September 28, 2023

SUMMARY OPINION

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TO: Anne Germain – Chief Operation Officer
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CC: National Waste and Recycling Association (NWRA) Recycling Committee

RE: Metrics on the Lithium-based Battery Threat to U.S. Single Stream Material Recovery Facilities ("MRFs") Summary Opinion

NWRA has requested a Summary Opinion utilizing RRS and my expertise[1] in municipal recycling to provide metrics on fires caused by lithium-based batteries[2] ("LBs")[2] found in the recyclable materials that are processed in U.S. single stream MRFs. Simple ways to describe the impacts these fires have on MRFs are essential to communicate with the public the importance of keeping them out of recycling streams. The impacts include damages that impact recycling in multiple ways, including costs, environmental impacts and safety issues. This report focuses on the frequency that MRFs will be forced to encounter these impacts and the financial implications.

After researching available documentation and interviewing MRF operators, insurance providers, and other experts on the matter, the following Opinion[3] on financial threat posed by LB fires in a MRF is considered below.

LBs are believed to be the main cause of increasing fires at MRFs according to everyone interviewed for this Opinion and my own research. Single Stream MRFs receive misplaced LBs every day and hour which are commingled with recyclables, due to a variety of public misconceptions. LBs receive physical abuse during the collection and processing of recyclables (loading, compacting, unloading, stacking, and crushing, sorting and densification) which damage the separator and circuit protection, and can lead to thermal runaway, and the consequent high temperature ignition of the battery materials. MRFs contain an abundance of material, paper and plastic, that can readily ignite and propagate fires. Between the potential damage to LBs and the presence of paper and plastic, damaged batteries igniting a fire can become severe.

To understand the current dangers of LBs in MRFs, the frequency and severity of fires should be reported accurately and with an assessment of loss for each category of fire event, since levels of severity determine loss, and the range of fire losses in MRFs is significant. Such information is not readily available or organized in a way it can be canvassed. Additionally, from reviewing known public data sets, there are no available data sets which classify MRFs as a standalone industrial category for any type of regular fire reporting.[5] This limited available reporting and data

limits the ability to comprehensively analyze the impacts of the fires. This Opinion recognizes those limitations and presents the requested metrics below with those reservations.

I. OPINION #1- Provide a directional metric design on estimated annual loss per Residential Single Stream MRF fire event based on public records search, interviews, and RRS expertise.

RRS obtained a cross section of confidential anecdotal feedback from MRF operator interviews[6] during September and October of 2023, and used the few detailed public accounts for Table 1, which confidentially summarizes input received.

Table 1: Summary of MRF Interviews

Description of Source [6] (interviews or from media)	# of MRFs	Frequency of Fires	Estimated Annual Frequency	Estimated Loss per Fire and other Comments
West Coast MRF Operator	1	2 per month	24 greater than smoldering event	Two hours loss at $1,000 per hour = $2,000 per fire. Some additional overtime.
East Coast MRF Executive	9 plus other recycling facilities	50 incipient fires/yr. or more severe.	50	$50,000-75,000/fire, with most not costing much except overtime, and a few losses over ten times as much
Rocky Mountain MRF Operator	1	2-4/month	24-36	Just overtime and clean up per event. Most don't stop production
Midwest MRF Operator	1	70+ YTD	70, 66 were battery related	No loss rate assigned.
National MRF Executive	Over 20 MRFs	2-3/ mo./MRF but does not hear of fires unless severe.	24-36 per MRF	We don't get a loss report. We have completed a lot of training and installed upgraded fire protection and response systems. Only losses would be overtime.
Midwest Operator	1	1.5 per month	15-18	We track every fire. We are very diligent, including 24-hour monitoring. Not much additional cost per event we catch them early.
West Coast Operator	3	Once a week probably per MRF	52	We had a big fire awhile back, but generally our fire brigade has them out without disruption. Small fires don't really change our cost.
Mid-South Operator	1	3 per month	36	No idea. All over the place.
National MRF Executive	Over 20 MRFs	More than 1 per month	12-18 or higher per MRF	We have had very bad fires but have become very good through technology and training in keeping impacts minimized otherwise. No sure if it impacts cost.
Midwest MRF Operator	2	1-2 per month	16 per MRF	We are getting better at tracking fires.
East Coast Operators	5	4 per year	.8	Fires "usually (cause) minimal damage >$5000". One larger fire with a $3 Million loss' and "5 significant fire events since 2020" which had larger losses.

1. MRF Fire Frequency (MRFFF)

MRFFF can be inductively inferred from *Table 1* for in the U.S. single stream MRF fleet.

Directional Metric 1: Annual Fleet MRFFF

A. 100% of the reported fires at MRFs from the Table 1 equate to 18.5 fires[7] per MRF/yr.
B. Applying this rate to the of 298[8] MRFs in the U.S. fleet equals an annual frequency is 5,519 fires/yr.
C. Conservatively, at 50% of reported fires, or 9.25 fires/MRF, annual frequency for the MRF fleet is 2,757/yr.

2. Average MRF Loss/Fire (AML/F)

Among the MRF owners, there was no universal definition of fire severity and a wide range of variability was expressed for their AML/Fs resulting in a large range where conclusions on impacts were difficult to draw. The following establishes the range based on estimates provided.

Directional Metric 2: Average MRF Loss/Fire (AML/F)

A. Minimum AML/F - Assuming an average MRF has an hourly operating cost of $2,173,[9] and each fire and response disrupts the business for one hour, a hypothetical base cost for each minor fire incident would be $2,173. Adding increased disposal, fire extinguisher servicing, clean-up, etc., minor fires are assumed to average around $2,600.

B. Large Fire AML/F - Most operators cited having one or more larger documented claim, that did not reach catastrophic levels. These ranged from $25,000 to as high as greater than $4 million dollars at a West Coast MRF, and over $3 million at two different eastern MRFs during the last three years. Another executive respondent said the average fire was easily "over $50,000 per fire (large and small combined)". Others mentioned similar incidents but said by changing their operations, they had large fire losses under control.

