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TETRA TECH
High Performance Buildings Group

BESS – Battery Failure Plume Assessment

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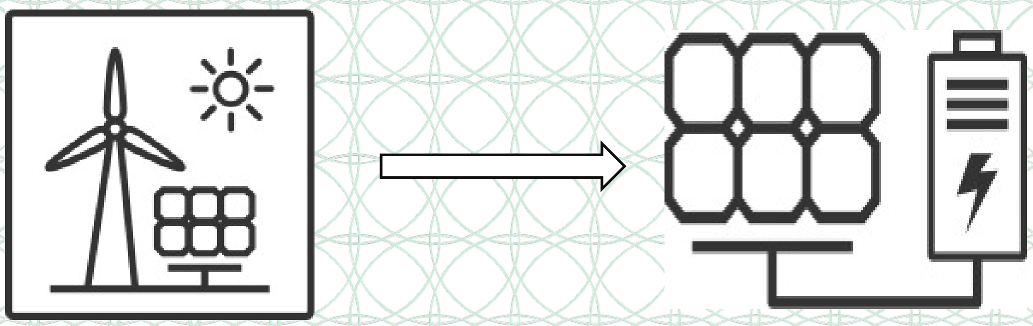
What is BESS?

Why is it Important?

Battery Energy Storage System (BESS)

- Stores energy from renewable sources for use when needed
- Supports net zero targets / aiming for a more sustainable future
- Enhances National Grid security and stability
- Maximises potential of renewable energy sources
- Reduction of energy costs



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Battery Failure Risks.

Thermal Runaway & Fires.

Different types of batteries are used in different BESS systems, here we consider:

LFP = Lithium iron phosphate Batteries $LiFePO_4$ – HF emissions are highly toxic

Lithium hexafluorophosphate ($LiPF_6$) **common electrolyte used in various Li ion battery types** decomposes to HF:

$$LiPF_6 \rightarrow LiF + PF_5$$

$$PF_5 + H_2O \rightarrow POF_3 + 2HF$$

$$LiPF_6 + H_2O \rightarrow LiF + POF_3 + 2HF$$

Thermal runaway occurs when the battery cells enter an uncontrolled self-heating state, resulting in high temperature, leading to potential ignition which can result in the emission of potentially hazardous gases including a mixture of hydrocarbons, carbon monoxide and hydrogen, which are **dependent on the battery type in use**.

Should ignition be initiated, the uncontrolled release of toxic gases is a potential risk to nearby receptors

