Aldington and Mersham Support Group Written Representation to PINS

December 2024

1 Executive Summary

There is in Aldington a convenient point of connection with the Grid, and this is not in dispute. Whilst the majority of the community would rather not have a solar scheme that disfigures the countryside where they have chosen to live, they recognise the country's legal commitment to Net Zero and the natural pressure there will always be for a scheme at this point on the Grid. What they cannot accept is this scheme as designed.

As a direct result of the Applicant's failure to engage with the community in a genuine and meaningful way from the earliest stages in this process the scheme will cause considerable harm which will outweigh the benefit it proposes to deliver. In short, the dis-benefits of the proposal far outweigh the benefits.

For all the reasons that we have set out in this submission and are summarised below, we ask the Examiner to agree with us that this application, on account of its failings in terms of design (and above all the unacceptable risk it will pose to public safety) is quite simply unacceptable and as such that he will make a recommendation to the Secretary of State for refusal.

Battery Energy Storage System (BESS)

- Lithium-Ion batteries are inherently dangerous with a significant risk of both fire and explosion.
- The distributed location of 26 BESS installations across undulating countryside is totally inappropriate.
- There are more than 25 houses within 300m of a BESS installation which are therefore at serious risk health risk from toxic fumes in the event of fire.
- The quantities of water proposed to be stored at Stonestreet Green are totally insufficient for one BESS fire let alone multiple fires occurring simultaneously.
- Contaminated water used to treat fires poses a serious environmental threat to fragile ecosystems along the East Stour River if adequate facilities for containment are not put in place.

Alternative Land

- The Applicant from an early stage made the conscious decision that it would rely on the land that it had been offered and failed to properly investigate other land that might have been reasonably available.
- The Sequential and Exemption tests do not provide evidence of any serious investigation with a view to seeking possible options that would allow the removal of land from areas of high flood risk – specifically fields 19, 23 and 24.
- Whilst there is a Human Rights aspect to consider as part of any proposed CA, this factor should not have inhibited serious investigation by the Applicant of the alternative possibilities there may have been available to the Applicant.
- Such opportunities may well have provided a better scheme, of good design while still allowing the Applicant to meet its stated "project requirements".
- The Applicant failed to properly assess this issue at the earliest stage in the life cycle of this project (as the guidelines indicate it should do). Instead, it chose to use the "reasonably available" caveat and as a direct result, has located parts of its scheme in areas which are incapable of adequate mitigation.

Visual Impact

- The visual impact of the elevated parts of the scheme on the Aldington Ridge is very significant and unacceptable.
- The parts of the scheme on the Aldington Ridge cannot be adequately screened, even after 15 years of growth.
- The Applicant has failed to adequately represent the visual impact of the scheme to consultees, because of the poor landscape visualisations produced.
- The visual impact of the scheme could be significantly reduced by excluding those areas higher than 58m, with the additional benefits of preserving the majority of BMV land, the rich archaeological heritage along Bank Road and important habitats for red listed Skylark.
- The 99.9MW output can still be achieved with this reduced area.
- The cumulative visual impact of the Stonestreet Green and East Stour schemes will be very significant and overwhelm the area.

Water Environment

- Existing surface water flooding at the junction of Laws Lane and Bank Road affects both Bow and Spring Cottages, which flood regularly.
- This area has been identified by the Environment Agency as having a high risk of surface water flooding, although the actual frequency of flooding is greater than predicted.
- The PEIR produced by the Applicant identifies a number of factors associated with the construction and operation of the scheme, that could impact the frequency and magnitude of surface water flooding.

- The Applicant has not modelled the effects of the construction and operation of the scheme on the magnitude and frequency of surface water flooding.
- The Applicant has not taken into account the key site specific factors of catchment area, topography and soil type.
- A case study from Ontario Canada has highlighted the impacts that these site specific factors can have on surface water flooding, that if not properly managed can result in negative impacts on neighbouring and downstream properties.

Construction Traffic

- Notwithstanding the responses provided by KCC to the Applicant's proposed arrangements for safe provision of construction access to this huge scheme we believe that the arrangements are completely inadequate.
- The Construction Route between the Smeeth Crossroads and the Primary Access and beyond is, in its unaltered state, not suitable for the huge amount of additional traffic it will have to accommodate nor, in terms of its width in certain areas, capable of enabling HGVs (scheme based and otherwise) to pass safely.
- The *need* to use of Goldwell Lane as both a construction access and route for cable laying has not been proven. There is no evidence that the Applicant has ever made any serious attempt to look at an alternative route to service this block of land.
- The disruption that this proposal will cause to local people and those living in the lane is unacceptable and disproportionate to the net additional output that the small area will deliver.
- The Primary Access is not the easy and safe access claimed by the Applicant. The configuration of the access itself means that those using Station Road will not only suffer severe disruption throughout the construction period, but the swept path arrangement is quite simply not safe without modification to the highway.
- Further, as we raised at the ISH2, it is as yet unclear whether fields 25 and 26 are capable of accommodating everything they need to provide for alongside the construction of the huge substation and a battery compound.
- The Applicant has yet to provide detailed plans showing the detailed layout of this compound area and through that demonstrate its ability to remove the inherent risk of vehicles waiting and/or parking in and on the verges of Station Road.
- The Applicant has failed to properly assess the cumulative impact the scheme will have on the local highway network and how, because of existing, ongoing and proposed infrastructure projects which are all accessed off the only other access route the village has to the A 20 (Church Lane) the problems in Station Road will be much worse than forecast.

- The scale of the issues relating to construction traffic is sufficient to require, in this instance, not a simple draft CTMP to be agreed before any Grant but instead consideration as to whether the proposal as a whole is fit for purpose (and safe for the travelling public) without properly planned prior Highway modifications.

The South Eastern Area – The Outlier

- We maintain that this remote remnant of the main farm holding was only ever included because of its awkward and small area.
- The Applicant estimates the scheme's maximum output at between 140 MW - 165 MW. It also says that multiplying the connection capacity by a factor of 1.4 is "normal". That being so, and knowing that this small area will only yield 7.9% of the overall scheme output why is its inclusion considered a necessity rather than a nice to have?
- If the overall scheme can still produce as much as 140 MW *without* the Outlier how can the case be made for its inclusion knowing the significant impacts it will cause?
- The way the Applicant has treated public rights-of-way on the scheme, involving the many and major diversions (and closures) is exemplified by what is proposed on the Outlier.
- The proposed changes to the footpath here may be indicative of the way in which the viability of this small area is very finely balanced and therefore requiring of every square metre of panel footprint to the detriment of footpath enjoyment.
- The proximity of this block to the North Downs AONB is something which the Applicant cannot change – nor adequately mitigate for the change of use it proposes.
- In a similar way only more so, this element of the scheme will jar with those using the most used footpath in the parish – footpath AE 474 - that leads from the village towards the original pre-plague village and the Grade 1 listed St Martin's Church.
- The Applicant has failed to properly investigate the way in which it could have negotiated (or indeed sought CA powers as it has done elsewhere) terms for a temporary access and cable laying route.
- At least 50% of this small block of land is BMV. All relevant policy guidance, states that this should be avoided *where possible*. This quite simply is one such case - it is possible to avoid it by excluding it from the scheme.
- We cannot know the extent to which the Applicant has provided for the badger population which we know from our own research is well established within this block of land. It however seems clear that the proposals will interfere with foraging areas and where excavation in open fields takes place.
- In short, there is insufficient justification for the Outlier being included within this proposal at all. The harms that it will cause during construction and throughout its operational life far outweigh the benefit that stands to be generated.

2 Battery Energy Storage Systems (BESS)

2.1 Background

The Government, statutory authorities and developers assume that BESS are fundamentally safe. Global experience has shown that this is not the case, with fire and explosions occurring on a regular basis. This doesn't mean that BESS can't be deployed, but rather that authorities have to plan on the basis that there is a significant risk of fire and explosion. Unfortunately, the current regulatory framework is insufficient to ensure that BESS are deployed safely. In what follows we outline the very significant hazards for the local population associated with the BESS, which we believe is not essential for either the viability nor the operation of the solar installation.

2.2 Location and Access

Grid scale BESS are normally located in a single compound away from human habitation. The Applicant is in essence proposing 26 different BESS installations located across the 192 Ha Stonestreet Green solar installation. It is noteworthy that there is no NFCC guidance on BESS units located in multiple locations and we believe this to be a unique proposition nationally and globally.

The Applicant does not provide any information on the size of the BESS. This information is essential in order to assess all safety considerations.

The information provided specifies 26 'compounds' each containing 4-8 'units' and the map provided shows 23 compounds with four units each and three compounds each with eight units. If we conservatively assume each unit will have approximately 2MWh battery storage we have 23 compounds of 8MWh and 3 of 16 MWh making at least 232MWh in total. This would not be untypical for a plant with 99.9 MW solar generating capacity, and we will take this as our working assumption. This assumption enables us to compare the Stonestreet Green BESS with others around the world that have been subject to fire and explosion. If built now it would be among the largest in the world and comparable with the Cleve Hill BESS (300MWh). Moreover, each individual compound at 8 or 16MWh is comparable with the Liverpool BESS (20MWh) which failed with catastrophic consequences in 2020 (see below). More notably they are much larger than the 1.5MWh BESS on the roof of the Dahongjimen shopping mall in Beijing which exploded in 2022 killing two firefighters and injuring a third. The scale of the firefighting operation required 235 firefighters and 47 fire engines (see below for comments on the inadequacy of water supplies proposed for Stonestreet Green).

The critical decision to choose a distributed approach to locating batteries rather than a single compound has not been justified by the Applicant. It is also difficult to believe that the community has not been consulted on this decision.

The distributed approach to locating the BESS will expose a far larger number of people to the effects of toxic fumes in the event of fire, than if the BESS had been located in a single enclosure away from residential properties, such as adjacent to the Sellindge Converter Station.

Access to 26 different BESS installations in a rural location will inevitably lead to difficult and tortuous access routes for the fire services. The internal site roads are very tortuous, travel through areas of standing water and often have significant grade. Whilst the onsite access roads are planned to be 3.7m wide the single lane roads of Laws Lane and Bank Road are not. The possibility of simultaneous distributed fires also needs to be taken into account in terms of the existing capacity of KFRS.

2.3 Fire Risk and Toxic Fumes

There is a high level of concern amongst local residents regarding the dangers associated with the potential for a major incident at the BESS given its distributed nature and unique proximity to local habitation.

Evidence demonstrates that lethal concentrations of emissions of the highly toxic Hydrogen Fluoride gas are produced in BESS thermal runaways (Larsson F et al, 2017, Research Gate).

In the Outline Battery Safety Management Plan it makes a project commitment that BESS units will be at least 150m from the nearest residential receptor. There does not appear to be any modelling of the potential toxic flume to support this commitment. Furthermore, this is totally at odds with modelling carried in the comprehensive independent Atkins report for the Health and Safety Executive (NI) (Atkins Technical Note TN45, 2021Appendix 1). It provides often cited and well established plume dispersal modelling for an example but relevant and rational “reference case” (single container 5 MWh BESS), and provides contours based on the HF concentrations reached at various distances, for concentrations assessed by reputable agencies in the UK and elsewhere corresponding to the following levels:

IDLH = Imminent Danger to Life and Health

AEGL-3 (30 min) = Acute Exposure Guideline Levels (30 minute exposure)

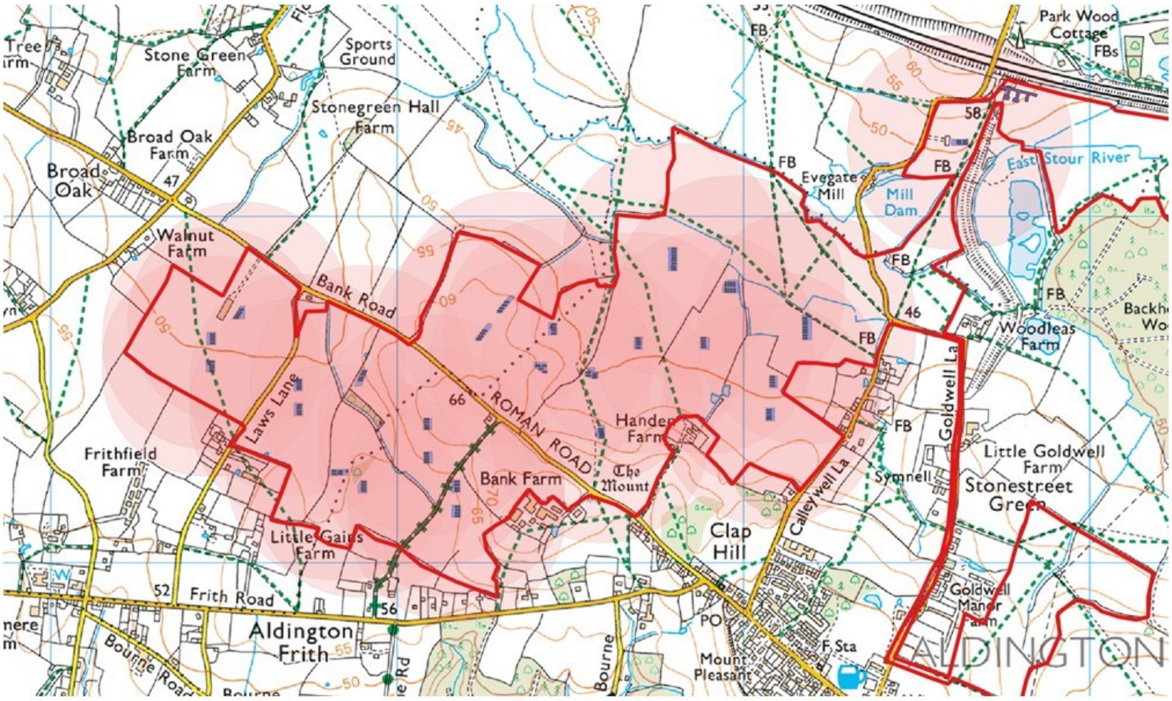
AEGL-3 (10 min) = Acute Exposure Guideline Levels (10 minute exposure)

SLOT = Specified Level of Toxicity (used by HSE in relation to Planning advice)

SLOD = Significant Likelihood of Death

Again this represents rational risk analysis against concentrations known (e.g.) to risk death in highly susceptible people (SLOT) or 50% mortality (SLOD). In the HSE(NI)Atkins illustration, the much more serious IDLH level of HF is reached **240m downwind** of the source (Appendix 1).

In the case of the proposed Stonestreet Green Solar development there are more than 25 residential properties (Figure 1)) within 300m of at least one battery enclosure. There will be imminent danger to life and health for people living in these houses in the event of fire, given the modelling uncertainty.



Areas shaded in pink are within 300m of one battery enclosure.

Figure 1. Areas within 300m of Battery Enclosure and at risk of Significant Likelihood of Death in the event of a battery fire (Ref Atkins Report prepared for NI HSE)

2.4 Water Storage

Large lithium-ion battery fires have been recorded as requiring very significant quantities of water and can reignite many times after the initial incident. There is a need to provide these large volumes quickly.

Many of the BESS fires to date have taken days to bring under control and have used and required vast volumes of water to both cool the containers (rather than try to put the fires out directly) and, where necessary, to contain toxic fumes via fogging. The developers appear to misunderstand this and are relying on the NFCC generic suggestion of a water-cooling system capable of delivering 'no less than 1,900 litres per minute for at least two hours' This would deliver a total of only 228,000 litres.

There is limited data on the measurement of water volumes deployed in previous BESS fires. However, there are at least two well-documented incidents which indicate that the requirement is very much larger and will be needed over many more hours, if not days: The 2017 fire and explosion at Moorabool, Victoria, Australia took 900,000 litres over 6 hours for a 4.25MWh fire, while Drogenbos, Belgium took 1.4million litres for a 1MWh fire. Summarising the above experience, Drogenbos (1 MWh) took 4 times the NFCC recommended volume of 228,000 litres, and the Victoria Big Battery fire at Moorabool, Australia(4.25MWh) 6 times. Each of these BESS were smaller than any single one of the proposed Stonestreet Green compounds.

A well-documented 20 MWh Liverpool BESS thermal runaway in September 2020 resulted in fire, explosion and release of toxic gases. It was theoretically protected by a fire suppression system that failed to activate. Once water was applied to the Liverpool BESS, the resulting run-off contained Hydrofluoric Acid (HF), a highly toxic substance which can dissolve concrete and whose fumes can be fatal to life. The incident released a plume of toxic gas. Efforts to douse the thermal runaway were hampered by the lack of available water from the hydrants (Merseyside Fire and Rescue Service, 2022). Escalation was narrowly forestalled only by the continuous presence of Merseyside FRS for 56 hours cooling the neighbouring container with uninterrupted hydrant water from urban fire hydrants. At the standard 1,900 litres per minute this implies a water volume of over 6 million litres.

A planning application for a 50MWh BESS (Leeds Planning Application, 2023) was withdrawn by the Applicant when Yorkshire Fire and Rescue raised objections. Yorkshire Fire Brigade made a number of important points in their letter to the Planning Authority: “The risks of vapour cloud, thermal runaway and explosion are unfortunately very real and are becoming more common as we see an increase in the number of BESS installations rise.” They also expressed their opinion that 5.5 million litres of stored water would be required (Yorkshire Fire and Rescue, 2023). Hereford and Worcester FRS have given advice similar to that of Yorkshire (c5million litres).

The quantities of water proposed to be stored at Stonestreet Green are totally insufficient for one BESS fire let alone multiple fires occurring simultaneously.

2.5 Battery Chemistry

Simple probability suggests that the chance of a failure somewhere in a BESS will increase with its size. This is reflected in a statement by a DNV GL employee at a webinar in 2020 that “Over the life of a (industrial) BESS at least one failure will occur. It is unrealistic to eliminate all chance of failure”. DNV GL (now DNV) are acknowledged as world experts in the risk analysis of large lithium-ion battery systems.

The developers suggests that LFP (lithium ferro-phosphate) batteries will be used on the grounds that they are safer than the NMC (Nickel Manganese Cobalt) type. This is not the case:

According to Professor Paul Christensen of Newcastle University, acknowledged to be one of the world's leading authorities on Li-ion battery safety, ''LFP batteries have a worse risk (than the more common NMC type) of Vapour Cloud Explosion simply because the cathode collapse leading to release of free oxygen internally results in delayed ignition. One of the key reactions that occur before thermal run away is the exothermic structural collapse of the cathode which produces oxygen and is believed to initiate ignition: this collapse occurs at a much higher temperature in LFP cells (310°C) [D. Ren et al., 'Investigating the relationship between internal short circuit and thermal runaway of lithium-ion batteries under thermal abuse condition', Energy Storage Mat., 34 (2021) 563 – 573]) hence LFP cells are considered "safer" than for example NMC. However, this can just delay ignition and hence LFP cells are perceived to have a higher risk of vapour cloud explosion. Further, recent work has shown that the vapour cloud from LFP cells has a lower explosion limit, larger explosion overpressure, higher explosion index and the ignited vent gas has a higher laminar flame speed [H. Wang et al., eTransportation 13 (2022) 100190.]'' In summary whilst NMC batteries pose a greater fire hazard, the LFP batteries proposed for Stonestreet Green carry a greater risk of explosion. Furthermore, recent installations have deployed factory built modular cabinets rather than shipping containers as previously. Again, to quote Christensen "Cabinets have a far higher energy density than containers and little free volume: this renders any form of suppression extremely challenging as water (which is still the best of the bad options when it comes to dealing with thermal runaway) will not be able to reach the cells in thermal runaway to prevent thermal propagation. Recognising this, NFCC recommends that the inevitable fires be allowed to burn out.'' This inevitable practice increases the likelihood of the fire spreading to nearby cabinets and of explosion as well as prolonged emission of toxic fumes.

2.6 Fire water runoff

Given the very large quantities of water (millions of litres) that could be required to cool a battery fire and prevent spreading, it is imperative that each of the bunds around the battery enclosures are sufficiently large to store this quantity of water. All runoff from the site ends up in the East Stour River and if not analysed and adequately contained, highly toxic acidic liquids would inevitably end up in the East Stour River. This would have serious implications for environmentally sensitive areas downstream such as the Stodmarsh National Nature Reserve.

2.7 Technical and Financial Competence

Companies House informs us that Applicant had zero employees in 2023. It is evident that all the work associated with the DCO application has been carried out by third party contractors. There is no evidence that the Directors of the Applicant have any experience of managing large infrastructure projects such as BESS, indeed there is little evidence that they have even built and operate a solar project. Given the critical safety risks specific to BESS, it is imperative that the operating company has the necessary management systems and competence to build and operate the project. There is absolutely no evidence that the Applicant has any of these necessary requisites. Furthermore, the operating company should have the necessary financial resources in the **event** that anything should go wrong, such as a major pollution event in the East Stour River. There is no evidence that Applicant has such financial resources.

2.8 The BESS is not essential for the viability of the solar project

The Applicant claimed at the recent Preliminary Hearing that the BESS is a necessary add on to the solar panels. This cannot be the case since the majority of large solar installations around the world operate perfectly well without an associated BESS. In reality the BESS is a separate project which the Applicant is unable to justify in terms of the viability of the solar project. We strongly believe that it is an unnecessary addition which, for the reasons we outline above, adds significant danger to life and health for the local population.

2.9 Security

The distributed nature of the 26 BESS installations which are bisected by small country lanes and byways will make the scheme vulnerable to security breaches. There needs to be a clear plan which ensures that members of the public are not exposed to the risks of straying from paths and lanes into hazardous areas. We also note that there has been no mention to date of cyber security threats and we urge that this should be covered in the BSMP. There have been warnings of threats to BESS similar to the DarkSide ransomeware attack on the Colonial Pipeline. Scientists at TUV Rheinland have shown that BESS are vulnerable to hacking and could be used to dump energy onto the grid or turn the BESS into a bomb.

2.10 Summary

Lithium-Ion batteries are inherently dangerous with a significant risk of both fire and explosion. As a consequence, the location of this infrastructure and the means of controlling fires and mitigating explosions has to be carefully considered and planned. The proposal to locate 26 BESS installations close to human habitation has not adequately taken into consideration the critical risks. More than 25 properties are located within 300m of a battery container and in the event of a fire,

modelling has shown that there would be a significant risk of death from toxic fumes for the residents of these properties. Global experience shows that the quantities of water proposed to be stored at Stonestreet Green are totally insufficient for one BESS fire let alone multiple fires occurring simultaneously. The very large quantities of water required to cool the fire and prevent spreading pose a significant threat to fragile ecosystems along the East Stour River if adequate facilities for containment are not put in place. For these reasons and others we strongly believe that the proposed Stonestreet Green BESS is totally inappropriate.

Written by

Professor Sir David Melville Kt, CBE, BSc, PhD, FInstP, CPhys, HonDSc, Sen Memb IEEE(USA)

Sir David Melville is a renowned physicist who was heavily involved in highlighting the safety issues regarding BESS at Cleve Hill near Faversham. He has subsequently advised on BESS projects globally.

Simon Lunn BSc. Environmental Sciences, MSc Geophysics, Fellow of Geological Society of London.

Appendix 1 Hazard Assessment of Battery Energy Storage Systems by Ian Lines Atkins

3 Alternative Land / Site Selection

3.1 Introduction

We consider that the Applicant's failure to consider in a meaningful and serious way, alternative land options is one its most serious failings in the design of this proposal.

Despite having had two public consultations it has failed to seriously engage on this issue. What follows raises the legitimate question as to whether, on account of the provisions contained in the Planning Act 2008 ("the Act") and those within EIA legislation and relevant policy guidance, alternative land parcels have been adequately researched, considered and weighed in the balance when assembling this scheme.

Assembling land in the best possible location is the most basic form of mitigation against the environmental harm that can be caused by such proposals. Applicants have the opportunity at the formative stage of a scheme to minimise significant adverse impact through careful landholding selection and the Applicant should demonstrate the endeavours they have made at this "macro" stage of the developmental phase.

Powers of Compulsory Acquisition (CA) are available to them through the DCO process where there are compelling reasons for seeking these.

The submissions we made when registering our interest include the following three aspects:

A. **The statutory scheme directs that schemes should be of Good Design and the development at the chosen location does not meet this requirement.**

B. **The Applicant has only considered land that has been offered to it and has not demonstrated that it has looked seriously at alternative areas.**

C. **The Applicant has included within its scheme land within Flood Zone 3 and has not demonstrated under the relevant tests that other more suitable land is not reasonably available.**

We refer to each of these in turn within this section.

3.2 Schemes should be of Good Design and the development at the chosen location does not meet this requirement.

1. Infrastructure Planning (Environmental Impact Assessment (EIA)) Regulations 2017 at regulation 14(d) and Schedule 4, para. 1(d) require the development to provide – "*A description of the* ***reasonable alternatives*** *(for example in terms of development design, technology,* ***location****, size and scale) studied by the developer, which are relevant to the proposed project and its specific characteristics, and an indication of the main reasons for selecting the chosen option, including a comparison of the environmental effects".* (bold font our emphasis).

2. The Applicant *is expected* to achieve "Good Design" (see **Overarching National Policy Statement for Energy EN-1 November 2023 section 4.6) and specifically 4.6.1** which states that as part of the EIA (Environmental Impact Assessment) requirements: -

   "*The visual appearance of a building, structure, or piece of infrastructure, and how it relates to the landscape it sits within, is sometimes considered to be* ***the most important factor in good design****" and at 4.6.4,*

   "Given the benefits of "good design" in mitigating the adverse impacts of a project, Applicants should consider how "good design" can be applied to a project during the ***early stages*** *of the project lifecycle" and at 4.7.6,*

   "Whilst the Applicant may not have any or very limited choice in the physical appearance of some energy infrastructure, ***there may be opportunities for the Applicant to demonstrate good design in terms of siting relative to existing landscape character, land form and vegetation….."*** (bold font our emphasis).

3. We believe that achieving Good Design envisages the Applicant looking at each geographical area available to it (field by field) and carefully considering those which present the greatest challenge to achieving Good Design. Fundamentally, are the visual (and any other) adverse impacts that the proposal will cause capable of being adequately mitigated or should alternative land be considered?
4. Whilst there is not an onus on the Applicant to provide various option locations for whole schemes, it is incumbent on Applicants to consider areas of nearby *alternative land* within the overall "scheme mosaic" during the early stages of the project's life cycle. This "optioneering" work is the logical first step towards developing a scheme of Good Design, and not something that is acceptable to consider retrospectively in some sort of "reverse engineering" exercise.

5. Not *every acre* of the landholding that has been offered to the Applicant and now included in this proposal can achieve Good Design through later on-site mitigation (i.e. landscaping etc).
6. The Applicant originally located infrastructure inappropriately and, in the interests of Good Design, it removed panels and other infrastructure from fields 26 – 29. Similarly, it has now moved batteries out of the floodplain.
7. In the same vein, how can designing its scheme in such a way that 116 battery units plus water towers so visible on high ground in the landscape, with poor emergency access be considered part of a scheme of Good Design?
8. Locating solar panels and other huge infrastructure on undulating land can seldom be mitigated merely by hedge and tree planting. Instead, alternative options (e.g. consolidation of battery units, alternative locations for these and even alternative land) should have been properly considered and weren't.

3.3 The Applicant has only considered land that has been offered to it and has not demonstrated that it has looked seriously at alternative areas.

