7th ANNUAL REPORTED WASTE & RECYCLING FACILITY FIRES US/CAN

2023

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2023 REPORT
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About the Author: Ryan Fogelman

Ryan Fogelman, J.D./MBA, has been a partner with Fire Rover since 2015. He focuses on bringing innovative safety solutions to market, and two of his solutions have won the distinguished Edison Innovation Award for Industrial Safety and Consumer Products. He has been compiling and publishing the monthly "Reported Waste & Recycling Facility Fires in the US/CAN" reports and the "Waste & Recycling Facility Fires Annual Report" since 2016. Fogelman regularly speaks publicly and gives presentations about the scope of fire problems facing the waste and recycling industries, early detection solutions, proper fire planning, and early-stage fire risk mitigation. Additionally, Fogelman serves on the Technical Committee for Hazard Materials for the National Fire Protection Association (NFPA).

Fogelman received his Juris Doctor (J.D.) and Master of Business Administration (MBA) from Case Western Reserve University School of Law and Weatherhead School of Management. He also received a bachelor's degree in general business administration and pre-law from Michigan State University's Eli Broad College of Business. Additionally Fogelman is earning a certificate on lithium-ion batteries through the Battery.MBA.

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The entire body of work published by Fogelman is available on LinkedIn. Readers may access his articles at www.linkedin.com/in/ryanjayfogelman/.

Image: Ryan Fogelman, J.D./MBA (2023)

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Acknowledgments

Firstly, I want to acknowledge the massive impacts of fires on the financial and human resources of governments and companies that operate waste and recycling facilities and collection fleets, the mental well-being of those individuals who work every day, and the environment. Minimizing the negative impacts of fires is the driving force behind what we do at Fire Rover.

I would also like to acknowledge the **early adopters of Fire Rover solutions** and all our customers within the waste and recycling industry. They welcomed us to their operations and allowed us to prove ourselves. Without these leaders, Fire Rover would not have the excellent use cases we share with the rest of the industry today. I am indebted to them.

The co-inventors and co-founders of Fire Rover, **Brad Gladstone, Pete Marry, and Jeremy Dusing**, have been integral to the success of our company and the solutions it offers. They have earned their stripes repeatedly, and we have put together something beneficial to the waste and recycling industry, communities, and the environment. Thank you for your partnership.

I want to draw attention to the friendship, dedication, and inspiration of Gladstone, the driving force behind Fire Rover, who unfortunately is not with us today to see his dream come true. I had known Gladstone since high school, and “protector” would perfectly sum him up in one word. He had a reputation for protecting his family, friends, and customers with a zeal unlike anyone else.

I want to thank those fire experts from inside and outside the waste and recycling industry who have helped me learn and understand fires, the issues we face, and how we can safely fight these issues on the frontlines. These include **George Thompson, Ph.D.**, President & CEO of Chemical Compliance Systems, Inc., **Jim Emerson** from Starr Insurance Companies, **Ronald Butler** of Energy Storage Safety Products International, **James “Andy” Lynch** of Fire Solutions Group, **Andrew Starnes** from Insight Fire Training, and countless others whose names I fail to mention but owe a deep debt of gratitude.

Additionally, I would like to recognize **Fire Rover’s critics** and those who have provided feedback on our solution over the years. Thank you. We learn the most valuable lessons when we listen to the criticism of wise people and act upon it. Hopefully, we have done right by them and improved our service offering and technology in line with their thoughts. Please do not hesitate to contact me about ways to enhance and protect your facilities.

Lastly, thank you to those who peer-reviewed this report and offered ways to improve it this year and maximize its future benefit, including **Ashlea Smith** of Gershman, Brickner & Bratton, Inc. (GBB).

About Fire Rover

Fire Rover is a remotely operated fire detection and suppression solution that works 24/7/365 to protect facilities worldwide by detecting and extinguishing fires before they start. Fire Rover achieves early detection of fire incidents using military-grade thermal detection equipment, smoke analytics, optical flame detectors, and high-definition video to facilitate final verification by human agents and targeted fire suppression using onsite, PFAS-free firefighting agents.

Brad Gladstone, Pete Marry, and Jeremy Dusing developed the Fire Rover solution and filed a patent for it in 2015. Since then, the solution has grown to protect over 600 facilities in five countries, including the U.S., Canada, Australia, the UK, and France. Fire Rover protects facilities that process waste and commingle recycling daily, including metals, paper, plastics, and other hazardous materials.

According to our 2022 and 2023 Performance Scorecards, included below and in more detail in Section 7, Fire Rover's solution performance has improved in the last year. "System pressurizations" is the critical line to look at this year. In 2023, our systems pressurized 301 times, hotspots, or actionable fire incidents we observed at one of our 500+ installations worldwide. This is down from 24.4% in 2022. Every time we pressurize a system, we must purge the line, so fewer pressurizations mean less waste. The systems are observing more hotspots, are being more discerning about which to act upon, pressurizing our systems less, and activating only when necessary. All of this results in less waste. Like last year and the years before, I am proud to say that no catastrophic losses of life or assets started in any of the area we protect.

Table 1 - Fire Rover's Performance Data (2023)

FIRE ROVER SOLUTION PERFORMANCE 2022 & 2023

Performance Indicator	Total Events 2022	Total Events 2022 (%)	Events Per System 2022	Total Events 2023	Total Events 2023 (%)	Events Per System 2023	% Change ('22-'23)
Actionable Fire or Hotspot	1409	100.0%	4.56	1809	100.0%	4.09	28%
System Pressurization	344	24.4%	1.11	301	16.6%	0.68	-13%
Fire Suppression Activation	137	9.7%	0.44	183	10.1%	0.41	34%
Fire Dept / Fire Brigade Dispatches*	146	10.4%	0.47	217	12.0%	0.49	49%
Catastrophic Losses in Areas Fire Rover Protects	0	0.0%	-	0	0.0%	-	0%

Fire Rover has proven that it can help shield the waste and recycling facilities from catastrophic fires and help the solid waste management industry recover from a decade-long plague of infrastructure-destroying fire events.

With Fire Rover, we are ushering in a new era of targeted fire suppression with minimal negative impacts on the environment, human health, and operations. Gone are the days of massive deluges drowning everything in their path, thanks to Fire Rover's efficient and effective firefighting strategies and remote-operated solutions.

By harnessing advanced technologies, Fire Rover empowers facility managers by helping them get back to work sooner, with minimal downtime and minimized collateral damage. This means that we are not only preventing the destruction of our waste management infrastructure but also mitigating the potentially devastating consequences of these massive fires on the environment.

Beyond where their systems are typically found today in materials recovery facilities (MRFs), they can be found in waste processing facilities, C&D debris recycling facilities, and waste transfer stations. We can expect to see more of them at composting facilities, battery storage facilities, landfills, construction sites, demolition sites, and more with their flexible solutions being developed.

To learn more about Fire Rover and see a solution demonstration, visit www.firerover.com.

Thank you.

Important Notes on Terminology

Like Fire Rover, this report spans two industries: Fire Protection and Solid Waste Management. Throughout this report, you will find references to both sectors; however, for the reader's sake, I will do my best to identify which industry to use. When in doubt, any reference to "our industry" means the Solid Waste Management industry.

Fire Protection Industry Terms

The terms "fire incident" and "fire" are used interchangeably throughout this report. To reduce confusion, please continue with the following understanding:

- A **hotspot** represents a thermal anomaly compared to a fire incident or event where flames are present.
- A **fire incident occurs when smoke and/or flames are present. The progression or severity of fire incidents or events may be described between level 1, "Pre-Incipient Stage," and level 6, "Major Fire Incident," whether or not they are** reported.
- Not all fires are reported. If a fire is not reported, there may be no way to know it occurred. This report presents information about **reported fires**. *See Figure 9 on page 23 for a description of the six stages of a fire incident.*
- If you are curious about the definitions of "one-alarm fire," "two-alarm fire," and beyond, these terms are not strictly defined across North America. Like how "10-codes" vary between police departments across the U.S., "alarm codes" differ between fire brigades. Visit Wikipedia to learn the basics about multiple-alarm **fires.**

Waste and Recycling Industry Terms

Below are some of the more common terms you will encounter in this report. To learn more, the Solid Waste Association of North America (SWANA) has compiled a comprehensive list of standard terms and their definitions for your reference.

- **Municipal Solid Waste (MSW)**: Non-hazardous solid wastes from commercial, residential, and institutional sources, also known as "garbage," trash," and "waste."
- **Recycling:** The process of sorting, collecting, processing, transforming, marketing, and converting or remanufacturing a discarded material into a recycled material or product, including the administration thereof.
- **Recyclable materials**: Vary by region based on what a municipal recycling program will accept and process at a **materials recovery facility (MRF); recyclable** materials can be recycled into recycled materials or products.
    - Common recyclable materials include **Paper** (i.e., office paper, newspaper), **Plastics** (#1-#7 containers, milk jugs, soda bottles), **Cardboard** (also known as Old Corrugated Cardboard ("OCC")), **Construction & Demolition (C&D)** debris, **Metals** (aluminum or steel cans, scrap metal), and **Glass** containers.

1 Introduction

So, the 2023 numbers are in, and the good news is that we had fewer reported fires in 2023 than in our prior high watermark hit in 2022. In 2023, it finally feels like the tide is turning. This is excellent because it seems to result from the steady adoption of Fire Rover solutions across North America at waste and recycling facilities. It feels like we have finally proven that the Fire Rover solution works!

Unfortunately, the overall decrease in reported facility fires includes some increases within specific categories, and we cannot ignore the fact that the past three years have seen our highest numbers of reported fires at US and Canadian waste and recycling facilities since I began consolidating and reporting the data in 2016. But I hope that these reported fires will continue to decrease (even with the increasing threat of lithium-ion batteries in our waste and recycling streams) as the industry continues to improve operational performance, educate the public, and we see an increase in the investment in and utilization of solutions like Fire Rover.

My team at Fire Rover has installed over 500 (607 as of this publication) of our early-detection fire response solutions globally. We know we are gaining more knowledge about which sites are having issues and which are not. Our performance has become extremely important for insurance companies in understanding and comparing risk mitigation with traditional fire protection solutions.

This year's report includes a more detailed section dedicated to Fire Rover performance. This data will include two full-year's of data highlighting the number of fire/ hot spots responded to, the number of pressurizations of our systems, the number of times we suppressed fire, and the number of dispatches to the fire professionals/fire brigade. See Section 7 starting on page 47.

We will also have the latest death/injury report, which shows that over 9% of these 373 fire incidents we incurred in 2023 had an injury or death, which typically comes to the extent of the fire professionals brought in to fight these fires once they have gotten out of control. See Section 8.1, which begins on page 58. And a state-by-state (province-by-province) analysis of your state's performance from a tonnage, number of fires perspective, and much more data and information.

Here is to a better 2024. I hope we reach our goal of fewer "major" and "catastrophic" fires at our waste and recycling facilities. To stay current on this data year-round, please subscribe to my Fire Safety Report newsletter on LinkedIn at: https://lnkd.in/gjwNpSph.

Fire Rover is what is stopping catastrophic fires at waste and recycling facilities in the US and Canada!

Why are US and Canadian waste and recycling facility operators leading the world in containing lithium-ion battery hazards? …Because they are adopting Fire Rover solutions, period.

It comes down to the US and Canada adopting the Fire Rover solution over Automatic Systems. 100% so-called “automatic systems” come with many downsides that the Fire Rover solution solves:

- The need for daily checks: Fire Rover is constantly checking for issues and fixing them remotely and on-site when necessary
- There is a lack of an intelligent suppression system like Fire Rover’s.
- Cameras are not adapting to the new position, causing issues with guiding risers.
- In outdoor use, a system that is not smart enough to adapt to environmental conditions, like a 32 kph side wind, requires the aim of a suppression cannon to be adjusted a few degrees to the right or left to hit the hotspot.
- False alarms: automatic systems are prone to them
- The potential threat to the operator’s safety – if an operator comes in with a fire extinguisher to start putting the fire out, the camera could detect and start too, placing the operator in danger and potentially pushing him into the flames: it cannot see a human and protect them!
- These canons are all about water, water, water – we at Fire Rover are all about using water intelligently and avoiding deluges that become environmentally problematic firewater.
- There are no programmable cameras can scan the entire area simultaneously, as Fire Rover's cameras do. Other cameras scan the area bit by bit and respect the VdS standard, meaning they must scan the whole area in less than 120 seconds. 120 seconds is a long time in the firefighting business. If you imagine the camera scanning an area with a threat under the temperature threshold, we will wait another 2 minutes before anything happens! 2 minutes in W&R can be dramatic!
- They only use thermal scanning and do not have thermal, flame and smoke.

The proof is in the pudding. I invite anyone who wants to learn more and invest in a Fire Rover solution to call me so I can arrange a tour at one of global demos sites currently located at our headquarters in Detroit, Michigan, along with our newest demo sites in France, UK and Australia.

2 The Causes

So, what causes most of the fires at waste and recycling facilities? If your guess is lithium-ion batteries, you would only be partially correct. As described below, there are many other causes of fires at North American waste and recycling facilities.

What Is Causing The Fires?

1. **Traditional Fire Hazards:** Unknown hazards of combustibles (i.e., aerosols, butane cans, chemicals, hot ashes, paints, fireworks).
2. **Lithium-ion Batteries**: The issue is not only the shire number of these batteries being manufactured and placed incorrectly in waste and recycling bins, but also the size makes them almost impossible to remove from the processing streams.
3. **Heat/Dry Environments**: We have seen an increase in fires during the summer months, but when we see weather patterns that are dry and hot, we see spikes during other times of the year.
4. **Inherent Risk**: Recycling chemicals and hazardous materials has explosive and combustible risk built in, especially when increased temperature is required as part of the recycling process.
5. **Sparks/Hot Works**: As buildings/equipment age or volumes increase, more work is required to maintain the equipment.
6. **Arson:** Competitive and desperate operators.
7. **Staffing:** It is hard to find good reliable staffing in the current environment. Our operators need to be fully staffed to process material efficiently.

Figure 1- Summary of Causes of Fires in the Waste & Recycling Industry

While the cause categories differ in name and order, the ignition risks are all related; the Waste Industry Safety and Health (WISH) Forum in the UK did a fantastic job summarizing the unique safety issues of waste and recycling processing facilities in its guidance document, "Reducing Fire Risk at Waste Management Sites".[1]

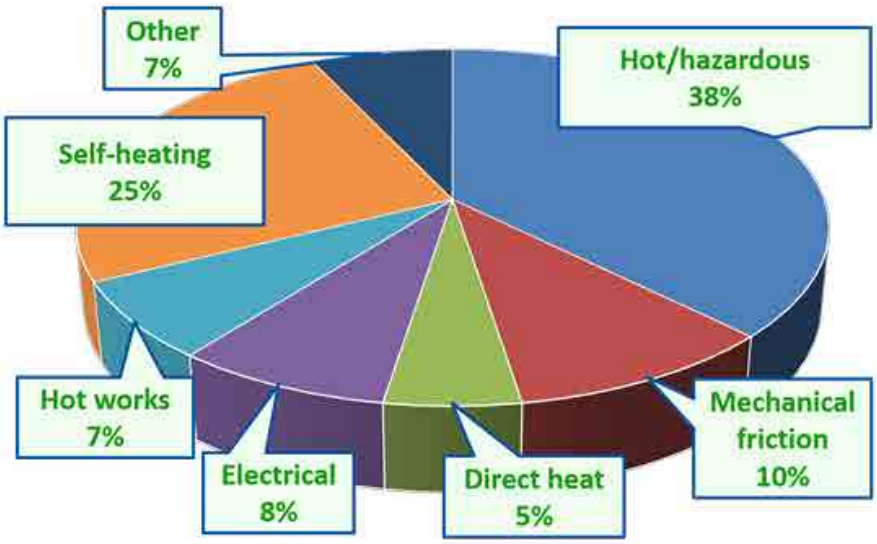
> *"Waste management sites are not warehouses, offices, or shops. Wastes are not standard stored products. Applying traditional fire systems to waste management sites/plants risks any system being ineffective during a fire. Knowledge of how waste burns and which types and specifications of fire systems are effective with waste fires is a rapidly developing area. What was acceptable five years ago is unlikely to be acceptable today. You may be able to identify fire engineering guidance and standards that apply to your waste management operations. However, you must also ensure that*

[1] Document download link (WISH Forum, "REDUCING FIRE RISK AT WASTE MANAGEMENT SITES", published March 2020, refer to pages 20 and 119, PDF): https://www.wishforum.org.uk/wp-content/uploads/2020/05/WASTE-28.pdf,

these are up-to-date and still relevant. The rapid development of understanding in this area means that standards based on older assumptions may no longer be valid.

"One of the major waste management companies [assumed to be in the UK} recently analyzed its fire report data. From five years, this data covered 120-plus sites and more than 300 reports of fires/smolders. This analysis was for general waste recycling and recovery type plants, […] the most likely causation of fires. The analysis provides some interesting data:

- *38% of fires were likely caused by hot or hazardous materials and items in wastes accepted at sites, such as hot ashes, lithium, vehicle and other batteries, gas cylinders, flammable liquids, aerosols, etc.*
- *25% of fires were likely caused by self-heating, both in waste reception and storage*
- *5% were likely caused by hot surfaces, 8% by electrical faults, 7% by hot works such as welding and grinding, and 10% by friction*
- *The remaining fires were caused by a variety of other smaller likely causes."*



Note – the data above is from one larger company with a wide range of recycling and recovery plants. This data may not reflect your specific situation, although it does give a starting point in terms of the common causes of waste fires.

Figure 2 - Overview of Causes of Fires in Waste Facilities, *Source: WISH Forum (UK)*

2.1 Traditional Fire Hazards

The modern waste and recycling industry has been plagued with fire hazards throughout its operational history. For the sake of shorthand, let us call them "traditional fire hazards." This section discusses the myriad risks we see on the frontlines of solid waste processing.

Although it would be impossible to list each hazard, I have included examples below of traditional fire hazards Fire Rover has witnessed during its operations:

- Pressurized Containers: (oxygen tanks, propane tanks, aerosol cans)
- Oil and Chemicals: (chlorine, paint thinners, accelerants)
- Equipment Failures: (metering drums, forklifts, loaders)
- Byproducts: (auto shredder residue, sawdust, rubber shredding)

Jim Emerson, engineering manager at Starr Insurance Companies, is a fire engineer that I worked with to develop the Combinational Approach™ to firefighting (see the appendix that begins on page 99); he believes that the public unknowingly places "explosives" in the trash.

> *Imagine a homeowner doing some light renovation around their house. In this case, they are painting several rooms. After completing the project, they put the rags soaked in paint thinner in a plastic garbage bag and tied it tightly to keep the smells to a minimum. Then, they place the bag into the garbage cart and leave it by the curb for collection. While at the curb, the cart is subjected to sunshine, which heats the cart's contents for hours. When the garbage truck finally comes and tips the cart's contents into the back of the truck to compact them, all that would be required to cause an explosion is a spark from a compacted aerosol can. This is just one example of how easily "explosives" unintentionally enter the waste stream.*

2.2 Inherent Risk

Several activities in the waste and recycling industry require heat, pressure, or shredding to complete the job. For example, in environmental services, the liquid hazardous material is mixed in large pits with flammable material like sawdust to help solidify it for the landfill. At Fire Rover, we have seen something as simple as friction cause an explosion in this material. Unlike fires that start after something goes wrong, a recycling process that is "controlled" can also get out of control and cause a fire incident. The solution we deploy to protect these facilities is unique in that we monitor and detect fires that are "out of spec" to ensure the operations stay safe from them.

Also, educating the public on the dangers of improperly disposing of items that cause fire hazards in the waste and recycling streams is a worthy endeavor. We cannot "educate our way out of" this problem. We must anticipate that waste streams contain infinite materials, some of which should not mix or be dangerous. Back-end protection to deal with a potential yet inherent fire hazard. For a high-level introduction to inherent risks faced by the waste and recycling industry, listen to my recent interview on the Impact Podcast by John Shegerian in November 2023:

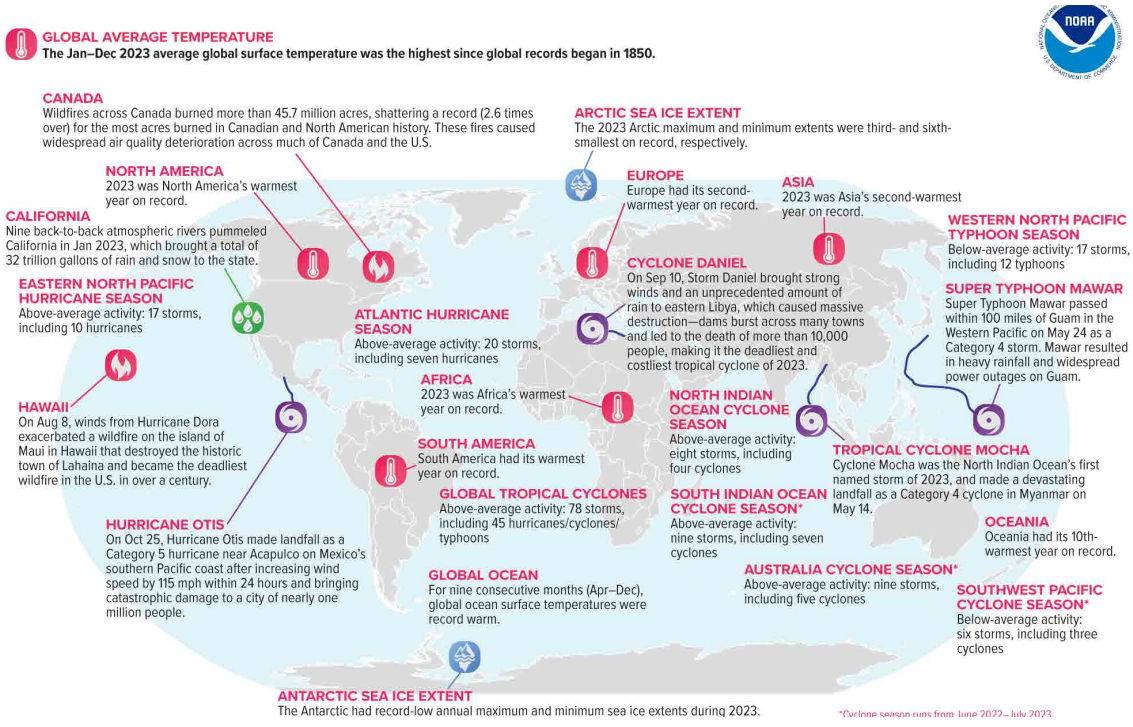
2.3 Heat and Dryness

Over the past eight years, there has been a trend of increasing fires during hotter months. According to the 2023 Global Climate Report published by the NOAA National Centers for Environmental Information, July 2023 was the world's hottest July, and 2023 was the world's hottest year in the 1880-2023 record.[2]

> *The Northern Hemisphere summer season (June–August) was the warmest on record, and the Northern Hemisphere autumn (September–November) was not only the warmest such period on record, but it exceeded the previous record from 2015 by 0.39°C (0.70°F) and was the largest positive seasonal anomaly for any season on record in the Northern Hemisphere.[3] The globally combined land and ocean surface average temperature in 2022 was 58.55 degrees Fahrenheit, 1.55 degrees Fahrenheit above the 20th-century average.*

Worldwide, we are experiencing hotter summers and dryer winters. Even if this is anecdotal, this cause will only become more important as we face continued global warming.

Figure 3 - Selected Significant Climate Anomalies and Events in 2023 (Source: NOAA)



[2] Website (NOAA, "2023 year-to-date temperatures versus previous years"): https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202313/supplemental/page-1

[3] Website (NOAA, Global Climate Report: 2023): https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202313)

2.4 Seasonal Spikes

For many years, we have experienced seasonal spikes in fire incidents during the summer and end-of-year holiday seasons due to increased temperatures and/or hazards entering the solid waste streams. We tend to see more propane tanks, fireworks, charcoal, and other flammable or explosive dangers enter the waste and recycling streams during the summer months, and we see an increase in the number of lithium-ion batteries in toys, gadgets, and other electronics during the end-of-year holiday season.

One of the main drivers of the increase in reported fire incidents from residential waste streams that culminate into the "summertime spike" is the result of annual spring cleaning and house projects. Those who take the easy way out and toss hazardous items such as fertilizers, pool chemicals, barbeque hot ashes, fireworks, paint thinners, and more in our curbside bin (instead of taking them for proper disposal at household hazardous waste drop-offs) are partly responsible for 50% of the fire incidents we experience in our waste and recycling facilities on an annual basis.

In 2023, we saw a seasonal spike in waste and recycling facility fires during the summertime, extending into September, which were also some of the hottest months in history.

- three months in 2023 topped the charts for the most fire incidents in a month since I began tracking the data in 2016: February: 28, May: 50, and July: 39.
- In May and June 2023, the US and Canadian waste and recycling industry incurred 50 and 44 reported fire incidents, respectively.
- From July through October, we incurred 39, 37, 29, and 27 each month, and
- Then, the monthly fire incidents tapered to about 20 per month in November and December.

As the second half of 2023 unfolded, we were pessimistic that we might have the most fire incidents in a year yet again, just like the trend had been every year since 2016. However, we were fortunate to see the number of monthly fires decrease to 16 in December, the lowest number we have experienced during December since I began reporting these events. I am cautiously optimistic that we will continue to plateau in 2024 or experience a downward trend. Still, I keep in mind that 2023 (with 373 fire incidents) was only second to 2022, which had 390 fire incidents and was our worst year on record for reported fires.

2023 COMPARED TO PRIOR YEARS REPORTED WASTE & RECYCLING FACILITY FIRES

Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
2019 27	**2023 28**	2018 38	2021 46	**2023 50**	2022 50	**2023 39**	2019 40	2019 36	2022 38	2020 28	2021 29	2022 390
2023 26	2022 25	2021 31	2022 39	2022 49	**2023 44**	2019 38	2022 38	2017 35	2020 33	2021 25	2016 26	**2023 373**
2022 25	2018 23	2019 24	2018 37	2021 44	2018 41	2016 37	**2023 37**	2022 33	2018 29	2018 24	2019 24	2021 367
2020 22	2020 21	**2023 21**	**2023 35**	2018 41	2021 37	2021 37	2018 35	**2023 29**	2017 28	2017 21	2017 23	2018 365
2018 22	2016 20	2022 21	2019 32	2019 30	2017 35	2017 36	2017 34	2020 28	2019 27	**2023 21**	2020 23	2019 345
2021 20	2021 18	2016 20	2020 25	2020 28	2016 35	2018 33	2016 30	2021 27	**2023 27**	2019 20	2022 22	2020 317
2017 17	2017 17	2020 18	2016 22	2017 17	2020 34	2022 32	2020 30	2018 24	2021 24	2016 19	2018 18	2016 272
2016 4	2019 14	2017 14	2017 13	2016 16	2019 33	2020 27	2021 29	2016 21	2016 22	2022 18	**2023 16**	2017 290

Source: Ryan Fogelman, rfogelman@firerover.com

Figure 4 - 2016-2023 US/CAN Waste & Recycling Facility Fires by Month

2.5 Sparks/Hot Work

If you work in the solid waste management industry, you may know that hot work activities occur daily at some facilities. Hot work is when cutting, welding, or heating is typically used to install, maintain, and/or fix equipment. At Fire Rover, we have experienced fire incidents due to embers flying into areas like the rafters or under equipment during hot work, where they cause fire incidents after the hot-work activities, sometimes hours later.

2.6 Arson

Arson is far from a fact of life; it is the criminal act of purposefully setting fire to property and is often highly destructive. However, it is also often hard to prove. I would be remiss to believe that fires set for reasons of compulsion, retribution, “insurance benefits,” or “competitive advantage” are not risks when they certainly are. For instance, see the images and links below regarding the unfortunate fires at recycling facilities that involved arson in Virginia and Minnesota in 2020.

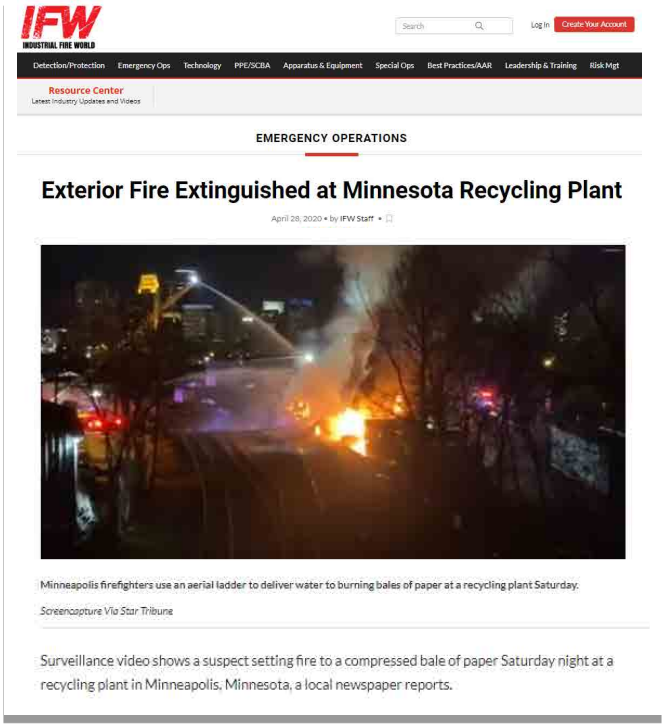


Figure 5 - Example fires involving arson at recycling facilities in Virginia and Minnesota in 2020.

Sources:

- *Virginia fire: https://www.wric.com/news/crime/man-charged-for-starting-tire-recycling-plant-fire-on-school-street-last-year/*
- *Minnesota fire: https://www.industrialfireworld.com/552682/exterior-fire-extinguished-at-minnesota-recycling-plant*

2.7 Staffing

'Staffing' is the newest factor to make the list of common causes of fires at waste and recycling facilities in 2021 and continues to impact the industry today. Across the U.S., we have seen workforces tighten. In November 2021, Alex Kamczyc, a reporter for *Waste Today Magazine*, wrote a great article highlighting the issue.[4]

> *Last year, the United States was estimated to lose 10 million jobs during the pandemic, according to the U.S. Department of Labor. However, as the economy began to rebound from the effects of social distancing and state and local stay-at-home orders that were enacted to avoid the spread of the coronavirus, "help wanted" signs began decorating a spectrum of businesses across the country, including recyclers and waste haulers.*
>
> *While life seems to be returning to normal with the availability of the [COVID-19] vaccines, a labor shortage is in full force in many places. Recyclers and waste haulers are now competing with other industries to hire candidates for open positions.*
>
> *"Hiring has grown and changed during the pandemic," says Patrick Hudson, vice president of customer experience for Phoenix-based Leadpoint Business Services, a*

[4] Website (Recycling Today, "Examining the hiring crisis for waste and recycling jobs", published November 29, 2021): https://www.wastetodaymagazine.com/news/waste-recycling-hiring-crisis-job-market/

> *provider of work teams and operations support services to the recycling industry. "Due to several reasons, we've seen a reduced interest in applying for these kinds of jobs for both passive and active applicants."*
>
> *This has disrupted waste collection, recyclables, and scrap and slowed processing times, creating cash flow issues.*

Adding to the "Great Resignation" movement[5] that launched after the COVID-19 pandemic, more than 47 million Americans voluntarily quit their jobs in 2021, according to a February 2022 article by *CNBC.*[6] An additional 37.4 million U.S. employees were forecasted to leave their jobs by the end of 2022, according to an April 2022 prediction by Gartner, Inc.[7]

From a fire risk reduction perspective, a waste processing facility operator's biggest issue is properly staffing sorting and pre-sorting activities along with the increased spacing requirements for sorting lines built pre-COVID. Removing hazards from the waste stream takes human action, with or without assistance from robotics. Every time a hazard, such as a battery or propane tank, gets through the screening process, there is a chance for something to go wrong.

The waste and recycling industry often does not stand out as a top career choice, which makes finding candidates even more challenging, but it does have many benefits. According to Mallory Szczepanski, vice president of member relations and publications at the National Waste & Recycling Association (NWRA) and editor-in-chief of *Waste Recycling magazine*, "To some, the solid waste and recycling industry is considered one big family. To others, it is an opportunity to influence the world. No matter how you view the industry, it is a sector that has a role for everyone, from drivers and mechanics to landfill and materials recovery facility (MRF) operators, engineers and equipment manufacturers, and policymakers. As an industry, it is time for us to come together and better address the labor shortage we, unfortunately, know all too well."

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[5] Website (Waste Recycling magazine, "The Great Resignation: An opportunity to think about the current and future workforce", by Mallory Szczepanski, Winter 2023 issue): https://www.wasterecyclingmagazine-digital.com/nwraq/0123_winter_2023/MobilePagedReplica.action?pm=1&folio=6#pg6

[6] Website (CNBC, "Roughly 47 million people quit their jobs last year: 'All of this is uncharted territory'", published February 1, 2022): https://www.cnbc.com/2022/02/01/roughly-47-million-people-quit-their-job-last-year.html

[7] Website (Gartner, "Gartner Says U.S. Total Annual Employee Turnover Will Likely Jump by Nearly 20% From the Prepandemic Annual Average", published April 18, 2022): https://www.gartner.com/en/newsroom/04-28-2022-gartner-says-us-total-annual-employee-turnover-will-likely-jump-by-nearly-twenty-percent-from-the-prepandemic-annual-average#:~:text=U.S.%20employee%20annual%20voluntary%20turnover,%2C%20according%20to%20Gartner%2C%20Inc.