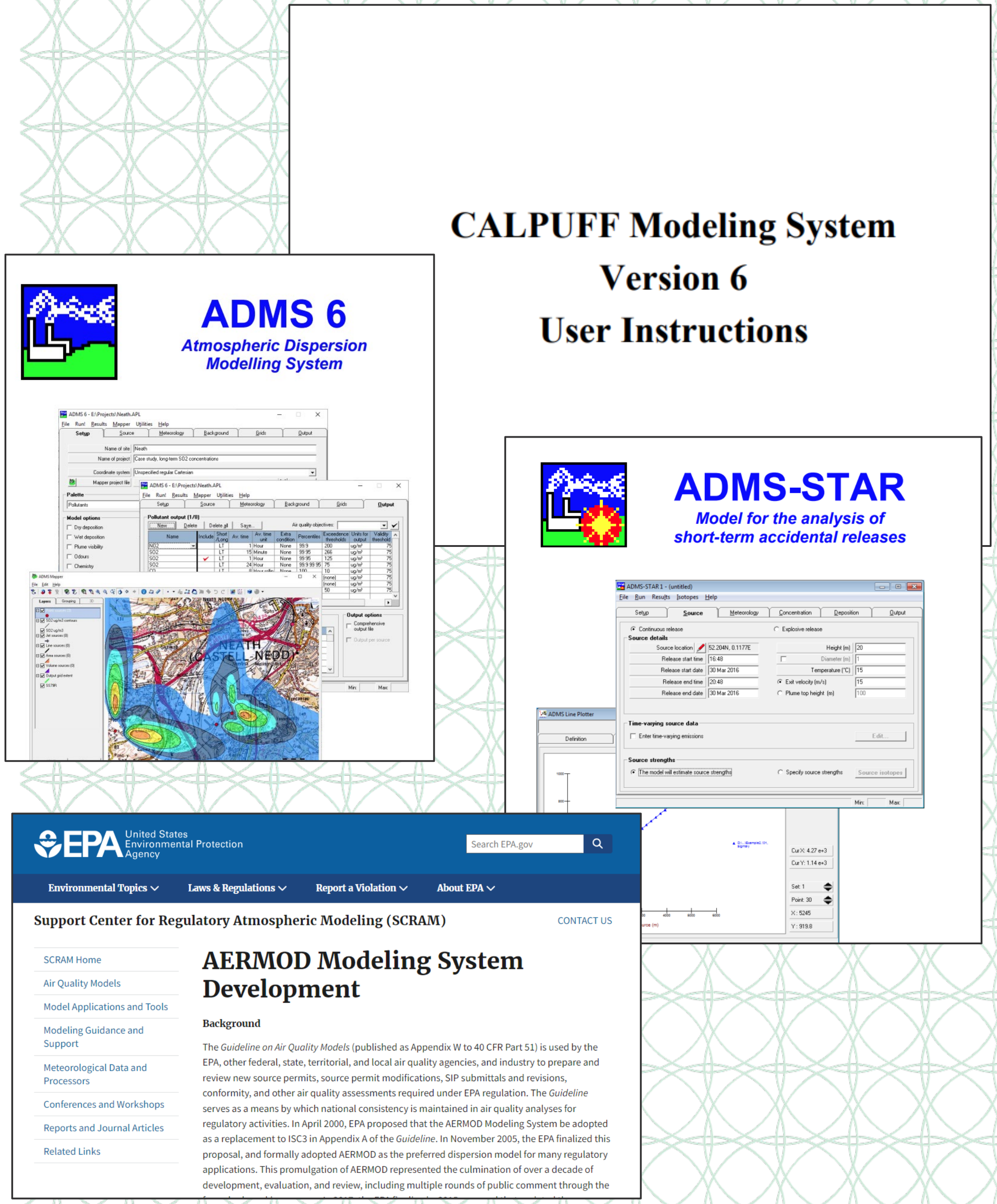
BESS Battery Type	Description
LFP	Lithium iron phosphate
LCO	Lithium cobalt oxide
NCA	Nickel Cobalt Aluminium Oxide
NMC	Lithium Nickel Manganese Cobalt Oxide

Dispersion Models

What to use?

Modelling for local assessment and to inform Battery Safety Management Plans (BSMP).

- Accidental release
- Consideration in terms of complex terrain, distance from coast, etc…
- Assessment of risk for a potential event that has not occurred
- Impact is local – less than a few kilometres from source
- Generic stability class meteorology or sequential meteorology
- ADMS-6 for this assessment



Modelling Approach

Scenarios and Pollutants

Area source: represents the emissions distributing equally across the top of the container at the peak flame height

Volume source: Cannot specify gas velocity or temperature

Assessment criteria – AEGLs for HF

HF emission plumes have been assessed as HF has high toxicity and some level of information on emission rates is available.

1 hour averaging period

AEGL Level	HF Concentration (ppm)
1	1
2	24
3	44

Modelling Approach

Scenarios and Pollutants

Robust approach: 100th percentile or Peak concentration – worst case meteorological conditions over 3 years

- Assessment of a “made up” scenario.
- Non-reactive emissions
- Testing source input parameters only

The scenario considered involves a single battery container of interest (20m² area).

Modelled emission rate of 1 g/s equates to

Area Source – 0.05 g/m²/s

Volume Source – 0.0143 g/m³/s

Assessment is undertaken to understand the likely credible and worst-case credible scenarios.