II. OPINION 2- Define an Annual Rate Catastrophic Fire Loss for Single Stream MRFs in the last 3-Years

1. RRS has defined catastrophic losses as >$10 million dollars/loss from a reported fire event due fire damage, loss of business, or the building/function of a MRF is destroyed by fire[10] for this Opinion. The following ten (10) publicly reported fires by geographic location, occurred over the three-year period which fit these criteria:

Table 2: MRFs with catastrophic fires in the last three years

Table 2

Month and Year	Location of MRF	Damage Estimate	Total Loss?
Jan-21	Passaic, NJ	$22 million	
Jun-21	Phoenix, AZ		X
Nov-22	Anaheim, CA	$60 million	
Mar-23	York, PA	$35 million	
Apr-23	Hernando County, FL		X
Apr-23	Shelton, CT	$10 million	
May-23	Birmingham, AL		X
May-23	Columbia County, WI	$10 million	
Jun-23	Milwaukee, WI	$10-15 million	
Aug-23	Newport, Tennessee		X

2. A proposed "Catastrophic Loss Rate " can be reached by dividing those ten facilities by 298 total MRFs in the U.S. fleet to get to a useable metric:

Directional Metric 3- Estimated Catastrophic Fire Loss Rate: 1.1% of all Single Stream MRFs per year

   A. Around 3.3 MRFs per year have experienced catastrophic losses over the last three years.
   B. Six had verified damage estimate/losses which average over $22 million dollars.
   C. Using older data from 2018 and 2019, the U.S. EPA[11] the Catastrophic Loss rate then was .78%, when the MRF fleet was ~13% larger than today.[12]
   D. Comparatively, the rate 41% is greater for the last three years than the previous two-year period.

III. OPINION 3- MRFs have had measurable Increases in Property Insurance Rates in the last five (5)-years due to increased frequency and severity of fires. Can we measure the rate of cost increase in dollars/hundred valuation and cost/ton?

1. Commercial insurance rates for Material Recovery Facilities have increased markedly.
   A. Every property insurer and underwriter and many MRF operators in this Opinion confirmed that the risk at MRFs 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[13].
2. RRS recommends using an insurance industry common metric to measure this alarming change in property insurance premium costs.
   A. Annual premium cost for a property insurance policy can be expressed as a percentage of the 'guaranteed cost' (total replacement cost borne by insurer aka "insured value") of property valuation:
      i. Insurers use a ratio of dollars/hundred dollars of insured value to compare policy estimates.

ii. For example, if an annual premium for property insurance is 1% of the insured value, the policy cost is $1.00 per hundred dollars insured valuation. For a ten-million-dollar MRF, the annual premium would be $100,000 for the owner of the MRF. In today's market of $40-million-dollar MRFs, the annual premium would be $400K.

3. Rates five years ago were far below one dollar per hundred of Insured value. During recent confidential interviews, one insurer told me the range could be as little 'fifteen cents before 2017.' Another insurance underwriter used eighteen cents as an example "before Covid."
4. The range current annual policy rates are quoted from the waste industry insurance brokers and underwriters, and several discussions with MRF operators:

Directional Metric 4. MRF property insurance has increased tenfold, from $0.15 to $0.18 dollars (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.

5. The local impact to MRF costs can be illustrated from 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

6. Deductibles continue to rise as well. Underwriters are requiring MRFs to share the risk by increasing property insurance deductibles (self-insurance) into the millions of dollars, especially if a reported fire loss has occurred. Deductibles mentioned by those interviewed in the insurance industry and at MRFs were from 0.5% of the insured valuation of the MRF property to 4% of the insured valuation. As an example, a forty ($40) million-dollar MRF at 4% deductible would see their deductible increase from $200,000 to $1.6 million dollars.
7. According to Scott Snowden, President of Solid Waste insurance Marketing in California, determining the quality of the customer and extent of the risk is key, 'those MRFs which are verified by underwriters as having high standards of loss-mitigation, are large and/or loyal customers, or have no claims, get the best rates':

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

IV. CONCLUSION

RRS recommends the following simple talking points based on this Opinion:

1. Each MRF has an average of more than 18 fires per year.
2. Annual Fleet MRF Fire Frequency - For the 298 single stream facilities operating the U.S., there are thousands of fires each year. A recent estimate from surveying MRF operators confidentially showed a rate of over 5,000 fires per year when applied to the whole fleet of single stream MRFs.
3. Depending on severity, the cost of a fire at a MRF can range from a minimum of $2,600 to over $50 million for a catastrophic fire, with some fires destroying MRFs completely.
4. The rate of catastrophic losses has increased by 41% in the last five years.
5. More than ~1% of MRFs experience a catastrophic loss annually, with an average of $22 million in damage.
6. MRF property insurance has increased tenfold due to fires, from around $0.15 to $0.18 dollars per hundred insured value, to $1.80 (or 1.8%) up to $10 per hundred dollars (10%), with no cap on the top side. Some MRFs may pay as much as $40 per processed ton just for Property Insurance. This is then passed on to MRF customers.
7. MRF property insurance is 10-50 times greater now than in 2017.
8. MRF property insurance alone costs between $7.50 to more than $40 per ton of recyclables.

Note: RRS believes the metrics proposed are a starting point. They deserve better attention through accurate reporting because of the wide variation in anecdotal reports in this Opinion. However, they do allow for powerful and simple talking points to communicate the battery fire risk to customers who are placing these dangerous vectors in their recyclables, provide impetus for arguments to change contract terms, and are simple to use.

Section 2

Opinion #1 Discussion and Recommendations

Provide a directional metric design on estimated annual loss per LB fire event based on public records search, interviews, and RRS expertise, as well as frequency of the average annual loss.

1. There is a lack of reporting of fire events below the reported "catastrophic" level for MRFs, which makes this Opinion's metrics directional, gives enough information to verify consensus, but is not statistically proofed.

