

IWMA 2026

Suppression of Battery Energy Storage System Fires

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Tian Li^a, Kristian Hox^a

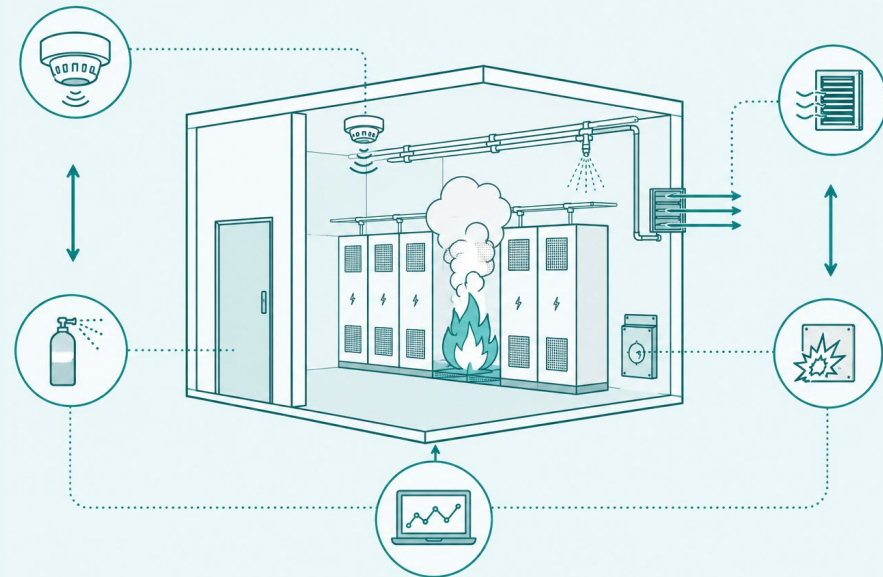
^a RISE Fire Research
^b SINTEF Energy Research



2026 **IWMA**
International Water Mist Conference

Investigate **interactions** between **suppression, ventilation, detection, and explosion protection** systems in a battery room...

to address the lack of fire safety data for **building-integrated BESS**.

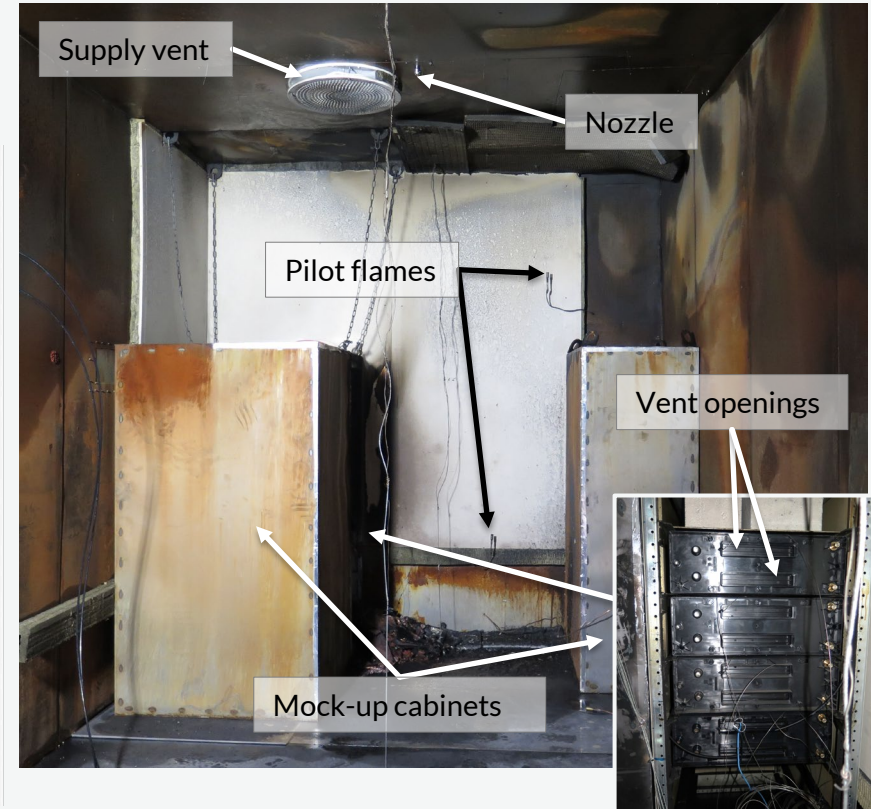
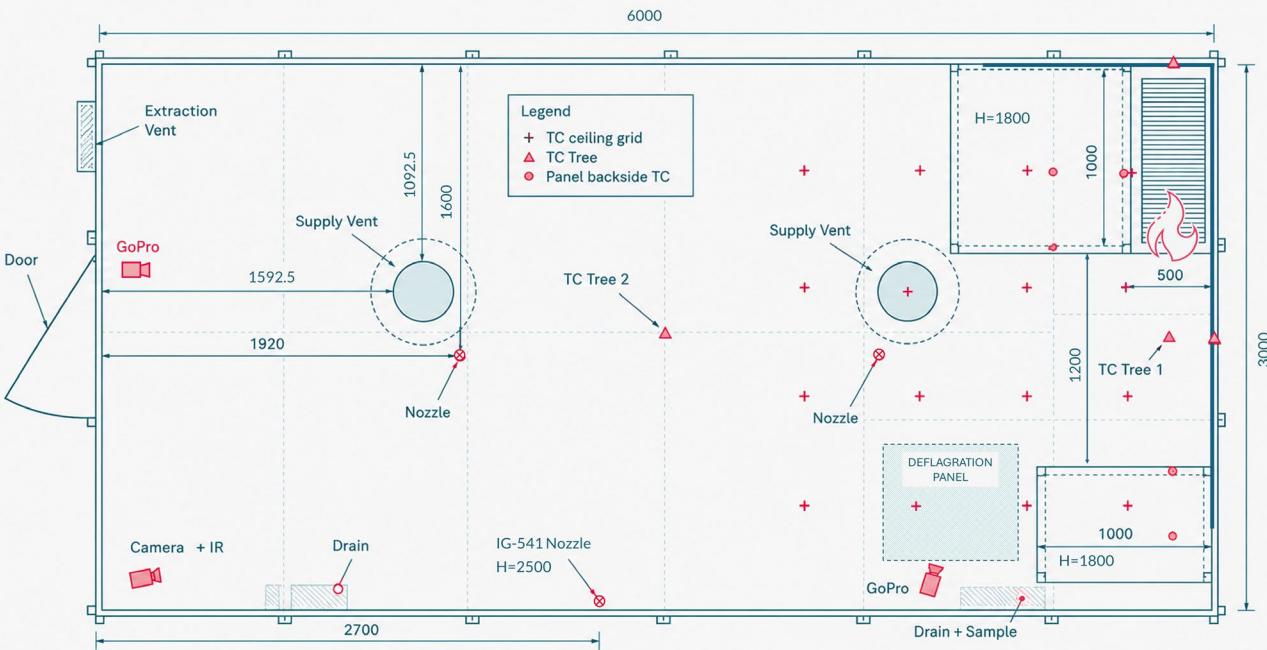


The Battery Rom

- **Dimensions:** 3 m × 6 m, H = 3 m
- **Steel panels:** 1 mm thick
- **Ventilation:** Independent supply and exhaust fans
- **Pressure relief:** door and roof panel
- **Water supply:** Two ceiling-mounted nozzles
- **IG-541 gas supply:** One nozzle installed in a side wall
- **Drainage connection:** Drainage system with a water sampling pump



The Battery Rom



The Battery System

Battery cabinet

- Dimensions: **0.5 m × 1 m × H=1.8 m**
- Installed capacity: **26.4 kWh**
- Module arrangement: **4 modules installed, 5 empty slots**



