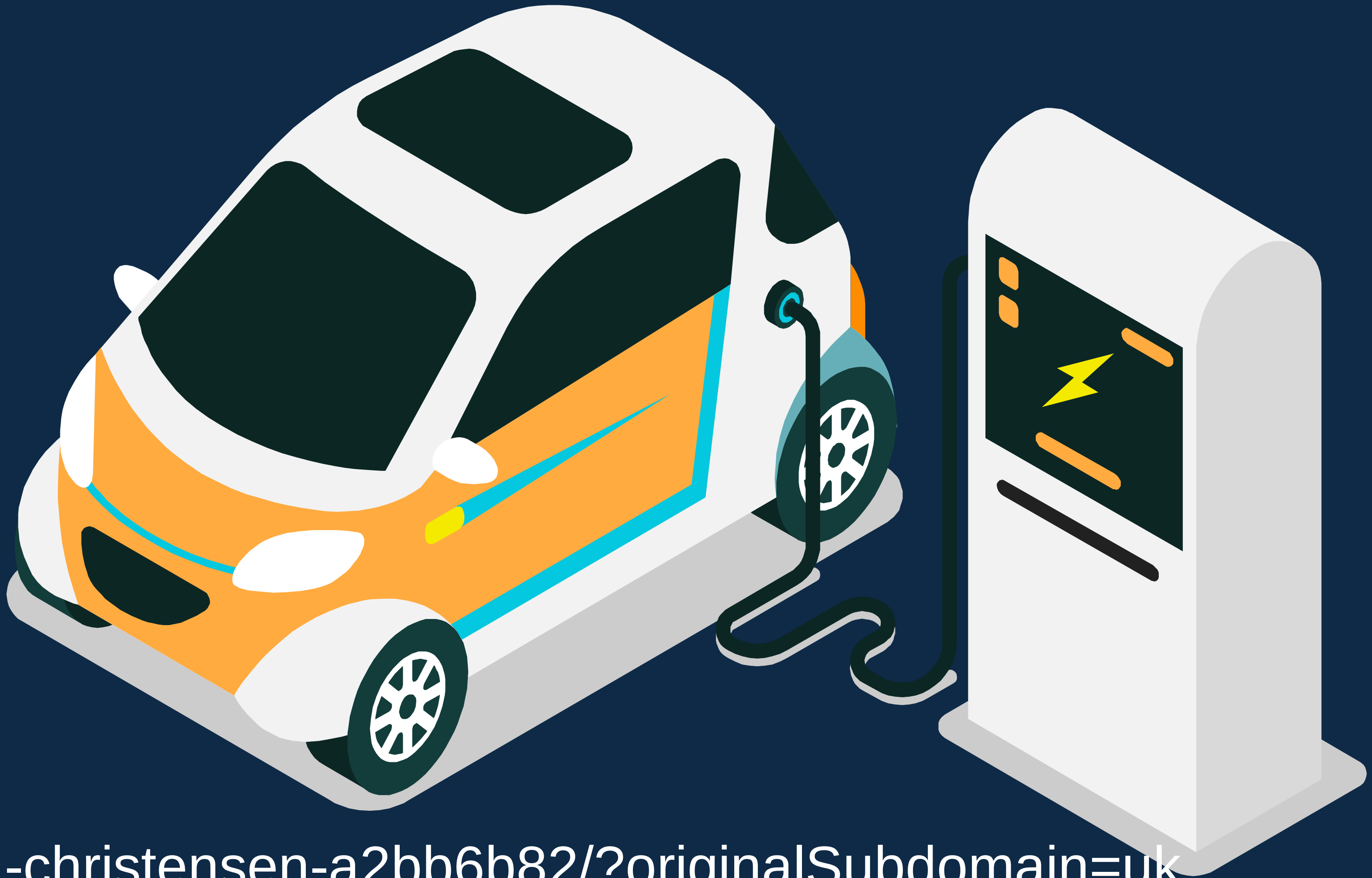
BATTERY ENERGY STORAGE SYSTEMS (BESS)

