

# Chemical and toxicological concerns about the SMCC (SungEel) facility proposed for Endicott, NY

by

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## Executive Summary

We believe that the location proposed for the SungEel (SMCC) high temperature lithium-ion battery recycling facility (incinerator) in Endicott, NY is unreasonable and contrasts sharply with the location of the sister plant in Gunsan, South Korea. The proposed location in Endicott, NY is immediately adjacent to sensitive receptors such as residences, parks, and many other community features, while the South Korean facility is in an isolated industrial area.

Under these circumstances, we expected that the NYS Department of Environmental Conservation (DEC) would have carefully assessed the pollutants that one could anticipate would result from heating the cells from lithium-ion batteries to high temperatures and then burning the gases formed. However, we believe a number of risks associated with this proposed operation have been overlooked.

Such assessments should have begun with an analysis of the substances contained in these batteries. Instead, the DEC simply took at face value the very limited emission data collected by the company itself. No verification of sampling was conducted, and the lab used to generate data for target air pollutants was not a lab approved by the DEC.

In this paper, we explain that the emission data used by the DEC to issue the Title V air permit for the Endicott, NY SMCC facility on March 27, 2020 was inadequate with respect to four key pollutants: dioxins, PFAS, hydrogen fluoride and nanoparticles. Considering that lithium-ion batteries contain several fluorine rich compounds, we believe that the potential for the formation of hydrogen fluoride (HF) as well as other fluorinated compounds (e.g.,  $\text{POF}_3$  and fluorinated dioxins and furans) should have been thoroughly assessed.

Looking at the potential for HF emissions, we found that the information provided by SMCC were highly unlikely. We roughly estimated the HF emissions using two different methods. In the first method we use the knowledge of the chemical composition of two fluorinated compounds used in many lithium-ion batteries; their likely percentage by weight in batteries and a low and high conversion rate of F to HF. These produced a range of emissions of **24-48 kg hour of operation when the facility is burning 1000 kg of batteries per hour.**

In the second method, we used the actual measurements of HF collected in simulated fires involving seven different lithium-ion battery types, all containing  $\text{LiPF}_6$  in the electrolyte. For these batteries we estimated a range of emissions from **5- 50 kg of HF**

**per hour when the facility is burning 1000 kg of batteries per hour.** This number compares reasonably well with our estimates determined in the first method.

**Our estimates of HF emissions would greatly exceed the threshold level of 100 lbs of HF per year, that would trigger regulation by the DEC.**

Our estimates make the numbers provided by SungEel appear very low. SungEel claimed non-detectable amounts of HF at the stack and a concentration of 0.1 ppm at the exit of the kiln. Converting 5 - 50 kg HF per hour to ppm would yield a concentration of **380-3800 ppm!**

Such significant underestimations of HF calls into question the reliability of the emission data for the other pollutants that SMCC has provided to the DEC. Measurements of dioxins (PCDDs and PCDFs) relied on a single short-term measurement of four hours, though it is well-known that measurements of dioxins made on the same day can vary by a factor of 1000 times. That is why in Europe many countries use 4-week sampling to assess dioxin emissions.

Based on information the authors provided to the DEC, they have now recognized the presence of at least one PFAS in lithium-ion batteries and have put a hold on the current permit until further investigation has been done. While regulations regarding PFAS compounds are in the process of being promulgated, it is our understanding that environmental assessment of these compounds is a top priority for DEC and the potential for the release of them with regard to the proposed Endicott facility should be no exception.

Should this project go forward – and we sincerely hope that it won't – the DEC should insist on 4-week sampling for PFAS and dioxins (chlorinated, brominated and fluorinated). They should also collect a baseline measurement of current background levels of nanoparticles in the ambient air in Endicott and commit that if these levels are exceeded when the plant goes online then it will be immediately shut down.

The proposed facility is the first of its kind operation in the USA, and when huge profits are at stake, we believe it is imprudent to rely on SMCC for air pollutant emission data without oversight by the DEC itself or an independent third party paid by DEC.

When it is known that a community like Endicott has already been impacted by a significant pollution event and has already shown health effects (increased cancer rates) from that event, the DEC should adjust its permits to take that into account. In such situations, we would recommend that the DEC reduce the normally *allowed* pollutant emissions by at least 90%. Additionally, the community deserves a thorough environmental impact statement and formal accident analysis covering the transport, storage and handling of the batteries, which are a well-known fire risk. In this case, the Endicott community did not get either of these.

**Introduction.** We have serious reservations about the adequacy of the DEC air permit issued for the SungEel (or SMCC, used interchangeably in this document) lithium-ion battery recycling facility proposed for Endicott. The facility is to be located on the edge of the Huron campus on the corner of Robble Avenue and Clark Street very close to where people live and children play (see photos below).

**Aerial View Endicott, NY showing the proposed SungEel facility (light blue siding) at the corner of Robble Avenue and Clark Street.**



**Endicott, NY (note proposed emission stacks in the background)**



The operation will involve heating dismantled lithium-ion battery cells in a rotary kiln operating at 600 degrees C, followed by an afterburner operating at 800 degrees C (subsequent developments have prompted SungEel to say they will operate at 1000 deg C).

Because of a number of fluorinated compounds used in these batteries, this is potentially a very dangerous operation both for the workers in the plant and the adjacent community.

This is the first of its kind operation in the USA and bearing in mind the vulnerability of the local community, because their health has already been compromised by previous pollution from IBM, very special care should have been taken to ensure that any air permit be based on very careful measurements or projections of anticipated pollutants.

**In many situations** where air emissions are a potential issue for a facility there will be other examples of the type of the process operating elsewhere in the country or in the world. A range of likely emissions could then be estimated by taking the geometrical mean of all the data as well as the lower 5% and upper 95% confidence intervals.

**In this case** there is only one example of another operating facility and that is the sister plant operating in South Korea. To ask this company to provide emission data raises **an obvious conflict of interest** for the company between doing an accurate job of measuring the emissions of key toxic materials and their desire to obtain a permit to facilitate their pursuit of a very lucrative business.

In our view, because of where this facility is going to operate the DEC should have done two things:

1. made sure that any measurements made at the South Korean facility were carefully overseen by a third party and preferably by a DEC approved lab. This was not done.
2. temper the information provided to it by the company with theoretical estimates of some of the anticipated pollutants (especially hydrogen fluoride) based upon the chemical substances known to be present in the feedstock. The DEC did not attempt this. The potential air emission issues are described in a recent (2020) review article by Mossali et al. (2020) as well as Larsson et al., (2017).

In this paper we will analyze weaknesses in the data provided by SungEel and used by the DEC in the Air Permit. Then we will do what we think the DEC should have done and that is estimate the emission level of a key pollutant (in this case hydrogen fluoride) and compare the levels with the levels provided by SungEel (and used without qualification by the DEC).

#### **Weaknesses in the SungEel data:**

1. They grossly underestimated the dioxin and furan emissions.
2. They used a ridiculously low emission rate for Hydrogen Fluoride (HF) emissions.