1. In view of the inevitable visual harm that elements of the proposal will cause (especially the batteries and all infrastructure on high ground), where are the details of the careful consideration given to various alternative locations, areas that could have been used in conjunction with the land offered to the Applicant from the outset?
2. The briefest reference to this important aspect of the scheme's development is in its **Planning Statement Doc.7.6**. Had Ashford Borough Council (ABC) not raised in their representation to the Statutory Consultation on the issue of other land potentially suitable for inclusion in the scheme one wonders if the Applicant would have referred to it in any detail at all.
3. The implications of what the Applicant says in its **Appendix 2 Site Sequential Report** (referred to in more detail in Section C below) is that this land and indeed all other areas that it has considered within the 5Km stated maximum radius are not of sufficient scale to meet "project requirements". This is to completely miss the point. If seriously considered at the outset there may have been a scheme that could still meet the "project requirements" through combining other land with elements of the land offered to the Applicant from the outset more than 3 years ago.
4. The Applicant in the **Environmental Statement, Volume 2, Chapter 5: Alternatives and Design Evolution Table 5.1** briefly addresses this representation about the failure to look at alternative land. At 5.7.1 it states: -

   "Two parcels of land were identified to the north and south of the M20, to the north of the Site (identified in ES Volume 3, Figure 5.1: Potential Developable

Land Locations and Cumulative Schemes (Doc Ref. 5.3) as Potentially Developable Land 1 and Potentially Developable Land 2). These sites are not of a sufficient scale to deliver the Project requirements....” **Why is the fact that these areas self-evidently aren’t big enough to incorporate the *whole scheme* a reason for dismissing them altogether?**

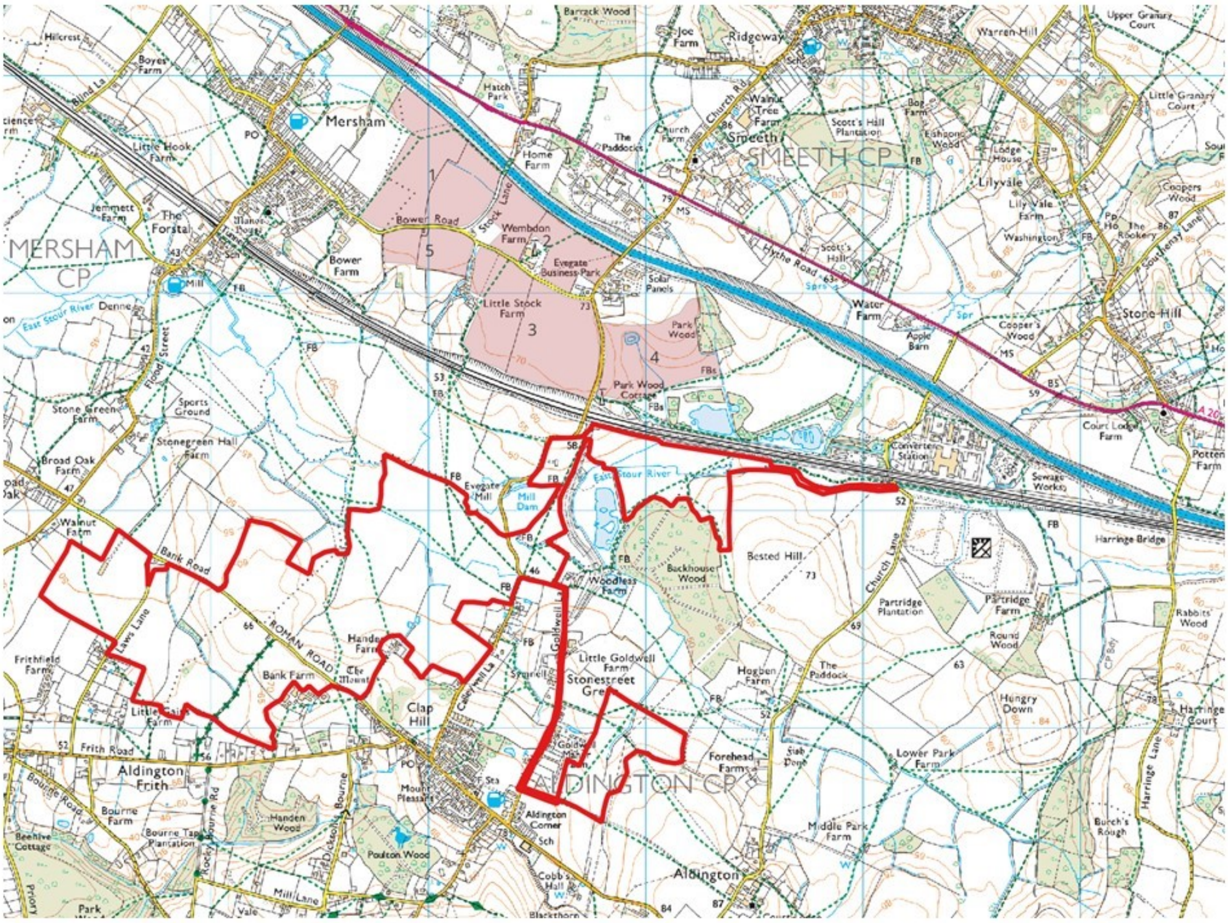
“Potentially Developable Land 1 is north of the M20 motorway and as such would also involve technical challenges associated with cables having to cross the M20 carriageway”. **The M 20 is carried on a substantial bridge over Church Lane. Talk of having to “cross the M 20 carriageway” is misleading in the extreme. There is an easy cable route beneath the bridge.**

“A significant part of Potentially Developable Land 2 is subject to three planning applications”. **Yes, but why does this preclude consideration of the remaining large areas that are not affected by planning applications?**

“These areas have therefore been discounted by the Applicant as not being suitable alternatives for the Project”. T**his appears therefore to have exhausted the Applicant’s consideration of alternatives.**

5. These areas are shown on the plan towards the end of this section being an extract from the Applicant’s plan in **Chapter 10: Water Environment (Figure 10.4).** We discuss below at section (**C**) the context of flood risk.
6. Even from our cursory review of farmland within reach of the POC (and within the stated 5Km radius) it is evident that there are areas of land more suitably located and better able to mitigate the impacts caused by areas included within the Applicant’s proposal.
7. The plan on the next page shows (shaded pink) land that lies between the M20 and the HS1 railway line. If this land has been investigated at all we can find no reference to this.
   We have carried out our own research (talking to landowners and agents), and it appears that no serious enquiry was ever made by the Applicant about the possibility of incorporating some, or all of this land in its application.
8. The Applicant appears to dismiss the possibility of suitable alternatives when at **paragraph 3.3.1 of its Planning Statement Doc. Ref 7.6** it states:

   “A review of potentially suitable land has confirmed that there would be no suitable land which is on the open market, or where the owner or occupier has confirmed they would be willing to sell or lease the land, or land that is free of restrictions that would not prevent the sale or lease of land, such as restrictive leases, or option agreements. This demonstrates that there are no suitable and reasonably available alternative sites”.



9. The land shown shaded pink comprises about 77 Ha – about 40% of the Applicant's submitted scheme. If just 60% of the pink shaded area had been incorporated this would, at a stroke, have allowed most of the land that lies above the 58m contour (as described in our Visual Impact section) either side of Bank Road on Aldington Ridge and within the outlying Eastern Block to be removed. This would have substantially mitigated the scheme's visual impact.
10. We know from our own research that some of this pink land is held under an Option Agreement. Even if it were to be said that this is a restriction which is not capable of being negotiated out oris in some way invulnerable to CA – which we do not accept - there are other areas comprising nearly half the of the area shown which have no such restriction and there are also parts of PDL1 and PDL 2 (see plan later at 3.4.14) which the Applicant has for the wrong reasons dismissed as unsuitable.
11. This alternative land area is generally flat in all directions either side of Bower Road. The established hedges could have been allowed to grow up and, where these are missing on some boundaries, new hedges planted. If all were maintained at a height of 2.5/3.0m virtually no visual harm would have been caused.
12. The entire area is only crossed by two footpaths which broadly traverse the site north/south so would have had little interference with panel positioning as compared with much of the submitted scheme where they often run diagonally

to the panel row alignment and substantial disruption and harm to them is proposed.

13. The M20 and HS1are both in cuttings adjacent to this land so there would have presented little risk of glint and glare.
14. The land is not allocated for development in the ABC's Local Plan (2019-2030).
15. A cursory review of the likely soil type (based on existing ALC mapping data) suggests that it is similar in quality to the land on much of the high ground either side of Bank Road on the Applicant's submitted scheme.
16. The land is naturally well screened from the north (mainly because of established woodland on both sides of the M 20). Views from the A20 are also largely screened by mature planting along the southern boundary of the M20.
17. Whilst partially visible from the high ground near Bank Road, if hedge and tree planting at key locations along the edge of the northern boundary of HS 1 was incorporated this would soon screen the area from the Aldington direction.
18. Access to any part of this alternative land area for both construction and decommissioning phases would be much closer to the A20 providing quicker and easier access for emergency services avoiding the need for extensive internal tracks which is a feature of so much of the submitted scheme.
19. Only three residential properties would be close to the panel footprint – much fewer than those that stand to be directly affected around and outside the village of Aldington. These houses could be protected by providing a generous area of panel setback coupled with strategic hedge and tree planting.
20. Cabling from this area to the Applicant's substation would have required (as with the proposed HS1 crossing at the Converter Station) the availability of ducting within the Station Road bridge or elsewhere in the vicinity (there is also a farm access bridge over HS1 nearby that may have also offered opportunities).
21. Whilst we cannot know the potential benefits and disbenefits of incorporating some or all of this land, the fundamental issue is that the Applicant should, *at the very least*, have fully investigated this land and other such opportunities within its stated radius of search. We can find no evidence that such work was ever undertaken and if it was only in a very high-level way and, for some reason, the Applicant thinking that it only had to concern itself with an alternative that would accommodate the whole scheme.
22. If we are right and these investigations and discussions with landowners did not take place this is a serious flaw in the developmental process of this huge project and is, at this stage in the DCO process, now incapable of rectification.

Compulsory Acquisition (CA)

23. At **5.6.2 of the ES Vol 2 Chapter 5** it states that *"The site was selected by the Applicant based on a series of influencing factors"*. There is no evidence of it being "selected" which implies special suitability. The significant majority of the Applicant's site is land that was offered to it from the outset by the original and main landowner. It is therefore not so much land that was selected as "land that was made available".

24. However, the Applicant did not have to make do solely with what had been made available to it. The Act makes provision, where considered appropriate and necessary, for Applicants to seek CA powers.
25. These powers are not solely for the acquisition of *rights* over land (e.g. for access, cable laying etc) which, as we heard in the CA hearing, the Applicant is relying on elsewhere on the scheme (if commercial terms are not agreed with third parties in time), but also for the *acquisition* of land where there is a compelling need.
26. The Act, the EIA legislation, the government's numerous statements and its "direction of travel" coupled with the stated Climate Emergency and legal requirement to meet Net Zero by 2050, allows NSIP Applicants to make the case for acquiring other land, if necessary, by CA where a compelling case can be made.
27. Looking hard at site selection and alternatives at the *earliest stage* in a project's life cycle is the most fundamental and basic form of mitigation. CA is a process adopted generally as a safeguard to cover against an agreement holder defaulting. But it also provides some leverage in cases where a compelling case can be made for acquiring alternative land as part of a well-designed scheme.
28. There are various locations where the land chosen for inclusion in this scheme is clearly unsuitable. Foremost of these are the highly visible areas either side of Bank Road on high ground (generally above the 58m contour), the outlying and separate South-Eastern Area and land in the floodplain.
29. It is not enough for baseline land assembly questions to be answered by reference to Land Registry Titles as some sort of "desk based" afterthought. The Applicant's earliest scheme development should have included detailed site inspections, contact and discussions with potential landowners and occupiers as well as an indication of the commercial terms the Applicant would be prepared to offer to acquire such areas.
30. Evidence of such endeavours should be available for a scheme which presents so many significant impacts that are well beyond the scope of adequate mitigation. It is not acceptable for this, or any other similar scheme to steer clear (as a matter of course) of trying to assemble the best possible landholding and instead maintain that every acre offered from the outset is suitable for development and capable of mitigation.
31. By way of example, it would have been perfectly *possible* for the Applicant to have laid its cable to the POC via the highway network (as it is already proposing to do in Goldwell Lane). However, it has instead elected to adopt a route over a long section of third-party land (owned by Messrs Price and occupied by others) and is endeavouring to negotiate financial terms for the required rights (with the threat of CA in the background if acceptable terms cannot be agreed).
32. Why then has it not in the same way considered much more carefully and more openly where it can most safely, and with least impact, locate 116 battery units? Apart from the fact that it may be easiest to locate these on land that has been

offered to the Applicant what other rationale drives the proposed location of these on farmland around the village of Aldington?

33. It may be feasible (easy and convenient) for the Applicant to make this decision unilaterally, but if approved the result will be neither easy nor convenient for those who will have to endure the fallout from this poor design, not only during its construction, but for at least the next 40 years.
34. Nor will it be easy or convenient for fire appliances and emergency services to attend battery fires and/or explosions at the various remote off-highway locations over the next 40 years.
35. Whether with a view to securing the least visible location for the solar panels or the best/safest positioning of battery units (and associated above ground water tanks), the CA powers, in the absence of agreed terms, were always available to the Applicant.
36. It has been widely reported that landowners have been offered £1000 per acre per annum indexed linked for the 40-year life of the scheme. These commercial terms are at least three times gross margins achievable on Grade 3a and 3b arable land.
37. If land is acquired by the CA route this would be at "existing use value" (i.e. basic agricultural value). Why would a landowner, knowing of that situation, not want at the very least to engage in a conversation about the proposals to see whether there was an opportunity worth considering for some if not all their land?

3.4 The Applicant has included within its scheme land within Flood Zone 3 and has not demonstrated under the relevant tests that other more suitable land is not reasonably available.

1. The NPS states that *"Inappropriate development in areas at risk of flooding should be avoided by directing development away from areas at highest risk (whether existing or future). Where development is necessary in such areas, the development should be made safe for its lifetime without increasing flood risk elsewhere".*
2. Whilst the Applicant has removed fields 26 – 29 from its scheme (much of which area lies within Flood Zone 3) it maintains that the fields downstream of the Aldington Flood Storage Area (AFSA), despite also being within Flood Zone 3 can safely accommodate solar panels, related infrastructure and, critically, mesh security fencing (mesh apertures being 10cm square and fencing just 200cm above ground level).
3. The AFSA dam periodically overtops, and flood water spreads out across the floodplain downstream. Even if the gantries for the panels do not present an obstruction to the free movement of such flood water, the security fencing most certainly will.

4. **The Environment Agency in its representation to the Exa of 5th September 2024 at Flood Risk Overview (paragraph 2.1)** concludes that *"the Examiner must decide whether or not the proposal provides wider sustainability benefits to the community that outweigh Flood Risk".* It seems inherent in this statement that some as yet unknowable flood risk is going to be caused by siting infrastructure and security fencing in fields 19, 23 and 24.
5. We maintain that not nearly enough detail has been presented by the Applicant about increased run off from all areas of the project lying within the East Stour River catchment. "Channelling" in the fields will develop taking stormwater from the array to the river much more quickly than before notwithstanding the Applicant's claims about the way in which the switch from arable to grass will improve absorption rates.
6. Not nearly enough has been presented to address soil compaction that will be caused partly during the construction phase - particularly when ground conditions are unsuitable (and following installation of the array impossible to remediate) but also throughout the operational phase in the sections between panel rows routinely trafficked for panel maintenance and glass cleaning.
7. These aspects alone will affect the way in which floodwater behaves downstream (including at Mersham just 1.25 miles downstream). Add to this the periodic overtopping of the AFSA dam when the security fencing will obstruct floodwater debris, causing water to back up and producing unpredictable flooding effects downstream.
8. The AFSA was designed to achieve a relatively uniform flow (even during an overtopping event). Whilst the Applicant claims that any effects downstream will be "negligible", how can this view be so emphatic when there will be so many different factors at play for which meaningful modelling is impossible and when the Environment Agency's above-mentioned comment is so equivocal?
9. We do not believe the work done by the Applicant in terms of flood risk and the associated drainage plans, nor the response from the Environment Agency adequately addresses these issues and believe that if consented the scheme will create additional flood risk to people and property downstream of the AFSA.
10. **The Overarching National Policy Statement for Energy (EN-1) (November 2023)** –states:

    5.8.7 Where new energy infrastructure is, exceptionally, necessary in flood risk areas (for example where there are no reasonably available sites in areas at lower risk), ***policy aims to make it safe for its lifetime without increasing flood risk elsewhere and, where possible, by reducing flood risk overall****. It should also be designed and constructed to remain operational in times of flood.*

    5.8.8 Proposals that aim to facilitate the relocation of existing energy infrastructure from unsustainable locations which are or will be at unacceptable *risk of flooding, should be supported where it would result in climate-resilient infrastructure.*

The National Planning Policy Framework (December 2023) – ("NPPF") states:

167. "*All plans should apply a sequential, risk-based approach to the location of development – taking into account all sources of flood risk and the current and future impacts of climate change – so as* ***to avoid, where possible, flood risk to people and property".***

168. "*The aim of the sequential test is to steer new development to areas with the lowest risk of flooding from any source. Development should not be allocated or permitted if there are* ***reasonably available sites appropriate for the proposed development in areas with a lower risk of flooding".***

173. "*When determining any planning applications,* ***local planning authorities should ensure that flood risk is not increased elsewhere".*** (bold font our emphasis).

11. With the above in mind, we find it extraordinary that field number 19, which is in the floodplain (Zone 3) and was not part of the original landholding offered to the Applicant, *was subsequently added*. Is this really a case where, as detailed in EN-3 "*new energy infrastructure is, exceptionally, necessary in flood risk areas"?*
12. Not least because of the inclusion of this land, the Applicant accepts the need to pursue the relevant Sequential and Exemption tests.
    However, it indicates in its **Planning Statement (Doc.7.6) Appendix 2: Site Sequential Report at paragraph 3.3.1** that there is no other land *"reasonably available".*

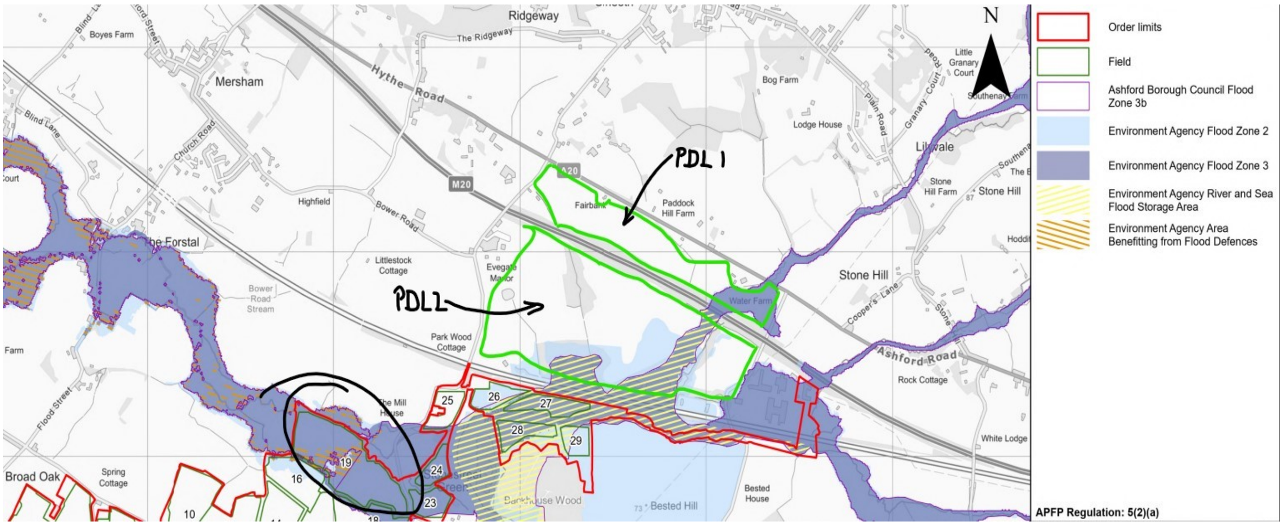
    It goes on to say:

    "*Figure 1 shows the constraints within the Search Area. A review of potentially suitable land has confirmed that there would be no suitable land which is on the open market, or where the owner or occupier has confirmed they would be willing to sell or lease the land or land that is free of restrictions that would not prevent the sale or lease of land, such as restrictive leases, or option agreements. This demonstrates that there are no suitable and reasonably available alternative sites".*

13. Contrary to this statement, we maintain as indicated earlier in this section, that there are areas of reasonably available land (including elements of the areas reviewed by the Applicant – PDL 1 and PDL 2) and only through lack of early

planning has the Applicant has now missed the opportunity for incorporating these.

14. An extract from the Applicant's **Chapter 10: Water Environment** (Figure 10.4) is included below. On this we have annotated the extent of PDL 1 and PDL 2. As can be seen, there are certainly elements of each that are zoned in terms of flood risk. However, to claim that these alternative areas are in their *entirety* unsuitable for replacing fields 23, 24 and in particular the subsequently added, field19 - all of which are within Flood Zone 3 - is misleading to say the least. We maintain that this throws into question the rigour that has been applied to the statutory relevant tests.



3.5 Summary

1. **It is clear that the Applicant decided, at the very earliest stages of this enterprise, that it would concern itself with developing only those areas of land that were made available to it and that it would not make any serious enquiry or engage in discussions with landowners and occupiers about other land that might be reasonably available.**
2. **Whilst the Applicant indicates what it considers to be the definition of "reasonably available" why should this not encompass "reasonable enquiry" which might have presented a mix of options with the potential of producing a scheme that causes much less environmental harm than this proposal will?**
3. **If to be "reasonably available" requires securing land within a reasonable timeframe then why didn't the Applicant undertake detailed investigations much earlier in the development process (as it is encouraged to do) and in that way provide itself with adequate time?**

4. **For the conclusions reached in the Sequential and Exemption tests to be of valid, the Applicant should have engaged with landowners and occupiers of other land within the 5Km radius that had the potential to replace land in the scheme located within Flood Zone 3.**
5. **Whilst the Applicant may claim there is the Human Rights aspect to consider as part of any proposed CA, this, if it does arise, comes later in the process and does not preclude proper engagement with possibilities.**
6. **In any event, whether such discussions are fruitful or not does not change the fact that Applicants are expected to pursue discussions with landowners and occupiers of areas of land that might achieve, when taken together with land that has already been made available, a scheme which meets the test of Good Design while also meeting "project requirements".**
7. **The Applicant has, in summary, failed - at the earliest stage in the life cycle of this project - to properly investigate the opportunities there may have been for agreeing terms for acquiring alternative land. Not land that could necessarily provide sufficient space for the whole scheme, but land which importantly could have helped mitigate the serious impact caused by the Applicant including in its scheme areas of land that were offered to it, but which are incapable of adequate mitigation.**

Written by Jonathan Tennant (retired Chartered Surveyor and Fellow of the Central Association of Agricultural Valuers)

4 Visual Impact

4.1 Background

Large parts of the proposed development are located on the Aldington Ridge which consists predominantly of arable farmland. From the ridge there are wide ranging views to the north across the East Stour Valley and the North Downs and to the south across Romney Marsh. The Aldington Ridge is a designated Landscape Character Area which Kent County Council and Ashford Borough Council have identified as landscape that needs to be conserved and restored. The construction of a solar generating station and BESS does neither and will be significantly detrimental to the landscape.

4.2 Landscape Visualisations

Given the very significant visual impact of the proposed project the Landscape Visualisations carried out by the Applicant should form a critical part of the consultation for both Statutory and Community consultees alike.

At the 2022 Statutory Consultation held in Aldington Village Hall, the Applicant displayed landscape visualisations that were at a totally inappropriate scale that did not meet the standards set out by the Landscape Institute. The consequence of this was that it was impossible to determine the likely visual impact of the development. This issue of inadequate visualisations was raised with Applicant in a consultation response following the 2022 Consultation Meeting, however at the 2023 Statutory Consultation Meeting no visualisations (revised or otherwise) were presented by the Applicant. When questioned about the lack of visualisations Giles Frampton of the Applicant responded "*that it is not necessary as we are just carrying out a statutory consultation*".

An alternative source of Landscape Visualisations for consultees was available in the PEIR Addendum (Planning Inspectorate Reference EN010135). With particular reference to the Final Camera matched photomontage for View Point 30 (page 17 Appendix 7.9 of the PEIR Addendum Vol 3), it is evident that the images presented are of insufficient resolution to determine the visual impact of the proposed scheme. Due to the poor resolution of the imagery, it is difficult to determine whether the battery enclosures and water towers have been simulated in the final photomontages, although on balance that does not appear to be the case.

Revised Landscape Visualisations are contained within the Environmental Statement (APP-082). Whilst these are higher resolution than those produced previously, they are still insufficient to match the human perception of the view from the key View Point 30.

Figure 1 View 30 proposed 90 degree pano - LVIA View Summer at year 15 planting

The Planning Act 2008: Guidance on the pre-application process states "that consultation should be based on accurate information that gives consultees a clear view of what is proposed" (paragraph 20). In the critical case of the Landscape Visualisations this criterion has not been met for community nor statutory consultees, nor indeed for that matter the Examiner.

4.3 Visual Impact

The benefits to the community of our local rural environment have greatly underestimated by the Applicant, who has sought to present changes to the landscape as slight or even beneficial.

The visual impact of the parts of the scheme that are located on the Aldington Ridge have a very significant visual impact.

Far reaching views across open countryside characterise the area and many of these will be lost as a result of the scheme. Of particular concern is the effect on PROWs , where walkers will be "penned in" by a wall of solar infrastructure, resulting in a significant loss of visual amenity.

In many instances long distance views across the East Stour Valley such as at Viewpoint 12 (APP082 pages 11-13) , are simply obscured totally by solar panels.

4.4 Mitigation

The Applicant has proposed mitigation measures to screen the proposed development. With reference to View Point 30 - LVIA View Summer at year 15 planting (APP-082 page 43) (Figure 1) it is clear that the proposed mitigation is completely ineffectual in screening the elevated areas of the Aldington Ridge, even after 15 years.

4.5 Reducing the Visual Impact

The decision to utilise land on the Aldington Ridge for the proposed development was made for no other reason than it formed part of the original land holdings of Wanstall and Sons at Bank Farm.

What would be the effect of removing the parts of the scheme above 58m (above mean sea level) from the Aldington Ridge (Figure 2)?

Visual Impact - The visual impact of the scheme would be significantly reduced

Best, Most Versatile Land – 23.4 hectares of BMV would be preserved as the vast majority of such land is located on the higher ground (Figure 3).

Archaeology – the important heritage assets either side of Bank Road would be preserved

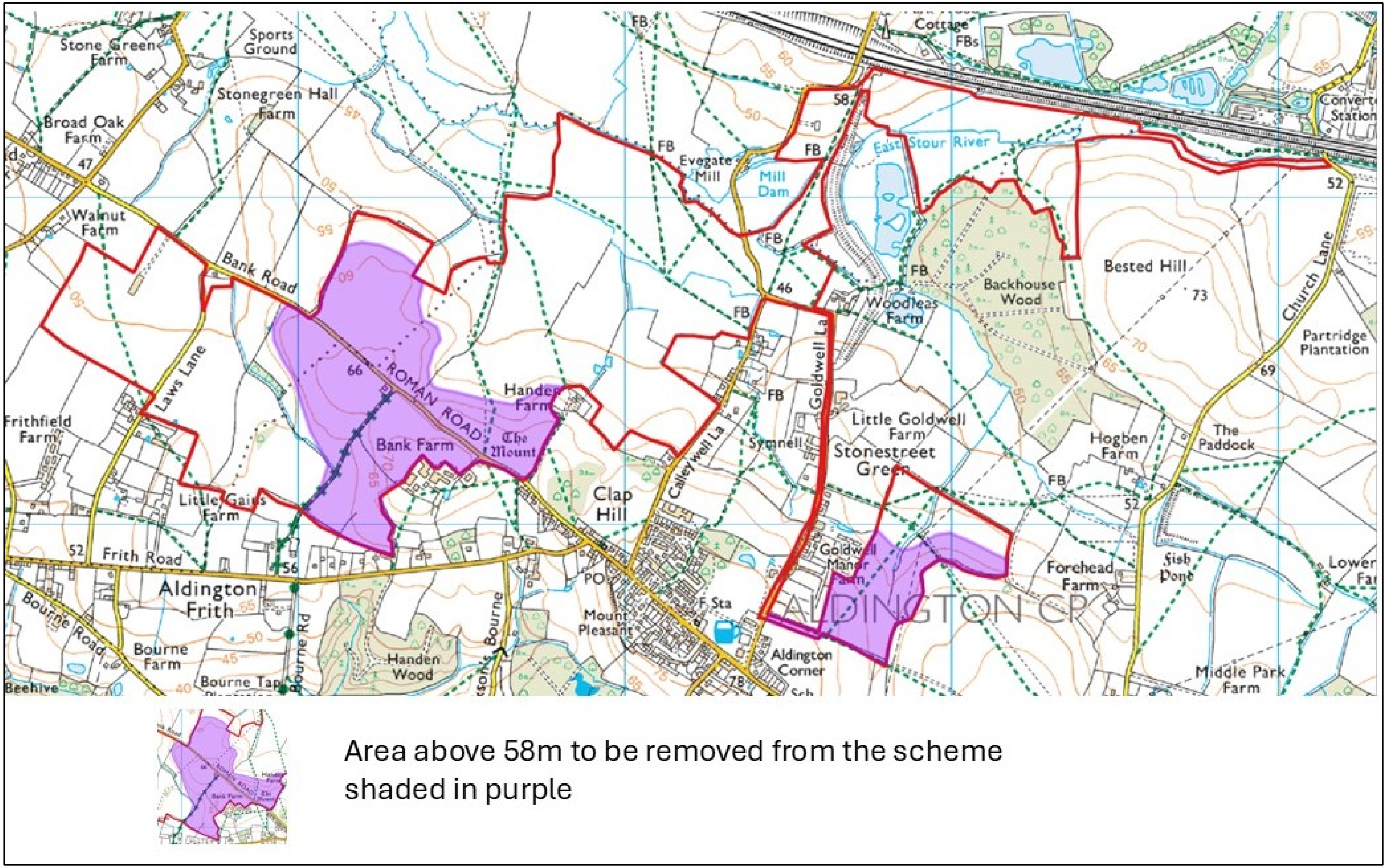


Figure 2 Proposed area of exclusion above 58m

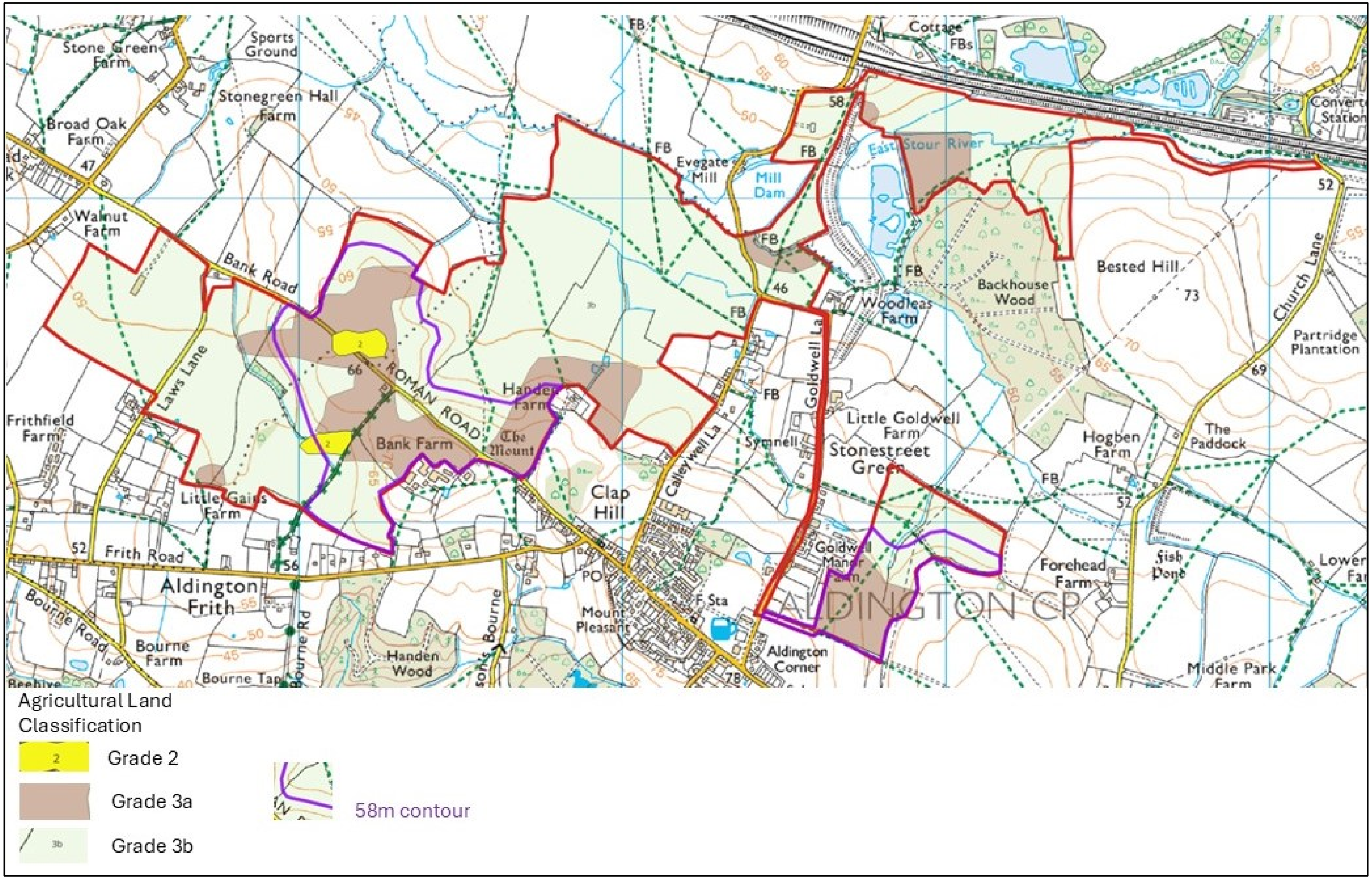


Figure 3 Agricultural Land Classification and 58m exclusion zone

Biodiversity – the important habitats of the skylark (red list species) would be preserved

Removing the parts of the scheme above 58m would reduce the area of the development from 191 hectares to 143 hectares a reduction of 25%. This would leave a capacity in excess of the stated export capacity of 99.9MW.