RRS Recommendations for Directional Metrics

1. It is a matter of severity that drives the reporting of fires. NWRA's Recycling Committee should review and agree on a common set of fire severity levels at MRFs. I highly recommend determining a simple and useful classification for fire severity that can be taught and monitored at MRFs, where all levels of fires are recorded. Presently there are different classifications of fire severity (see Eunomia, USEPA, and Fire Rover references in the Annotated Bibliography). I am proposing for consideration a condensed and simplified variant of the 6th Annual report by Fire Rover for severity, whose original categories were established by the fire protection industry, from lowest severity to highest and added solid waste terms for explanation.

Table 5

Fire Industry or Garbage Term	Characteristics	Reporting Frequency
1. Hot spot, or pre-incipient - thermal anomaly, smoke, or material discoloration.	Smoke, smolder, or smoldering pile. without flames. Heat, flash, and brightness of material.	Not usually recorded or reported unless operations cease, fire department is called, evacuation is ordered, or operator and/or management require reporting.
2. Incipient (Fire)	New fire incidents with flames or contained explosions in baler chamber with no apparent damage. Usually not reported to fire authorities. Response is from installed fire protection systems or trained employee fire brigade. Some service disruption.	Not usually reported to public responders unless by regulation. Evacuation may be ordered. MRFs vary in reporting. Some require reporting of all flame-bearing fires, others not unless reported to a fire agency. Others, no set policy of reporting.
3. Reported (Fire)	Requiring a response from a fire department, with the worst requiring multiple emergency vehicle responses. Moderate property damage and business losses from smoke or fire. Disruption in service moderate.	Many contributors said this level requires Internal reporting.
4. Catastrophic (Fire)	For the purposes of this Opinion, over $10 million dollars loss from engulfing fire damage, loss of business, etc. or business and business purpose destroyed.	Generally reported by media and community sources.

2. A related issue is the difficulty in identifying LBs as the root cause in MRF fires because self-oxidation and the size and composition of LBs don't allow post-fire discovery. It is ironic that perceptions of frontline operators and waste insurance practitioners both 'feel' that LBs cause most fires in MRFs. However, when asked to estimate or when publishing all accounts, numbers are conservative and rather old, ranging from Eunomia's 38% root cause to the interviewee's 40-60% root cause level, with those fires where no root cause was found positing that it was LBs which were responsible for most fires. Perhaps, fire-resistance identifiers should be required in LBs, like the black box requirements for trucks and airplanes. RRS believes that would certainly increase the published root cause certainty that LBs cause fire.
3. NWRA should consider building and using a confidential voluntary fire reporting system to monitor frequency and severity. For instance, two methods are proposed.
    A. An industry-wide confidential reporting day, week, month on fire frequency and severity, that could become an industry-wide event. This would render data more quantifiable and useful. This has been used in the past and requires senior management buy-in but is efficient and takes the least time.
    B. A secure, confidential, and easy-to-use industry fire registry may be established.
4. Another way to get more routine, better directional numbers would be by utilizing Fire Rover data that Ryan Fogelman generates and regularly updates. Fogelman told me for this Opinion that he could easily ensure Single Stream MRFs are counted as a subset of the "waste facilities" categories he reports on regularly. Perhaps NWRA should partner with Fire Rover to cross reference RRS' list of MRFs, and report on MRF-reported fires quarterly or in his next report. This may be one of the cheaper alternatives.
5. In general, reporting commercial fires, including those in high-risk MRFs, are rarely accurate or measured on a consistent basis, unless catastrophic. NWRA and industry leaders should consider overcoming barriers in the waste industry to good reporting accuracy on frequency and severity of fires, most can be found in the internal cultures of waste companies:
    A. Unless a fire department is called and the information is reported to a publicly available news source, or required by their company, the accounting of MRF fires in MRFs becomes oblique and scattershot in most cases, and actual fire data is generally not available externally from the MRF.
    B. Some of the better operators interviewed require absolute reporting of all fire events.
    C. Managers and executives admitted to me that company programs like bonus compensation structure, with qualifiers in safety which include fire lowering reportable safety events, contribute to the many fires which are never heard about by management for the 1-2 severity levels in Table 5.
    D. Insurance Concerns- Two Insurance provider interviewees suggested that companies often do not want to catalog fires in writing that may result in higher incidence rates that must be then reported, at the risk of fraud if an investigation occurred.
    E. Unless a fire department is called and the information is reported to a publicly available news source, or required by their company, the accounting of MRF fires in MRFs becomes oblique and scattershot in most cases, and actual fire data is generally not available externally from the MRF.

F. Some of the better operators interviewed require absolute reporting of all fire events.

G. Managers and executives admitted to me that company programs like bonus compensation structure, with qualifiers in safety which include fire lowering reportable safety events, contribute to the many fires which are never heard about by management for the 1-2 severity levels in Table 5.

H. Insurance Concerns- Two Insurance provider interviewees suggested that companies often do not want to catalog fires in writing that may result in higher incidence rates that must be then reported, at the risk of fraud if an investigation occurred.

I. If the local manager does not have time to fill out paperwork or the paperwork means extra work, fires may not get reported unless strictly required by management.

J. NWRA attempted to survey the wider recycling industry (including scrap yards) confidentially through EREF in 2020, and the response results were very poor, most likely for the above serious reasons (to the companies involved).

Opinion #2 Discussion and Recommendations

Define an Annual Rate of Catastrophic Fire Losses at Single Stream MRFs over the last Three Years

1. RRS thoroughly scrubbed the list of potential waste facilities to ensure the fleet presented are confirmed Single Stream MRFs. RRS compared those to the list of waste facility fires provided by others.
2. RRS requested that Ryan Fogelman check the Single Stream list against his list of fires where the damage met or could meet fleet or fire criteria, and RRS did the same for candidates it thought could make the list from the Fire Rover input. Initially between RRS research which verified nine facilities, and the list provided by R. Fogelman at Fire Rover who provided an additional seventeen candidates for the list, ten facilities were verified as operating and accepting Single Stream materials. The others fire cases presented were transfer stations, C&D facilities, composting facilities called recycling centers, mixed waste processing facilities, mixed use facilities, or source separated paper or plastic facilities, or drop off centers.
3. As a result, numerous facilities with larger fires, including one of over $6.2 million claimed, one of $4 million, one over $2 million, and two between $500,000 and $800,000, did not make the final MRF list.
4. Two New York borough "Recycling Facilities" in the media accounts, one in Islandia, New York, and one in Westbury, New York, which had catastrophic fires are not on the list because they are not technically Single Stream MRFs. For instance, both were operating as transfer points and managed other material in addition to large quantities of Single Stream materials.
5. At least four massive outside bale fires were reported during the period but did not reach catastrophic loss levels. Most took over twenty-four (24)-hours to extinguish, were multiple alarm, and had extensive media coverage in their markets.
6. LBs can impact any type of MRF. Some of these Single Stream MRFs were local, manual, and old, with low tonnages; while others were large, automated facilities processing over 100,000 tons per year.