3. They failed to note the presence of a PFAS (**per-** and **poly fluorinated alkyl substances**) in some lithium ion batteries and failed to require this or other PFAS to be monitored in both the water effluent or in the air emissions.
4. They paid no attention to the issue of nanoparticles which are believed to be the most serious issue associated with any form of incineration.

We will discuss each of these problems in turn.

## 1. Dioxans and Furans

**1.1 Dioxins and Furans (PCDDs and PCDFs).** The company provided data for only one short test of 4-hour duration. Such a short and single test provides no notion of the range of emissions that can occur on different days. Nor does it give any notion of what can occur during start-up and shut-down or during upset conditions. Nor was the test overseen by a third party.

**1.2** It has been well established in Europe that emissions during such situations can increase by 1000 times or more. That is why today, in several European countries, incinerators are required to undertake continuous sampling of 4-week duration and repeated throughout the year.

**1.3** A sampling of the most recent state-of-the-art trash incinerator in the Netherlands conducted side by side 6-hour monitoring and 4-week monitoring and found that the 4-week monitoring yielded dioxin emissions 1260 and 460 times higher than 6-hour tests. (<https://zerowasteurope.eu/library/hidden-emissions-a-story-from-the-netherlands/>)

**1.4** SungEel cannot argue that they were unaware of this more accurate testing because the German company EUROFIN that did the analysis of the 4-hour testing in South Korea was actually involved in the monitoring of the Netherlands incinerator above (1.3) and should have been aware of the inadequacy of the 6-hour testing in the Netherlands let alone the 4-hour testing that they oversaw in South Korea. (Arkenbout, 2017, 2018 cited in Toxicowatch, 2018).

**1.5** As far as the awareness of the DEC was concerned Dr. Paul Connett had warned them about the inadequacies of the short-term testing on Dec 5 – long before they issued the air permit in late March, 2020. This is what he wrote on Dec 5, 2019:

“6) I note that the SUNGEEL facility operating in South Korea has been measured for dioxin - but only a single figure (one test?) has been provided for dioxin emissions - i.e. 0.016 ng I-TEQ/SM3.”

“QUESTIONS: Was only one test performed on this facility? For what duration? 6 hours? Under what conditions? Such spot tests are notorious

for underestimating emissions during start-up, shut-down and upset conditions. As a result, in Germany, Belgium and some other countries companies are required to use a 4-week continuous sampling system (the AMESA system). Emissions when estimated using this sampling system (emissions) can be several orders of magnitude higher than the 6-hour spot tests. **Thus, the conclusions by Plumley Engineering copied below - are not based on adequate science and are cavalier to say the least.” (link to my full submission) (DEC, 2020)**

1.6 The DEC responded to this comment as follows:

*Comment 13: One commenter questioned whether only one test for dioxin was conducted in South Korea and suggested that the conclusions drawn by the consultant are not based on adequate science and recommended continuous sampling over a whole year...*

*Response 13: The dioxin test on the South Korean facility was one run...the inclusion of enforceable conditions within the Air State Facility permit require compliance with the High Toxicity Air Contaminant limits, nonetheless...(DEC, 2020)*

1.7 Based upon this non-answer the DEC proceeded to use this single 4-hour test (unvalidated by a DEC approved party) to estimate annual dioxin emissions from the plant.

1.8 Because of the known presence of fluorinated compounds and the probable presence of brominated fire retardants in some of the batteries, the dioxin testing should have included brominated and fluorinated dioxins and furans in addition to their chlorinated cousins. The AMESA 4-week testing systems would allow this extra safety measure.

## 2. HF (hydrogen fluoride) emissions

2.1 We are paying particular attention to HF because it is a well-known pollutant associated with pyro-metallurgical processes for recycling lithium-ion batteries, as used by SungEel.

2.2 According to Mossali et al., 2020, “High temperature thermal treatments (which) improve Lithium recovery efficiency up to 90% thanks to carbon removal, but require air-filtering systems and gas scrubbers due to significant toxic gaseous emissions (e.g. dioxins, HF, CO, CO<sub>2</sub>, etc.) and also see Larsson et al, 2017 discussed in section 7.

2.3 SungEel provided very low emission levels for hydrogen fluoride in their air permit application.

2.4 The emissions from the rotary kiln dryer, recorded as “fluoride compounds” (a category that combines HF and NaF), was given as 0.1 ppm (see their attachment C).

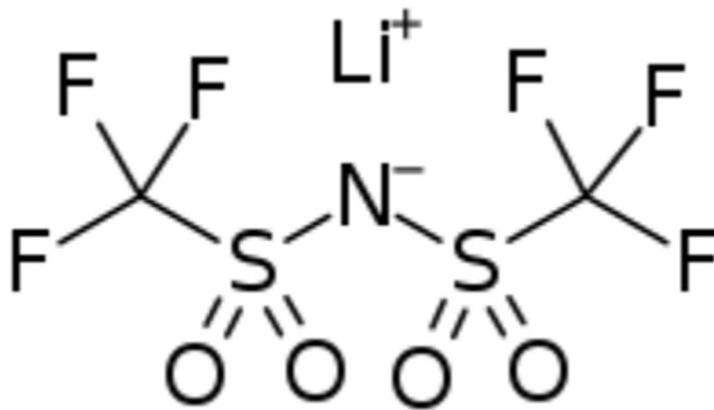
It is unlikely that NaF would have been present in this sample because it is not volatile. However, it can be anticipated that it will be in the effluent of the wet scrubber, where NaOH (sodium hydroxide) will neutralize some of HF passing through the system. The resulting sodium fluoride will become a potential water pollutant that should be monitored as well. The EPA's maximum contaminant level (MCL) for fluoride in drinking water is 4 ppm. With kilograms of HF going through the system the MCL will be exceeded by a very large amount.

- 2.5 The emissions from the stack (see their attachment D, pilot exhaust gas analysis), for three different battery types was reported as ND, ND and ND. ND stands for not detected.
- 2.6 Based upon a knowledge of the number of fluorinated compounds used in a whole range of lithium-ion batteries as binders and electrolytes, and a rough idea of the percentage by weight they represent, as well as information derived from battery fires, these emission numbers bear little relation to reality. We will pursue this issue more fully below (see sections 5 - 7).