4.6 Cumulative Impact

Figure 8.11.3 of SSG 5.3 ES Vol 3 Ch8 landscape and Views (Ref APP-050) shows the Cumulative Zone of Theoretical Visibility for the Stonestreet Green and East Stour schemes. The visual envelope (the area from which the scheme can be seen) in the immediate vicinity of the schemes (south of the A20) is in excess of 20km2 , with both schemes being visible from approximately 40% of this area and each individual scheme from approximately 30% of the area. Both schemes will be visible along the edge of the North Downs AONB.

4.7 Summary

- **The visual impact of the elevated parts of the scheme on the Aldington Ridge is very significant and unacceptable.**
- **The parts of the scheme on the Aldington Ridge cannot be adequately screened, even after 15 years of growth.**
- **The Applicant has failed to adequately represent the visual impact of the scheme to consultees, because of the poor landscape visualisations produced.**
- **The visual impact of the scheme could be significantly reduced by excluding those areas higher than 58m, with the additional benefits of preserving the majority of BMV land, the rich archaeological heritage along Bank Road and important habitats for red listed Skylark.**
- **The 99.9MW output can still be achieved with this reduced area.**
- **The cumulative visual impact of the Stonestreet Green and East Stour schemes will be very significant and overwhelm the area.**

Written By Simon Lunn

B.Sc. Environmental Sciences M.Sc. Geophysics Fellow of Geological Society of London

5 Water Environment – Surface Water Flooding

5.1 What is the flood risk?

The Environment Agency risk of surface water flooding map (Figure 1) shows that there is a high risk (3.3% chance of flooding in any given year) of flooding at the NW corner of the DCO limits adjacent to Spring and Bow Cottages, located at the intersection of Laws Lane and Bank Road. The reality is that flooding occurs more frequently at these properties. Bow Cottage (Figure 2,3 & 4)) has flooded three times in the last 25 years, with more frequent events that affect the curtilage of the property occurring almost every year. In the nineties the fire brigade was called to pump out the living room and the property last flooded in 2020.

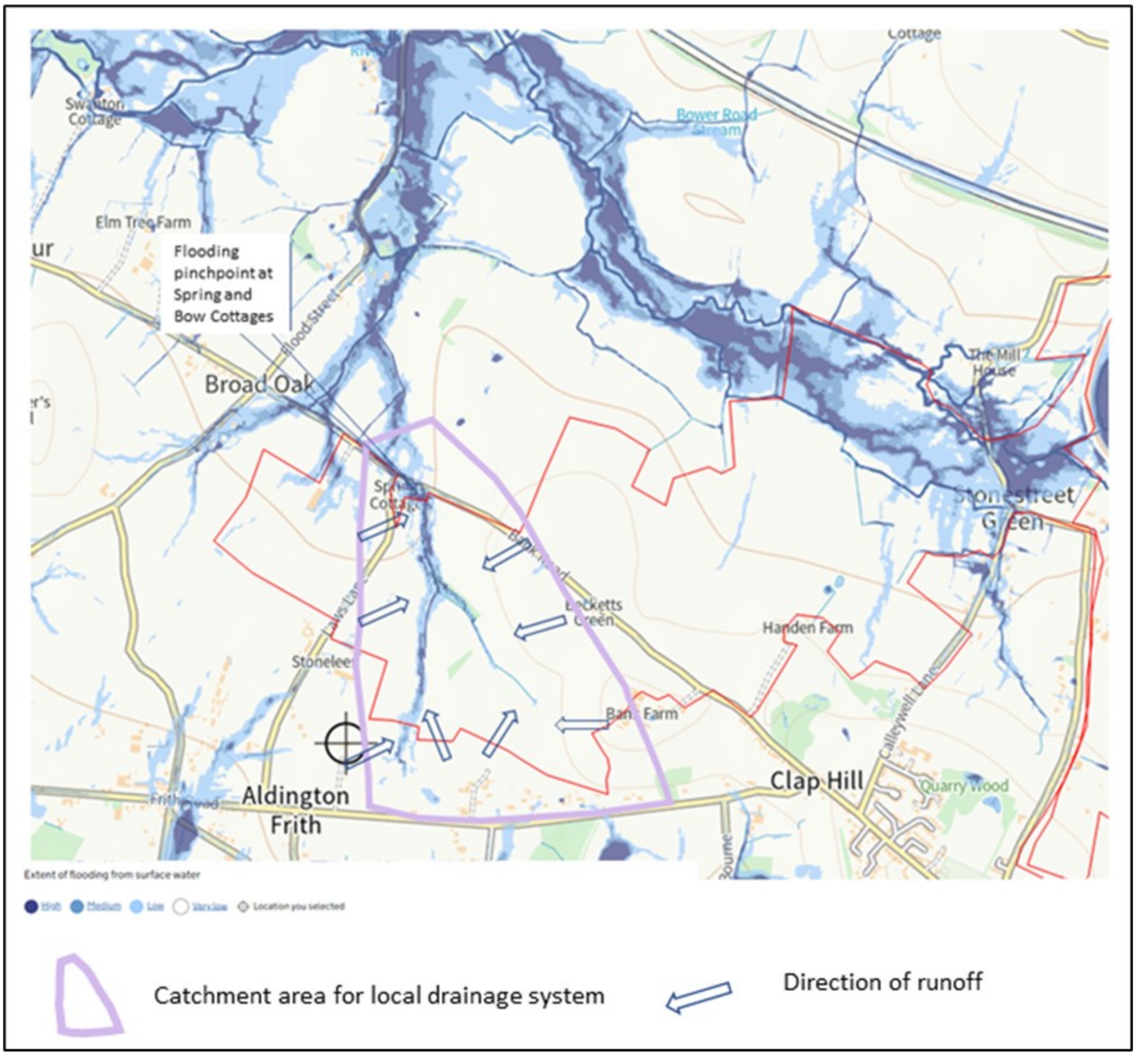


Figure 1 Flood Risk Map for surface water - note dark blue is high risk of flooding (Zone 3)

Figure 2 Flooding at Bow Cottage

Figure 3 Flooding along Bank Road adjacent to Spring and Bow Cottages

Figure 4 Flooding of driveway to Bow Cottage

Figure 5 Surface Water Flooding in northern parts of Fields 3 and 4

5.2 What causes the surface water flooding?

The stream/drainage system that runs adjacent to Spring and Bow Cottages collects water form a catchment area in excess of 100 acres (purple polygon in Figure 1). During high rainfall events the drainage system is overwhelmed, and serious flooding occurs at the two properties.

5.3 What effects will the Solar Generating Station have on flood risk?

The majority of the catchment area will be covered by solar panels and impermeable surfaces such as battery enclosures and foundations for water towers.

Chapter 9 of the Preliminary Environmental Information Report identified a number of effects that the construction and subsequent operation of the solar power station will have on surface water flood risk as follows:

Soil compaction from vehicle plant – compaction due to use of heavy machinery reduces infiltration, increases runoff and shortens the rainfall -runoff response and may lead to flooding

Vegetation removal – Removal of vegetation reduces interception and increases runoff

Presence of substation and impermeable surfaces - Reduction in recharge to the underlying aquifer therefore locally reducing groundwater levels. This will also increase runoff to surface water drains/ponds and may lead to flooding.

Presence of Solar panels – Rainfall onto the angled panels may cause erosion beneath the lower edge of each panel, resulting in erosion and sediment laden runoff

Installation of solar panels – Interception of rainfall by panels increases runoff and reduces interception and evapotranspiration rates.

The key factor in this area is the heavy clay soil which is extremely susceptible to compaction which reduce significantly reduces permeability and infiltration, leading to greater runoff. Local farmers avoid accessing the land with machinery during the winter months (November to March) because of this.

Figure 2 shows the effects of solar farm construction on infiltration and consequent surface water flooding on a similar soil type. At the existing solar farm in Church Lane Aldington the ground had to be consolidated prior to the installation of the panels, which greatly increases run off.

A case study from Ontario has highlighted the surface water flooding risks associated with clay soils and significant topography (Appendix 2). Quoting from the study:

"*In hindsight, it has become apparent that the selection of sites must place great significance on topography, existing site conditions and constraints such as nearby watercourses and soil types. All of these factors readily influence the volume and flow rate of runoff that, if not properly managed, can result in negative impacts to downstream and neighbouring properties*".

Figure 2 Solar installation at New Romney showing the effects compaction (associated with Solar Panel installation) has on surface water

5.4 What they said?

The issue of surface water flooding was raised with Applicant in a consultation response following the 2022 Consultation Meeting.

The Flood Risk Assessment states that "the surface water flood risk is shown in Figure 10.2.10", although this figure does not appear to exist within the document. Furthermore, the Environmental Statement contains no references to the surface water flooding that occurs at Laws Lane/Bank Road. Section 9.5.2 of the Flood Risk Assessment states that "*In rural areas, the mechanisms that drive surface water flooding are often the same as those that result in fluvial flooding. It is therefore considered that where the mapped areas of surface water flooding align with a watercourse (of the fluvial floodplain), the detailed hydraulic model developed to inform this FRA provides a more robust assessment of the flood risk from both fluvial and pluvial sources*". This may be correct except that the modelled extent did not include the area of surface water flooding at Spring and Bow Cottages.

Section 9.5.10 states that "*Localised areas of "medium" and "high" risk are associated with the field drainage ditches and ordinary watercourses running along the boundaries of the fields, including the Spring and Bow cottage properties located at the Laws Lane/Bank Road junction. During the extreme 0.1% AEP event maximum flood depths are shown to be between 0.9m and 1.2m within the drainage ditches, with maximum flood depths between 0.15m and 0.30m outside of these channels. The Project is not expected to worsen effects in this area*". The source of the predicted flood depths is not referenced, but it is clear that the reality is that surface water flooding currently occurring at this location is of a greater magnitude and frequency than models predict. The statement that the Project is not expected to worsen effects in this area is completely unsubstantiated.

5.5 What happens further downstream?

The drainage system in question eventually feeds into the East Stour River in Mersham. Flood Street is at high risk of surface water flooding (Figure 1) and flooding here is almost an annual event. Additional stormwater from the proposed Stonestreet Green Solar generating station also has the potential to increase the frequency and magnitude of flooding at this location and at the residential properties there.

5.6 Summary

- **Existing surface water flooding at the junction of Laws Lane and Bank Road affects both Bow and Spring Cottages, which flood regularly.**
- **This area has been identified by the Environment Agency as having a high risk of surface water flooding, although the actual frequency of flooding is greater than predicted.**
- **The PEIR produced by the Applicant identifies a number of factors associated with the construction and operation of the scheme, that could impact the frequency and magnitude of surface water flooding.**
- **The Applicant has not modelled the effects of the construction and operation of the scheme on the magnitude and frequency of surface water flooding.**
- **The Applicant has not taken into account the key site specific factors of catchment area, topography and soil type.**
- **A case study from Ontario Canada has highlighted the impacts that these site specific factors can have on surface water flooding, that if not properly managed can result in negative impacts on neighbouring and downstream properties.**

Written By Simon Lunn

B.Sc. Environmental Sciences M.Sc. Geophysics Fellow of Geological Society of London

External References

Appendix 2 Lessons learned: Solar projects present unique stormwater management challenges – Environmental Science and Engineering https://esemag.com/stormwater/lessons-learned-solar-project-present-unique-stormwater-management-challenges/

6 Construction Traffic

6.1 Introduction

The villages of Aldington and Mersham lie to the west of the A20 that runs between Ashford and the village of Sellindge.

Of the two villages, Aldington stands to be the most affected by the Project in terms of traffic disruption. The population in the village, and through traffic have only two routes to choose from. Church Lane lies to the north-east of the village, an unclassified singletrack lane with few passing places. Those using this lane also have to contend with traffic generated by various infrastructure installations (these either existing or under construction) and, except in unusual circumstances it is unlikely to be the route of choice for anyone travelling from the village to the A 20 particularly as EDF Renewables may be constructing a solar scheme accessed from this lane in 2026.

Station Road, a classified highway (C609), is the more direct route to the A 20 albeit that it is tortuous and narrow in places to the point where, on the section by Evegate Mill it is not possible for cars to pass, mainly on account of two narrow bridges on tight bends. There are other sections close to Evegate Business Centre, which are narrow enough to make it difficult for HGV vehicles and large agricultural machinery to pass each other.

Station Road, which links with the A 20 at the Smeeth Crossroads, is the construction traffic access proposed for the Project. Every item of infrastructure, equipment and materials to build out the Project will arrive via the M20 (junction 10 a), travel along the A 20, turn right at the Smeeth Crossroads and turn into the Primary Access and Compound at a point immediately south of the HS1 railway bridge.

Although internal haulage roads are proposed the Project additionally expects to use Goldwell Lane, a continuation of Station Road, as a construction access to serve the only geographically separate area of the scheme (the so-called Eastern Area). Not only is this to be used for construction traffic but also for cable laying. Goldwell Lane forms an integral part of a "circuit" of roads within the village of Aldington (along with Roman Road and Calleywell Lane) and is the route generally chosen for those driving to the village primary school from the A20.

We made a representation at the Construction Traffic ISH on the 21st of November. As we explained, whilst the proposed outline Construction Transport Management Plan (CTMP) does not claim to be definitive, its brevity and lack of adequate detail in the 22-page draft is unacceptable. We maintain that this scheme should not proceed to a decision on the DCO application without the Applicant addressing the issues which we raised at the ISH 2 and additionally those which are covered in this submission.

We have considered in detail the case which the Applicant and its expert, Mr Stoddard, have put forward, principally contained in **Chapter 13 ES Volume 2 Main Text "Additional Submissions (AS.009),** and maintain the implications for the safety and disruption to other traffic using the Construction Route during the estimated 12 months of construction has been underplayed both by the Applicant and the Highways Authority at Kent County Council (KCC).

Whilst it may in most cases be accepted that only an outline CTMP need be presented prior to a DCO Grant (pending a much more detailed and definitive arrangement being finalised at a later stage in conjunction with the highways authority) this approach is inappropriate in the case of this Project.

One wonders how unsuitable, unsafe and disruptive a proposed construction route for a DCO project would have to be for an "outline only" CTMP to be acceptable prior to Grant. The prospect of some as yet unknown Principal Contractor setting about later applying to make a variety of alterations to sections of the adopted highway "on the hoof" prior to the commencement of construction, relying on the provisions contained in the draft DCO (dDCO) is irresponsible. KCC, in its role of safeguarding the interests of all those living and working in the locality that rely on the smooth and safe running of the highway network in the area, should surely want to avoid this. We are equally concerned that the dDCO only gives a very limited period for KCC to conclude the final terms on traffic management following a Grant.

We sense a laissez-faire approach has been adopted by KCC Highways in their consultation with the Applicant in this matter. The way KCC Highways' submission of 12th September is written conveys a sense of an authority that feels beholden to the Applicant rather than the other way round. KCC should be in the role of ensuring that every conceivable potential impact on the highway network has been thoroughly investigated and where merited, requirements placed firmly on the Applicant to cover off every eventuality assuming the worst-case scenario.

We do not believe that the proposals have been adequately scrutinised, and we hope the ExA will probe the responses that KCC's "professional officers" (notably a phrase much employed in the Applicant's presentation at the ISH 2) who regrettably did not attend the Hearing to answer his questions and those raised by others directly.

To our mind the question is whether the scheme as a whole can be constructed safely relying on the only construction route available? We maintain that it *cannot* without unacceptable safety implications for those that will either share the route with the enormous amount of construction traffic for a period of at least one year or which will be displaced onto other less suitable and inconvenient routes.

We now comment on the Applicant's **Doc 5.2 Chapter 13** and where pertinent, the responses provided by KCC Highways in their representation of 24th September 2024.

6.2 The inadequacies of the Construction Route

13.1 The Applicant maintains that the Operational Phase is Scoped Out. We understand from the comments made by the Applicant at the ISH 2 that the provisions contained in the dDCO at paragraph 21 relating to the right to "maintain" the development should remain as drafted. This issue was raised by Counsel on behalf of Aldington and Bonnington Parish Council (ABPC) **(Counsel's Note 05.11.24).** We agree with him that it is far too widely drawn. Specifically, the dDCO provides, inter alia, for "reconstruction". With the rapidly improving technology that was discussed during the Preliminary Meeting, there is every prospect that within the 40-year life of this scheme, the panels across the entire site will be replaced on more than one occasion. They will anyway need to be replaced at some point because their projected useful life is much shorter than the length of the temporary permission applied for.

Furthermore, in the **Operational Management Plan (OMP) (Doc 7.11)** the operational phase is claimed to only require *"infrequent HGV access"* throughout the 40-year duration. The provisions as drafted in the dDCO provide the opportunity for a vastly different scale of access at all times as may be desired from time to time by the owner of the completed scheme.

KCC Response: *"The Local Highway Authority notes that normal operational traffic levels for the completed site would be so low as to have near zero impact on the highway network".* This completely misses the point we make above about the provision contained in the dDCO allowing *full reconstruction* during the Operational phase.

13.4 The Applicant maintains that throughout the scheme there will be an average of 16 construction traffic two-way trips per hour along the Construction Route based on a 12-hour day. The Applicant claims that it will avoid using the route during peak hours and in particular will not interfere with school drop-off and pickup times. If it adheres to this, the working day will be materially shorter than 12 hours and consequently this will serve to condense the number of two-way trips into a shorter period causing more impact. We maintain that averaging is a misleading basis for assessing this increased traffic impact.

KCC Response: KCC also believes this an overlooked aspect when it says: *"The figures as presented are averaged out over the whole workday to present a vehicle number per hour value. This may be reasonable for delivery vehicles; however, for workers, their arrivals are usually prior to a set start time or to meet a specific shift pattern and as such would be far more concentrated than shown".*

However, within its response, just four paragraphs later, KCC simply repeats the Applicant's estimated *average* number of vehicle movements and goes on to state (unequivocally) *"This level of HGV traffic accessing Station Road only from the A20 is* *acceptable to the County Council, as Local Highway Authority".* **Page 13-10** The Applicant maintains that Station Road north of the primary site access provides *"sufficient width"* for HGVs to pass (but see next point below). This is quite simply not the case where the road narrows in areas between the bridge over the M 20 and a point approximately 200 m south of Bower Road's junction with Station Road.

The restrictions in this area are particularly problematic because the busy access to and from Evegate Business Centre is located centrally within this section. No amount of cutting back of hedges and verges will alter this. The Exa, at his USI1 (on 11th July 2024) walked this section and will therefore be familiar with its constraints as well as the amount of traffic (and its speed) that using this C class road. It is not a place where anyone would choose to walk.

13.7.43 – Here the Applicant contradicts the point it makes about there being sufficient width when it says *"There is evidence of vehicles overrunning grass verges on Station Road, which may have occurred where two HGVs, including agricultural vehicles have attempted to pass. The instances where two HGVs will need to pass will be limited, however it is acknowledged that the increase in HGVs using Station Road during the construction phase may result in a limited degree of conflict with other HGVs using the road".*

13.7.63 Here the Applicant states without qualification that *"no unusually hazardous or dangerous loads are anticipated for the construction phase of the Project".*

What criteria is being used in this assessment bearing in mind that the Project will require the importing by lorry of well over 100 battery units for which there is no special provision made? Provision is only made for the estimated two abnormal loads (that relate to the substation equipment).

In the IEMA 2023 guidelines there is a requirement for qualitative analysis. The Applicant refers often to the need to anticipate the "worst case scenario". Why then has it not looked at these loads as "abnormal loads" and explained how, when using the Construction Route (where, as already explained, there are sections where HGV cannot easily pass) these battery deliveries will be safely managed along with an emergency plan if an accident occurs?

At the ISH2 the Applicant made much of the point that the drivers of the articulated lorries delivering to the site would be "*professionally qualified drivers*". *Anybody* driving an articulated lorry must have passed an HGV Class 1 (C + E) This is the standard highest level of test. Anything over and above is very specialist and relates to specific types of abnormal load. We therefore believe unless the Applicant can explain otherwise that the vast majority of articulated lorries will be driven by those that have passed the standard HGV Class 1 test.

6.3 Goldwell Lane - access to the South-Eastern Area

13.5 Refers to Goldwell Lane which is proposed to form part of the Construction Route solely in order to service the outlying small South-Eastern Area. The Applicant maintains that *"there is no feasible alternative access to the south-eastern area"*.

At no point within the application does the Applicant explain why this is the case. It should be noted that the dictionary definition of the word "feasible" is that which can be done *"easily or conveniently"*. There is going to be nothing easy or convenient for those living in or choosing to use Goldwell Lane when construction traffic is using it to reach this tiny16 Ha separate landholding over an estimated period of five months. Especially not when cable laying is undertaken in the highway. It will create unjustified disruption and misery to those who live in the lane and, whilst there is no proposal for closing the highway during construction (which might have offered a more palatable proposal), the inevitable consequence will be to drive traffic along Roman Road and Calleywell Lane (most notably school run traffic).

We have spoken to the owner of the land immediately to the north of the south-eastern area. This is Little Goldwell Farm which has land which abuts Goldwell Lane. The land is permanent grass and used mainly for sheep grazing and offers an obvious opportunity of a much shorter construction route to reach this outlying area. The impacts of taking this route (including the cable laying) would be short lived. It would involve a "soft dig", much reduced traffic management and disturbance, and we suggest a shorter construction period.

We understand that whilst the Applicant approached the landowner to ascertain whether they would be interested in including their land within the proposed solar development itself the possibility of this temporary access and cable laying (and an offer of commensurate compensation) was never mentioned by the Applicant.

It is now too late to know whether or not the landowner would have been amenable to such a proposal and if so upon what terms. Our assessment is that the Applicant elected (without any enquiry) to make use of as much of the public highway as it possibly could – irrespective of the disruption and misery it would cause to numerous residents along the route and those choosing to use the lane (particularly those on the school run to the village school) to get to the village.

At the Compulsory Acquisition (CA) hearing, the Applicant referred to another section of the scheme where temporary access and cable laying rights are sought over third-party land (Messrs Price). We know that negotiations on terms for this facility have been ongoing for at least two years and the Applicant is making provision for CA if those negotiations do not reach a satisfactory conclusion. The Applicant's Counsel in the CA hearing stated that *"the development is categorized as a critical national priority, and* *we say that plainly creates an in principle compelling case in the public interest to respond to and meet that need………"*

If this outlying small element of the scheme is essential to the viability of the project (and not been included because it is now an isolated and remote area in the ownership of the original landowner that promoted this scheme) then why is both the access and cable route not treated in the same manner as the section through Messrs Price?

Why were the interests and concerns of the residents in the lane (none of whom, other than the owner of Little Goldwell Farm ever had the courtesy of a communication still less a visit from the Applicant) investigated?

Is the issue of so little concern to the Applicant that it simply decided to proceed without even endeavouring to look at mitigation? It is not simply a question of cost/benefit. Whilst the Applicant may deploy this argument when comparing the outright *need* for an alternative route to the south-eastern area, it is clearly the case that it did not follow the appropriate high level/macro analysis and properly consider and research other options, including this one, for access. Instead, we suggest it knew that access and cable laying down the highway was the quickest way to resolve this matter and having taken that decision set about proving that it was acceptable in environmental terms.

KCC Response: Not only did KCC not have the curiosity to enquire about what alternatives were considered by the Applicant (as far as we can see from their submissions) but they apparently believe that all of the proposed works within this long section of narrow highway are acceptable in terms of highway safety and resident/business/emergency access and egress alongside all other traffic that will continue to try and use this lane for 5 months.

KCC's only suggestion in terms of mitigation is regarding some overgrown hedges and for these it *"recommends that these sections should be trimmed back to a reasonable level prior to the start of works such that this vegetation does not prevent users being able to use the full width of the road to pass other large vehicles"*.

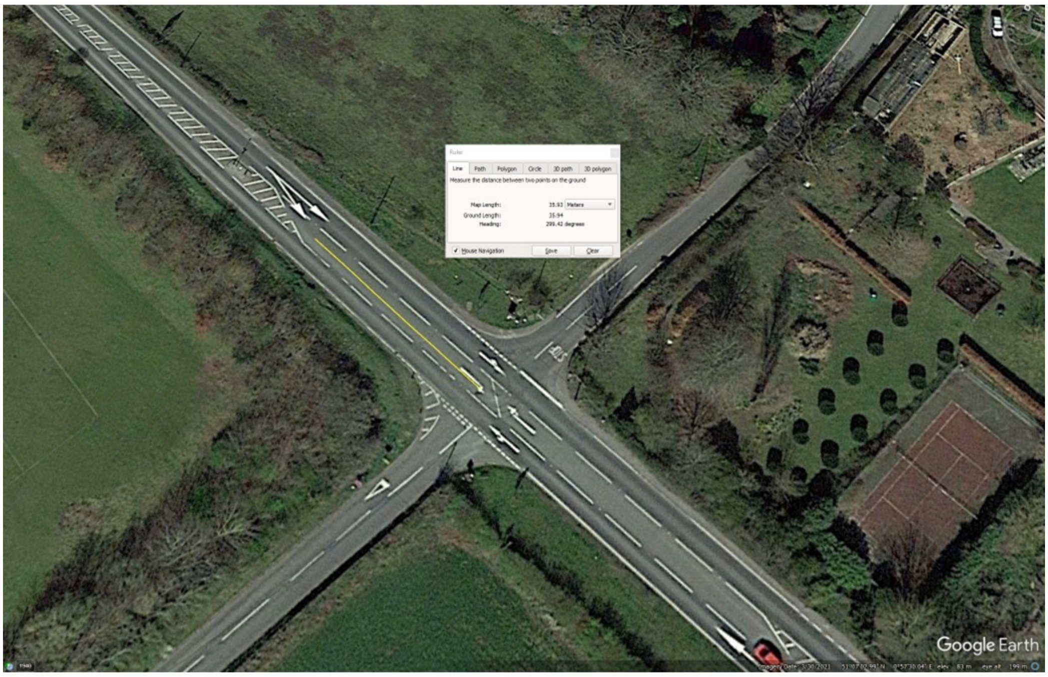
The ExA must appreciate that in a number of places the metalled highway is as narrow as **4m.** How will it be possible for the Applicant's articulated wagons (that are so large that they need to have an escort to navigate the sharp bend in the lane) manage to pass other HGVs that will remain free to use the lane at the same time?

We doubt that Stop/go/temporary traffic lights are going to work when the 2m wide trench is being installed (on varying alignments to avoid services in the road). How can this work on a "half and half" basis when there are sections of the lane where there is insufficient space to allow even small vehicles to get past each other alongside such excavations (and safe working areas) let alone HGVs for which the standard width in the UK is **2.55m**?

6.4 The Smeeth Crossroads

We maintain that configuration of the Smeeth Crossroads has been inadequately assessed by both the Applicant and KCC. There could not be better evidence of this claim based on the fact that the Applicant's Expert explained at ISH 2 that the ghost lane was capable of accommodating THREE 16.5m long articulated lorries. This is factually incorrect.

13.7.4 It is here that Applicant refers to the ghost lane as having an effective length of 50 m. This is not correct. It cannot accommodate up to 3 articulated lorries. Its measured length is at most 36 metres and as such it can barely accommodate two HGVs and the second of these is likely to be encroaching into the east bound through lane, and certainly so if there is already a car in the lane ahead of two lorries. (See extract from Google Earth below).



Google Earth extract – Smeeth Crossroads – Ghost Lane Dimensions

The issues that confront a driver on any approach to this junction are multilayered. The challenges are particularly acute for those turning in or turning out of Station Road. Those turning in must judge the speed of approaching traffic from the east before making their turn. If they are an articulated HGV, they cannot in any event complete the manoeuvre until queueing traffic that wants to exit Station Road has cleared. Cars can arrive at the junction very quickly and therefore lorries waiting for the queueing cars to clear can take some time. Cars wanting to turn right into Station Road end up queueing behind any “waiting to turn” HGV and other traffic.

Some of the cars wanting to exit from Station Road in this scenario will want to cross straight over into the northern arm – Church Road - and some will want to turn right to go east towards Sellindge. Such drivers have no option but to communicate nonverbally with the waiting HGV driver in the ghost lane and, at the same time, with drivers that are waiting to exit from Church Road opposite.

While they are doing this, the exiting driver is expected to judge the speed of approaching traffic from their right (coming from Sellindge) and make sure that they have not missed traffic approaching from the other direction that may be hidden from view but managing to get past the queueing traffic waiting in the ghost lane.

The most recent serious accident at the crossroads occurred only a matter of days after the ISH 2 on Traffic. It was on the 26th of November and involved two cars. Whilst there are as yet no detailed reports on what happened, based on the position of the written off cars, it appears that a turning vehicle was hit by a car coming from the Sellindge direction (see photo below).

Aftermath of crash at Smeeth Crossroads on 26th November 2024

The above brief summary explains some of the issues that already face drivers at this junction and ask anybody locally and they will tell you that it is a junction that is considered dangerous. Indeed, many local people prefer to find an alternative route round to the A 20 if they can – even if longer and through the lanes.

Turning to the detail submitted by the Applicant and responses from KCC:

13.5.4 There is reference to *"illuminated traffic islands".* In fact, these are no more than two sets of raised bollards with reflective directional arrows and two white lights on a column above each set.

13.5.31 The detail here refers to an accident in March 2023 when it was *"dark with no streetlights and an HGV driver failed to see a car"*. This comment emphasises the fundamental problem with the junction – there is no street lighting.