2.8 Combustible Dust

While combustible dust may be grouped into traditional or inherent fire risks, it is severe enough to deserve its mention. Dust at waste processing facilities introduces myriad lung health and other bodily health challenges and is also a fire risk.

Processing waste and recycling materials have inherent risks to workers, emergency responders, and the environment. The spectrum of materials to be processed includes almost anything in commerce, including potentially dangerous ***chemicals*** (e.g., ammonia, chlorine, hydrogen peroxide), ***pressurized containers*** (e.g., aerosol cans, propane tanks, compressed gases), ***oils*** (lubricant, cooking, cosmetics), ***glass***, ***dust***, ***rags soaked in flammable liquids***, ***batteries*** (e.g., lithium-ion, lead acid, alkaline).

Additional types of processed materials can include rubber, concrete, gypsum, and other building products. The contents of waste processing facility dust can be explosive, reactive, corrosive, oxidative, ignitable, and flammable. Not only are dusty solid waste facilities indicators of poor maintenance, but they are also at higher risk of fire.

2.9 Batteries

Lastly, batteries are a hazard and cause many waste and recycling facility fires. Storing enormous amounts of energy, whether it is in larger rechargeable batteries or smaller disposable ones, batteries can be inherently dangerous. When two electrodes come in contact, the batteries can short-circuit, leading to a chemical chain reaction known as thermal runaway.[8]

Based on recent media coverage, the world is finally catching up to the problem that we in the waste and recycling industry have known for years: **Lithium-ion batteries are causing fires everywhere.** In November 2022, the New York City Fire Department reported "191 fires, 140 injuries, and six deaths from lithium-ion fires in the city." According to Councilwoman Joann Ariola, chair of the Committee on Fire and Emergency Management, "the city is on track to more than double the number of lithium-ion battery-related fires from last year and quadruple the number from 2020."

According to a survey released by Material Focus in the UK[9] in December 2022, "The results suggest batteries that have not been removed from unwanted electrical products cause more than 700 fires annually in refuse collection vehicles and at household waste

[8] Report download link (Underwriters Laboratory, "The Science of Fire and Explosion Hazards from Lithium-Ion Batteries: An introduction to lithium-ion battery construction, thermal runaway and potential hazards, by Adam Barowy, Research Engineer, Fire Safety Research Institute, published 2012): https://d1gi3fvbl0xj2a.cloudfront.net/2023-01/The%20Science%20of%20Lithium%20Ion%20Batteries%20Guide%20by%20FSRI_0.pdf?VersionId=Hbr6R4t7SxnBlvVElqyn02A4qxOXrBL

[9] Website (LetsRecycle.com News, "Batteries cause 'three times more' waste fires than thought", published December 22, 2022): https://www.letsrecycle.com/news/batteries-cause-three-times-more-waste-fires-than-thought/

recycling centers, while nearly 90% of the 60 local authorities surveyed said fires caused by batteries are 'an increasing problem.'" The equivalent number of fires would be 4,200 in the U.S., almost double the number of fire incidents I have reported based on my assumptions since 2016.

So, what took them so long? In 2017, based on my research, analysis, and unique position on the frontlines with Fire Rover, I was forecasting a wave of lithium-ion battery fires in waste streams due to several factors. In 2018, we saw that bump on a global scale. From 2019 until today, the leadership of the waste and recycling industry has heard the call and has taken action to deal with these fires. These industry-wide efforts included campaigns to educate the public on the dangers of lithium-ion batteries in the waste stream, operational best practices, and adopting innovative technologies like the Fire Rover.

Most data show that batteries are responsible for about half of the fires in the waste and recycling streams managed at processing facilities. Other factors like accelerants, pressurized tanks, explosives, and more have long been causing fires at waste and recycling operations and cannot be overlooked.

During thermal runaway, temperatures can climb to more than 1,000 degrees Fahrenheit, which creates intense pressure that causes the flammable liquid electrolyte to combust. Contrary to what the media coverage implies, lithium-ion batteries do not typically explode for no reason. The causes of lithium battery failure can include puncture, overcharge, overheating, short circuits, internal cell failure, and manufacturing deficiencies.

We are tough on the materials we manage in the waste and recycling industry. Try telling those in our industry to "avoid any scenario that may introduce the threat of action;" this is impossible. Yes, we can do all we can to educate the public and our employees on properly disposing of and handling lithium-ion batteries in the waste stream. Still, we would be naïve to assume that handling them any more gently would remove all inherent hazards of accepting them in the first place. No, we will continue to face these hazards soon.

Example pictures for damage classes of portable batteries:

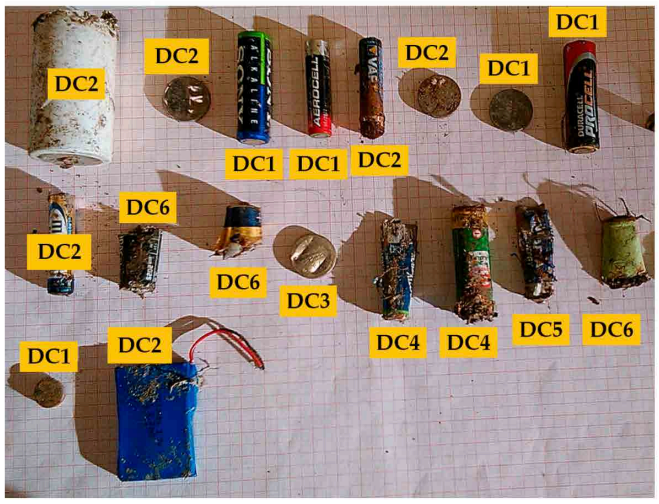


Figure S1. Damage classes of end-of-life portable batteries (after sampling campaign).

Specific risks that I have seen in Fire Rover's clients' waste and recycling operations include loaders driving over batteries; shredders mincing batteries; batteries exploding on tip floors; and deep-seated fires that sparked from one of the traditional risks of charcoal,

fireworks, fertilizers, and other materials that start the reaction near a battery.

These small batteries are pervasive and seemingly everywhere. In June 2023, a video made by Johns Disposal Service of Whitewater, Wisconsin, a version of which was shared on my LinkedIn profile, circulated online highlighting how some simple paper marketing materials with batteries included caught on fire with the simple throw of a stone to mimic the effect of recycling facility processing equipment. During the video, the paper marketing materials caught fire within seconds of simple impact (abuse factor 6 in the Consolidated Edison list referenced in the quote below.)

And it is not just the media overhyping the hazards we, as the public, face. In a report developed by Consolidated Edison, there was a great question that outlines the real risks of dispelling the media's approach of overhyping these incidents.[10]

Time lapsed stills from the video:
32 seconds *36 seconds* *42 seconds*

Figure 6 - Stills from a video posted by Johns Disposal Service of Whitewater, WI, on June 26, 2023

> *Question: Are the commonly cited battery fires in the media due to spontaneous ignition events? Finding: No. […] In the context of fire risk and firefighting for batteries, it is helpful to summarize the abuse tests performed in United Nations (UN) 38.3, the required testing scope to ship and transport Li-ion batteries. The eight tests in UN 38.3 are a checklist of nearly all physically conceivable abuses that could cause a Li-ion battery to catch fire. These abuse events are: 1. Low ambient pressure, 2.*

[10] Report download link (NYSERDA, "Report No.: OAPUS301WIKO(PP151894, Rev. 4", February 9, 2017): https://www.nyserda.ny.gov/-/media/Project/Nyserda/files/Publications/Research/Energy-Storage/20170118-ConEd-NYSERDA-Battery-Testing-Report.pdf

Overheating, 3. Vibration, 4. Shock, 5. External short circuit, 6. Impact 7. Overcharge, and 8. Forced discharge

All safety incidents commonly reported in the general media can be traced to one of these abuse mechanisms. In some cases, contaminants in the battery (due to manufacturing defects) weaken the ability of the battery to withstand instances of these eight abuse factors. In general, avoiding any scenario that may introduce the threat of any action on the above list is good practice.

2.9.1 A Worrisome Lithium-ion Battery Subset: Vapes

Like many of our clients, I spend much time trying to understand what is happening in our waste stream. We hear the term "lithium-ion batteries" thrown around, but most folks do not understand battery chemistry or what is doing the charging; they know the product by its utility. For example, I do not walk around with a lithium-ion battery in my pocket; it is a cell phone. Similarly, a person does not inhale nicotine through a "personal electronic;" they vape using a vape pen or "e-cigarette."

Watch the video below of an influencer who is quitting smoking. He is not deliberately trying to inundate his trash with batteries; he is doing what millions of folks around the globe have done hundreds of thousands of times: quitting smoking by removing ALL the products from their household to "white knuckle" it through addiction.

Watch as he throws away handfuls of vapes. Not only does he throw them away, but he places them into the water. I would assume this is so they cannot be used, but he certainly has no idea these are electronic with fuel inside them that can ignite and burn, like the dangers traditional cigarettes used to pose. Everyone knew, or at least should have known, that cigarettes or matches used to light them have the potential for danger. I have heard fewer and fewer stories of fires in recycling facilities that operators believe started from a still-lit cigarette butt, but vapes have some of these risks, too. If one of these vapes catches fire or explodes, it is dangerous, even more so when the fire lights around another accelerant, gas, or worse.

According to The Bureau of Investigative Journalism article, “Young people in the U.S. are throwing five disposable vapes away every second despite the devices containing reusable lithium-ion batteries. Over a year, this amounts to 150 million devices.” This article used the data to show how much lithium is wasted—enough to power 6,000 Teslas—but what it is missing is that those 150 million devices, which is a very conservative number, are ending up in our waste bins, scraped cars, demolished buildings, and elsewhere.

In the same article, “The Environmental Protection Agency (EPA) told the Bureau that vapes are being incorrectly discarded in household trash because they are often branded as ‘disposable.’ This leads to the entire device, including its battery, being thrown away in household trash. Despite this, it is perfectly legal to dump these batteries in the household trash in the U.S.”

Should we ban vapes from being thrown in the trash? Maybe, especially if done purposely by a business or in large quantities. But policing the policy would be difficult and not very good. I would be open to a deposit program, which is a good idea as it has worked well with taxing our other vices, which gives it value. I would rather have one of these collected and returned for a quarter than have another hazard in our waste and recycling streams. We should stop the manufacturers of vapes from saying they are “single-use” or “disposable.” We must clarify to consumers that these are not disposable, can be recycled, and, most importantly, set up convenient and safe ways to collect and recycle them properly.

3 Lithium-ion Batteries 101

I am often asked about the cause or causes of increased fire incidents in recent years; the answer is simple: Lithium-ion batteries. According to my colleague Ronald Butler, CEO of Energy Storage Safety Products International (ESSPI) and whom I call the "Jedi Master of Lithium-ion Batteries:"

> *"Lithium batteries can spontaneously ignite and subsequently explode from overheating. That may be caused by electrical shorting, rapid discharge, overcharging, manufacturers' defects, poor design, or mechanical damage, among other causes. Overheating results in thermal runaway, a reaction within the battery causing internal temperature and pressure to rise quicker than can be dissipated."*
>
> *Question: How long does it take for a Li-ion battery to go into thermal runaway if it is being heated? Finding: This depends entirely on the rate of heat absorption into the cell. […] A Li-ion cell can smolder for over an hour if the heat transfer rate is slow. When temperatures near 120°C (248°F) were reached, all Li-ion batteries tested (including LiFePO4 and LTO chemistries) were off-gassed and/or ruptured. If the threshold near 120°C is never crossed, the battery may smolder and gas but never ignite unless an external spark ignites its flammable gases. It was common for LiFePO4, LTO, and the BM-LMP cells to off-gas without flame, but their off-gas composition contains the same flammable and toxic constituents as batteries with higher temperature failures. (Source: Final Report, Considerations for ESS Fire, Safety, Consolidated Edison and NYSERDA, New York, NY, Report No.: OAPUS301WIKO(PP151894), Rev. 4, Page 15, February 9, 2017)*

The image below, courtesy of E-cell Secure, LLC, shows the four stages of the thermal runaway for batteries. It is relevant to understanding the chain of events associated with fires that result from them.

Figure 7 - Thermal Runaway Process - Source: E-cell Secure, LLC (2020)

Most research on lithium-ion battery dangers has focused on energy storage operations. These are major installations where batteries are part of a larger infrastructure, such as power banks that store enormous amounts of power. In 2019, the wake-up call for these hazards was an explosion at the Arizona Public Service's (APS) McMicken Energy Storage facility[11] in Surprise, Ariz., where several fire professionals responding to the scene sustained chemical and chemical inhalation burns. The facility housed utility-sized batteries used in storing and distributing solar energy. Although this incident did not occur in a waste and recycling facility, the implications for first responders in facilities that store and house lithium-ion batteries have been far-reaching.

At the APS McMicken Energy Storage facility, racks of battery modules were stacked from the floor to the ceiling. Unfortunately, a faulty battery cell shorted out in one of those racks, overheated, and damaged other nearby modules. This chain of events led to a thermal runaway, a buildup of heat that can lead to a fire. While the building had a fire suppression system, it was designed to extinguish a small fire. Although the fire suppression system discharged, the batteries continued overheating with no flames (known as a "hotspot"), eventually leading to flammable gas buildup.

Figure 8 - Progression of the incident at the APS facility.

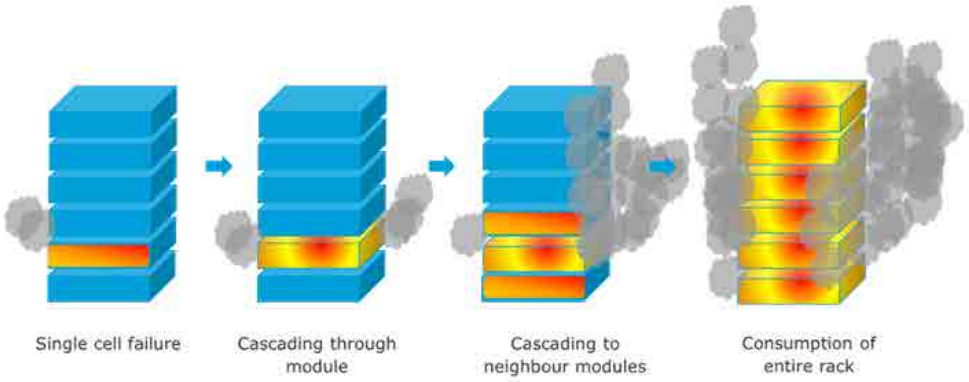


Figure 25 A single cell failure propagated through Module 2, then consumed the whole rack, releasing a large plume of explosive gases. This process could have occurred without visible flame, which would explain why the gases were not burned as they were emitted.

When firefighters opened the door to enter the building, those gases encountered a heat source or spark and exploded. The full technical report about the incident published by Arizona Public Service is available online, but a snippet is provided below.

> *4.5 Contributing Factor #5: Emergency response plan (ERP) did not have an extinguishing, ventilation, and entry procedure. The ERP […] did not have instructions*

[11] Website (AZCentral.com news, "8 firefighters hurt in explosion at APS facility in Surprise; 3 flown to Phoenix burn center ", published April 19, 2019): https://www.azcentral.com/story/news/local/surprise-breaking/2019/04/19/firefighters-hurt-battling-transformer-fire-surprise/3527645002/

> *on how to respond to a potential explosion or how to enter the system after the fire suppression system had been discharged. Most of the detail in the ERP was associated with electrical shutdown procedures […] and when/if to notify the fire department. A smoke alarm and fire suppression trigger procedure were in place, but it did not address when or how to initiate entry into the system—[…] monitoring, measurements, ventilation, and extinguishing. At the time of the development of this plan, [no one …] had conveyed that a large flammable gas hazard or cell-to-cell and module-to-module cascading thermal runaway was possible. […] This communication breakdown must be remedied to avoid future incidents. It is helpful to examine and demonstrate the need for open communication between all parties involved […]. (Source: McMicken Battery Energy Storage System Event Technical Analysis and Recommendations Arizona Public Service Document No.: 10209302-HOU-R-01, Issue: A, Page 38, July 18, 2020.)*

According to the same report by Consolidated Edison,[12] first responders had similar training in fighting any fire, including battery fires.

> *9.7 Project Development Considerations for Interaction with First Responders and AHJs, DNV GL surveyed several handbooks for fire departments in large cities nationwide and found a universal theme in firefighter training concerning extinguishing. Firefighters are trained to achieve the following objectives when arriving at the scene: Objective 1: Remove endangered person(s) and treat the injured. Objective 2: Stabilize the incident and provide for life safety. Objective 3: Provide for personnel's safety, accountability, and welfare (this priority is ongoing throughout the incident). Objective 4: Protect the environment. Objective 5: Property conservation. Note that Objective 5 is often the primary concern of the property owner. It is on the priority list of the first responder, but the safety of life at the scene takes precedence.*

Victoria Hutchison, a research project manager at the Fire Protection Research Foundation, says, "One out of every 10 million lithium-ion batteries fail, a condition that almost always leads to a fire".[13] The ones that burn typically stem from batteries that are treated improperly, incorrectly charged, or made with substandard parts or materials. Just like the public is hard on their electronic scooters by hitting corners, jumping on and off sidewalk curbs, and charging 20 rechargeable batteries at a time, the waste and recycling industry is harsh on the waste streams they manage.

A crucial point for those dealing with lithium-ion battery risk is this: the first responders are not to put their lives at risk to save the property. On the contrary, their role is to protect

[12] Report download link (NYSERDA, "Report No.: OAPUS301WIKO(PP151894, Rev. 4", February 9, 2017): https://www.nyserda.ny.gov/-/media/Project/Nyserda/files/Publications/Research/Energy-Storage/20170118-ConEd-NYSERDA-Battery-Testing-Report.pdf

[13] Website (The New York Times, "Lithium-Ion Batteries in E-Bikes and Other Devices Pose Fire Risks", published November 2022): https://www.nytimes.com/2022/11/14/us/lithium-ion-ebike-battery-fires.html#:~:text=One%20out%20of%20every%2010,with%20greater%20risk%2C%20she%20said

the lives of people inside the building. If no one is in the building, the first responders will take a defensive approach to fight these fires.

Fire Rover developed a solution for lithium-ion battery recycling facilities—providing primary versus supplemental solutions—and has expanded to waste, scrap, C&D debris, and other operations to help fire professionals and property owners have the best chance to protect their employees and property. Along with early detection and remotely operated fire suppression, Fire Rover added a quick connection to an additional water supply just outside the building—this unique solution has received variances as a replacement for traditional fire sprinkler equipment in some jurisdictions. It allows for continued thermal monitoring, remote-operated targeted suppression, and the ability to apply water until the heat level is safe for professionals to enter the building because lithium-ion battery fires can "re-ignite" depending on the risk factors.

> *"The term "re-ignition" is a misnomer due to the factors described in the incident history of Li-ion battery fires. Upon extinguishing, great care must be taken to neutralize all electrical, thermal, and mechanical abuse factors. If any remains, it poses a hazard for continuing (not reigniting) the fire. Therefore, it is technically inaccurate to classify this as re-ignition if the primary cause of the hazard is never removed. After a fire, a battery module or system may contain intact cells with DC voltage, meaning there is a persisting electrical hazard." (Source: Report No.: OAPUS301WIKO(PP151894), Rev. 4, Pages 12-13, February 9, 2017)*

Solutions that detect flames, heat, smoke, and gas early are necessary to prevent incidents like this in the future. Additionally, fire professionals must focus on halting the chain reaction in instances where thermal runaway is achieved, allowing collateral assets to ignite.

In 2021, New York began to experience an uptick in fires caused by lithium-ion batteries. At least six incidents[14] have occurred since late 2021, including a massive high-rise fire that injured at least 38 people and a house fire[15] that injured 10 and killed one. According to The Guardian, at least 200 fires have been caused by e-bike batteries.[16] This drastic increase in fires has led New York State Sen. Liz Krueger to introduce two bills[17] (S.9597 and S.9596) designed to address the proliferation of fires caused by malfunctioning lithium-ion batteries used to power e-bikes, e-scooters, and other micro-

[14] Website (New York Daily News, "Here are the six times a lithium-ion battery caused a deadly fire in NYC", by Leonard Greene, published November 14, 2022): https://www.nydailynews.com/new-york/ny-fire-e-bike-deaths-20221115-doccesb445acdefyrunpy3m73y-story.html

[15] Website (CBS News, "U.S. House fire that killed 1 and injured 10 was sparked by lithium-ion battery, FDNY says", by Kerry Breen, published January 23, 2023): https://www.cbsnews.com/news/house-fire-that-killed-1-injured-10-was-started-by-lithium-ion-battery-fdny-says/

[16] Website (The Guardian, "E-bike batteries have caused 200 fires in New York: 'Everyone's scared'", by Wilfred Chan, published November 15, 2022): https://www.theguardian.com/us-news/2022/nov/14/new-york-e-bike-batteries-fires-delivery-workers

[17] Website (NY Senate, Press Release, "Krueger Introduces Bills to Address Rapid Increase in Fires Caused by Lithium-Ion Batteries", by Liz Krueger, published on November 17, 2022): https://www.nysenate.gov/newsroom/press-releases/liz-krueger/krueger-introduces-bills-address-rapid-increase-fires-caused

mobility devices. Also, in response to the growing concerns around the number of fires caused by e-bike and e-scooter batteries, the National Fire Protection Association (NFPA) has created a new micro-mobility device safety webpage[18] that includes safety tips.

On the West Coast, iDiskk, LLC, a San Jose, Calif.-based recycling company, was fined $25,000 in 2022 by a Santa Clara County Superior Court judge for improperly disposing of lithium batteries,[19] which resulted from an investigation after three different garbage trucks caught fire within two months in 2021.

> *"This case demonstrates the risks of throwing lithium-ion batteries away in the regular trash or recycling," says Deputy District Attorney Christopher Judge in an SFGATE article. "These fires are incredibly dangerous to the safety of the garbage truck drivers and first responders who must act quickly to deal with the fire."*

So, if a waste and recycling processor is not salvaging electronic scrap, large storage batteries, or electric vehicle batteries, why should they care about how to fight these batteries? Because the waste and recycling industry sees this scenario play out within its infrastructure daily—albeit on a smaller scale—there are lessons to learn. Remember that all catastrophic fires began as smaller fires, so the same needs apply to detect fires early and stop the chain reaction to prevent fire escalation.

🔥 Watch the Fire Rover Detect and Eliminate a Lithium-ion Battery Fire 🔥

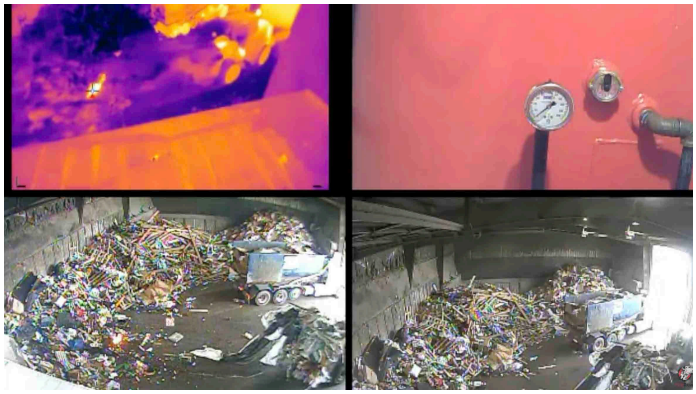
[18] Website (NFPA, "SAFETY WITH E-BIKES AND E-SCOOTERS"): https://www.nfpa.org/ebikes

[19] Website (SFGATE, "Recycling Company Fined for Causing 3 Fires by Improper Battery Disposal", by Thomas Hughes, published December 4, 2022): https://www.sfgate.com/news/bayarea/article/Recycling-Company-Fined-For-Causing-3-Fires-By-17630163.php

Look at the video above, where a battery fire starts on the backside of a pile actively worked on. A battery smokes, lights on fire, and eventually burns itself out. Still, if the Fire Rover does not apply a suppressant to the surrounding material, the fire can grow from a small, manageable fire to a catastrophic fire event in minutes.

Unlike in large storage operations, waste and recycling processing facilities can cause batteries to explode by processing and treating them with compaction, shredding, sorting, and baling by heavy equipment and exposing them to the elements. All of this can damage batteries in storage and electronic equipment.

If you watch the video to the right[20] (clicking the image will take you to a video), you can watch a video of a truck running over a battery. In this incident, you can see the loader drive over batteries that explode under its tire. Meanwhile, a nearby truck dumps cardboard next to the fire on the tip floor. This same scenario occurs daily on tipping floors in waste and



[20] Website (YouTube – Fire Rover): https://www.youtube.com/watch?v=sGLfVBOFMF4

recycling facilities, scrap metal facilities, and C&D debris processing operations nationwide. However, such fires do not always happen directly due to a truck's force. Incidents like this take more than water to extinguish. Fire Rover uses an environmentally friendly cooling agent that helps slow down or eliminate thermal runaway and uses the surrounding collateral material as a sponge for the firefighting agents to allow the fire to burn itself out to break the fire chain.

When combating electric vehicle (EV) fires, fire protection specialists often hear about the "dunk method." According to Tony Markovich of *Autoblog*[21], "Because of the chemistry of the lithium-ion batteries found in most EVs, their chemical fires can take massive amounts of water to put out and keep out. So, instead of dousing a car *with* water, it is smarter to put it *in* water, where it will safely be stifled." This approach may effectively extinguish such a fire, but executing it as a ready solution for the waste and recycling industry may not be timely, practical, or affordable.

Since the dunk method may not be a good fit for most operations, we must focus instead on other fire mitigation methods, including proper separation, quick reaction time, and reduced collateral risks. Separation makes sense for lithium-ion battery operations, such as large banks of batteries for power supplies; however, waste and recycling operations deal with smaller, more disbursed hazards. Instead, they must focus on reaction time and stopping the collateral risks. In my opinion, the industry's current best practices around controlling pile sizes of discarded materials and adequate separation of the piles are correct if the proper solutions for early detection and response are in place, such as Fire Rover.

[21] Website (Autoblog, "Why firefighters dropped a smoldering BMW i8 into a water tank ", by Tony Markovich, published March 26, 2019): https://www.autoblog.com/2019/03/26/firefighters-dropped-smoldering-bmw-i8-water-tank/

4 Prevention and Response

Fire is not the problem until it becomes the problem.

Knowledge of appropriate fire prevention activities and responses for the waste and recycling industry is critical to understanding the prevention and mitigation of fires. Early in my industry tenure, I heard this saying, "*Fire grows in size and scope every X second or minute."* Whichever compounding factor you select to replace 'X' with, the reality is the same: The earlier you identify a fire, the better the chance to minimize it from becoming a major fire incident. Likewise, the earlier you identify a fire, the better the chance of reducing harm to employees, fire professionals, facility operations, physical infrastructure, and the surrounding area. See Figure 9 for the six progressive stages of fire incidents, including a new stage I created for the "Pre-incipient Stage" of fire incidents. The pre-incipient stage is a heat or smoke "abnormality" that eventually leads to a fire.

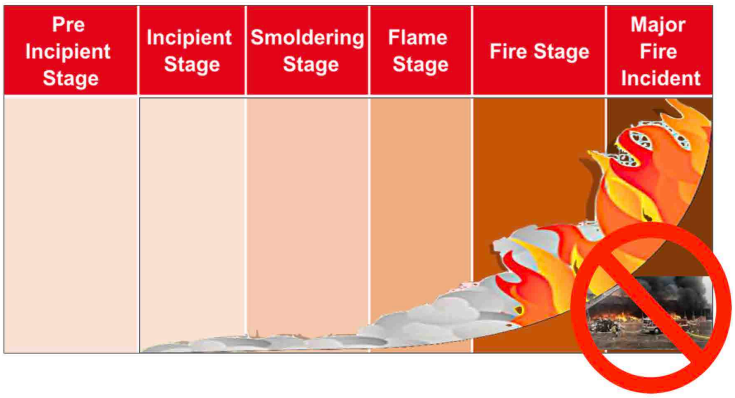


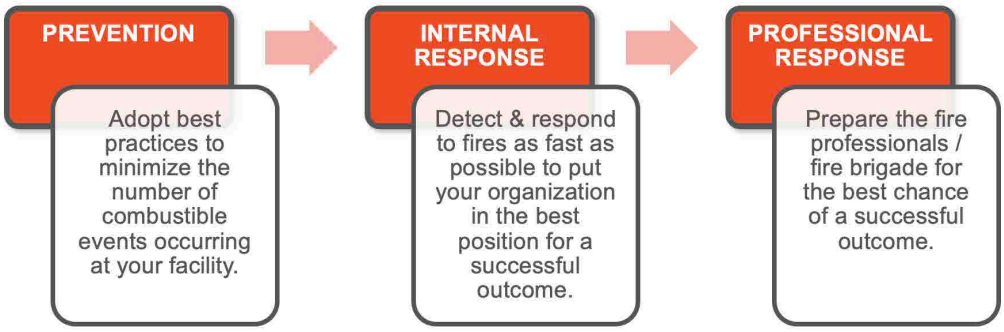
Figure 9 - The six stages of fire incidents

While the goal should be never to have a major fire incident, the risks are ever-present at waste and recycling facilities. Therefore, the only way to attain the goal is to consider prevention and your response fully. Prevention will pay for itself with every fire incident avoided (no matter the stage) because all major incidents stem from the earlier stages. When it comes to responses, fully considering your internal and professional (external) response needs and actions and executing those plans could mean the difference between a facility closed for a day or total loss.

The fact is that fire is ugly, and no two incidents are identical. You must prepare for the relative unknown and react within seconds to overcome constantly changing factors and challenges. However, the facilities still need agency. Building on knowledge from studying previous fires at waste and recycling facilities and a thorough understanding of the ignition risks, indicators of fire types, how fire incidents progress, and how to effectively control them, a waste and recycling facility can work to prevent them and effectively respond when they occur.

So, what are the differences between prevention and types of response?

Figure 10 - Prevention, Internal Response, versus Professional (External) Response



After prevention, the real opportunity is improvement in internal response time!

4.1 Prevention

Prevention includes following the operator's best management practices to minimize the risks of fires. Each facility has unique conditions and equipment that dictate the actions necessary to ensure safety. It is the facility operator's job to ensure all employees and visitors know what to do to minimize fires.

> *"The most important part of fire prevention is to develop a plan of attack. Prevention is the basic blocking and tackling and should include all components of minimizing the potential number of events at your facility. Examples of this include having limits on the size and height of your in-feed and feedstock piles; regularly cleaning the facility so it is free of dust that can combust; developing a disciplined hot-work program; clearing your working floor; keeping proper pile separation so fire professionals have room to maneuver; having the proper fire protection in place proportional to the amount of material processed at your facility; identifying aerosols or propane tanks during presort; having frequent safety training of employees; and educating the public on proper disposal of nonhazardous material in the waste and recycling stream." - Ryan Fogelman.*

For more specifics around the Combinational Approach to fighting waste and recycling facility fires, see the Appendix of this report and read the article "*How to reduce the fire risk profile of your waste and recycling facility*",[22] published in *International Fire Protection Magazine* in December 2018.

[22] Website (LinkedIn, "How to reduce the fire risk profile of your waste and recycling facility" by Ryan Fogelman, published December 6, 2018): https://www.linkedin.com/pulse/how-reduce-fire-risk-profile-your-waste-recycling-ryan-fogelman-1f/

4.2 Internal Response

Outside of fire brigade training, waste and recycling facility operators must train their employees on best fire incident management practices, such as when it is safe to respond to a fire incident and when they must evacuate. In addition, they should invest in solutions, such as the Fire Rover system, which detects fires early with thermal cameras, optical flame, and smoke detectors to eliminate the need for a response in the first place and can engage the fire professionals when warranted.

> *"I typically tell folks that early detection is the key to catching and mitigating a fire early. The goal is not just to catch fire when there are flames but to understand that there are situations where hotspots can be cooled before they flame. Overlaying smoke analytics into detection is imperative, as it helps when dealing with deep-seated fires where smoke is the first sign. The faster we can detect a fire and apply an environmentally friendly cooling agent to the affected area, the better the chance the firefighters will arrive on the scene with the fire fully suppressed or under control." – Ryan Fogelman.*

The goal is to set the "tripwire" as early as possible. This can be done through top-grade thermal detection in combination with smoke and other analytics, as well as, most importantly, a highly trained agent who can weed through false positives to fight only the incidents that need fighting. It is important to note that anyone can purchase top-grade equipment like a thermal camera. Still, like most hardware and software, they are not off-the-shelf solutions, and neither are these highly sophisticated pieces of equipment. Working properly in the highly active environments of a waste processing facility requires investment, skill, training, and experience.

At Fire Rover, we eat, breathe, and sleep, thinking about better protecting our customers from fire. We constantly update our software, analytics, equipment, and more to help us meet this goal every day.

4.3 Professional (External) Response

Preparing and equipping local fire professionals with the proper tools, training, techniques, and education to fight these fire hazards successfully. Successfully fighting fires over time requires a combination of all parties working together to be ready to respond when the situation arises. Since no two fire incidents are the same, no two responses will be the same either, which is why a framework that allows for flexibility, quick thinking, and proper actions is needed to ensure safety and help prevent a waste management facility operator from having a fire incident that is not "major" or "catastrophic".