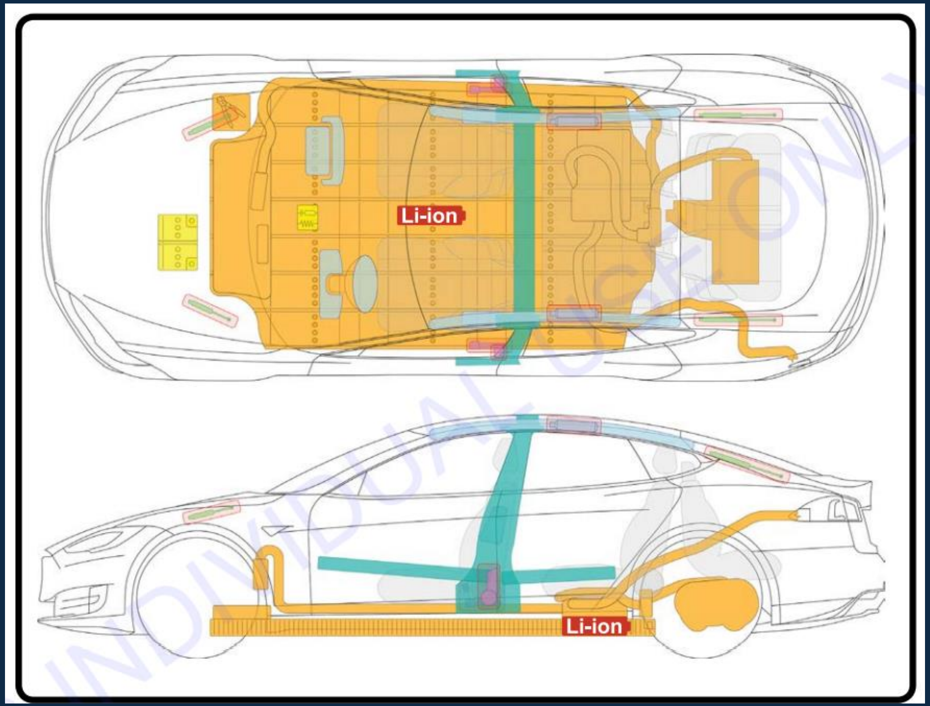
Safety systems and thermal runaway in lithium ion batteries

Paul Christensen



https://www.linkedin.com/in/paul-christensen-a2bb6b82/?originalSubdomain=uk

Large lithium-ion batteries



Large lithium-ion batteries

Lithium ion Battery Energy Storage Systems LiBESS

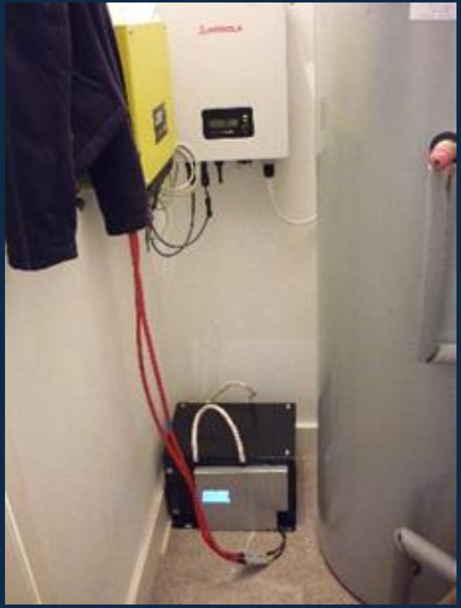
Domestic LiBESS (DLiBESS)

Commercial

2 kWh → 130 kWh or more (Tesla S 100 kWh)