Based on the hours of working indicated by the Applicant (08:00 hours – 18:00 hours, excluding start-up) the estimated 12-month scheme will include at least four months that have the additional impediment of no daylight. Couple this with the complexities of the Smeeth Crossroads junction and increased traffic flows around the beginning and end of each day it is only logical that there will be an increased risk on account of the extra construction traffic, especially HGVs and particularly at peak times.

13.5.33 The detail here refers to an accident which was believed to have been caused by *"misjudging the speed of other cars".* This goes to the heart of the detailed explanation that we provided at the beginning of this section and is we expect likely to be at least part of the cause of the accident last month, and many others. There can be an overload of considerations for drivers that are exiting Station Road and most particularly for those that are intending to go straight over to Church Road or turn right towards Sellindge.

KCC Response: KCC have clearly now had second thoughts and, contrary to their previous correspondence with the Applicant indicate that the crossroads has, since their formal response to this matter in July 2023, been flagged for inclusion in their crash investigation cycle.

They say that the accident record over the last three years means that it now meets the criteria for investigation. Despite this statement, and in advance of that investigation, KCC's professional officers state *"it is not considered that the resulting uplift in traffic would significantly worsen the crash record in this location. In reaching this conclusion, several assumptions in relation to the traffic generation from the proposal have been made based on the supporting application information – commentary raised in this representation should be clarified by the Applicant <u>prior commencement of the Examination</u> to ensure this view is maintained".*

We are not aware whether this requested clarification has yet been provided by the Applicant, but it was not mentioned at any point during the ISH 2.

6.5 The Primary Site Access and internal haulage routes

Table 13.11 provides details of construction traffic vehicle trips and indicates an average figure (an aspect we have already explored) of two HGVs per hour. When it comes to staff numbers the Applicant provides a maximum number of 199 and an average number of 132 on site throughout the 12 months.

Why is there no such indication of the expected peak number of HGV trips along the Construction Route? Inevitably there will be periods of much more intense activity. The Applicant is keen to talk about the way it has assumed the “worst case scenario” on numerous aspects but in this respect, there is no sign of it having done that. How bad could it be?

It will be on such days (or indeed perhaps weeks) of more intensive use that the suitability of the Construction Route will we believe be found wanting. The averaging of the number of trips contains hidden risks and these should be fully investigated.

13.6.16 The Applicant confirms that the internal haulage roads will be installed again for the decommissioning phase. There is however no provision that we can find that any will be reinstalled at any point during the Operational Phase. However, the section between the primary site access and the crossing of Station Road will again be essential as and when major refurbishment or indeed a complete reconstruction is undertaken. If construction traffic were to use the full length of Station Road for such an operation (involving the impossibly narrow section past Evegate Mill) this would be as unacceptable as it would be for Construction. This should be clarified within the dDCO (paragraph 21).

13.7.31 The Applicant states that *“HGVs will only require infrequent access to the Site, such as for maintenance, servicing or to deliver replacement equipment, across the lifetime of the Project”.* As per 13.6.16 above, this broad statement is incorrect because it ignores what is likely to be major works of refurbishment/reconstruction during the lifetime of the temporary consent, if granted.

13.7.33 The Applicant maintains that the only delay will be through construction traffic slowing down to make a left turn into the primary site access. The swept path analysis (reference P22034-001D-00) indicates that the 16.5m long articulated lorries will inevitably have to swing across onto the opposite carriageway to complete their manoeuvre into the access. Why is this not referred to other than on this swept path plan? What about the risk associated with a slowing vehicle behind the left turning HGV swinging out into the path of another vehicle coming in the opposite direction heading towards the A20 that will be unsighted?

13.7.40 The Applicant says that it “aims” (not “will”) to time deliveries so that they avoid school drop-off times and pick up. It is notable that there is reference only to the Caldecot School in relation to Station Road traffic whereas this route is a primary route for the school run to the school in Aldington as well.

Evegate Business Centre: For some reason, the Applicant makes no reference at all to the peak periods of travel to and from Evegate Business Centre. This centre caters for at least 150 cars. For some it is the place of work no doubt with varying shift patterns while others are just visiting. This user will exacerbate traffic issues at the Smeeth Crossroads either side of peak school run times and potentially clash with Project staff shifts (which we believe will quite possibly involve a similar number of cars) running to and from the primary site access.

13.8.3 The Applicant claims that it will undertake monitoring (including the monitoring of collisions at 13.8.2). Whilst it may claim that this will afford the opportunity for amending the CTMP if necessary, it will, once the scheme is in operation, be impossible to stop the project if, as we suspect, the inadequacy and dangers associated with the Construction Route (particularly at the Smeeth Crossroads junction) are found to be such that it is, viewed as unsafe for such an increased use.

13.7.60 The Applicant’s sweeping final remark in terms of Road User safety (irrespective of the many issues and concerns we have raised) seems extraordinary and even manages to include a typo: “*there is no evidence to suggest that the Project will exacerbate the frequency or severity of (sic) local residents”.*

6.6 Cumulative Impact

13.4.27 Church Lane is scoped out because, what are referred to as *“significant effects”* are not expected.

The crossing point in the lane immediately south of the bridge over the East Stour River is also the access and egress point for the EDF Renewables solar project (APP/E2205/W/24/3352427) currently at Appeal. This other adjoining scheme also anticipates construction during 2026. There is, as we have heard during the CA hearing, the confluence of cable laying from both schemes crossing over at exactly this access point adjacent to the highway. It is inconceivable that the Applicant’s project will not exacerbate the impact on traffic at this location by virtue of the crossing point here serving two separate projects and necessitating substantial excavations at the point of the access for cable laying and quite possibly directional drilling operations.

13.10 The Applicant in this section refers to cumulative effects but in its reference to “other schemes” it has failed to adhere to the guidelines to which it refers. It should also refer to “existing” schemes and in the case of Church Lane it has not mentioned the two

UKPN substations, the Southern Water Sewage Works and most important of all the huge National Grid Converter Station.

At the Traffic ISH 2 we made the point that consideration should be given to the potential closure of Church Lane during the construction of the EDF Renewables project and that this should be included in the Applicant's traffic modelling. The Applicant indicated that it was not required to anticipate such a situation. As we have said before, we suggest that the Applicant should always look at the "worst case scenario" (as it does elsewhere). Even if there is not a temporary closure of Church Lane during the anticipated year of the Project's construction (2026) then at the very least it should seriously consider the cumulative effect of the *existing*, ongoing and proposed developments at this end of the lane resulting, we believe, in through traffic tending to use Station Road in preference.

Page 13-18 The response from KCC in relation to maintaining safe roads clear of mud and debris indicates that there should be a mechanised street sweeper on site. "*The Site workings should have available on-Site a mechanised street sweeper to ensure that any material dragged from the Site onto the highway is cleared as soon as possible so as to prevent a hazard to highway use".*

This means KCC's requirement is for the machine to be available on site whereas the Applicant states at **Page 13-50** *"A mechanised road sweeper will be deployed on the approach to the Primary Site Access, the Goldwell Lane access and at the highway crossing points to remove any debris, if required."* This does not appear to be the same thing unless the Applicant can confirm otherwise.

6.7 Summary

1. **Notwithstanding the responses provided by KCC to the Applicant's proposed arrangements for the safe provision of construction access to this huge scheme we believe these are inadequate.**
2. **The Construction Route between the Smeeth Crossroads and the Primary Access and beyond is, in its unaltered state, not suitable for the large amount of additional traffic it will have to accommodate nor is it, in terms of its width in certain areas, capable of enabling HGVs (scheme based and otherwise) to pass safely.**
3. **The *need* to use of Goldwell Lane as both a construction access and route for cable laying has not been proven. The disruption that this decision will cause to local people and those living in the lane is unacceptable and disproportionate to the net additional renewable energy output that the small area will deliver.**
4. **The Primary Access is not the easy and safe access claimed by the Applicant. The configuration of the access itself means that those using**

Station Road will not only suffer severe disruption throughout the construction period, but the swept path arrangement is quite simply not safe without making significant modifications to the highway.

5. **Further, as we raised at the ISH2, it is as yet unclear whether fields 25 and 26 are large enough to provide the site compound facilities that are going to be required – in all weathers, whilst the construction of the huge substation and a battery compound is carried out concurrently within this area.**
6. **The Applicant has failed to appreciate and factor in the cumulative impact the scheme will have on the local highway network.**
7. **The scale of the issues relating to construction traffic is sufficient to require, in this instance, not a simple draft CTMP to be agreed before Grant (if consented) with a view to finalisation at a later stage but instead a very much more detailed assessment now to understand whether or not *the proposal as a whole* is fit for purpose (and safe for the travelling public) without carrying out Highway modifications.**

Written by Jonathan Tennant (retired Chartered Surveyor and Fellow of the Central Association of Agricultural Valuers)

7 The South-Eastern Area – Fields 20,21 and 22

7.1 Introduction

This area of the project is the only element of the Applicant's proposal that lies remote from the main part of the scheme and for all the reasons we will cover in this section, its inclusion seems perverse.

Unsurprisingly, it is referred to in the context of the Project by local people as "*the Outlier*" many of whom, unfamiliar with the workings of the Planning Act 2008 and NSIPs, believe it has only been included by the Applicant in order for it ultimately to be withdrawn as some sort of "sop" to the community. For ease of reference, we will refer to it as the Outlier.

We do not believe that the Applicant has demonstrated that in the face of the significant environmental impact that will be caused by its inclusion in the scheme, that the benefits of this small additional area outweigh the considerable harm it will cause both during construction and throughout the proposed 40 years.

7.2 Background

At the inception of this Project, this land formed part of a larger land holding on this eastern side of the village and was owned by the original landowner who initiated this NSIP solar scheme.

The landowner concerned has been successful in getting part of the holding allocated for residential development in the Local Plan adjacent to Church View in Goldwell Lane.

In Ashford Borough Council's "Call for Sites" last year, the same landowner has put forward land to the rear of the already allocated area. This other area runs up to the new hedge line, which he planted in the last few years presumably to try and establish the next logical "natural" boundary to the village for a future phase of residential development.

With these proposals, both allocated and planned, the residue of land is the Outlier which, being remote from the main farm holding and requiring farm vehicles to reach it through the centre of the village (and criss-crossed with footpaths) it has presumably become unfeasible to continue farming. No doubt this is why it has been included within the Project and the Applicant set the task of making the case that it will cause no material impact and any that is caused can be easily mitigated.

7.3 The question of Necessity

The Outlier only comprises approximately 15Ha of good agricultural land which is about 8% of the area of the whole scheme. In terms of its energy output, the Applicant indicates a figure of just 7.9% of the whole scheme.

At the Preliminary meeting, the Applicant indicated that there was every prospect that the performance of the panels ultimately installed would be better than the current assessment.

Counsel for the Applicant went on to say at the Preliminary Meeting that any such improvement in performance was simply "optimising" output. He would not accept that such improved performance might logically suggest that the development might not need such a big acreage. Instead, the Applicant sought to rely on Rochdale (adopting the worst-case scenario – which in this case means seeking to include the maximum amount of land based on the current rule of thumb figure of needing up to 4 acres per megawatt - even if this, at the time of construction is likely to be bettered).

We cannot accept the Applicant's claim to be entitled to achieve whatever extra-over output the scheme will produce at the expense of greater acreage than is needed. If this scheme at the very lowest estimate will generate between 140 MW and 165 MW, how can it be a necessity to include the Outlier at all when its removal would only reduce this extra-over generation down to between 129 MW and 152MW and if you apply the 1.4 multiplier to 99.9MW it gives a figure of 140MW ?

7.4 Public Rights of Way (PROW)

As other representations have already demonstrated, the Outlier stands to be uniquely affected in another way. Despite being small it plays host to 3 footpaths. The most major of these is AE 454 which runs broadly North/South on a diagonal "line of desire" taking the walker gradually from arguably the most used footpath in the village (AE 474) on the Aldington Ridge, down into the valley floodplain. It is during this descent that one of the special features of this ancient way becomes clear, which is its views into the East Stour Valley and beyond towards the North Downs (AONB).

AE 454 showing "Line of desire" running diagonally across Fields 20 & 21

<u>Footpaths within Field 20</u>

Instead of retaining AE 454 on its existing line, the Applicant has chosen to divert it down into the valley feature in the field which will remove the views. Why was this a necessity? Why in the face of so much opposition has the Applicant not left things as they are? Could it be that the inclusion of the Outlier in the scheme is already so "borderline viable" that it is critically important to maximise the panel footprint at all costs (including the cost there will be to those who enjoy these paths).

Presumably footpath AE 455 is seemingly even more inconvenient since it is proposed to remove this path altogether.

If it is necessary to treat these paths in this way, how is it that this land has been "*<u>selected</u> by the Applicant* …. *based on a series of influencing factors" (*which bizarrely includes PROW*)* **(5.6.2 of the ES Vol 2 Chapter 5)**.

The reality is that the landowner found it awkward to farm and with no prospect of an uplift in value through any other change of use in such a sensitive location presumably asked the Applicant to include it in the scheme. The result, in terms of the footpath network alone, is much more harm than benefit.

Footpath AE 474

The Applicant confirms that this footpath (which runs adjacent to the southern boundary of field 20) is, from its own survey work, frequently used by villagers. It provides an easily walkable path for those living in the centre of the village through unspoilt countryside on the Aldington Ridge, to St Martin's Church and the original pre-plague village settlement (and village's only Conservation Area) and the remains of the Archbishop's Palace at Court Lodge Farm.

Not only do those walking on this path enjoy far-reaching views towards the North Downs but shortly after leaving the village have a panoramic view towards the Church. This Grade 1 listed building may seem to be remote from the Outlier. The photograph below provides context in terms of the Church, the last remaining "beacon" standing where the old village was, and a point for the walker to aim for when walking AE 474. The view from the church tower is below:

View of Field 20 in from St Martin's Church Tower (June 2024). Field 20 is edged red

PROW AE 474 is marked brown

The Applicant proposes to obtain access for construction along part of AE 474. It indicates the precautions it will take because of this imposition which are a 5-mph limit for its contractors, provision of a banksman and a barriered off area apparently 8 m wide for walkers.

The planned daily (including Saturday mornings) disruption to possibly the most used path in the parish, is *estimated* to last for five months. In all likelihood walkers – particularly those with dogs – will choose to no longer use it. They will very likely take to their cars to find an alternative option.

Where were the discussions with the community about options for the temporary diversion of the path rather than imposing this disturbance on it? Bearing in mind the original owner of the Outlier also owns the adjoining land to the south of the construction access in the first field, presumably a better protected and therefore safer diversion would have been feasible if it had been considered with the community and then planned for at an earlier stage.

Once again, how can it be considered reasonable for the Applicant to go out of its way to include the Outlier when it will create this further unacceptable impact for local people who regularly use this much-loved footpath?

7.5 North Downs AONB (National landscape)

The Outlier is just 330 m from the North Downs AONB from where it can be readily viewed from footpath AE 473 and is also visible to motorists and walkers on Roman Road. The Applicant has belatedly made a further attempt to mitigate the impact by proposing additional planting along the southern boundary of field 20 with AE 474. This will take many years to establish and particularly during the winter months when the leaves are off the trees glint and glare will impact walkers in the AONB and from locations within its immediate setting between it and the Outlier.

The North Downs AONB extends into the Aldington parish on this eastern side of the village. . Why therefore has the Applicant gone out of its way to include the Outlier when its location is so sensitive in the landscape and within the setting of the AONB?

7.6 Goldwell Lane - Haulage Route and cable laying in the public highway

We have addressed this issue in detail in what we have said in the section about Construction Traffic. The decision to use the public highway will take the disruption closer to residential and business premises here than any other part of the scheme.

Those living and working in Goldwell Lane remain horrified at the disruption this choice of construction route will cause to their lives and their work. They will have to contend with articulated construction traffic, that traffic meeting other HGVs and large farm traffic and even greater disruption when the cable laying commences. This decision to use the lane will unavoidably impact properties and businesses in the lane on account of queueing traffic (assuming, as we have said elsewhere, that it is actually physically possible to use the lane in the way proposed without a total road closure).

Not only is the disruption that will be caused disproportionate to the contribution this tiny element of the scheme will make to the output but as explained in our Construction Traffic section, it is the way in which the Applicant has gone about this. Not even the courtesy of talking to any of the residents in the lane over the last 2 to 3 years nor, in the early stages of developing the design, seriously investigating the possibility of an alternative route which could have substantially reduced the impact of this scheme on so many people.

7.7 Best and Most Versatile Land (BMV)

Based on the surveys carried out by the Applicant's appointed soils experts approximately 18% of the proposed scheme is BMV. However, the BMV percentage on the Outlier is substantially higher than this at approximately 50%. This should be no surprise since the better quality free draining land throughout the parish is the "Hythe Beds" soils series on the higher ground – on much of the Aldington Ridge and here between the Church and the village.

The Written Ministerial Statement (WMS) of 15th May (Solar and protecting our Food Security and Best and Most Versatile (BMV) Land) made some important points that are relevant in relation to the Outlier - in particular: –

*"Where the proposed use of any agricultural land has been shown to be necessary, poorer quality land should be preferred to higher quality land avoiding the use of "Best and Most Versatile" agricultural land **where possible**"*.

The WMS goes on to state that *"Applicants for Nationally Significant Infrastructure Projects should avoid the use of Best and Most Versatile agricultural land **where possible**"* (bold font our emphasis).

Whilst a solar developer may argue that it is impractical to extract small elements of BMV land from a large ring-fenced scheme and instead it is the percentage of BMV land affected that should be looked at in the round, how can this approach apply when the land concerned is a discreet separate parcel and remote from the main scheme? It would most certainly be *possible* to avoid the use of this small discrete area which is going to cause such significant environmental impact in both the short and long term.

7.8 Badgers

We are conscious of the need to observe confidentiality when it comes to these protected mammals but suffice it to say that we are well aware of their presence and whereabouts in relation to the Outlier.

Conversations with adjoining house owners about the presence of badgers on their land, walking the fields prior to harvest (2024) and observing a huge number of latrines, and talking with the East Kent Badger Group (EKBG) confirms their presence here in larger numbers probably than anywhere else on the scheme.

The EKBG have surveyed and catalogued badger activity for many years in East Kent and whilst not a statutory Consultee, are recognised as the logical point of reference when development is proposed in an area where badgers are likely to be present.

Whatever the protocols for confidentiality and not publishing reports as noted in relation **at APP 090 (Appendix 9.5m)** why were these details not thought to be shared with EKBG to cross check with their own data? We believe in any event that there is a case for making these reports available to the public on request anyway in case something has been missed which someone living in the area and observing badger activity could usefully provide. Without access to these reports, we can only rely on our own research and the knowledge of EKBG members.

The EKBG have advised us that although they wrote to the Applicant, they never received any response. They were certainly never contacted by the Applicant to see what information they might hold concerning badgers – not just within the Outlier but across the scheme as a whole. Whilst the Applicant may have had its own expert with specialist knowledge on badgers it is concerning that chose not to contact EKBG.

Google Earth maps: Intense badger activity in the eastern part of Field 20

The design of the Project includes a "public orchard" as a new facility for the community. As far as we are aware there was no consultation with the community about this idea. We surmise that the area was offered mainly because it is an awkward and small sloping part of the field and for that reason alone unlikely to be suited to siting solar panels. It also happens to be immediately underneath the National Grid 400KV power lines which are low at this point probably making installation ill-advised.

Be that as it may, if unexpectedly the orchard was frequented by the public (and dog walkers) what thought has been given to the disturbance this might cause to the badgers? Is this covered in the confidential report and who is the competent authority that reviews these reports? What are their views about the juxtaposition of the new public orchard, dogs and badger habitat?

It is clear from the plans that the Applicant proposes to have some form of site compound in the valley, presumably where site offices will be located and where articulated wagons will be offloaded. What does the confidential report say about the potential impact of this construction activity on badgers? How much of an improvement would it have been to have located this compound at the northern end of Field 21, possible if the Applicant had taken the opportunity of securing a temporary haul road and cable route between that boundary and Goldwell Lane.

Finally, what has been the recommendation on the security fencing that will enclose the solar panel areas? As far as we can see this makes no provision for badger access into and across the proposed solar panel area and if that is the case it will obstruct their access to established foraging areas.

7.9 Summary

1. **Everything we have raised concerning the impact that including this small and geographically separate element of the Applicant's Scheme will cause, suggests that it is only included because it is a remote remnant of the main farm holding and without any prospect of another more valuable use.**
2. **The Applicant has accepted that by the time the whole scheme is constructed it should be able to produce in excess of the currently estimated maximum output of between 140 MW & 165 MW – which is already well above the licensed output capacity of up to 99.9 MW at the point of connection.**
3. **The Applicant states that multiplying the connection capacity by a factor of 1.4 is "normal". Applying this to the 99.9MW maximum output at the point of connection gives a figure of 140MW. The scheme can, based on the Applicant's own data produce 140MW *without* the inclusion of the Outlier (because it represents only 7.9% of the scheme's output).**
4. **The cavalier way in which the Applicant has treated public rights-of-way on the scheme as a whole is best illustrated by reference to this small block of**

land. The apparent need to make so many changes is indicative of the way in which the viability of this small area, with its tortuous access and long cable route, is so finely balanced.

5. **The proximity of the Outlier to the North Downs AONB is something which the Applicant cannot change – nor adequately mitigate for because of the significant change of use it proposes.**
6. **In a similar way only more so, this visual aspect of the scheme will jar with those using the most used footpath in the parish – footpath AE 474 - that leads from the village towards the original pre-plague village and the Grade 1 listed St Martin's Church. The whole panoramic vista enjoyed by walkers on this path stands to be changed forever.**
7. **The Applicant has failed to properly investigate the way in which it could have negotiated terms (or indeed sought CA powers as it has done elsewhere) for an alternative temporary access and cable laying route.**
8. **At least 50% of this small block of land is BMV. This compares with an estimated 20% of BMV affected by the scheme as a whole. BMV land, in all relevant policy guidance, should be avoided *where possible*. This quite simply is one such case - *it is possible* to avoid it by simply excluding it.**
9. **We cannot know the extent to which the Applicant has provided for the protection of badgers which we know from our own research are to be found within this block of land in large numbers. The proposal does not have proper regard for the huge nearby set and both the construction and operational phases will obstruct badger activity not only in areas where they forage but areas where the animals excavate land in the scheme area as shown in the Google Earth photograph.**
10. **In short, the case has not been made for the inclusion of the Outlier within this proposal. The harms that it will cause during construction and throughout its operational life far outweigh the small amount of benefit that is to be derived.**
11. **There remains adequate "headroom" in terms of meeting the Applicant's planned renewable energy output from the remainder of the scheme without the need to include this completely separate small area of mainly good agricultural land.**

Written by Jonathan Tennant (retired Chartered Surveyor and Fellow of the Central Association of Agricultural Valuers)

Hazard Assessment of Battery Energy Storage Systems
By Ian Lines, Atkins Ltd

1 INTRODUCTION

1.1 Scope

HSENI is aware of the hazards associated with large scale lithium-ion Battery Energy Storage System (BESS) sites. Consideration has been given to whether such sites should come under the COMAH and Hazardous Substances Consent Regulations, and following discussions with COMAH colleagues in HSE and HSA the view is that batteries alone would not bring a facility under COMAH (as batteries are regarded as articles and not dangerous substances under CLP).

Nevertheless, HSENI is still interested in the consequences of a fire in a battery container unit as there may be a need for HSENI to provide advice to Local Planning Authorities, comment on an environmental assessment, provide advice to fire fighters or review an operator's own risk assessment.

HSENI is aware that this is a relatively new area, with little available guidance, and has therefore requested that Atkins provide some initial advice based on the following scope:

- Review of incidents involving lithium-ion battery energy storage sites (and manufacturing sites)
- Review of technical papers/information, concentrating on any information relevant to major accident hazards
- Consideration of fire load (associated with the electrolyte)
- Consideration of potential for flammable vapour explosion
- Assessment of HF dispersion toxic hazard ranges to DTL/IDLH using ADMS
- Brief consideration of washout/deposition from fire plumes
- Brief consideration of firewater run-off issue (environmental hazard)
- Summary of key issues

It is emphasised that this Technical Note is only intended to provide brief advice in most of the above areas, and that in some areas there is very little available good information. HSENI has indicated that their main concern is the firefighter who could be facing a fire at one of these facilities, and therefore their principal interest is in the potential toxic fire plume, and potential explosion, associated with a single BESS container. This Technical Note therefore concentrates on those areas.

It is recognised that this has been a rapidly developing area over the last few years, and so the information presented in this Technical Note would benefit from regular review.

1.2 Background

A recent issue of Energy Storage News (11 January 2021) summarises the key hazards for firefighters:

> *Energy storage is a relatively new technology to fire departments across the US. While different fire departments have differing levels of exposure to battery energy storage systems (or BESS for short), the primary concern of each is the same: the safety and well-being of their first responders.*
>
> *Departments and local officials are, however, becoming increasingly aware of the hazards associated with battery storage and it is important that their concerns be properly addressed. Addressing these concerns in a complete and transparent manner has been seen not only to promote overall first responder safety but also to ensure project success. Perhaps the most defining characteristic of lithium-ion battery failures is a state known as 'thermal runaway', in which a battery cell experiences uncontrollable overheating, often accompanied by the release of large quantities of flammable off-gases.*
>
> *Thermal propagation from the failing cell may lead to incipient thermal runaway of adjacent cells, thus creating a cascading failure across the system, resulting in tremendous amounts of heat and gas. When these gases are allowed to accumulate in an enclosed space (such as a BESS container), an explosive atmosphere may develop, which, given an ignition source, may lead to a devastating deflagration (explosion) event. This blast wave can cause damage to nearby buildings and structures, as well as first responders who may be arriving on the scene, as was seen in the incident that unfolded in Arizona in 2019. Deep-seated fires are also common in lithium-ion failure events. These fires are not easily extinguished and may continue for hours, fuelled by heat and gas from cascading cell failures. Even if*

suppressed by water, stranded energy within the cells often causes reignitions, thus perpetuating the event.

Concerns based on environmental risks are also often cited by fire departments across the country. Large quantities of smoke and gas are often released during battery fires, with high levels of carbon monoxide and hydrogen cyanide measured on-site in Arizona at the time of the incident. Contaminated runoff water may also affect the surrounding area. Electrical hazards also exist during and after battery failure events and should not be overlooked.

2 REVIEW OF INCIDENTS

This section provides a brief review of incidents involving lithium-ion cells, and key lessons learned in terms of major hazard assessment. It is not intended to be comprehensive, but highlights important events such as the 2019 McMicken (Arizona) BESS explosion.

2.1 Incidents Involving Single Cells

Many billions of individual lithium-ion cells have been produced worldwide over the last 30 years, and there have been thousands of incidents which have been potentially hazardous. Many of these have been well reported in the press, and some have led to major product recalls. The majority of these incidents relate to Thermal Runaway (TR) events due to a short circuit within a cell between the anode and cathode. Such events are often apparently spontaneous and the precise cause of the short circuit is often not clear. Common causes can include:

- Impact/vibration/penetration
- Manufacturing defect
- Failure of the battery management system
- Overheating
- Overcharging
- Undercharging

It is also noted that as the widespread use of such cells has grown very rapidly, there is relatively little data on incidents that may be related to aging for current cell designs.

Incidents are generally most severe when a cell has a high State of Charge (SOC). Any major failure of a charged cell can lead to the rapid and energetic ejection of the electrolyte liquid, as a short (e.g. 1 to 2 m long) jet flame. It is noted that such failure events with charged cells are highly likely to ignite, but there are also situations where cascading thermal runaway can occur due to heat transfer between cells without any ignition, due to the highly exothermic nature of the thermal runaway.

The precise nature of an incident may depend on the cell size and whether the cell is cylindrical, pouch or prismatic. Large pouch cells are generally used in large scale BESS container units.

2.2 Incidents at BESS Facilities

Table 2-1 lists a number of incidents which have occurred at BESS facilities.