### 3. PFAS

- 3.1 Since the DEC issued the Air permit in late March 2020, the science team at No Burn Broome has alerted local officials to the presence of a PFAS in at least one type of lithium-ion battery. We appreciate that when the DEC heard about the possibility of PFAS being in some lithium-ion batteries, they re-opened the permit while this matter is being investigated.
- 3.2 The substance in question is Lithium bis (Trifluoromethane sulphonyl) imide (Li C<sub>2</sub>F<sub>6</sub>S<sub>2</sub>O<sub>4</sub>N). This is a lithium ion salt with the cation being Li<sup>+</sup> and the anion being the PFAS<sup>-</sup>. It is used as an electrolyte in some batteries in place of lithium hexafluorophosphate for safety reasons. <https://echa.europa.eu/registration-dossier/-/registered-dossier/18080/3/1/4>

## Lithium bis(trifluoromethanesulfonyl)imide



**3.3** As noted in a WBNG news article published on May 21, 2020, SMCC’s strategy to address this issue appears to be a process modification in which the incinerator temperature in the afterburner would be raised from 800 degrees C (noted in the Title V air permit) to 1000 degrees C in an attempt to destroy PFAS compounds present in the lithium ion batteries:

*“-Update our process to operate the after burner at 1,000 c.”*

**3.4** In our letter sent to Reginald Parker of the DEC on May 26, 2020 (**See Appendix A**), we pointed out that a recent presentation by USEPA, (**See Appendix B**) calls into question a) the adequacy of incineration to destroy PFAS compounds; b) the lack of knowledge regarding the nature of breakdown products of PFAS during incineration; and c) the lack of fully developed lab methods to determine PFAS levels in air samples collected at emission stacks.

**3.5** We recommended the following:

**3.5.1** Empirical data be obtained by a worst-case test incineration of PFAS bearing lithium ion batteries, noting that not all of lithium batteries contain PFAS compounds.

**3.5.2** Using ELAP certified laboratory with experience running PFAS stack samples and the ability to modify the test method to determine lithium bis(trifluoromethanesulfonyl) imide and other non-target PFAS method compounds identified by SMCC or others.

**3.5.3** Using a 4-week stack sampling commercially available AMESA system.

- 3.5.4 The DEC should be present to observe all sampling procedures as is frequently done for various environmental projects across New York.
  - 3.5.5 The DEC should consult the NYS Dept of Health regarding the sampling procedure, which should in principle, mirror worst case sampling of indoor air quality performed for soil vapor intrusion.
- 3.6 We fully understand that PFAS are not currently regulated as Title V air pollutants; however, we do know that DEC is carefully evaluating all environmental media from drinking water to import soil for site remediations to perform at least a rough analysis of whether PFAS concentrations are problematic. We expect the same consideration and standard of care in this matter as well, with the understanding that this is an important emerging concern that is rapidly developing.

#### 4. Nanoparticles

- 4.1 A glaring example of the inadequacies of the DEC Air permit is their total neglect of the issue of nanoparticles and the need to give special attention to protecting the residents who live near the proposed site for this facility in Endicott, who are already suffering from an increase in cancer rates due to previous pollution in the area.
- 4.2 It is true that neither the EPA nor the DEC has developed a way of monitoring combustion sources for nanoparticles but that does not mean the risks they pose to human health do not exist. Indeed, a paper published online in November 2019 found an association between 10,000 nanoparticles per cubic meter of air in a city and an increase of 10% in brain cancer (see a news article in *The Guardian* (UK), “Air pollution nanoparticles linked to brain cancer for first time” and the published paper Weichenthal et al. (2020).
- 4.3 See the section on nanoparticles in the **position paper** of the No Burn Broome group at their website at [noburnbroome.com](http://noburnbroome.com).
- 4.4 In the sad event that this project goes forward, it would be prudent to monitor the ambient air in Endicott for nanoparticles prior to the SungEel going into operation. With an already high cancer incidence in Endicott any increase in nanoparticles in the ambient air should not be tolerated. The DEC should make it clear that if the levels increase over this baseline, the plant would be shut down immediately.

#### 5. Projected emissions of Hydrogen Fluoride (HF) based on the chemical composition of the batteries in question.

**Introduction:** The following calculations would have been greatly simplified if the percentage of fluorine by weight for each lithium-ion battery type was known. Despite enquiries to many sources accurate information on this was not easy to find. Thus, we were forced to consider estimates of the percentage fluorine contributed by various substances

known to be in some of the batteries and use these to estimate low and high emissions of the HF they would yield in high temperature and burning processes.

In Section 7, we will compare these estimates with measurements made in lithium-ion battery fires.

**5.1** There are several sources of fluorine in the batteries which when subjected to high temperatures would yield hydrogen fluoride and other by-products containing fluorine, some of which are likely to be very toxic causing acute symptoms (e.g. HF, PF<sub>5</sub>, POF<sub>3</sub>, OF<sub>2</sub>) and others that may present long-term health hazards (e.g. PFDDs, PFDFs, PFBs, PFAS, etc.,).

**5.2 PVDF (polyvinylidene di fluoride).** This fluorinated polymer has a repeat unit (or monomer) of CH<sub>2</sub>CF<sub>2</sub> to give a formula for the polymer (CH<sub>2</sub>CF<sub>2</sub>)<sub>n</sub> where n is a value in the 100s. It is approximately 60% fluorine by weight. It is used as a binder in the batteries.

**5.3** In **Appendix C** we show the calculations of the predicted HF admitted per hour when 1000 kg of lithium -ion batteries are burned. This assumes the percentage of PVDF by weight in the batteries is approximately 1.5%.

**5.4 We predict the emission rate of HF per hour from this facility due to the PVDF binder will be 5-10 kg/hour.**

## 6. Fluorine in electrolytes in lithium ion batteries

**6.1** According to Wikipedia:

“The electrolyte in lithium ion batteries is typically a mixture of organic carbonates such as [ethylene carbonate](#) or [diethyl carbonate](#) containing [complexes](#) of lithium ions.<sup>[91]</sup> These non-[aqueous](#) electrolytes generally use non-coordinating anion salts such as lithium hexafluorophosphate (LiPF<sub>6</sub>), lithium hexafluoroarsenate monohydrate (LiAsF<sub>6</sub>), lithium perchlorate (LiClO<sub>4</sub>), lithium tetrafluoroborate (LiBF<sub>4</sub>), and [lithium triflate](#) (LiCF<sub>3</sub>SO<sub>3</sub>).”

**6.2** In **Appendix D** we have provided a sample calculation for the amount of HF that might be generated when burning batteries (1000 kg/hour) using a **lithium hexafluorophosphate (LiPF<sub>6</sub>)** as an electrolyte. This assumes that LiPF<sub>6</sub> makes up 5% of the battery by weight; all the batteries burned contain LiPF<sub>6</sub> and we assume a low (50%) and high (100%) conversion rate to HF.

**6.3** We estimate that in this worst-case scenario **19 to 38 kg of HF** will be released when burning 1000 kg of batteries per hour.

**6.4** If the batteries had contained both PVDF and LiPF<sub>6</sub> we predict a combined emission rate of **24 to 48 kg of HF per hour.**

**6.5** We believe that if we had used other fluorinated electrolytes in place of we would have obtained figures in the same ballpark range as this. These other fluorinated electrolytes include: lithium hexafluoroarsenate, lithium tetrafluoroborate, lithium triflate and lithium bis(trifluoromethane sulfonyl) imide.