RRS Recommendation for Directional Metrics

1. From the research and earlier USEPA data, RRS believes 1% of the fleet is a fair metric to share and can be backed by the data.
2. RRS selected $10 million dollar loss to define 'catastrophic.' If a lower number had been selected (e.g. $3-5 million), the rate would be significantly higher.

Opinion #3 Discussion and Recommendations

MRFs have had measurable Increases in property insurance rates in the last five (5)-years due to losses from increased frequency and severity of fires. Can we measure the rate of cost increase in dollars/hundred valuation and cost/ton?

1. But for the rare exception, insurers interviewed universally blame the increased fire risk on lithium-based batteries as the primary cause for the increasing fires in MRFs, and the designation as high-risk potential could not come at a worse time for their operators. Overall, the property insurance industry has suffered increasing losses from their entire Property portfolios in the last five years and has lost the 'capacity' to take on or retain high risk property policies and claims. Some are exiting whole geographic regions like coastal states and drought-impacted forest lands with similar high-risk loss potential. In addition, their increased claim burden from the burgeoning environmental impacts of stronger storms and natural disasters, as well as the resultant rising numbers of claims, added to the secondary impact of high inflationary rebuilding costs, have made insurers extremely adverse to insuring high risk properties. The property insurance market "has become a loser", said two competitors in this space, with little chance of turning around anytime soon.
2. Much of the property insurance for MRFs today is being underwritten by foreign insurance companies who take on high risk properties by bundling partial risk policies and require high self-insurance.
    A. Some brokers can piece together U.S. policies in rare cases due to other factors like size of a client's entire portfolio (auto, truck, liability, health coverage, etc.), or a client's record of claims, or an underwriter opinion on the state of fire prevention and. readiness at the MRF.
    B. Similarly, older policies without claims are allowed to renew in rare cases for the same reason and skew the increases mentioned in directional metric 4.
3. Insurers reported the likelihood of fires is directly related to two factors- higher tonnage and age of facility.

RRS Recommendations for a Directional Metric

1. Property insurance rates are dependent on several factors, the biggest being risk/loss potential, the rate of increase in that potential, and the characteristics of the insured company, which includes size of insurance portfolios, exclusivity and loyalty to a provider, number of policy claims made, performance on underwriter audits of fire prevention practices at the facility, etc. The risk of losing insurance increases for independent, small MRF operators or those MRFs that have had multiple claims, the larger the claim the worse. However, the trend is clear that for the bulk of those who purchase property insurance rates are going up fast and are very expensive.
2. Using dollars/hundred insured value of the insured property seems reasonable and shows a dramatic increase in a short period.

CONCLUSION

RRS recommends the following summary:

1. MRFs average over an estimated 18 fires per MRF per year.
2. Annual Fleet MRF Fire Frequency- For the 298 single stream facilities operating the U.S., there are thousands of fires each year. A recent estimate from surveying MRF operators confidentially showed a rate of over 5,000 fires per year when applied to the whole fleet of single stream MRFs.
3. Depending on severity, each average fire costs a MRF a minimum of $2,600 up to over $50 million for a catastrophic fire, with some fires destroying MRFs completely.
4. The MRF fleet Catastrophic losses are greater than three MRFs per year or ~1% of the total fleet, and the average loss in these catastrophes is over $22 million.
5. MRF property insurance has increased tenfold due to fires, from $0.15 to $0.18 dollars per hundred insured value, to $1.80 (or 1.8%) up to $10 per hundred dollars (10%), with no cap on the top side. Some MRFs may pay as much as $40 per processed ton just for Property Insurance. This is then passed on to MRF customers.

Note: RRS believes the metrics proposed are a starting point. They deserve better attention through accurate reporting because of the wide variation in anecdotal reports in this Opinion (also in the USEPA study). However, they do allow for powerful and simple talking points to communicate the battery fire risk to customers who are placing these dangerous vectors in their recyclables, provide impetus for arguments to change contract terms, and are simple to use.

ANNOTATED BIBLIOGRAPHY AND SELECTED SOURCES

Cover Letter

1. RRS has provided qualifications for Michael Timpane to render this opinion in the Appendix.
2. "LBs" include primary single use batteries like lithium metal in coin, button, watch, and micro configurations (i.e., like those used in greeting cards and electronic vapers and cigarettes, and, secondary rechargeable batteries, the most ubiquitous being lithium-ion batteries which charge much of the portable tools and electronics in the U.S., which are manufactured as cordless cylinder, prism, geometric, and polymer configurations, which are either embedded, Snap-on, or stand-alone. Many complete descriptions exist on the types and functions of lithium batteries, for instance, USEPA website on Lithium-Ion Recycling *https://www.epa.gov/hw/lithium-ion-battery-recycling,* and page 11, Timpane, et. al, " South Bayside Waste Management Authority Lithium-Based Battery Assessment", 2017. *https://rethinkwaste.org/wp-content/uploads/legacy_media/7-a-attachment-d-lithium-based-battery-assessment-2017.original.pdf, w*hich is highly annotated.
3. This is a Summary Opinion Report. RRS opinions are non-legal, professional judgements utilizing RRS' and this author's investigations and expertise, interviews, and publicly available documents, to summarize the evidence presented therein, within the time limitations and the scope of work. The broad nature of this report requires the disclaimer that RRS found sources for its conclusions wherever possible, and the paper is the opinion of RRS today for the underpinnings of its conclusion. Information provided may be incomplete or not completely vetted by some of these sources.
4. See, for instance, among many, Brainard, N.D. presentation, "Property Insurance Issues for the Waste & Recycling Industry", slides 5-7, NWRA Webinar, original 1999, modified 2022. Brainard is a leader in MRF insurance and notes losses by category. LBs lead the list behind shredders, which are not part of the typical MRF profile. Also, shredder fires, which have their own classification, have a large co-dependence with MRF lithium-based batteries as an ignition source.
5. See " Fire Reporting Systems, Sources on Frequency, Severity, & Cause, & Research on LB Fires in Waste Systems" in the Annotated Bibliography below. My research was also confirmed through conversations with Ryan Fogelman, who has the most comprehensive list of MRF fires.