Table 2-1 Incidents at BESS Facilities

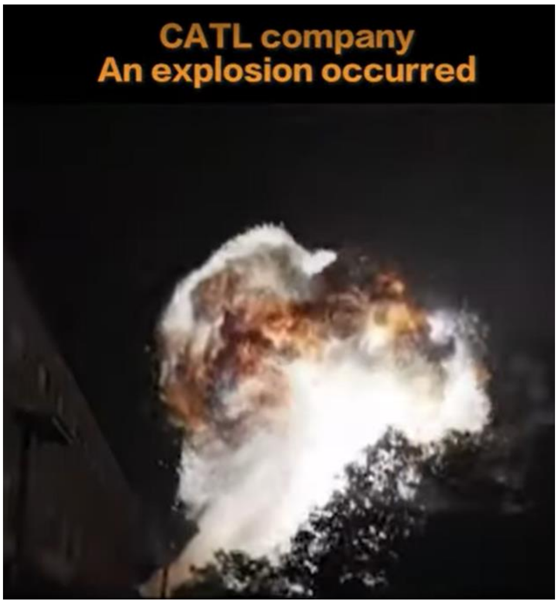
Location (Company)	Date of Incident	Description of Incident
Arizona, USA (Arizona Public Service Company)	Nov 2012	In November of 2012, a fire occurred at a state-of-the-art solar energy storage system that the Arizona Public Service Company (APS) was testing. The system, the relative size of a shipping container with a capacity of 1.5 MW, had been running since February of 2012. Similar to the First Wind fires, the fire department personnel allowed the fire to burn freely for some time. The cause of the fire was not reported. Ref. Blum and Long (2016)
Unknown	2014	A fire in a Li-ion battery storage unit caused an explosion that seriously injured fire fighters. Ref. Ronken (2017)
Yeongju, South Korea	Nov 2018	Fire at lithium-ion PV power plant. Ref. INERIS (2021)
Cheonan, South Korea	Nov 2018	Fire at lithium-ion PV power plant. Ref. INERIS (2021)
Geochang South Korea	Nov 2018	Fire at lithium-ion PV power plant. Ref. INERIS (2021)
Munyeong, South Korea	Nov 2018	Fire at lithium-ion PV power plant. Ref. INERIS (2021)

Location (Company)	Date of Incident	Description of Incident
South Korea Jecheon	Dec 2018	Fire at lithium-ion peak load reduction plant. Ref. INERIS (2021)
Samcheok, South Korea	Dec 2018	Fire at lithium-ion PV power plant. Ref. INERIS (2021)
Yangsan, South Korea	Jan 2019	Fire at lithium-ion peak load reduction plant. Ref. INERIS (2021)
Wando, South Korea	Jan 2019	Fire at lithium-ion PV power plant. Ref. INERIS (2021)
Jangsu, South Korea	Jan 2019	Fire at lithium-ion PV power plant. Ref. INERIS (2021)
Ulsan, South Korea	Jan 2019	Fire at lithium-ion peak load reduction plant. Ref. INERIS (2021)
Chligok, South Korea	May 2019	Fire at lithium-ion PV power plant. Ref. INERIS (2021)
McMicken Substation, Surprise, West Valley, Arizona, USA (Arizona Public Services)	19/4/2019	The incident occurred at two twinned grid-scale energy storage systems of 2 MW / 2 MWh at the McMicken substation. The explosion caused a "significant pressure wave" resulting in the injuries of four firefighters. Technical analysis by certification and standards group DNV GL indicated that the event had begun with internal cell failure in a single LG Chem 0.24 kWh pouch cell in the ESS. The fire suppression system onsite worked as designed, but it was inadequate to prevent or stop the cascading thermal runaway. Heat transfer between the cells in a module, and then between modules, in one of the battery racks caused the thermal runaway to propagate - facilitated by the absence of "adequate thermal barrier protections between battery cells," which could have stopped or slowed the propagation. Whilst the incident was at first thought to be a fire, it was in fact a cascading thermal runaway from a single cell, through every other cell in the module, and then through all the modules in Rack 15 via heat transfer. It took around two hours from the first report of a suspected fire at the facility, at 17:48 local time on 19 April 2019, to around 20:04 before an explosion happened from inside the BESS. The BESS and its container were "essentially destroyed" and the incident left several firefighters injured. On the day of the incident, the BESS was performing solar smoothing applications - charging during the daytime from local solar generation and discharging electricity to the grid during the evening peak load. Data collected by APS found that just before 5pm on 19 April, there was a sudden drop in voltage during one of the system's charge cycles. Thermal runaway began shortly after that. Smoke detection systems went into operation but off-gassing of battery cells as the thermal runaway cascaded through neighbouring modules caused a "flammable atmosphere within the BESS," the DNV GL report said. Then, when firefighters opened the side container door around three hours after thermal runaway began, an explosion occurred within 2-3 minutes, causing the side and rear doors of the BESS as well as other debris to be ejected by the explosion. It is thought that opening the doors agitated flammable gases that remained and brought the gases into contact with a spark or heat source - causing the explosion. Ref. McKinnon, DeCrane and Kerber (2020) – Detailed incident report. DNV GL (2020) – Technical incident report. Energy Storage News (23 April 2019, 29 July 2020, 12 March 2021, 25 March 2021)

Location (Company)	Date of Incident	Description of Incident
Carnegie Road, Liverpool, England (Ørsted) See Figure 2.1	15/9/2020	Large grid battery system container fire at 20 MW BESS site which lasted several hours. Merseyside Fire & Rescue Service, local first-responders, said that crews were alerted shortly before 1am on 15 September and arrived to find a "large grid battery system container well alight". A "massive bang" was heard as fire crews rushed to tackle the blaze. One resident said he "heard an explosion after midnight" while another said their house "shook". Five fire engines were immediately on the scene after being alerted at 12.52am to reports of a blaze on Carnegie Road in Tuebrook. The fire service said that it had used main jets and ground monitors in tackling the fire, asking residents nearby to keep their windows and doors closed due to smoke from the incident. The blaze went on for several hours, with an update from the service at 7:30am noting that although operations at the site had been scaled down, firefighting was ongoing, with two ground monitor units and a main water jet still in use. A further update at 11:45am said one fire engine was still at the scene, with firefighting still continuing, although by that stage only one hand-held pump was in use. It was reported that the explosion caused a "significant pressure wave", causing debris to be thrown between 6 and 20 metres away according to the fire department's response report. The environmental impact from firewater runoff was also a major concern. Ref. Energy Storage News (16 September 2020 and 25 March 2021) • Fire at 20MW UK battery storage plant in Liverpool - Energy Storage Virtual Summit [redacted]
Ningxiang, Hunan Province, China (CATL Brunp Recycling Technology plant) See Figure 2.2	7/1/2021	Explosion and fire occurred at one of the old workshops of the battery recycling plant - 1 person was killed and 6 were seriously injured. CATL is a battery supplier to Tesla. • [redacted] • #177 Explosion at CATL-owned company #shorts - YouTube

Figure 2.1 Incident at Carnegie Road, Liverpool (15/9/2020)

Figure 2.2 Incident at Ningxiang, Hunan Province, China (7/1/2021)



It is noted that there have been many incidents in Asia relating to BESS facilities, but details are generally scarce or unavailable.

2.3 Incidents at Battery Manufacturing Facilities

Table 2-2 lists a number of incidents which have occurred at battery manufacturing facilities.

Table 2-2 Incidents at Battery Manufacturing Facilities

Location (Company)	Date of Incident	Description of Incident
Koriyama City, Japan	4/11/1995	An explosion occurred at a Sony battery factory in Koriyama City, Japan, where cylindrical lithium-ion batteries for notebook PCs were manufactured. The fire occurred on the floor where batteries underwent final testing. Cells in this location were stored in racks 4-high under ambient temperature conditions. Ultimately, approximately 3 million cells burned, 7,000 m^2 of facility was damaged and two people were injured. Ref. Mikolajczak et al (2011)
Moriguchi, Osaka, Japan (Matsushita Battery Industry Factory)	Aug 1997	An explosion occurred at the Matsushita Battery Industry factory in Moriguchi, Osaka. The owner of the factory, T&T Dream, was a subcontractor for Matsushita. The factory carried out charge/discharge and check processes of cylindrical lithium-ion batteries. Cells in this location were stored on thirteen layers under ambient temperature conditions. Ultimately, approximately 1.22 million cells burned, 1,700 m^2 of facility was burned, buildings within a 175 m radius were damaged, and two people were injured. Ref. Mikolajczak et al (2011)
Karlstein, Germany (BMZ)	Aug 2008	A fire occurred at Batterie-Montage-Zentrum (BMZ) in Karlstein, Germany. The fire destroyed a production area and a warehouse. Ref. Mikolajczak et al (2011)
Pawcatuck, Connecticut, USA (Yardley Technical Products)	Sep 2008	A large format lithium-ion battery that was undergoing testing at Yardney Technical Products in Pawcatuck Connecticut caught fire. Ref. Mikolajczak et al (2011)
Dongguan City, China	2014	Fire in a lithium-ion battery factory in Dongguan City in China, which caused 5 deaths and 6 injuries. Ref. Niu and Li (2018)
China (Samsung SDI battery manufacturing facility)	8/2/2017	The fire occurred in the battery waste area of the factory, after faulty lithium-ion batteries went up in flames. • [redacted]
North Phoenix, Arizona, USA (Gruber Motor Company)	6/5/2017	Pallet of Li batteries caught fire and 5 minutes later the whole building was burning, producing toxic smoke which spread all over the north valley and forced evacuation of nearby buildings. • Fire breaks out at factory that produces lithium batteries - Bing video
Peera Garhi, New Delhi India See Figure 2.3	2/1/2020	Battery factory collapses after explosion in fire during firefighting operations – killing 1 and injuring 19 other firefighters. • Battery Factory In Peeragarhi Collapses During Fire Fighting Operations | CNN News18 [redacted] • Battery factory collapses in fire in New Delhi, killing 1 [redacted]

Figure 2.3 Incident at Peera Garhi, New Delhi, India (2/1/2020)

The incidents in Table 2-2 show that major incidents at battery manufacturing facilities are most likely to occur in the Formation, Aging and Testing stage, where large numbers of cells are being charged for the first time. Such events are less likely at BESS sites as the cells have been through all the necessary testing, but the nature of the potential incidents is similar due to the large number of cells present.

2.4 Other Incidents

Table 2-3 lists a number of incidents which have occurred at other facilities.

Table 2-3 Incidents at Other Facilities

Location (Company)	Date of Incident	Description of Incident
Germany	2017	A major fire broke out in a bicycle warehouse in Germany that also contained a large number of electric bicycles with Li-ion batteries. It proved an extraordinary challenge for the fire brigade and ultimately resulted in a total loss in the warehouse. Four employees suffered minor injuries. Ref. Ronken (2017) • [redacted]
Lyons Park industrial estate, Coventry, England	20/2/2020	Factory storing Li batteries goes up in flames. • Factory where lithium batteries stored goes up in flames - CoventryLive [redacted]

Mikolajczak et al (2011) also lists a number of air transport incidents involving lithium-ion batteries.

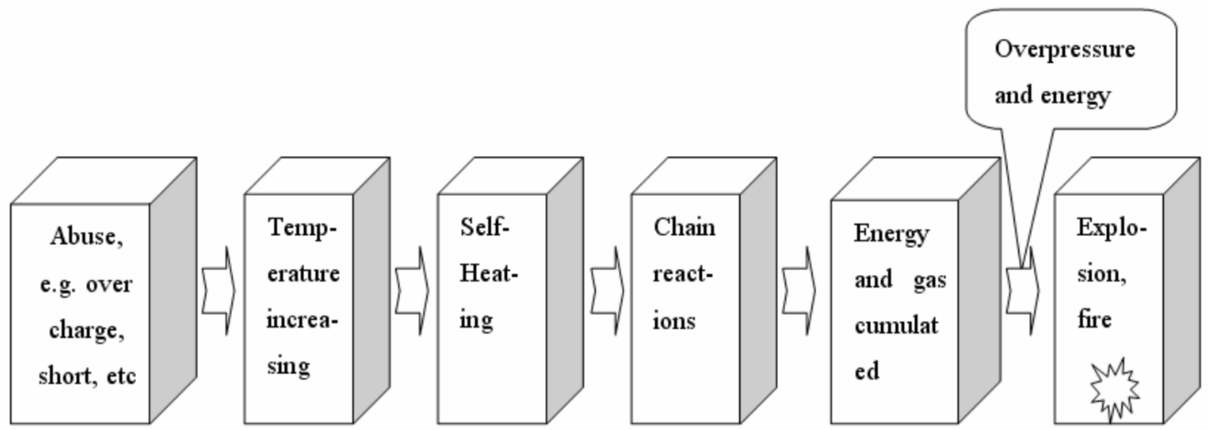
3 REVIEW OF LITERATURE

This section presents a brief literature review concentrating on information which is relevant in terms of major hazard safety issues.

3.1 Published Papers and Reports

Wang, Sun & Chu (2005) provide an overview of how lithium-ion cells can fail, leading to fire and explosion.

Figure 3.1 Development of Cell Failure (Wang, Sun & Chu, 2005)



Ditch and de Vries (2013) and **Ditch (2014)** describe a detailed study of the flammability characterisation of lithium-ion batteries in bulk storage, which tested the effectiveness of sprinklers and measured heat release rates etc. The overall goal was to develop sprinkler protection recommendations for bulk storage of Li-ion batteries. The test results show that fires can develop rapidly, reaching heat release rates of several MW for a single pallet of batteries.

Mikolajczak et al (2011) present a literature review of battery technology, failure modes and events, usage, codes and standards, and a hazard assessment during the life cycle of storage and distribution. The failure modes and root causes are discussed, together with information on flammable cell components and the fire behaviour of cells and battery packs. Key gaps in knowledge, such as the vent gas composition, are identified.

Blum and Long (2016) summarise a literature review and gap analysis related to Li-ion battery ESSs, as well as full-scale fire testing of a 100 kWh Li-ion battery ESS. The overall objective was to help enable the development of safe installation requirements and appropriate emergency response tactics.

Larsson, Andersson, Blomqvist and Mellander (2017) provide a useful study of toxic fluoride emissions from lithium-ion battery fires. It is shown that lithium-ion battery fires generate intense heat and considerable amounts of gas and smoke. It is noted that although the emission of toxic gases can be a larger threat than the heat, the knowledge of such emissions is limited. The 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 are 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 to 22 mg/Wh of another potentially toxic gas, phosphoryl fluoride (POF_3), was measured in some of the fire tests. Gas emissions when using water mist as an extinguishing agent were also investigated. It is concluded that 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. The paper states that:

> *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. The immediate dangerous to life or health (IDLH) level for HF is 0.025 g/m^3 (30 ppm) and the lethal 10 minutes HF toxicity value (AEGL-3) is 0.0139 g/m^3 (170 ppm). 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.*

Ronken (2017) also describes the risks and safety measures required for lithium-ion batteries, and emphasises the importance of a suitable risk assessment. Several incidents are also identified (see Section 2.2).

Niu and Li (2018) describe a fire risk assessment method for use in lithium-ion battery factories, and summarise the key areas where fire risks are significant, based on experience with such facilities in China. It is suggested that in the event of a short circuit, lithium can react with the various electrolyte components (ethylene carbonate, propylene carbonate, dimethyl carbonate) to form flammable gases such as propene (C_3H_6). A risk matrix is used to assess all stages of the battery manufacturing process. Several events are identified as likely to result in severe injury, but none are identified as likely to result in death. Serious events such as the spontaneous ignition of batteries in storage are identified as unlikely to happen in a lifetime.

Finegan et al (2019) describe detailed experiments where internal short circuits (ISCs) were caused in cylindrical 18650 cells. These ISCs cause the Li-ion battery to fail catastrophically due to thermal runaway. That is, at a critical temperature and in the presence of non-aqueous liquid electrolytes and oxygen, the active materials within a Li-ion battery can exothermically react. Exothermic reactions can become self-sustaining when local heat generation is greater than heat dissipation, resulting in violent combustion and total cell failure. During thermal runaway, it is estimated that about 2 litres of gas is generated per amp hour (Ah) of commercial $LiFePO_4$ and $LiNi_xCo_yAl_zO_2$ 18650 cells. It is noted that modern 18650 cells have capacities greater than 3 Ah, and can generate more than 6 litres of gas within about 2 seconds during thermal runaway, which is mostly flammable. In this short time (< 2 seconds), more than 70 kJ of heat can also be generated.

The Department for Business, Energy & Industrial Strategy (BEIS, 2020) reviewed the safety risks associated with domestic battery energy storage systems. The authors state that even though few incidents with domestic battery energy storage systems (BESSs) are known in the public domain, the use of large batteries in the domestic environment represents a safety hazard. Three hazard categories are identified:

- Excessive heat generated deep inside a battery pack as cells fail and thermal runaway propagates through the pack, highlights the need to design packs to minimize risk for propagation and limit spread of fire between cells/modules. Early detection and means for cooling individual cells as they begin to fail are important for avoiding thermal runaway of the full system.
- Cell and pack failures can generate large volumes of gases resulting from the rapid pressure build-up and vent release as the system heats up. Management of gases generated must be considered in pack and system design.
- The toxicity of gases generated from battery fires may require specific consideration in the design of ventilation systems.

Key considerations regarding risk mitigation are summarised as:

- The Battery Management System (BMS) has a central role in keeping cells within their operating window for voltage, current and temperature. BESS safety standards have specific requirements and tests which apply for the BMS.
- Internal cell faults, though rare, do occur. For well-constructed 18650 cells, the failure rate from an internal event is estimated as one in ten million (0.1 ppm). This translates to a single cell failure in every 10,000 BESS (assuming a 5 kWh BESS containing 500 18650 cells). This is not to say that 1 in 10,000 BESSs will fail, with significant risk of fire. Proper BESS design and construction should be capable of preventing propagation of cell failure across the battery pack. A single cell failure should be controllable.
- If the system is well designed, it should take into consideration propagation of a thermal event arising from a single cell. This is of great importance for the risk mitigation and will have a large impact on the overall risk assessment for the system. Control of single cell failures within a pack reduces the risk of complete system failure and residential fire. Assessment of cell failure propagation is captured in the standards applicable for domestic lithium-ion battery storage systems such as BS EN 62619 and IEC 62933-5-2.

The BEIS report also provides some statistics for the likelihood of failures, although it doesn't deal with large scale BESS installations. Hydrogen fluoride, CO and CO_2 are all identified as potential toxic combustion products following a thermal runaway. The potential for an explosion is also mentioned, either as a result of a cell failing violently due to an internal build-up of pressure, or as a result of ignition of flammable gases released from a cell. The total heat released during total combustion of lithium-ion batteries ranges from 30 to 50 kJ/Wh, or 4 to 10 MJ/kg, which is about 5-10 times less than for organic materials like plastic or paper. No projectiles were observed in any full scale testing of larger racks of batteries for energy storage systems. The violence of thermal runaway, and the gas volume generated, tends to increase with SOC.

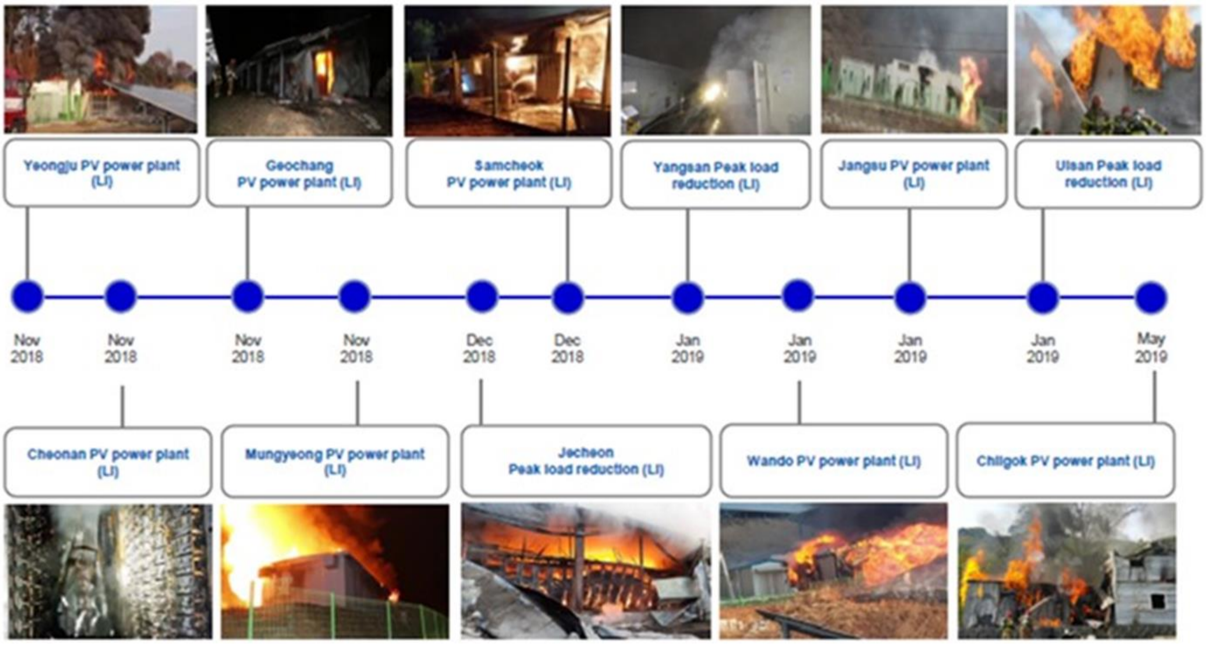
The BEIS report discusses the vent gases that can be generated, including volatile organic compounds (such as alkylcarbonates, methane, ethylene and ethane), hydrogen, carbon monoxide, carbon dioxide, soot and other particulates containing nickel, cobalt, lithium, aluminium, copper. The authors note that a major point of discussion is the amount of HF and other fluorinated compounds found in vent gases, because of their toxicity, and that this is still an open question. Some tests have indicated HF concentrations well in excess of 100 ppm.

Diaz et al (2020) provide a comprehensive review of fire safety information for lithium-ion batteries. The authors note that the majority of research has considered single cells, and there is much less safety information relating to larger scale fires involving pack, modules, or large numbers of cells. The review includes information on the various challenges faced by the industry, including detection and reliability issues and emergency response challenges. The use of water for fire fighting appears to be preferred, although there are still issues with reignition.

Rosewater et al (2020) presents a systematic hazard analysis of a hypothetical, grid scale lithium-ion battery powerplant to produce sociotechnical 'design objectives' for system safety. This includes key considerations for firefighter training objectives.

INERIS (March 2021) recently presented an overview of the lithium-ion cell assessments and modelling that they are currently undertaking in France. The presentation included brief details of fires at large scale energy storage sites in South Korea, as illustrated in Figure 3.2.

Figure 3.2 Examples of Fires at BESS Sites in South Korea (INERIS, 2021)



It was concluded that there was no single root cause for these events.

INERIS noted that there have been similar fires in Belgium, UK, France, US (Arizona) and Australia. A number of issues and uncertainties were identified in relation to fire protection and firefighting for such sites:

- Fixed fire fighting systems: water (sprinklers, water mist)?, Foam?, Inert gas?, Others?
- Fire fighter capacities for such a fire: drowning a battery container in water is not really an option
- Safety aspect of emergency response: gas toxicity and explosivity

One conclusion from their presentation was that the toxic combustion products from a small fire involving a lithium-ion battery are generally not significantly more hazardous than a comparable sized fire with packaging and plastics etc. However, for a large fire involving many lithium-ion cells, the view expressed was that the HF vapour was the most significant toxic concern.

3.2 Project Specific References

HSENI has provided several documents which relate to BESS sites. These are considered briefly below in terms of the key data which is relevant in terms of the assessment of major hazards.

Haigh (2020) provides an analysis of what might occur under a loss of control scenario at the Kells BESS and what chemical reactions might take place. The site is described as having a total energy capacity of 26.3 MWh with:

25 ISO containers
28 racks in each ISO container
6 modules in each rack
22 lithium-ion cells in each module

The total quantity of electrolyte on site is 28.6 tonnes, together with 9.5 tonnes of polyvinylidene difluoride, all of which may generate HF in a fire. A fire involving a single container is predicted to generate 20 to 210 kg of HF. This corresponds to 19 to 200 mg/Wh, consistent with the range suggested by Larsson et al (2017).

Marks (2020) provides technical details for the Newry Energy Storage Ltd BESS located approximately 85 m North of No. 68 Cloghanramer Road, Newry, BT34 1QG. The site is described as having a total energy capacity of 18.635 MWh with:

5 ISO containers (3,727,000 Wh for each ISO container)
10 racks in each ISO container (372,700 Wh for each rack)
26 modules in each rack (14,336 Wh for each module)
16 lithium iron phosphate (LFP) cells in each module (896 Wh for each cell)

Each of the 20,800 cells on site, each with a mass of 5.46 kg, includes:

540 g of polyvinylidenefluoride-hexafluoropropylene copolymer (PVDF-HFP)
486 g of ethylene carbonate
432 g of dimethyl carbonate
432 g of propylene carbonate
378 g of diethyl carbonate
378 g of ethyl methyl carbonate
162 g of lithium hexafluorophosphate ($LiPF_6$)

It is predicted that a full stoichiometric decomposition of $LiPF_6$ will generate 4 moles of HF (plus other fluorine compounds). This corresponds to 354.2 kg of HF per ISO container. Similarly, a full stoichiometric decomposition of the PVDF-HFP would generate 1,679 kg of HF. Marks states that these stoichiometric results are considered worst case, and a more foreseeable prediction is based on the work of Larsson et al (2017) (i.e. 200 mg/Wh) giving 738 kg of HF per ISO container.

3.3 Standards

Standards for energy storage systems include:

NFPA 855 - Standard for the Installation of Stationary Energy Storage Systems, 2020
This debut edition addresses the dangers of toxic and flammable gases, stranded energy, and increased fire intensity associated with BESS sites. It is designed to give first responders and those who design, build, maintain, and inspect facilities the information they need to prepare for ESS safety.

IEC 62619 - Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications, 2017
Specifies requirements and tests for the safe operation of secondary lithium cells and batteries used in industrial applications including stationary applications.

There are obviously many other standards which are important, but the above are some of the most directly relevant. NFPA 855 is one of the most useful in terms of major hazard and firefighting considerations.

4 CONSIDERATION OF FIRE LOAD

The main fire load within a BESS container is the electrolyte within each cell. The precise composition of the electrolyte generally involves several flammable liquids and lithium hexaflurophosphate, as detailed in Section 3.2 by Marks (2020).

The overall heat of combustion of the electrolyte is approximately 20,000 kJ/kg.

Electrolyte typically makes up about 40% of the mass of a cell in a BESS. For other cell designs, such as cylinder cells, it is typically closer to 15% of the mass.

Any fire is likely to start as a result of failure of a single cell, which then escalates by involving progressively more cells. In the very early stages, the fire may not be ventilation controlled, but the container would rapidly begin to fill with combustion products, and the fire would become ventilation controlled. If the container becomes breached then the fire will no longer be ventilation controlled.

The growth of the fire is therefore likely to be similar to fire growth in other situations, such as a warehouse fire, although the rate of fire growth is likely to be higher due to the exothermic nature of the thermal runaway event.

For the purposes of assessing the fire, a conservative assumption typically adopted by the HSE is that the entire contents are combusted over a relatively short period of 30 minutes (Atkinson and Briggs, 2019). This assumption can be useful for defining a heat release rate and maximum source term for toxic combustion products, but it is noted that in reality such fires could continue to burn for many hours. Lithium-ion fires are also well known for re-igniting after having been apparently extinguished.

5 POTENTIAL FOR EXPLOSION

The potential for explosion during the course of a major incident in a BESS ISO container is an important issue which has recently become better understood following several incidents.

It is well known that individual cells may fail explosively due to the build-up of pressure within the cell, but this will depend on the cell design. Pouch cells tend to fail easily on seams, and so, considered individually, may be less likely to explode than, for example, cylinder cells. However, when pouch cells are packed into a module it may be more difficult for gases to vent, and so an explosion may still be possible. The energy of such an explosion would depend on the module design. Such an event could produce a loud bang as the module fails, but the event is likely to be contained within the ISO container.

More significantly, it is also known that cell failures can generate quantities of flammable vapour. If a 10 Wh 18650 cell can generate 6 litres of gas (Finegan et al, 2019), an 896 Wh pouch cell could theoretically generate over 500 litres of flammable vapour. Several such failures could occur before the vapour ignites. Suppression systems can prevent flaming, though flammable vent gases can continue to be released due to cascading thermal runaway as a result of heat transfer between cells and modules. Ignition can then lead to a vapour cloud explosion (VCE) within the ISO container. The worst case is if such flammable vapour fills the entire ISO container (typical dimensions are 40 x 8 x 8.5 feet, or 77 m^3). It is noted that the 2019 McMicken incident only involved thermal runaway of the cells in a single rack, and this was still sufficient to generate enough flammable gas for a significant explosion.

Table 5-1 provides hazard ranges to various levels of overpressure for hydrocarbon vapour cloud volumes of 0.5, 5 and 50 m^3, based on a standard analysis using the TNO Multi-Energy Model with a typical ignition strength of 7 (based on the type of approach typically adopted by HSEGB for VCEs).

Table 5-1 Distances to Various Levels of Explosion Overpressure

Volume of vapour involved (m^3)	0.5 m^3	5 m^3	50 m^3
	Distance (m) to various levels of overpressure		
600 mbar	2	5	10
300 mbar	3	7	16
140 mbar	6	12	26
70 mbar	10	21	45

Any flammable vapours released from cells may be ignited almost immediately, without any generation of overpressure, but there have been several incidents where explosions have been reported in containers. This delayed ignition of vapour can occur if a fire suppression system prevents flaming. Continued release of vent gases from failed cells after the suppression system operates can then lead to a build-up of flammable gas, which can then ignite leading to an explosion. There have also been incidents with no suppression system where a build-up of flammable gas has occurred without a fire, until delayed ignition caused an explosion.

It is noted that HSEGB typically use 600, 140 and 70 mbar as the basis for defining the Inner, Middle and Outer land use planning zones for explosion hazards.

Table 5-2 provides some data from HSE (2005) on the effect on structures of various levels of blast overpressure.

Table 5-2 Effect of Various Levels of Explosion Overpressure

Damage Description	Incident Peak Side-On Overpressure (mbar)
General effects on buildings	
5% of exposed glass panes broken	1-3
50% of exposed glass panes broken	6-13
Near 100% of exposed glass panes broken	50-110
Limited minor structural damage	20-30
Doors and window frames may be blown in	50-90
Partial demolition of houses - rendered uninhabitable	70
Lower limit of serious structural damage	140
Partial collapse of walls and roofs of houses	140
Nearly complete destruction of houses	340-480
Probable total destruction of houses	690
Effects on UK brick built houses	
Category A damage (completely demolished)	690-1830
Category B damage (badly damaged and beyond repair)	240-590
Category Cb damage (uninhabitable without extensive repairs)	140-240
Category Ca damage (uninhabitable but repairable)	70-120
Category D damage (inhabitable but repairs required)	20-50
50% destruction of brickwork	280-480
Effects on plant	
Reinforced structures distort and unpressurised storage tanks fail	210-340
Wagons and plant items overturned	340-480
Extensive damage	>480
Failure of a pressurised storage sphere	>700

A recent Energy Storage News (25 March 2021a) focussed on the potential explosion issue at BESS sites, stating:

> *The challenges of explosion prevention – with flammable gases needing to be vented "very rapidly" – in the event of a battery fire have been highlighted at this week's Energy Storage Summit USA.*
>
> *Speaking at the event, hosted by our publisher Solar Media, Matthew Paiss, technical advisor, battery materials & systems at Pacific Northwest National Laboratory (PNNL), referenced the two most recent high-profile battery fires, with one at utility Arizona Public Services's (APS) energy storage facility in 2019 and one at Ørsted's 20 MW project in Liverpool, England in 2020.*
>
> *Both explosions caused a "significant pressure wave", with the APS incident resulting in the injuries of four firefighters and the Liverpool incident causing debris to be thrown between six and 20 meters away according to the fire department's response report.*
>
> *Paiss explained that there are "many similar battery enclosures operating today that could experience the exact same kind of failure".*
>
> *He said that most systems being deployed today do include a deflagration vent – which is used to vent gases after deflagration occurs – but "what is not very common in systems is deflagration prevention" which he described as typically being a mechanical exhaust system.*

It was also stated (Energy Storage News, 25 March 2021b) that:

Per Onnerud … said that statistically, some failures will always happen.

While some experts have said that failure may only occur in one of every 10 million battery cells, energy storage projects are getting larger and contain more cells. Meanwhile the cells themselves are individually getting larger and therefore produce more gas if active materials like electrolyte catch fire.

Explosions caused by that gas and fires caused by propagation should not be acceptable, Onnerud said. Battery design should be such that failures should be prepared for, and so that those failures can be dealt with "elegantly".

The incident report for the 2019 McMicken Arizona incident (McKinnon, DeCrane and Kerber, 2020) provides photos which show that, when the fire service arrived, there was a low level cloud of vapour around the container (possibly associated with the suppression system), as shown in Figure 5.1.