**Had the DEC done these ballpark (worst case) calculations prior to giving their permit they would have quickly realized that this facility had the potential to emit over the ANNUAL THRESHOLD of 100 lbs per year of HF in just one hour of operation!**

**It would have also made them realize that both the emission rate of 0.1 ppm from the kiln and ND after the wet scrubber, as reported by SungEel, were both highly suspicious on the one hand and exquisitely dependent on 100% effective operation of the wet scrubber system, on the other.**

## **7. Validation of calculations**

**7.1** Clearly, the above calculations are only designed to give rough ball-park (worst case) figures to see if the numbers reported by SungEel for HF emissions (0.1 ppm from the kiln and ND from the chimney located after the pollution control devices) were reasonable. Based upon our calculations they were not.

**7.2** It would be better if we could get some reliable measurements from the SungEel facility or others like it made by independent research teams and reported in the literature. But we cannot find any such reports. However, we found one excellent paper published in *Nature* that measured the HF emissions in simulated lithium-ion battery fires for “seven different types of commercial lithium ion batteries.” Larsson et al., 2017.

**7.3** Here is the abstract from that paper:

### **Abstract**

Lithium-ion battery fires generate intense heat and considerable amounts of gas and smoke. Although the emission of toxic gases can be a larger threat than the heat, the knowledge of such emissions is limited. This paper presents quantitative measurements of heat release and fluoride gas emissions during battery fires for seven different types of commercial lithium-ion batteries. The results have been validated using two independent measurement techniques and show that large amounts of hydrogen fluoride (HF) may be generated, ranging between 20 and 200 mg/Wh of nominal battery energy capacity. In addition, 15–22 mg/Wh of another potentially toxic gas, phosphoryl fluoride (POF<sub>3</sub>), was measured in some of the fire tests. Gas emissions when using water mist as extinguishing agent were also investigated. Fluoride gas emission can pose a serious toxic threat and the results are crucial findings for risk assessment and management, especially for large Li-ion battery packs.

**7.4 Here is an excerpt from their paper which provides the key pieces of data for our calculation in Appendix E:**

*Significant amounts of HF, ranging between 20 and 200 mg/Wh of nominal battery energy capacity, were detected from the burning Li-ion batteries. The measured HF levels, verified using two independent measurement methods, indicate that HF can pose a serious toxic threat, especially for large Li-ion batteries and in confined environments. The amounts of HF released from burning Li-ion batteries are presented as mg/Wh. If extrapolated for large battery packs the amounts would be 2–20 kg for a 100 kWh battery system, e.g. an electric vehicle and 20–200 kg for a 1000 kWh battery system, e.g. a small stationary energy storage.”*

**7.5** We were able to determine the emissions in kg of HF per hour by converting their unusual units of mg/Wh to kg/hour using a report from Tesla which uses Lithium -ion batteries in their cars [https://en.wikipedia.org/wiki/Watt-hour\\_per\\_kilogram](https://en.wikipedia.org/wiki/Watt-hour_per_kilogram).

**7.6** Our calculations indicate that burning 1000 kg/hour of batteries under the conditions used by Larsson et al. (2017) in fires would yield **5-50 kg HF per hour**

**7.7** This agrees fairly well with our ballpark calculations in sections 5 and 6 of **24-48 Kg of HF per hour**

**7.8** In conclusion, using **two different methods** for assessing the potential HF emissions from burning lithium ion batteries in the SungEel facility, each result (24-48 kg/HF/hour and 5-50 kg/hour) puts into serious question the HF emissions provided by SungEel and their acceptance by the DEC.

**7.9** The DEC ruled that HF would not exceed 100 lbs per year and left this criteria pollutant unregulated. However, the calculations above indicate that this threshold would be reached in about one hour of operation!

**7.10** Moreover, it can be shown that an emission rate of 5-50 kg HF/hour would translate to an emission concentration of 380-3800 ppm (see Appendix F). This is 3800 to 38000 times higher than the number provided by SungEel of 0.1 ppm and used by the DEC without further consideration.

## **Overall Conclusions:**

**C.1** In the absence of real data from the kind of incineration facility operated by SungEel, validated by third parties, it is not reasonable to simply rely on the company to provide the data on which regulators have to make key decisions on the likely safety of this facility.

**C.2** The DEC should have insisted on a comprehensive set of data validated by third parties. This should have included the commercially available (AMESA) 4-week testing method for dioxin (and other similarly toxic halogenated compounds) a testing method known to the company

monitoring the SungEel facility in South Korea. The Amesa system could have also been used to monitor other dioxin-related compounds (e.g. PCBs, PBBs, brominated dioxins and furans, fluorinated dioxins and furans) as well as the PFAS.

**C.3** A very brief review of the constitution of lithium-ion batteries, in which several fluorinated compounds are key components, should have alerted the DEC that the very low HF emissions provided to them by SungEel, were extremely unlikely. If the DEC had performed calculations as we have done above (**in two different ways**) they would have seen that HF needed to be included in the Air permit and carefully regulated.

**C.4** Overall, we conclude that:

- 1) The annual dioxin emission estimate was unreasonable and would be much larger than the number used by the DEC in issuing the air permit.**
- 2) The reported HF emissions were unreasonable, and actual emissions would likely be several orders of magnitude higher than they used by the DEC in the Air permit (actually 3800 to 38000 times higher than the level provided by SungEel of 0.1 ppm). Moreover, the actual emissions of HF would have easily exceeded the DEC 100 lbs per year threshold.**

**C.5** These failings are especially serious when one considers the project will operate in the immediate proximity of where people live and kids play baseball and will operate with a short stack (111 feet) in hilly terrain subject to temperature inversions. This is unlike SungEel's sister plant in South Korea which operates with a 500-foot stack in flat terrain, and located in a large industrial estate (approximately 8000 acres) close to the sea, with the nearest community located about 3 miles away (see pictures below).

**C.6** Furthermore, failing to get a handle on how much HF will be passing through this system means that not enough warning has been made available to **OSHA** (Occupational Health and Safety Agency) with respect to the safety of workers in the facility. Both OSHA and the workers should have been warned as to the dangers posed should kilogram amounts of HF leak from any of the piping between the kiln and the wet scrubber. As the article we cited above indicates:

*The immediate dangerous to life or health (IDLH) level for HF is 0.025 g/m<sup>3</sup> (30 ppm)<sup>22</sup> and the lethal 10 minutes HF toxicity value (AEGL-3) is 0.0139 g/m<sup>3</sup> (170 ppm)<sup>23</sup>. The release of hydrogen fluoride from a Li-ion battery fire can therefore be a severe risk and an even greater risk in confined or semi-confined spaces. (Larsson et al., 2017)*

**C.7** Based on information the authors provided to the DEC and local officials, the DEC has now recognized the presence of at least one PFAS in lithium-ion batteries and have put a hold on the current permit until further investigation has been done. While regulations regarding PFAS compounds are in the process of being promulgated, it is our understanding that environmental assessment of these compounds is now a top priority for DEC and the potential for the release of them with regard to the proposed Endicott facility should be no exception. More measurements

must be made at the SungEel facility to directly address this issue to ensure that incineration of PFAS found in lithium ion batteries can be safely conducted.