Opinion #1

6. RRS contacted twenty-seven MRF operators for interviews. Twelve responded and ten were used for the data in Tables 1 and 2.
7. I used the midpoint of the ranges to obtain estimated frequency for the fleet of MRFs to be conservative.
8. RRS keeps a current list of single stream MRFs in its database, which is cross referenced and updated regularly with other national lists (including lists from the Recycling Partnership and Resource Recycling Magazine https://recyclingpartnership.org/residential-mrfs/; Waste Today, "North America's largest MRFs", https://www.wastetodaymagazine.com/news/largest-material-recovery-facilities-2020-north-america/ Greenpeace.org; "2022 U.S. MRF Survey: Survey of U.S. Residential Material Recovery Facilities - Acceptance of Post-Consumer Plastic Products (August 15, 2022)" https://www.greenpeace.org/usa/wp-

content/uploads/2022/10/2022-MRF-Survey-August-15-2022-Final.pdf ; public company annual reports and websites (various), RRS' own database, GAA, EPR rosters in affected states, state permits, and other sources. The number of MRFs are often verified for different regions of the company depending upon projects, and scrubbed to remove those locations where single stream is not processed.

9. RRS has an updated 'average" MRF model, with current levels of cost, which it uses for a variety of current and past projects. Utilizing data from EREF, trade journals, as well as interviews with equipment manufacturers, the model assumes a 35 TPH facility with current CAPEX estimates, labor loading and an average volume of 8,000 tons per month.
    A. RRS calculates that the average MRF processes between 7- 8,000 tons per month and used 8,000 tons as the capacity on one 9.5-hour shift per day for this Opinion for a 35 TPH MRF, which is the most popular sized MRFs (the range of capacities begins at 5 tons per hour to 60 tons per hour for MRF design in 2023). This produces a conservative cost/ton outcome based on full shift capacity.
    B. Depending upon methodology used, other sources had lower numbers, like the solid waste foundation. EREF, who reported average MRF volumes over 7,500 tons per month in 2018. RRS believes that average has increased, as larger hub and spoke MRFs (transfer stations pushing volumes to a regional automated MRF for efficiency) continue to push out inefficient and smaller manual MRFs. Finally, in an article originally appearing in the September 2018 issue of Resource Recycling, an assessment that reported the average sized MRF was 5,500 tons per month (Powell, Jerry, " Sortation by the numbers", Resource Recycling, Oct.1, 2018). The average from these three sources, with MRFs getting larger and the fleet getting smaller, is approximately 6,500 or 288 tons per day.
    C. All references to average MRF, used the cost variables from the RRS model, for instance a 35-ton per hour MRF now costs approximately $40 million (RRS used 2023 examples), with a range between $28 million (800K per ton/hr.) and $46 million ($1.31 million per ton/hr.), depending upon budget and chosen technologies.
    D. All costs used, including cost per hour was taken directly from the model which frequently vetted from RRS' MRF visits, due diligence projects, etc. and is representative for this class MRF.

Opinion #2

10. A good example of a how a facility fire was vetted for catastrophic was the Omaha MRF fire, which was eventually eliminated after I spoke to the facility manager, D. Gubbels, who identified that far-reaching press reports were hyperbolic, the building was not substantially disabled or destroyed, and costs were far, far below the criteria for inclusion into the Catastrophic list. The MRF was also up and running much faster than original 12–15-month disruption estimates.
11. "An Analysis of Lithium-ion Battery Fires in Waste Management and Recycling", U.S. Environmental Protection Agency, July 2021, EPA ref. EPA 530-R-21-002
12. Database report out in 2019 in RRS power point presentations with the MRF fleet then of 338 MRFs (various).

Opinion #3

13. Following is a list of key sources used for this Opinion:
    A. Insurance Industry Interviews in September/October 2023

i. Kim Roberts- Waste & Environmental Risk Advisor, USI Insurance Services
ii. Nathan Brainard, Vice President, Insurance Office of America (IOA)
iii. Scott Snowden, Managing Principal, EPIC Brokers and President, Solid Waste Insurance
iv. Morris Yeh, Senior Underwriter, Environmental Property and Casualty at XL Catlin
v. Mario Tromba, Sr. Vice President, Solid Waste Insurance Marketing, The Rule Group
vi. Ryan Fogelman, Fire Rover. Ryan is not in the insurance industry but works closely with this group and has written on and seen multiple presentations on the impacts to insurance coverage at MRFs

B. Videos and Webinars (recorded)
i. Waste Today, "Today's Innovations: Risk Finance Take Control of Your Insurance Costs by Different Risk Financing Options in The Waste Space", Will Denbo, - President - CIA - Commercial Insurance; Jimmy Whitehar, Principal, CIA Commercial Insurance
ii. Resource Recovery Coalition of California and West Coast Refuse and Recycling Council, "Fire Safety and Lithium-Ion Battery Management at Your Solid Waste Facilities", Fall, 2022
iii. "Preventing Lithium Battery Fires in the Recycling Industry", SWANA, March 2023
iv. Sustainable Materials Management (SMM) Web Academy Webinar: "An Introduction to Lithium Batteries and the Challenges that they Pose to the Waste and Recycling Industry", USEPA, https://www.youtube.com/watch?v=OjFHYpI7GrM, March 1988