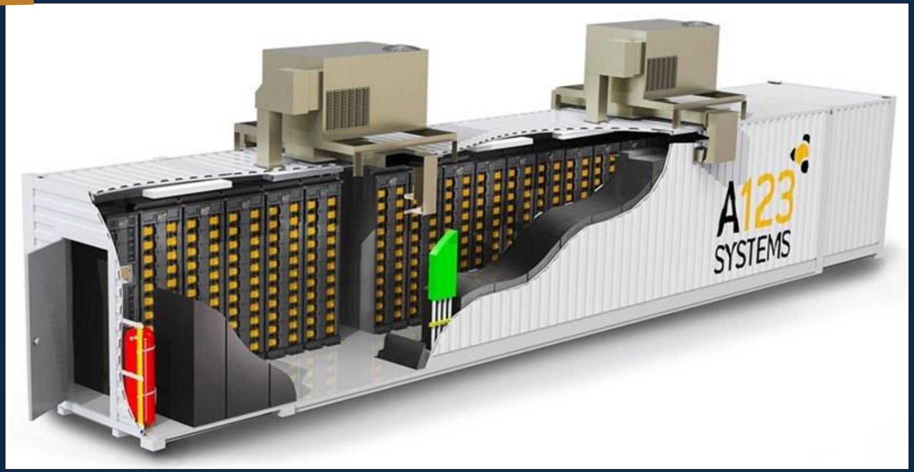
UK absolutely NO regulations

DIY



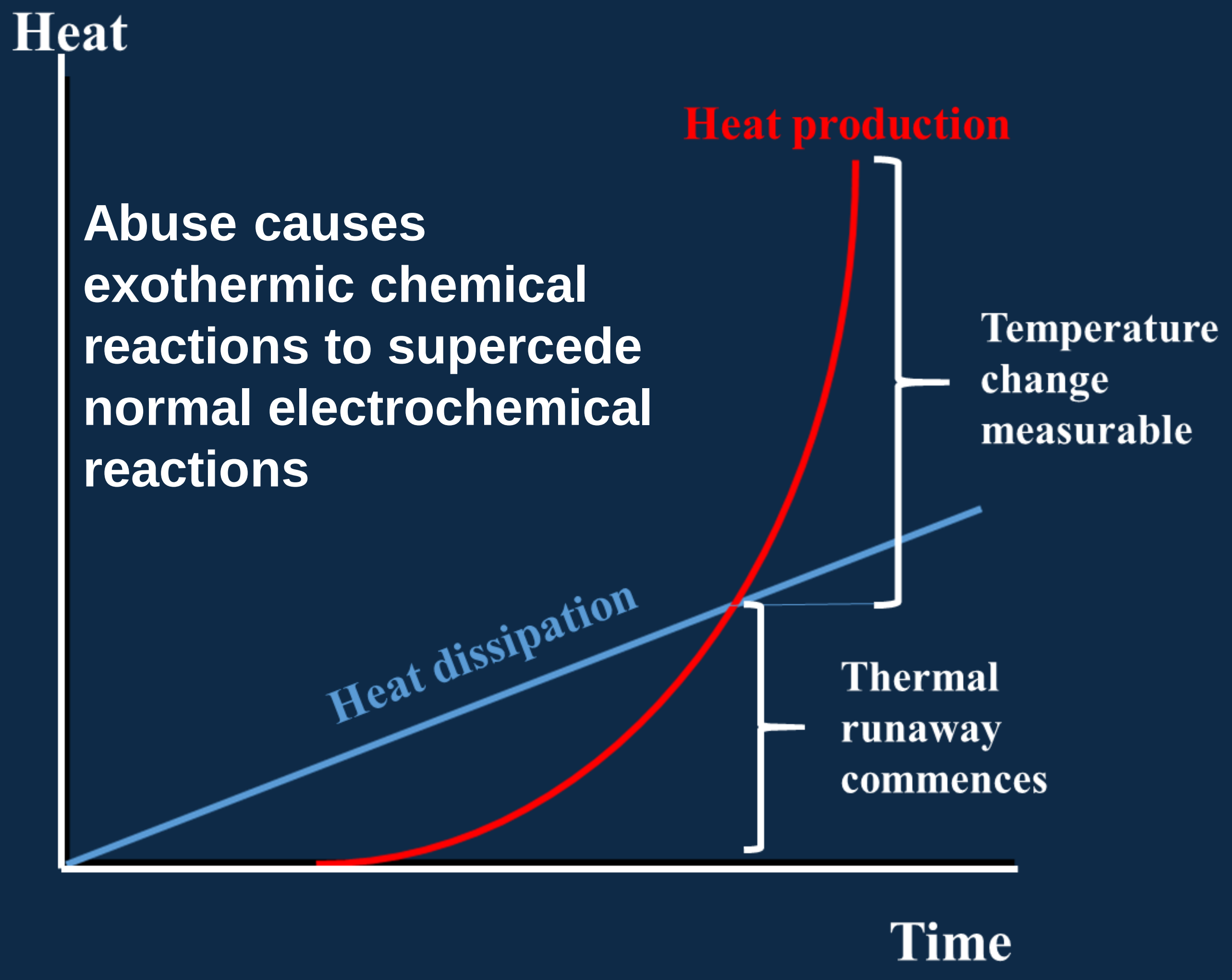
??kWh

Grid-scale LiBESS



1MWh → 1000’s MWh

Thermal runaway



A key factor with respect to the stability lithium ion batteries, and hence thermal runaway, appears to be the composition of the cathode:

LCO 130˚C

NMC 240˚C

LMO 270˚C

LFP 310˚C

Tesla is launching a new LFP battery option for the Model 3 in the United States.