**C.8** Should this project go forward – and we sincerely hope that it won't - the very least the DEC should do is to insist on 4-week sampling for PFAS and dioxins (chlorinated, brominated and fluorinated). They should also collect a baseline measurement of current background levels of nanoparticles in the ambient air in Endicott and commit that if these levels are exceeded when the plant goes online then it will be immediately shut down.

**Recommendation:** By any moral, social, environmental and scientific point of view this facility should not be allowed in Endicott. However, for future reference, in consideration of other sites, when it is known that a community like Endicott has already been impacted by a significant pollution event and has already shown health effects (increased cancer rates) from that event, the DEC should adjust its permits for new facilities to take that into account. At the very least, in such situations the DEC should reduce the normally *allowed* pollutant emissions by at least 90%.

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[https://journals.lww.com/epidem/Fulltext/2020/03000/Within\\_city\\_Spatial\\_Variations\\_in\\_Ambient.4.aspx](https://journals.lww.com/epidem/Fulltext/2020/03000/Within_city_Spatial_Variations_in_Ambient.4.aspx)

**Acknowledgements:** We would like to thank Chris Neurath, Senior Science Advisor to the American Environmental Health Sciences, Inc, for his calculations of Hydrogen Fluoride emissions and William Huston and George Fiedler for providing us with the Google Earth images we have used. We would also like to thank Thomas O’Brien and Ellen Connert for their extremely helpful editorial advice. All typographical and other mistakes remain the responsibility of the authors

**The following aerial photos compare the proposed site in Endicott, NY with the SungEel's sister plant in Gunsan, South Korea.**

**Aerial View Endicott, NY showing the proposed SungEel facility (light blue siding) at the corner of Robble Avenue and Clark Street.**

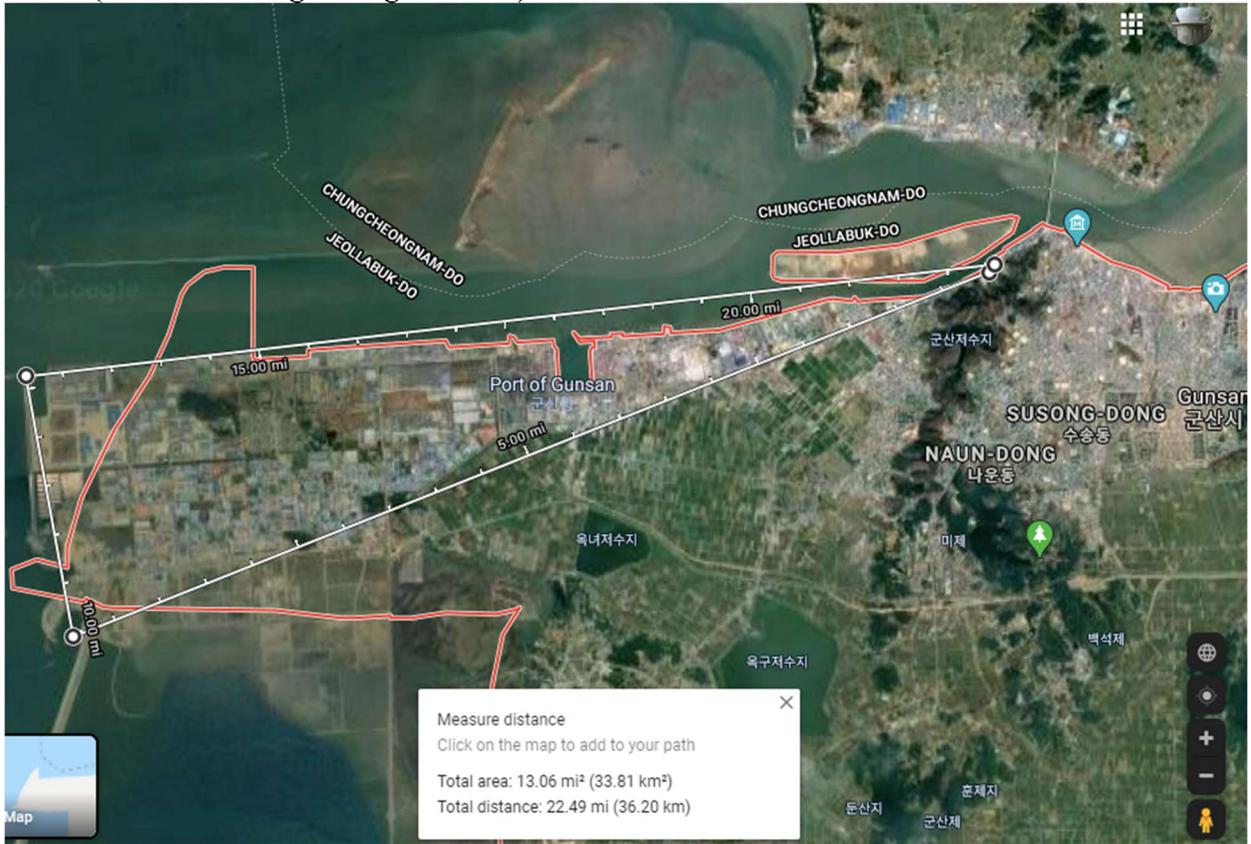


**SungEel facility, in Gunsan, South Korea. Image from Google Earth. Estimated stack height is 500 feet.**



*Photo and stack height estimate by William Huston of Endicott*

Gunsan, South Korea. industrial area hosting SungEel facility. Estimated land area = 8000 acres. (Source of image Google Earth.)



**Comparing Air Quality Index (AQI) and PM 2.5 micron particles (microgram / M<sup>3</sup>) for Endicott and Gunsan (readings taken on May 25, 2020).**

Endicott, NY Air Quality & Pollen ★ 🏠  
☀️ 75° FLORENCE ST. STATION | CHANGE ▾

TODAY   HOURLY   10-DAY   CALENDAR   HISTORY   WUNDERMAP

AIR QUALITY INDEX ⓘ

TODAY:  
**GOOD**

Help keep air quality good by biking to work and enjoying outdoor activities.

AQI: **36**      DOMINANT POLLUTANT: **O3**

AQI Source: Contains Copernicus Atmosphere Monitoring Service information 2020 and/or modified Copernicus Atmosphere Monitoring

PURPLE AIR

Keep you and your family safe

Monitor your outdoor air with an air

**IQAir**    🔍 Search    World Air Quality    Community    Products    Solutions    Supp

South Korea > Jeollabuk-do > **Gusan**    📍 LOCATE

**Gusan** air quality index (AQI) and PM2.5 air pollution is 80, ...    7.16K people follow

35:00, May 23 (local time)

Moderate

**80** US AQI

PM2.5 | 26 µg/m<sup>3</sup>

IQAir Map 🗺️

Iksan

Gusan

## Appendix A

Mr. Reginald Parker, P.E.  
Regional Engineer  
New York State Department of Environmental Conservation  
615 Erie Blvd  
Syracuse, NY 13204

Subject: SMCC Lithium Ion Battery (LIB) Incinerator - PFAS  
DEC Permit No. 7-034-00218/00001

### *Sent Via Email*

Dear Mr. Parker:

Our citizens' group known as No Burn Broome brought the lithium ion battery (LIB) PFAS issue to the attention of local officials, who subsequently raised the matter with the DEC. We understand that SMCC is now in the process of responding to a letter you sent to them dated May 20, 2020 in which the DEC calls for a permit modification to address the PFAS matter. In a recent statement that SMCC made to the local media, it appears that they are modifying their process temperature in an attempt to destroy PFAS compounds present in the batteries. It should be noted that a recent presentation by USEPA, attached hereto, calls into question a) the adequacy of incineration to destroy PFAS compounds, b) the lack of knowledge regarding the nature of breakdown products of PFAS during incineration, and c) the lack of fully developed lab methods to determine PFAS levels in air samples collected at emission stacks.