> ***"****Another extremely important part of the internal response is to prepare the professional response. Investing in the proper equipment for the fire department on*

site can be a huge timesaver. Even going as far as having attached and rollout hoses so the firefighters can immediately apply suppressants to the affected area can make a huge difference. Investing in a compressed air foam system can save valuable time for the fire professionals as well, as they can fight a fire within less than a minute of arrival." – Ryan Fogelman.

Most importantly, having a functional working relationship with your local fire department is imperative, as it will be the one to decide whether to actively fight the fire or take a defensive position. In a defensive position, firefighters do their best to contain the fire within the immediate area. The fire department's goal is to ensure that all its department members and anyone else on the scene make it home to their families. Fighting waste and recycling fires is difficult enough when the fire department is familiar with the facility's layout, exits, equipment, waste streams, and storage areas, among other aspects. However, fighting these fires without this knowledge would worry any rational fire chief.

4.4 The Undertraining of Fire Response Teams is a Problem without Boundaries

I have said this in past reports of this kind, and I'll say it even more emphatically again: *outsourcing the burden of fighting fires to others who may be undertrained on the complex combination of ignition risks the waste and recycling industry faces daily is irresponsible. With solutions like Fire Rover available today, waste processing facilities operators and their remote firefighting agents at Fire Rover are their best first lines of defense.*

The existing knowledge of fighting waste fires has not kept pace with the training for local fire departments. Therefore, the burden and responsibility should be on the waste and recycling operators to train their staff to fight these fires, develop a formal fire brigade, and provide their local fire department with the information they need to support a facility in fighting a fire when the facility's resources are exhausted.

Concerning battery fires, Professor Guillermo Rein, an engineer and professor of fire science at the Imperial College London in the UK and editor of *Fire Technology*, is justifiably concerned: Typical fire professionals are not adequately trained on the hazards of these batteries. According to Andy Sterns, founder of Insight Fire Training, there were 1.2 million firefighters in the U.S. and Canada in 2022, of which almost 700,000 were volunteers. Less than 2% of their budgets were spent training firefighters in all hazards, not just fighting lithium-ion battery fires. See Rein's tweet from February 2022 below:

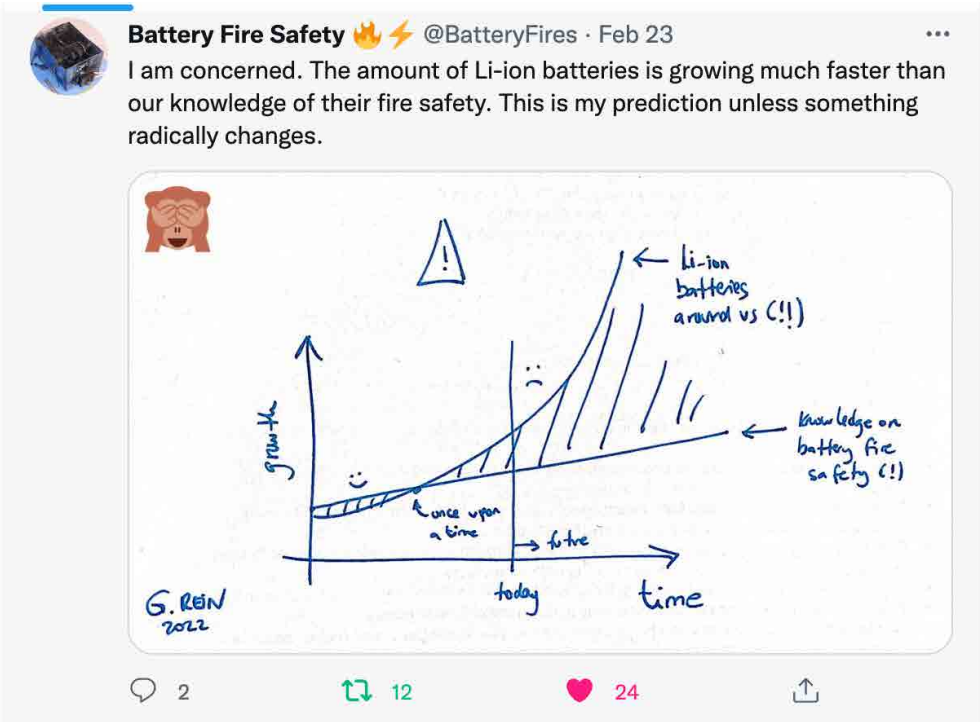


Figure 11 - Battery Fire Safety post, Feb 23, 2023

In 2018, globally as an industry, we were caught off guard by this new hazard of lithium-ion batteries. In 2022, most companies had a plan. As lithium-ion batteries have become commonplace in industry operations, the focus on fire prevention has now been realized. While some people may prefer to hide from innovation and technology and “do it the way it has always been done” without understanding the full consequences of their actions to themselves and the public. Others shine as examples industry professionals can point to say they are doing well to protect their people and their physical infrastructure assets.

But the question is this: Is all that focus and all these strategies enough to turn the trends in the other direction? If they are working with a reputable and dependable company, Fire Rover, then yes. All fire incidents are unique and have complicating factors, and each will cause a slightly different chain of events. Through monitoring equipment, early detection, human verification, quick reaction speed, expertise, fire threat prevention, and mitigation, Fire Rover helps prevent small fires from becoming catastrophic.

Figure 12 - Remotely operated Fire Rover Water Tower versus Manually Operated Water Tower. As you can see, one option requires humans to be proximate to a potential fire, whereas the other is remotely operated and does not.

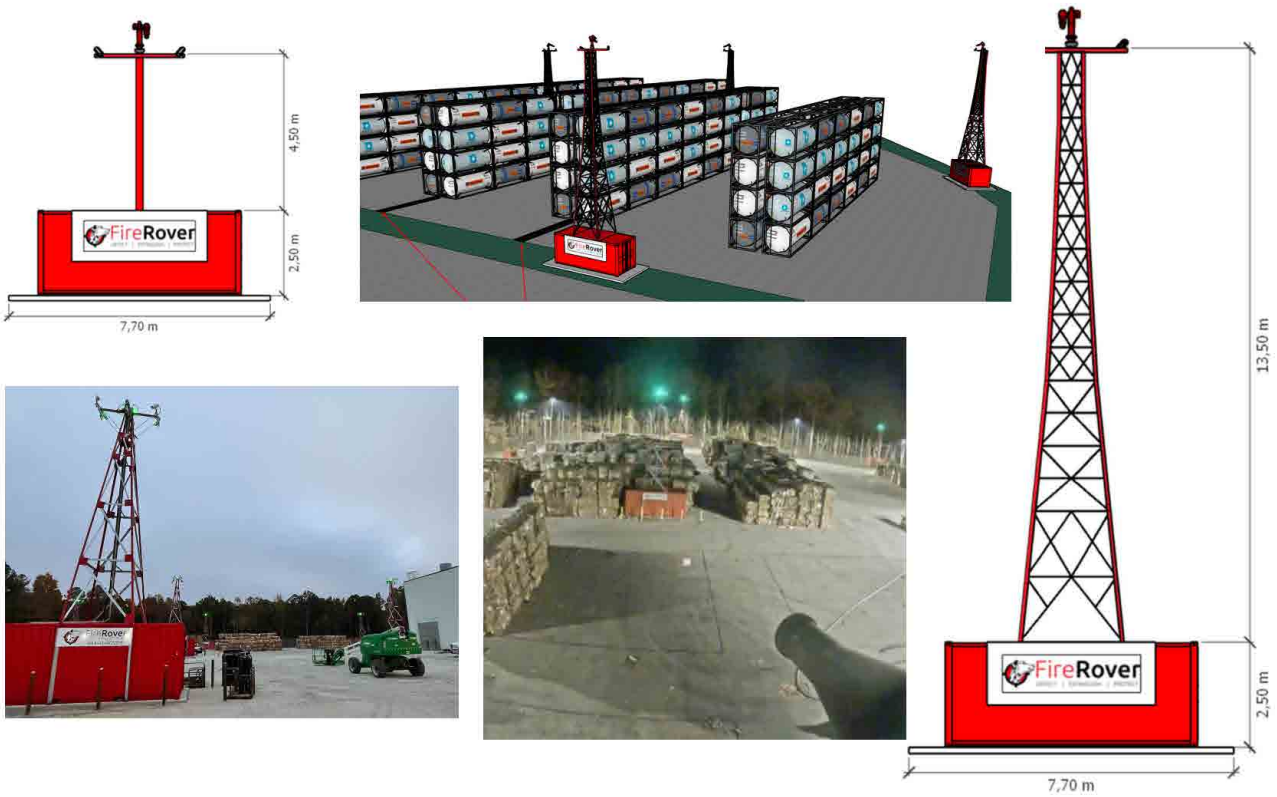


Figure 13 - Example Placement of Remotely Operated Fire Rover Water Towers in a storage area containing baled commodities

As humans, we typically perceive dangers from our experiences. Humans do not tend to fear small fires that are easily put out or controlled, but we will fear catastrophic fires with large consequences. *But how will most catastrophic fires begin?* If you guessed "as small fires," you guessed correctly. Never underestimate the potential of a small fire to destroy if it happens in a waste processing facility, which is typically full of flammable and combustible materials.

Years of firefighting expertise lay behind the system, and cameras are used to monitor the waste-handling facilities protected by Fire Rover carefully. The fire prevention specialists, engineers, and remote firefighters we employ have seen and lived through *what-if* scenarios, regularly anticipate *what is next* to break for chains, and help our clients avoid needing to pick up the pieces of *what is left* after a major fire incident.

When talking to business owners, operators, or business executives, I aim to help make them experts on the Fire Rover solution by educating them on how the layers of protection that make up our firefighting framework can apply to any situation. However, the hardest thing to do is change a perception. For example, some people focus on one factor that can cause a fire, like a lithium-ion battery in the bottom of a pile, when fires can start many ways.

Contrary to most people's opinions, most fires occur during the daytime and on the surface. Fire Rover's solution quickly resolves these fires, stopping them from becoming major events. Deep-seated fires can happen day or night and are harder to deal with, but we have successfully fought all these fires that start in an area we protect with our solution.

At Fire Rover, we define fires that start at the bottom of a pile as deep-seated versus the alternative of a surface fire. Deep-seated lithium-ion battery fires are fought by soaking the hazard area and ensuring that no other material can burn once the battery has burnt through its fuel, breaking the chain and stopping the incident. When attacking a deep-seated fire for our clients, we aim to cool the entire pile if it is small enough. For larger piles, we pre-wet and pull away layers. We then continued this process until we found the cause of the fire. Instead of having the equipment onsite to remove the layers, we soak the material and intentionally spray the collateral assets so the fire stays contained until the fire department can arrive on the scene. Fire Rover's solution protects against this one factor and millions of other potential causes of fires, but trying to educate while changing someone's perception is the biggest challenge we must deal with

If a company chooses to fight the fire with its employees, it must develop a strategy and train its staff to deal with these incidents when they do occur. One company's solution for dealing with fire risks may differ from another. *So, which path is correct?* Only time will tell but at the risk of using a cliché saying, the first step to solving a problem is admitting that a problem exists in the first place. For the waste and recycling industry, it comes to

recognizing and understanding that there are inherent fire risks in our daily work. The next step is solving it and developing best practices that mitigate risks to operations, employees, the public, and the environment. The truth is that many firefighting solutions are available. While most can work theoretically, their effectiveness is not fully known until "game time," when fire protection layers are tested.

Fire Rover's solution has tested and proven its efficacy in more than 500 of our clients' daily operations. We have learned from thousands of fire events that the framework, technology, and response-ready deployment capabilities work. The solution has provided a consistent record of accomplishment that insurers use to mitigate their risk of catastrophic losses in the waste and recycling facilities they insure, and the waste and recycling industry has benefitted from the peace of mind that their operations, livelihoods, and employees are protected.

4.5 What OSHA Changes to Fire Brigade Standard (29 CFR 1910.156) Means to the Waste and Recycling Industry

Per an article I wrote for Waste Advantage magazine in January 2024, most know the Occupational Safety and Health Administration (OSHA) plays a pivotal role in ensuring workplace safety and health standards across various industries in the U.S.[23]

One of the key regulations under OSHA's purview is **29 CFR 1910.156**, which addresses specific aspects of fire brigade operations. When the new OSHA standard was released, I was contacted by several of my waste and recycling industry colleagues, asking if I had read it and whether I understood what the 600-page document was attempting to achieve. I reached out to one of my fire engineering colleagues, James "Andy" Lynch, and asked him if he was up to the challenge of reviewing the document with me and sharing his opinion. Together, we combined our expertise and thought through how the updated standard will affect the waste and recycling industry.

Firstly, it is essential to note that this update was major. It was the standard's first significant revision in 44 years (since September 1980). The new standard started with a substantial change in wording: switching from "Fire Brigade" to "Emergency Response." OSHA is clearly expanding the definition to include more than just responding to fire hazards; it is also how an organization plans for and responds to onsite emergencies. Other changes align this standard with existing standards and incorporate several already practiced and accepted procedures, including National Fire Protection Association (NFPA) codes and standards.

[23] Website: https://wasteadvantagemag.com/what-osha-changes-to-fire-brigade-standard-29-cfr-1910-156-means-to-the-waste-and-recycling-industry/?swcfpc=1

OSHA's primary goal is to reduce fatal and non-fatal injuries, and with fire emergency professionals and employees in mind, there are many changes. While this list is not extensive, there are several areas of the updated standard for which waste and recycling facility operators should consider and act proactively:

- **Vulnerability assessments:** The standard will necessitate a vulnerability assessment that identifies structure, process areas, and other locations where a Pre-Incident Plan (PIP) is needed. An accurate, up-to-date PIP is a valuable tool for assisting team members with safe and effective incident mitigation and will be a critical component of preparedness in the future.
- **Required personnel and equipment:** The standard updates for what resources are needed, including personnel and equipment, regarding facility preparedness and personal protective equipment (PPE) information. PPE is equipment worn to minimize exposure to hazards that cause serious workplace injuries and illnesses. Even if there is a good reason for the lack of resources to quickly respond to fire and emergency incidents.
- **Definition of emergency response levels:** Facilities will need to define the types and levels of emergency response it will provide. Industry operators will need to define the types of training and equipment they will provide. For example, firefighting can be highlighted and trained without opening the requirement to provide emergency services or other hazards.
- **Incorporating team members and responders in ERP planning efforts**: The standard will require WERE to establish and implement a process for involving team members and responders in developing, inspecting, investigating, reviewing, implementing, and updating ERPs.
- **Policies for rescues of people in imminent peril:** OSHA recognizes there are extraordinary instances where a team member or responder would need to deviate from the ordinary procedures set out in the risk management plan to rescue a person in imminent peril. Risk management plans should include a policy for handling extraordinary situations like attempting to rescue a person in imminent peril, potentially without the benefit of PPE, tools, equipment, etc.
- **Medical and physical requirements**: The standard updates medical and physical requirements and provides additional guidance to the site on maintaining medical records and establishing a medical evaluation program and fitness program for certain employees.
- **Minimum training requirements:** The standard updates the minimum training requirements for team members and responders so that WEREs establish the minimum knowledge and skills required for each team member and responder to participate in emergency operations safely. These minimum requirements will vary based on the emergency response type. For example, firefighters will have different training requirements than technical rescuers.

The biggest question I have been asked is how this standard will affect the requirements of deploying an "informal fire brigade" versus evacuating and waiting for local fire professionals to arrive on the scene. Lynch says, "We will not know the full effects on the incipient fire brigade requirements until we see OSHA's enforcement efforts or it releases follow-up documentation. But it is clear OSHA is focusing on making WEREs more accountable to specific requirements that might not have been defined well in the past."

The bar has been raised for our industry facility operators, and I am sure this will come into play in any formal or informal fire brigade. In a nutshell, in the future, any waste and recycling employee who fights a fire needs to be formally trained and able-bodied, and

they will need to follow a documented plan. I used to be able to tell operators that having an employee put water on a fire from a safe distance was an easy decision. However, that might not be enough in the future without action by a cleared, trained, properly suited employee, clearly spelled out in a PIP.

5 What Hazards are we dealing with when we face recycling and waste facility fires?

Waste materials are handled hard from the point of generation to their final destination (such as a landfill or recycling facility). It is the nature of the work. Along the way, waste is tipped, dumped, compacted, trucked, dumped again, transferred, recompacted, buried, burned, or sorted and baled. The fire risks will continue unless someone can figure out a gentler way to process waste and recycling. Until then, the waste and recycling industry deserves resources to help it deal with the inherent risks of its daily work.

Recognizing the dilemma and the fire risks associated with waste management, Fire Rover's highly trained remote agents know how to identify the risks and understand when to act. Their actions lessen the chance of these incidents becoming significant events. Our expertise in dealing with these hazards in MRFs, transfer stations, scrap metal yards, electronic recyclers, and lithium-ion battery processors is improving as we all continue to fight this growing risk in mission-critical operations across the globe.

5.1 Human and Environmental Safety and Health Concerns at Waste Processing Facilities

In an Austrian study, "Lithium-Ion Batteries as Ignition Sources in Waste Treatment Processes—A Semi-Quantitate Risk Analysis and Assessment of Battery-Caused Waste Fires",[24] the research team developed the following table that separated the processing activity by the possible threats and subsequent risk assessment. Most lithium-ion fire incidents occur within collection vehicles, on tipping floors, during consolidating and processing, and once in finished product storage.

[24] Website (Nigl, Thomas, Mirjam Baldauf, Michael Hohenberger, and Roland Pomberger. 2021. "Lithium-Ion Batteries as Ignition Sources in Waste Treatment Processes—A Semi-Quantitate Risk Analysis and Assessment of Battery-Caused Waste Fires" Processes 9, no. 1: 49): https://doi.org/10.3390/pr9010049

Table 5. Qualitative risk assessment of possible hazards and threats of portable batteries (waste stream: residual household waste).

Facility Area/Process	Possible Hazards and Threats	Risk Assessment
Collection bins	Damage due to external short-circuit	low
Loading activity	Damage due to external short-circuit	low
Collection vehicle	Mechanical damage due to compaction	medium
Unloading activity	Mechanical damage due to tip-off	low
Waste bunker/input storage	Damage due to external short-circuit Damage due to external heating (self-heating of waste)	medium–high
Waste transfer activity	Mechanical damage due to (wheel) loader or gripper	medium
Treatment facility	Mechanical damage due to pre-shredding process Mechanical damage due to post-shredding process Dangerous heat generation after damage Carry-over through the processing facility	high–very high
Output storage	Damage due to external short-circuit Damage due to external heating (self-heating of waste) Dangerous heat generation after damage	low–medium

Table 2 - Qualitative risk assessment of possible hazards and threats of portable batteries in waste.

The same study concludes that:

> *No other substance or material has ever comparably endangered the whole waste industry. Hence, besides research and development activities for investigating and understanding the hazards and risks of lithium-based portable batteries, increased technological development and innovation efforts are indispensable for reducing the risk potential of end-of-life portable batteries. The waste sector must aim to source-segregate as many batteries as possible via separate collection systems and take-back schemes to minimize risks. These options help ensure a reduced or damage-free return system. That requires increased efforts in public relations and consumer awareness. However, a 100% separate collection rate for portable batteries is highly unrealistic without a comprehensive deposit system. Hence, operators of treatment facilities have to find ways to […] protect critical infrastructure and treatment processes (e.g., including new detection and extinguishing methods) or … detecting and separating portable batteries during their treatment processes.*

While this is a helpful report, I hoped to find several others like it but have yet to be successful. For years, I have been searching for studies or reports on fire hazards—specifically about the risks faced by the waste industry, such as frontline chemical exposure because of waste materials catching fire—but unfortunately, little research has been done on them.

Given the explosive hazard of specific material types, I found myself frustrated by why folks would market handheld fire extinguishers labeled to fight lithium-ion battery fires when they necessitate a human being close enough to the fire and, therefore, potentially exposing them to hazards like the inhalation of toxic fumes and explosions. Safety [should] know no competition. There is no scenario where I suggest standing within six feet of a lithium-ion battery fire with a handheld fire extinguisher, particularly for *industrial*

applications like at waste processing centers. The risks to life and health are so great. Fire suppression by a remote firefighter with thermal imagining capability and as much physical space between them and the fire hazard as the internet can provide is better.

So, based on industry experience and my observations working with Fire Rover to address fire incidents at waste and recycling facilities, I decided to press on and try to document the issues with exposing humans to the risks of waste processing facility fires and put together a list of the typical materials processed by (and therefore also potentially exposed to if they burn at) various waste processing facility types in Table 3 below.

Table 3 - Typical Waste Materials Processed at Waste Processing Facility Types

	Processing Facility Types									
Typical Waste Materials Processed	**MSW / Mixed Wastes**	**MRF**	**Metal**	**Paper**	**Organics**	**Chemicals (Hazmat)**	**Plastics**	**C&D Waste**	**Rubber/ Tire**	**E-Scrap**
Plastics	X	X			X		X		X	X
Paper	X	X		X	X					
Ferrous Metals	X	X	X					X	X	
Non-ferrous Metals	X	X	X			X		X	X	X
Fats, Oils and Grease	X				X	X		X		
Auto Shredder Residue			X							
Lithium-Ion Batteries	X	X	X	X			X	X		X
Lead Acid Batteries	X	X	X	X			X	X		X
Alkaline Batteries	X	X	X	X			X	X		X
Organic Materials	X	X		X	X			X		
Rubber	X	X	X					X	X	
Accelerants	X	X	X			X	X	X		
Concrete								X		
Gypsum	X							X		
Glass	X	X						X		
Fines	X	X	X	X			X	X		X

After compiling an early version of the table above, I received a message from George Thompson, Ph.D., President & CEO of Chemical Compliance Systems, Inc., a toxicologist with over 50 years of experience in chemical, product, and process hazard and risk assessments. Dr. Thompson has published 22 books about hazardous chemicals,

organized four national and international conferences, given hundreds of technical presentations over his distinguished career, and developed the world's largest relational chemical and product databases. He also has served as an expert witness in 54 cases and spent considerable time analyzing the highly hazardous chemicals released into the air at the East Palestine, Ohio, train derailment and fire in February 2023.[25]

So, I asked Dr. Thompson if he knew anything about lithium-ion battery fires, waste industry fires in general, and the potential dangers of the off-gases during and after thermal runaway of battery fires. Fortunately, he did and was willing to be interviewed about it.

The next section of this report is dedicated to examining the environmental and human health hazards of waste and recycling facility fires with Dr. Thompson and is based on an article that I wrote for Waste360.com, entitled Waste & Recycling's Frontline: A Toxicologist's Perspective, which was published on March 5, 2024.[26]

5.1.1 Waste & Recycling's Frontline: A Toxicologist's Perspective

The materials we process at our waste and recycling facilities can present physical and health hazards ranging from minimal to severe. One hazard can be found in batteries, which contain highly flammable and toxic gases. The type of gas released depends on the battery chemistry involved but typically includes carbon monoxide, carbon dioxide, hydrogen, methane, ethane, and other hydrocarbons. So, I met with a career toxicologist to better understand what can be done to protect our frontline workers and fire professionals from the threats they face due to the materials they handle.

Since I began working in this industry in 2015, I have had a concern I cannot get out of my head: The dangers of lithium-ion batteries, which can shoot shrapnel when they hit thermal runaway or explode. This happened in the video below when a loader ran over an electric bike battery earlier in 2023.

🔥 Watch the Fire Rover Successfully Fight An Explosive Lithium-Ion Battery Fire🔥

[25] East Palestine, OH, train derailment: https://en.wikipedia.org/wiki/East_Palestine,_Ohio,_train_derailment

[26] Article, "Waste & Recycling's Frontline: A Toxicologist's Perspective," written by Ryan Fogelman, published by Waste360.com on March 5, 2024. Available online: https://www.waste360.com/industry-insights/waste-recycling-s-frontline-a-toxicologist-s-perspective

What are the Materials and Potential Effects of These on Frontline Workers and Fire Professionals?

Processing waste and recycling materials presents inherent risks to workers, emergency responders, and the environment. The spectrum of materials to be processed includes anything in commerce. Some potentially hazardous materials include chemicals (e.g., ammonia, chlorine, hydrogen peroxide), pressurized containers (e.g., aerosol cans, propane tanks, compressed gases), oils (lubricant, cooking, cosmetics), glass, dust, rags soaked in flammable liquids and batteries (e.g., lithium-ion, lead acid, alkaline).

Additional types of processed materials can include rubber, concrete, gypsum, and other building products. As indicated in Table 4 below, common hazards associated with the initial materials are also quite broad. Physical hazard descriptors for this selected list of waste materials include explosive, oxidizer, reactive/highly reactive, ignitable, flammable/highly flammable, and even spontaneous fires. Personal health hazard descriptors are even more comprehensive, ranging from corrosive to asthma, poisonous, irritants/strong irritants, toxic/highly toxic, asphyxiants, carcinogenic, and caustic.

Table 4 - Hazards from Example Waste Materials

Waste Materials	Common Hazards
Ammonia	Corrosive: skin, eyes, and lungs; reactive with other chemicals; explosive
Chlorine	Strong irritant to skin, eyes, throat, and lungs; highly reactive
Hydrogen Peroxide	Irritant to the eyes, nose, skin, and throat; oxidizer
Aerosol Cans	Explosive if heated/crushed; toxic contents, ignitable
Propane Tanks	Explosive if heated/fire; contents asphyxiant, skin burns from cold liquid

Waste Materials	Common Hazards
Compressed Gases	Asphyxiants, fires, explosions, and toxic gas exposures
Lubricant Oils	Skin irritant: itching or skin rashes (dermatitis)
Cooking Oils	Highly flammable, may contain carcinogenic contaminants
Cosmetic Oils	Highly flammable, some are also highly toxic
Glass	Physical injuries
Dust	Inhalation irritation – nose, throat, lungs, asthma; explosive in air
Rags Soaked in Flammables	Fires and explosions if containers are sealed
Lithium-Ion Batteries	Spontaneous fires, highly toxic emission products
Lead Acid batteries	Acid is corrosive to skin, eyes, nose, throat, and lungs; flammable; poisonous.
Alkaline Batteries	Leaked white powder is caustic/corrosive – skin, eyes, nose, throat, lungs
Mixed Wastes	Potentially ALL OF THE ABOVE combined

What is Your Advice for Protecting Frontline Workers and Fire Professionals?

Since both physical and health hazards associated with these materials are potentially severe, **the best protection for employees, their associates, the community, and the environment is awareness—knowledge and best practices learned through training and supervised experience, not from accidents and injuries!**

The first step is for each employee to learn the hazard vocabulary. For example, what is the difference between the following terms:

- Corrosive, irritant, and caustic
- Flammable, highly flammable, spontaneous fire, and oxidizer
- Reactive, highly reactive, and explosive
- Toxic, highly toxic, poisonous, carcinogenic, asphyxiant
- Dermatitis, asthma, and asphyxiant .

Once these definitions are understood, the second step to greater personal, associate, community, and environmental safety is correctly associating each hazard with the processed waste material. Obviously, “highly” materials must be handled more consciously than other materials.

The third step in improving safety and avoiding accidents is to learn what PPE is needed to handle each type of hazardous waste material. Corrosive or irritating materials may require appropriate gloves, safety glasses, goggles, or coveralls. Any flammable or potentially explosive waste materials warrant spark-avoidance barriers and grounding resources *before processing.*

Appropriate breathing protection is warranted for flammables, corrosives, irritants, caustics, asphyxiants, and carcinogens. Finally, waste materials that are reactive, oxidizers, or explosives must be processed separately to avoid mixing with incompatible

materials that will result in unintended consequences. Implementation of a formal employee training program, starting with initial employment, will significantly minimize the risk of either physical or health accidents and injuries.

What are the Increased Hazards When a Fire or Explosion is Introduced into the Equation?

As formidable as the many types of waste materials processed daily can be, their hazards during and following a fire are much greater. Table 4 above lists 15 selected waste materials and their common hazards. In a fire, these 15 waste materials become over 70 fire chemical hazards (see Table 5 below).

Fire breaks down each waste material into various chemical products that multiply the hazards. These risks are not only much greater for the employees but are also for the associates, community, and environment. *Preventing fires in waste and recycling facilities becomes an extremely high priority!*

Table 5 - Chemical Hazards from Burning Waste Materials

Waste Materials	Fire Chemical Hazard
Ammonia	**Reacts violently with acids, halogens, calcium hypochlorite** **Nitrogen Oxide** (NOx; acid rain) **Ammonium Hydroxide (**weak caustic)
Chlorine	**Highly Reactive Chlorine Radicals** – cancer, cardiovascular and inflammatory disease, cataracts **PCB** – toxic to the body's immune, reproductive, nervous, and endocrine systems **PCDD (dioxins)** –cancer, reproductive & immune systems toxicity; bio accumulative; long body half-life (>8 years) **PCDF (furans)** - cancer, reproductive & immune systems toxicity; bio accumulative; long body half-life (>8 years)
Hydrogen Peroxide	**Explosive; oxidizer; combustion promoter** – increases flame temperature; toxic when mixed; breathing vapors irritate the nose, eyes, throat, and lungs.
Aerosol Cans	**Explosive: toxicity depends upon contents** – irritants and toxic to lung, liver, brain, blood
Propane Tanks	**Explosive** – when heated **Soot** - Cancers – lung & bladder – asthma, heart disease, death **Aldehydes** - Cancer – nasopharynx - cardiovascular disease, skin, eyes, nose, throat, lungs irritant, headache, dizziness, fainting **Ethylene** – Carbon Monoxide – poisonous gas **Propylene** – Carbon Monoxide; Soot **Carbon Monoxide** – poisonous gas
Compressed Gases	**Asphyxiants; gas specific** – explosive, flammable, toxic lung, liver, brain, blood
Lubricant Oils	**Ash/Particulates with Persistent Free Radicals** – Cancer – lung, asthma, cardiovascular disease, COPD, persists in air. **Soot** -Cancers – lung & bladder – asthma, heart disease, death **Polycyclic Aromatic Hydrocarbons (PAHs)** – cancers – lung, skin, bladder, scrotum, male/female reproduction, COPD, cardiovascular disease, confusion, mutagens **Dioxins** – cancer – breast, pancreas, colon, lung, liver, prostate, chloracne, liver/immune/cardiovascular diseases, hormone disrupters, persistent environ. pollutants **Aldehydes** – cancer – nasopharynx, cardiovascular disease, respiratory irritant, headache, dizziness, fainting **Substituted Benzenes** – Cancer- blood, kidneys, lungs, liver, respiratory irritant, bronchitis, headache, fainting hand coordination **Sulfur Dioxide** – cancer – lung, pharynx, respiratory irritant, asthma, bronchitis, sulfur particles, air acidification

Waste Materials	Fire Chemical Hazard
	Nitrogen Oxides – respiratory irritant & increases infections, bronchitis, bronchiolitis, emphysema, COPD, headache, fatigue, dizziness, in many other highly toxic chemical families and 13 trace elements
Cooking Oils	*Similar to Lubricant Oils*
Cosmetic Oils	*Similar to Lubricant Oils*
Glass	**Fractured glass;** dust (asthma); heavy metals (e.g., cadmium, lead, cobalt), arsenic oxides (cancer+)
Dust	*Similar to Lubricant Oils*
Rags Soaked in Flammables	*Similar to Lubricant Oils*
Lithium-Ion Batteries	**Lithium salt** – nervous/kidney/hormone systems damage; severe eye/respiratory irritant **Nickel** – cancer of the nose and lungs; asthma; bronchitis; toxic to lungs, stomach, kidneys; skin sensitizer **Manganese** –fumes damage the lung, liver, kidney, and nervous systems, causing manganism, Parkinson's, and heart effects. **Cobalt** – cancer; harms heart, lungs, eyes, nose, throat, and skin; allergic dermatitis, rhinitis, and asthma **Copper** – flu-like illness – headache/fever/chill/aches/cough; metallic mouth taste; nose/throat irritant **Graphite** – respiratory irritation; pneumoconiosis **Hydrogen Fluoride (HF**) Gas – very poisonous & corrosive; lung irritation & hemorrhage; heart arrhythmia **Phosphoryl Fluoride Gas** – forms HF with water, causing severe respiratory damage and lung edema.
Lead Acid batteries	Acid corrosive to skin, eyes, nose, throat, lungs; flammable; poisonous
Alkaline Batteries	Leaked white powder is caustic/corrosive to skin, eyes, nose, throat, and lungs
Mixed Wastes	**Dioxins; Furans; Mixed metal dusts & fumes** – metal fume fever – Potentially ALL OF THE ABOVE combined

Fire chemical hazards from waste materials are more numerous than those from raw waste materials but are also more severe and profound. Responsible management of a waste or recycling facility must not only provide appropriate personal protective equipment in case of a fire in their facility, but they must also educate and train local firefighters and other emergency responders to ensure they are adequately equipped and knowledgeable in case of a waste material fire. Local first responders are often volunteers and minimally equipped and undertrained. As a result, they can be exposed to severe, life-threatening exposures from a waste materials fire that can shorten their lives. Preparation through training and equipment acquisition are the keys to maintaining maximum safety and health for all.