Figure 5.1 Photos of ESS Prior to Explosion (McKinnon, DeCrane and Kerber, 2020)

When firefighters were satisfied that HCN and CO concentration had dissipated sufficiently, they proceeded to open the container door. The report describes what then happened to the four firefighters, stating:

At the moment of the deflagration event, the firefighters outside the hot zone described hearing a loud noise and seeing a jet of flame that extended at least 75 ft outward and an estimated 20 ft vertically from the southeast-facing door. In the event, E193 Capt and E193 FE were ballistically propelled against and under the chain-link fence that surrounded the ESS. E193 Capt came to rest approximately 73 ft from the opened door beneath a bush that had ignited in the event. E193 FE came to rest approximately 30 ft from the opened door. HM193 FF1 was projected toward the transformer and distribution box to the east of the ESS and remained within the fenced area. The entire HAZMAT team lost consciousness in the deflagration event. The event also dislodged or removed the SCBA face pieces and helmets from all of the HAZMAT team members.

6 ASSESSMENT OF TOXIC FIRE PLUME

The literature is clear that a wide range of toxic combustion products could be generated in a fire. However, there seems to be reasonable agreement that for a major fire the most significant in terms of toxicity is hydrogen fluoride.

The quantity of HF generated can be estimated based on stoichiometric decomposition, or on experimental data. The approach of Larsson et al (2017), who suggest 20 to 200 mg/Wh based on experimental data, seems to be the most widely adopted approach, and use of the upper bound is likely to provide a cautious best estimate. For a fire involving an entire 5 MWh ISO container (i.e. slightly more than the 3.7 MWh ISO containers at Newry) this would correspond to 1,000 kg of HF.

The duration of the release is conservatively taken to be 30 minutes, which is consistent with the approach recommended by Atkinson and Briggs (2019) for warehouse fires. This implies a release rate of 0.56 kg/s. It is emphasised that in reality there would not be a constant release rate for 30 minutes, but it would grow exponentially to a maximum before gradually decaying over much longer than 30 minutes. However, it is noted that the HSE SLOT and SLOD are based on integrated dose, and so the precise time variation is not important for such criteria.

The other key factor in any toxic fire plume dispersion assessment is the buoyancy of the fire plume, as defined by the convective heat content of the fire plume. The major source of any heat release is likely to be the electrolyte, of which there could be up to about 10 tonnes in a single ISO container. Based on a typical heat of combustion of 20 MJ/kg for the electrolyte, and a release duration of 30 minutes, this would correspond to about 100 MW. In practice, combustion would not be complete and only a fraction would become convective heat in the fire plume (see below). It is noted that BEIS (2020) indicated a heat release of 30 to 50 kJ/Wh, which would correspond to 83 to 138 MW over 1800 seconds for a 5 MWh facility, which is reasonably consistent with the value of 100 MW.

Any generation of HF which is released from the ISO container will be advected downwind, though the plume will tend to rise due to the buoyancy of the hot fire plume. The container may also entrain some or all of the fire plume into its downwind wake, which may spread the plume out and bring it down to ground level, depending primarily on the wind speed.

The dispersion of a fire plume depends principally on the wind speed. At low wind speeds, a fire plume tends to rise buoyantly (see Figure 2.1) and ground level concentrations tend not to be significant. At higher wind speeds, there is generally more dilution of the plume, but it may not lift off the ground, and so moderate to high wind speeds generally represent the worst case for such fire plumes. A range of weather conditions has therefore been considered, namely D2, D5, D10 and F2. It is noted that atmospheric stability may also have some effect, and so stable F2 conditions have also been considered, although (unlike many toxic gas assessments) it is not expected that F2 will be the worst case in terms of hazard ranges.

As noted above, the heat content of the fire plume is a key parameter in determining the degree of buoyant plume rise - a higher heat flux leads to greater plume rise and lower ground level concentrations. Based on CERC (2018), the heat flux is typically calculated as:

$$F_b = (1 - \alpha_r)\, \varepsilon\, H_c\, m$$

Where F_b = Heat flux (W)
α_r = Fraction of heat radiated (typically 0.3)
ε = Efficiency of combustion (taken as 0.5)
H_c = Heat of combustion (J/kg) - taken as 2×10^7 J/kg (based on electrolyte)
m = Mass rate of combustion (kg/s) (taken as 1,000 kg of electrolyte over 1800 seconds)

This suggests a relatively high heat flux of 4 MW.

However, in view of the considerable uncertainty associated with making such an estimate of the effective heat flux, and the extent of possible heat losses (e.g. to sprinkler water) the approach adopted was to assume an effective source diameter of 5 m, with a flux of hot air with a vertical velocity of 1 m/s and an excess temperature of 100°C. This corresponds to a lower heat flux of $\pi \times 2.5^2 \times 1 \times 100 \times 1012 \times 0.9 / 10^6 = 1.8$ MW (NB heat capacity of air is 1012 J/°C/kg, density of air at 115°C is 0.9 kg/m^3). The source was conservatively assumed to be located on the lee side of the ISO container at a height of 1 m, leading to significant entrainment in the wake of the container.

Dispersion modelling of the HF releases has been conducted using ADMS 5.2.4 which is well suited to modelling the dispersion of such fire plume releases. In addition to the source term and weather categories referred to above, the following input data has also been used in ADMS.

ISO container dimensions	2.6 m high, 2.4m wide, 12.2 m long
Atmospheric temperature	15°C
Surface roughness length	0.1 m
Surface energy flux	0 kW/m^2 for D2, D5 and D10 conditions; -6 kW/m^2 for F2 conditions
Boundary layer height	800 m for D2, D5 and D10 conditions; 100 m for F2 conditions
Relative humidity	65%
Averaging time	30 minutes

Most of these parameters have relatively little effect on the dispersion results; the most significant inputs being the wind speed and heat flux. The entrainment of the release in the container wake has been included in the ADMS modelling. This entrainment increases as the wind speed increases, and in D10 conditions the release is almost fully entrained in the container wake and the plume centreline is effectively at ground level.

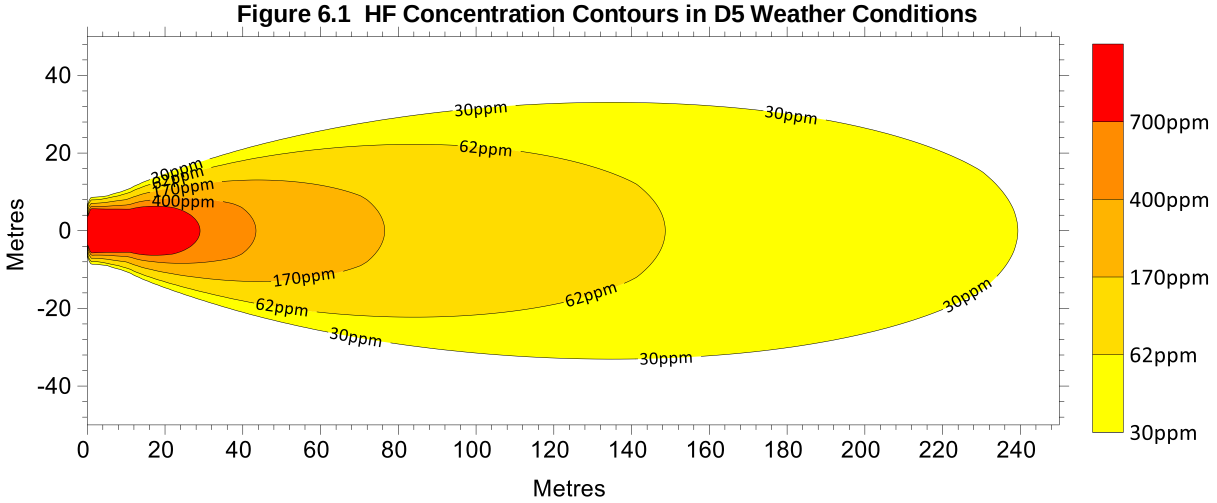
Table 6.1 presents results for the downwind hazard ranges to the HF IDLH, AEGL (10 and 30 minute), HSE SLOT and HSE SLOD for each of the representative weather categories.

Table 6.1 Outdoor Hazard Ranges to SLOT for HF Releases

Criterion	Concentration (ppm)	Outdoor hazard range (m)			
		D2	D5	D10	F2
IDLH	30	85	240	200	85
AELG-3 (30 min)	62	50	150	130	50
AELG-3 (10 min)	170	25	80	70	25
SLOT	400	20	45	40	20
SLOD	700	15	30	30	15

Table 6.1 shows that the worst case hazard ranges tend to occur at moderate wind speeds of 5 m/s. At this wind speed the plume rise is not very significant. As the wind speed increases, the plume rise still decreases, but this is more than compensated by the additional dilution. Figure 6.1 illustrates the ground level concentration results for the worst case D5 weather conditions.

Figure 6.1 HF Concentration Contours in D5 Weather Conditions



It is worth noting that the worst case conditions for toxic hazard ranges may occur in very typical (i.e. D5) weather conditions.

The analysis presented above is considered to be conservative in that the actual heat release rate is likely to be higher, so the worst case conditions would probably occur in higher wind speeds (e.g. D10), but with shorter hazard ranges. There are also some conservatisms in the magnitude of the HF source term, and in the assumption that all the HF is released over 30 minutes, and that people remain exposed in the plume rather than escaping.

It is also noted that, even without a significant fire (due to the fire suppression system), the 2019 McMicken Arizona incident showed that significant concentrations of toxic gases from cell venting, such as HCN and CO, could escape from a container.

7 ASSESSMENT OF WASHOUT AND DEPOSITION

Any fire plume which contains particulates will tend to deposit these particles to the ground, which can lead to issues relating to foodstuffs and clean-up.

Whilst a fire involving a BESS ISO container may generate some such particulate matter, including metal oxides, this has not been regarded as a significant issue in the literature.

Similarly, if there is rain, or water sprays are used on the fire, then there will be some washout (wet deposition) of both particulate and soluble gases. It is noted that gases such as HF are reasonably soluble in water, so water curtains are sometimes used to reduce the airborne concentration of HF following an HF release.

This washout can lead to contamination of ground and water, but again it is not considered to be a significant issue in the literature.

8 FIREWATER RUN-OFF

The HSEGB generally assesses major fires using methods developed by Carter (1989 and 1991) and Atkinson and Briggs (2019). Atkinson and Briggs (2019) state that:

> *There are many examples of chemical warehouses fires that have caused major environmental damage through contaminated firewater run-off. One use of fire plume toxicity assessment is to support "let burn" decisions in planning for and dealing with large fires.*

It is noted that a major concern at the Carnegie Road fire (see Table 2-1) was fire water run-off and potential environmental harm.

There is currently no good data on the significance of firewater from such fires in terms of their impact on the environment, but it is likely to be similar to that from comparable sized fires involving plastics and packaging. There may be specific concerns if the firewater is not contained and can reach sensitive environmental receptors.

9 SUMMARY

This Technical Note provides a high level review of the major hazard issues associated with large scale Battery Energy Storage System (BESS) sites using lithium-ion batteries in an ISO container. It is emphasised that the intention was not to provide a comprehensive review or assessment, but to provide an overall understanding of the key issues, with the principle aim of assisting HSENI to provide more informed advice.

The review has considered published literature and project documents provided by HSENI to establish current best practice for the analysis of such hazards, in terms of source terms and heat loads. A number of incidents involving lithium-ion batteries have been reviewed to provide context and understanding, and some quantitative assessment of fire and explosion hazards has been presented, concentrating on the hazards associated with explosions and dispersion of the toxic fire plume.

Key points which have been identified in the course of producing this Technical Note are:

- Any ISO container BESS has the potential to catch fire due to an unpredictable and spontaneous thermal runaway in a cell. The event may escalate to a fire involving the entire container. There is also a potential for an explosion. The design and mitigation measures in place should ensure that thermal runaway events do not escalate to involve an entire ISO container, but this remains a credible event which should be considered for emergency planning purposes.

- The generation of toxic combustion products from such fires can pose a hazard to those in the vicinity. The main concern appears to be hydrogen fluoride, although there are many other toxic combustion products. Toxic gases such as CO and HCN can also be generated in vent off-gas. This Technical Note provides a reasonably cautious assessment of the HF dispersion and hazard ranges for a worst case fire event, and shows that the HSE SLOT could be exceeded at up to about 45 m, with much higher concentrations in the immediate vicinity.

- The most significant risk to those in the immediate vicinity, or to firefighters, is from potential explosions of flammable vent gases from cells failing due to thermal runaway (either with or without fire). This Technical Note provides some predictions of the potential consequences of such explosion events in terms of the possible levels of blast overpressure. It is noted that there have been several incidents involving significant explosions at BESS sites. It is recognised that cells and modules can undergo cascading thermal runaway without any flaming or ignition, and still generate significant quantities of toxic and flammable gas, with the potential for a delayed explosion.

It is stressed that the assessment of BESS containers in terms of major accident hazard analysis is a new and rapidly developing area, and whilst the assessments here are considered to be reasonably robust, and consistent with current thinking, it is likely that there will be significant developments in the coming months and years.

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Safety of Grid Scale Lithium-ion Battery Energy Storage Systems

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Safety of Grid Scale Lithium-ion Battery Energy Storage Systems

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Sources of wind and solar electrical power need large energy storage, most often provided by Lithium-Ion batteries of unprecedented capacity.

Incidents of serious fire and explosion suggest that the danger of these to the public, and emergency services, should be properly examined.

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Executive Summary

1. Li-ion batteries are dominant in large, grid-scale, Battery Energy Storage Systems (BESS) of several MWh and upwards in capacity. Several proposals for large-scale solar photovoltaic (PV) "energy farms" are current, incorporating very large capacity BESS. These "mega-scale" BESS have capacities many times the Hornsdale Power Reserve in S. Australia (193 MWh), which was the largest BESS in the world at its installation in 2017.
2. Despite storing electrochemical energy of many hundreds of tons of TNT equivalent, and several times the energy released in the August 2020 Beirut explosion, these BESS are regarded as "articles" by the Health and Safety Executive (HSE), in defiance of the Control of Major Accident Hazards Regulations (COMAH) 2015, intended to safeguard public health, property and the environment. The HSE currently makes no representations on BESS to Planning Examinations.
3. Li-ion batteries can fail by "thermal runaway" where overheating in a single faulty cell can propagate to neighbours with energy releases popularly known as "battery fires". These are not strictly "fires" at all, requiring no oxygen to propagate. They are uncontrollable except by extravagant water cooling. They evolve toxic gases such as Hydrogen Fluoride (HF) and highly inflammable gases including Hydrogen (H_2), Methane (CH_4), Ethylene (C_2H_4) and Carbon Monoxide (CO). These in turn may cause further explosions or fires upon ignition. The chemical energy then released can be up to 20 times the stored electrochemical energy. Acute Toxic gases and Inflammable Gases are "dangerous substances" controlled by COMAH 2015. Quantities present "*if control of the process is lost*" determine the applicability of COMAH.
4. We believe that the approach of the HSE is scientifically mistaken and legally incorrect.
5. "Battery fires" in grid scale BESS have occurred in South Korea, Belgium (2017), Arizona (2019) and in urban Liverpool (Sept 2020). The reports into the Arizona explosion [8, 9] are revelatory, and essential reading for accident planning. A report into the Liverpool "fire" though promised for New Year 2021, has not yet been released by Merseyside Fire and Rescue Service or the operator Ørsted; it is vital for public safety that it be published very soon.
6. No existing engineering standards address thermal runaway adequately, or require measures (such as those already used in EV batteries) to pre-empt propagation of runaway events.
7. Lacking oversight by the HSE, the entire responsibility for major accident planning currently lies with local Fire and Rescue Services. Current plans may be inadequate in respect of water supplies, or for protection of the local public against toxic plumes.
8. The scale of Li-ion BESS energy storage envisioned at "mega scale" energy farms is unprecedented and requires urgent review. The explosion potential and the lack of engineering standards to prevent thermal runaway may put control of "battery fires" beyond the knowledge, experience and capabilities of local Fire and Rescue Services. BESS present special hazards to fire-fighters; four sustained life-limiting injuries in the Arizona incident.
9. We identify the well-established hazards of large-scale Li-ion BESS and review authoritative accounts and analyses of BESS incidents. An internet video [10] is essential initial instruction.
10. We review engineering standards relating to Li-ion BESS and concur with other authorities that these are inadequate to prevent the known hazard of "thermal runaway". We conclude that large-scale BESS should be COMAH establishments and regulated appropriately. We respectfully request evidence from the HSE that "mega-scale" BESS are *not* within the scope of COMAH.
11. We seek the considered response of relevant Government Departments as well as senior fire safety professionals to these concerns.

Contents

1. Introduction

Lithium-ion (Li-ion) batteries are currently the battery of choice in the 'electrification' of our transport, energy storage, mobile telephones, mobility scooters etc. Working as designed, their operation is uneventful, but there are growing concerns about the use of Lithium-ion batteries in large scale applications, especially as Battery Energy Storage Systems (BESS) linked to renewable energy projects and grid energy storage. These concerns arise from the simple consideration that large quantities of energy are being stored, which if released uncontrollably in fault situations could cause major damage to health, life, property and the environment.

Table 1. Comparison of some recent "battery fires" since 2014.
Note: this is not a comprehensive list of all Li-ion BESS battery "fires."

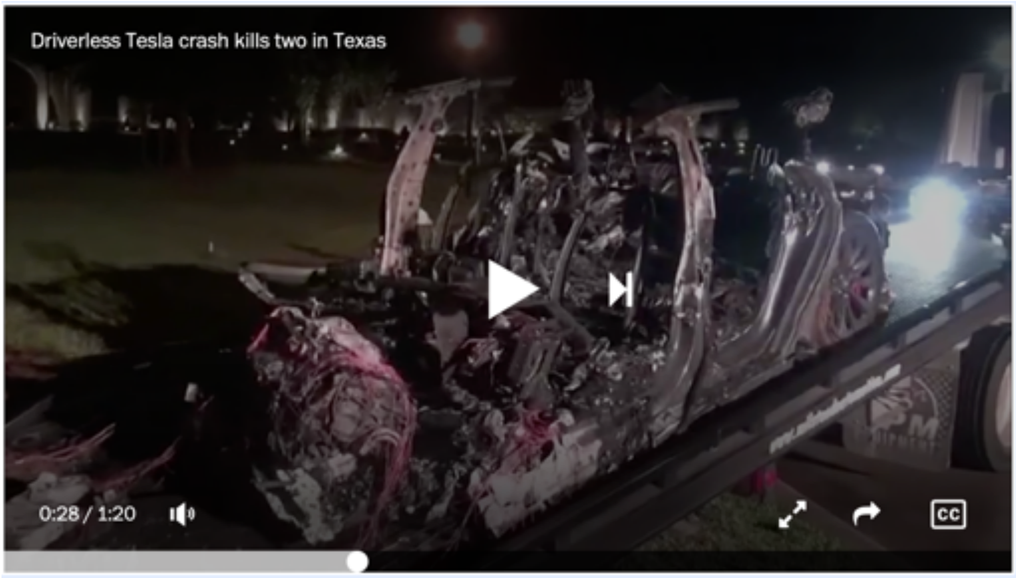
Location	Size	"Battery fire" cause	Time to bring under control	Water needed for cooling	Comments
Houston, Texas, April 2021	0.1 MWh	Driverless vehicle crash	4 hours	30,000 (US) gallons	Tesla Model S
South Korea	Various; 21 fires during 2018-19	Not known to Korean Ministry of Trade Industry and Energy	various	Not known	522 out of 1490 ESS facilities in Korea suspended (Korea Times 2 May 2019)
Drogenbos, Belgium. 2017	1 MWh	Not known.	"rapidly extinguished"	Not known	Occurred during commissioning of system by ENGIE
McMicken Facility Arizona, USA. 2019	2 MWh	Thermal runaway in a single rack out of 27 that were in the cabin – hence 74 kWh electrochemical energy released – less than the Tesla Model S crash.	2 hours from first report to "deflagration"		Explosion as H_2 and CO mixed with air and ignited. Critically injured 4 fire-fighters. Extensive forensic report.
Carnegie Rd, Liverpool, UK, 2020	20 MWh	Not known	11 hours		Full report [1] delayed 4 months; still unpublished.

Even battery electric vehicle (BEV) batteries store energy sufficient for "fires" that have taken hours to control. A Tesla Model S crashed In Texas on the weekend of 17-18 April 2021 igniting a BEV battery fire that took 4 hours to control with water quantities variously reported [2] as 23,000 (US) gallons or 30,000 gallons (87 -115 m^3). Yet the energy storage capacity in even the latest Tesla Model S vehicles is only 100 kWh. This is 1/20 the size of the BESS in Arizona [3] which failed in 2019, and 1/200 the size of the BESS in Liverpool [4] which caught fire [5] in September 2020, and 1/7000 the capacity of the Cleve Hill Solar Farm and Battery Store [6] approved in May 2020.

The past decade has seen a number of serious incidents in grid-scale BESS, which are summarised in Table 1. Despite these incidents, and our growing understanding of these, these large scale Li-ion BESS are not currently regarded by HSE as regulated under the COMAH

Regulations 2015. The legal basis for this attitude is unclear – simple calculations summarised in this paper argue that they should be – and the issue may yet be challenged in judicial review.

The reason the COMAH regulations should apply is the scale of evolution of toxic or inflammable gases that will arise in BESS "fires". In the Drogenbos incident (2017, Table 1), the inhabitants of Drogenbos and surrounding towns were asked to keep all windows and doors shut; 50 emergency calls were made from people with irritation of the throat and airways[1]. A chemical cloud which "initially had been enormous", was charted by helicopter. The Belgian Fire Services could not control what was described as "the chemical reaction" and filled the cabin with water. Fears of an explosion with 20 metre flames kept people confined for an hour. Although the initial visible flames were controlled quickly, cooling continued over the next 36 hours.



Two men died after a Tesla vehicle, which authorities said was operating without a driver, crashed into a tree in a Houston suburb on April 17. (Reuters)

Figure 1: Remains of the Tesla Model S crash and fire, 17 Apr 2021, after 4 hours and 30,000 gallons. Battery capacity 100 kWh.

Figure 2: Remains of a Korean BESS destroyed by a "battery fire". An energy storage system was destroyed at the Asia Cement plant in Jecheon, North Chungcheong Province, on Dec. 17. Courtesy of North Chungcheong Province Fire Service Headquarters (Korea Times 2 May 2019)

[1] Tom Vierendeels (2017) "Explosiegevaar by brand in Drogenbos geweken : 50-tal oproepen van mensen die zich onwel voelen door rook." *Het Laatste Nieuws,* 11 November 2017

Figure 3: "Battery Fire" at Drogenbos, Belgium 11 Nov 2017. Taken at the start of the incident and 15 minutes later (eye-witness footage). 1 MWh facility; fire occurred during commissioning.

Figure 4: The 2 MWh McMicken (Arizona) BESS after the explosion on 19 April 2019

Figure 5: The 20 MWh BESS at Carnegie Rd, Liverpool. Courtesy Ørsted.

Figure 6: The fire at Carnegie Road, 15 Sep 2020. Liverpool Echo report, which took 11 hours to control.

The incidents recorded in Table 1 are all in relatively small BESS or a single BEV. Yet “mega-scale” BESS are now planned on a very large scale in many current proposals in the UK, listed in Table 2 and illustrated in the subsequent Figures.

And no engineering standards are currently applied to pre-empt future accidents in grid-scale BESS, the most critical of which would be design features aimed at preventing the phenomenon of “thermal runaway”, the process whereby failure in single cell causes over-heating and then propagates to neighbouring cells so long as a temperature (which can be as low as 150 °C) is maintained.

BEV batteries do now include thermal barriers or liquid cooling channels between all cells to safeguard against this phenomenon, but no such engineering standards exist for grid-scale BESS. A large BESS can pass all existing engineering design and fire safety test codes and still fail in thermal runaway – by now a well-known failure mode. This must be urgently addressed.

The consequences of major BESS accidents could be significant and emergency services need adequate plans in place to handle any such incident.

Table 2. “Mega” scale solar plant and/or Li-ion BESS in Australia and the UK*

Project	Location	Status	Solar PV Scheme Size	Battery Stores	Battery type	Battery capacity
Hornsdale Power Reserve	S. Australia	Operational	Not directly associated	Single site	Li-ion	193 MWh
Cleve Hill Solar + Battery Store	Kent	Permission granted (2020)	350 MW; land coverage 890 acres	Single site	Li-ion	700 MWh
Sunnica Solar + Battery Store(2)	Cambridgeshire/ Suffolk	Pending submission	500 MW; land coverage approx. 2792 acres	31.5 ha of land over 3 compounds [7] of 5.2, 10.7 and 15.6 ha	Li-ion	Undeclared. Estimate 1500 – 3000 MWh
Longfield Solar + Battery Store	Essex	Pending statutory consultation	500 MW; land coverage approx. 1400 acres	Stated as 3.7 acres: number of sites TBD	Li-ion	Undeclared. Estimate: 150 MWh

* Li-ion technology has been assumed in all these proposals as Li-ion battery electrochemistry is dominant in grid-scale BESS applications (deployment at this scale is unlikely to involve technologies with lesser experience). Estimated values for Battery Capacity for the Sunnica are calculated based on the McMicken facility in Arizona (Appendix 1) and the Cleve Hill DCO. For the Longfield site it is estimated from Energy Institute guidance on energy density [25] at about 100 MWh ha^{-1}. The exact specification for the battery units has not been disclosed by the developers at this present time.

Figure 7: The Hornsdale Power Reserve (South Australia) in the process of expansion from 100 MW/129 MWh to 150 MW/193.5 MWh, as of November 2017.

Plate 3-10. Typical battery storage compound configuration (*image reproduced courtesy of Fluence Energy*).

Figure 8: a "typical" BESS compound (abstracted from Sunnica PEIR, Ch 3)

Figure 9: Artists impression of Tesla 250 MWh "Megapack".
Sunnica may have 3 ×this capacity in just one of its three BESS compounds.

2. Leading Concerns

The main concerns regarding large scale Li-ion BESS are:

1) The potential for failure in a single cell (out of many thousands) to propagate to neighbouring cells by the process known as "thermal runaway". Believed to be initiated by lithium metal dendrites growing internally to the cell, a cell may simply discharge internally releasing its stored energy as heat. Even sound Li-ion cells will spontaneously discharge internally if heated to temperatures which can be as low as 150 °C, releasing their stored electrical energy, thus overheating neighbouring cells and so on. Temperatures sufficient to melt aluminium (660 °C) at least have been inferred from analyses of such thermal runaway accidents. Eye-witness reports consistently speak of repeated "re-ignition" which is inevitable, even in the complete absence of oxygen, so long as the temperature anywhere exceeds the thermal runaway initiation threshold.
2) The emission of highly toxic gases – principally Hydrogen Fluoride – for prolonged periods, in the event of thermal runaway or other battery fires. At a minimum, respirators and complete skin protection would be required by any fire-fighters. Measures to protect the public from toxic plumes would also be necessary.
3) The emission of large quantities of highly inflammable gases such as Hydrogen, Methane, Ethylene and Carbon Monoxide even if a fire suppression system is deployed. These gases will be evolved from a thermal runaway accident regardless of such measures, with explosion potential as soon as they are mixed with air and in contact with hot surfaces. Such an explosion was the cause of the "deflagration event" at McMicken, Arizona in 2019 in a 2 MWh BESS, which critically injured four fire-fighters and was triggered simply by opening the cabin door.
4) The absence of any adequate engineering and regulatory standards to prevent or mitigate the consequences of "thermal runaway" accidents in Li-ion BESS.
5) The potential for thermal runaway in one cabin propagating to a neighbouring cabin. In Arizona [3] there were reports of *"fires with 10-15 feet flame lengths that grew into 50 - 75 feet flame lengths appearing to be fed by flammable liquids coming from the cabinets*".
6) The significant volumes of water required to thoroughly cool the system in the event of a "fire", and how this water will be contained and disposed of (since this will be contaminated with highly corrosive hydrofluoric acid and, therefore, must not be allowed to drain into the surrounding environment).

Such incidents are routinely and repeatedly described in the Press as "battery fires" though they are not "fires" at all in the usual sense of the word; oxygen is completely uninvolved. They represent an electrochemical discharge between chemical components that are self-reactive. They do not require air or oxygen at all to proceed.

Hence the traditional "fire triangle" of "Heat, Oxygen, Fuel" simply does not apply, and conventional fire-fighting strategies are likely to fail (Figure 10, over).

Thermal runaway events are uncontrollable except by *cooling* all parts of the structure affected – even the deepest internal parts – below 150 °C. This basically requires water, in large volumes.

Figure 11 The fire triangle and its relationship to thermal runaway

Figure 10: The traditional "fire triangle" does not apply to "thermal runaway".

3. Thermal Runaway (Battery "fires")

Li-ion batteries are sensitive to mechanical damage and electrical surges, both in over-charging and discharging. Most of this can however be safeguarded by an appropriate Battery Management System (BMS) and mechanical damage (unless deliberate and malicious) should not be a hazard. Internal cell failures can arise from manufacturing defects or natural changes in electrodes over time; these must be regarded as unavoidable in principle. Subsequent escalation into major incidents can propagate from such apparently trivial initiation.

In July 2020 a thorough failure analysis by Dr Davion Hill of DNV GL [8] was prepared for the Arizona Public Service (APS), following the April 2019 thermal runaway and explosion incident in the 2 MWh Li-ion BESS facility at McMicken, Arizona. This report is revelatory and more detailed than any other failure analysis known to us. It is essential reading for any professional involved in fire safety planning for major BESS. (Figures 11 to 13).

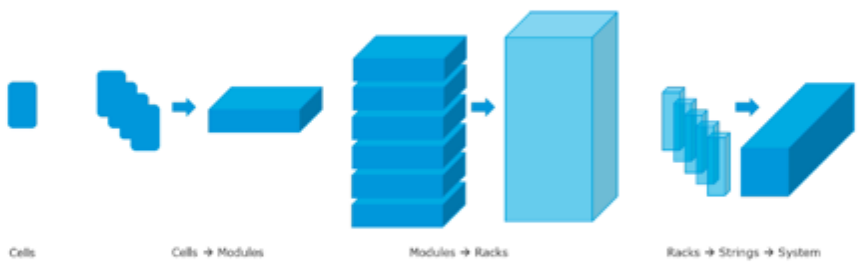


Figure 11: Cells stack into Modules; Modules into Racks; Racks into Strings; Strings into Systems.