Illustration based on <https://www.directindustry.com>

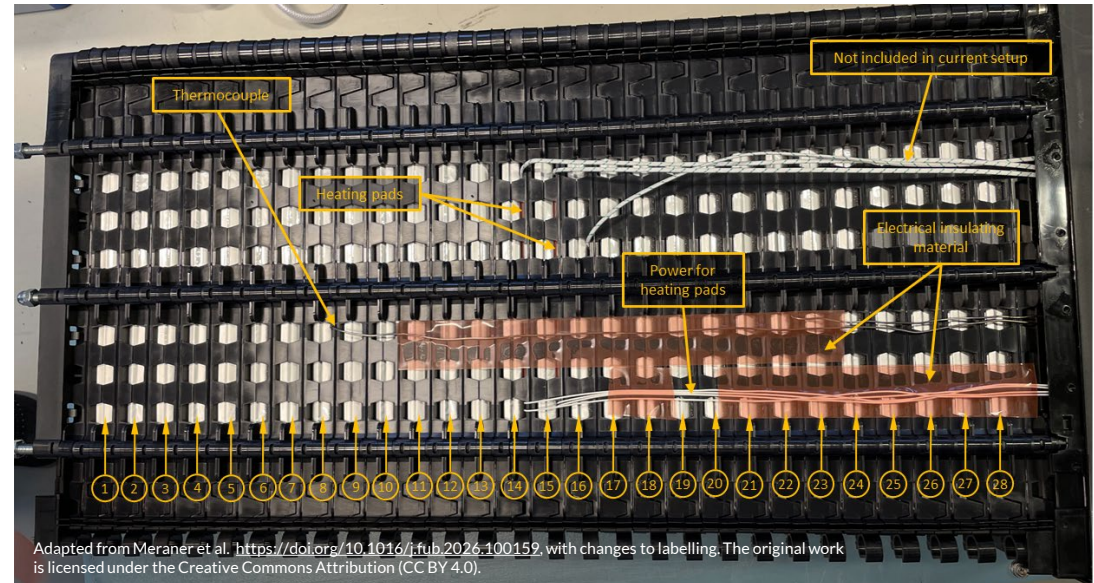


Battery Modules

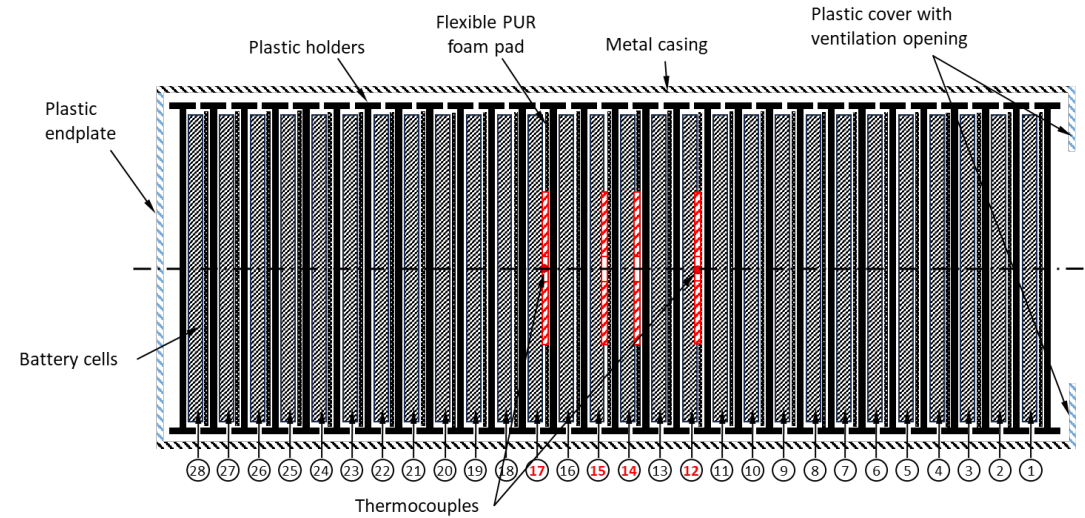
- Capacity: **6.6 kWh**
- Cell arrangement: **28-cell array**

Battery Cells

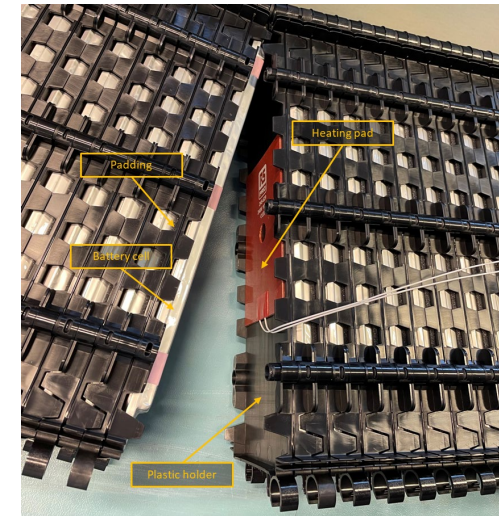
- Cathode: **NMC** (Nickel Manganese Cobalt Battery)
- Form factor: **Pouch**
- Capacity: **64 Ah**



Trigger Method^[1]



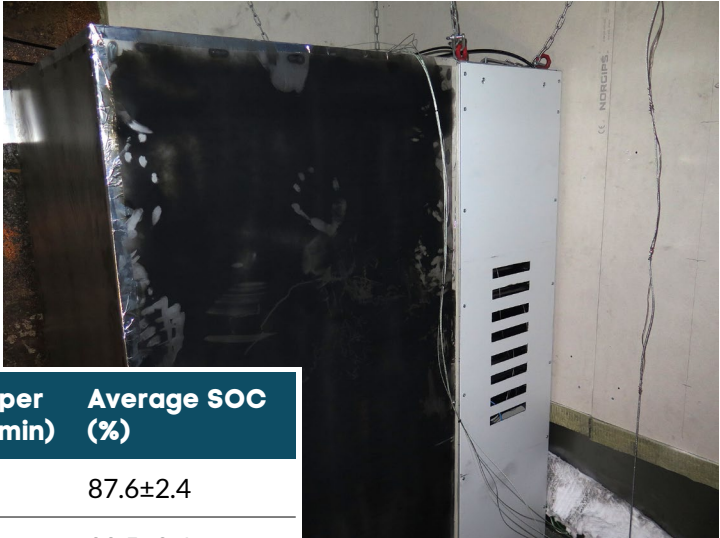
- **Heating multiple cells** with heating pads has consistently triggered **cell-to-cell thermal runaway (TR) propagation**.
- Overcharging of one or two cells will not lead to propagation.
- The initial **cell-to-cell propagation within internal cells is unaffected by** the presence or absence of **external flames**.



[1] C. Meraner, et al. "The effects of different trigger methods on thermal runaway propagation in a 6.6 kWh lithium-ion pouch-cell battery module," Future Batteries, vol. 9, Feb. 2026. <https://doi.org/10.1016/j.fub.2026.100159>

Adapted from Meraner et al^[1] (CC BY 4.0)

Experimental Scenarios



#	Name	ACH (1/h)	Supply/Initial temperature (°C)	K factor (L/min/ $\sqrt{\text{bar}}$)	Water pressure (bar)	Flow rate per nozzle (L/min)	Average SOC (%)
1	Venting*	62	0.9	N/A	N/A	N/A	87.6±2.4
2	Freeburn	27	49.3	N/A	N/A	N/A	92.5±2.4
3	HP WM	28	51.3	5.1	50.4	36.2	90.6±3.2
4	IG-541	N/A	9.9	N/A	N/A	N/A	94.7±1.7
5	LP WM	29	51.3	8.5	8.5	39.0	93.7±1.5
6	Sprinkler	29	47.5	1.5	1.5	97.6	94.3±2.5