For more on this topic, refer to section 4.4, "The Undertraining of Fire Response Teams is a Problem without Boundaries."

6 Fire Causation Trends at Waste & Recycling Facilities

When I started consolidating the reported waste and recycling facility fires in 2016, I realized that the first few years would drive the baseline data and define the scope of the problem. This would provide a basic understanding of the consequences and help find and evaluate the effectiveness of solutions to address problems. Now, with seven years of data, we can highlight the trends and identify where we need to act.

According to the data, **2023 was the second-worst year for publicly reported fire incidents at waste and recycling facilities in the U.S. and Canada since I began reporting in 2016.** The industry experienced 373 reported fire incidents, higher than the average of 340.

So, how do we make sense of that number from a historical perspective?

During 2018, the waste and recycling industry had limited data and a minimal understanding of the problem. Now, with five more years of data, it better understands the problem. As a society and industry, we are in a much different place, socially and technologically speaking, than in 2018. Today, it is well established that there are inherent risks of fires in waste and recycling streams, whereas before, we were more unsure.

The scariest part of this data is not that one of these fires occurred at any of the over 500

Figure 14 - Waste & Recycling Facility Fires (reported) in U.S. & Canada (2016-2023), by year

Source: Ryan Fogelman, rfogelman@firerover.com

facilities equipped with the Fire Rover system. That is not to say fires did not occur at our

clients' facilities, but only one rose to the point of being reported, and the fire did not start in an area protected by Fire Rover. Additionally, publicly reported incidents are typically "two-alarm" or larger, which makes them newsworthy.

Figure 15 - Waste & Recycling Facility Fires (reported) in U.S. and Canada (2016-2023), presented by material processed (waste, paper, and plastic combined)

REPORTED WASTE & RECYCLING FACILITY FIRES BY MATERIAL US/CANADA

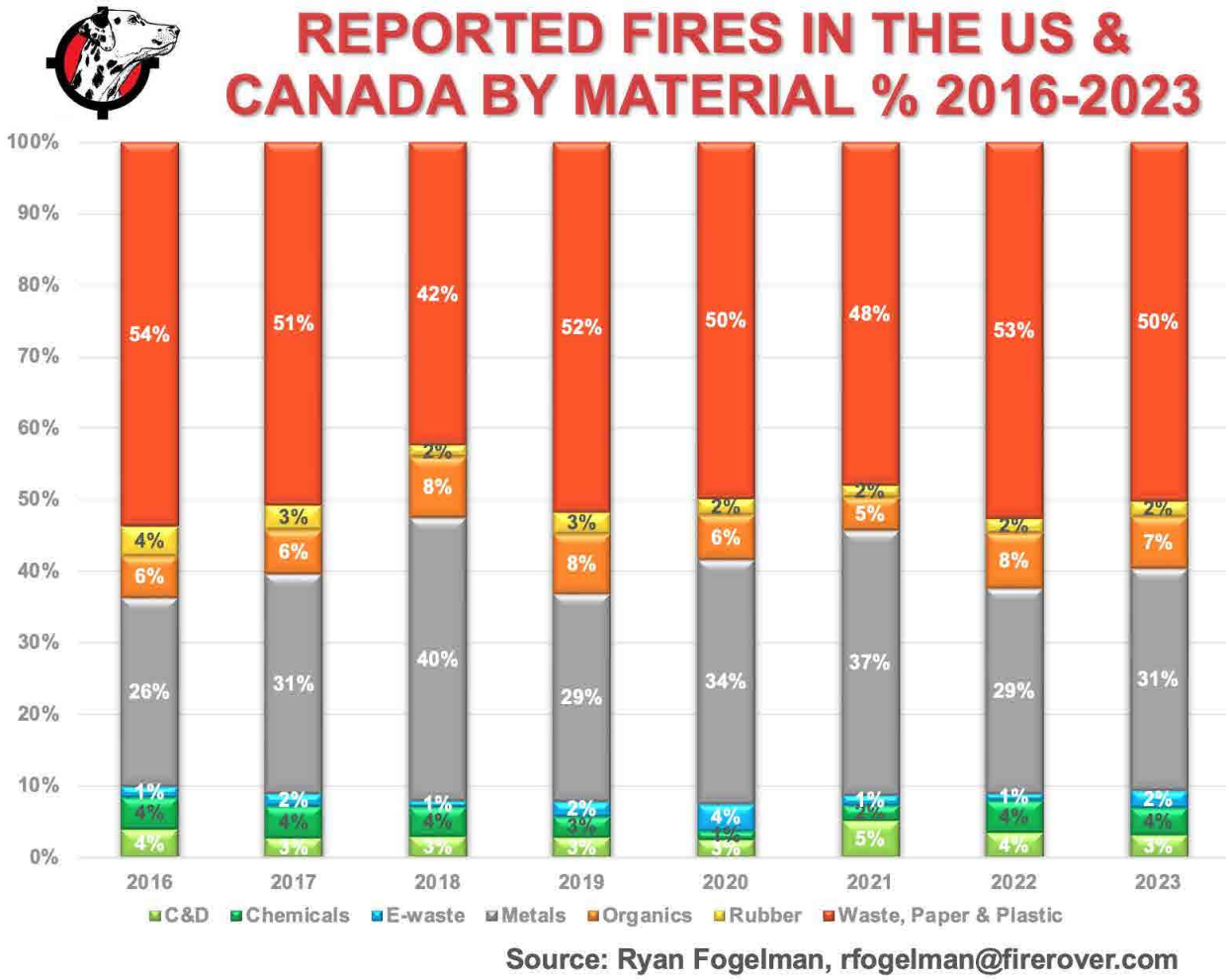
Incidents By Type Of Material Processed	2016	2017	2018	2019	2020	2021	2022	2023	Total	Average '16-'23	% of Total Incidents 2016-2023	2023 % Change v. Average	2023 % Change v. 2022
Waste, Paper & Plastic	146	147	154	177	158	176	205	187	1350	168.8	49.7%	10%	-10%
Metal	72	89	145	100	108	136	112	116	878	109.8	32.3%	5%	3%
Organics	16	18	31	29	20	17	30	27	188	23.5	6.9%	13%	-11%
Chemicals	12	13	15	10	4	8	17	14	93	11.6	3.4%	17%	-21%
C&D	11	8	11	10	8	19	14	12	93	11.6	3.4%	3%	-17%
Rubber	11	10	6	10	7	6	8	8	66	8.3	2.4%	-3%	0%
E-Scrap	4	5	3	7	12	5	4	9	49	6.1	1.8%	32%	56%
Total	272	290	365	343	317	367	390	373	2717	339.6	100%	9%	-5%

Waste, Paper and Plastics have made up almost half of the reported fire incidents with Scrap Metal Recycling coming at a third of reported fires annually.

To evaluate the data from 2023 more closely, it is best to focus on trends and percentages of the specific material processed. As we can see from the table above, in 2023, there was a 5% decrease in fires compared to 2022, but a 9% increase compared to the average number of fires over the last eight years. Fire incidents at waste, paper, and plastic processing facilities decreased 10% from last year but increased by 10% compared to the eight-year average. However, when it comes to organics, chemicals, and e-scrap facilities, there were 13%, 17%, and 32% increases in fire incidents compared to their respective historical averages.

Typically, I group waste, paper, and plastic into one group for analysis. This is for several reasons, but most importantly, newspapers do not typically list the cause of the fire, so characterizing them can become challenging. I have broken out the materials in the graph below as a percentage of the total.

Figure 16 - Waste & Recycling Facility Fires (reported) in U.S. and Canada (2016-2023), presented by year and % material processed



Looking at the data this way helps us more easily observe the categories or categories of materials with more yearly fires. In 2018 and 2021, that stand-out category was scrap metal fires; in 2019 and 2022, it was waste, paper, and plastic. Interestingly, in 2023, we observe a representative breakdown of fires by material category compared to the previous seven years, with waste, paper, and plastic fires leading at about 50% and scrap metal fires at about 31%.

The fact that most fires are in the waste, paper, and plastic category is not a surprise, as these are the materials processed by MRFs and transfer stations across the U.S. and Canada. The major distinction in the materials is that they are traditional channels for other improperly disposed of hazards, like lithium-ion batteries, chemicals, gasoline, and propane tanks, a type of contamination that carries additional fire risk.

Other categories that serve as channels for commonly disposed of hazards include C&D debris, scrap metal, and e-scrap. The incidents in these categories are separate, as each

occupancy has its unique characteristics and is collected and disposed of at different processing facilities; however, they all share similarities in that most of their risks are avoidable with proper front-end preparation.

Let us look at these category trends in 2023...

6.1 Decrease in Waste, Paper, and Plastic Fires

Waste, paper, and plastic recycling fires decreased in 2023 compared to 2022. The total number of reported fires in the U.S. and Canada was 187, compared to last year's total of 205. These facility types comprised nearly 50% of the fire incidents affecting the waste management industry for both years. While we cannot pinpoint the exact material that caused each fire, the continued improper disposal of lithium-ion batteries likely played a role in these fire incidents.

This is a global issue, and its cost to the industry was outlined in a 2021 report[27] based on research conducted by Eunomia. According to the report, this problem is only set to worsen, with increasing amounts of lithium-ion batteries placed on the market each year. The positive news is that those focused on safety, proper fire prevention planning, and investments in technology solutions have experienced fewer fires. The survey results by Eunomia outline its recommended best practices for risk reduction to the industry, such as getting lithium-ion batteries out of the waste stream through education, fines, deposit programs, and more. Still, it does not single out technology innovations like Fire Rover, which has proven to be key to mitigating these risks in the United States.

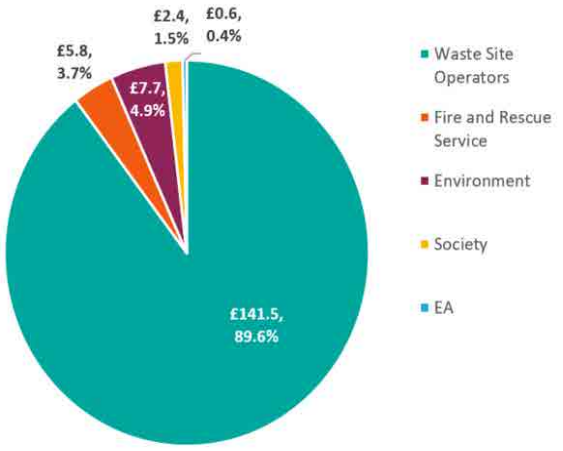


Figure 17 - UK's Cost of Waste Fires Caused by LIBs by 'Cost Incurred By' (Millions of GBP (£) and %)

Another report released by the U.S. Environmental Protection Agency in 2021 also backed this viewpoint. The report, "An Analysis of Lithium-ion Battery Fires in Waste Management and Recycling", which includes information from various sources, including my research, draws attention to the following facts:

1. The waste and recycling industry has an inherent risk of fire incidents.

[27] Website (Eunomia, "Lithium-ion Battery Waste Fires Costing the UK Over £100m a Year " Report, published January 13, 2021): https://www.eunomia.co.uk/lithium-ion-battery-waste-fires-costing-the-uk-over-100m-a-year/

2. Most of the costs of these incidents unfairly fall on waste and recycling facility operators and local fire professionals.
3. There is no consensus solution to the problem, but effective solutions exist, such as best practices and technology.

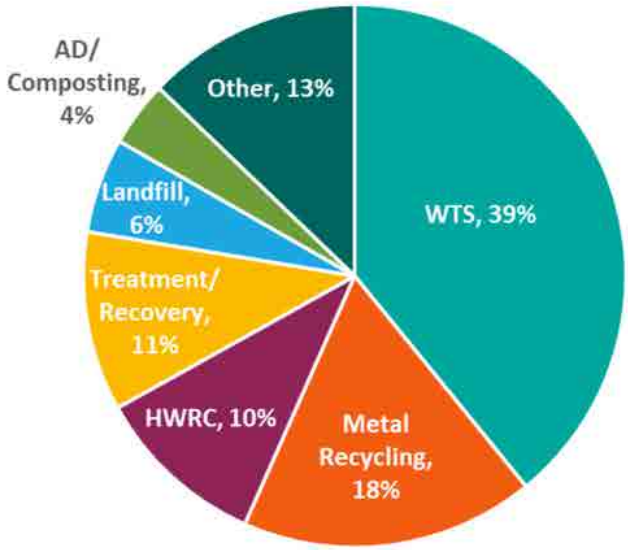
6.2 Slight Increase in Scrap Metal Fires

After compiling eight years of data, it now seems as though 2018 and 2021 spikes in a lower yet steady incline from 2016 to 2023. In 2023, we saw a slight increase in scrap metal facility fire incidents over 2022. After a few years of steady inclines, scrap metal fires finally decreased in 2022, but that reversed in 2023. To slow this slight upward momentum, the industry must continue to rely on implementing best practices developed by traditional industry fire experts rather than rest on its laurels from 2022. This industry has spent much time and effort implementing "best practices." Still, I believe the waste and recycling industry could benefit the most from investment in new fire technology and evaluation and recommendations from fire experts outside the industry.

🔥Watch the Fire Rover Fight A Light Tin Pile Fire 🔥

My team members at Fire Rover have learned from being on the frontlines that scrap metal processing facility operators have more alarms per site than their counterparts in waste, paper, and plastic processing. There can be many factors that contribute to this. We see several thermal events in auto shredder residue piles, but that does not account for all of them. Do not get me wrong; these are great operators who understand that they need to invest in proven technologies to help mitigate their specific risks. Can the fire risk be mitigated in other ways? Of course, many operators have done so successfully. There are several potential fire risks for the operators—from the automotive shredder residue piles to light tin piles, shredders, storage, and more.

The truth is that insurance companies are willing to provide policies to all types of high-fire-prone industries. They only leave when they feel the risks are uncontrollable or there is no end in sight.



Source: EA data, provided by the EA on 15.10.20 (2020) Waste fires reported for England 2014 - 2019

Figure 18 - Waste Fires in England by Facility Type 2014-2019 (UK EA Data)

England's data provided in Eunomia's report shows that only 18% of its fires occur at "metal recycling" operations. This data looks at all waste fires, not just fires caused by lithium-ion batteries. According to my data, scrap metal fire incidents make up 32.3% of all reported fires in the U.S. and Canada (2016-2023); this number is even higher if you include e-scrap fire incidents. In the same data, waste, paper, and plastic fires make up nearly half of all fires (49.5% for 2016-2023).

After seeing this data, we must ask ourselves why the scrap metal operators in the U.S. are experiencing significantly more fire incidents than in England.

There is no easy answer to this question. Still, I can confidently state that any scrap processing facility operators that have added Fire Rover's technology to their operational best practices have not had a major or catastrophic fire incident while our solution has been in place. Only time will tell whether the fire prevention planning strategy that the Institute of Scrap Recycling Industries (ISRI) has developed and rolled out to its members is enough to stem the tide of these fires alone or if investment in tech will be required.

6.3 Decrease in C&D Debris Fires

With eight years of data, it now seems that the number of C&D Waste fire incidents in 2021 (19 total C&D fires) was a spike. In 2022, we saw that number drop to 14; again, in 2023, it decreased to 12. Fortunately, this category has decreased again to align with the average (11.6) and the 2016 to 2020 trend. There has been continued investment in these facilities, with several being early adapters to Fire Rover's solutions, which may be the reason for the decrease, but it is difficult to assign causation here.

🔥 Watch the Fire Rover Work Quickly to Stop a Mobile Shredder Fire in its Tracks 🔥[28]

6.4 Decrease in E-scrap Fires

While we saw a 25% drop in e-scrap fire incidents from 2021 to 2022 and a 43% decrease from the average from 2016 to 2021, we unfortunately saw a dramatic jump in the number of e-scrap fires in 2023. There were 9 e-scrap facility fire incidents in 2023, 5 more than the 4 incidents we saw in 2022 and 3 more than the average annual number over the last eight years.

Recycling personal electronics and personal storage is still new from a historical perspective. I have heard that the global recycling rate for lithium-ion batteries is exceptionally low (between 1% and 5%, depending on the source). This leaves much opportunity for improvement and investment, as this is a fast-growing solid waste stream due to increased demand for these products and their shorter product cycles.[29]

The public's push to recycle these materials has two positive effects: less personal storage and/or electronics go into waste and single-stream recycling streams, and we can better recycle and reuse all the components, including rare earth metals (also referred to as "critical minerals") we so desperately need because they play a part in the production of clean energy technologies.

Due to the incredible value of the components of electronic devices, a burgeoning industry has developed with under-trained and under-protected workers that handle e-scrap around the world. Depending on their location, anyone with the desire, a pair of pliers, and a garage can hang a shingle may claim to recycle electronics. There are some great e-scrap operators out there, but the process is custom and different than return merchandise authorization programs, which have existed for years and allow a specific manufacturer to control how they disassemble and reuse or dispose of their products' components, specifically batteries.

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[28] Website (YouTube – Fire Rover): https://www.youtube.com/watch?v=cVlb-47Q8t8

[29] Website (Science Direct – "A global perspective on e-waste recycling", K. Liu, Q.Tan, J. Yu, M. Wang; published Feb 2023 and accessed online in January 2024): https://www.sciencedirect.com/science/article/pii/S2773167723000055

Regardless of the operators' experience, recycling general electronics comes with many different processes, such as disassembly and removal of lithium-ion batteries in products, which exposes them to fire risks. Unfortunately, operators performing this necessary function for society are often left to hold the bag with most of the risk and cost of fire dangers.

7 Performance of Fire Rover's Solution

When modern technology hits the market, there is a lifecycle that it must go through before it can make it to the wide-acceptance stage. So many companies go down this path only to fizzle out well before hitting this desired stage. For Fire Rover, we started developing our technology in 2015. Our solution is a culmination of different layers that include the technology and solution-integrating people, software, services, warranties, and more. When we started Fire Rover, there was no guarantee that our solution would work, nor was there a guarantee that customers would adopt it.

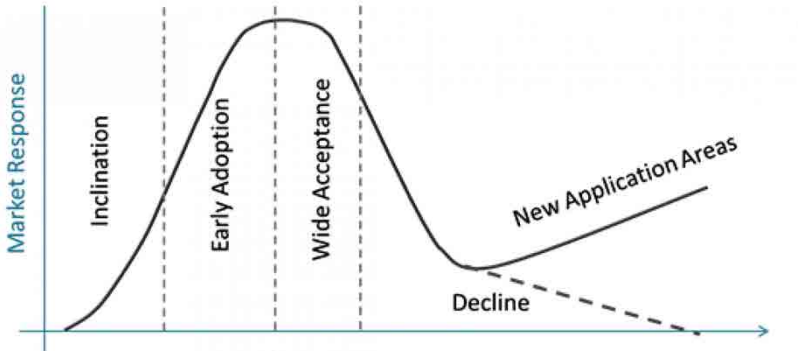


Figure 19 - New Technology Acceptance Stages

Fortunately for the inclination stage of our technology (but also unfortunately for the waste and recycling industry), we had some amazing partners in the scrap and recycling industry with a burgeoning problem invading their commodity streams: lithium-ion batteries. These batteries were an impending threat to the business's very existence. Compounded forecasts for these hazards added to the base of traditional fire hazards already inherent in the business and made for a significant shakeup that required new and innovative solutions to deal with the hazards.

Most people do not like change. Sometimes, change is self-driven, but usually, there is an outside force that drives us to change. In this case, the hazard increased fires from 2016 to 2018 and was truly driven by an increase in unpreparedness for the lithium-ion battery onslaught that punched the industry in 2018. At that time, some customers started looking to fire technology to solve the impending problem.

The fire experts and operators did what they had always done when dealing with traditional fire hazards in the waste and recycling industry: clean up their operations and develop processes and "best practices" to deal with the problem. The fire protection industry has used the same approach to fight fires for over a century: "water, water, water." Sprinkler and deluge systems have become the standard across all industries, as well as commercial and residential fire hazards across the globe. However, traditional

sprinkler systems, which are required by law in most jurisdictions, are only there for "containment," not initial or final extinguishment. In areas that had fast-moving, explosive fires, typically due to accelerants like jet fuel, the fire industry pushed and implemented expansive foam deluge solutions that were not only expensive but came with headaches, like false deluges, which could severely hurt anyone caught inside, as well as ruin any equipment.

As we continued to press on, it became clear there were two sides to both the operators and the fire protection experts: those for change and innovation and those against change and innovation. I am certainly not saying that those against or skeptical of innovation were in any way unjustified. Many technologies come and go. Operators and fire professionals have been "sold" the idea of innovative technology solving a problem hundreds of times. Typically, these solutions had limitations on how they could perform when in a real environment. Many of our early adopter customers took risks, both monetarily and with their resources, to help us prove that our solution was worth the investment.

Fast forward to today, and not only have we kept all but one of our customers—one ceased operation—but we have never had a catastrophic facility loss start in an area we protect. Additionally, we have been awarded a utility patent for our solution, won a Gold Edison Award for industrial innovation, have been included in several National Fire Protection Association (NFPA) codes, secured many variances for industrial uses that replace traditional sprinkler systems, have been highlighted in NFPA's Fire Protection Handbook;[30] and are in the final stage of being accepted for two insurance industry certifications that will provide us the credibility needed for our solution to be accepted by the fire industry.

7.1 The Fire Rover Performance Scorecard

In the last year, from January 1 to December 31, 2022, Fire Rover systems across the U.S. and Canada responded to the following numbers of incidents (events). 2,880 events were observed and verified by remote agents at all facilities protected by Fire Rover. Of those events, only 12% required system pressurization, and less than half (5%) required the activation of the fire suppression system and dispatch to the fire local fire department or fire brigade.

[30] See Chapter 4, Section 11 on Fire Prevention Practices of the 21st edition of the National Fire Protection Handbook (2023), published by the National Fire Protection Association. This section deals with Fire Hazards of Construction, Alteration, and Demolition of buildings and was revised by Bruce Campbell from Jensen Hughes. Fire Rover unit was highlighted as an alternative "new technology" recognized by NFPA 241.

FIRE ROVER SOLUTION PERFORMANCE 2022 & 2023

	Total Events 2022	Total Events 2022 (%)	Events Per System 2022	Total Events 2023	Total Events 2023 (%)	Events Per System 2023	Yr./Yr. Change (%)
Actionable Fire / Hotspot	1409	100.0%	4.56	1809	100.0%	4.09	28%
System Pressurizations	344	24.4%	1.11	301	16.6%	0.68	-13%
Fire Suppression Activations	137	9.7%	0.44	183	10.1%	0.41	34%
Fire Dept / Fire Brigade Dispatches*	146	10.4%	0.47	217	12.0%	0.49	49%

Source: Ryan Fogelman, rfogelman@firerover.com

The table above represents a breakdown of the events recorded by the central stations for the Fire Rover systems during 2022 and 2023. It demonstrates the highly volatile and hazardous areas in which the systems are installed. Typical fire detection and suppression systems can last their entire lifecycle without detecting a confirmed fire. However, each Fire Rover system averages six to nine confirmed fires or hotspots per year, with roughly half the systems activating their suppression system yearly.

A hotspot represents a thermal anomaly compared to a fire incident (event) where smoke and/or flames are present. The central station operators confirm and filter false positives after utilizing thermal and visual cameras, reducing unwanted alarms to the site or local fire department. Considering the broad coverage of each system and high-hazard areas covered by Fire Rover, the event numbers provide a statistically significant set to base future performance. Compared to the small number of suppression activations, many events are testaments to the system's early detection capabilities.

So, let us dig into the numbers. If you follow my data and reports, you will see we adjusted the data to include now “Actionable Fire/Hotspot.” These are the verified fire hazards that our Fire Rover agents encounter during their main monitoring. Think along the lines of a loader pulling a lithium-ion battery out of a pile or an auto shredder residue pile. The main difference between our solution and any other one on the market is that we are the only ones looking at every piece of hay to find the needle in the haystack. Our agents look at thousands of hay straws (false triggers like machinery and equipment) to find the needles (Actionable Fire Events). In 2022, we experienced 1,409 Actionable Fire/Hotspot events,

which increased to 1,809 events in 2023. This makes sense based on the number of our installations increasing from an average in the 400s to an average in the 500s.

“System Pressurizations” are every time our Fire Rover agent brings water to our strategically placed nozzles. You can see this number has decreased year over year. This makes sense because our agents have gotten better at knowing when to prepare for combat. The fact is there are consequences for our clients when we fill a “dry” system with water. In our Fire Rover box systems, it might waste some of our supply as we must purge the suppressant if it is not used so it does not freeze. Similarly, our continuous flow solution utilizes water from the city or an outside tower, so the pipes must be drained after shooting. As a company, we have worked extremely hard to learn from our experience to be as efficient as possible with our client’s resources, especially those that can lead to any disruption in their business operations.

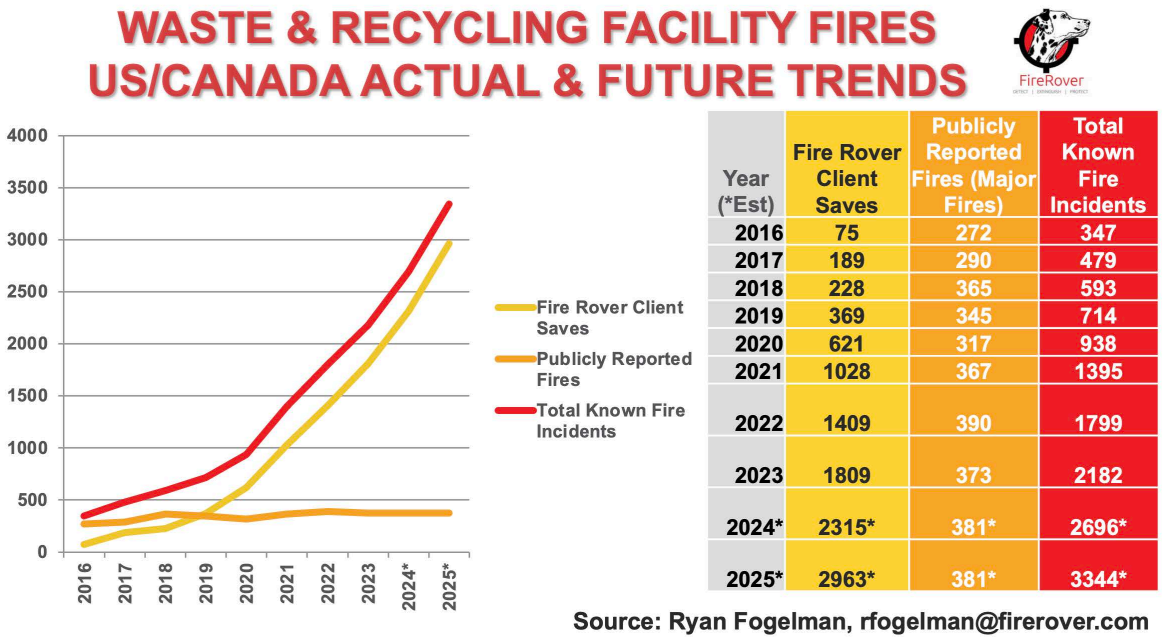
Now we get to the fun part: “Activations.” These are exactly what they sound like. Our agent is shooting one of our nozzles to suppress an active fire. This number accounts for about 10% of our incidents and has remained consistent year over year.

The final key performance indicator is when we dispatch the fire department or formal fire brigade to our client’s operations. This number increased by almost 50% yearly and 2% in total events from 2022 to 2023. We have a degree of discretion regarding whether an event will require fire professionals to arrive on the scene. Collaborating with our clients, we have determined that a more aggressive dispatch approach is warranted to keep workers safe during an active fire and in the overhaul/clean-up phase.

The other number that deserves explanation is the number of dispatches compared to the number of sprays or suppressions. We offer our customers detection-only solutions at their operations through our OnWatch Mobile Landfill Detection Unit and our Fire Watch Replacement solution, where identifying a fire hazard results in an immediate dispatch to the fire department. Additionally, we commonly encountered incidents where our detection equipment identified fire incidents out of our nozzles’ range.

In 2023, my team at Fire Rover was responsible for 2,880 saves at our more than 500 client operations. Fortunately, we have never had a catastrophic incident that began in an area we protect. We currently safeguard eight of the country's top 10 waste and recycling companies and family-owned operations, municipalities, and corporations in the U.S., Canada, the UK, France, and Australia. We have fought against any major incident with minimal damage to our clients’ facilities. Even with our performance, 2022 was the highest year for reported waste and recycling facility fires that we have experienced since I began consolidating the data in 2016. We even beat last year’s record.

Why is this number significant? We know the number of batteries we use in personal electronics and storage equipment is growing. I previously stated that 2021's high number of reported incidents was possibly due to 2020's pullback during the COVID-19 pandemic. The assumption was that the waste and recycling tonnage would slow down in 2020 and then be pushed into 2021.



Year (*Est)	Fire Rover Client Saves	Publicly Reported Fires (Major Fires)	Total Known Fire Incidents
2016	75	272	347
2017	189	290	479
2018	228	365	593
2019	369	345	714
2020	621	317	938
2021	1028	367	1395
2022	1409	390	1799
2023	1809	373	2182
2024*	2315*	381*	2696*
2025*	2963*	381*	3344*

Source: Ryan Fogelman, rfogelman@firerover.com

With Increasing Lithium-ion Battery Contamination, Additional Fire Protection Solutions like Fire Rover Should Result in Fewer Major Fire Incidents

Figure 20 - Waste and Recycling Facility Fires (Reported) in the US & Canada: Actual & Future Trends

What can we hope for? We can hope that our educational efforts will begin to pay off in the coming years, investments in prevention and modern technologies (like x-ray sorters and Fire Rovers) will protect more facilities, ultimately cutting the number of major fires and consequently reading about fewer reported fires in the news.

7.2 Tracking Reported Fires in the U.S. & Canada

The monthly reports I develop help identify trends where the waste and recycling industry is struggling concerning fires and how my company can improve its service and product offering to help the industry operate more safely and efficiently.

The chart below shows the total monthly fires between February 2016 and December 2023.

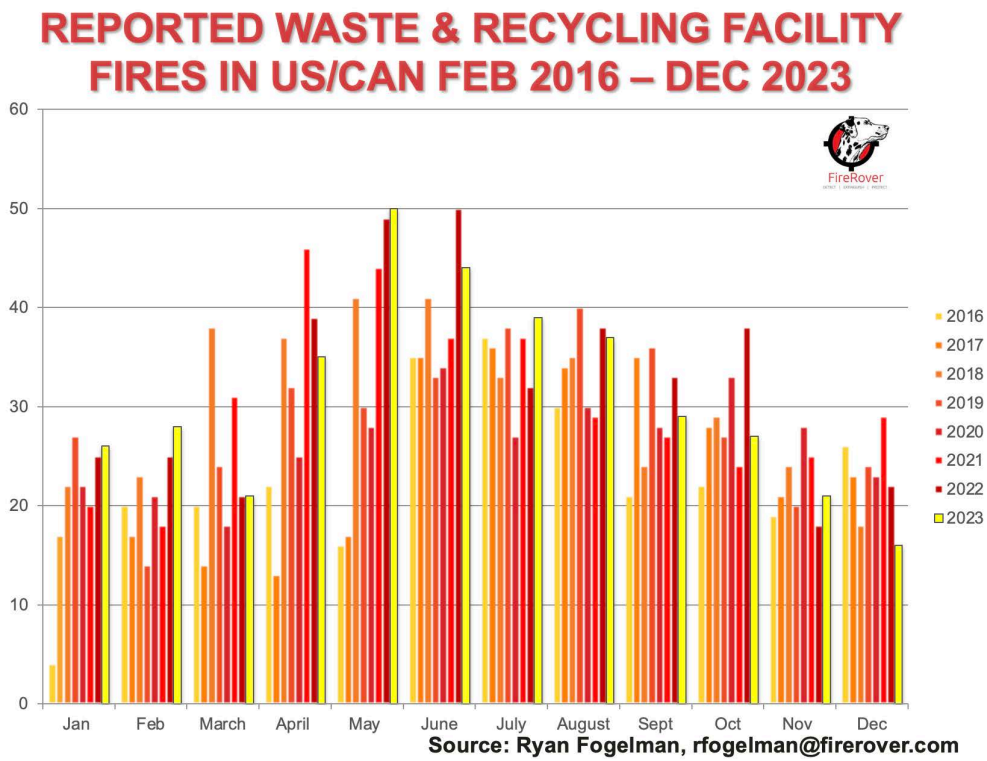
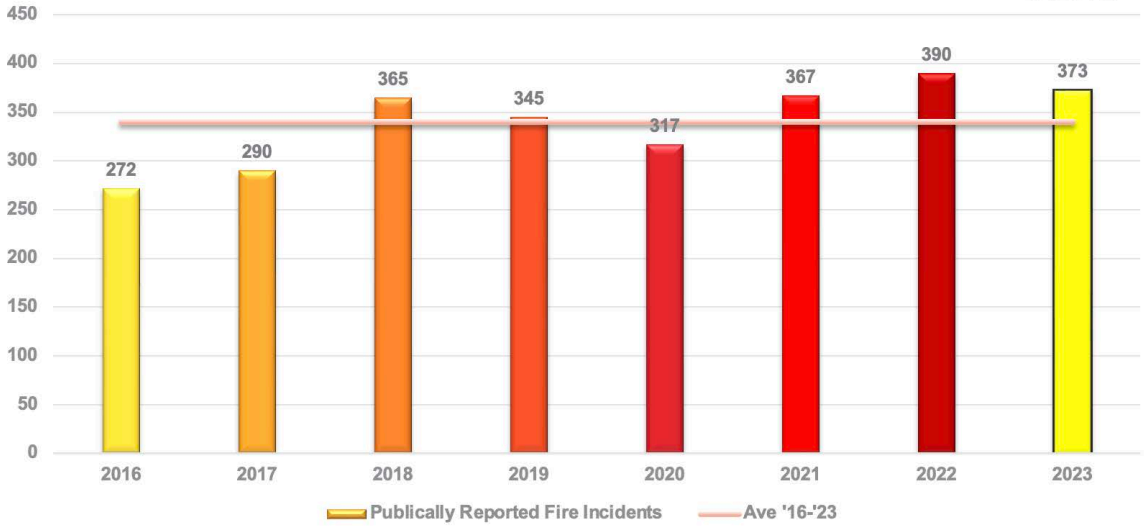


Figure 21 - Summary of Reported Waste & Recycling Facility Fires in the US and Canada from February 2016 to December 2023

Over the years, I have collected important data on reported facility fires. I define "reported facility fires" as any fire reported by the media at a waste or recycling facility in the U.S. and Canada. Typically, the media reports larger fires that require fire professionals to arrive on the scene and where the public can witness the effects.