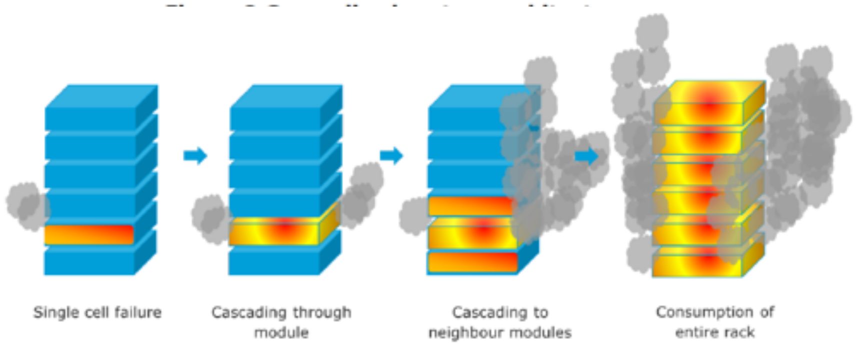
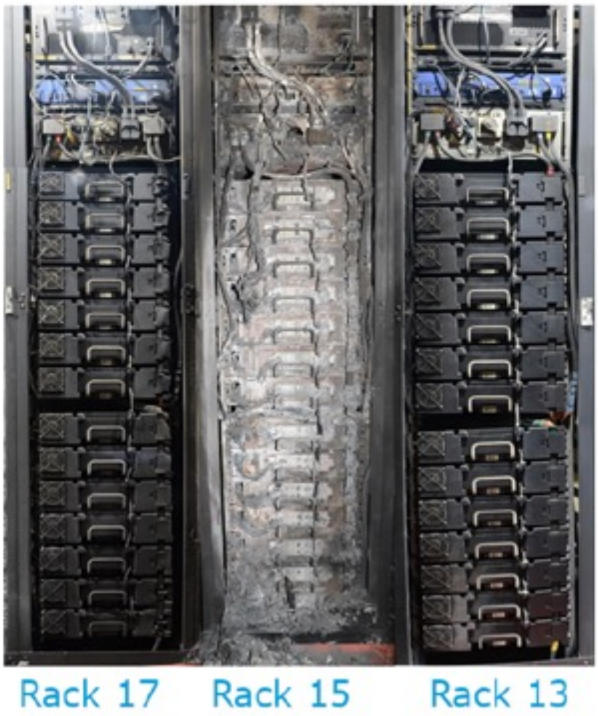


Figure 25 A single cell failure propagated through Module 2, then consumed the whole rack, releasing a large plume of explosive gases. This process could have occurred without visible flame, which would explain why the gases were not burned as they were emitted.

Figure12: Propagation of single Cell failure through Module; cascade to entire Rack.

A report by Underwriters Laboratories (UL) on the same incident [9] is less technical on the physics and engineering of the underlying causes and failure modes, but more comprehensive in terms of practical situations and consequences found, and suffered, by the “first-responders”. Two fire-fighters suffered life-limiting brain injuries, one suffered spinal damage and fourth facial lacerations. This report is similarly essential reading for any fire and emergency response planning.

Figure 13: Destruction of Rack at McMicken.



Detail: molten aluminium pools (exceeded 660 °C)

Figure A.1: Photograph taken during decommissioning of the ESS shows a pool of solidified aluminum on the floor in front of Rack 15 [11].

Forensic analysis [8] of the 2019 Arizona “fire” identified a failure mode different from mechanical abuse or electrical mis-management. The initiating failure was localised to a single cell at a known position in the rack. Although the cell itself was of course destroyed during the incident, the failure mode is believed to have been lithium metal deposition and abnormal growth of lithium metal dendrites. These phenomena were also found in randomly selected *undamaged* cells from the same BESS and also from a different BESS of the same manufacture elsewhere. These phenomena must be regarded as common, and inherent to the cells themselves.

The lithium metal deposits will react with air moisture, causing overheating and smoke. Battery swelling, electrolyte degradation, and internal short circuits are all possible modes of failure with internal discharge and generation of locally intense heat.

Because of the known thermal breakdown of even non-faulty cells, above a threshold temperature (which can be as low as 150 °C), the loss of even a single individual cell can rapidly cascade to surrounding cells, resulting in a larger scale “fire.” This is “thermal runaway” in which failures propagate from cell to cell within “modules” and from module to module within a “rack”.

This is what happened at McMicken [8], with temperatures sufficient to melt Aluminium (660 °C) being reached. Such “fires” can be extremely dangerous to fire fighters and other first responders because, in addition to the immediate fire and explosion risks, they would have to deal with toxic gases (principally hydrogen fluoride HF, also hydrogen cyanide HCN and other fluorine compounds such as phosphoryl fluoride POF_3) and exposure to other hazardous materials.

Rack to rack propagation fortunately did not happen at McMicken, though an explosion did [8]. A local conventional fire involving the plastics materials or gases evolved from them could have initiated rack-to-rack propagation; the only essential factor would have been sufficient heat to trigger thermal breakdown in just one cell in a neighbouring rack. Li-ion cells have been observed to eject molten metal during thermal runaway, another possible mode of propagation over distance. Propagation through a subsequent rack would then occur by exactly the same thermal runaway mechanisms, and potentially beyond between neighbouring cabins in large-scale BESS.

Thermal runaway is illustrated in dramatic fashion with tiny commercial Li-ion cells in a useful internet video [10] (Figure 14). The commercial cells involved in this demonstration have tiny capacities: a mere 2.6 Ah or about 10 Wh for typical terminal voltages.

A Tesla Model S would have the capacity of about ***10,000*** such cells.
A 20 MWh BESS has the capacity of about ***2 million*** such cells.

In the video, the cell is deliberately over-heated on a small electric stove. The fully charged cell goes into thermal breakdown, eventually rupturing the can. The cell flies off as a rocket and seconds later is discharged but red hot and will burn anything combustible. Although not illustrated, it is evidently hot enough to produce the same thermal breakdown in an adjacent cell within a battery.

This illustrates the damage done to a non-faulty cell, simply by overheating externally.

Figure 14: (a) A charged 2.6 Ah cell being deliberately overheated. (b) at the point of rupture (c) the cell takes off as a rocket (d) seconds later the discharge is complete, and the cell is red hot.

4. Toxic and flammable gas emissions

During a Li-ion "battery fire," multiple toxic gases including Hydrogen Fluoride (HF) [11], Hydrogen Cyanide (HCN) [13] and Phosphoryl Fluoride (POF_3) [11] may be evolved. The most important is Hydrogen Fluoride (HF), which may be evolved in quantities [11] up to 200 mg per Wh of energy storage capacity.

HF is toxic in ppm quantities and forms a notoriously corrosive acid (Hydrofluoric Acid) in contact with water. It is toxic or lethal by inhalation, ingestion and by skin contact. The ERPG-2 concentration (1 hour exposure causing irreversible health effects) given by Public Health England is just 20 ppm; the workplace STEL (15 minute Short-Term Exposure Limit) is just 3 ppm [12]. Major emissions of HF would form highly toxic plumes that could easily threaten nearby population centres, workplaces and schools.

Appendix 3 contains calculations of projected toxic gas quantities for 3 grid-scale battery stores that have been approved or are pending review by the Planning Inspectorate (Table 2).

The calculated capacities at the "mega-scale" sites listed in Table 2 are tens, or even hundreds, of times larger than the facilities in Table 1, which experienced significant fires or explosions.

In addition to evolution of toxic gases, even in an inert atmosphere (without Oxygen), multiple flammable gases (such as Hydrogen H_2, Carbon Monoxide CO, Methane CH_4, and Ethylene C_2H_4) would be evolved during thermal runaway. These are "typical of plastics fires" [8] and have been measured in sealed vessel tests [13]. As noted by Hill/DNV [8] and others [13], the proportions of H_2, CO, CH_4 and C_2H_4 do not in fact vary greatly between different cell technologies, simply because the chemical nature of the envelope polymers, separators, electrolyte solvents and electrolytes themselves do not differ greatly. The variations between Li-ion technologies are in the electrode systems, which are typically not polymeric.

Such inflammables can clearly create (ordinary, air-fuel) fires or explosions once mixed with air/oxygen. It is important to note that the Heats of Combustion of the inflammables may be up to 15 – 20 $\times$ the rated electrical energy storage capacity of the BESS. This has been demonstrated by the same tests which determined the quantities of HF evolved [11]. These were fire tests, not sealed vessel tests [13]. The stored electrical energy is therefore by no means a conservative estimate of the total energy release which could be released in a major (air-fuel) fire in a BESS, irrespective of whether the initiating cause was a conventional fire or Li-ion cell thermal runaway.

Appendix 2 estimates the inflammables potentially evolved from the BESS given in Table 2.

5. Total Energy Release Potential

Any large energy storage system has the risk that energy released in malfunction will be uncontrollable in ways that will do major damage. BESS can release electrochemical energy in the form of thermal runaway or "battery fires". In addition they can release chemical energy in the form of explosions or conventional fires of inflammable gases, or of polymer components. Many thermal runaway "fires" have now happened, as has explosion of evolved inflammable gases.

An important indicator of the foreseeable scale of a "worst credible hazard" is provided by the total stored energy in the system. For BESS, this comprises two components:

(i) The stored electrical energy which might be released in the event of thermal runaway incidents, a self-reactive electrochemical energy release not requiring oxygen at all, and

(ii) Stored chemical (fuel) energy which might be released in complete combustion of the inflammable gases which might be released by (i).

Electrochemical energy release is uncontrollable once started, by any measure except cooling – of all cells and cell parts – below about 150°C. Water is the only fire-fighting substance with the necessary heat capacity. Concurrent conventional fire would first heat cells above the thermal runaway temperature, causing more thermal runaway. Chemical energy release from inflammable gases is also uncontrollable once those gases are mixed with air and ignited: explosions result.

What might be the scale of such energy releases? The Sunnica proposal is estimated to have a stored energy between 1.5 – 3.0 GWh in total, spread across 3 separate sites called Sunnica East A, Sunnica East B and Sunnica West A (see calculations in Appendix 1). It is between 2 – 4 times the capacity projected for Cleve Hill (700 MWh). It is 8 – 15 times the capacity (193 MWh) of the "Hornsdale Power Reserve" in Australia, at installation (2017) the world's largest.

Compared to other energy storage technologies, the Dinorwig Pumped Storage Scheme in Snowdonia stores about 9 GWh [14]; the Sunnica BESS corresponds to 17 – 33 % of Dinorwig.

Compared to major explosions, the energy released in the Beirut warehouse explosion of August 2020 has been estimated [15] by Sheffield University at about 0.5 kilotons of TNT (best estimate) with a credible upper limit of 1.12 kilotons. A totally independent estimate [16] (based on seismic propagation instead of eye-witness footage) gives the same range, without specifying a "best" estimate. The popular measure of major explosions in "kilotons of TNT" has an agreed definition[2] of 1.162 GWh of released energy; in this paper we shall take "one Beirut" to be an explosive energy of 0.5 kilotons of TNT or about 580 MWh of released energy.

The projected BESS storage at Sunnica corresponds to 1.4 – 2.7 kilotons of TNT in total, across all three sites. In the "low" case, this would be "0.92 Beiruts" at the Sunnica West A site alone, or "2.7 Beiruts" over the whole scheme. In the "high" case "2.7 Beiruts" could be stored in the Sunnica East B site alone. Note that these are stored electrochemical energy only; the potential for conventional fire or explosion of evolved inflammables could be **up to 20 × larger** [11]. See Table 3, Appendix 1.

This is plainly a quantity of stored energy which, if released uncontrollably, could do major damage. Explosions and fires at individual BESS are matters of record. They can propagate from failure in a single cell out of many thousands. Cell-to-cell and module-to-module propagation occurred at McMicken. Rack-to-rack propagation was avoided, but could readily occur if continuous

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[2] See e.g. Wikipedia.

fires start. Cabin-to-cabin propagation of a major BESS “battery fire” would be the critical link that would escalate major but manageable fires into catastrophes.

Yet this propagation route remains unanalysed. Significantly, Commissioner Sandra D Kennedy of the Arizona State Commission [3] reviewed reports on the 2019 McMicken battery fire and also a 2012 battery fire at the APS Eldon substation facility in Flagstaff, AZ. She quotes the Flagstaff fire department report on the latter incident as referencing :

> “*Fires with 10-15 feet flame lengths that grew into 50 - 75 feet flame lengths appearing to be fed by flammable liquids coming from the cabinets*”.

Finally, in the context of BESS, “Stranded Energy” will remain a hazard at any affected BESS cabins even assuming an initial incident is controlled. The accident investigation at McMicken required nearly 3 months, simply to discharge “stranded energy” safely [8].

‘”Mega-scale” Li-ion BESS should, in all prudence, require the highest level of regulation. The COMAH regulations are designed for this, including establishments where dangerous substances may be generated “if control of the process is lost” [17] in a thermal runaway accident.

6. Applicability of the COMAH (Control of Major Accident Hazard) Regulations 2015

The governing criteria for application of the COMAH Regulations [17] are:

1. The presence of hazardous materials, or their generation, "if control of the process is lost."
2. The quantity of such hazardous materials present or that could be potentially generated.

There is no doubt that hazardous substances such Hydrogen Fluoride (an Acute Toxic controlled by COMAH) would be generated in a BESS accident (i.e., in "battery fires"). Similarly highly Inflammable Gases (also controlled by COMAH) would be evolved even if the atmosphere remained oxygen-free. Depending on the size of the "establishment" these could be produced in sufficient quantities to be in the scope of COMAH. In Appendix 2 we estimate quantities guided by the literature, where fire tests have directly measured evolution of the hazardous gases.

For small capacity BESS installations, under 25 MWh capacity, the quantities ("inventory") of the evolved hazardous substances might be outside COMAH. This paper however addresses the recent trend towards "mega-scale" Li-ion BESS (Table 2) with very large quantities of stored energy, where the inventory should be large enough to bring the installation within scope.

Broadly speaking, the threshold for applicability of COMAH will be dependent on the precise BESS technology chosen, but likely to be for BESS in the region of 20 – 50 MWh. See Appendix 2.

A letter to the HSE regarding applicability of COMAH to large-scale BESS (dated 25 Nov 2020 [18]) received no reply until follow-up letters were sent addressed personally to the Chief Executive on 7 February 2021, with the intervention of Mrs Lucy Frazer MP. The reply from the Chief Executive [19] dated 22 February 2021 stated that "*Li-ion batteries are considered articles and are not in scope of COMAH*".

We believe the current attitude of the HSE – that even large-scale Li-ion BESS are "articles" best regulated by operators – is not consistent with the law.

Unless tested in the Courts however, this throws the entire responsibility for ensuring the safety of major BESS "battery fires" onto the Fire and Rescue Services. Currently the HSE makes no representation to the Planning Inspectorate in respect of BESS hazards.

7. Engineering standards for BESS

As with any hazard, the basic principles of Prevention and Mitigation must be applied to minimise the risk to life, property and the environment. A major contribution of the Hill/DNV report [8] is a review of current engineering and fire protection standards. This did not concern planning, siting and electrical standards, but simply addresses the question: which standards, if any, offer Prevention or Mitigation of the phenomenon of thermal runaway? The answer appears to be none.

"Thermal runaway" is an electrochemical reaction, well-known in Li-ion BESS, that is largely uncontrollable once started. Since failures in single cells (among many thousands) can be sufficient to initiate thermal runaway, the only known Prevention measure is that adopted by the BEV industry, viz. thermal isolation of neighbouring cells, so that if failure occurs in any one cell, insulation or water cooling prevents easy thermal spread to neighbouring cells. Various design strategies have been adopted in BEV Li-ion batteries, usually involving some form of thermal barrier.

However these are not widely used in grid-scale Li-ion BESS. Current practice is the assembly of stacks of cells, typically "pouch" cells which are externally flat polymer bags, that are stacked side by side in low profile modules with no thermal isolation. This is not the construction adopted in current generation BEV batteries; BEV practice *(with* thermal isolation) extended to grid-scale BESS would obviously increase costs and complexity considerably.

The engineering standards reviewed by Hill/DNV [8] included NFPA 855, UL 1973 and UL 9540/9540A. UL 9540A is a US standard that is widely used in grid-scale BESS engineering, is routinely recommended by insurance and risk consultants [20] and was appealed to by the developer of the Cleve Hill solar farm (Table 2). The problem is that UL9540A is fundamentally a test procedure. It mandates no design features. It requires absolutely nothing that would prevent thermal runaway in any BESS design. This means that an operator can say truthfully that a given BESS is "fully compliant" with UL9540A, yet this would provide no assurances at all regarding thermal runaway prevention. It is therefore wholly insufficient as a safeguard to either the operator, the public, or to emergency services.

NFPA 855 [21], uniquely, requires evaluation of thermal runaway in a single module, array or unit and recognises the need for thermal runaway protection. However, it assigns that role, with complete futility, to the Battery Management System (BMS). Thermal runaway is an electrochemical reaction which once started cannot be stopped electrically. It is uncontrollable by electronics or switchgear. A BMS can locate faults, report and trigger alarms, but it cannot stop thermal runaway.

The Hill/DNV report [8] highlights the many shortcomings of existing standards, see Appendix 4. The basic issue is simple:

(1) Thermal Runaway has very few means of Mitigation once started.
(2) It is therefore essential to address Prevention as a priority.
(3) ***No current engineering or industry standards require the Prevention of thermal runaway events by thermal isolation barriers.***

Nothing in existing standards prevents runaway incidents happening again, requiring for initiation only single-cell failures from known common defects in cell manufacture.

8. Fire Safety Planning for BESS "fires"

Taking the recent Sunnica BESS proposal as an example, a joint statutory consultation response has been submitted by the four Local Authorities concerned. The Local Authorities in this case are Cambridgeshire and Suffolk County Councils, and West Suffolk and East Cambridgeshire District Councils. This joint consultation response [22] included a section on Battery Safety (pp 74-75) and states as follows:

Suffolk Fire and Rescue Service (SFRS) *will work and engage with the developer as this project develops to ensure it complies with the statutory responsibilities that we enforce.*

Sunnica should produce a risk reduction strategy as the responsible person for the scheme as stated in the Regulatory Reform (Fire Safety) Order 2005. It is expected that safety measures and risk mitigation is developed in collaboration with services across both counties.

The response also later states: *As with all new and emerging practices within UK industry, the* ***SFRS would like to work with the developers*** *to better understand any risks that may be posed and develop strategies and procedures to mitigate these risks.*

It is clear that local Fire and Rescue Services have been given the lead responsibility for independent emergency planning, in concert with the developers. Because of the attitude of the HSE refusing to exercise regulatory control over BESS safety, local Fire and Rescue Services become the sole independent public body able to influence BESS safety issues at the planning stage.

Many detailed recommendations have been made by the Local Authorities in the case of Sunnica. It is unclear how much opportunity or input Suffolk FRS has had in these. However the recommendations offered betray some serious misunderstandings and a complete lack of awareness of the lessons and recommendations made in publicly available documents such as the Hill/DNV report [8] into the McMicken explosion.

These are taken point by point in Appendix 4 but some general points are made here.

1. Thermal runaway cannot be controlled like a regular (air-fuel) fire. The only way to mitigate "re-ignition" (a regular report of eye-witnesses) is by thorough cooling. Water is the only fire-fighting material with the necessary thermal capacity. Sprinkler systems, though with good records in conventional building fires, are likely to be completely inadequate. The purpose of the water is absorbing a colossal release of energy. The Hill/DNV report [8] called for so-called "dry pipe" systems allowing first responders to connect very large water sources to the interior without having to access the interior.

It is critical to appreciate that all parts of the battery system must be cooled down. Playing water on a battery "fire" may cool the surface, but so long as Li-ion cells deep inside the battery remain above about 150°C, "re-ignition" events will continue. It is not sufficient to estimate water requirements on the basis of calculations assuming water reaches everywhere, uniformly.

For example, in the recent Tesla car fire [2] the BEV battery kept re-igniting, took 4 hours to bring under control and used 30,000 (US) gallons of water (115 m^3). This was for a 100 kWh BEV battery, designed with inter-cell thermal isolation barriers.

In the case of Sunnica, the Local Authorities have suggested that water supplies of 1900 litres per minute for 2 hours (228 m^3) will be needed [22]. But this is grossly inadequate. Using the above Tesla BEV fire experience, this amount of water would suffice for just ***two*** Tesla Model S car fires. Scaling this up to even the smallest 2 MWh BESS (such as that in McMicken [8]), which contains stored energy equivalent to ***twenty*** Tesla Model S cars, it is clear to see that a much greater amount of water would be needed.

The actual amount of water required will depend on the energy storage capacity per cabin which, in the case of Sunnica, is still unstated. Some simple estimates are, however, made below. **The requirements suggested to date by the Local Authorities for the Sunnica installation are completely inadequate and, if not addressed, would leave Suffolk FRS without the means to control a major BESS "fire".**

Taking a storage capacity of 10 MWh in just one of the Sunnica cabins (see Appendix 1), a complete thermal runaway accident in such a BESS would release that stored electrochemical energy, plus an indeterminate quantity of heat from combustion of hydrocarbon polymer materials or inflammable gases evolved from them. Such Total Heat Release may be up to twenty times the amount of the stored electrochemical energy in the BESS [11].

The thermal capacity of water is 4.2 kJ kg^{-1} K^{-1} or in kWh terms, about 1.17 kWh m^{-3} K^{-1}. If heated from 25 °C to boiling point about 87.8 kWh m^{-3} of thermal energy is required.

Hence the water volume required to absorb 10 MWh of released energy without boiling is about 114 m^3 or 30,000 US gallons, the same amount as required in practice to control a fire in a single Tesla Model S car with a mere 100 kWh battery, 100 times smaller than a 10 MWh BESS.

The quantity suggested by the Local Authorities' joint response is 228 m^3 (1900 L min^{-1} for 2 hours), twice the above estimate, which would naively be sufficient for a 20 MWh BESS fire. **However, from the experience of recent BEV fires, it could be insufficient by a factor of 100.**

No such calculations were presented in the Examination of the 700MWh Cleve Hill BESS [6].

2. "Clean agent" fire suppression systems are a common fire suppression system in BESS, but are ***totally ineffective*** to stop "thermal runaway" accidents. The McMicken explosion was an object lesson in this: the installed "clean agent" system operated correctly, as designed, on detection of a hot fault in the cabin [8]. There was no malfunction in the fire suppression system. But it was completely useless because the problem was not a conventional fuel-air fire, it was a thermal runaway event. Only water will serve in thermal runaway.

Indeed in the McMicken explosion the "Novec 1230" clean agent arguably contributed to the explosion by creating a stratified atmosphere with an air/Novec 1230 mixture at the bottom and inflammable gases accumulating at the cabin top.

The most probable cause of the explosion was mixing caused by the opening of the door by first responders. The explosive mixture contacted hot surfaces and ignited [8].

3. A further recommendation of the Hill/DNV report [8] into the McMicken explosion is for a means of ***controlled venting*** of inflammable gases ***before*** first responders attempt access. In the Local Authority response to the Sunnica consultation, ventilation is listed as a BESS requirement [22] but the reason given, bizarrely, is "to control the temperature" – at which ventilation or air-conditioning (also listed) would be totally ineffective, lacking any significant thermal capacity.

The critical reason for controlled ventilation is the removal of inflammable gases ***before*** an explosive mixture forms. Deflagration panels (to decrease the pressure of explosions that do occur) are also recommended.

It should be noted that although controlled venting provisions would mitigate the consequence of inflammable gas evolution, they would also require simultaneous venting of Hydrogen Fluroide that would be evolved concomitantly.

Toxic gas hazard would continue to present a risk to the community and the environment for the duration of the incident. Fire-water will be contaminated with, *inter alia*, highly corrosive Hydrofluoric Acid. Contamination of water supplies and waterways ***must*** be prevented.

It is strongly recommended that Fire Services study the Hill/DNV report [8], and the related Underwriters Labs report [9], act upon their recommendations, and make realistic, physics-based, calculations of the water quantities required to be available at every single BESS cabin. There could be as many as 150 BESS cabins at the Sunnica East B site alone – see Appendix 1; each of these would need a sufficient water supply.

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[17] Understanding COMAH – a Guide for new entrants
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Appendix 1 Figure 1 flowchart.

[18] Letter from Dr E J Fordham to HSE, 25 November 2020.
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[19] Letter from Ms Sarah Albon, Chief Executive of HSE, to Dr E J Fordham, 22 February 2021.

[20] Allianz Risk Consulting (2019) Battery Energy Storage Systems (BSS) using Li-ion batteries,
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Standard for the Installation of Stationary Energy Storage Systems Standard 855, Table 9.2

[22] Response of affected Local Authorities
(Cambridgeshire and Suffolk County Councils, West Suffolk and East Cambridgeshire District Councils) to Sunnica Consultation.
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[23] Note (2/11/20) from Councillor Andrew Douch, Freckenham Parish Council, meeting 30 October 2020

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[25] Energy Institute (2019) Battery Storage Guidance Note 1: Battery Storage Planning, Sec 4.2 page 16

[26] A guide to the COMAH regulations (2015): [redacted]

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Appendix 1: Battery Capacity Calculations for the Grid-scale BESS proposed at the "Sunnica" site.

The Sunnica scheme will be taken as an example of a "mega-scale" solar plant with BESS. If approved, it would cover approximately 2800 acres and will include BESS on 3 separate sites.

The proposed BESS capacity in the Sunnica scheme has not been specified. Estimates of storage capacity can be made on the basis of the land areas allocated to the BESS compounds, assuming full use (per meeting with Parish Councillors, 30 October 2020 [23]). Li-ion battery technology has also been assumed because it is the most widely used in the industry today. Li-ion batteries have a high energy density, and the costs of these have fallen significantly over the past few years [24] .

Land areas and cabin size are quoted in the Sunnica Scheme Description as:

Sunnica East A: 5.23 ha
Sunnica East B: 15.6 ha
Sunnica West A: 10.65 ha
Total: 31.48 hectares.

One storage cabin size is 15 m length × 5 m width × 6 m height. This height is *double* that of a so-called "hi-cube" shipping container and has a larger footprint (75 m^2 *vs* 30 m^2 for a standard 40-foot shipping container).

Storage capacity can be estimated based on other BESS and storage cabin volumes:

Single cabin energy storage capacity:

The McMicken, Arizona, Li-ion BESS was a single cabin, footprint of 60 m^2 and 'shipping container' height. The Sunnica BESS cabins are 75 m^2, with 'double shipping container' height (6 m).
Energy storage at McMicken was 2 MWh.

Scaling by footprint and height yields a *single cabin* energy storage capacity estimate of 5 MWh for each of the "Sunnica" BESS cabins.

The Arizona cabin had empty space for expansion racks, so a larger single cabin energy storage capacity, up to say 10 MWh, is entirely conceivable.

Density of BESS cabins on allocated land:

This is unstated by Sunnica. We assume that 7.5% of the allocated land area will be occupied by the BESS cabins themselves (this allows for safety separations, fire access routes, Battery Management Systems (BMS) and other electrical plant, bunding for firewater in the event of incidents). This implies a total of 315 BESS cabins allocated over the three sites.

Total scheme storage capacity:

5 MWh (single cabin capacity) x 315 cabins yields a total energy storage capacity of **1575 MWh** (or 1.574 GWh), distributed over 3 separate battery compounds of unequal size (31.48 ha total). If the single cabin capacity were 10 MWh, the total doubles to **3150 MWh.**

A storage capacity between 1500 – 3000 MWh is therefore credible for the Sunnica proposal, depending on single cabin storage and the density of cabins on the land.

The area density of storage at this cabin density would be 50 MWh ha^{-1} for a single-cabin storage of 5 MWh. This figure of 50 MWh ha^{-1} is independent of the total area allocated; it depends only on the assumed fraction (7.5%) occupied.

For comparison, the corresponding density at Cleve Hill [3] is a very similar 69.2 MWh ha^{-1}.

The Energy Institute [25] gives 100 MWh ha^{-1} as ‘typical’ for Li-ion BESS planning. This density would be reached in our assumptions if the single cabin capacity were 10 MWh. The latter figure is entirely conceivable because the “base estimate” derives from an incompletely populated cabin. It is also readily achievable if the spacing of cabins is closer than implied by the assumption of 7.5% land occupancy.

The “base case” estimate of 315 cabins and 1574 MWh is an overestimate *only if* the project does *not* fully occupy the allocated land (i.e. BESS cabin density is less than the 7.5% assumed), but this would be contrary to advice from the developer in meetings with local Councillors.

It is also an overestimate if the single cabin storage capacity is less than 5 MWh. This is unlikely because it is estimated from a BESS cabin still incompletely populated.

These estimates are summarised in the following Table.

Table 3. Estimates of electrical stored energy under various assumptions at Sunnica.
Note: “1 kiloton TNT” is equivalent to 1.163 GWh. “One Beirut” is equivalent to 580 MWh.

Compound	Area	No. of cabins at area density of 7.5%	Energy storage capacity		Comments
(Single cabin) (per cabin land)	75 m^2 1000 m^2	1	5 MWh	10 MWh	Per cabin assumptions
Sunnica East A	5. 23 ha	52	260 MWh	520 MWh	Per compound estimates of stored energy
Sunnica East B	15.6 ha	156	780 MWh	1560 MWh	
Sunnica West A	10.7 ha	107	535 MWh	1070 MWh	
Whole Scheme	31.5 ha	315	1575 MWh 1.575 GWh 1.36 kilotons 2.72 “Beiruts”	3150 MWh 3.150 MWh 2.71 kilotons 5.44 “Beiruts”	Stored electrochemical energy only. Does not include chemical energy from inflammables.

Appendix 2: Applicability of the COMAH Regulations to large-scale BESS

The COMAH regulations (2015): COMAH regulates establishments with quantities of dangerous substances (categorised as toxic, flammable or environmentally damaging) that are present above defined thresholds. The substances do not need to be present in normal operation. If dangerous substances could be generated "if control of the process is lost", the likely quantity generated thereby must be considered. If the mass of dangerous substances that could be generated in loss of control exceeds the COMAH thresholds, the Regulations apply.

There are two "tiers" to COMAH, the "upper tier" imposing more stringent controls. Thresholds of hazardous substances are listed with thresholds for both tiers.

The regulations specify aggregation rules when more than one substance in a hazard category (e.g. flammables) may be present; even if all such substance are below the COMAH thresholds, others in the same hazard category must be quantified and the proportions of the threshold aggregated. If the total exceeds one, the establishment is subject to COMAH. It is also clear that the inventories of all "installations" – including pipework – must be considered as a whole.