Sensitivity Analysis

Scenarios

Scenario no.	Source Type	HF emission rate	Temperature (°C)	Gas velocity (m/s)
A	Volume	0.014 $g/m^3/s$	15*	N/A*
B	Area	0.05 $g/m^2/s$	15	0.01**
C			25	0.01**
D			200	0.01**
E			400	0.01**
F			800	0.01**
G			800	0.1
H			800	1.0
I			800	2.0

*A limitation of volume source is that you cannot specify the temperature (set to default of 15°C) or the gas velocity (fixed at 0 m/s)
**A non-zero gas velocity must be specified to make sure plume rise is considered for thermal buoyancy effects

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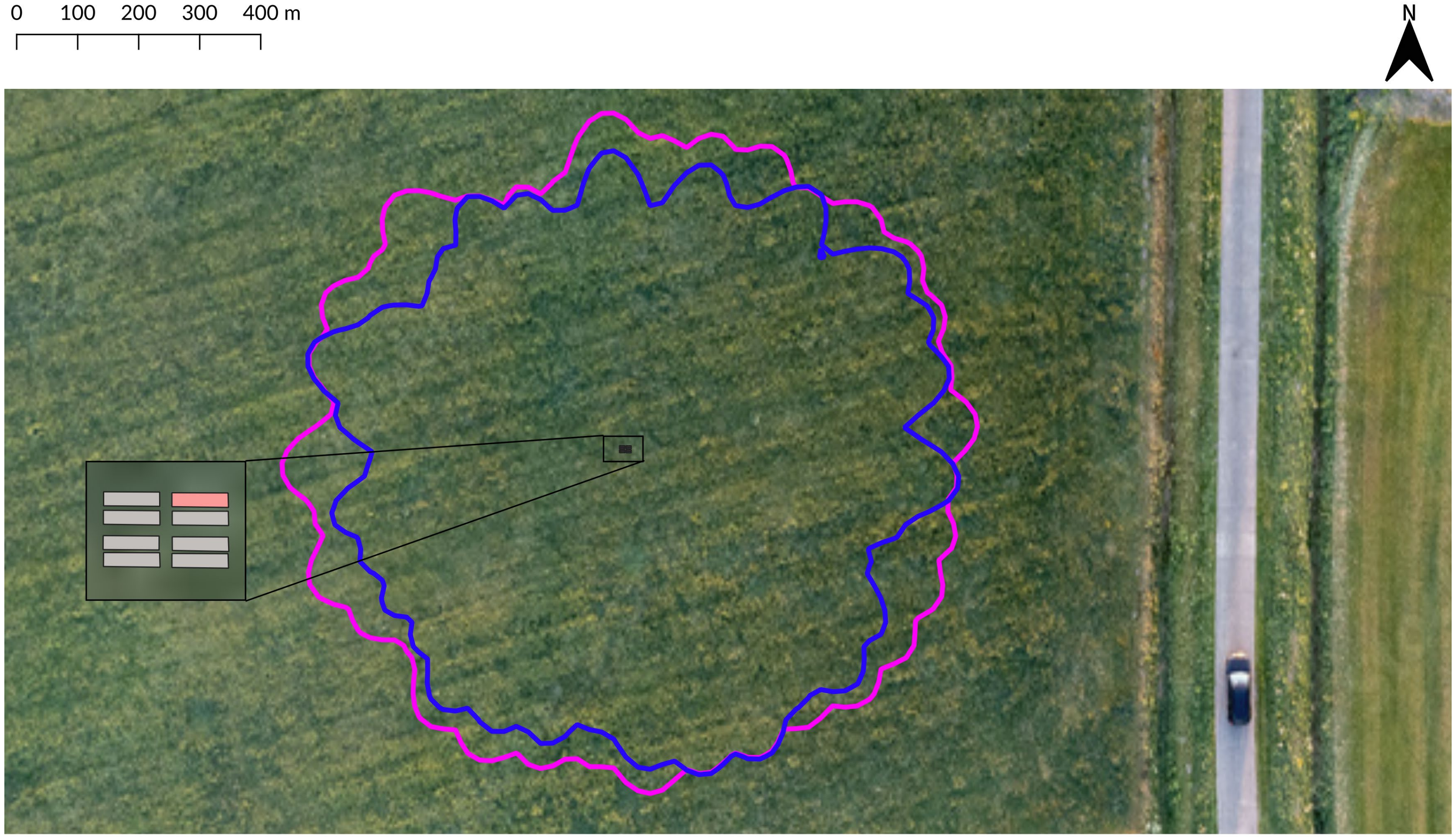
Plume Contour Comparisons