Some industry professionals suggest that most fires related to waste and recycling go unreported. Others disagree. One thing the industry can agree on, however, is that any fire is one too many.

ANNUAL WASTE & RECYCLING FACILITY FIRES US/CAN 2016-2023



Source: Ryan Fogelman, rfogelman@firerover.com

2023 COMPARED TO PRIOR YEARS REPORTED WASTE & RECYCLING FACILITY FIRES

Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
2019 27	**2023 28**	2018 38	2021 46	**2023 50**	2022 50	**2023 39**	2019 40	2019 36	2022 38	2020 28	2021 29	2022 390
2023 26	2022 25	2021 31	2022 39	2022 49	**2023 44**	2019 38	2022 38	2017 35	2020 33	2021 25	2016 26	**2023 373**
2022 25	2018 23	2019 24	2018 37	2021 44	2018 41	2016 37	**2023 37**	2022 33	2018 29	2018 24	2019 24	2021 367
2020 22	2020 21	**2023 21**	**2023 35**	2018 41	2021 37	2021 37	2018 35	**2023 29**	2017 28	2017 21	2017 23	2018 365
2018 22	2016 20	2022 21	2019 32	2019 30	2017 35	2017 36	2017 34	2020 28	2019 27	**2023 21**	2020 23	2019 345
2021 20	2021 18	2016 20	2020 25	2020 28	2016 35	2018 33	2016 30	2021 27	**2023 27**	2019 20	2022 22	2020 317
2017 17	2017 17	2020 18	2016 22	2017 17	2020 34	2022 32	2020 30	2018 24	2021 24	2016 19	2018 18	2016 272
2016 4	2019 14	2017 14	2017 13	2016 16	2019 33	2020 27	2021 29	2016 21	2016 22	2022 18	**2023 16**	2017 290

Source: Ryan Fogelman, rfogelman@firerover.com

7.3 Why Do We Share These Numbers?

When I started with Fire Rover in 2015, I noticed a void in the waste and recycling industry for fire incident data. I searched for data on fire incidents at waste and recycling facilities across the U.S. and Canada. I browsed online sources and spoke with facility owners, operators, safety and insurance personnel, and investors—all without success.

I knew this data was much needed, and I became determined to uncover and share it to provide the industry with this valuable information and to determine the true scope of the

problem. Through my research, I also proved that Fire Rover is both a fire suppression system and a business continuity solution backed by a return on investment that helps justify the executives' investment.

By 2016, I had gathered enough data to produce a report called "Reported Waste & Recycling Facility Fires In The US & CAN," published monthly in *Waste360*.[31] The monthly report provides updated data for the U.S. and Canada; the 2,000-plus actual facility fire number I use for this data is based on the assumptions from the data the UK Environment Agency (UK EA) collected in the table below.

Table 6 - CFOA Reported Fires 2001-2013

Year	Regulated[1] Sites	Unregulated[2] Sites**	Total Fires
2001	154	92	246
2002	203	140	343
2003	288	110	398
2004	254	83	337
2005	239	107	346
2006	284	95	379
2007	236	54	290
2008	227	48	275
2009	282	55	337
2010	286	59	345
2011	348	77	425
2012	247	55	302
2013	248	50	298

[1] Regulated – where a permitting regime specific to the source has been identified, e.g., waste operations and waste installations

[2] Unregulated – where no permitting regime specific to the sources has been identified.

Based on my research and information made available in published news stories and other published reports, we can assume that the number of non-reported fires occurring at waste and recycling operations across the U.S. and Canada is significantly higher.

In 2018, CPSC released survey results[32] from 26 waste facilities in California. According to the results, 83% of the surveyed facilities experienced a fire in the two years before, and this number has only gotten worse.

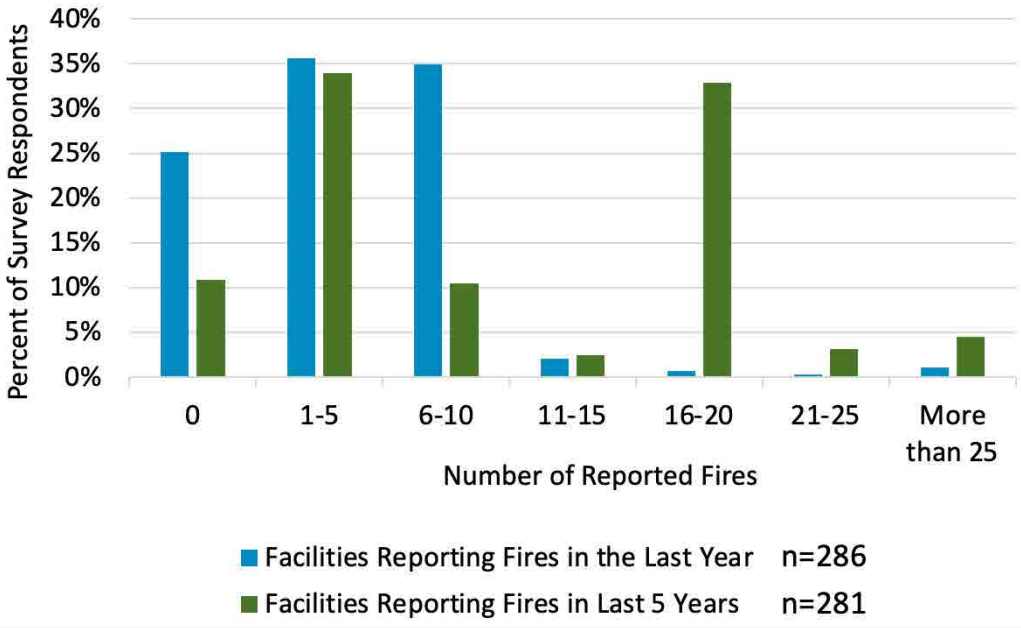
Based on reports such as the one published by CPSC, **I believe the number of waste and recycling facility fires in 2022 in the U.S. and Canada is more than 2,400.** That is six times the reported number of 390, which includes the Fire Rover reported client incidents I highlight later in this report—based on the number of MRFs, scrap yards, and transfer stations estimated by the Environmental Research and Education Foundation

[31] Website (Waste360 online magazine, Author bio and list of articles by Ryan Fogelman): https://www.waste360.com/author/Ryan-Fogelman

[32] Report download link (CPSC - Fire Incident Survey Results 4/9/18 - PDF): https://4aef0410-d204-448c-9525-d5fbfceb006e.filesusr.com/ugd/ad724e_312a645a03374a038119f5e7790dc79a.pdf

(EREF), which is close to 8,000 facilities, **more than 30% of facilities in the U.S. and Canada suffered from a two-plus alarm fire in the past year.**

To close the gap between estimating the number of reported fires and unreported fires, EREF has partnered with NWRA, ISRI, and the Solid Waste Association of North America (SWANA) to develop a research study featuring data from MRFs, scrap yards, and transfer stations during 2019 and 2020. To date, the preliminary results indicate that **more than 35% of the respondents had between one and five facility fires during the year**. Over five years, 33% of respondents stated they had 16 to 20 facility fires.



The survey also included questions about the number of fires that required an external response. While not all fires that require an external response will inherently be serious, these are most likely to be reported on by news outlets.

According to Dr. Suzi Boxman[33], who managed the study for EREF, 26% of respondents reported having one to five fires that required an external response in the case of MRFs. When we extrapolate this data to the estimated number of U.S. MRFs, 215 to 355 MRFs experienced, at minimum, one fire that required an external response; assuming these fires are more likely to attract media attention and represented in my annual reports, the survey data suggests 1.4 times to 2.3 times more facility fires than the 156 average reported fires in the "4th Annual Waste & Recycling Facility Fire Report."[34]

[33] Website (LinkedIn, Suzanne Boxman): https://www.linkedin.com/in/suzanne-boxman-phd-79b06852/

[34] Website (4th ANNUAL REPORTED WASTE & RECYCLING FACILITY FIRES US/CAN - Published March 11, 2021, by Ryan Fogelman): https://www.linkedin.com/pulse/4th-annual-reported-waste-recycling-facility-fires-/

Table 7 - Extrapolated number of facilities needing an external response[35]

	Estimated US Facility Count	Number of Survey Responses	Number of Facilities with 1-5 External Response	Extrapolated Number of Facilities with 1-5 External Response	Margin of Error
MRF	799 - 1,316	111	29 (26%)	215-355	8.6% - 8.9%
Scrap Yard	2940	62	13 (20%)	588	12%
Transfer Station	4,565	129	10 (7%)	319	9%

Overall, these results suggest that more fires are significant enough to require an external response, but they are not reported by the media, as I have said in my findings for the past seven years. On another note, EREF is finalizing the estimated MRF, scrap, and transfer stations, which I will use in my analysis.

Why am I sharing this data? The biggest issues in the waste and recycling occupancy are a lack of insurance options, increasing premiums, and the overarching decrease in appetite for the risk we see in the industry. I believe the only way to change the insurer's opinion is by showing them we are investing in solving the problem. I will say it repeatedly, but our system virtually eliminates the risk of catastrophic loss due to fire. In addition, almost all facilities are back up and running within hours, with very few instances of damage requiring repair. Insurance companies need to understand the mitigation of fire risk and that it is manageable with an investment in our solution and operational best practices. In the U.S. and Canada, a commitment has been made that I believe will result in FEWER-reported fire incidents in the future, even with MORE fire hazards entering our waste and recycling streams over the coming years.

Again, I want to thank our early adopters who initially believed in our solution. We are seeing so many other supposed "AI Systems" that promise to work in the real world and fail for varied reasons due to false alarms, false deluges, spraying into employees and/or equipment, and so many other issues when dealing with "active" situations. FM has classified our solution as the first "Smart Monitor" due to our unique layering approach that allows for early detection and safe and controlled suppression of any fire hazard that we come across. Fortunately, we are now replacing some of these systems across the globe and continue to work to help the waste and recycling industry stay safe and operate continuously with little to no downtime, as shown in our 2022 and 2023 scorecards.

[35] Website (EREF, "Assessment of the Frequency and Cause of Fires at Material Recovery and Scrap Recycling Facilities and Collection Vehicles"): https://erefdn.org/assessment-of-the-frequency-and-cause-of-fires-at-material-recovery-and-scrap-recycling-facilities-and-collection-vehicles/

8 The Consequences

When planning for safety at a waste processing facility, the adage "What can go wrong, will go wrong" is a good place to start. Imagine the hyperbolic example presented below.

Many of the potential chemical and biological threats to humanity and the environment are systematically placed into bags and/or containers near businesses and homes, where they wait in the cold or heat for often up to a week (or more) to be collected by an organized fleet of vehicles driven by trained collection professionals. These threats are then shaken (at least) moderately along a route to a central receiving facility of unknown size and sophistication, where they are unloaded and stacked into piles for sorting using rough mechanical means at slow or fast speeds. Once sorted, they may or may not be compacted again and then disposed of or stored for an indefinite time indoors or outdoors, waiting for a recycled commodities broker to say they will buy them.

Now, you must think through all the consequences of fire along the path of waste and recycling management and plan to control them at every step. *Is it any wonder that fire protection engineers require the immense training they do? No.*

A 2021 research article in the *Fire Safety Journal*, "Fires in waste facilities: Challenges and solutions from a Scandinavian perspective,[36] summarizes the potential consequences of waste handling.

> *Awareness that fires can cause dramatic and persistent adverse effects on the environment has risen since numerous high-impact incidents over the past 25 years. Traditionally, discussion of the environmental impact of fires has focused on the emissions that fires can cause to the air, water, and soil; however, in recent years, the concept of sustainability has been developed to encompass ecological, economic, and social dimensions. […] Fire in waste can impact all three dimensions of sustainability in terms of:*
>
> > *1) Ecological impact through emissions to the environment, from the fire itself and activities to mitigate the impact of the fire […].*
> >
> > *2) Economic impact through the cost of loss of a resource used to provide energy or heating, damage to equipment and buildings, rehabilitation of resources and/or the environment, and the cost of fire prevention and response.*
> >
> > *3) Social costs through redirection of taxes to recuperation of resources and/or the environment or by impact on health [… of residents] exposed to emissions.*
>
> *These effects are general for fires, but this does not lessen their relevance for waste fires, particularly because dangerous goods and mixtures of goods are often handled and stored*

[36] Website (Fire Safety Journal, "Fires in waste facilities: Challenges and solutions from a Scandinavian perspective, Fire Safety Journal, Volume 120, 2021, 103023, ISSN 0379-7112, Ragni Fjellgaard Mikalsen, Anders Lönnermark, Karin Glansberg, Margaret McNamee, Karolina Storesund): https://www.sciencedirect.com/science/article/pii/S0379711220300382.

in waste facilities. The impact of a fire goes inherently beyond the specific waste facility involved in the fire to encompass proximate facilities or communities.

Below, I have summarized several of the consequences of waste and recycling facility fires from a fire protection point of view concerning the direct impact on humans (injuries, illnesses, and fatalities), environmental consequences, and economic consequences.

8.1 Injuries, Illnesses & Fatalities Report

REPORTED WASTE & RECYCLING FACILITY FIRES INJURIES & DEATHS IN US/CAN

	2018	2019	2020	2021	2022	2023	Ave 2018-2022	% Injuries Over Ave
Injuries	19	49	23	37	56	65	36.8	52%
Incidents w/Injuries and/or Deaths	12	25	14	22	28	34	20.2	39%
Injuried Per Incident	1.6	2.0	1.6	1.7	2.0	1.9	1.8	11%
Deaths	2	2	3	2	2	2	2.2	-9%
Total Fires	365	343	317	367	390	373	356	4%
% of Incidents w/ Death or Injury	3%	7%	4%	6%	7%	9%	6%	27%

Source: Ryan Fogelman, rfogelman@firerover.com

In 2023, we experienced 65 injuries and 2 deaths due to these fires. 9% of the total reported facility fire incidents had an injury or death. Most of these injuries are incurred by fire professionals on the scene.

Figure 22 - Reported Waste & Recycling Facility Fires, Injuries & Deaths - US & Canada (2018-2023)

Not all injuries, illnesses, and fatalities in the waste management industry are due to fires; however, the potential is there regardless. According to my research, **in 2023, waste and recycling facilities in the U.S. and Canada experienced 373 fires, two deaths, and 65 direct and indirect injuries.** Compared to 2022, the number of fires decreased, the number of deaths was the same, and the number of injuries increased.

These fires ranged from small incidents to complete burnouts. They occurred in all operations, including those handling metals, rubber, fibers, C&D debris, plastics, waste, compost, hazardous materials, chemicals, and fuels.

In 2021 and 2022, waste collection has been listed as the 7th deadliest job according to the U.S. Bureau of Labor and Statistics' press release on its National Census of Fatal

Occupational Injuries.[37] Unfortunately, this remains true even though the rate of fatalities has decreased for refuse and recyclable material collectors decreased in 2022.

Waste Dive reported in December 2023 that MRF fatalities had increased in 2022. The waste and recycling industry continues to be where injuries, illnesses, and deaths can happen at a moment's notice if safety procedures are not strictly followed.

> *"We will work to continue the reduction in worker fatalities through continued industry engagement," said Amy Lestition Burke, executive director and CEO of the Solid Waste Association of North America, in a statement. She added that the data "is a reminder that we need to ensure that safety is a core value and top priority across all lines of business."*

Industry members are constantly looking for ways to operate more safely and ensure workers return home safely at the end of each workday. These efforts include supporting and implementing Slow Down to Get Around legislation, ramping up employee safety training, and utilizing more safety technology.

As the waste and recycling industry members look at these numbers, they should resolve to renew their focus on improving safety planning in their facilities. Also, remember that most injuries occur to the fire professionals who arrive at the scene and face grave danger. The fewer major fires that occur, the fewer firefighters are required to fight them, which should, in turn, lead to fewer injuries. Fire Rover can help with the latter.

8.2 Environmental Consequences

The uncontrolled burning of waste in facilities that are not intended for it has been known for a long time to pose negative environmental consequences. Uncontrolled waste fires emit chemicals, such as acid vapors, dioxins, and carbon monoxide, as well as heavy metals, such as lead, cadmium, and chromium, among many other toxic substances. The more proximate to uncontrolled waste burning, the higher the risk of exposure to these dangers and pollutants. In addition to the adverse effects of exposure to pollutants, flying sparks and embers can easily lead to uncontrolled fires, posing a substantial threat to life, property, and the environment.

8.2.1 Firewater

When it comes to fighting fires, one of the fire industry's go-to solutions also has the potential to cause longer-lasting problems after the fire is quieted. "Firewater" refers to water that has been used during firefighting operations. Any amount of firewater requires proper disposal, but when fire brigades use too much water, there is a potential spillover

[37] Report download link (US Bureau of Labor Statistics, Press Release, "National Census of Fatal Occupational Injuries in 2021", published December 16, 2022): https://www.bls.gov/news.release/pdf/cfoi.pdf

impact of firewater in the surrounding environment. In many cases, firewater is highly polluted, containing dissolved and particulate matter from combustion processes, materials generated through quenching, and materials in the building and equipment.

Firewater's pollution levels can vary depending on the building or site being extinguished. For example, a building containing pesticides, organic and inorganic chemical reagents, fertilizers, etc., can increase the pollution level of firewater as those materials will likely be present in the firewater.

Proper disposal of firewater is important because improper disposal can lead to problems down the line if firewater enters the water supply for communities, such as a river or lake that supplies drinking water. One of the most common disposal techniques is to contain the firewater in the drainage system using pneumatic bladders or lockable non-return valves.

So, how much water is used in the typical industrial fire? Jim Kirvida, president of Custom Fire Apparatus, said, "You'd need over 4,000 gallons of a water and foam solution per minute for 65 minutes to snuff out an industrial fire." His example is based on a 180-foot diameter tank filled with hydrocarbons and comes to 260,000 gallons (984,207 L) of firewater. If we try to equate that to the typical waste and recycling facility fire, that is fair, except sometimes, an hour is not enough. We can look at a few examples of waste and recycling facility fires that dwarfed that number to get a feel for the issue.

The first incident is at an organics facility, which has used 8 million gallons (30,283,280 L) of water to contain a fire thus far. Yes, you read that right. To hold that much water, you would need to build a pool 2,136 feet long (that is almost six American football fields or four Australian football fields), 400 feet wide, and 80 feet deep.

According to Sarah Reiff Swan, a senior code specialist at the Fire Protection Consortium, Inc.:

> *"It is startling when you consider that commercial user fees for water in Lee County, Fla., are $6.54 per 1,000 gallons, while sewer fees are $5.85 per 1,000 gallons. With the discharge discussed above, that would work out to approximately $52,320 in water fees and $46,800 in sewer fees if the property were required to pay for the water used!"*

The video to the right[38] shows another fire incident in Ohio where more than 1,000,000 gallons (about 3,785,410 L) of water was trucked in to eliminate a fire at a scrap metal facility successfully. If we use Swan's numbers above, the water and sewer fees cost about $20,000, which does not include the cost of firewater cleanup after the event. A simple Google search will show you many more such incidents.

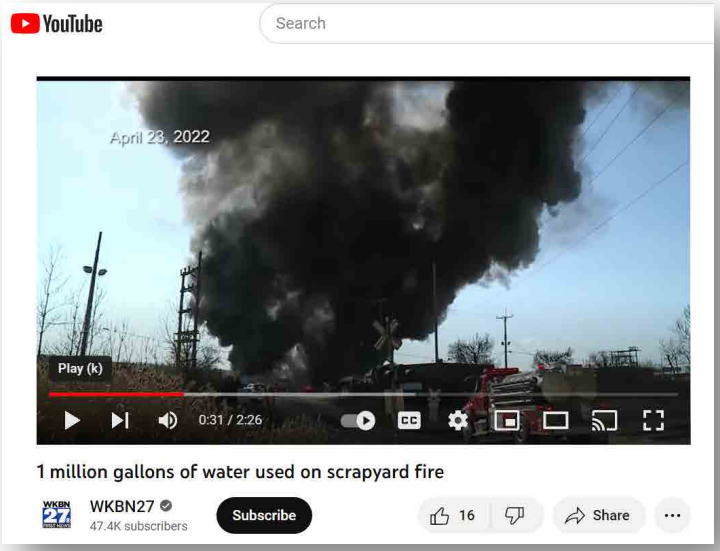


Figure 23 - A fire incident in Ohio in 2022 used more than 1,000,000 gallons of water to fight it.

Link to video: https://www.youtube.com/watch?v=q0FHxLKDqiI

The less water, the better. Early detection when the fire is small, targeting the fire, and putting copious amounts of water in this initial growth stage reduces total water usage. This was the finding of a 2020 Factory Mutual (FM) Research Technical Report entitled "Reducing Water Demands with Innovative Fire Protection Solutions." In this report, smart monitors demonstrated the ability to reduce the amount of water necessary for uncartoned, unexpanded plastic and cartoned, unexpanded plastic fire sources by up to 88%. According to James Andy Lynch, founder and CEO of Fire Solutions Group, Fire Rover would be classified as a smart monitor by FM and is defined in the FM standard 1421 Approval Standard for Fire Protection Monitor Assemblies.

> *"Having been in the fire industry for more than 20 years and working with several new and emerging technologies, I feel comfortable saying that Fire Rover has positioned itself as a must-have tool in the box of fire protection equipment we as engineers must consider when designing fire protection for a facility," says Lynch, who has worked with my team and me in multiple capacities including designing systems for proper coverage, preparing variances using technical data to support its use, assisting with the FM approval process, and submitting text changes to various fire codes.*

Keeping pace with the industry's changes and needs, we added a "quick connection" to our solution for fire professionals. The quick connection allows fire professionals to take a defensive approach to fighting fires effectively while remaining safely outside the facility.

[38] Website (YouTube - Posted by WKBN27 News, on April 24, 2022): https://www.youtube.com/watch?v=q0FHxLKDqiI

Fire Rover's solution is installed in 500-plus facilities across the U.S., Canada, the UK, Australia, and France. As a complement, we recently launched the OnWatch solution for early detection, verification, and dispatch of active landfill facings. The unit comes on a trailer, is 100% wireless and runs on 4G, is powered by renewable energy, and is developed for harsh outdoor environments. The goal for the unit is to ensure that little or no water is used and dispatch either employees or fire professionals early enough for "cover material" to be applied to snuff out most fire hazards instead of adding it to a landfill, which already has issues with firewater.

Additionally, Fire Rover has designed and installed a continuous flow solution for waste-to-energy facilities, hangers, refineries, and industrial facilities that use the operators' existing water infrastructure. The targeted deluge solution can replace a traditional deluge system and target any fire with water, providing more control of the event, alleviating the accidental discharge issue, and allowing dual control of the system by both the Fire Rover agents and the operator.

For example, one of Fire Rover's latest industrial installations protects a high-hazard plastic recycling facility. The installed solution includes 56 thermal cameras and 47 nozzles. The local fire authorities approved it to enhance the primary sprinkler requirement using a performance-based methodology from the NFPA codes.

Fire protection is moving from the "water, water, water" approach to early detection and fire elimination solutions for several reasons, the environment being just one huge benefit.

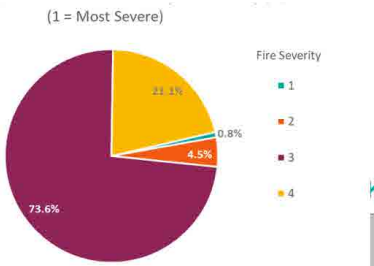
8.3 Economic Consequences

8.3.1 Interrupted Operations & Loss of Assets

You will hear me say that it is not an issue that we have a fire, but it is important to understand that the severity of the fire is the issue. Based on the performance of the Fire Rover solution that I shared above, we successfully extinguished more than 183 fire incidents in 2023 ("Fire Suppression Activations"). The key is that most of these fires required little to no cleanup or downtime of the operations afterward.

It's All About The Severity Of The Fire!

Figure 2-1: England Reported Waste Fire Occurrences by Fire Severity Category (%) 2014 - 2019



Source: EA data, provided by the EA on 15.10.20 (2020) average % split of waste fire severity reported to the EA (2014 – 2019)

Almost 80% of fire incidents in the UK burn for 4 hours or more and burn 50+ Tons of Waste/Recycling Material

Key Assumptions

	Fire Severity			
	1	2	3	4
Duration Range (hours)	> 72	24 - 72	4 - 24	1 - 4
Modelled Duration (hours)	120	72	24	4
Waste Tonnage Burnt (t)	> 500	250 - 500	50 - 249	< 50
Modelled Tonnage Burnt (t)	1,000	375	150	25
No. Fire Trucks Attending	10	6	4	2

Figure 24 - Severity of the Fire Analysis (Source: Eunomia, U.K. data)

A report published by UK consulting firm Eunomia broke down the UK data to show the severity of waste and recycling facility fires. Almost 80% of the fire incidents it reported burned for more than four hours and burned more than 50 tons of material. Along with the cost of the material that needs to be sent to the landfill, a reasonable assumption can be made that when more than 50 tons of material burns, there will be damage to the building and equipment.

Add to it the cost of replacing the equipment, especially in an environment like the one we face today, where equipment is sometimes backordered for years when it needs to be replaced. If the building is damaged, there is that cost, but all the factors lead to the biggest cost: revenue loss from business operations.

Most industry members will say that when an operation is unable to operate, not only do you lose revenue, but you typically lose the customers or suppliers that a business has spent years developing. So, after replacing the building and equipment, there is a significant cost to reacquiring the customer base.

Eunomia also estimated the real cost of lithium-ion battery fires in the UK to be about £158 million.[39] If I were to use this figure, compare it to my data and assumption, and extrapolate an estimated cost to the US and Canadian industry in US dollars, the cost to

[39] Website ("Cutting Lithium-ion Battery Fires in the Waste Industry" Report, published January 13, 2021): https://www.eunomia.co.uk/reports-tools/cutting-lithium-ion-battery-fires-in-the-waste-industry/

the U.S. and Canada due to lithium-ion battery fires would be **unfairly more than $1.2 billion (USD).**

Since Eunomia's study only attributed lithium-ion batteries as the cause of about 50% of fires, which aligns with past U.S. surveys that I have shared, the actual cost borne by waste and recycling facility operators—and indirectly their insurance carriers—was likely $2.5 billion (USD) annually.[40] If we $2.5 billion by the number of reported fires at solid waste processing facilities in the US and Canada in 2023 (2,717), it is approximately $920,000 per fire.

Another report released by the U.S. Environmental Protection Agency in 2021 also backed this viewpoint. The report, "An Analysis of Lithium-ion Battery Fires in Waste Management and Recycling", which includes information from various sources, including my research, draws attention to the following facts:

1. The waste and recycling industry has an inherent risk of fire incidents.
2. Most of the costs of these incidents unfairly fall on waste and recycling facility operators and local fire professionals.
3. There is no consensus solution to the problem, but effective solutions, such as best practices and technology, exist.

This year, I have an opportunity to compare my estimated cost per fire to a new report published on the financial impacts of fires in the US because of risks posed by lithium-ion batteries. According to a report written in 2023 by RRS and announced by the National Waste & Recycling Association (NWRA) in January 2024, there is an enormous range in costs per fire at MRFs in the US, ranging from a theoretical baseline of $2,600 for one hour of downtime with minimal cleanup, to $50 million for a catastrophic fire, with the average cost of a catastrophic loss being $22 million. However, this average cost seems extremely high for drawing broad brush strokes, but my estimate is within their range.

While reading this report, I could not help but notice the many times that Fire Rover is mentioned (on pages 7, 8, 9, 14, 17, 20, 22, 23). I am extremely honored to have helped contribute in part to their report, but it's important to note that neither Fire Rover nor I sponsored the RRS/NWRA report; rather, the mentions are testaments to the good work we have done over the past decade to stem the tide of waste and recycling facility fires.

Several quotes in this report from operators gave me hope that our efforts are not for naught. Due to the anonymity of this report, I cannot say with certainty that those quoted are Fire Rover's clients, but I am confident that Fire Rover clients could say similar things. Below are direct quotes from Table 1 on Page 2 of the report.

[40] In 2021 dollars.

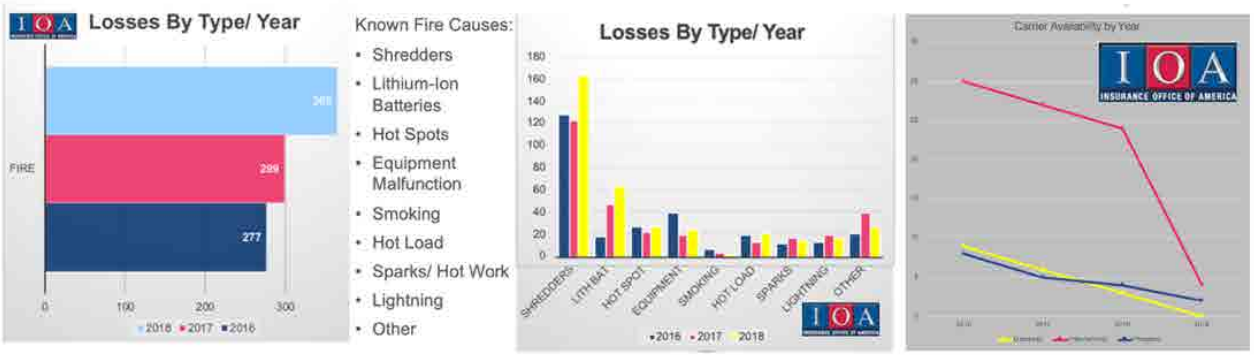
"We track every fire. We are very diligent, including 24-hour monitoring. There is not much additional cost per event if we catch them early."
"We have had very bad fires but have become very good through technology and training in keeping impacts minimized otherwise. Not sure if it impacts cost."
"We are getting better at tracking fires."
"Just overtime and clean up per event. Most [fires] don't stop production."

8.3.2 Insurance Companies Continue to Leave the Industry

In the past five years, I have observed insurance and reinsurance companies react to the solid waste and recycling industry's increasingly fire-prone nature by high-tailing it in the other direction or substantially increasing rates. The reasoning behind their actions lies within insurance companies' actual claims data, as the cost of insuring solid waste facilities has also increased dramatically, particularly for operators who do not "harden" their facilities against the risks of fires.

According to data provided by Nathan Brainard of the Insurance Office of America (IOA), 2018 was a major year for claims, and consequently, insurance companies began to leave the market. An uptick in claims was caused by the increases in lithium-ion batteries in the waste stream and shredders.

The images below show Brainard's incident data, and the totals are eerily similar to the publicly reported numbers I share. The only major difference is that he includes landfill fires; mine does not. Although there are similarities, the real story behind Brainard's data is that it is part of the set of consequences the industry is experiencing due to the uptick in fire incidents.



Source: Nathan Brainard, nathan.brainard@ioausa.com

Figure 25 - Insurance Claims Data (Source: IOA)

In addition to the possibility of injuries, illnesses, and deaths caused by fire incidents, the waste industry continues to see insurance companies flee from the sector. In 2016, the waste industry had almost 50 insurance options. Now, it has far less. When asked in 2019 what this contraction meant to the private waste and recycling facility operator, Brainard said, "Those with no losses could expect a 25% to 35% premium increase, those with moderate losses would have a 75%-plus increase, those with catastrophic losses could see their premiums double, and those with multiple issues could be uninsurable."

Some of Brainard's predictions became a reality as higher premiums increased across the industry.

- For example, South Bayside Waste Management Authority in Northern California saw its MRF's insurance premium increase[41] from $100,000-plus to more than a million after its first major fire. The MRF operators were told it would be uninsurable if another incident occurred. That was a 10x increase.
- In Alexandria, Minnesota, the Pope/Douglas Solid Waste Management-owned waste-to-energy facility faced a possible increase of $300,000-plus for insurance fees in 2021[42] due to claims in other parts of the country. In a nearby area, the Perham waste-to-energy facility saw a $76,000 increase in insurance costs[43] in 2021.
- Also, in April 2021, after hours[44] at Tulsa Recycle & Transfer in Tulsa, Oklahoma, a large fire, which took operator American Waste Control several months to recover from, sparked. While insurance covered basic costs, the company was left with the displacement of 40 workers and repair costs upwards of $11.4 million.