Moreover, this facility is being touted as a first of its kind LIB recycling plant in the US, yet the chemistry of burning LIBs has not been fully elucidated. Clearly, fluorinated compounds such as polyvinylidene fluoride in the binders of LIBs and lithium bis (trifluoromethyl sulfonyl) imide, lithium hexafluorophosphate, lithium hexafluoro arsenate monohydrate (LiAsF<sub>6</sub>), lithium tetrafluoroborate (LiBF<sub>4</sub>), and [lithium triflate](#) (LiCF<sub>3</sub>SO<sub>3</sub>) found in the electrolytes, could break down to form very highly reactive fluorinated moieties as well as liberating the PFAS. There is scant information in the literature on this topic and what is currently known is research based on LIB fires as shown in an article which appeared in Nature Scientific Reports Larsson et al, 2017. <https://www.nature.com/articles/s41598-017-09784-z>

With such little research having been done on LIB incineration chemistry, it seems incongruous that DEC would allow a Title V emission permit to be issued to a company, right next to a residential neighborhood, ballfields and public swimming pools without thoroughly investigating the esoteric chemical nature of this incineration process. After all, we are talking about potential emission of hydrofluoric acid and PFAS compounds here, just for a start. Personally, we would

say a bit more research would be needed before they should be allowed to begin LIB incineration in the USA. Their research and experimentation should be done in South Korea where they are located inside an 8000-acre industrial estate. In our view, Endicott, NY is not the place for their experiment.

If SMCC is intent on modifying its process to destroy PFAS compounds, we would suggest requiring them to do worst case air sampling as is done with indoor air quality testing to ensure protection of the public. Since it is unclear just how many LIBs actually contain PFAS or how many might be in the plant for processing at any given time, we suggest the following:

1. The test burn data should be based on the maximum number of PFAS-bearing LIBs present in the kiln; ideally all of them should be PFAS-bearing for the test burn. Running a test burn to determine PFAS without an appreciable sample population of PFAS-bearing LIBs would be inadequate.
2. The lab testing should be performed by a reputable ELAP certified laboratory with experience running PFAS stack samples and the ability to modify the test method to determine lithium bis(trifluoromethyl sulfonyl) imide and other non-target PFAS method compounds identified by SMCC or others.
3. Fortunately, the company that SungEel hired to analyze the results of the **4-hour** stack test for dioxins (Eurofin, a German based company) in South Korea was involved in monitoring a Netherlands incinerator in which 6-hour testing was compared with the 4-week sampling using the commercially available AMESA system. So, they are familiar with the system. This system can monitor both the PFAS and the dioxins so two birds can be killed with one stone. (<https://zerowasteurope.eu/library/hidden-emissions-a-story-from-the-netherlands/>).

## Long-term sampling flue gas

AMESA® D

TPV

ICERT

- For the **first time in the history** of the Netherlands a long-term continuous sampling of flue gas in the chimney of the incinerator
- Analysis of regulated dioxins and furans (PCDD/F) and also the non-regulated POPs like dioxin-like PCBs, brominated and fluorinated compounds (PBB, PBDE, PBDD, PBDF, PFOA, PFOS)
- All results publicly accessible
- [www.harlingen.nl/reclonet](http://www.harlingen.nl/reclonet)

## Short- vs long-term measurements

Sampling	hours	ng TEQ/Nm3	Factor
Short-term, March 30, 2016	6	<0,00001	
Long-term March 26– April 26, 2016	256	0,01290	>1290
Short-term, 8 March 2017	6	0,00001	
Long-term March 7 – April 5, 2017	690	0,00460	460

Sampling for official monitoring purposes must be *representative*.  
Short-term sampling underestimating emission dioxin levels.

- The DEC should be present to observe selection of the batteries for incineration (see comment 1 above) and all sampling related to the process.

5. The New York State Department of Health should be consulted in this matter and concur that the methodology for testing and data evaluation meets reasonable guidance regarding exposures to PFAS to ensure protection of human health proximate to the proposed facility.

We fully understand that PFAS are not currently regulated as Title V air pollutants; however, we do know that DEC is carefully evaluating all environmental media from drinking water to import soil for site remediations to perform at least a rough analysis of whether PFAS concentrations are problematic. We expect the same consideration and standard of care in this matter as well, with the understanding that this is an important emerging concern that is rapidly developing.

Thank you so much for your consideration in this matter. Please feel free to contact us at [pconnett@gmail.com](mailto:pconnett@gmail.com) or [jjruspantini@nptusa.org](mailto:jjruspantini@nptusa.org) if you have any questions or comments.