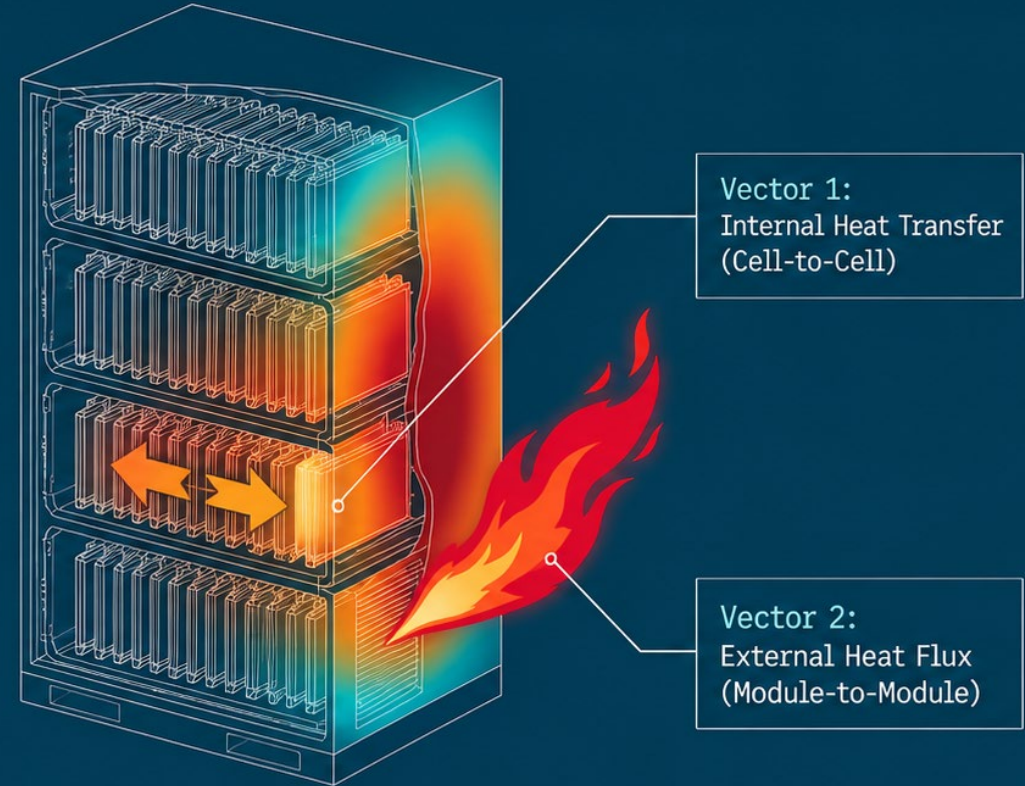
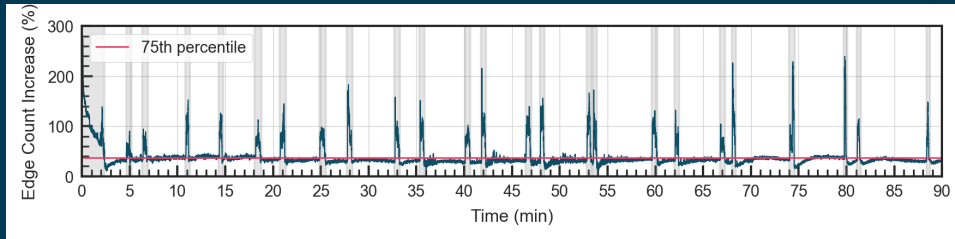
N/A = not applicable.

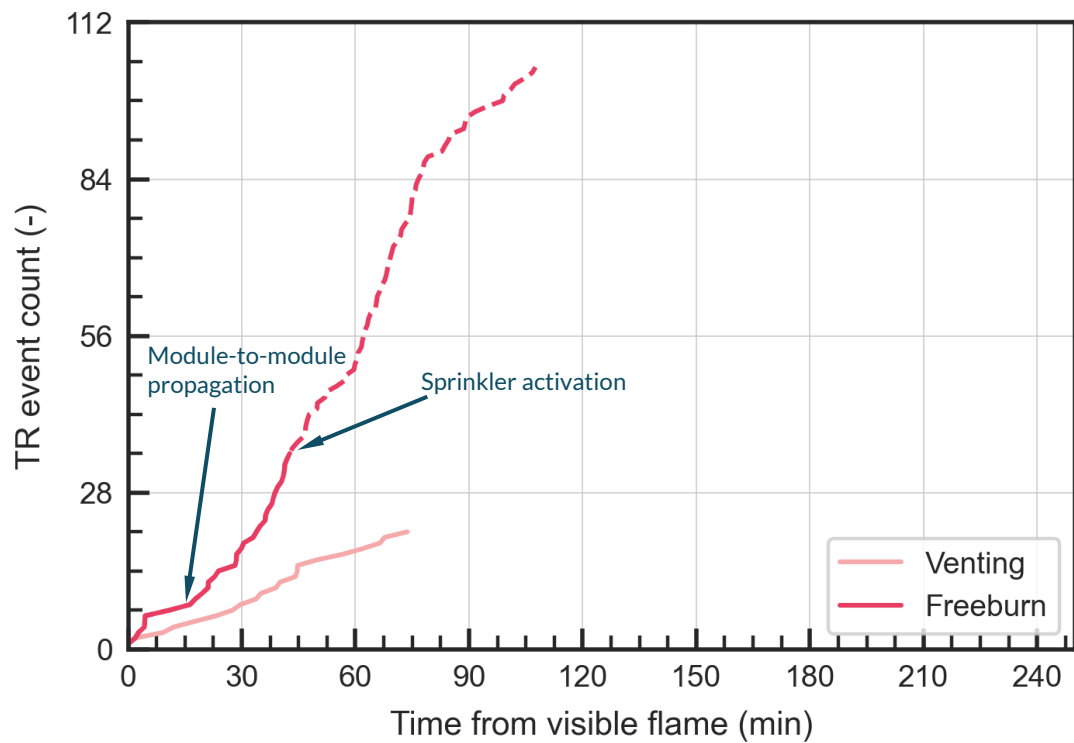
* After the first experiment, the cabinet's front panel was removed, ACH were reduced, and the supply air was preheated.



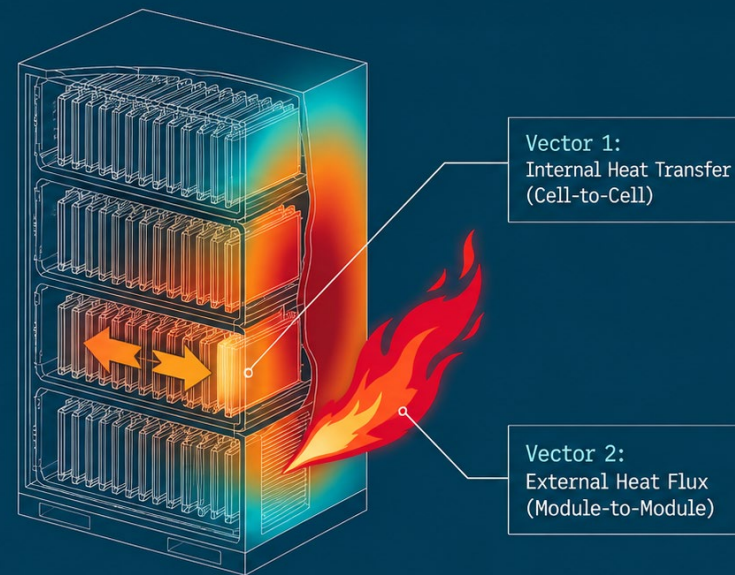
Thermal Runaway Cascade

- Cell-to-cell and module-to-module **TR propagation** are highly **specific to the BESS design**.
- **Heat transfer between cells and modules**, as well as heat transfer from **external flames** contribute to TR propagation.