In 2023, we can view these examples above as no longer the exception but the norm. According to the same NWRA-RRS report referenced in an earlier section (see 8.3.1), the alarming increases in insurance costs are commonplace.

> *"Commercial insurance rates for Material Recovery Facilities have increased markedly.*

[41] Website (Waste360, "Lithium-ion Batteries are Causing Five-alarm Fires in Garbage Trucks, Waste and Recycling Facilities", by Waste360 staff, published on May 21, 2018): https://www.waste360.com/safety/lithium-ion-batteries-are-causing-five-alarm-fires-garbage-trucks-waste-and-recycling

[42] Website (Echo Press, "Insurance costs could quadruple for waste-to-energy plants like the one in Alexandria", by Celeste Edenloff, published on October 23, 2020): https://www.echopress.com/business/insurance-costs-could-quadruple-for-waste-to-energy-plants-like-the-one-in-alexandria

[43] Website (DL-Online, "Insurance cost for Perham incinerator complex shoots up this year", by Nathan Bowe, published January 05, 2021): https://www.dl-online.com/news/insurance-cost-for-perham-incinerator-complex-shoots-up-this-year

[44] Website (Tulsa World): https://tulsaworld.com/news/local/icymi-curbside-recycling-in-tulsa-resurrected-with-mr-murph-nothing-short-of-a-miracle/article_69e298b2-67f4-11ec-98bb-9b4d7bf4c0ff.html

A. Every property insurer and underwriter and many MRF operators in this Opinion confirmed that the risk at MRFs is increasing for high loss claims from fires from damaged LBs in single stream materials.

B. The insurance industry has responded by limiting access to coverage, or by reducing coverage, or by increasing deductible requirements and annual premiums.

The increases in insurance premiums are no longer easily attributable to the "cost of doing business" but now squarely require their own budgetary line items. I believe in helping the industry interpret and visualize the cost increases in terms that are more familiar to them; the NWRA/RRS report presents the cost increases per ton before and after the COVID-19 pandemic. According to the NWRA/RRS report:

Rates five years ago were far below one dollar per hundred of Insured value. During recent confidential interviews, one insurer [said] the range could be as little 'fifteen cents before 2017.' Another insurance underwriter used eighteen cents as an example "before Covid." […]

MRF property insurance has increased tenfold, from $0.15 to $0.18 (0.15-.018%) per hundred insured value to a minimum of $1.80 (or 1.8%). Rates now can be as much as $10 per hundred dollars (10%), with no cap on the top side.

The local impact on MRF costs can be illustrated by taking these rates and applying them to an average-sized 35-ton-per-hour MRF, processing 8,000 tons, which is valued at $40 million for insurance purposes:

Table 3: Insurance cost per ton of material processed

Time Period	Cost per Hundred Valuation	Annual Property Ins. Policy	Cost/Ton
Range prior to Increased MRF Fires	$ 0.15	$60,000	$0.63
	$ 0.18	$72,000	$0.75
Current Quoted Range	$ 1.80	$720,000	$7.50
	$ 10.00	$4,000,000	$41.67

While few parts of the NWRA/RRS report thrill me— *if I am being honest, it is a depressing report but not because it fails to be helpful; it is quite beneficial*—one of the parts that gives me hope is the left column of Table 4 that starts on page 5. To me, this column exemplifies some of the characteristics of Fire Rover customers across North America:

Table 4: Impacts to insurance premiums

Lower Premiums	Higher Premiums
1. Small or no property claim history	1. Have reportable claims
2. Fare well during inspections by underwriters for 'hardening' their MRF against fire risk.	2. Poor housekeeping, poor fire training, unacceptable site management practices during inspections.
3. Exclusive for all coverages or long-term policy holders with the same company	3. New policies or small total insurance portfolio to balance the risk of MRF property insurance

Because Fire Rover provides waste and recycling facilities with an edge in dealing with inherent and traditional fire risks, including the increased risk of fire posed by batteries disposed of into waste streams, they enjoy lower premiums.

’s clients enjoy it. We can all agree that we must make safety changes to mitigate insurance companies’ risks. We must implement changes at the site level, and the insurability of each site must be evaluated based on a range of factors, such as historical claims, incident data, response, training, preparedness, other facilities in a portfolio, and so on.

To get the ball rolling on bringing insurance companies back to the waste and recycling industry, I have helped several insurance companies understand the risks they face. I have explained that **good operators have fewer fires than bad operators. However, novel solutions outside basic fire prevention tactics are needed when good operators still have fires.** That said, the waste and recycling industry needs to continue implementing real fire prevention and disaster response plans at all waste and recycling industry facilities. However, in the waste and recycling industry, where good operators still have fires, we need to take more steps to help solve the problem.

Insurance companies want to protect our industry occupancy. However, they want to see a real effort in defining the actual scope of the problem, solutions, and paths forward for strategies that will mitigate the specific risks of the occupancy. If they do not see this, the only thing they must go on is historical claims data.

Fire prevention and disaster preparedness plans are the basic blocking and tackling strategies insurance underwriters expect good operators to have in place.

They are not good operators if they do not have them. The insurance companies want to see operators who will face problems head-on and not try to avoid them or wish they would disappear.

How to help insurers insure the waste industry

Operators can prove to insurance companies that they take fire prevention seriously by investing in practical technologies. In a Waste360 article, Stuart Kinsella of Rokstone Underwriting[45] states, "Early detection methods linked with monitoring stations and installation of suppression systems that are fit for purpose are key in reducing exposure and ultimately enticing the insurance market to provide terms." Another way that operators can prove they are approaching fire prevention seriously is by planning for a live event with adequate planning around internal and professional responses.

The Fire Rover solution is working. How do we know this is the case? Insurance companies have noticed. According to the 2018 data from Brainard[46] and my experience, insurance companies were readily exiting from our industry. Since that time, good facility operators have been gradually gaining options. I had personally fought and won favorable outcomes by proving that **our customers who have developed operational best practices, in combination with having our early thermal detection and fire elimination solution in place, have less fire risk than at any point in history, including the time before the wave of lithium-ion batteries began.**

The waste and recycling industry should expect continued limited availability of insurance and rate increases for the next six months in the 10% to 50% range, according to Risk Strategies' "State of the Market Report".[47] This is due to the increased severity and frequency of claims and the industry's facilities being more at risk of fires. So, if we want to see more capacity and lower rates, we must make the necessary changes mentioned above.

9 A Global Problem

While my research focuses on data from facilities within the U.S. and Canada, fires at waste and recycling facilities are a global problem. Presented below are just some examples of what is happening around the globe concerning fire incident response. Unsurprisingly, we are all challenged and working toward fire prevention and reduction.

United Kingdom

[45] Website (Waste360, "November 2021 Fire Report: Bucking the Global Insurance Trend", by Ryan Fogelman, published on December 14, 2021): https://www.waste360.com/safety/november-2021-fire-report-bucking-global-insurance-trend

[46] Website (IOA, Broker profile, "Nathan Brainard"): https://www.ioausa.com/brokers/nathan-brainard/

[47] Website (Risk Strategies 2022 Wrap-Up, 2023 Initial Outlook): https://www.risk-strategies.com/state-of-the-market

In the UK, for example, a 2021 report entitled "Cutting Lithium-ion Battery Fires in the Waste Industry",[48] published by Eunomia and the Environmental Services Association (ESA) revealed that the waste industry faces an estimated 201 waste fires caused by lithium-ion batteries each year. According to the report, of the 670 fires recorded by ESA waste management members across the UK in 2019-2020, 38% were either recorded as caused by lithium-ion batteries or "suspected" to have been, which is higher than the percentages recorded in the previous three years by the body (21% in 2016-2017, 25% in 2017-2018, and 22% in 2018-2019).

However, in December 2022, *Material Focus,*[49] the not-for-profit organization funded by the waste electrical and electronic equipment compliance fee in the UK, published results from a survey of local authorities on fires[50] and found that batteries cause about three and a half times more fires in the waste stream than previously thought. These results suggest that "batteries that have not been removed from unwanted electricals cause more than 700 fires annually in refuse collection vehicles and at household waste recycling centers, while nearly 90% of the 60 local authorities surveyed said fires caused by batteries are 'an increasing problem.'"

These findings go hand in hand with Veolia UK's 2020 finding that the average UK resident throws away around 24.5 kilograms of electronics annually. Only 43% of the public knows lithium-ion batteries can spark fires. Additionally, fires in waste vehicles have increased by 37.5% since 2017,[51] a major concern because anyone operating a waste and recycling fleet knows the high price tag that comes with downtime, repairs, replacement vehicles, etc.

Japan

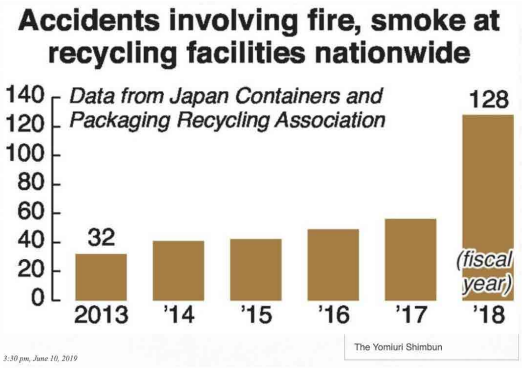
[48] Website (Eunomia - Report: Cutting Lithium-ion Battery Fires-in-the-Waste-Industry"): https://www.eunomia.co.uk/reports-tools/cutting-lithium-ion-battery-fires-in-the-waste-industry/

[49] Website (Material Focus): www.materialfocus.org.uk

[50] Website: Letsrecycle.com News, "Batteries cause 'three times more' waste fires than thought", by James Langley, published December 2, 2022): https://www.letsrecycle.com/news/batteries-cause-three-times-more-waste-fires-than-thought/

[51] Website (Veolia, "Preventing Battery Fires"): https://www.veolia.co.uk/press-releases/preventing-battery-fires

In Japan, there has been an increase in incidents of smoke or fires, according to an article published by *The Asahi Shimbun* in 2019. The article shares survey results from the Japan Containers and Packaging Recycling Association, which reveals that in the 2019 fiscal year, recycling facilities for plastic containers reported 230 incidents of smoke or fires, up from 128 incidents in 2018 and less than half that number from 2013 to 2017. See the table, which clearly shows that something has changed in the waste stream—and that "something" is likely lithium-ion batteries based on global trends and data.



New Zealand

Across the globe, in Auckland, New Zealand, firefighters worked to extinguish 26 fires in the last 18 months[52] due to improper disposal of lithium-ion batteries, and Suez's UK's Altens East MRF in Aberdeen, Scotland[53], experienced a large fire in July 2022 that left the facility with serious damages. The cause of Suez UK's fire is still unknown. Still, the company released a statement saying it is "highly probable" that the fire was caused by a battery or battery-operated device placed in a residential recycling bin. These recent incidents from around the world are just a handful of incidents covered by the media that highlight just how real and serious this problem is.

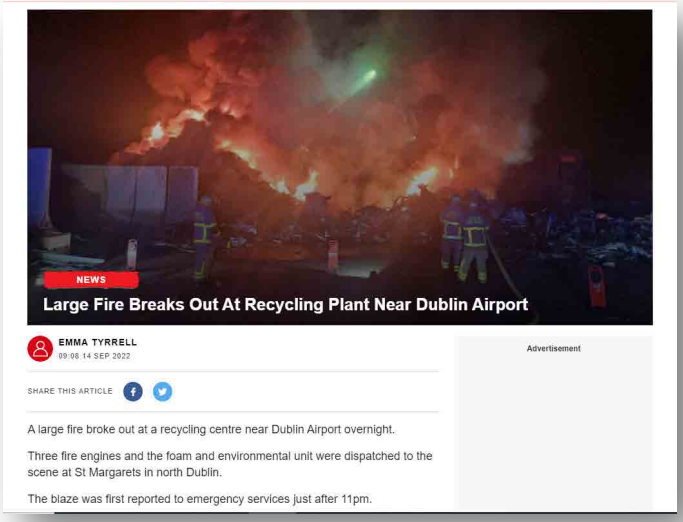


Figure 26 - Example of a 2022 fire around the globe (near Dublin, Ireland – Sept. 2022).

Source: www.98fm.com/news/large-fire-breaks-out-at-recycling-plant-near-dublin-airport-1382313

Australia

[52] Website (Stuff, a New Zealand-owned media organization, "Batteries discarded in Aucklanders' recycling cause 26 fires in 18 months", by Sapeer Mayron, published December 6, 2022): https://www.stuff.co.nz/national/300758419/batteries-discarded-in-aucklanders-recycling-cause-26-fires-in-18-months

[53] Website (BBC News, "Cause of major Aberdeen recycling plant fire remains a mystery", published October 6, 2022): https://www.bbc.com/news/uk-scotland-north-east-orkney-shetland-63152961

In Australia, after noticing these fire incident trends worldwide and within their own country, the Victoria State Government, for example, established the Resource Recovery Facilities Audit Taskforce chaired by the Australian Environmental Protection Agency (EPA) to inspect resource recovery facilities and tackle stockpiles that might pose a fire risk. By 2017, according to that year's Australian Fire Preparedness Report, 73 of the 500 recycling centers and tipping floors across Victoria had been inspected. Perhaps not surprisingly, most lacked the planning and resources to deal with a fire event. "While some operators are considered to be at best practice, the audit program identified that the resource recovery sector is generally poorly prepared and ill-equipped when managing fire risks at their facilities,'' stated the Australian EPA on its website.[54]

Also in Australia, a December 2023 Waste Management Review article[55] reported that the Australian Council of Recycling (ACOR) report raises the alarm that fires caused by batteries are now widespread across material recycling facilities, in trucks, and depots — in short, at every point across waste and recycling systems. ACOR said the increasing number of electronic items containing embedded and sealed batteries, poor product stewardship, a lack of access to safe disposal options, and low community awareness have contributed to the steep rise in batteries in conventional waste and recycling streams.

> *"Over the past year, there were more than 1000 battery-related fire incidents reported in the waste and recycling sectors nationwide, amounting to over three a day. It is unlikely that this figure will even begin to reveal the true extent of the battery crisis for recyclers," said ACOR Chief Executive Suzanne Toumbourou.*
>
> *"The cost of these incidents is being borne by the community through rising rates, by councils through truck fires and service disruption, and by the recycling industry in the loss of critical infrastructure and future risk.*
>
> *"A major priority is a comprehensively accessible network of collection points for the community to safely deposit loose and embedded batteries, including vapes." […]*
>
> *Governments across Australia must take critical actions to address these risks, including comprehensive and convenient safe collection locations for all forms of loose and embedded batteries, a community education campaign, e-stewardship reform including a deposit scheme, and regulatory harmonisation and enforcement.*

[54] Website (Australian Environmental Protection Agency): https://www.epa.vic.gov.au/about-epa/our-programs-and-projects/resource-recovery-facilities-audit-taskforce

[55] Website (Waste Management Review, "ACOR releases issues paper on battery crisis", Published December 21, 2023, Accessed online in January 2024): https://wastemanagementreview.com.au/acor-releases-issues-paper-on-battery-crisis/

10 The Solutions

10.1 The Fire Rover

I spent my first few years in the market trying to understand the problem and being cautious about saying that our patented product is the solution. Sometimes, you need to call a spade a spade. I am now 100% confident that our solution is the only solution on the market today that can lower the risk profile of a good operator to levels seen before the lithium-ion hazards hit our industry.

Figure 27 - Image of a Fire Rover

To prevent and eliminate fire incidents, you must invest in solutions that work for your facility type. This means that traditional fire suppression methods such as water sprinkler systems and smoke alarms may not be the best option to stop a fire at a facility where there is a lot of activity, such as a MRF, scrap metal facility, transfer station, or waste-to-energy facility.

It is great to provide fire protection equipment for employees onsite, but no employer can force any employee to fight a fire incident at their facility. According to the Occupational Safety and Health Administration (OSHA):

> *"If a fire breaks out in the workplace, employees have two options: fight or Flight. What they don't have, however, is an obligation to do one action or the other. The decision on whether to Fight or Flee is entirely up to the employee. Proper employee training helps people take the right action faster."*

This quote exemplifies why we developed Fire Rover, a comprehensive firefighting solution that combats incipient fires and explosions within seconds of ignition. This system is specifically designed for the waste and recycling industry and has eliminated 10,000-plus fires in waste and recycling facilities across the U.S., Canada, UK, Australia, and France since 2015.

There are many advantages to using the patented Fire Rover system, including:

1. Fire Rovers are equipped with FLIR thermal cameras paired with listed optical flame and smoke detectors to satisfy code compliance. The Fire Rover detects early heat abnormalities, sometimes before visible smoke or flames are present.

2. Once a heat abnormality is detected, alarms received from the detectors are transmitted to a UL central station. A Fire Rover agent verifies if it is a false positive or a threat, and action must be taken.

3. If action must be taken, the Fire Rover agent alerts the facility, the fire department, and authorities and then shoots an environmentally friendly cooling agent from the Fire Rover's nozzles onto the hotspot to eliminate a fire before or after it starts. This allows ample time for fire professionals to arrive on the scene and for the facility operator and fire professionals to respond appropriately to the hazard level.

4. Fire Rover is capable of superior suppression, partially due to the elevated water density a monitor delivers compared to the design densities of a typical sprinkler system and partially due to the targeted suppression from controlling the monitor from the central station.

By detecting early when the fire is small, targeting the fire, and putting copious amounts of water in this initial growth stage, the total water usage is significantly reduced. This was the finding of a 2020 FM Research Technical Report entitled "Reducing Water Demands with Innovative Fire Protection Solutions." In this report, smart monitors demonstrated the ability to reduce the amount of water necessary for uncartoned unexpanded plastic and cartoned unexpanded plastic fire sources by up to 88%. According to James Andy Lynch, founder and CEO of Fire Solutions Group, Fire Rover will be classified as a smart monitor by FM and is defined in the FM standard 1421 Approval Standard for Fire Protection Monitor Assemblies.

This solution, currently installed in 600-plus facilities across the U.S., Canada, the UK, Australia, and France, received NWRA's 2020 Innovator of the Year – Recycling Equipment award[56], which celebrates innovation in design and manufacturing that increases the effectiveness or efficiency of recycling equipment and operations. In 2019, the Fire Rover received the gold Edison Innovation Award[57] in the category of Industrial Safety. The Fire Rover solution also received the Innovative Product & Technology award[58] from the Fire Protection Association Australia, the Australian equivalent of the National Fire Protection Association, for bringing our innovative solution to the Australian market.

In 2020, Fire Rover designed and installed a box-less solution for waste-to-energy and industrial facilities that utilizes the operators' existing water infrastructure. The targeted deluge solution can replace a traditional one with the ability to target any fire incident with water, providing more control of the event, alleviating the accidental discharge issue, and allowing dual control of the system by both Fire Rover's remote agents and the local

[56] Website (Waste Recycling magazine, "2020 Innovator of the Year – Recycling Equipment: Fire Rover",, published January 11, 2021): https://wasterecycling.org/articles/2020-innovator-of-the-year-recycling-equipment-fire-rover/

[57] Website (Fire Rover, "FIRE ROVER WINS 2019 GOLD EDISON AWARD", by Lindsey Scharg, posted April 8, 2019): https://firerover.com/2019-gold-edison-award/

[58] Website (FPAA, "FIRE AUSTRALIA 2022: FIRE PROTECTION INDUSTRY AWARDS 2022", posted on May 4, 2022): http://www.fpaa.com.au/news/news/2022/05/fire-australia-2022-fire-protection-industry-awards-2022.aspx

facility operators. This solution is currently installed and working successfully in large industrial operations nationwide. When allowed, we post these fire elimination videos on Fire Rover's YouTube Channel.[59]

Also, in 2021, we developed and piloted a new solution called OnWatch, powered by Fire Rover.[60] This mobile unit utilizes solar and wind power to monitor thermal cameras remotely and detect abnormal heat signatures at landfills. The system communicates via a 4G/5G cellular network and connects to the Fire Rover Monitoring Center for quick detection, identification, and dispatch of emergency personnel. The OnWatch mobile unit is heavy-duty for landfill environments, including dust, wind, and uneven surfaces. It has been proven to work in the field by successfully getting to landfill fires before they became too large to extinguish quickly.

Figure 28 - Fire Rover's OnWatch

10.2 Our Newest Innovation: Fire Rover Water Tower Solution

In 2022, we released yet another advancement that supports our goal of protecting industry employees and firefighters from unnecessary hazards.

If you have been to a paper mill, scrap metal facility, chemical processing facility, refinery, or any outdoor storage operation, it is typical to see water towers with manually operated monitors and a set of ladders or stairs for access popping out of the sky. These manually operated towers are extremely useful in fighting fires but have several downsides, such as 1) They must guess where the heat source is if the human operators atop the tower do not have thermal imaging to see through the smoke. 2) They require firefighters to climb the stairs or ladders in low visibility due to smoke and darkness. 3: If the towers or operators are not outfitted with safety gear, these towers pose a smoke inhalation risk. 4) Tower operators could get trapped on these units should the fire isolate them. Ask most firefighters, and they would agree that these risks can be mitigated when firefighters are properly trained to operate; however, **at no point should an untrained employee use these towers without formal fire brigade training and protective gear.**

[59] Website (YouTube - Fire Rover): https://www.youtube.com/c/FireRover/videos
[60] Website (Fire Rover, Introducing OnWatch): https://firerover.com/tag/onwatch/

To avoid these risks, we have created a Fire Rover outdoor water tower solution that allows us to remotely operate the streams of targeted water, just like our typical solution does but adds in the early detection and efficiency of placing a combination of water and our environmentally friendly wetting/cooling agent directly on the heat sources and continually hitting the hotspots until the fire is under control or extinguished. Like our lithium-ion battery protection solution, this approach gives our clients the best chance at safely controlling and eliminating fire during an event without requiring employees or firefighters to place themselves at risk.

As we continue to innovate and evolve our solution, we can assure our customers that our solution will improve over time.

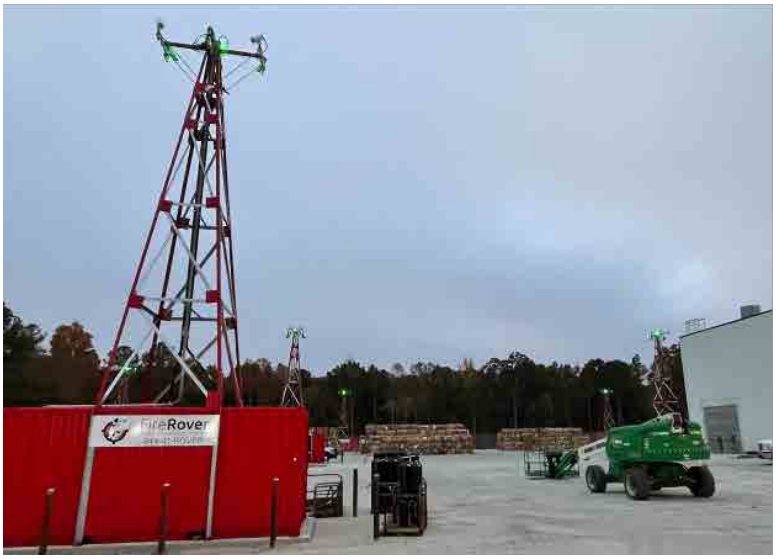


Figure 29 - Fire Rover Protecting Paper Storage Yard 2023

We partner with our clients to understand their business and work with them on their solutions. Be it remote control, cameras for preemptive maintenance on parts of their equipment, or helping them build a new operation from the ground up; we are there with them every step of the way. Are we perfect? No, but fighting fires is not just a science. Human beings have been trying to control fire since the beginning of time. Anyone who says they can “guarantee” your operation will not have a fire is off their rocker. We are an outsourced fire department, like the Pinkertons of fire, which is there to help you fight fires early. No fire professional would argue that the earlier you identify and start fighting a fire, the better the result. We know that 100% success is impossible, but insurers are not looking for 100% success—they are looking for risk mitigation to a level that allows them and our customers to sleep at night, which is our goal.

10.3 Use Less Water

The best practice of dosing a fire with water, a fire response approach used for hundreds of years, is evolving into early detection and immediate response by means inclusive of but not exclusive to water. Lowering the risk of catastrophic incidents through operational, technological, and professional best practices puts the waste and recycling industry in an advantageous position to stem the tide of fire incidents over the next several years, even with the onslaught of hazards continuing to affect the waste and recycling industries worldwide.

In my role with Fire Rover, I have been fortunate to be on the frontlines of the next generation of firefighting. The industry has been on a slow-moving trajectory of a "water, water, water" approach instead of seeking out and utilizing solutions that use less water. Gone are the days when it was acceptable to deluge 30,000 gallons (113,562 L) of foam into a hangar or one million gallons of water to contain an out-of-control fire.

When we first started Fire Rover, potential customers would question the amount of water we have in our tanks. Our traditional solution uses 1,000 gallons (3,785 L) of water and our environmentally friendly encapsulator agent. We use this amount of water to have enough spray to fight a fire before the authorities (typically dispatched with more than enough time to spare) arrive on the scene and perform final extinguishment activities.

The team at Fire Rover has learned that, most of the time, 1,000 gallons (3,785 L) are more than enough to deal with the hazards faced in a waste and recycling processing facility. A Fire Rover installation will often spray for one minute or less using less than 10% of the reserve capacity. In the rare occurrence (less than 20 incidents since 2015) where the fire department or fire brigade needs to come onsite and extinguish a fire, they show up to a controlled situation that needs more water to remove hotspots and wet the collateral material.

In a recent FM research report, "Reducing Water Demands Using Innovative Fire Protection Solutions",[61] smart monitors have demonstrated the ability to reduce the amount of water necessary for uncartoned, unexpanded plastic, and cartoned unexpanded plastic fire sources by up to 88%.

Table 2-12: Water demand for SMART sprinklers and AWC compared to traditional ceiling sprinkler protection for low-piled HC-3 occupancies under a 9.1 m (30 ft) high ceiling.

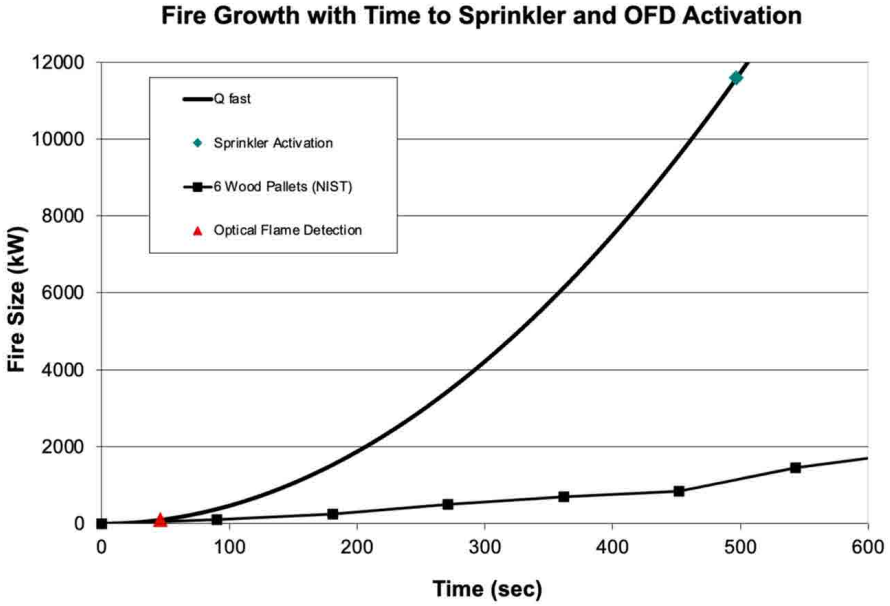
	Water demand lpm (gpm)	Reduction compared to DS 3-26
DS 3-26	2,800 (750)	NA
SMART	570 (150) for 5 sprinklers or 1,000 (270) for 9 sprinklers	80% or 64%
AWC	230 (60)	92%

Table 8 - Water Demand based on sprinkler types (Source: FM Global)

Keep in mind that these results were evaluated in controlled test environments. In live settings, our Fire Rover solution deploys the benefits outlined by the FM report and creates the most effective spray patterns in any situation. This has led to successful

[61] Report download link (FM Global, "Reducing Water Demands with Innovative Fire Protection Solutions", published April 2020): https://www.fmglobal.com/research-and-resources/research-and-testing/-/media/25C4E9A7288D4ED3B04017A09DCB49B1.ashx

putouts and successes while dealing with other factors such as higher piles, human activity onsite, unique hazards, and collateral assets, among others.



In the same study, FM evaluated the difference in detection times between optical flame detection (OFD) and sprinkler system activation using calculations from the Society of Fire Protection Engineers handbook along with t-squared fire growth rates and provided the sprinkler activation time based on the plume gas temperature and velocity. The calculations resulted in sprinkler activation at a fire size of approximately 11 megawatts and 8 minutes 30 seconds (510 seconds) after ignition. This example used a 40-foot ceiling height and 286 degrees Fahrenheit sprinkler head activation temperature. OFDs are tested to FM 3260 Approval Standard for Radiant Energy-Sensing Fire Detectors for Automatic Fire Alarm Signaling. The standards test the detectors to a one-square-foot pan fire of heptane, 100 to 200 kilowatts. The OFD would detect at 45 to 65 seconds at that fire size. The difference in activation time for the fast growth rate will be more than 7 minutes. With the higher ceilings and slower fire growth rates, the difference in activation time grows significantly.

It is important to note that when using military-grade thermal cameras, as Fire Rover's solution does, we can catch fires earlier than the 45 to 65 seconds that an average OFD would take. In addition, we set our temperature gauges earlier than any other solution since we are clearing many false alarms to identify the fire during its incipient or even pre-incipient stages.

It is understood that once you detect, you need to suppress. Our team identifies the fire quickly and alerts the fire department with a live verification of a real incident. The problem is that once the fire professionals arrive on the scene and assess the situation, the fire

has more than 10 minutes to grow. While the fire professionals work to control the fire and the overall outcome is positive, it is a situation that all parties involved would have preferred to have suppressed much sooner, not to mention the additional water that needed to be used to put the fire out.

In my initial stages of researching the industry fires, I published a series of articles on LinkedIn called "The Anatomy Of…" series. In these articles, I would piece together snippets of reported information on a fire incident that gave the inside story, highlighting the layers of waste and recycling fires from initial detection through the full consequences. Similarly, I want to share some highlights from articles that provide insights from a fire professional's perspective.

Since my early research on this subject, I have learned so much. In my position at Fire Rover, I can have a front-row seat to fire incidents, their causes, and the best way to avoid and fight them. We typically see smoke from the fire fill up the affected building faster than a fire plan had expected. Check out this video of an incident where the building fills with smoke within moments of the fire starting.[62]

Once the fire is at this stage, the idea that your employees must do anything more than evacuate the building and get to a safe position is unreasonable. I have heard numerous times of fire plans that required manual water cannons to be positioned toward the fire by an employee before they evacuated the scene. This plan might seem logical, but in a live fire incident, the smoke fills the structure so fast that employees should evacuate to stay safe and wait for fire professionals to arrive. Remember that smoke easily fills warehouse structures with 30-to 50-foot ceilings.

In this specific incident, we fought the fire remotely and were unaffected by the smoke due to our thermal cameras. As we cool the flames and hotspots, the fire and smoke dissipate so that an evaluation can occur safely without putting anyone at risk of injuries. We continue our fire watch of the scene to deal with any hotspots or flare-ups, as necessary.

If this incident had been left to a traditional fire sprinkler to fight, the cleanup could have been days versus the results that allowed the business to return to work within hours of the fire incident. Even if the sprinklers worked correctly, the fire professionals would have been responsible for final extinguishment, which is another chance for a major fire to occur, putting fire professionals at risk of injury. The goal for us as an industry is to ensure that firefighters are not put in a position to make a Hobson's Choice (having the necessity of accepting one of two or more equally objectionable alternatives, such as fighting the

[62] Website (YouTube - Fire Rover, "Tip Floor / Metering Drum Elimination Incident", posted November 21, 2018): https://youtu.be/BDddVWYOgZA

fire and risking injuring or losing firefighters, or not fighting the fire and risking losing the facility and dealing with the aftermath of catastrophic property loss).

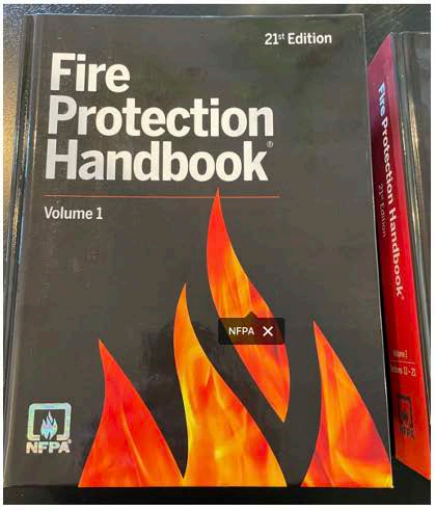
Of the hundreds of fire incidents successfully detected and eliminated by Fire Rover over the years, the firefighters who arrive on the scene show up to a controlled setting where they may add a water stream to ensure no hotspots or flare-ups. Trust me when I say that no firefighter is unhappy that they did not have to fight a waste or recycling facility fire that day and can safely go home to their families after their shift.

