPILE PROGRAM
12	CDPHE Takes Direct Control of Cleanups
13	Develop/Map Site List
14	Examine Sites/Prepare Summaries
15	Prioritize Sites
16	Develop Contractor RFQ
17	Develop Site Bid Document
18	
19	MARKET DEVELOPMENT
20	CIVIL ENGINEERING
21	CDOT APPLICATIONS
22	Develop Educational Seminar Plans
23	Implement Seminars
24	Initiate Project Identification
25	Assist Project Design
26	Assist Project Implementation
27	
28	LANDFILL APPLICATIONS
29	Develop Educational Seminar Plans
30	Implement Seminars
31	Initiate Project Identification
32	Assist Project Design
33	Assist Project Implementation
34	
35	ENERGY/FEEDSTOCK UTILIZATION
36	Assist Cement Company Evaluations
37	Assist Cement Plants as Warranted
38	Assess Biomass Facilities/Plans
39	Assist Steel Mill Evaluations
40	Support Renewable Energy Designation as Warranted
41	
42	GROUND RUBBER
43	Assess Processing Capabilities and Needs
44	Identify End Users by Category
45	Explore Educational Seminars/Meetings/Needs
46	Develop Educational Seminar(s)Plans for RMA
47	Implement RMA Seminars
48	Identify Specific Market Accelerators
49	Implement Feasible Accelerators
50	Explore Public Information Needs and Vehicles
51	Identify Targeted Markets for Initial Demonstration Grants

Task Summary

Thu 5/9/13

TETRA TECH

6.0 References

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