Thermal runaway should be prevented by a number of safety systems:

The Solid Electrolyte Interface

The Battery Management System (BMS)

Physical safety systems
- **Safety vents**
- **Temperature cut-off (TCO) circuitry (part of the BMS)**
- **Positive temperature coefficient (PTC) thermistors**
- **Shutdown separators**

Chemical additives

System-level safety
- **Thermal barriers**
- **Cooling**

The Battery Management System

The BMS:

Ensures safe operation

Facilitate longevity

Monitors state of function (current [charge passed] and voltage)

- **State-of-Charge, SoC**
- **State-of-Health, SoH**

Alerts for e.g.

- **High temperature**
- **Cell imbalance**
- **To indicate End-of-Life**

Prevents overcharge and overdischarge

The sophistication and functionality of the BMS depends strongly upon the application

But: lithium-ion batteries still fail, sometimes catastrophically.

Most safety systems are targeted at cutting the flow of electrons or ions, or disconnecting from the mains.

By the time this occurs it is too late and the cell is in thermal runaway.

Thermal runaway and the vapour cloud

Thermal runaway → gases+heat → gases vent → white vapour cloud

Immediate ignition

Flare-like flames, thin fume

Remaining plastics burn with black smoky fume

Cathode material ejected as black “smoke” of heavy metal nanoparticles

Delayed ignition

Toxic cloud

Vapor Cloud Explosion

What happens when the BMS fails…..immediate ignition….

Delayed ignition ……

Nail penetration of an 8 54Ah cell module, mimicking delayed ignition and build-up of vapour cloud: container fills from roof down.

If the vapour cloud does not ignite immediately…. different chemistry and form factor

Container fills from floor upwards…..LEL 6-11%

The LiBESS fire at Drogenbos, Belgium Nov 2017.

Hyundai Kona, January 2021

Vapour Cloud Explosions due to lithium-ion batteries have involved EVs, submarines, marine vessels, aircraft and domestic & industrial battery energy storage systems.

Thankyou for your kind attention

Over to Tony and a Firefighter’s perspective

Battery Energy Storage Fires – A disaster waiting to happen? Future Intervention models

Tony McGuirk MSc. FIFireE

Challenges will increase

Volume The number of “unknown” BESS systems will increase exponentially.

High Profile Safe firefighting requires a different intervention model

Skills New skills needed to handle accidents and to ensure the safety of themselves and others.

Risk BESS systems present new risks and it is obvious this requires new skills, techniques and technologies

The shift to alternative power vehicles leads to new risk – no consistency on “best practice”

Need for new skills, new training and new response technology

Successful conclusion will not be quick and/or slick

New infrastructure with limited regulation

New techniques, training and equipment will require investment and cost

Key Questions and answers for Fire Services and other agencies

01

- ✓ Do we understand the full picture of how these systems will behave in a variety of fire scenarios? NO
- ✓ Do Firefighters and officers in charge have the requisite knowledge and training to understand the problem with a BESS container fire? NO