10.4 NFPA Handbook

Fire Rover's solution has been accepted in the waste and recycling industry. Still, there also is a compelling case for occupancies outside of waste and recycling, such as refineries, construction sites, demolition sites, historical structures, airplane hangars, and garages, specifically housing lithium-powered electronic vehicles. As you can see from our submissions for inclusion in the National Fire Protection Association (NFPA) codes, our solution is progressing due to its results proven in the waste and recycling occupancy.

Fire Rover was recently included in the 2023 edition of the "NFPA Fire Protection Handbook." See Chapter 4, section 11 on Fire Hazards of Construction, Alteration, and Demolition of Buildings, revised by Bruce Campbell from Jensen Hughes. Our Fire Rover unit was highlighted as an alternative "new technology" recognized by NFPA 241.

Fire Rover Recently Included In The 21st Edition of NFPA's Fire Protection Handbook



FIRE ROVER
PROFESSIONAL ADOPTION - NFPA

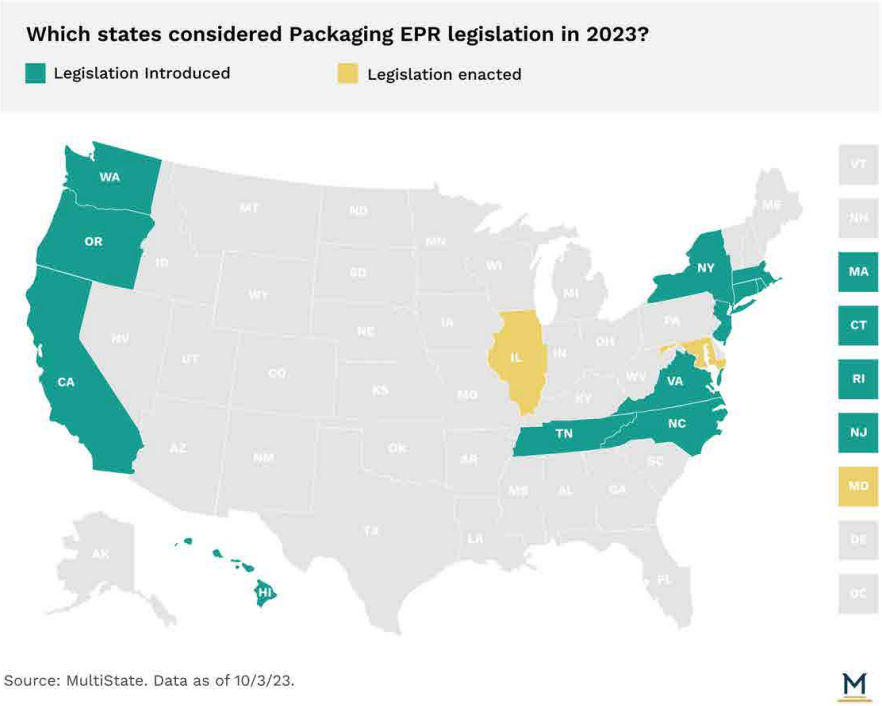
Code Name and Number	Text Submission	Result	Next Step
NFPA 18A Standard on Water Additives for Fire Control and Vapor Mitigation	Updated Text submitted	Accepted	Jan 7th, 2025
NFPA 80A Recommended Practice for Protection of Buildings from Exterior Fire Exposures	Text submitted	TBD	June 4th, 2024
NFPA 102 Standard for Grandstands, Folding and Telescopic Seating, Tents, and Membrane Structures	Text submitted	TBD	Jan 4th, 2024
NFPA 120 Standard for Fire Prevention and Control in Coal Mines	Waiting for revision cycle to open		Jan 7th, 2026
NFPA 122 Standard for Fire Prevention and Control in Metal/Nonmetal Mining and Metal Mineral Processing Facilities	Waiting for revision cycle to open		Jan 7th, 2026
NFPA 140 Standard on Motion Picture and Television Production Studio Soundstages, Approved Production Facilities, and Production Locations	Waiting for revision cycle to open		Jan 7th, 2026
NFPA 241 Standard for Safeguarding Construction, Alteration, and Demolition Operations	Updated Text Submitted	Accepted as Appendix material	June 4th, 2024
NFPA 303 Fire Protection Standard for Marinas and Boatyards	Open for input (2023)		March 21, 2024
NFPA 307 Standard for the Construction and Fire Protection of Marine Terminals, Piers, and Wharves	Text submitted	TBD	March 21, 2024
NFPA 409 Standard of Airport Hangars	Text submitted	TBD	Jan 4th, 2024
NFPA 418 Standard for Heliports	Open for input (2024)		
NFPA 914 Code for Fire Protection of Historic Structures	Text Submitted	Committee meeting June 2021	Jan 7th, 2025

Figure 30 - NFPA Professional Adoption: Fire Rover

10.5 Extended Producer Responsibility (EPR)

In 2023, EPR continued to be discussed at state-level legislatures, with EPR bills considered in 14 states this past year, as reported by Multistate in October 2023:

> *In recent years, state legislatures have devoted increased attention to Extended Producer Responsibility (EPR) standards for packaging waste. During the 2023 legislative sessions, lawmakers considered 43 bills in 14 states related to EPR standards for plastics and packaging materials. Two were enacted in Illinois and Maryland, while high-profile efforts were frustrated by last-minute amendments in Connecticut and New York. Additionally, states with packaging EPR laws on the books attempted to tweak their processes and further regulate packaging products. This year built upon the developments of the 2022 legislative session, and we anticipate its continuation in 2024 as interest in packaging and EPR-related issues increases.*



In 2021, Oregon and Maine announced new packaging policies[63] at the state level, making them the first in the nation to officially pass extended producer responsibility (EPR) laws for packaging sold or distributed in their states. This move has paved the way for other states to create and implement their own EPR policies in the future.

Also, in 2021, Washington, D.C.'s all-battery bill was officially passed into law,[64] making it the first all-battery EPR law in the country. Under the law, producers now fund and manage an effective recycling program in Washington, D.C., for both single-use and rechargeable consumer batteries. Along with Vermont's EPR law that covers all household primary batteries, this new law sets the bar for changes that need to happen to ensure that costs shift from operators and taxpayers to product manufacturers.

In 2022, California took similar action by passing two new laws[65] (AB 2440 and SB 1215) that will overhaul the state's battery EPR program and expand its e-waste program. AB 2440, the Responsible Battery Act of 2022, creates a singular EPR program for batteries

[63] Website (Waste360, Press Release, "Oregon Joins Maine and Passes EPR Legislation", published August 9, 2021): https://www.waste360.com/legislation-regulation/oregon-joins-maine-and-passes-epr-legislation

[64] Website (Waste Advantage Magazine, "Washington D.C. Battery EPR Bill Officially Becomes Law", published March 18, 2021): https://wasteadvantagemag.com/washington-d-c-battery-epr-bill-officially-becomes-law/

[65] Website (Beveridge & Diamond, News Alert, "California Passes Two New Laws to Overhaul State's Battery Extended Producer Responsibility Program and Broadly Expand State's E-Waste Program", by Russ LaMotte, Jeff Clare, Updated October 6, 2022): https://www.bdlaw.com/publications/california-passes-two-new-laws-to-overhaul-states-battery-extended-producer-responsibility-program-and-broadly-expand-states-e-waste-program/

within the state. SB 1215 expands the Electronic Waste Recycling Act (EWRA) of 2003 to include battery-embedded products and broadens the EWRA's definition of manufacturers.

During a conversation with Courtney Scott,[66] household hazardous waste (HHW) program manager for Zero Waste Sonoma, she explained why she backs EPR policies and is currently trying to get her idea approved.

> *"A few years ago, we looked into creating a new battery collection program at either retail locations or at government buildings like fire stations and community centers. However, with the uptick in lithium-ion battery fires, we realized that it would be both expensive and dangerous to have batteries collected at more locations.*
>
> *"During that same period, EPR for batteries was being discussed at the state level, so we wanted to see how that played out. Since a couple of different battery bills failed in recent years, Zero Waste Sonoma was approached by the California Product Stewardship Council to see if we were interested in joining a handful of other local jurisdictions to implement our own battery EPR ordinances.*
>
> *"We brought the idea to our Zero Waste Sonoma Board of Directors in September 2021 to gauge their interest. We received support to create a model ordinance for true EPR of all battery chemistries, both loose and embedded. I'm currently working on a more specific draft ordinance based on their feedback and will bring it back to the board soon. This will be a long process, but it's one we believe in because batteries are so prolific," she said.*

The European Commission published a Proposal for a Regulation concerning batteries and waste batteries, repealing Directive 2006/66/EC, and amending Regulation (EU) No 2019/1020. The European Parliament Committee on the Internal Market and Consumer Protection voted and decided that there was a need for a deposit refund scheme, which could ensure the safe collection of batteries and accumulators and help avoid fire risks in waste facilities. According to a 2021 article in *RECYCLING* magazine[67]:

> *"Incorrectly disposed lithium batteries and accumulators pose a high risk of fire incidents everywhere, and not only in waste battery installations. When this arises, sorting systems for lightweight packaging, paper collection, commercial waste processing, etc., can be considerably damaged by fires, and workers and other people from the wider community can be put at great risk. As a result, the purpose of making batteries more circular is weakened because processing and treatment facilities are damaged, sometimes beyond repair, reducing the overall capacity to recycle batteries.*

[66] Website (Waste360, "October 2021 Fire Report: Q&A with The Battery Queen", by Ryan Fogelman, published Nov 18, 2021): https://www.waste360.com/safety/october-2021-fire-report-qa-battery-queen

[67] Website (Recycling Magazine, "Battery regulation: IMCO vote on draft opinion", published Sept 12, 2021): https://www.recycling-magazine.com/2021/12/09/battery-regulation-imco-vote-on-draft-opinion/

Consequently, mandatory DRS is essential if we are to achieve high collection rates, safe battery flows, and safeguard treatment facilities."

It will be interesting to see how that process works overseas and how our EPR policies in the U.S. will play out. Since awareness around this issue has increased, it is time for the stakeholders to come together and solve this problem.

While some view EPR policies as problematic, I view them as opportunities. Battery manufacturers need to be held responsible for the products they bring to market and the costs their products cause down the supply chain. Currently, our operators and fire professionals who protect our facilities are footing the bill for the costs generated by fires. The waste sector needs help from governments and associations, but it also deserves support from battery manufacturers. We need to hold the entire lithium-ion battery supply chain accountable for the products it manufactures—not because the battery producers are evil corporations but simply because they should be good stewards in sharing the benefits and costs of their products.

11 Breakdown by State and Province

In my previous reports, you may remember charts like the one below. Those charts would show the top reported waste and recycling facility fires by states and provinces with 20 or more waste and recycling facility fires per year. However, I received some valuable feedback that certain states and provinces were reliably not shown on my charts (which I thought would be good), making it challenging for people in those states.

Reliably, states or provinces with large populations, like California, Texas, New York, and Ontario, were displayed, but states and provinces with smaller populations might not. Therefore, the *de facto* takeaway from charts was this: *if you have a sizeable population, you have a sizeable fire problem.* While that alone is worth considering—particularly for growing areas that may not have yet invested in advanced fire protection, like Fire Rover's solution, to protect their waste management infrastructure—it is far from the whole picture, making it challenging to relate to the data.

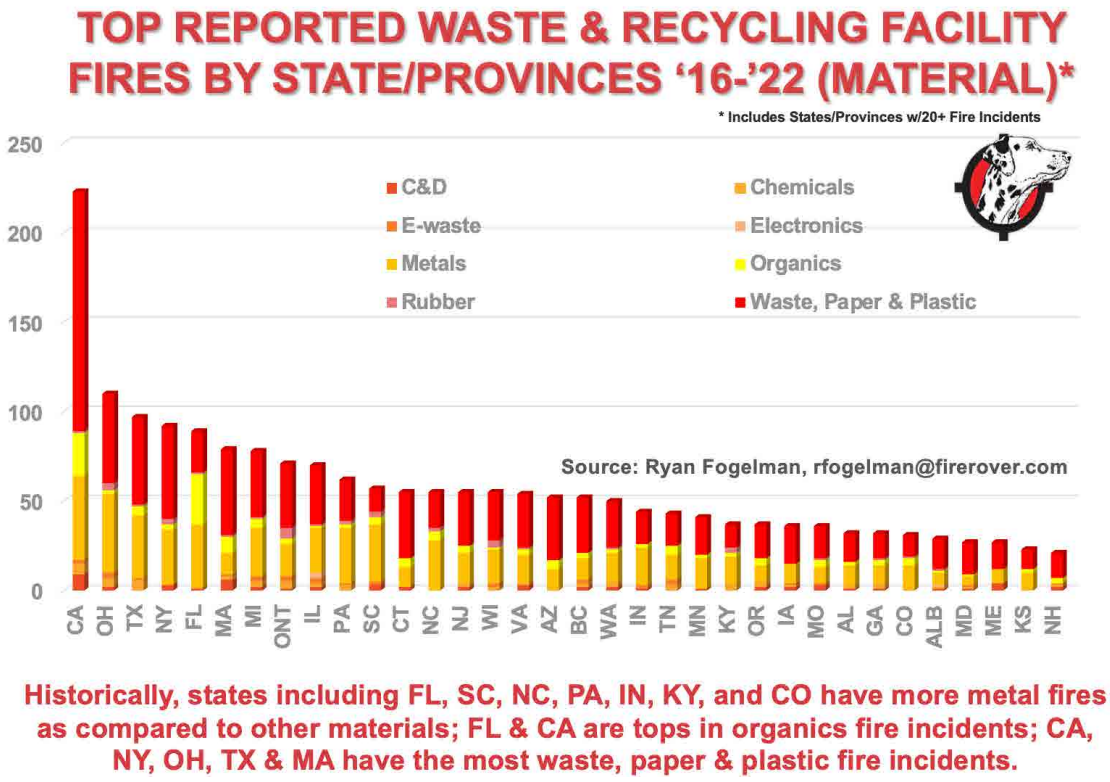


Figure 31 - Top Reported Waste & Recycling Facility Fires by State/Provinces (2016-2022)

To address some feedback, see Table 9 below for the yearly reported facility fire totals for each state, province, and the larger US territories from 2016 to 2023.

Table 9 - Fires by Year for each US state, Canadian province, and major US Territories: 2016-2023

US States, Territories, and Canadian Provinces	Years								Total Fire Incidents: 2016-2023
	2016	2017	2018	2019	2020	2021	2022	2023	
Alabama	3	1	6	8	2	8	6	5	39
Alaska	1		1						2
Arizona	12	3	7	5	5	12	15	15	74
Arkansas	1	1	1	2	5	3	2	1	16
California	34	26	32	33	29	29	36	14	233
Colorado	3	3	10	3	4	2	7	3	35
Connecticut	6	5	9	12	9	9	6	8	64
Delaware	1	2	4	1				2	10
District Of Columbia						2	2		4
Florida	7	6	16	22	11	12	18	18	110
Georgia	5	2	3	6	4	8	7	12	47
Guam		1			1				2
Hawaii	1	1	3	2	3		2	1	13
Idaho	4	4	4	1	2	2	1	1	19
Illinois	8	8	14	15	9	11	9	11	85
Indiana	3	6	3	11	4	15	4	9	55
Iowa	7	6	4	4	5	6	6	7	45
Kansas		4	5	2	3	4	6	2	26
Kentucky	5	4	12	6	3	3	4	7	44
Louisiana		3	6		2	2	4	3	20
Maine	6	2	4	4	6	4	3	18	47
Maryland	6	5	4	3	3	3	4	2	30
Massachusetts	9	8	10	11	13	13	16	11	91
Michigan	15	12	15	9	9	7	12	8	87
Minnesota	2	5	5	9	10	6	4	10	51
Mississippi		1	1	1		3	1	1	8
Missouri	4	6	4	3	8	6	8	5	44
Montana	2	1	1	2	1		3		10
Nebraska	2	1	5	2	2	6	4	4	26
Nevada	3	4		1	5	2	4		19
New Hampshire		2	3	4	7	3	3	1	23
New Jersey	12	5	3	7	6	16	12	5	66
New Mexico	1	2	3	2	2	1	6	3	20
New York	14	12	14	14	11	13	20	11	109
North Carolina	7	12	10	7	1	15	7	12	71
North Dakota	1	1		1	1	2	1	1	8

US States, Territories, and Canadian Provinces	Years								Total Fire Incidents: 2016-2023
	2016	2017	2018	2019	2020	2021	2022	2023	
Ohio	13	15	25	11	12	18	26	15	135
Oklahoma			3		5	9	4	4	25
Oregon	4	8	8	8	4	4	2	9	47
Pennsylvania	2	17	7	7	9	13	15	16	86
Puerto Rico		1							1
Rhode Island				1		2		2	5
South Carolina	5	6	11	12	12	9	5	8	68
South Dakota	1			1	2	2	1		7
Tennessee	6	3	11	12	5	1	6	8	52
Texas	6	13	15	17	14	13	22	32	132
Utah	1	1	4	2	3	6	1	1	19
Vermont		2	1		2		2	2	9
Virgin Islands			2	4		1			7
Virginia	12	12	5	6	8	4	7	5	59
Washington	7	6	8	10	9	7	7	8	62
West Virginia		4		1	1	4	4	1	15
Wisconsin	8	6	9	8	8	13	9	14	75
Wyoming		1	1		1			1	4
Alberta	4	4	3	3	4	5	8	4	35
British Columbia	5	11	6	8	9	10	8	12	69
Prince Edward Island				2					2
Manitoba		1		2	1	2	1	2	9
New Brunswick			1	2	4	2		2	11
Newfoundland and Labrador			1	1	4	2	1	1	10
Nova Scotia	1	2	2	3	2		2		12
Nunavut							1		1
Ontario	12	11	15	9	7	9	11	11	85
Quebec			2	1	2		4		9
Saskatchewan		1	3		3	3		4	14
Yukon			1						1
Totals	**272**	**290**	**366**	**344**	**318**	**367**	**390**	**373**	**2720**

To address the second aspect of the feedback, about the data's relatability, I have restructured it again to provide better context. But before we dive into the data, I would like to give some background information.

Using this new format on the following pages, I can highlight how the states compare to one another better by using a common denominator. That common denominator is based upon assumptions, namely an estimated amount of waste generated per person per day in the United States and the yearly population in a state.[68] While I do not anticipate that the US Census Bureau will change its population figures for a given year,[69] waste generation assumptions do change. I will update these tables in future reports when a key assumption changes. I also must apologize in advance. I know I will get an earful from my colleagues in the north because I decided to use US waste generation estimates for select Canadian provinces.

The new approach allows me to highlight the state, territory, and province data, but the same rule applies to the data in this new format as it did to the old one: I am reported on *reported fires only*. Some fires may go unreported by news agencies or facility operators for several reasons. Suffice it to say that if a fire goes unreported by them, it may not appear in my report.

The conditional coloring of the rightmost columns is purposeful. It shows the states with the highest number of facility fires per 100,000 tons of solid waste *generated*. Emphasis on the word "generated," not disposed. Waste generation was estimated, and my tables and footnotes show my process.

Notably, the US EPA's waste generation per person per year estimate includes municipal solid waste (MSW) generation, which covers trash, recycling, and composting, as well as some portions of waste streams that would logically be included in residential and commercial MSW (such as a small portion of construction & demolition (C&D) waste).[70] To incorporate more of the C&D waste stream that local waste management facilities could manage, I have also included the "landfilled" portion of the US EPA's C&D waste generation estimate from 2015.[71] Again, if these sources are updated, I will update my tables in the future.

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[68] Formula for estimated tons of waste generated in a state per year = ((((Population that year x (MSW + C&D waste pounds per person per day)) ÷ 2000 lbs.) x 365 days in a year), and the formula for Fires per 100,000 tons of estimated solid waste generated = (Number of fires ÷ (Estimated tons of waste generated in the state per year ÷ 100,000 tons))

[69] US State Population estimates, US Census Bureau, (2016-2019): https://www.census.gov/data/tables/time-series/demo/popest/2010s-state-total.html, and (2020-2023): https://www.census.gov/data/tables/time-series/demo/popest/2020s-state-total.html; Canadian Population estimates are based on the 2016 and 2021 Canadian Censuses, for years other than 2016 and 2021, I used the anticipated rate of growth and estimated the population of provinces in those years: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=9810000101&geocode=A000011124

[70] US EPA National Overview: Facts and Figures on Materials, Wastes, and Recycling, https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials; Notes:

a. See the table labeled "MSW Generation Rates 1960-2018" for estimated annual waste generation rates per capita.

b. The US EPA has not published an Annual Generation Rate per person since it was last reported for 2018. Fire Rover's spreadsheet will be updated when national waste generation per person estimates are reported for years 2019 and after. For my purposes, I used the figure 4.9 pounds per person for years 2018 to 2024.

[71] US EPA report, "Construction and Demolition Debris Management in the United States, 2015," published March 2020, Table ES-1. "2015 C&D Debris Sent to Landfills or Next Use (tons)" on page 4, the "Landfill" category of C&D was 132,184,998 tons of waste. The US Census Bureau

I did not perform a full accounting of waste disposal across North America for this report, nor did I feel that was necessary; therefore, I decided to use waste generation estimates and compare them to reported facility fires to put things into perspective. This may be obvious, but using a uniform waste generation figure does not reflect the fact that different states and regions can generate more or less waste per person than EPA's national estimate. The national estimate should be treated as a baseline for analysis, not a reflection of any precise amount of waste generated, processed, or disposed of.

Also, some states may import more waste for processing than they generate. This may be because some regions need more waste disposal or processing capacity for the waste they generate and must rely on disposal facilities in other states. The reasons for exporting waste to another region or state may also be economic if the cost to dispose of waste locally may be high enough that decision-makers choose to send waste out of state to an area where tipping fees are lower.

Geography has an impact, too. Some cities or towns in tri-state areas may be closer to waste disposal facilities in other states. An example of an area dependent on waste disposal facilities elsewhere is New York City: New York City's waste generation well exceeds its ultimate disposal capacity within its borders and exports a tremendous amount of waste outside the city annually for disposal. New York City is also closer to other states, like New Jersey, than the rest of New York state.

Keep in mind the driving forces behind all my research on waste and recycling facility fires since 2016. They have been to 1) better understand the scale of the problem, 2) shed light on the problem, including who it affects and what the causes are, 3) extract and translate key information so I can draw high-level conclusions, 4) best communicate how solid waste facility operators can prevent catastrophic fires and all the negative consequences that come from them. As I have learned more about the issues, the Fire Rover solution has tailored its offering to meet the industry's needs. Due to all this research and a nimble team focused on results, the Fire Rover solution has proven to be the best way to stem the tide and prevent catastrophic fires from destroying North America's waste management facilities.

Without further ado, please see the new state-by-state analysis for 2016 to 2023 on the following pages.

estimated that the population in 2015 was 320,635,163. Therefore, the pounds of C&D waste per person per day was 2.26 and rounded up to 2.3 in the table above. More recent estimates of C&D Waste are not available from the US EPA. https://www.epa.gov/sites/default/files/2020-03/documents/final_cd-eol-management_2015_508.pdf

11.1.1 2023 State-by-state Comparison

State, Province, or Territory	2018-2024 National Pounds of solid waste generated per person (US EPA[1])	C&D waste generation estimate per person (US EPA[2])	2023: Population Estimate (US Census4, Estimate using 2021 Canadian Census)	2023: Tons per year generated (Formula[5])	2023: Solid Waste & Recycling Facility Fires (Ryan Fogelman)	2023: Fires per 100,000 tons of estimated solid waste generated (Formula[6])
Maine	4.9	2.3	1,395,722	1,833,979	18	0.9815
Vermont	4.9	2.3	647,464	850,768	2	0.2351
British Columbia	4.9	2.3	5,000,879	6,571,155	12	0.1826
Wisconsin	4.9	2.3	5,910,955	7,766,995	14	0.1802
Connecticut	4.9	2.3	3,617,176	4,752,969	8	0.1683
Iowa	4.9	2.3	3,207,004	4,214,003	7	0.1661
Oregon	4.9	2.3	4,233,358	5,562,632	9	0.1618
Nebraska	4.9	2.3	1,978,379	2,599,590	4	0.1539
Arizona	4.9	2.3	7,431,344	9,764,786	15	0.1536
Delaware	4.9	2.3	1,031,890	1,355,903	2	0.1475
Rhode Island	4.9	2.3	1,095,962	1,440,094	2	0.1389
Minnesota	4.9	2.3	5,737,915	7,539,620	10	0.1326
Wyoming	4.9	2.3	584,057	767,451	1	0.1303
Massachusetts	4.9	2.3	7,001,399	9,199,838	11	0.1196
Kentucky	4.9	2.3	4,526,154	5,947,366	7	0.1177
South Carolina	4.9	2.3	5,373,555	7,060,851	8	0.1133
New Mexico	4.9	2.3	2,114,371	2,778,283	3	0.1080
Indiana	4.9	2.3	6,862,199	9,016,929	9	0.0998
North Dakota	4.9	2.3	783,926	1,030,079	1	0.0971
Ohio	4.9	2.3	11,785,935	15,486,719	15	0.0969
Pennsylvania	4.9	2.3	12,961,683	17,031,651	16	0.0939
West Virginia	4.9	2.3	1,770,071	2,325,873	2	0.0860
Tennessee	4.9	2.3	7,126,489	9,364,207	8	0.0854
North Carolina	4.9	2.3	10,835,491	14,237,835	12	0.0843
Georgia	4.9	2.3	11,029,227	14,492,404	12	0.0828
Texas	4.9	2.3	30,503,301	40,081,338	32	0.0798
Washington	4.9	2.3	7,812,880	10,266,124	8	0.0779
Oklahoma	4.9	2.3	4,053,824	5,326,725	4	0.0751
Alabama	4.9	2.3	5,108,468	6,712,527	5	0.0745
Alberta	4.9	2.3	4,262,635	5,601,102	4	0.0714
Illinois	4.9	2.3	12,549,689	16,490,291	11	0.0667
Missouri	4.9	2.3	6,196,156	8,141,749	5	0.0614
Michigan	4.9	2.3	10,037,261	13,188,961	8	0.0607
Florida	4.9	2.3	22,610,726	29,710,494	18	0.0606
Ontario	4.9	2.3	14,611,666	19,199,729	11	0.0573
New Hampshire	4.9	2.3	1,402,054	1,842,299	1	0.0543
Hawaii	4.9	2.3	1,435,138	1,885,771	1	0.0530
Kansas	4.9	2.3	2,940,546	3,863,877	2	0.0518
Louisiana	4.9	2.3	4,573,749	6,009,906	3	0.0499
Virginia	4.9	2.3	8,715,698	11,452,427	5	0.0437
New York	4.9	2.3	19,571,216	25,716,578	11	0.0428
New Jersey	4.9	2.3	9,290,841	12,208,165	5	0.0410
Colorado	4.9	2.3	5,877,610	7,723,180	3	0.0388
Idaho	4.9	2.3	1,964,726	2,581,650	1	0.0387
California	4.9	2.3	38,965,193	51,200,264	14	0.0273
Mississippi	4.9	2.3	2,939,690	3,862,753	1	0.0259
Arkansas	4.9	2.3	3,067,732	4,031,000	1	0.0248
Maryland	4.9	2.3	6,180,253	8,120,852	2	0.0246
Utah	4.9	2.3	3,417,734	4,490,902	1	0.0223
District of Columbia	4.9	2.3	678,972	892,169	0	0.0000
Montana	4.9	2.3	1,132,812	1,488,515	0	0.0000
Nevada	4.9	2.3	3,194,176	4,197,147	0	0.0000
South Dakota	4.9	2.3	919,318	1,207,984	0	0.0000
Alaska	4.9	2.3	733,406	963,695	0	0.0000
Average:			*6,644,261*	*8,730,558*	*7*	*0.0989*

In 2023, Maine experienced a significant spike in reported fires. Far more than more populated states like Pennsylvania. While this report will not venture to guess what exactly happened in Maine in 2023, we observe a dramatic increase in fires that were not observed previously. Texas led the nation with the most fires that year (35), ahead of America's most populous state, California.

11.1.2 2022 State-by-state Comparison

State, Province, or Territory	2018-2024 National Pounds of solid waste generated per person (US EPA[1])	C&D waste generation estimate per person (US EPA[2])	2022: Population Estimate (US Census[4], Estimate using 2021 Canadian Census)	2022: Tons per year generated (Formula[5])	2022: Solid Waste & Recycling Facility Fires (Ryan Fogelman)	2022: Fires per 100,000 tons of estimated solid waste generated (Formula[6])
Vermont	4.9	2.3	647,110	850,303	2	0.2352
District of Columbia	4.9	2.3	670,949	881,627	2	0.2269
New Mexico	4.9	2.3	2,113,476	2,777,107	6	0.2161
Montana	4.9	2.3	1,122,878	1,475,462	3	0.2033
Massachusetts	4.9	2.3	6,982,740	9,175,320	16	0.1744
West Virginia	4.9	2.3	1,774,035	2,331,082	4	0.1716
Ohio	4.9	2.3	11,759,697	15,452,242	26	0.1683
Maine	4.9	2.3	1,389,338	1,825,590	3	0.1643
New Hampshire	4.9	2.3	1,399,003	1,838,290	3	0.1632
Kansas	4.9	2.3	2,936,716	3,858,845	6	0.1555
Arizona	4.9	2.3	7,365,684	9,678,509	15	0.1550
Nebraska	4.9	2.3	1,968,060	2,586,031	4	0.1547
Alberta	4.9	2.3	4,262,635	5,601,102	8	0.1428
Iowa	4.9	2.3	3,199,693	4,204,397	6	0.1427
Connecticut	4.9	2.3	3,608,706	4,741,840	6	0.1265
British Columbia	4.9	2.3	5,000,879	6,571,155	8	0.1217
Wisconsin	4.9	2.3	5,890,543	7,740,174	9	0.1163
Hawaii	4.9	2.3	1,439,399	1,891,370	2	0.1057
New Jersey	4.9	2.3	9,260,817	12,168,714	12	0.0986
Missouri	4.9	2.3	6,177,168	8,116,799	8	0.0986
North Dakota	4.9	2.3	778,912	1,023,490	1	0.0977
Nevada	4.9	2.3	3,177,421	4,175,131	4	0.0958
Colorado	4.9	2.3	5,841,039	7,675,125	7	0.0912
Michigan	4.9	2.3	10,033,281	13,183,731	12	0.0910
Alabama	4.9	2.3	5,073,903	6,667,109	6	0.0900
Pennsylvania	4.9	2.3	12,972,091	17,045,328	15	0.0880
South Dakota	4.9	2.3	909,869	1,195,568	1	0.0836
New York	4.9	2.3	19,673,200	25,850,585	20	0.0774
Oklahoma	4.9	2.3	4,019,271	5,281,322	4	0.0757
South Carolina	4.9	2.3	5,282,955	6,941,803	5	0.0720
California	4.9	2.3	39,040,616	51,299,369	36	0.0702
Washington	4.9	2.3	7,784,477	10,228,803	7	0.0684
Kentucky	4.9	2.3	4,511,563	5,928,194	4	0.0675
Louisiana	4.9	2.3	4,588,023	6,028,662	4	0.0663
Tennessee	4.9	2.3	7,048,976	9,262,354	6	0.0648
Florida	4.9	2.3	22,245,521	29,230,615	18	0.0616
Virginia	4.9	2.3	8,679,099	11,404,336	7	0.0614
Ontario	4.9	2.3	14,417,804	18,944,994	11	0.0581
Texas	4.9	2.3	30,029,848	39,459,220	22	0.0558
Illinois	4.9	2.3	12,582,515	16,533,425	9	0.0544
Minnesota	4.9	2.3	5,714,300	7,508,590	4	0.0533
Arkansas	4.9	2.3	3,046,404	4,002,975	2	0.0500
North Carolina	4.9	2.3	10,695,965	14,054,498	7	0.0498
Maryland	4.9	2.3	6,163,981	8,099,471	4	0.0494
Georgia	4.9	2.3	10,913,150	14,339,879	7	0.0488
Indiana	4.9	2.3	6,832,274	8,977,608	4	0.0446
Idaho	4.9	2.3	1,938,996	2,547,841	1	0.0392
Oregon	4.9	2.3	4,239,379	5,570,544	2	0.0359
Mississippi	4.9	2.3	2,938,928	3,861,751	1	0.0259
Utah	4.9	2.3	3,381,236	4,442,944	1	0.0225
Rhode Island	4.9	2.3	1,093,842	1,437,308	0	0.0000
Wyoming	4.9	2.3	581,629	764,261	0	0.0000
Delaware	4.9	2.3	1,019,459	1,339,569	0	0.0000
Alaska	4.9	2.3	733,276	963,525	0	0.0000
Average:			*6,610,236*	*8,685,850*	*7*	*0.0935*

In 2022, while California led the pack in the number of facility fires, its fires per 100,000 tons of waste generated ranked about midway down from the top of the list. Vermont seemed to suffer a tough year with its two fires. Remember that the fewer solid waste facilities an area has, the more is at stake if a fire destroys one, as disposal options can become limited quickly.