Area vs Volume Source at 15°C



Legend

Battery Container of Interest Battery Containers Area source (0.01 m/s velocity) Volume source

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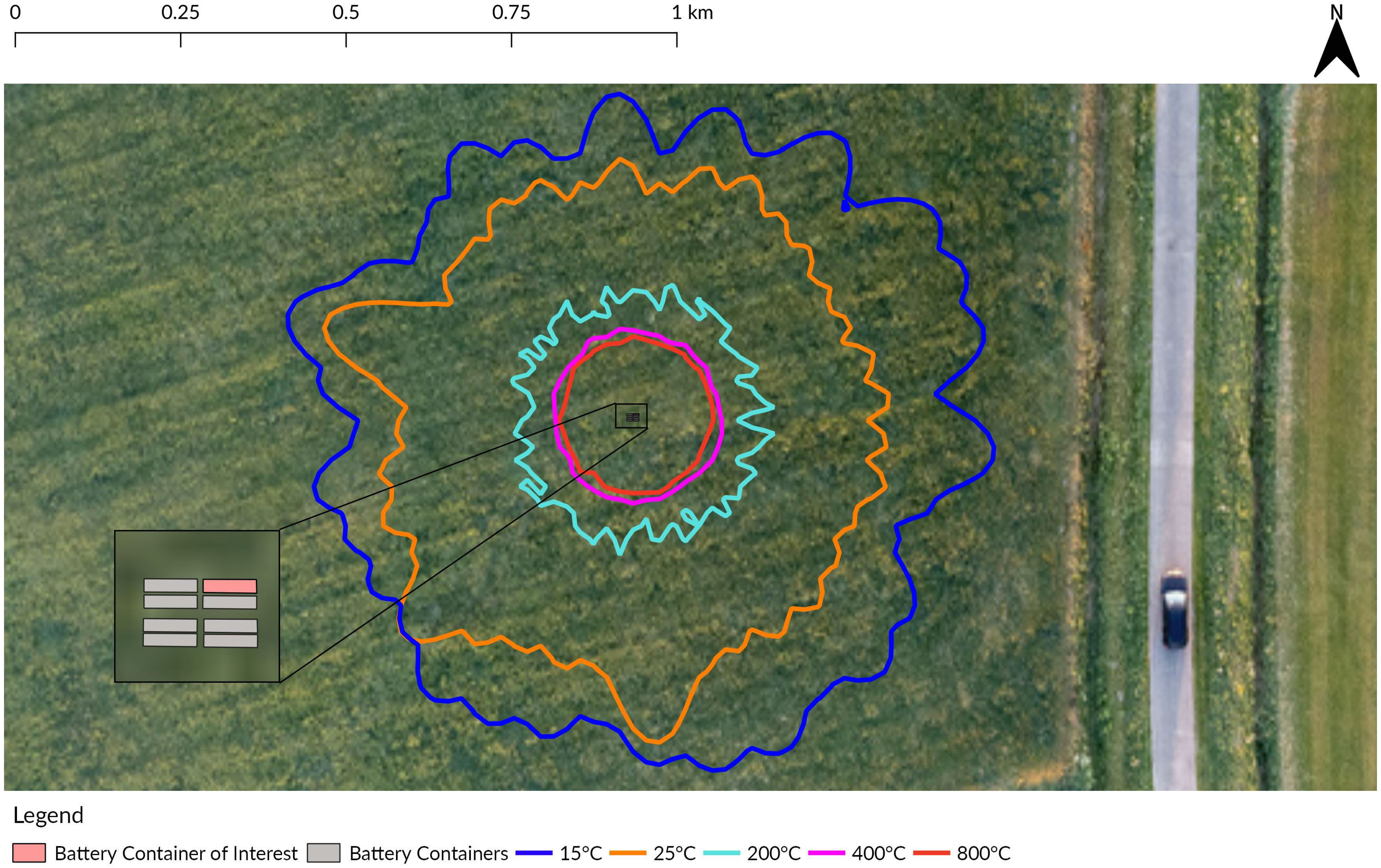
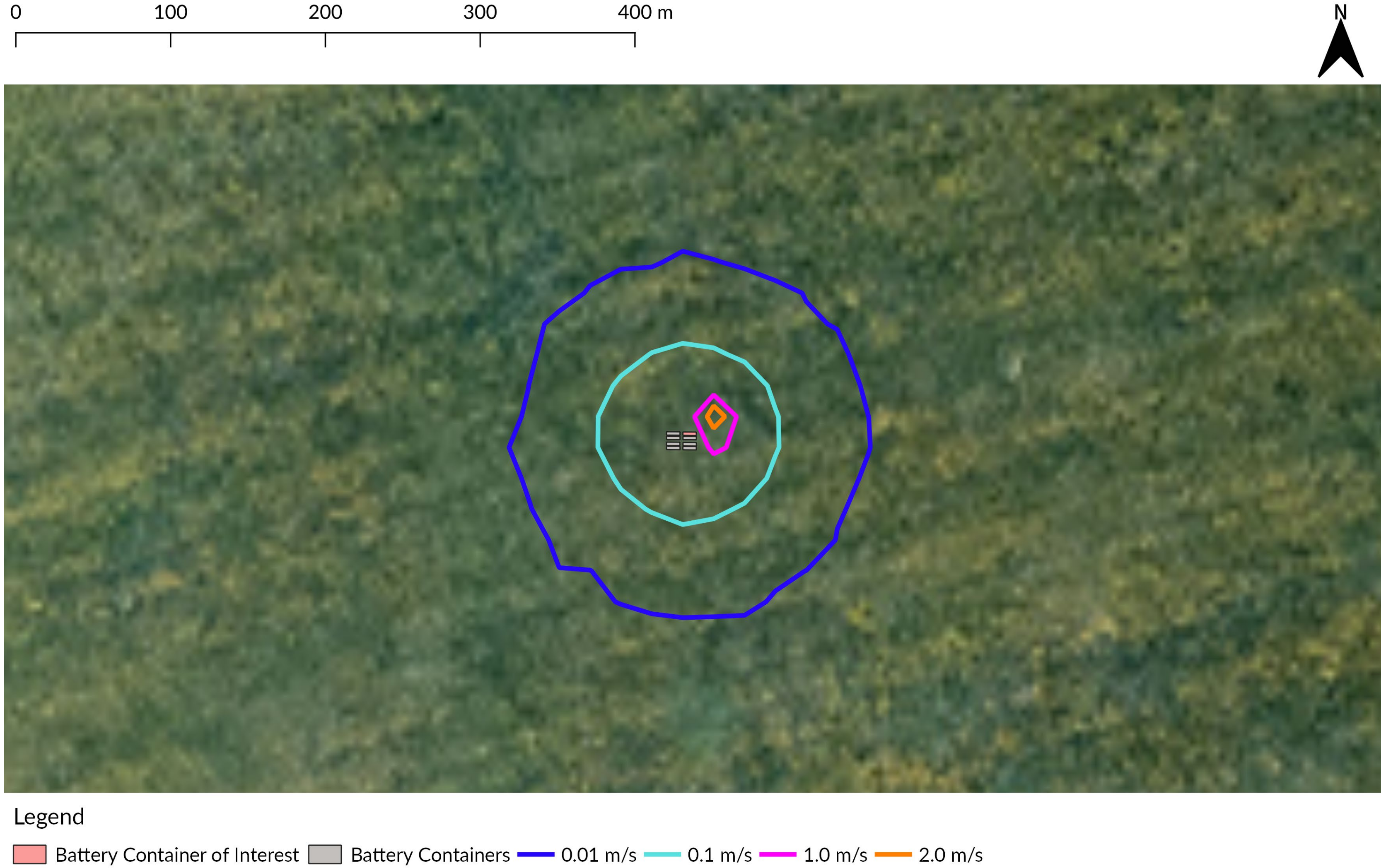
Plume Contour Comparisons