Very kind regards,



John Ruspantini, CHMM, PMP



Paul Connett, PhD

## **Appendix B**

**EPA Presentation April 27, 2020  
PFAS Incineration**



# USEPA PFAS THERMAL TREATMENT & METHODS RESEARCH – OPPORTUNITIES FOR COLLABORATIVE INCINERATION FIELD TESTING

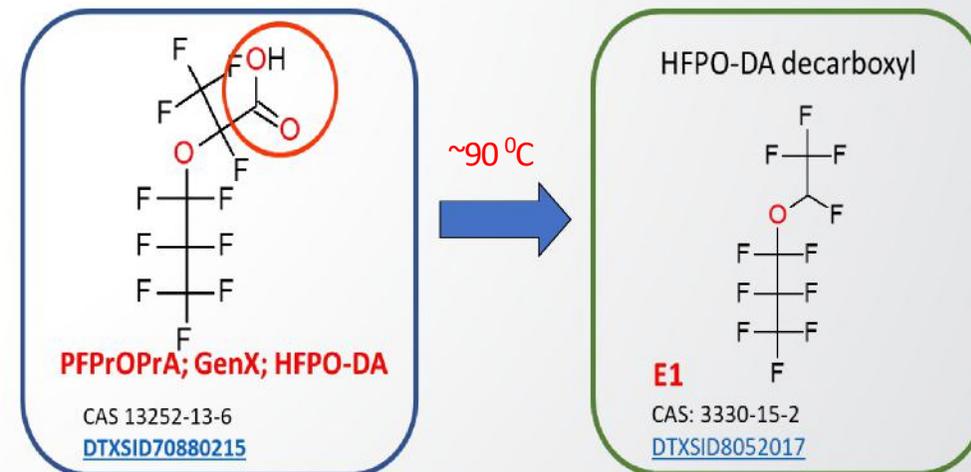
*Lara Phelps*

*US EPA ORD Center for Environmental Measurement and Modeling*

ECOS-EPA PFAS Bimonthly Call

April 27, 2020

- Group of >4000 per- and poly-fluorinated organic compounds
  - PFAS often composed of non-polar fluorinated alkyl chain and polar functional group
  - Used by the military and industry and present in a large variety of consumer products
  - Valued for their hydrophobic and lipophobic properties, thermal and chemical stability
  - Present in many industrial and municipal waste streams including air, water and land discharges
- Highly electronegative fluorine makes C-F bonds particularly strong, require high temperatures for destruction
  - Unimolecular thermal destruction calculations suggest that  $\text{CF}_4$  requires 1,440 °C for >1 second to achieve 99.99% destruction (Tsang et al., 1998)
  - Sufficient temperatures, times, and turbulence are required
- Functional group relatively easy to remove/oxidize
  - Low temperature decarboxylation as an example
  - Information regarding potential products of incomplete combustion (PICs) is lacking





# Products of Incomplete Combustion (PICs)

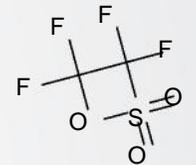
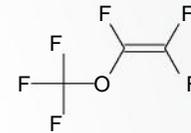
- When formed in flames, F radicals quickly terminate chain branching reactions to act as an extremely efficient flame retardant, inhibiting flame propagation
- PICs are more likely formed with F radicals than other halogens such as Cl
- PICs may be larger or smaller than the original fluorinated Principal Organic Hazardous Constituents (POHC) of concern
  - $\text{CF}_2$  radicals preferred and relatively stable, suggesting the possibility of reforming fluorinated alkyl chains
  - Remaining C-F fragments may recombine to produce a wide variety of fluorinated PICs with no analytical method or calibration standards
  - May result in adequate PFAS destruction but unmeasured and unquantified PICs
- Very little information is published on PFAS destruction
  - Fluorine chemistry sufficiently different than Cl that we cannot extrapolate
  - Analytical methods and PFAS standards are lacking
  - Measurements focusing on POHC destruction may miss the formation of PICs
- Hazardous Waste Incinerators and cement kilns may well be effective, but what about Municipal Waste Combustors and Sewage Sludge Incinerators (lower temperatures)?



# Incinerability & Mitigation Research

- Explore minimum conditions (temperature, time, fuel  $H_2$ ) for adequate PFAS destruction
- Investigate relative difficulties in removing PFAS functional groups (POHC destruction) vs. full defluorination (PIC destruction)
- Effects of incineration conditions (temperature, time and  $H_2$ ) on PIC emissions
- Examine relative differences in the incinerability of fluorinated and corresponding chlorinated alkyl species
- Collaborative projects with DoD, universities and industry partners to explore fundamental science questions and evaluate existing technologies
  - Investigate and add PFAS to incinerability index
  - Compare experimental and modeling results for incineration of C1 and C2 fluorinated species
  - Thermal treatment system for PFAS contaminated soils in Alaska
  - Fate of PFAS during Granular Activated Carbon (GAC) reactivation from treatment systems

- PFAS emission measurement methods are needed to inform regulatory decisions
  - Comprehensive emissions characterizations
  - Technology evaluations
  - What methods are available and appropriate?
- What kind of PFAS measurement methods are needed?
  - Ability to measure volatile/semivolatile/nonvolatile and polar/nonpolar PFAS compounds
  - Ability to measure targeted PFAS compounds and identify nontargeted PFAS compounds
- What PFAS to measure?
  - Targeted compounds?
    - Legacy (537) compounds
    - What about PFAS wastes (e.g., AFFF) constituents?
  - What about Products of Incomplete Combustion (PICs)?
- What about measurement data quality?
- Accepted emissions measurement methods for PFAS do NOT exist but are a core EPA ORD research topic





# Near-Term Deliverables

- **Fundamental Understanding of Thermal Treatment**

- List of Air Relevant PFAS Compounds
- Data on TGA/MS thermal destruction temperature points with off gas measurements, on potential defluorination, and journal article on thermal destruction temperature points and defluorination derived from report data
- PFAS Modeling: Report summarizing the feasibility and initial results of incorporating published C1 and C2 fluorocarbon kinetics into existing CFS model to predict simple PFAS behavior in incineration environments
- Low Temperature Interactions of PFAS with Sorbents: Draft research paper describing results of experimental studies examining PFAS decomposition via heterogeneous reactions with calcium species at low temperature
- Thermal Destruction of PFAS: Draft research paper describing results of experimental studies examining CF<sub>4</sub> incineration in EPA's 65 kW Rainbow Combustor

- **Efficacy of thermal treatment for a variety of contaminated media**

- Data on efficacy of lime kiln incineration of spent drinking water sorbent materials

- **Measurement methods for PFAS**

- Quantitative Assessment of Modified Method 5 Train for Targeted PFAS
- Draft Targeted PFAS Method (OTM 45) for State and source characterization use
- Development of Total Organic Fluorine methods (e.g., water, air)
- Non-targeted measurement approaches to identify PFAS compounds and support comprehensive source characterizations



# Collaborative Field Opportunities

- EPA ORD is supporting OAQPS and OLEM to provide incineration guidance as part of the National Defense Authorization Act. They have established a list of incineration and thermal treatment sources whose timely field characterization would help inform this process and provide a fundamental opportunity to better understand PFAS thermal treatment behavior in sources of regulatory interest.
- ***Specifically, these tests would seek to:***
  - Investigate how well thermal disposal processes such as hazardous waste and solid waste incinerators work for PFAS waste.
  - What temperature, residence time or other conditions are required for PFAS destruction?
  - Are products of incomplete combustion (PICs) present in process emissions and, if so, do PICs include PFAS compounds and other toxic compounds?
  - Is there a minimum level of destruction of the PFAS compound in the feed (or an appropriate surrogate compound in the feed) that ensures problematic PIC formation can be assumed to be of limited concern?
  - Investigate whether surrogate Principal Organic Hazardous Constituents (e.g. CF<sub>4</sub>, C<sub>2</sub>F<sub>6</sub>) be used in emission tests to ensure PFAS compounds would be adequately destroyed. If so, what demonstrated Destruction and Removal Efficiency would be required?



## Contact

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## Appendix C

### Calculations for HF emissions from PVDF in lithium ion batteries

**1.1** In a personal communication from someone associated with the recycling industry we learned that the percentage of PVDF by weight in the batteries is approximately 1.5%. We used this to calculate a low and high range of HF emissions from processing 1000 kg batteries per hour.