C. Selected Articles
i. Fogelman, Ryan, "March 2019 Updated Fire Report: Insurance Carriers Hightail It Out of Industry", Waste 360, March 2019, https://www.waste360.com/safety/march-2019-updated-fire-report-insurance-carriers-hightail-it-out-industry
ii. Nugent, Clara, "Why Recycling Plants Keep Catching on Fire", Time Magazine, 2023. https://time.com/6271576/recycling-plant-fire-
iii. Heffernan, H., Paben, J., "For Facility Operators, Insurance is now a Wild Ride", Resource Recycling, Inc. magazine, August 2023
iv. Denbo, D., "Considerable Risk", Recycling Today, July 2019

Other Selected Sources for Comments used in this Opinion

1. "U.S. Property & Casualty and Title Insurance Industries – 2022 Full Year Results", National Association of Insurance Commissioners
2. "Lithium-Ion Battery Recycling: A Review of the Current Methods and Global Developments", CAS American Chemistry Society, page, 13, 2022.
3. Germain, T., "Yes, You Need to Recycle Your Old Batteries", Consumer Reports, March 11, 2022
4. The Recycling Partnership's, "Personal Electronics & Battery End of Life Management Guide", *https://recyclingpartnership.org/wp-content/uploads/dlm_uploads/2023/01/Personal-Electronics-Battery-End-of-Life-Management-Guide.pdf (note*-co-authored by M. Timpane)

Fire Reporting Systems, Sources on Frequency, Severity, & Cause, & Research on LB Fires in Waste Systems

1. NFIRS Data System, https://www.fema.gov/about/openfema/data-sets/fema-usfa-nfirs-annual-data

A. The National Fire Incident Reporting System (NFIRS), used by the nation's firefighters to categorize each case of firefighting voluntarily under FEMA, serves as the national clearing house for, and explains incidences of, reported fire in the U.S. Over 29 million responses to all types of incidents were reported by participating fire departments, including nearly 1.1 million fire responses in 2021.
B. The NFIRS is very hard to use.
C. A study by the National Fire Protection Association corroborates our experience during the preparation of this Opinion. RRS attempted to review the NFIRS incidents in the last three years, but the volume and the summaries of each fire were around very broad codes.
    i. Access was the first issue. Even then, explanations in each individual fire report were diverse and language surrounding material recovery facilities or recycling centers were very sparse to non-existent.
    ii. Additionally, the NFIRS is not a complete census of fires and only comprises 70% of all fire incidents that occur annually.
    iii. Just last month, the state of California put out a bulletin where the NFIRS has finally directed that lithium batteries have its own codes as a fire agent. Up to this point despite thousands of accounts of fires caused by LBs. in all facets of life from damage and misuse, such a coding did not exist...and the new coding is oblique.
    iv. The problem with NFIRS data is the manual need to deeply scrub the data through the utilizing addresses and business types, against the code classifications of 'special properties or 'outside" incidents, or 'recyclable material', which are the proper codes to use, and the proliferation of miscoding to other group codes referenced in the NFIRS manual.
    v. What gets classified, and the gaps provides a backdrop to this big data issue. Many answers as to frequency, severity and root cause may be in the data but scraping it is difficult under these general classifications.
    vi. This type of research is well beyond the scope of this summary Opinion.

2. K. Kinsey, M. Ahrens, "NFIRS Incident Types- Why Aren't We Getting a Clearer Story", 2016.
3. Office of the State Fire Marshall, California Incident Data and Statistics Program, National Fire Incident Reporting System (NFIRS), "Coding Fires Related to Lithium-ion batteries and Electric Vehicles. This is a needed addition to the coding system.
4. "An Analysis of Lithium-ion Battery Fires in Waste Management and Recycling", U.S. Environmental Protection Agency, July 2021, EPA ref. EPA 530-R-21-002 (also mentioned above in the selected bibliography for the Opinion.
    A. In this late-to-the-table report, after much criticism for their slowness of response, the U.S. Environmental Protection Agency (USEPA) stated, "LIB-caused fires throughout the waste management process are already risking the safety of workers, by-standers, and emergency responders and costing the industry money. This problem is only going to get worse ..."
    B. Yet, in the same report, the data and case studies are anecdotal and incomplete for assessing frequency of battery fires at MRFs or their severity. In fact, since RRS' 2017 report for SBWMA, none of the reports that are publicly available effectively group the kinds of facilities together to confirm

the danger to Single Stream MRFs quantitatively. Together with hub and spoke transfer stations who manage Single Stream materials, which have more and more common severe fires, MRFs have enormous amounts of available fuel; for the average MRF, about 74% (222 tons) of the conservative ~300 tons per day is plastic, paper, and flammable multi-material residue. MRF materials also enter the MRF with fire-prone contaminants. Among them are the batteries themselves, but they also include fire accelerants like half empty bottles of hand cleaner, used oil in HDPE oil containers, spray can cleaners and paints, and personal pressurized gas containers with fuel still inside, to name a few.

C. Unfortunately, this report did not identify single stream facilities but did identify paper and plastic facility fires. RRS needed to cross-reference the cases to the MRF database for comparison.
D. Reported Fires- USEPA concluded landfills and the MRFs have the most LB fires. RRS is unsure that this is verified yet, compared to transfer stations, which are far more numerous than MRFs and landfills, but according to the way EPA measured, that is what was reported.
E. USEPA found frequency of fires increased at the facilities studied:
    i. 2013 waste facilities researched had two fires affecting each facility.
    ii. In 2019 and 2020 that number was up to 67 fires at 17 facilities (3.94 fires).
F. (LB) Fires are happening across the full spectrum of the waste management process, but MRFs appear to have faced the brunt of the negative impact (due to fuel).
G. Researchers suspected that the waste industry is underreporting the (amount of) fires and severity of destruction.
H. The EPA, in a related May 2023 regulatory publication, recommended "that all lithium batteries be managed with care during use and at end of life and that businesses consider managing all their used lithium batteries as hazardous waste under the federal “universal waste” regulations in Title 40 of the Code of Federal Regulations (CFR) part 273. Though the EPA has always considered lithium batteries as universal waste, this updated hazardous designation, which eases the confusion of the last eight years the issue has surfaced, may have some policy and municipal contracting issues for NWRA to consider since MRF permits, by and large, do not allow the acceptance of hazardous materials. The rule makes it consistent with other regulatory agencies and the military, for instance, "lithium batteries are regulated as a hazardous material" under the U.S. Department of Transportation's (DOT) Hazardous Materials Regulations (HMR; 49 C.F.R., Parts 171-180). The HMR apply to materials DOT determines with an unreasonable risk to health, safety, and property when transported in commerce.