Increase in Temperature at 0.01 m/s Gas Velocity



Plume Contour Comparisons

Increase in gas velocity at 800°C



Plume Contour Comparisons

Area with Parameters vs Volume Source

Legend

Battery Container of Interest · Battery Containers · Volume source · Area source (800°C, 1.0 m/s velocity)

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Sensitivity Analysis Results

Parameter Influence

1. Small difference in area vs volume source at the same temperature and gas velocity.

2. Increase in gas velocity → Increase in vertical momentum of gas → Increase dispersion

3. Increase in temperature → Increase in gas buoyancy → Increased dispersion

4. Large disparity in plume dispersion with the use of area source with parameters vs volume source.

Modelling Limitations.

Limitations

- Source of input data is crucial – ideally emissions data from full burn test of battery specification itself can be used in calculating gas emission rates.
- In absence of test data, the HF emission rates, fire temperature and gas velocity from literature can be used.
- Professional judgement and experience is key to assess whether the data available is representative of the fire scenario and decide what assumptions will be made.

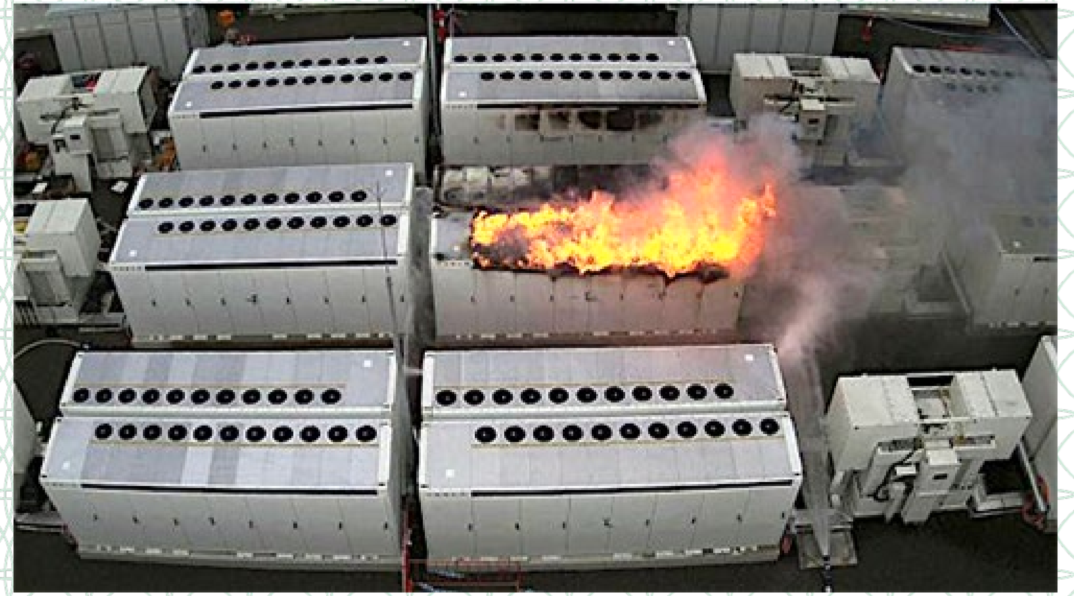
Moving forward…

New Assessment - Lack of emission rate data during manufacturer fire testing of batteries

More detailed testing of battery under forced fire conditions are being asked for from the battery manufacturers, as such, data availability should improve over time to improve the inputs for representative models.

Summary

- BESS is an important technology for energy storage, particularly from renewable sources.
- There is a risk of fire which can impact human health.
- In absence of regulations & key guidance – best approach is to represent a reasonable worst case assessment.
- Model inputs are critical - quality and quantity of data available (battery manufacturer module free burning test data)
- Model a reasonable worst-case, based on information provided by the client on level of risk and professional experience.



Estero Bay News - Questions Over Battery Plants After Moss Landing Incident

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Thank you.
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