**1.2** If we assume that 50% of the F in PVDF yields HF when subjected to high temperatures and burning, we can calculate the low HF emission rate:

$1000 \text{ kg/hour} \times 1.5/100 \text{ (\% of PVDF in batteries)} \times 60/100 \text{ (\%of F in PVDF)} \times 50/100 \text{ (conversion rate to HF)} \times 20/19 \text{ (HF/F)} = 4.8 \text{ kg HF per hour, say } \mathbf{5 \text{ kg HF /hour.}}$

**1.3** If we assume 100% of the PVDF is converted to HF, then we would estimate  $2 \times 5 = \mathbf{10 \text{ kg HF/hour.}}$

**1.4** Thus, the range we would predict for HF emissions (from the PVDF constituent) would be **5-10 kg Hydrogen fluoride (HF)/hour.**

## Appendix D

In Appendix D we have done a sample calculation for the amount of HF that might be generated when burning batteries (1000 kg/hour) using a lithium hexafluorophosphate as an electrolyte.

Exact data is not readily available from online sources but we can make some ballpark assumptions.

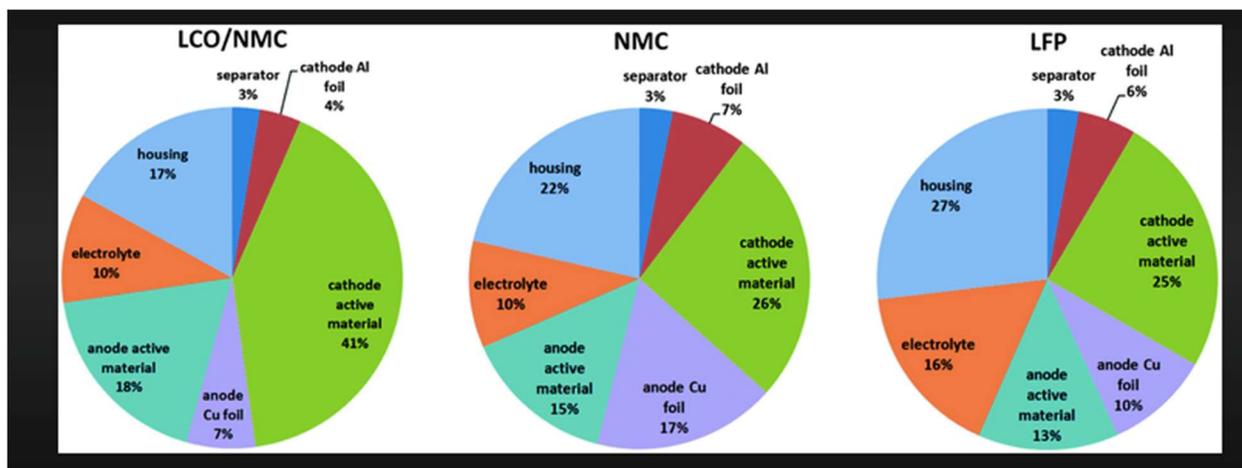
**1.1 Lithium Hexafluoro Phosphate (LiPF<sub>6</sub>).** The following assumptions were made for this ballpark calculation.

**1.2 LiPF<sub>6</sub>** is the electrolyte used in many lithium-ion batteries. In this scenario we will assume all the batteries contain this electrolyte.

**1.3** Using atomic weights, F is 75% by weight of this substance.

**1.4** If we assume that the electrolyte represents 5 % of weight of the whole battery. This is a low estimate because the pie-chart figures of several lithium-ion battery types (below) indicate that the electrolyte may be 10 -16% of the mass of three different types of lithium-ion batteries. However, there are other materials in the electrolyte including a polymer matrix, so we are assuming only 50% of the electrolyte is LiPF<sub>6</sub>.

**Figure: Images of lithium-ion battery composition of three common types**  
( see [Percentage Composition Of Lithium Ion Batteries Images - Image Results](#) )



**Legend:** LCO = Lithium Cobalt Oxide; NMC = Lithium Nickel Manganese Cobalt Oxide and LFP = Lithium Iron Phosphate (three common types of Lithium ion battery)

**1.5** We will consider two scenarios: a low (50%) and high conversion rate (100%) of the F in this material to HF during high temperature and burning processes.

**1.6** Using a 50% conversion rate:

$$1000 \text{ kg/hour} \times 5/100 \text{ (\% LiPF}_6 \text{ in battery)} \times 75/100 \text{ (\% F in LiPF}_6 \text{)} \times 50/100 \text{ (conversion rate to HF)} = 18.75 \text{ kg HF/hour} = \text{approx. } 19 \text{ kg/hour}$$

**1.7** Using a 100% conversion rate:

$$\text{the HF emissions will be } 2 \times 19 = 38 \text{ kg HF/hour.}$$

**1.8** Thus, the range of emissions of HF from LiPF<sub>6</sub> burning 1000 kg of batteries per hour would be = 19-38 kg HF/hour.

**1.9** If we combine HF emissions from both PVDF and LiPF<sub>6</sub> assuming they were both present in the same battery.

$$\text{The combined total would be: } 5 + 19 \text{ (LOW)} - 10 + 38 \text{ (HIGH)} = 24 - 48 \text{ kg HF/ hour}$$

**1.10** We believe that if we had used other fluorinated electrolytes in place of LiPF<sub>6</sub>, we would have obtained figures in the same ballpark range as this. These other fluorinated electrolytes include: lithium hexafluoroarsenate, lithium tetrafluoroborate, lithium triflate and lithium bis (trifluoromethane sulfonyl) imide

## Appendix E

- 1.1 Working from the units used in Larsson et al, 2017 we were able to deduce the following emission rates for HF for burning car-size batteries.
- 1.2 We first converted the unusual units of mg/Wh to mg/Kg using a report from Tesla which uses Lithium -ion batteries in their cars [https://en.wikipedia.org/wiki/Watt-hour\\_per\\_kilogram](https://en.wikipedia.org/wiki/Watt-hour_per_kilogram).
- 1.3 According to Tesla their batteries have an energy rating of 250 Watt-hours per kg. So, 1 Wh would be equivalent to 4 grams or 0.004 kg
- 1.4 If the F in the batteries equals 20-200 mg/Wh then that means there 20-200 mg F per 4 grams of batteries or 250x that amount per 1 kg of battery. So, that is 5000 - 50,000 mg F per kg of battery. In grams, that is 5 to 50 grams F per kg of battery.
- 1.5 If we assume all the F in the batteries is turned into HF gases and if 1000 kg of batteries were burned per hour, that means is 5,000 to 50,000 grams of HF would be released per hour, or 5 to 50 kg HF released per hour. That would equate to an emission rate of **5- 50 kg of HF/hour**.

This estimation is certainly in the same ball park range as our calculations above: **24 - 48 kg HF/hour**, in which we were forced to use a number of crude assumptions

## **Appendix F**

### **Converting 5-50 kg HF per hour into ppm F**

1. If the flow rate in the facility is approximately 6000 standard cubic feet per minute.
2. 6000 cubic feet = 170 cubic meters.
3. 60 minutes in an hour, so about 10,000 cubic meters per hour
4. 10,000 cubic meters weighs about 13,000 kg
5. 5 kg per 13,000 kg is a concentration of about 380 ppm
6. 50 kg per 13,000 kg is a concentration of about 3800 ppm