5. Eunomia, Waste Facilities Fires in the U.K, " Cutting Lithium-ion Battery Fires in the Waste Industry", January 2021
    A. Eunomia's approach to severity is detailed and based on variables like # fire trucks, alarms, and other qualitative classifications like business disruption periods and fire duration.
    B. It was very difficult to calibrate MRF information for frequency or severity from the UK study to the Fogelman or the USEPA study. The nuanced approach of each and the facilities covered, Eunomia's included 'residual' MRFs (MWPFs) in its count, while the Fogelman paper covered transfer stations, scrap yards, Paper and Plastic, and general waste facilities' fires.

C. '48% of all fires in the UK at waste facilities can be directly attributed to "LBs;" this equates to approximately 201 waste fires in the UK each year.' There were 201 reported events with a damage dollar value (converted from Pounds) over $950M per event. In another part of the report, Eunomia arrives at a similar amount $1.02M per event. RRS believes the percentage low for LBs.
D. ESA, the NWRA equivalent in the UK, reported that of the 670 fires recorded by ESA members across the UK in 2019-20, 38% were either recorded as LIB cause or a 'suspected' LIB cause. RRS thinks these percentage counts are low and rather 'academic', that is, standards for inclusion into a LB-caused fire list have high hurdle rates for acceptance, given oxidation of fire sources (batteries) from the temperatures generated by battery failures.
E. Paper facility publicly reported fires increased by 14% YOY 2022 v. 2021, and 8% in the last three years compared to the previous three years.
F. Waste Facility operators are most likely to have reported LB fires (90%) compared to other segments covered by this study.

6. Fogelman J.D./MBA, "6th Annual Reported Waste & Recycling Facility Fires US/CAN 2022 Report", March 2023, Fire Rover, LLC publication. Fogelman's work is the first on-going log of its kind. The EPA and most other N. American sources borrow from it, and it is quoted frequently by insurance agencies and regulators when discussing waste facility fires. Fogelman was very gracious to spend time offering data and advice, and by double checking my assumptions and inputs to the metrics presented in this report.
    A. The critical information Fogelman is reporting is the increase in fire incidents for the entire universe of waste and scrap facilities industry. Unfortunately, for the purposes of this Opinion, the report does not identify Single Stream facilities but does identify paper facility fires. which include Single Stream facilities.
    B. Waste and recycling reported facility fires have increased 43% from 2016 to 2022, from 272 reported fires to 390 fires. Paper facility publicly reported fires increased by 14% YOY 2022 v. 2021, and 8% in the last three years compared to the previous three years.
    C. It should be noted that in the R. Fogelman study, the California Product Stewardship Council (CSPC) pegged actual investigated fires being caused by LBs at 39%, but also had an unknown cause category for the same 26 plants surveyed, and that 65% of the fires were caused by LBs. Finally, operators of California facilities pegged the number of fires from lithium batteries to be as much as 59%. However, the severity of the fires and actual events is more than likely much more attributed to LB fires than what is reported and another 28% of those fires, a cause could not be determined.
    D. The larger the facility and tonnage, the more likely a reportable lithium battery fire will occur.
    E. R. Fogelman identifies qualitative levels of fire threat in his report using fire industry terms. The following Opinion on metrics incorporates and provides waste management terms for those categories.
    F. R. Fogelman noted causation is difficult to impossible to ascertain (which is noted one-way or the other in each of these source documents).
7. Timpane, Michael, et al; King, Dwight, Gans, Hillary, "RRS' South Bayside Waste Management Authority Lithium-Based Battery Assessment". Importantly for my conclusions, the rate of severe fire events (over $1M)

was approximately 1% in 2017 in the SBWMA study. https://rethinkwaste.org/wp-content/uploads/legacy_media/7-a-attachment-d-lithium-based-battery-assessment-2017.original.pdf

A. For an extended time-period during the study, ~5.5 batteries per hour were measured in a series of statistical count tests on the manual sort line per hour. This only represents part of the total story, batteries, and personal electronic devices (greeting cards, power tools, button batteries, phones, toys, e-cigarettes, etc.) are often covered by two-dimensional paper and not discovered.
B. SBWMA's Shoreway Environmental Center MRF reported during this Opinion study that the counts have increased since 2017 significantly.
C. Executives and operators representing a vast majority of MRFs in N. America said LBs caused at least 64% of all fires, up to 80% when the question was posed in a different way.

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   B. The data and case studies are anecdotal and incomplete for assessing frequency of battery fires at MRFs or their severity. In fact, since RRS' 2017 report for SBWMA, none of the reports that are publicly available effectively group the single stream MRF together quantitatively. Usually a combination is grouped together, here, hub and spoke transfer stations who manage Single Stream materials which have more and more common severe fires and landfills together as the smallest grouping. RRS needed to cross-reference the cases to the MRF database for comparison.
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APPENDIX

I. APPROACH

The purpose of this Opinion was to begin to measure and establish easy-to-understand metrics that quantitatively describe the severe impact of lithium batteries on Single Stream MRFs. I used the following methods to provide the Opinions requested:

1. NWRA commissioned RRS to provide a concise Summary Opinion in a short time frame in three areas regarding lithium battery fires in Single Stream MRFs in North America. The industry wants to begin building easy-to-understand, and annually repeatable metrics for conveying the severity of these misplaced materials entering MRFs and causing fires. RRS was asked to specifically:
    A. Provide a directional metric design on estimated annual loss per LB fire event based on public records search, interviews, and RRS expertise, as well as frequency of the average annual loss.
    B. Provide the Annual Rate of Catastrophic MRF Losses (total loss of operations or infrastructure, or over $10 million damage) of Single Stream recycling operations in the U.S. annually
    C. Provide an easy-to-understand metric for the increase in MRF Property Insurance Rates over the last five (5)-years due to Fires.
2. I am one of the subject matter experts on lithium batteries and their impacts on MRFs in the solid waste industry. I used my background to write the Opinions on the questions asked by NWRA. I have written extensively and have published articles and interviews on the subject. I have assisted the EPA and five other national recycling associations and have spoken nationally on the subject several times.
3. I surveyed available analytical studies on lithium battery fires in MRFs. Literally hundreds of periodicals, journals, on-line newsletters, and other sources are available that address the growing concern from damaged LBs entering environments where there is available fuel. As stated above in Many mention material recovery facilities as being particularly vulnerable, and the facts bear this out in the literature.
    A. For this limited scope, RRS surveyed well over fifty of them and provided an annotated bibliography of the most important.
4. Unfortunately, MRFs who handle Single Stream material have not been isolated or categorized in any of these studies, articles, surveys, or newsletters in a meaningful way, and other than cross-referencing the available case study data in these studies and media sources with RRS and public and private databases of verified Single Stream MRFs, there simply was no other way to get to the Opinions expressed below.
5. I also conducted eighteen total interviews in a five-week period on the subject. Twenty-seven MRF operators, executives and representative were contacted, and I spoke to eleven of them confidentially on lithium battery fires at their facilities. One reported the information in an email. Big public companies, regional leaders in the business, NGOs, and public MRFs were interviewed. RRS has promised anonymity and received very candid remarks on the frequency and severity of MRF fires from LBs found in inbound recyclable materials. I also spoke to five insurance executives in lengthy conversations. I consulted frequently with Ryan Fogelman at Fire Rover who is the notable 'town crier' on fires in the waste industry, and who keeps the only on-going log of publicly available case study/incidents on fires in waste facilities. Ryan has a keen grasp on how many fires are

publicly reported and how to fight these fires utilizing Fire Rover technology. Ryan has provided his services to allow me to test assumptions and come up with the necessary rubrics to render the Opinion.

6. I also consulted frequently with NWRA's Anne Germain of NWRA who asked for this Opinion and provided key resources in developing the outcomes.
7. From RRS' standpoint this is a directional opinion, and not a statistical study.
8. The metrics do need further testing from better data. Additionally, work on statistical root cause verification, given the difficulty of directly implicating LBs as the source of increased fires. Notwithstanding, the results from this Summary Opinion were dramatic and confirmed a deep threat from LBs in MRFs.

II, SUMMARY OF QUALIFICATIONS

I am a Principal and Vice President of Process Optimization and Material Recovery at RRS (aka Resource Recycling Systems, Inc.), an independent and nationally recognized recycling consultancy. My office is in Ponte Vedra Beach, Florida, and the corporate headquarters is in Ann Arbor, Michigan. I have spent most of my career focused directly upon the recycling supply chain in various capacities. I have directly managed recycling collection systems, MRFs, recycling markets and logistics, developed greenfield Single Stream MRFs (with a combined value of over $250M), and participated in the writing, proposing, executing, and negotiations of more than 120 solid waste and recycling contracts and franchises.

I have over 40+ years with the largest public recycling companies (of their time) in North America, including Waste Management Inc. (WM), BFI, and Reynolds Aluminum (acquired by Alcoa). In the last nine plus (9+)-years at RRS, I have provided support to clients on Single Stream recyclable material issues, including stream characteristics, costs, revenues and commodity prices, contracts, rates, threats, and technology trends. Prior to RRS, I was employed with WM for 13 years, as a member of the Recycling Executive Leadership team.

I prioritize my practice work within the community recycling value chain- the largest two being public sector solid waste management and private, integrated solid waste service providers (ISPs). My practice also includes stand-alone MRF, scrap, and organics operating companies who run processing centers. These are the field managers who collect, haul, process, and market recyclables and organics. I also work with dedicated recycling companies and mills. Finally, my clients also include material makers (paper, glass, plastics, and metals), packagers, CPGs, A&M/capital formation firms, and EPR PRO organizations, all of whom seek to have a better view of the current conditions of their portion of the recycling supply chain and points of access. Finally, I am my clientele also includes groups involved in consumer recycling behavior and contamination, and end-markets and their specifications (mills, furnaces, brokers, integrated material companies, exporters, and importers).

One of my practice areas is the presence and consequences of lithium batteries at MRFs. I have had clients and collaborations which include work in the following areas:

- MRF surveys on the frequency of lithium battery fire events.
- Threat of Lithium Batteries and other fire sources to recycling facilities as part of NWRA and ISRI special committees and appointments.
- On-the-ground case studies and postmortem assessments at various MRFs focusing on the presence and consequences of lithium batteries at their facilities.
- Development of best practices collection and management for municipalities and waste authorities.
- Independent Audit of state battery management programs for Call2Recycle; and,
- development and authorship of municipal best management practices for personal electronics and lithium batteries for The Recycling Partnership.

I am a member of the Institute of Scrap Recycling Industries (ISRI) Recycling Committee, ISRI Paper Stock Industries chapter, and ISRI Paper and Plastics Division. I am also a member of National Waste and Recycling Association (NWRA) MRF Committee and former Lithium Battery subcommittee. Finally, I am a Florida Chapter member of NWRA, and a national and Florida member of the Solid Waste Association of North America. Further information on my background can be found on the RRS website www.recycle .com.

Resource Recycling Systems (RRS) is a nationally recognized recycling, diversion, and recovery consulting firm with its main offices in Ann Arbor, Michigan, and field offices in Florida, Georgia, North Carolina, Oregon, Washington, Washington, DC, Virginia, Illinois, and California. Throughout RRS 30+ years and its cumulative staff experiences, our experts are regularly involved in negotiations with public and private sector clients engaged in municipal residential recycling and diversion. In addition, RRS experts are noted authors and research contributors, and are regularly called upon by the industry and all levels of local, state, and national government, to render judgement and present findings on technical matters related to recycling value chain. RRS' full qualifications, selected case studies, and organization, can be found at the website, *recycle.com*.