Thermal Runaway Cascade





Freeburn



IG-541



HP WM



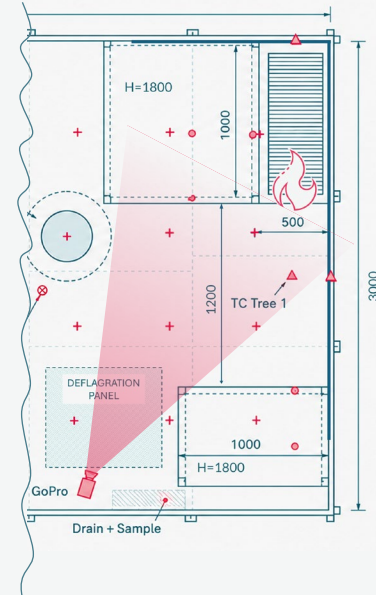
LP WM



Sprinkler

Playback speed: 1x
Suppression: Off

SRC TC: 01:00:00:00



03-17-2025 14:28:07

RI
SE



RISE Fire Research

RISEFR-1653

03-17-2025 14:28:08



REC TC: 00:41:48:04

RISE Fire Research

RISEFR-1638

03-17-2025 14:28:07



>158.0°C

130.4°C

RISE Fire Research

RISEFR-1653-IR

03-17-2025 14:28:08

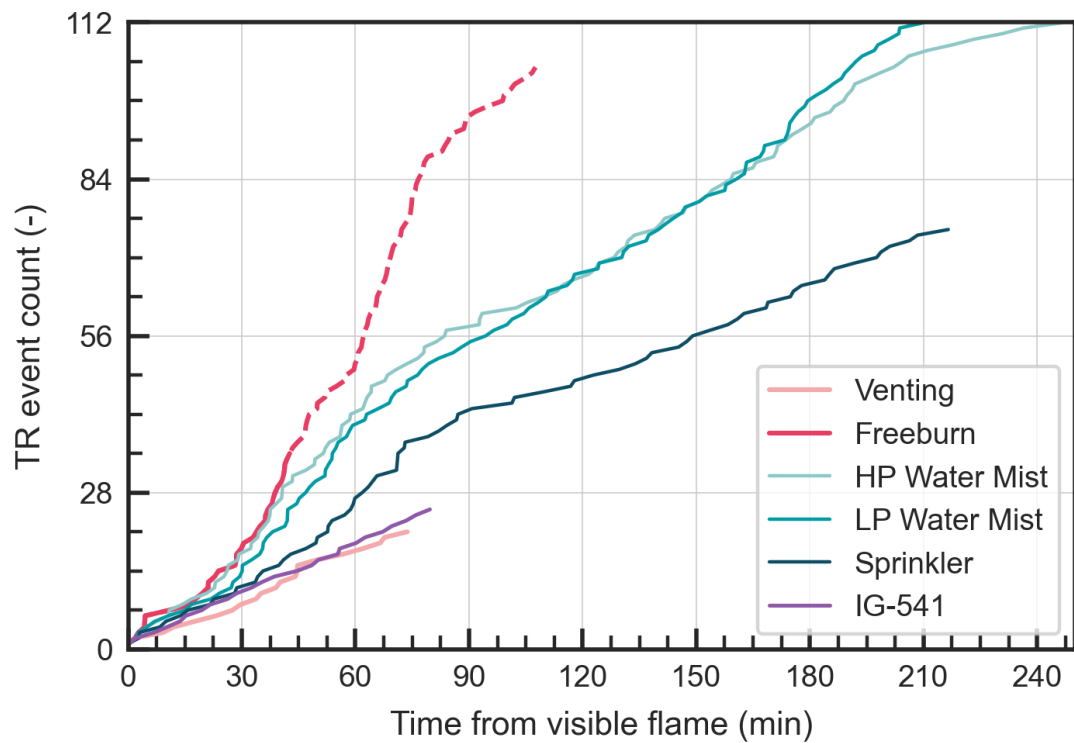


503.8°C

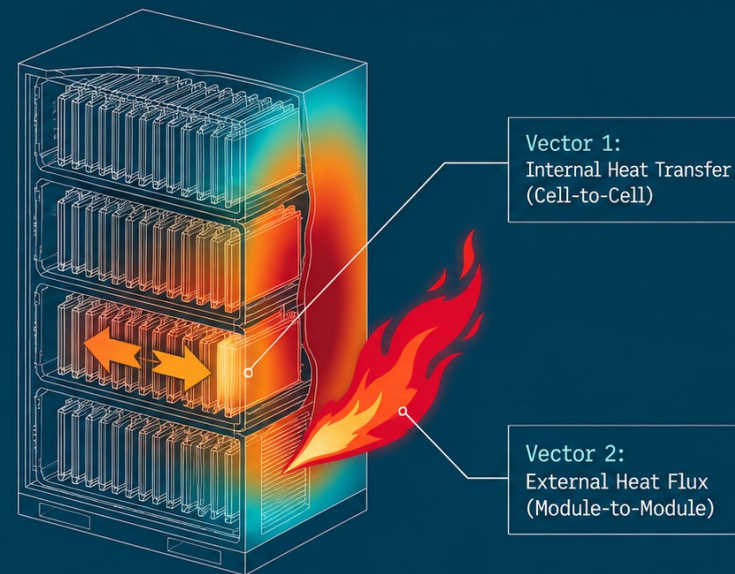
27.5°C

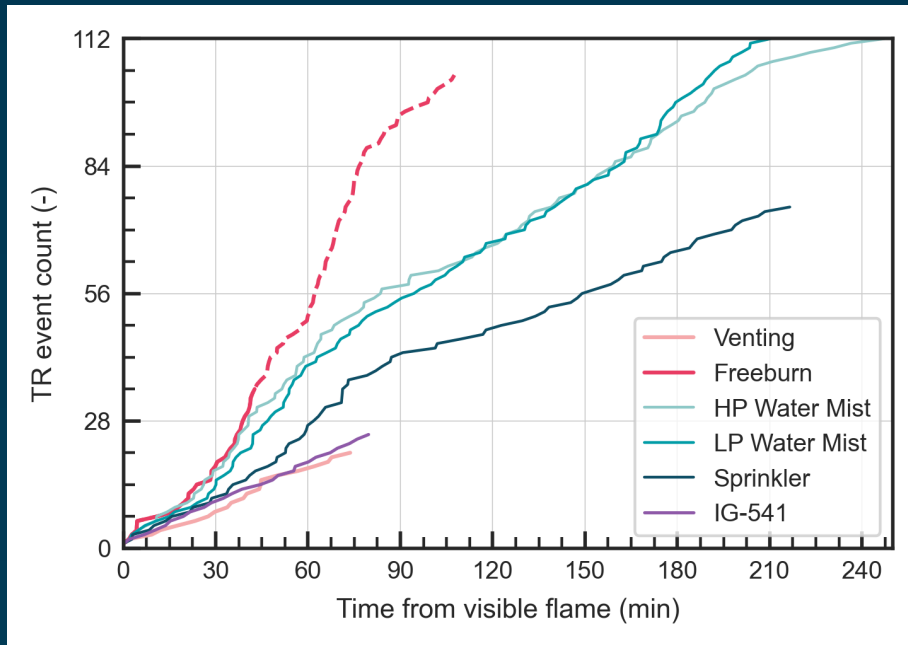
RISE Fire Research

RISEFR-1638-IR



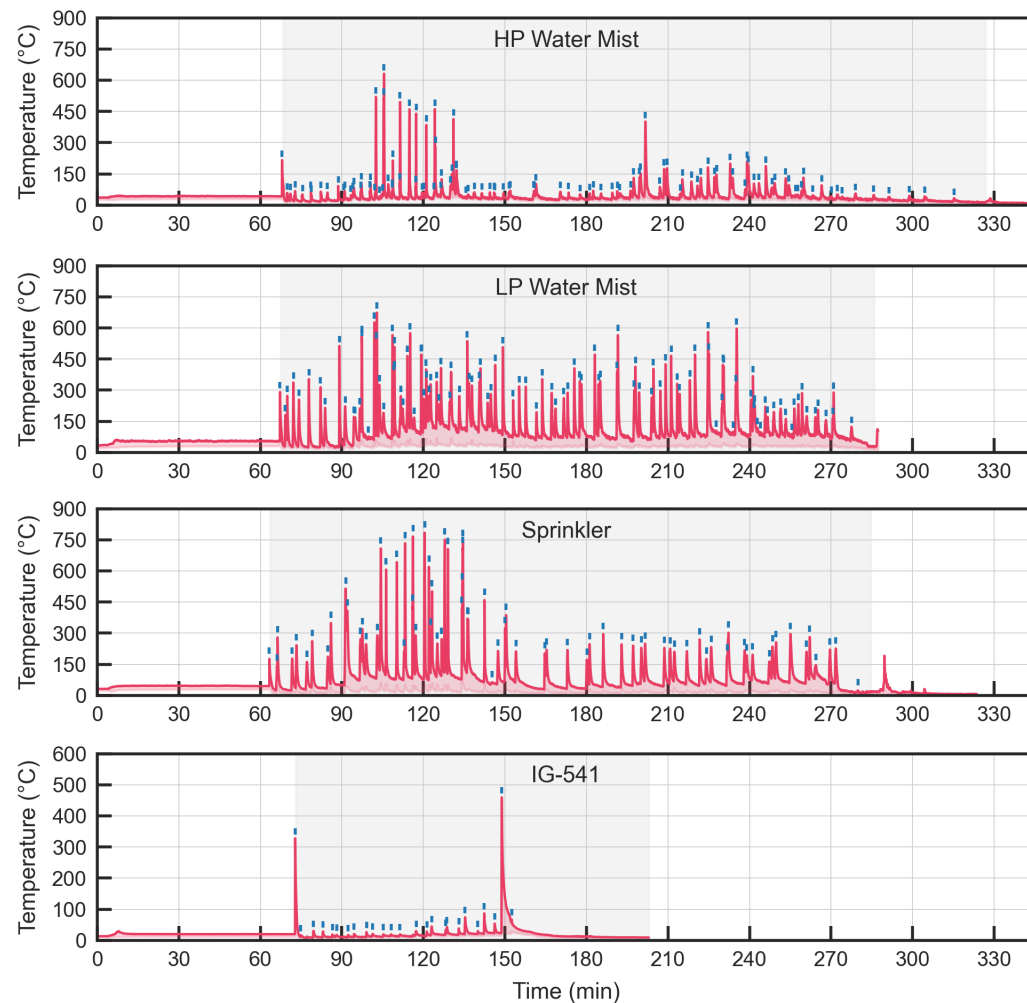
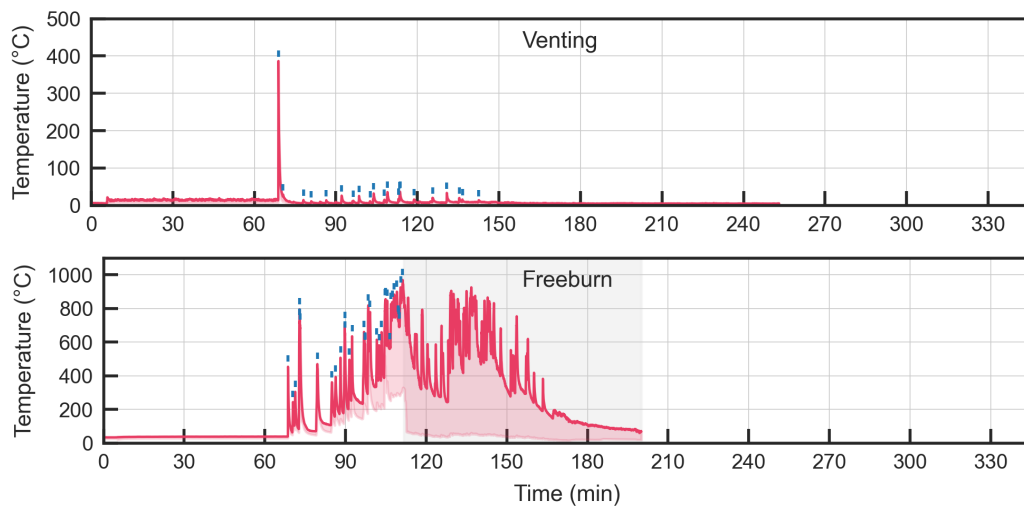
Thermal Runaway Cascade



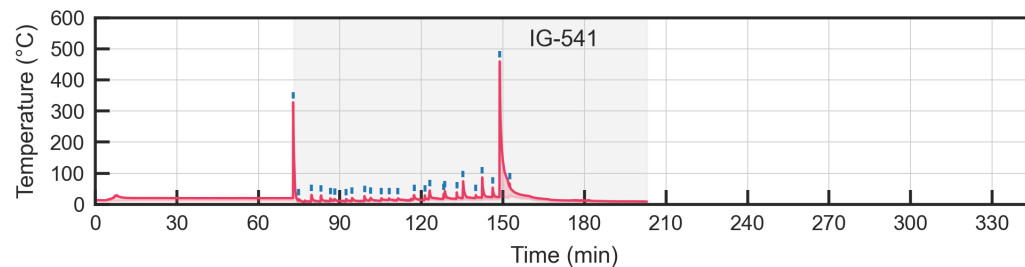