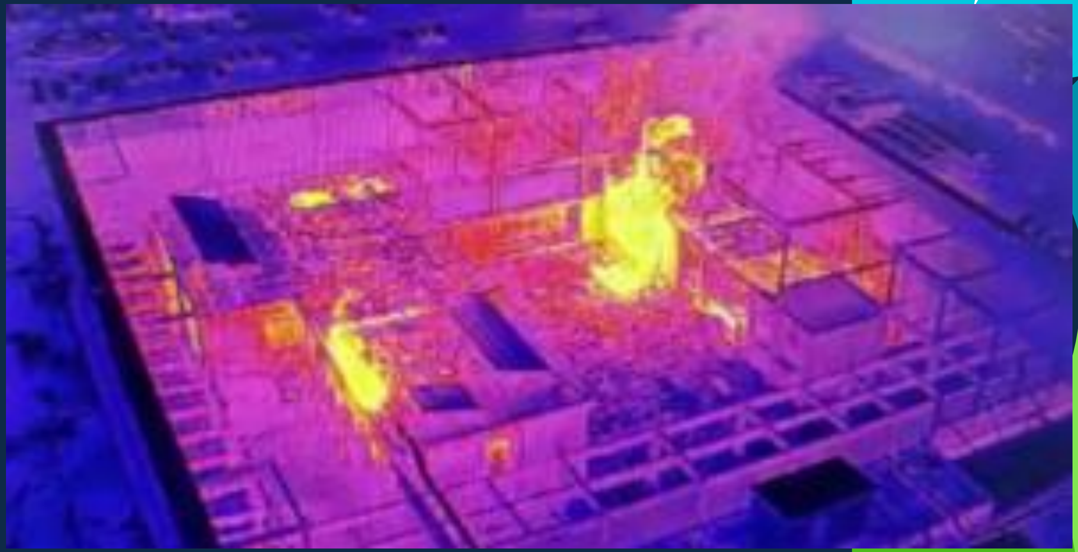
02

- ✓ Do we undertand the environmental pathways of contamination? YES
- ✓ Do we understand the need for an integrated model? NO
- ✓ Do we understand how the technology will behave in a fire or thermal runaway? Not fully.

03

- ✓ First responders need to be aware of additional risks – electrocution, arc flash explosion, vapour cloud explosion, highly toxic fumes

Engineered Intervention Models



Contain

Contain the fire by limiting oxygen supply to the fire, but especially to the lithium batteries.

Cool

Smart use of water to achieve maximum cooling whilst minimising contaminated and toxic water run-off.

Control

First responders will need to develop new techniques such as the use of thermal monitoring

Conclusion

BESS fires will not be resolved quickly, easily or cheaply –how will the waste industry respond?

What do we know?

- Early detection through data and hardware - its your problem! Every wants to talk about prevention – its currently impossible.
- Plan for failure – its inevitable - firefighters will not take risks for a few second-hand batteries in shipping containers !
- Regulations will catch up – and existing regulations already put the legal obligation on the “responsible person”
- Plan for reality – long duration, no risks taken, problem handed back to the owner

Key takeaways - Plan (and insure) for reality .

- Planning assumptions for the fire service response must not be overly optimistic or ambitious.
- Operational planning procedures for failure, response and recovery are vital.
- Credible fire risk assessment must include fire fighting expertise, and not just fire engineers.
- BESS incidents will be highly visible

Final thought – it's a small world and emergency services talk!

NEWS

Investigation begins into overheating incident at world's biggest battery storage facility

By Andy Colthorpe

September 8, 2021

Americas, US & Canada | Grid Scale | Market Watch, Technology

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Battery Energy Storage Fires – A disaster waiting to happen?
Future Intervention models