11.1.3 2021 State-by-state Comparison

State, Province, or Territory	2018-2024 National Pounds of solid waste generated per person (US EPA[1])	C&D waste generation estimate per person (US EPA[2])	2021: Population Estimate (US Census4, 2021 Canadian Census)	2021: Tons per year generated (Formula[5])	2021: Solid Waste & Recycling Facility Fires (Ryan Fogelman)	2021: Fires per 100,000 tons of estimated solid waste generated (Formula[6])
Nebraska	4.9	2.3	1,964,253	2,581,028	6	0.2325
District of Columbia	4.9	2.3	669,037	879,115	2	0.2275
Maine	4.9	2.3	1,378,787	1,811,726	4	0.2208
North Dakota	4.9	2.3	777,982	1,022,268	2	0.1956
Connecticut	4.9	2.3	3,603,691	4,735,250	9	0.1901
Oklahoma	4.9	2.3	3,991,634	5,245,007	9	0.1716
West Virginia	4.9	2.3	1,785,249	2,345,817	4	0.1705
South Dakota	4.9	2.3	896,299	1,177,737	2	0.1698
Wisconsin	4.9	2.3	5,879,978	7,726,291	13	0.1683
Indiana	4.9	2.3	6,813,798	8,953,331	15	0.1675
New Hampshire	4.9	2.3	1,387,494	1,823,167	3	0.1645
British Columbia	4.9	2.3	5,000,879	6,571,155	10	0.1522
Iowa	4.9	2.3	3,197,944	4,202,098	6	0.1428
Massachusetts	4.9	2.3	6,991,951	9,187,424	13	0.1415
Rhode Island	4.9	2.3	1,097,092	1,441,579	2	0.1387
Utah	4.9	2.3	3,339,284	4,387,819	6	0.1367
South Carolina	4.9	2.3	5,193,848	6,824,716	9	0.1319
New Jersey	4.9	2.3	9,269,175	12,179,696	16	0.1314
Arizona	4.9	2.3	7,272,487	9,556,048	12	0.1256
Alabama	4.9	2.3	5,050,380	6,636,199	8	0.1206
Ohio	4.9	2.3	11,765,227	15,459,508	18	0.1164
North Carolina	4.9	2.3	10,567,100	13,885,169	15	0.1080
Kansas	4.9	2.3	2,937,946	3,860,461	4	0.1036
Alberta	4.9	2.3	4,262,635	5,601,102	5	0.0893
Idaho	4.9	2.3	1,904,537	2,502,562	2	0.0799
Minnesota	4.9	2.3	5,717,968	7,513,410	6	0.0799
Mississippi	4.9	2.3	2,949,582	3,875,751	3	0.0774
Pennsylvania	4.9	2.3	13,013,614	17,099,889	13	0.0760
Arkansas	4.9	2.3	3,028,443	3,979,374	3	0.0754
Missouri	4.9	2.3	6,170,393	8,107,896	6	0.0740
Oregon	4.9	2.3	4,256,465	5,592,995	4	0.0715
Washington	4.9	2.3	7,741,433	10,172,243	7	0.0688
Illinois	4.9	2.3	12,690,341	16,675,108	11	0.0660
Georgia	4.9	2.3	10,790,385	14,178,566	8	0.0564
California	4.9	2.3	39,145,060	51,436,609	29	0.0564
Michigan	4.9	2.3	10,038,117	13,190,086	7	0.0531
Kentucky	4.9	2.3	4,507,600	5,922,986	3	0.0507
New York	4.9	2.3	19,854,526	26,088,847	13	0.0498
Nevada	4.9	2.3	3,146,632	4,134,674	2	0.0484
Ontario	4.9	2.3	14,223,942	18,690,260	9	0.0482
Florida	4.9	2.3	21,830,708	28,685,550	12	0.0418
Maryland	4.9	2.3	6,175,045	8,114,009	3	0.0370
New Mexico	4.9	2.3	2,116,950	2,781,672	1	0.0359
Virginia	4.9	2.3	8,657,348	11,375,755	4	0.0352
Texas	4.9	2.3	29,561,286	38,843,530	13	0.0335
Louisiana	4.9	2.3	4,627,047	6,079,940	2	0.0329
Colorado	4.9	2.3	5,811,596	7,636,437	2	0.0262
Tennessee	4.9	2.3	6,963,709	9,150,314	1	0.0109
Vermont	4.9	2.3	647,093	850,280	0	0.0000
Hawaii	4.9	2.3	1,446,745	1,901,023	0	0.0000
Wyoming	4.9	2.3	579,548	761,526	0	0.0000
Montana	4.9	2.3	1,106,366	1,453,765	0	0.0000
Delaware	4.9	2.3	1,004,881	1,320,414	0	0.0000
Alaska	4.9	2.3	734,923	965,689	0	0.0000
Average:			*6,584,008*	*8,651,387*	*7*	*0.0926*

11.1.4 2020 State-by-state Comparison

State, Province, or Territory	2018-2024 National Pounds of solid waste generated per person (US EPA[1])	C&D waste generation estimate per person (US EPA[2])	2020: Population Estimate (US Census4, Estimate using 2016 Canadian Census)	2020: Tons per year generated (Formula[5])	2020: Solid Waste & Recycling Facility Fires (Ryan Fogelman)	2020: Fires per 100,000 tons of estimated solid waste generated (Formula[6])
New Hampshire	4.9	2.3	1,378,702	1,811,614	7	0.3864
Maine	4.9	2.3	1,364,517	1,792,975	6	0.3346
Vermont	4.9	2.3	642,936	844,818	2	0.2367
Connecticut	4.9	2.3	3,577,586	4,700,948	9	0.1915
South Carolina	4.9	2.3	5,132,151	6,743,646	12	0.1779
South Dakota	4.9	2.3	887,852	1,166,638	2	0.1714
Hawaii	4.9	2.3	1,451,181	1,906,852	3	0.1573
Massachusetts	4.9	2.3	6,997,713	9,194,995	13	0.1414
British Columbia	4.9	2.3	5,000,879	6,571,155	9	0.1370
Minnesota	4.9	2.3	5,710,578	7,503,699	10	0.1333
Wyoming	4.9	2.3	577,664	759,050	1	0.1317
Arkansas	4.9	2.3	3,014,348	3,960,853	5	0.1262
Nevada	4.9	2.3	3,115,840	4,094,214	5	0.1221
Iowa	4.9	2.3	3,190,904	4,192,848	5	0.1193
Wisconsin	4.9	2.3	5,896,700	7,748,264	8	0.1032
Missouri	4.9	2.3	6,154,426	8,086,916	8	0.0989
North Dakota	4.9	2.3	779,563	1,024,346	1	0.0976
Oklahoma	4.9	2.3	3,965,234	5,210,317	5	0.0960
Washington	4.9	2.3	7,724,566	10,150,080	9	0.0887
West Virginia	4.9	2.3	1,791,562	2,354,112	2	0.0850
Idaho	4.9	2.3	1,849,339	2,430,031	2	0.0823
Kansas	4.9	2.3	2,938,124	3,860,695	3	0.0777
Nebraska	4.9	2.3	1,963,273	2,579,741	2	0.0775
Ohio	4.9	2.3	11,798,292	15,502,956	12	0.0774
New Mexico	4.9	2.3	2,118,488	2,783,693	2	0.0718
Oregon	4.9	2.3	4,245,044	5,577,988	4	0.0717
Alberta	4.9	2.3	4,262,635	5,601,102	4	0.0714
Virginia	4.9	2.3	8,637,193	11,349,272	8	0.0705
Montana	4.9	2.3	1,087,211	1,428,595	1	0.0700
Utah	4.9	2.3	3,283,982	4,315,152	3	0.0695
Michigan	4.9	2.3	10,070,627	13,232,804	9	0.0680
California	4.9	2.3	39,503,200	51,907,205	29	0.0559
Tennessee	4.9	2.3	6,926,091	9,100,884	5	0.0549
Illinois	4.9	2.3	12,790,357	16,806,529	9	0.0536
Arizona	4.9	2.3	7,186,683	9,443,301	5	0.0529
Pennsylvania	4.9	2.3	12,995,477	17,076,057	9	0.0527
Colorado	4.9	2.3	5,785,219	7,601,778	4	0.0526
Kentucky	4.9	2.3	4,508,155	5,923,716	3	0.0506
New Jersey	4.9	2.3	9,272,392	12,183,923	6	0.0492
Indiana	4.9	2.3	6,789,098	8,920,875	4	0.0448
New York	4.9	2.3	20,104,710	26,417,589	11	0.0416
Florida	4.9	2.3	21,591,299	28,370,967	11	0.0388
Ontario	4.9	2.3	14,223,942	18,690,260	7	0.0375
Maryland	4.9	2.3	6,173,689	8,112,227	3	0.0370
Texas	4.9	2.3	29,234,361	38,413,950	14	0.0364
Louisiana	4.9	2.3	4,652,022	6,112,757	2	0.0327
Alabama	4.9	2.3	5,031,864	6,611,869	2	0.0302
Georgia	4.9	2.3	10,732,390	14,102,360	4	0.0284
North Carolina	4.9	2.3	10,453,812	13,736,309	1	0.0073
District of Columbia	4.9	2.3	670,839	881,482	0	0.0000
Rhode Island	4.9	2.3	1,096,444	1,440,727	0	0.0000
Mississippi	4.9	2.3	2,958,409	3,887,349	0	0.0000
Delaware	4.9	2.3	991,862	1,303,307	0	0.0000
Alaska	4.9	2.3	732,964	963,115	0	0.0000
Average:			*6,574,341*	*8,638,683*	*6*	*0.0871*

11.1.5 2019 State-by-state Comparison

State, Province, or Territory	2018-2024 National Pounds of solid waste generated per person (US EPA[1])	C&D waste generation estimate per person (US EPA[2])	2019: Population Estimate (US Census[3], Estimate using 2016 Canadian Census)	2019: Tons per year generated (Formula[5])	2019: Solid Waste & Recycling Facility Fires (Ryan Fogelman)	2019: Fires per 100,000 tons of estimated solid waste generated (Formula[6])
Connecticut	4.9	2.3	3,565,287	4,684,787	12	0.2561
Maine	4.9	2.3	1,344,212	1,766,295	4	0.2265
New Hampshire	4.9	2.3	1,359,711	1,786,660	4	0.2239
South Carolina	4.9	2.3	5,148,714	6,765,410	12	0.1774
Oregon	4.9	2.3	4,217,737	5,542,106	8	0.1443
Montana	4.9	2.3	1,068,778	1,404,374	2	0.1424
Tennessee	4.9	2.3	6,829,174	8,973,535	12	0.1337
Indiana	4.9	2.3	6,732,219	8,846,136	11	0.1243
Alabama	4.9	2.3	4,903,185	6,442,785	8	0.1242
British Columbia	4.9	2.3	4,912,673	6,455,252	8	0.1239
Massachusetts	4.9	2.3	6,892,503	9,056,749	11	0.1215
Minnesota	4.9	2.3	5,639,632	7,410,476	9	0.1214
Hawaii	4.9	2.3	1,415,872	1,860,456	2	0.1075
Wisconsin	4.9	2.3	5,822,434	7,650,678	8	0.1046
Kentucky	4.9	2.3	4,467,673	5,870,522	6	0.1022
Washington	4.9	2.3	7,614,893	10,005,969	10	0.0999
North Dakota	4.9	2.3	762,062	1,001,349	1	0.0999
Iowa	4.9	2.3	3,155,070	4,145,762	4	0.0965
Illinois	4.9	2.3	12,671,821	16,650,773	15	0.0901
South Dakota	4.9	2.3	884,659	1,162,442	1	0.0860
Nebraska	4.9	2.3	1,934,408	2,541,812	2	0.0787
Delaware	4.9	2.3	973,764	1,279,526	1	0.0782
Florida	4.9	2.3	21,477,737	28,221,746	22	0.0780
New Mexico	4.9	2.3	2,096,829	2,755,233	2	0.0726
Rhode Island	4.9	2.3	1,059,361	1,392,000	1	0.0718
Ohio	4.9	2.3	11,689,100	15,359,477	11	0.0716
Michigan	4.9	2.3	9,986,857	13,122,730	9	0.0686
California	4.9	2.3	39,512,223	51,919,061	33	0.0636
New Jersey	4.9	2.3	8,882,190	11,671,198	7	0.0600
New York	4.9	2.3	19,453,561	25,561,979	14	0.0548
Alberta	4.9	2.3	4,213,770	5,536,894	3	0.0542
Virginia	4.9	2.3	8,535,519	11,215,672	6	0.0535
Arizona	4.9	2.3	7,278,717	9,564,234	5	0.0523
Kansas	4.9	2.3	2,913,314	3,828,095	2	0.0522
North Carolina	4.9	2.3	10,488,084	13,781,342	7	0.0508
Arkansas	4.9	2.3	3,017,804	3,965,394	2	0.0504
Ontario	4.9	2.3	14,030,080	18,435,525	9	0.0488
Utah	4.9	2.3	3,205,958	4,212,629	2	0.0475
Texas	4.9	2.3	28,995,881	38,100,588	17	0.0446
Georgia	4.9	2.3	10,617,423	13,951,294	6	0.0430
Idaho	4.9	2.3	1,787,065	2,348,203	1	0.0426
West Virginia	4.9	2.3	1,792,147	2,354,881	1	0.0425
Pennsylvania	4.9	2.3	12,801,989	16,821,814	7	0.0416
Colorado	4.9	2.3	5,758,736	7,566,979	3	0.0396
Maryland	4.9	2.3	6,045,680	7,944,024	3	0.0378
Missouri	4.9	2.3	6,137,428	8,064,580	3	0.0372
Mississippi	4.9	2.3	2,976,149	3,910,660	1	0.0256
Nevada	4.9	2.3	3,080,156	4,047,325	1	0.0247
Vermont	4.9	2.3	623,989	819,922	0	0.0000
Wyoming	4.9	2.3	578,759	760,489	0	0.0000
Oklahoma	4.9	2.3	3,956,971	5,199,460	0	0.0000
Louisiana	4.9	2.3	4,648,794	6,108,515	0	0.0000
District of Columbia	4.9	2.3	705,749	927,354	0	0.0000
Alaska	4.9	2.3	731,545	961,250	0	0.0000
Average:			*6,507,334*	*8,550,637*	*6*	*0.0776*

11.1.6 2018 State-by-state Comparison

State, Province, or Territory	2018-2024 National Pounds of solid waste generated per person (US EPA[1])	C&D waste generation estimate per person (US EPA[2])	2018: Population Estimate (US Census[3], Estimate using 2016 Canadian Census)	2018: Tons per year generated (Formula[5])	2018: Solid Waste & Recycling Facility Fires (Ryan Fogelman)	2018: Fires per 100,000 tons of estimated solid waste generated (Formula[6])
Delaware	4.9	2.3	965,479	1,268,639	4	0.3153
Maine	4.9	2.3	1,339,057	1,759,521	4	0.2273
Kentucky	4.9	2.3	4,461,153	5,861,955	12	0.2047
Nebraska	4.9	2.3	1,925,614	2,530,257	5	0.1976
Connecticut	4.9	2.3	3,571,520	4,692,977	9	0.1918
Idaho	4.9	2.3	1,750,536	2,300,204	4	0.1739
New Hampshire	4.9	2.3	1,353,465	1,778,453	3	0.1687
South Carolina	4.9	2.3	5,084,156	6,680,581	11	0.1647
Ohio	4.9	2.3	11,676,341	15,342,712	25	0.1629
Hawaii	4.9	2.3	1,420,593	1,866,659	3	0.1607
Oregon	4.9	2.3	4,181,886	5,494,998	8	0.1456
Colorado	4.9	2.3	5,691,287	7,478,351	10	0.1337
Wyoming	4.9	2.3	577,601	758,968	1	0.1318
Kansas	4.9	2.3	2,911,359	3,825,526	5	0.1307
Tennessee	4.9	2.3	6,771,631	8,897,923	11	0.1236
Vermont	4.9	2.3	624,358	820,406	1	0.1219
Wisconsin	4.9	2.3	5,807,406	7,630,931	9	0.1179
Michigan	4.9	2.3	9,984,072	13,119,071	15	0.1143
Massachusetts	4.9	2.3	6,882,635	9,043,782	10	0.1106
New Mexico	4.9	2.3	2,092,741	2,749,862	3	0.1091
Alaska	4.9	2.3	735,139	965,973	1	0.1035
Louisiana	4.9	2.3	4,659,690	6,122,833	6	0.0980
Iowa	4.9	2.3	3,148,618	4,137,284	4	0.0967
Utah	4.9	2.3	3,153,550	4,143,765	4	0.0965
British Columbia	4.9	2.3	4,824,467	6,339,350	6	0.0946
Alabama	4.9	2.3	4,887,681	6,422,413	6	0.0934
Illinois	4.9	2.3	12,723,071	16,718,115	14	0.0837
Ontario	4.9	2.3	13,836,218	18,180,790	15	0.0825
Washington	4.9	2.3	7,523,869	9,886,364	8	0.0809
Arizona	4.9	2.3	7,158,024	9,405,644	7	0.0744
North Carolina	4.9	2.3	10,381,615	13,641,442	10	0.0733
Montana	4.9	2.3	1,060,665	1,393,714	1	0.0718
Minnesota	4.9	2.3	5,606,249	7,366,611	5	0.0679
California	4.9	2.3	39,461,588	51,852,527	32	0.0617
Oklahoma	4.9	2.3	3,940,235	5,177,469	3	0.0579
Florida	4.9	2.3	21,244,317	27,915,033	16	0.0573
Alberta	4.9	2.3	4,164,905	5,472,685	3	0.0548
New York	4.9	2.3	19,530,351	25,662,881	14	0.0546
Maryland	4.9	2.3	6,035,802	7,931,044	4	0.0504
Missouri	4.9	2.3	6,121,623	8,043,813	4	0.0497
Virginia	4.9	2.3	8,501,286	11,170,690	5	0.0448
West Virginia	4.9	2.3	1,804,291	2,370,838	1	0.0422
Pennsylvania	4.9	2.3	12,800,922	16,820,412	7	0.0416
Texas	4.9	2.3	28,628,666	37,618,067	15	0.0399
Indiana	4.9	2.3	6,695,497	8,797,883	3	0.0341
New Jersey	4.9	2.3	8,886,025	11,676,237	3	0.0257
Mississippi	4.9	2.3	2,981,020	3,917,060	1	0.0255
Arkansas	4.9	2.3	3,009,733	3,954,789	1	0.0253
Georgia	4.9	2.3	10,511,131	13,811,626	3	0.0217
Nevada	4.9	2.3	3,027,341	3,977,926	0	0.0000
North Dakota	4.9	2.3	758,080	996,117	0	0.0000
South Dakota	4.9	2.3	878,698	1,154,609	0	0.0000
Rhode Island	4.9	2.3	1,058,287	1,390,589	0	0.0000
District of Columbia	4.9	2.3	701,547	921,833	0	0.0000
Average:			*6,472,465*	*8,504,819*	*7*	*0.0928*

11.1.7 2017 State-by-state Comparison

State, Province, or Territory	2017 National Pounds of solid waste generated per person (US EPA[1])	C&D waste generation estimate per person (US EPA[2])	2017: Population Estimate (US Census[3], Estimate using 2016 Canadian Census)	2017 Tons per year generated (Formula[5])	2017 Solid Waste & Recycling Facility Fires (Ryan Fogelman)	2017: Fires per 100,000 tons of estimated solid waste generated (Formula[6])
Vermont	4.53	2.3	624,344	778,229	2	0.2570
West Virginia	4.53	2.3	1,817,004	2,264,850	5	0.2208
Idaho	4.53	2.3	1,717,715	2,141,089	4	0.1868
British Columbia	4.53	2.3	4,736,261	5,903,631	11	0.1863
Delaware	4.53	2.3	956,823	1,192,656	2	0.1677
Oregon	4.53	2.3	4,143,625	5,164,925	8	0.1549
Iowa	4.53	2.3	3,141,550	3,915,864	6	0.1532
Wyoming	4.53	2.3	578,931	721,623	1	0.1386
Maine	4.53	2.3	1,334,612	1,663,560	2	0.1202
New Hampshire	4.53	2.3	1,348,787	1,681,229	2	0.1190
Virginia	4.53	2.3	8,463,587	10,549,650	12	0.1137
Connecticut	4.53	2.3	3,573,297	4,454,025	5	0.1123
Kansas	4.53	2.3	2,908,718	3,625,644	4	0.1103
Nevada	4.53	2.3	2,969,905	3,701,912	4	0.1081
Pennsylvania	4.53	2.3	12,787,641	15,939,475	17	0.1067
North Dakota	4.53	2.3	754,942	941,016	1	0.1063
Ohio	4.53	2.3	11,659,650	14,533,462	15	0.1032
Michigan	4.53	2.3	9,973,114	12,431,237	12	0.0965
South Carolina	4.53	2.3	5,021,268	6,258,885	6	0.0959
North Carolina	4.53	2.3	10,268,233	12,799,096	12	0.0938
Massachusetts	4.53	2.3	6,859,789	8,550,555	8	0.0936
Wisconsin	4.53	2.3	5,790,186	7,217,322	6	0.0831
Missouri	4.53	2.3	6,106,670	7,611,811	6	0.0788
Alberta	4.53	2.3	4,116,040	5,130,541	4	0.0780
New Mexico	4.53	2.3	2,091,784	2,607,356	2	0.0767
Montana	4.53	2.3	1,052,482	1,311,893	1	0.0762
Indiana	4.53	2.3	6,658,078	8,299,128	6	0.0723
Kentucky	4.53	2.3	4,452,268	5,549,641	4	0.0721
Minnesota	4.53	2.3	5,566,230	6,938,167	5	0.0721
Maryland	4.53	2.3	6,023,868	7,508,601	5	0.0666
Washington	4.53	2.3	7,423,362	9,253,035	6	0.0648
Ontario	4.53	2.3	13,642,356	17,004,856	11	0.0647
Hawaii	4.53	2.3	1,424,393	1,775,470	1	0.0563
California	4.53	2.3	39,358,497	49,059,383	26	0.0530
Louisiana	4.53	2.3	4,670,560	5,821,736	3	0.0515
Illinois	4.53	2.3	12,778,828	15,928,490	8	0.0502
New York	4.53	2.3	19,589,572	24,417,912	12	0.0491
New Jersey	4.53	2.3	8,885,525	11,075,585	5	0.0451
Colorado	4.53	2.3	5,611,885	6,995,074	3	0.0429
Nebraska	4.53	2.3	1,915,947	2,388,180	1	0.0419
Texas	4.53	2.3	28,295,273	35,269,350	13	0.0369
Tennessee	4.53	2.3	6,708,799	8,362,350	3	0.0359
Arizona	4.53	2.3	7,044,008	8,780,180	3	0.0342
Mississippi	4.53	2.3	2,988,510	3,725,103	1	0.0268
Arkansas	4.53	2.3	3,001,345	3,741,102	1	0.0267
Utah	4.53	2.3	3,101,042	3,865,371	1	0.0259
Florida	4.53	2.3	20,963,613	26,130,620	6	0.0230
Alabama	4.53	2.3	4,874,486	6,075,925	1	0.0165
Georgia	4.53	2.3	10,410,330	12,976,216	2	0.0154
Alaska	4.53	2.3	739,700	922,018	0	0.0000
Oklahoma	4.53	2.3	3,931,316	4,900,287	0	0.0000
South Dakota	4.53	2.3	872,868	1,088,008	0	0.0000
Rhode Island	4.53	2.3	1,055,673	1,315,870	0	0.0000
District of Columbia	4.53	2.3	694,906	866,183	0	0.0000
Average:			*6,434,818*	*8,020,840*	*5*	*0.0793*

11.1.8 2016 State-by-state Comparison

State, Province, or Territory	2016 National Pounds of solid waste generated per person (US EPA[1])	C&D waste generation estimate per person (US EPA[2])	2016 Population Estimate (US Census, 2016 Canadian Census)	2016 Tons per year generated (Formula[5])	2016: Solid Waste & Recycling Facility Fires (Ryan Fogelman)	2016 Fires per 100,000 tons of estimated solid waste generated (Formula[6])
Maine	4.55	2.3	1,331,317	1,664,313	6	0.3605
Idaho	4.55	2.3	1,682,380	2,103,185	4	0.1902
Iowa	4.55	2.3	3,131,371	3,914,605	7	0.1788
Montana	4.55	2.3	1,040,859	1,301,204	2	0.1537
Arizona	4.55	2.3	6,941,072	8,677,208	12	0.1383
Connecticut	4.55	2.3	3,578,141	4,473,124	6	0.1341
Michigan	4.55	2.3	9,950,571	12,439,458	15	0.1206
Virginia	4.55	2.3	8,410,106	10,513,684	12	0.1141
Wisconsin	4.55	2.3	5,772,628	7,216,507	8	0.1109
New Jersey	4.55	2.3	8,870,827	11,089,643	12	0.1082
Alaska	4.55	2.3	741,456	926,913	1	0.1079
North Dakota	4.55	2.3	754,434	943,137	1	0.1060
Massachusetts	4.55	2.3	6,823,608	8,530,363	9	0.1055
South Dakota	4.55	2.3	862,996	1,078,853	1	0.0927
Kentucky	4.55	2.3	4,438,182	5,548,282	5	0.0901
Ohio	4.55	2.3	11,634,370	14,544,417	13	0.0894
British Columbia	4.55	2.3	4,648,055	5,810,650	5	0.0860
Delaware	4.55	2.3	948,921	1,186,270	1	0.0843
Nebraska	4.55	2.3	1,905,616	2,382,258	2	0.0840
Nevada	4.55	2.3	2,917,563	3,647,318	3	0.0823
South Carolina	4.55	2.3	4,957,968	6,198,080	5	0.0807
Maryland	4.55	2.3	6,003,323	7,504,904	6	0.0799
Alberta	4.55	2.3	4,067,175	5,084,477	4	0.0787
Oregon	4.55	2.3	4,089,976	5,112,981	4	0.0782
Washington	4.55	2.3	7,294,771	9,119,376	7	0.0768
Tennessee	4.55	2.3	6,646,010	8,308,343	6	0.0722
Ontario	4.55	2.3	13,448,494	16,812,299	12	0.0714
California	4.55	2.3	39,167,117	48,963,792	34	0.0694
New York	4.55	2.3	19,633,428	24,544,239	14	0.0570
Hawaii	4.55	2.3	1,427,559	1,784,627	1	0.0560
North Carolina	4.55	2.3	10,154,788	12,694,754	7	0.0551
Missouri	4.55	2.3	6,087,135	7,609,680	4	0.0526
Illinois	4.55	2.3	12,820,527	16,027,261	8	0.0499
Alabama	4.55	2.3	4,863,525	6,080,014	3	0.0493
Colorado	4.55	2.3	5,539,215	6,924,711	3	0.0433
Georgia	4.55	2.3	10,301,890	12,878,650	5	0.0388
New Mexico	4.55	2.3	2,091,630	2,614,799	1	0.0382
Indiana	4.55	2.3	6,634,304	8,293,709	3	0.0362
Minnesota	4.55	2.3	5,522,744	6,904,120	2	0.0290
Florida	4.55	2.3	20,613,477	25,769,423	7	0.0272
Arkansas	4.55	2.3	2,989,918	3,737,771	1	0.0268
Utah	4.55	2.3	3,041,868	3,802,715	1	0.0263
Texas	4.55	2.3	27,914,410	34,896,502	6	0.0172
Pennsylvania	4.55	2.3	12,782,275	15,979,442	2	0.0125
Vermont	4.55	2.3	623,657	779,649	0	0.0000
West Virginia	4.55	2.3	1,831,023	2,289,008	0	0.0000
Wyoming	4.55	2.3	584,215	730,342	0	0.0000
New Hampshire	4.55	2.3	1,342,307	1,678,052	0	0.0000
Kansas	4.55	2.3	2,910,844	3,638,919	0	0.0000
Louisiana	4.55	2.3	4,678,135	5,848,254	0	0.0000
Mississippi	4.55	2.3	2,987,938	3,735,296	0	0.0000
Oklahoma	4.55	2.3	3,926,331	4,908,405	0	0.0000
Rhode Island	4.55	2.3	1,056,770	1,321,095	0	0.0000
District of Columbia	4.55	2.3	685,815	857,354	0	0.0000
Average:			*6,390,834*	*7,989,341*	*5*	*0.0696*

12 Thank You & Contact Information

When my team and I brought the Fire Rover solution to the market in 2015, we had no idea what the next few years would bring. Not only were we rolling out the newest technology to hit the fire industry in decades, but we had developed a life-changing innovation to protect more than a billion dollars in assets, thousands of employees, and fire professionals and ensure business continuity across a spectrum of facility operators. Like any startup venture, the road to realizing our goals has not always been smooth. Still, through the support of our customers, colleagues, insurance companies, fire professionals, and governments, the vision of Fire Rover's founder, Brad Gladstone, is becoming a reality. From our first location in the back of a scrap metal yard in Detroit to our current state-of-the-art sites, we have come a long way in nine years.

Fire Rover is not transactional with our customers—we do not just offer equipment and walk away. When we commit to collaborating with a customer, such as a waste and recycling facility operator, we enter a long-term partnership to protect them from the danger of fire incidents inherent in their operations. We stand shoulder-to-shoulder on the frontlines, detecting, reacting, and fighting fire hazards together. I hope we can collaborate with the readers of this report.

If you take away one thing from reading my report, let it be this: The fire hazards we face today will continue to evolve as the world changes. Having an agile, ready, and capable response plan built on industry best practices, supported by tested equipment and qualified personnel, and tailor-made for your operation are your keys to maintaining a safe and healthy infrastructure for you, your employees, your neighbors, the environment, and the waste and recycling industry.

For more information, contact:

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Appendix

The Combinational Approach™ to Fighting a Waste and Recycling Fire

COMBINATIONAL APPROACH™

A Combinational Approach uses the best pieces, people, equipment, communications, and training to provide your operations with the best chance of catching and eliminating a fire incident before it becomes a major fire incident and shuts down your business.

*-**Ryan Fogelman**, Fire Rover, and **Jim Emerson,** Starr Technical Risk Agency*

1. Thermal cameras (automatic thermal detection can often sense dangerous temperature differentials before a fire starts).
2. Use of a pre-wetting foam agent, possibly in combination with twin 1-1/2-inch or 1-3/4-inch water nozzles.
3. Remote, human-verified, manual control of foam agent dispersal from a safe location.
4. Pre-wetting should be configured to reach a 180-degree area with the best line-of-site coverage available and the ability to operate for sweeping and pre-wetting around the fire perimeter and collateral assets.
5. Eliminate the fire brigade as it puts valued employees at risk and is difficult to administer in compliance with Occupational Safety and Health Administration (OSHA) requirements. (OSHA allows a limited fire brigade to monitor evacuation and address incipient stage fires if they are not interior structural fires.)
6. Configure an emergency response such as providing a lancing nozzle, hookup, and rollout of a fire service hose and a deck gun to prepare for the fire professionals' arrival.
7. Ensure a pathway is maintained for the fire professionals to safely enter and move around the facility.
8. Train employees to start the fire pump and shut off the proper electrical circuits to save time for the fire response professionals.
9. Have a trained bulldozer/loader operator with the proper equipment, or ensure the fire department is trained on your equipment.

10. Have a working automatic sprinkler system and adequate water supply. The water supply may be lacking at some locations, so having a tank system is highly recommended.
11. Have a solid worker training program. This means regular inspections and testing of fire equipment. Also, have a simple but effective fire emergency response plan. Good housekeeping, contractor, and hot-work controls are essential.
12. Have manually operable roof vents to let heat escape. Heat is likely to get out through roll-up doors and melt light panels on exterior walls, but having the ability to open roof vents is much safer since the fire service will not have to cut a vent in the top of the roof manually. However, let the firefighters decide whether to open the vents.
13. Have secondary rally points in a safe place, potentially even offsite, for personnel who can stay and help the fire service with tasks such as crane operation and ensuring the plant is safely shut down. The fire service may wish to have personnel leave the site due to smoke and the need to assure personnel safety. Having a place offsite where you can rally and stay in communication can be instrumental.
14. Develop a rapport with the fire department, which includes training with the Texas A&M Engineering Extension Service/National Fire Protection Association on how to fight a fire in a recycling and trash-tipping floor/pit operation.

Benefits of the Combinational Approach™

- **Early detection** with fire detection technology and applying pre-wetting foam can eliminate fires, prepare for the firefighter response, and reduce or eliminate major fire incidents.
- Adding additional compressed air foam systems allows for **more manual foam applications** from a safe distance for employees.
- Installing a deck gun and setting it up for the fire department's arrival will **save valuable time upon arrival**. This process takes much longer than we see in the movies, allowing the fire department to get to work.
- If you can only provide one form of a sprinkler head, **protect the structural steel** columns in combination with an early detection and suppression system.
- **Roof vents can be opened**. Let the fire professionals do this, as they will want to control this vital aspect. Doing this with a button rather than mounting the roof manually and cutting with a saw protects emergency responders from a potentially dangerous situation.
- This approach reduces the threat to structural steel elements. This is the primary inflection point in firefighting. At this point, the fire department can become the most effective in the interior attack toward the seat of the fire.