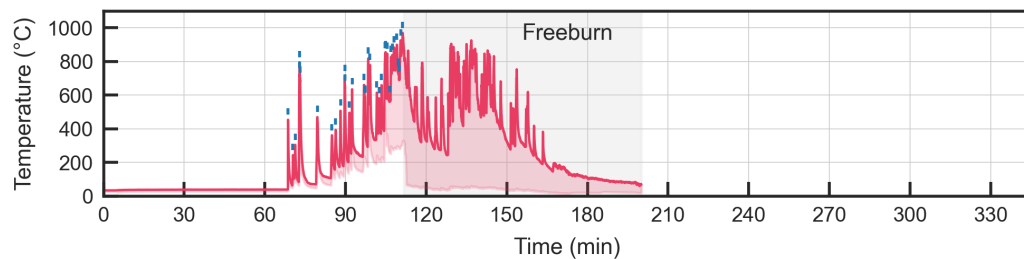
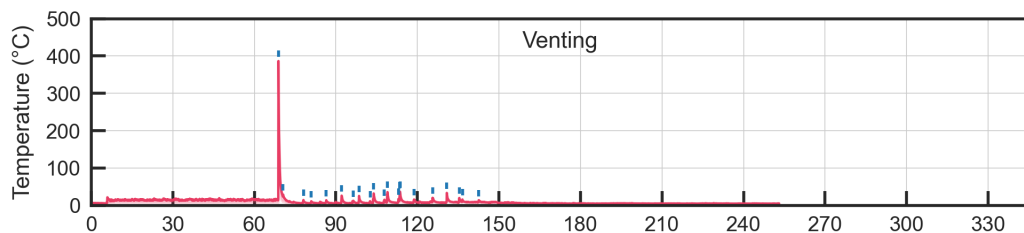
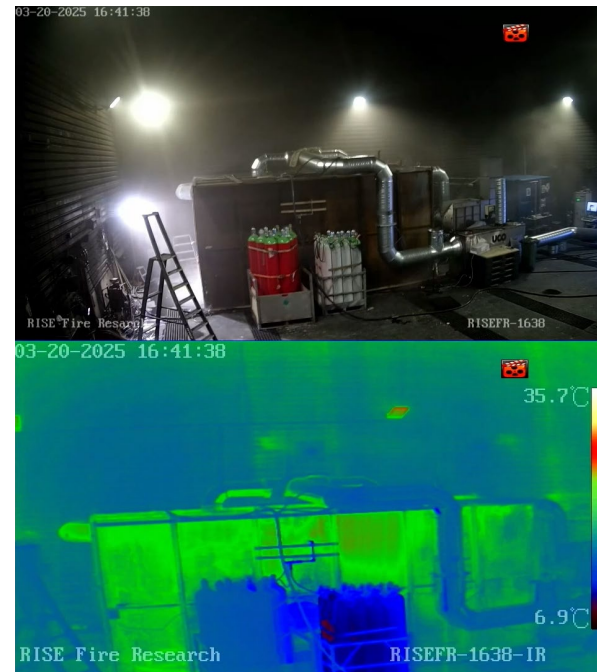
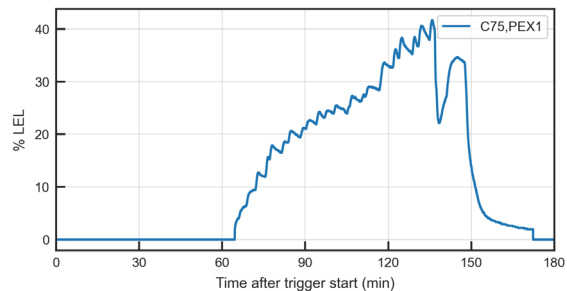


- It is likely that **multiple modules** are **involved** in the TR, even **before all cells in the first module** have been burned out.
- **Heat exposure to multiple modules** drives cascading failures and **must be prevented**.
- The wall temperatures of the **target mock-up units**, adjacent to and opposite the trigger battery unit, **significantly exceeded the TR onset** temperature during **Freeburn**.
- Sprinkler, HP WM and IG-541 would have **likely prevented unit-to-unit propagation**.
- The **adjacent target unit exceeded 400 °C** for ~30 minutes during the LP WM experiment, peaking at 520 °C.