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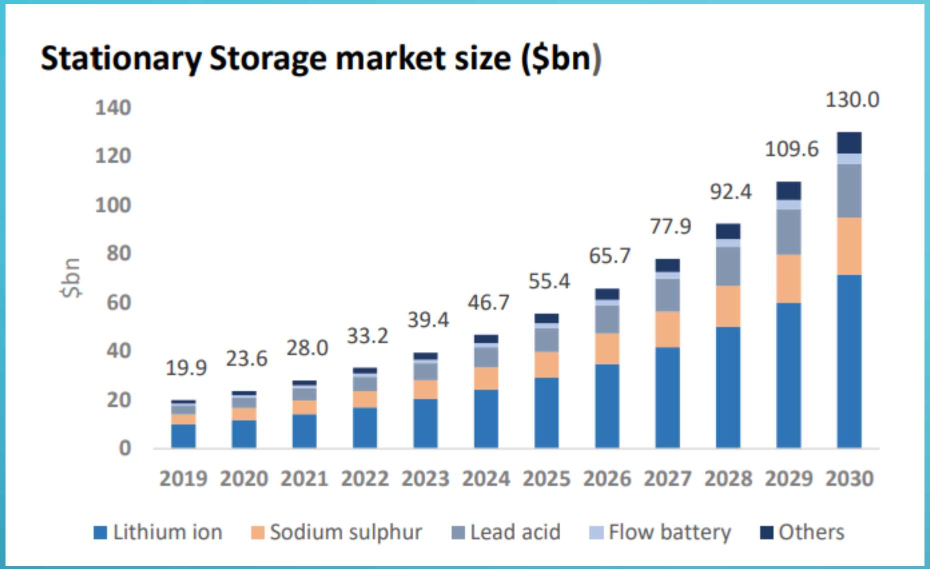
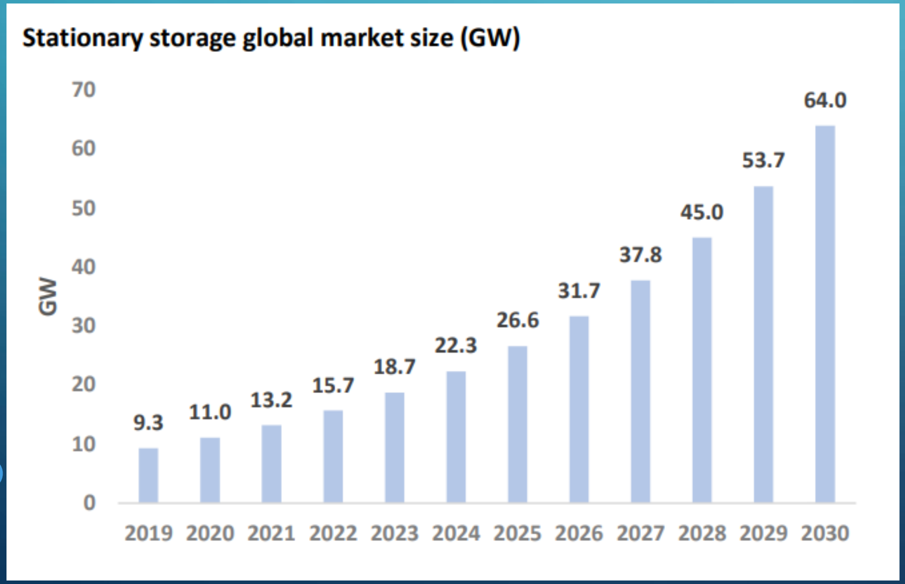
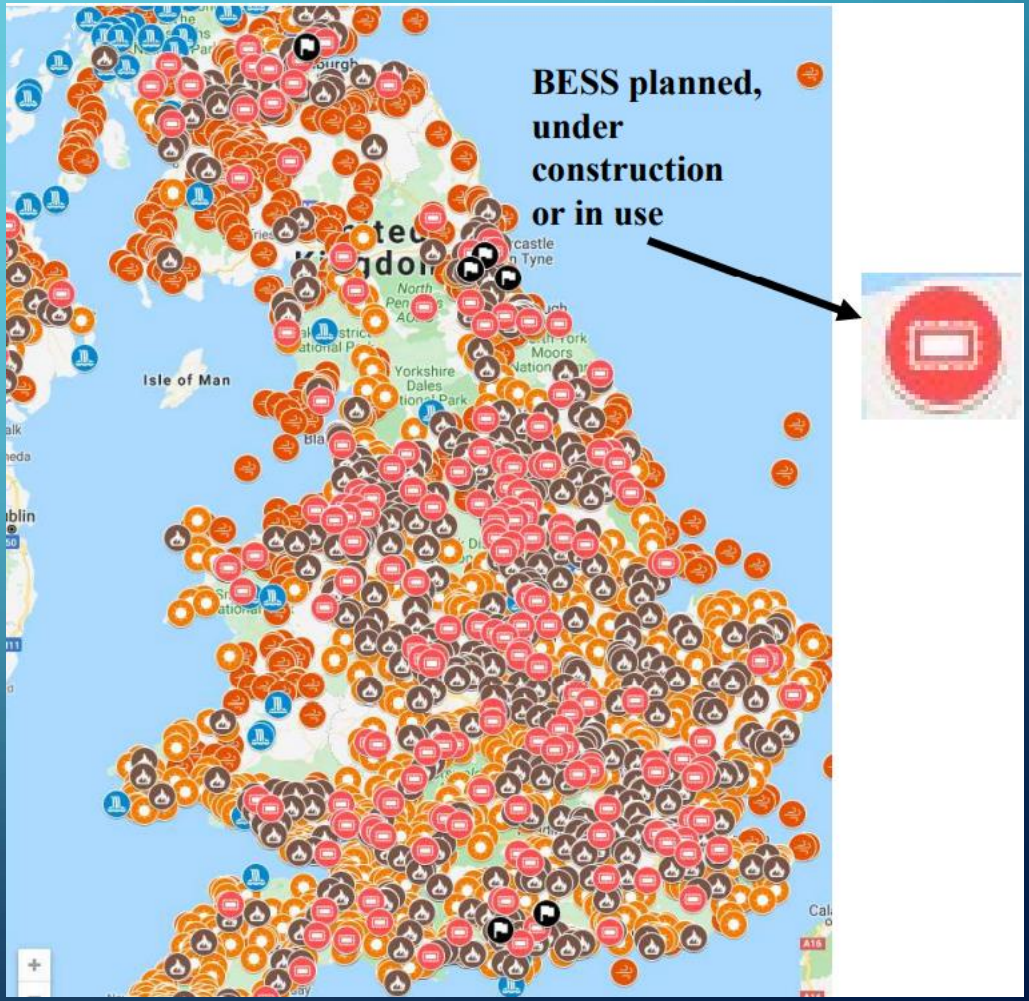
THE GLOBAL BESS MARKET REVENUE SET TO GROW FROM $24BN (2020) TO $55BN (2025) WITH GW GROWING FROM 11GW (2020) TO 27GW (2025)