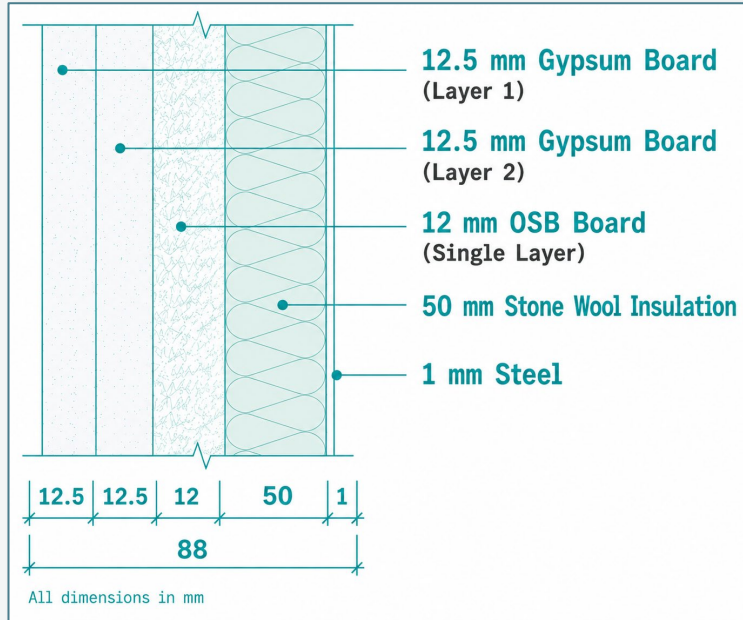
Rom temperature development



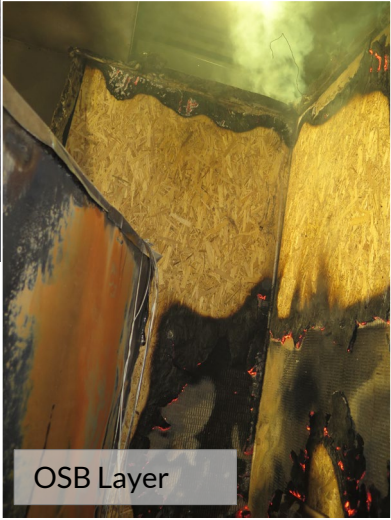
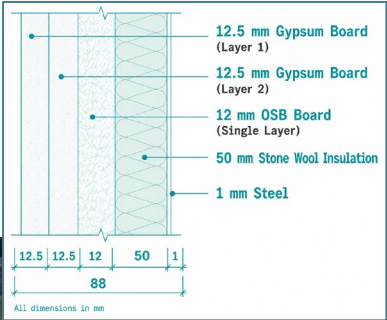
Rom temperature development



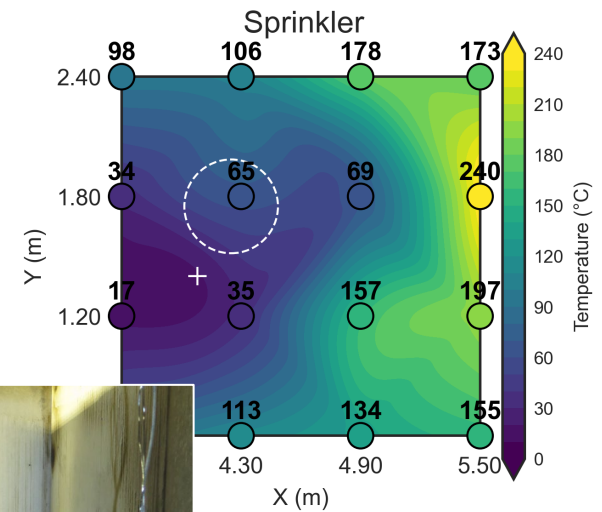
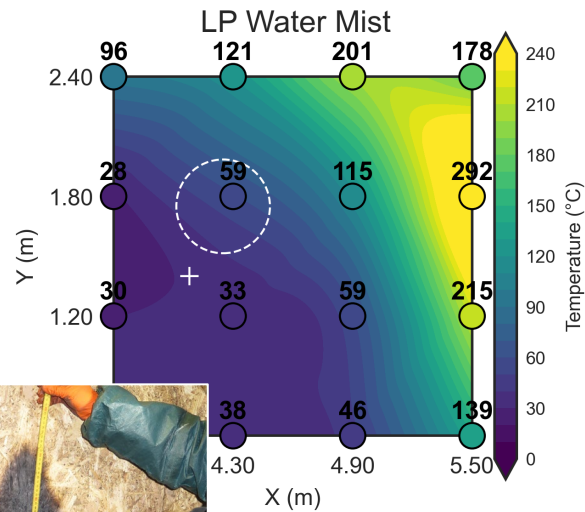
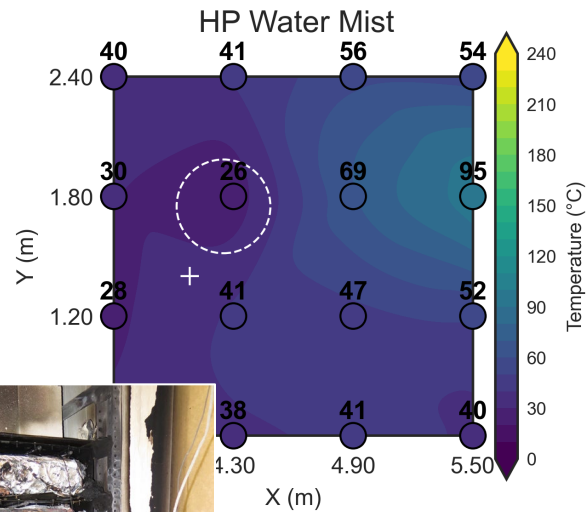
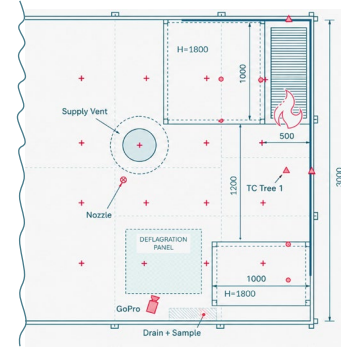
Wall construction for Damage Assessment



Freeburn - Damage Assessment



Suppression - Damage Assessment & Ceiling Layer Cooling



Suppression systems

Water based systems

- **Suppression systems can limit external TR propagation** (module-to-module/unit-to-unit) and **reduce damage**.
- **Performance depends on battery design;** internal cell-to-cell propagation is difficult to stop.
- Water based systems **do not address the explosion risk**.
- Contaminated **firewater run-off** needs to be treated as **hazardous waste**. Suppression systems that use less water are preferred.

Inert gas systems

- Can address both **explosion and fire risk** simultaneously.
- **Key challenge: Hold time** must last until thermal runaway has fully ceased.
- **Ideally**, inert conditions must also remain **until ignition sources are eliminated**.
- Any **post-event ventilation** should avoid reintroducing oxygen.

System Selection

Which suppression system is best suited for a specific project depends on the battery design, ventilation strategy and detection system.

Acknowledgement

The SAFE-BESS project, funded by the Norwegian Research Council (no. 336592) and partners, is acknowledged for financial support and for allowing the publication of the experimental data.



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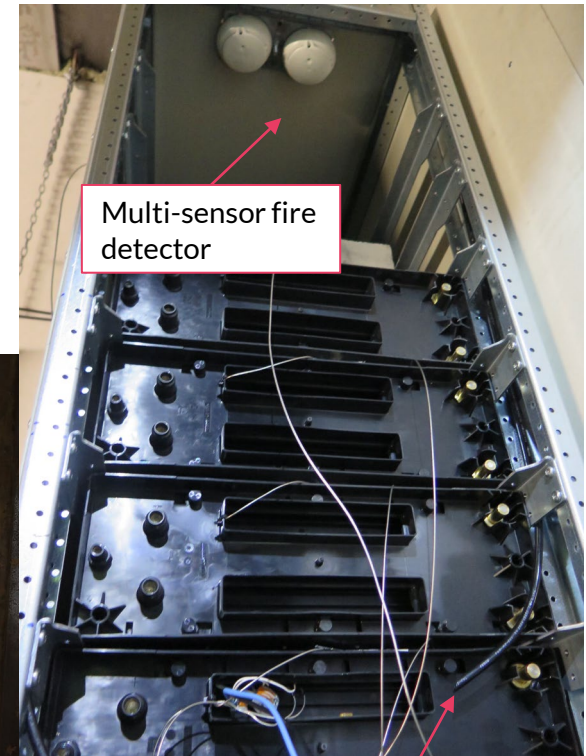
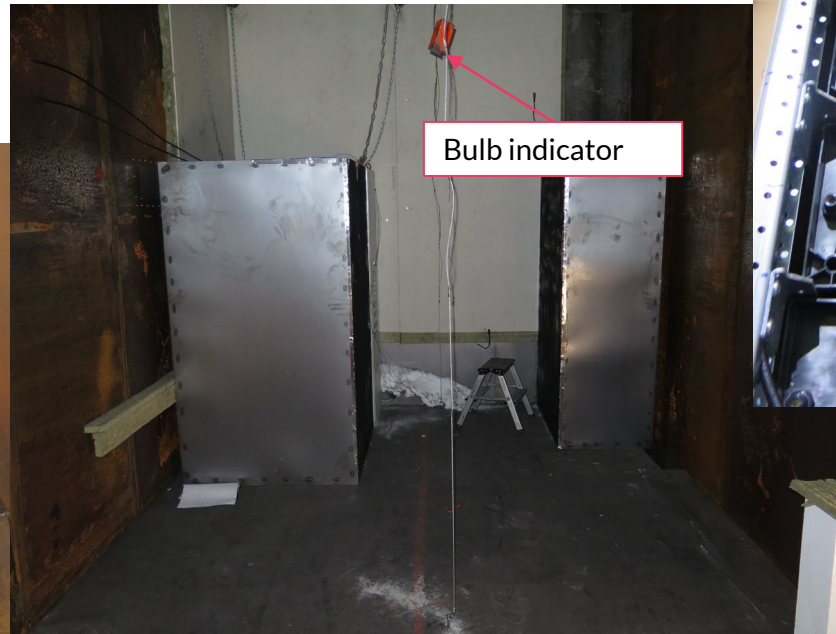
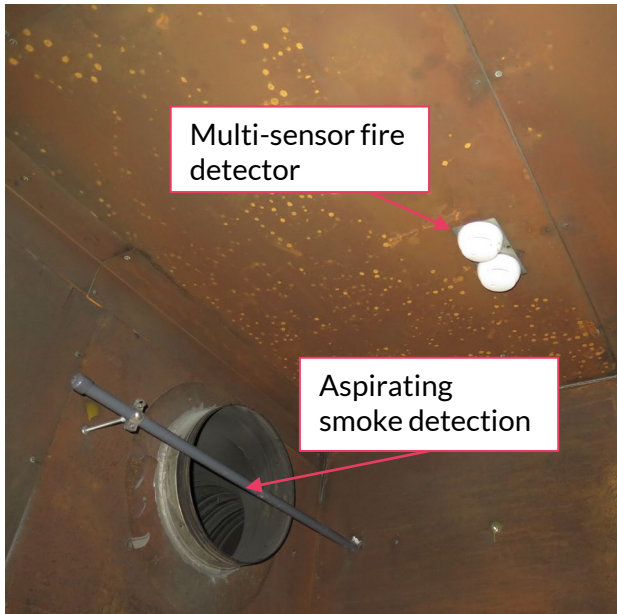
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Link to the open-access publication:
<https://doi.org/10.1016/j.firesaf.2026.104727>

Detection Systems

- BMS for Siemens Energy Batteries
- Thermocouples inside batteries



Aspirating
smoke detection

Detection time relative to the first visible thermal runaway [mm:ss]

#	Name	Detection based on cell temperature	Aspirating smoke detector	Multicriteria detector cabinet	Multicriteria detector rom
1	Venting*	-23:25	-22:56	-5:36	0:28
2	Freeburn	-19:11	-18:52	0:12	0:13
3	HP WM	-17:47	-17:26	0:09	0:14
4	IG-541	-19:32	-18:04	0:14	0:14
5	LP WM	-6:37	N/A	N/A	N/A
6	Sprinkler	-7:18	N/A	N/A	N/A

*After the first experiment, the cabinet's front panel was removed, ACH were reduced, and the supply air was preheated.

The expected **bulb activation time** based on the Freeburn test is **4 min 23 sec**.

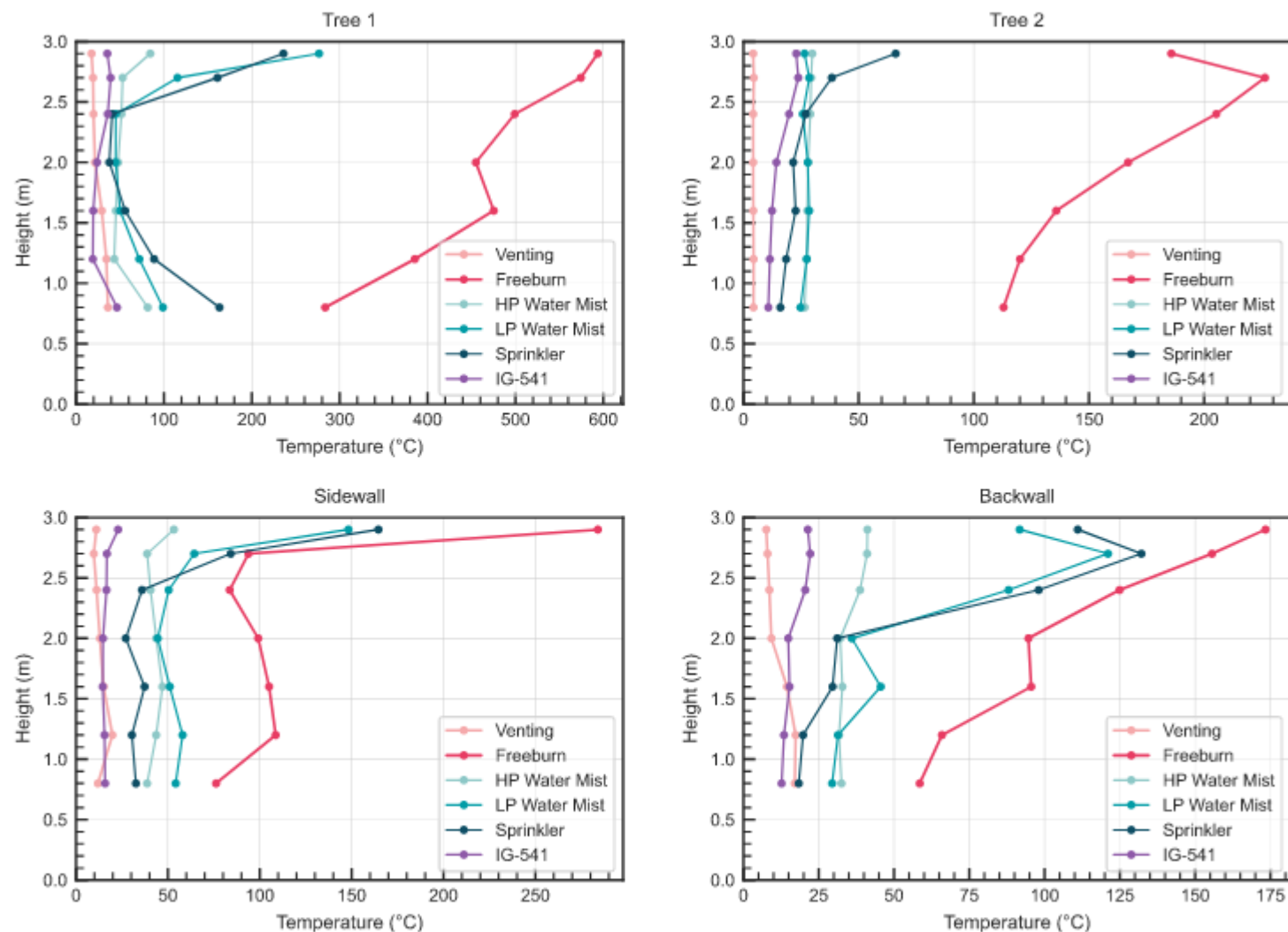


Fig. 4. Average peak temperature during TR as a function of height measured in TC Tree 1, positioned 0.5 m from and in line with the battery ventilation openings, TC Tree 2, in the centre of the room, the sidewall, perpendicular to the jet fire, and the backwall, behind the battery cabinet.