Moorabool
July 2021

PM RISK CONSULTANTS

NEW DISRUPTOR OWNERS

CONTRACTOR EXPERIENCE

STEEP LEARNING CURVES

REDUCING COSTS

TECHNICAL CONSIDERATIONS – FIRE IS THE OUTCOME

- Thermal
- Mechanical
- Chemical
- Explosion
- Electrical
- Fire
- EM Fields
- Unsuitable working conditions
- NatCat
- EPC contractors knowledge and experience
- Grid

NFPA 855 (2020)

UL 9540A

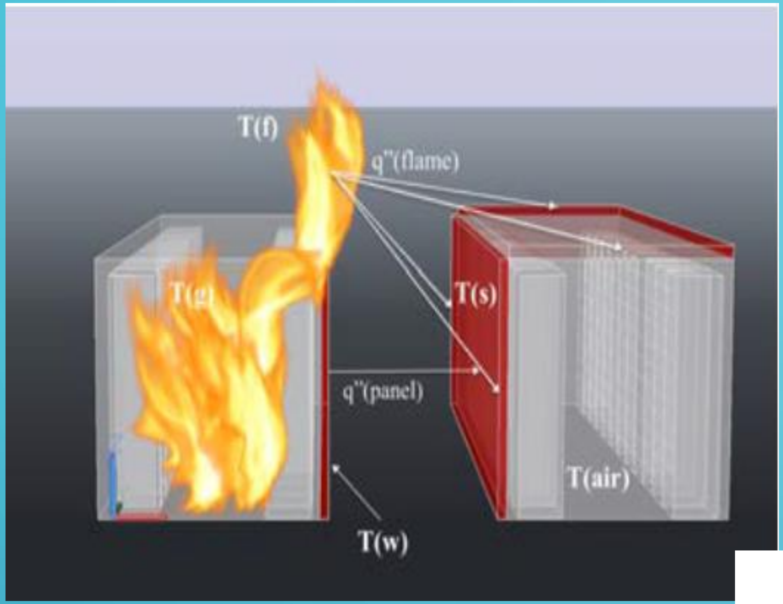
FM DATA SHEET 5-33

IEC

OTHER NATIONAL STANDARDS

ALL STILL IN DEVELOPMENT

PM Risk Consultants


T(f)
q"(flame)
T(g)
T(s)
q"(panel)
T(air)
T(w)


Time to Failure at Various Sepation Distances (53 ft Container)
5 MWh
4 MWh
3 MWh
2 MWh
1 MWh
0.5 MWh
Amount of Energy within ESS (MWh)
0
0.5
1
1.5
2
2.5
3
Time (hours)
10 ft
9 ft
8 ft
7 ft
6 ft
5 ft
3 ft

ERP

AGING – C RATE, CYCLING

QUESTIONS