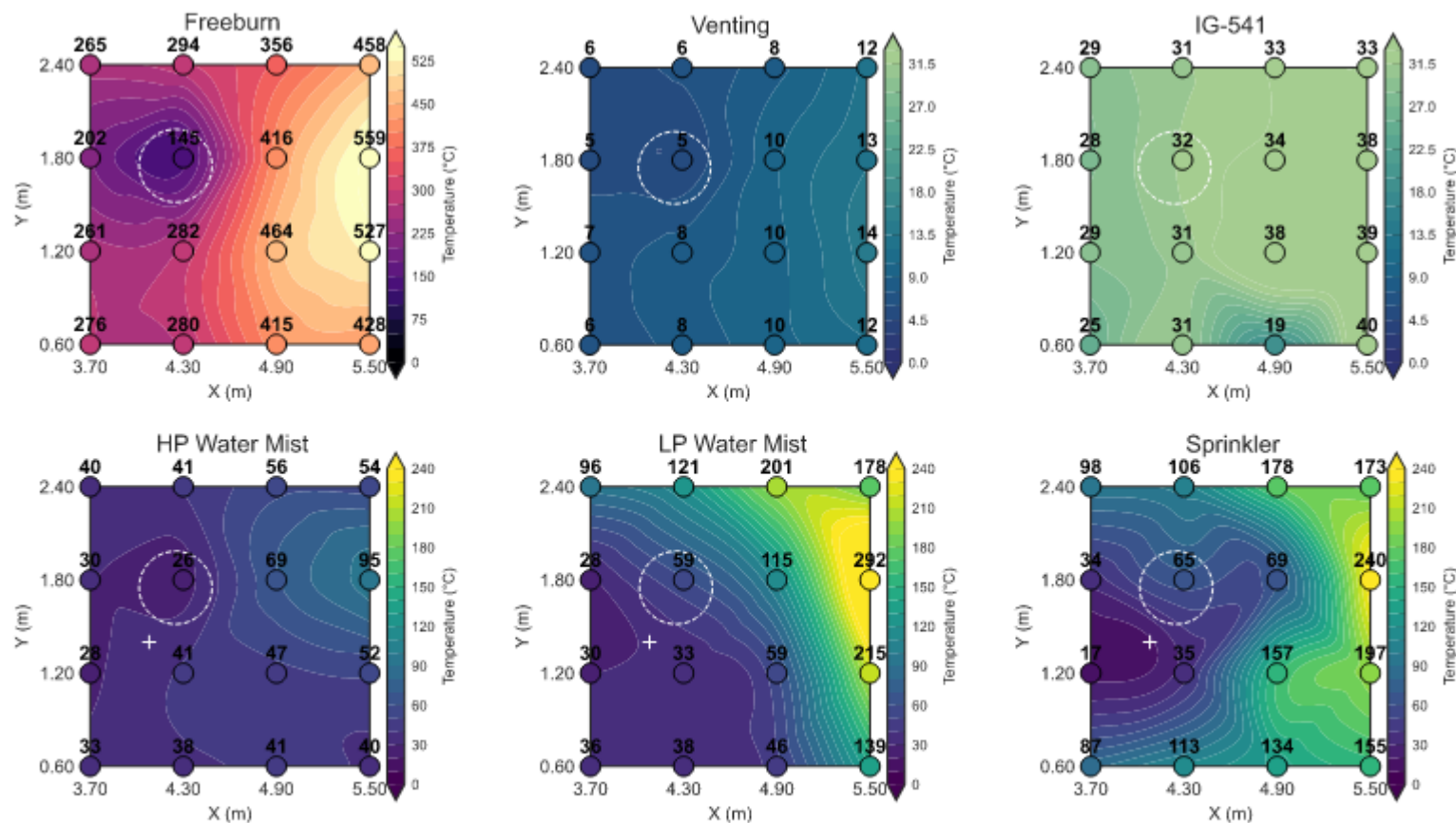


Fig. 5. Ceiling temperature contours based on the average peak temperature during thermal runaway measured in a 4×4 grid, 10 cm below the ceiling. The venting and IG-541 experiments, in which the flame was extinguished, share a colour scale. A common colour scale is also used for the three water-based suppression experiments. The position of air inlet and nozzle are indicated with white markers. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

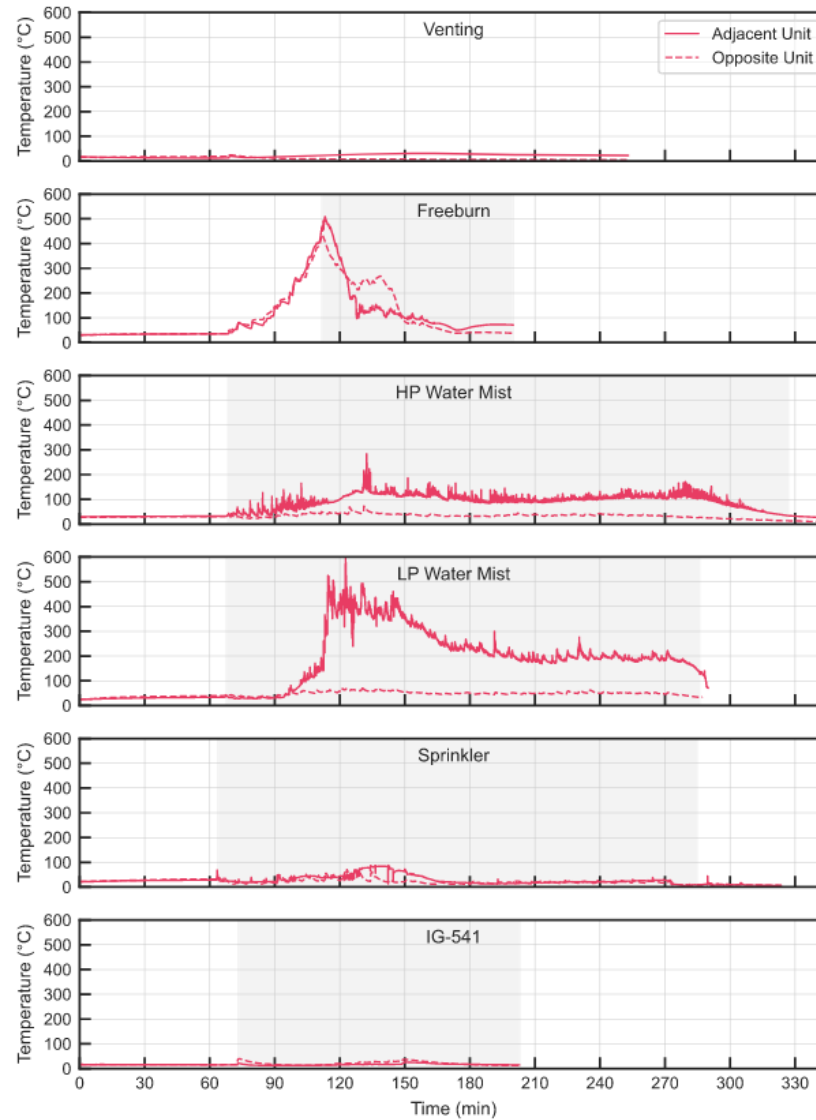


Fig. 8. Maximum temperature on the interior face of the steel targets. The temperature of the adjacent target unit is measured at four different points (i.e., low and high on the front panel, on the top, and on the side panel facing the trigger unit). The maximum temperature of the opposite target unit is based on three measurement points (i.e., low and high on the front panel, and on the top). The grey shaded region indicates the period during which the suppression systems were active.

The Challenge

High Ventilation

- **Eliminates explosion risk** once thermal runaway ends and gas generation ceases.
- **May increase fire severity** by continuously supplying oxygen.
- **Suppression systems can limit external TR propagation** (module-to-module/unit-to-unit) and **reduce damage**.
- **Performance depends on battery design**; internal cell-to-cell propagation is difficult to stop.

Compartmentation & Inerting

- Can address both **explosion and fire risk** simultaneously.
- **Key challenge: Hold time** must last until thermal runaway has fully ceased.
- **Ideally**, inert conditions must also remain **until ignition sources are eliminated**.
- Any **post-event ventilation** should avoid reintroducing oxygen.

The Risk Driver

The required ventilation rates, the suppression effectiveness and hold times are determined by the battery's safety level.