Extracts from COMAH Regulations [26] ***2(1) (definitions):***

"establishment" means the whole location under the control of an operator where a dangerous substance is present in one or more installations, including common or related infrastructures or activities, in a quantity equal to or in excess of the quantity listed in the entry for that substance in column 2 of Part 1 or in column 2 of Part 2 of Schedule 1, where applicable using the rule laid down in note 4 in Part 3 of that Schedule;

"presence of a dangerous substance" means the actual or anticipated presence of a dangerous substance in an establishment, or of a dangerous substance which it is reasonable to foresee may be generated during loss of control of the processes, including storage activities, in any installation within the establishment, in a quantity equal to or in excess of the qualifying quantity listed in the entry for that substance in column 2 of Part 1 or in column 2 of Part 2 of Schedule 1, and "where a dangerous substance is present" is to be construed accordingly;

Application to grid-scale BESS: The Regulations refer to "*a dangerous substance which it is reasonable to foresee may be generated during loss of control of the processes*". Both Flammable Gases (P2) and Acute Toxics (H1 and H2) are certainly "*reasonable to foresee*" in thermal runaway incidents which are now well-documented. The evolution of regulated, named and categorised hazardous substances from Li-ion battery cells in thermal runaway is also well-documented. A "worst credible accident" would have to consider that the entire inventory of Li-ion cells would be destroyed in a single BESS cabin at least. Cabin-to-cabin propagation should also be considered.

The Regulations apply to the entire "establishment", controlled by a single operator. Whilst the individual BESS compounds at Sunnica might be regarded as separate establishments, it is less reasonable that individual BESS cabins should be regarded as separate "establishments". They are separate "installations" but "establishment" means the entire area under control of an "operator".

Only if the most stringent safeguards were in place to ensure that the disastrous consequences of cabin-to-cabin propagation of "battery fires" could not conceivably occur, could it be argued that dangerous substances, exceeding the COMAH thresholds in quantity, were not "*reasonable to foresee* [being] *generated during loss of control of the process*".

We believe the COMAH regulations apply to BESS and that the approach of HSE is wrong in law.

Dangerous substances "reasonable to foresee … generated during loss of control of the processes": The literature and known experience of BESS accidents is clear that dangerous substances in the hazard categories H1 and H2 (Acute Toxic) and P2 (Flammable Gases) are foreseeable in the event of thermal runaway accidents. One of the Flammable Gases is Hydrogen, which is a "Named Dangerous Substance" in Part 2 of Schedule 1 of the COMAH Regulations 2015. Lower thresholds are specified for Hydrogen than for other P2 Inflammable Gases.

It remains therefore to consider the quantities of dangerous substances which could be generated if "control of the process is lost" in a thermal runaway incident. Published literature sources quantify evolution of flammable gases from tests of various Li-ion cells in sealed vessels. Open "fire tests" quantify the evolution of toxic gases particularly Hydrogen Fluoride. Many other test results exist in the records of specialist test laboratories, but here we rely upon two primary published sources.

Golubkov *et al.* (2014) [13] report quantities of evolved inflammables from Li-ion cells of three different electrode chemistries in thermal runaway situations. The proportion of Hydrogen (H_2), Methane (CH_4), Ethylene (C_2H_4) and Carbon Monoxide (CO) does not in fact vary greatly between different types of Li-ion cell, reflecting an underlying inventory of hydro-carbon material (plastics, electrolyte solvents etc) that remain similar in all Li-ion technologies. This is consistent with DNV/GL test data cited in the Hill/DNV report [8]. The quantitative estimates here are taken from results derived from cells with Nickel-Manganese-Cobalt (NMC) electrodes, as used in the McMicken BESS. It was not possible in the apparatus of Golubkov *et al.* to determine the concentrations of HF evolved.

Larsson *et al.* [11] report evolved quantities of Hydrogen Fluoride (HF) from Li-ion cells in open "fire tests", and also the Total Heat Released (THR) from combustion of the inflammables. Again these vary between cell technologies and "form factors", especially whether the cells have an outer metal cannister or are in the "pouch" format. Quantities between 20 – 200 mg / Wh are reported. The worst case figure is used in the following estimates; the lowest evolution reported for "pouch" cells was 43 mg/Wh.

Both sources report evolved gas quantities on a per Wh basis. We scale these to a Li-ion BESS cell size on the basis of stored energy since this will be roughly proportional to the electrolyte solvents and other polymer materials in the cell. Scaling on a per mass basis would be preferable, but this would require further information on the exact composition of the cells in the literature tests, and indeed those for the BESS in question. During the McMicken investigation, the cell manufacturers refused to release such data.

H1 and H2 Acute Toxics. The applicability of COMAH is easiest to determine in respect of Hydrogen Fluoride (HF). This has a dual hazard classification [12] as H1 Acute Toxic (skin exposure) and H2 Acute Toxic (inhalation) and both exposure routes would apply to the general public nearby. The lower tier COMAH threshold for H1 Acute Toxics is 5 tonnes [27]; using the upper estimate of 200 mg/Wh from Larsson, the BESS capacity at which a BESS enters the scope of COMAH (lower tier) is 25 MWh.

This is far below the projected storage capacities given in Table 3 (Appendix 1). With high storage capacity cabins (of e.g. 12.5 MWh), it would require propagation of a fire from just one cabin to a second, to generate HF above the COMAH threshold. It is not necessary to foresee a major conflagration involving multiple cabin-to-cabin propagation to bring the establishment within scope of COMAH; just two cabins would suffice. If 25 MWh were stored in a single large cabin, the question of cabin-to-cabin propagation is irrelevant.

The upper tier for “H1 Acute Toxics” is entered at four times higher capacity (100 MWh), which is well below the estimated capacity of Cleve Hill, and is also below *each* of the three Sunnica BESS compounds individually.

Even on the lowest evolution figure of 43 mg/Wh reported by Larsson *et al.* for “pouch” cells, the lower tier of COMAH is entered at a storage capacity of 120 MWh, again well within the “low case” capacity of each of the Sunnica BESS compounds, and Cleve Hill.

There is little doubt that either the lower or upper tier of COMAH is applicable to Cleve Hill and all three of the Sunnica BESS compounds, on the basis of “H1 Acute Toxics” (HF, skin route) alone.

Carbon Monoxide (CO) is categorised as an H2 Acute Toxic as well as a P2 Inflammable Gas, and will also be evolved, but in application of the aggregation rule its presence does not materially alter these conclusions. It is sufficient to consider HF alone.

P2 Inflammable Gases. Assessing applicability of COMAH on the basis of inflammable gases is more complicated because of the evolution of Hydrogen (H_2), Methane (CH_4), Ethylene (C_2H_4) and Carbon Monoxide (CO) in significant quantities, and because Hydrogen is a “named dangerous substance” for which different COMAH thresholds apply. These must be taken into account when applying the Aggregation Rule. Although proportions are generally similar, quantities do depend on the different electrode chemistries in the different Li-ion cell types.

Taking the largest evolutions reported by Golubkov *et al.* [13] for the LCO/NMC electrode type tested by them these are equivalent to 335 mg/Wh of P2 inflammables. For the NMC cells tested (the McMicken cells were NMC) the evolution was 214 mg/Wh. Taking the higher figure and applying the aggregation rule, grid-scale BESS enter the lower tier of COMAH at about 30 MWh capacity. Taking the lower figure, they enter the lower tier at 45 MWh capacity.

Hence there is little doubt that grid-scale BESS are lower tier COMAH establishments on the basis of “P2 Inflammable Gases” at storage capacities between 30 – 45 MWh.

Because of the variability between cell types, and the difficulty of scaling laboratory tests to actual BESS cells without detailed composition data, there is room for adjustment. However the calculated estimates of the thresholds for applicability of COMAH are so far below the projected capacities that it is inconceivable that the Cleve Hill and Sunnica BESS compounds would *not* be COMAH establishments, in lower tier at the very least, and probably the upper tier also.

Conclusion: Grid-scale Li-ion BESS should be considered COMAH establishments in the lower tier on the basis of “H1 Acute Toxics” (HF) alone, at energy storage capacities in the region of **25 MWh**. Upper tier would apply at about **100 MWh**. They should be lower-tier COMAH establishments on the basis of “P2 inflammable gases” alone, at storage capacities between **30 – 45 MWh**. Again larger establishments could become upper tier COMAH. Laboratory closed vessel and fire tests on actual Li-ion BESS cells proposed to be deployed would be required to refine these estimates definitively.

It is difficult to see how these conclusions could be avoided if tested in litigation.

Appendix 3: Shortcomings of Existing Engineering Standards for Li-ion BESS

The July 2020 report for the Arizona Public Service by Dr D Hill [8] provides a comprehensive discussion of existing engineering standards relating to BESS, and how they are *inadequate* to address the known hazards of “thermal runaway” incidents in Li-ion BESS. This was the failure mode leading to the explosion at McMicken, Arizona.

Unfortunately, when the UK’s first “mega-scale” solar plant and battery storage site was granted approval in May 2020, this paper had not been published. The Cleve Hill solar developers cited one standard, UL 9540A [3]. This is also cited by some insurance and risk consultants [20].

It is important to be clear that nothing in UL 9540A addresses thermal runaway, and as a test method standard, it can provide no “safety certification” for Li-ion BESS.

Specific criticisms made in the Hill/DNV report include the following:

1. UL 1973 allows for the complete destruction of a BESS and the creation of an explosive atmosphere so long as no explosion or external flame is observed. An installation can do all these things but still “pass” UL 1973. At McMicken one rack was completely destroyed and an explosive atmosphere created but no flame or explosion occurred until first-responders opened the cabin door.
2. UL 9540A is merely a test method for generating data. It does not define any “pass/fail” criteria for interpreting results. Specifically, it does not address cell-to-cell cascading in thermal runaway, nor the evolution of a potentially explosive atmosphere. It does not even prescribe that the cell-to-cell cascading rate be measured.
   It allows that thermal runaway may proceed to an entire rack (as at McMicken) and offers testing of fire suppression systems (which operated correctly at McMicken but cannot prevent thermal runaway, and did not prevent an explosion).
   Presentation of data generated under UL 9540A to an “AHJ” (Authority Having Jurisdiction) does not translate to a succinct understanding of potential risks.
3. NFPA 855 [21] does require evaluation of thermal runaway in a single module, array or unit and does acknowledge the need for thermal runaway protection. However, it assigns that role to the Battery Management System (BMS). Yet thermal runaway is an electrochemical reaction that once started cannot be stopped electrically. It is uncontrollable by electronics or switchgear, only by water cooling.

The evolution of engineering and safety standards has not yet incorporated the lessons of experience arising from the McMicken explosion [8] **or explosion incidents in the UK like the Liverpool explosion and fire of 15 September 2020** [1]**. Compliance with existing standards does not prevent such incidents happening again.**

Articles in the industry press[3] do now recognise and discuss the problem of thermal runaway but make proposals such as: “*If off-gases can be detected and batteries shut down before thermal runaway can begin, it is possible that fire danger can be averted*”.

Such statements betray a dangerous misunderstanding. Batteries cannot be “shut down”, except by complete discharge, which cannot be done quickly. Taking cells “out of circuit” is useless; thermal breakdown and runaway will still occur.

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3 [redacted]

Appendix 4 – Fire Safety Planning requirements in the Local Authorities' Joint Response to the Sunnica statutory consultation

This Appendix deals point by point with the BESS requirements in the Local Authority response (text in blue) pp 74 – 75.

Sunnica should produce a risk reduction strategy as the responsible person for the scheme as stated in the Regulatory Reform (Fire Safety) Order 2005. It is expected that safety measures and risk mitigation is developed in collaboration with services across both counties.

The Local Authorities require that the Fire Services work with Sunnica to prepare fire safety and risk mitigation measures. The Cambridgeshire and Suffolk Fire Services are therefore the only public bodies with independent oversight of BESS safety.

The use of batteries (including lithium-ion) as Energy Storage Systems (ESS) is a relatively new practice in the global renewable energy sector. As with all new and emerging practices within UK industry, the SFRS would like to work with the developers to better understand any risks that may be posed and develop strategies and procedures to mitigate these risks.

This paper is provided as input to this process, which appears to be insufficiently understood.

The promoter must ensure the risk of fire is minimised by:

- Procuring components and using construction techniques which comply with all relevant legislation.

This overlooks the points made in this paper that (i) existing legislation is being ignored by the statutory regulatory body, the HSE (ii) no adequate engineering standards exist to exercise Prevention measures over what is by now a very well-known hazard, viz. thermal runaway. Public Health and Safety cannot be assured whilst either of these situations continues.

- Developing an emergency response plan with both counties fire services to minimise the impact of an incident during construction, operation and decommissioning of the facility.
- Ensuring the BESS is located away from residential areas. Prevailing wind directions should be factored into the location of the BESS to minimise the impact of a fire involving lithium-ion batteries due to the toxic fumes produced.

This is impossible to satisfy. All the BESS compounds in the Sunnica proposal are sufficiently close to residential areas to present a major danger of toxic fumes in the event of an accident. Plume dispersal modelling should be performed to ensure that concentrations of HF cannot exceed dangerous thresholds in the event of the worst credible accident in a BESS compound.

- The emergency response plan should include details of the hazards associated with lithium-ion batteries, isolation of electrical sources to enable firefighting activities, measures to extinguish or cool batteries involved in fire, management of toxic or flammable gases, minimise the environmental impact of an incident, containment of fire water run-off, handling and responsibility for disposal of damaged batteries, establishment of regular onsite training exercises.

This requirement is very broad but insufficiently detailed. Means of cooling would require water volumes many times in excess of those requested. Management of inflammable gases is best addressed by venting, but that exacerbates the hazard of toxic gas plumes. Large water volumes may lead to unrealistic or impossible requirements for the containment, and subsequent disposal, of the contaminated water resulting from the fire-fighting activity. Other sections of this paper address these points.

- The emergency response plan should be maintained and regularly reviewed by Sunnica and any material changes notified to SFRS and CFRS.

- Environmental impact should include the prevention of ground contamination, water course pollution, and the release of toxic gases.

Preventing the release of toxic gases is all but impossible. A thermal runaway event WILL release toxic gases. If inflammables are vented to avoid /mitigate explosion risk, toxic gases WILL be vented. Ground contamination and water course pollution is almost certain to occur if sufficient water to control a major thermal runaway event is deployed. It will pose a significant challenge to contain, and safely dispose of, such large volumes of contaminated fire water.

The BESS facilities should be designed to provide:

- Automatic fire detection and suppression systems. Various types of suppression systems are available, but the Service's preferred system would be a water drenching system as fires involving Lithium-ion batteries have the potential for thermal runaway.

This is a correct precaution, but no specification is made of likely water volume requirements, nor for a "dry pipe" system allowing water to be deployed without cabin entry. We provide some water estimates elsewhere in this paper.

Other systems, such as inert gas, would be less effective in preventing reignition.

This is also a correct insight. The so-called "clean-agent" fire suppression system at McMicken was triggered correctly, but was useless to control thermal runaway. Moreover the stratified atmosphere created allowed the build-up of inflammables to a dangerous level, before the explosion occurred.

- Redundancy in the design to provide multiple layers of protection.
- Design measures to contain and restrict the spread of fire through the use of fire-resistant materials, and adequate separation between elements of the BESS.

This comment only vaguely considers the true essentials. The "elements of the BESS" could be: cells, modules, racks, strings, and the entire system. As discussed in the Hill/DNV report what is required is for the industry as a whole to accept that thermal runaway in an unacceptable hazard, and demand engineering standards that Prevent thermal runaway by design, or if it occurs, Prevent its cascade or escalation to larger system elements. This requires

a. Thermal barriers (i.e. Low thermal conductivity barriers, not merely refractory barriers, ideally with water cooling, between all cells, so that propagation from cell to cell cannot occur. This is precisely the requirement the industry has so far ***NOT*** made in the development of its engineering standards.
b. Separation of modules by similar barriers to Prevent module-to-module cascade.
c. Separation of Racks to prevent rack-to-rack cascade, even with ejection of molten metals.
d. Spacing of BESS cabins such that even with "75 foot flame lengths" cabin to cabin escalation is impossible. This is probably the most critical of all, since cabin-to-cabin escalation could turn a major fire incident into an unprecedented catastrophe, on the scale of the Beirut explosion or a small nuclear weapon.

- Provide adequate thermal barriers between switch gear and batteries,
- Install adequate ventilation or an air conditioning system to control the temperature. Ventilation is important since batteries will continue to generate flammable gas as long as they are hot. Also, carbon monoxide will be generated until the batteries are completely cooled through to their core.

This comment is very strange. There is no possibility whatsoever that air conditioning could be adequate "to control the temperature". The importance of ventilation is however recognised, as is the generation of carbon monoxide (toxic as well as inflammable). However the generation of Hydrogen Fluoride will also continue until the batteries are "completely cooled" and HF (H1 Acute Toxic by skin exposure) is much more toxic than CO (H2 Acute Toxic).

- Install a very early warning fire detection system, such as aspirating smoke detection.

The "very early warning" fire detection system required should be thermocouples to report continuously on the local temperature at every cell in the entire system. A single cell overheating can escalate via thermal runaway. By the time smoke is generated, this will be a "very late", rather than "very early" detection system. Just as thermal runaway events do not necessarily generate flame, neither do they necessarily generate smoke, until nearby combustibles are ignited.

- Install carbon monoxide (CO) detection within the BESS containers.

This is a good straightforward measure, but detectors for other gases expected (HF, H_2, CH_4) could equally well serve and multiple gas detection would provides additional security.

- Install sprinkler protection within BESS containers. The sprinkler system should be designed to adequately contain and extinguish a fire.

The excellent record of sprinkler systems in ordinary building fires shows they would help contain fire in regular combustible parts of the structure. However as discussed earlier in this paper, a mere sprinkler system would be useless to contain thermal runaway. Much larger water quantities would be needed.

- Ensure that sufficient water is available for manual firefighting. An external fire hydrant should be located in close proximity of the BESS containers. The water supply should be able to provide a minimum of 1,900 l/min for at least 2 hours. Further hydrants should be strategically located across the development. These should be tested and regularly serviced by the operator.

As discussed elsewhere, we believe these water requirements to be **under-specified by a factor of 100**, based on real experience with BEV fires. "Strategic location" is inadequate. Every single BESS cabin (potentially up to 150 of these at Sunnica East B alone) should have such a hydrant.

We remark elsewhere on the recommendation made by Hill/DNV for a "dry pipe" system to deploy water drenching inside via external connections, without cabin entry being needed.

- A safe access route for fire appliances to manoeuvre within the site (including turning circles). An alternative access point and approach route should be provided and maintained to enable appliances to approach from an up wind direction. Please note that SFRS requires a minimum carrying capacity for hardstanding for pumping/high reach appliances of 15/26 tonnes, not 12.5 tonnes as detailed in the Building Regulations 2000 Approved Document B, 2006 Edition, due to the specification of our appliances.

The requirement for safe access routes and space for appliances to manoeuvre could usefully be expanded into requirements for safe spacing of BESS cabins and thermal or flame barriers between cabins, to Prevent the "disaster scenario" of cabin-to-cabin propagation.

Final Comment: (over)

Final Comment:

The fundamental failure mode of Li-ion batteries presenting major hazard is thermal runaway. This paper is far from the first to identify the risk which is now well-known.

However the BESS industry as a whole has still not agreed or implemented adequate engineering standards to address basic Prevention measures to pre-empt thermal runaway accidents.

Until it does, Mitigation of major accidents by the Fire Services will remain the sole recourse for public protection and safety.

Lessons learned: Solar projects present unique stormwater management challenges

Dec 8, 2017

Turbid runoff from a solar project during construction.

By Jason Sharp, Adam O'Connor and Mark Priddle

With the passing of the Green Energy Act in Ontario in 2009, the design and construction of utility-scale solar projects in Ontario blossomed. Between 2010 and the end of 2016, it is estimated that more than 100 ten (10) Mega Watt (MW) solar farms were constructed in Ontario. Approvals for these sites were issued by the Ontario Ministry of the Environment and Climate Change (MOECC) under Environmental Compliance Approvals (ECA) or more commonly Renewable Energy Approvals (REA).

A typical 10 MW photovoltaic (PV) installation requires about 40 ha of land for solar panels. Sites selected for such solar projects in Ontario range from flat former agricultural fields with clay soils to rolling diamicton hills and areas of very shallow bedrock. Former land uses (prior to solar development) range from airport properties to scrub forests. Locations for such projects are found all across Ontario year.

During the course of construction of a number of these solar projects, unique challenges associated with stormwater management (SWM) arose. Issues relating to turbid runoff occurred, with subsequent impacts to nearby watercourses, neighbouring properties and other downstream locations.

This discussion paper presents a review of the issues with stormwater management, impacts that were caused and remedial measures. The focus is on the experience gained at solar projects located in southeastern Ontario in rolling terrain with adjacent farmlands and watercourses. Overall, the objective is to provide a series of SWM “lessons learned” in the context of utility-scale solar farm, design, construction, operation and maintenance in Ontario.

Site Selection

The selection of a site for solar development is typically based on a number of factors. These include:

- Land availability;
- Land cost;
- Topography;
- Existing site conditions (vegetated field (grass/hay), farmed (row crop), forested, etc.)
- Constraints (water courses, Provincially Significant Wetlands (PSW), incompatible uses, prime agricultural zoning);
- Community acceptance; and
- Proximity to power grid for connection.

In hindsight, it has become apparent that the selection of sites must place great significance on topography, existing site conditions and constraints such as nearby watercourses and soil types. All of these factors readily influence the volume and flow rate of runoff that, if not properly managed, can result in negative impacts to downstream and neighbouring properties.

In general, undeveloped sites either did not possess known existing stormwater concerns or were in locations where seasonal flooding occurred. In either case, the land is drastically transformed from a site that would see minimal usage/disturbance until planting to a site that requires complete year-round accessibility by machines and workers during construction and early stages of operation.

Regulatory involvement, review processes and contractual issues

Under the REA process, public consultation and regulatory review are to be undertaken. Typically, comments are received from the public, all municipal levels of government and Conservation Authorities (if they exist for the area). While the MOECC is the overall approval authority, the process relies on the proponent and their experts to design the project such that potential impacts to the natural environment are mitigated both during construction and when built-out and in commercial operation.

As it relates to the stormwater management component of the review process, these utility scale projects are approved based on a conceptual stormwater management report. These reports typically provided high-level information such as:

- Delineation of the site watersheds;
- Identification of internal drainage areas;
- Completion of high level calculations (typical reports rely on the rational method for calculating peak flows);
- Confirmation that stormwater management is or is not required for the site; and
- Estimation of the scale and locations to accommodate the required stormwater storage.

In some cases, preliminary grading plans are not provided, which may pose the question of whether the proposed drainage areas are constructible. While this information is very useful to identify potential concerns with regard to proximity to watercourses and requirements for stormwater management at a high level, once approved, the vast majority of projects enter into Design Build (DB) contracts with an Engineering, Procurement and Construction (EPC) Contractor. The EPC Contractor is then responsible for taking the preliminary information and bringing the project to completion.

EPC contracts must place appropriate emphasis on completing grading, stormwater management and erosion and sediment controls prior to installing panels on racking, cabling installation, making transformers operational, etc. Otherwise, civil work after the fact, which could include grading around piles and panels, would

Design (Stormwater Management)

The design of large (10 MW or more) solar projects in Ontario has experienced a learning curve with respect to minimizing stormwater management issues. A 40 ha solar farm represents a hard surface with concentrated flow developing during a precipitation event. This being said, the hard surface may be discontinuous, with solar panels arranged in rows, but with vegetated surfaces (post-construction) in the dripline of each row. This differs from the design of a typical hard surface such as a roof or parking lot. The design of stormwater management and grading for a solar project is markedly different from how such issues are addressed in urban development, municipal road projects or the construction of provincial highways.

The key issues are: 1) the amount of hard surface and 2) subsequent sediment loading. Non-solar projects generate sediment loading because of sanding and salting operations in winter months. Solar farms do not, in general, sand and salt their roadways. Therefore, a typical solar project is a 40 ha grass field with some gravel roadways (typically 5% of the site by area), ten (10) relatively small transformers and one (1) relatively small substation. In many instances, calculations post- to pre- may indicate that stormwater management is not required. However, based on our experience, stormwater management is generally required, specifically during construction and until the site is fully re-vegetated.

The following is a list of issues that have been identified that, based on our experience, affect the overall volumes and rates of runoff leaving the sites. There is no single guideline developed, to our knowledge, that addresses the calculations and design considerations relating to the issues experienced below:

graders/dozers working the fields, excavators, boom trucks installing racking, numerous trucks, ATVs and other vehicles, etc.); the resulting increase in compaction of soil may cause an increase in runoff and sediment transport until the site is fully re-vegetated.

- **Topsoil –** The removal of topsoil from a site may result in the loss of vital organic matter required for plant growth. This may result in much less vegetation and/or increased time to re-vegetate the site. On sites where topsoil is not replaced, or is contaminated with subsoil, the lag in full vegetation establishment could extend for a few years. During this time, the bare or partially bare soils may experience erosion and washouts. This may result in the need to re-start the vegetation process: fix the erosion, add topsoil and vegetation (seeding) and/or apply erosion and sediment control measures such as erosion control blankets.
- **Soils / depth to bedrock –** Often, geotechnical information is provided at the onset of a project, but further studies or investigations may not be conducted. The vast majority of sites are constructed based on soils information from ten test pits or boreholes over a 40 ha site. This may provide only a high level understanding of site soils that may be considered relatively limited information when completing grading, preparing a rock profile for the site or balancing the site based on the cut/fill required. Further complicating designs may be pockets of differing soil types found over a site of this size. The ten test locations may not identify these pockets and modifications in the field may be required.
- **Construction methods –** Contractors must be careful not to “open up” (remove vegetation and topsoil) an entire site all at once. When severe weather occurs, such a site may experience significant erosion issues and, in some cases, may not possess sufficient erosion and sediment controls to combat the increase in flow from a bare soil surface. The phasing of construction is of great significance with projects of this magnitude and must be addressed during the design stage and implemented during construction.
- **Concentrating flow (roadways) –** The requirement to access transformers and inverter houses may result in the need to develop an on-site road network. A road network is typically laid out on a plan and each transformer is apportioned a “block” of arrays which make up one-tenth of the area of the project. The road network may not account for the topography, sometimes resulting in roads being located in the least desirable areas, specifically, around the perimeter of the site. This may result in the need to direct runoff via culverts or other means across the roadway and into a ditch or adjacent field with limited opportunity to spread the flow. Sites that have roads that are located on +10% slopes have an increased probability of erosion during major rain/runoff events.

may be smoothed out to permit the piles/panels to be installed and to promote effective transportation networks. The challenge with this is that the combination of long reaches and the smooth surfaces may result in an increased runoff velocity. Under pre-development conditions, the areas may have had generally similar characteristics, however, without the grading activities, small pockets, depressions, etc. may have existed that would capture runoff, reduce flow velocities, provide opportunity for infiltration and/or ensure that not all runoff left the site. Once smoothed out, runoff may not have had these same opportunities, resulting in more flow running off, collecting and then eroding the soils. Generally speaking, runoff is considered overland sheet flow for up to 30 m (100'), at which point it tends to form shallow concentrated flow. This shallow concentrated flow could extend for several hundred metres and could give rise to issues. It is at this point where runoff could form rills and gullies leading to erosion concerns and sediment transport.

Temporary and permanent measures

As part of the stormwater management design, temporary erosion and sediment control (ESC) measures are required during construction of solar projects, as with any other construction project in Ontario. The design of such measures requires an understanding of construction activities and construction flow. Again, a solar farm differs from other development projects, such as a building, because of the continuous and long-term disturbance of typically un-vegetated ground during construction. This requires unique and more robust ESC measures compared to projects that are more conventional.

These temporary measures become the lifeline of the project. It is clear that any temporary controls should have a site-specific design. That is to say, the designer should be reviewing the flows, volumes and drainage area upstream to ensure the controls are sufficient and will be able to withstand the runoff flow and quality anticipated for the project. A few key examples include:

- Reviewing the sheet flow velocity over bare soils to ensure the need for erosion control matting is or is not required;
- Reviewing flow through rock flow check dams to ensure that runoff overtop is able to be conveyed in a major event (and not washout an adjacent roadway); and
- Reviewing flow through flow spreaders to ensure they are sufficiently wide to distribute the flow.

Permanent SWM and ESC measures may be required to control water and possible sediment transport after full buildout of a solar project. These measures differ from measures that are proposed have generally assumed that the site is fully vegetated. In our experience, the design flows during construction should be increased from the typical post-development conditions to account for the bare or partially bare soils and lack of vegetation within ditches that may increase water velocities.

Construction

Challenges pertaining to SWM and ESC during construction have been encountered at numerous solar projects in Ontario. These challenges may appear early on in the development of sites that are stripped of vegetation (and topsoil) prior to solar panel installation and other site works. Heavy vehicular traffic during construction may exacerbate runoff issues. With the widespread disturbance over the entire area of 40 ha or more, ESC measures may be inadequate. In addition, the desire to complete projects on time may mean that year-round construction takes place, even during the winter and spring thaws.

As noted above, working throughout the winter and spring freshet is possible, and in some instances necessary, to meet tight deadlines. Designs must account for flows over frozen soils or an increase in runoff coefficient during winter/spring thaws. Consequently, standard ESC measures may be inadequate for winter runoff events. Given the scale of the typical solar project, this is an important area of design and enhanced ESC measures such as shot rock roads over existing vegetation and/or sediment traps should be considered.

Seasonal limitations must also be considered. For example, during winter, issues are exacerbated when:

- One cannot install silt fence in the winter into frozen ground (not very easily at least);
- Straw bales are typically not available;
- Straw wattles and mulch silt socks are also not easily installed or readily available.

Understanding that construction during winter months is very difficult to predict and provides a number of challenges, contractors should install specific controls, limit the areas that are opened up, and ensure additional materials (e.g. straw/mulch, erosion control blanket/matting and stone) are available on site to use, if necessary. Although these measures cannot guarantee there will be no issues with erosion and runoff during construction, they may provide a contractor with the necessary means to maintain and stabilize the exposed soils and limit the transport of suspended solids, if such a condition occurred.

Re-vegetation does not occur immediately following solar panel installation at most sites. In some cases, topsoil is removed and vegetative regrowth may be hindered. In other cases, works are completed late in the year and re-vegetation efforts may not be successful. These conditions may hinder or prevent re-vegetation in, and around, the solar panels. The design conditions for the SWM and ESC measures therefore may not be met. This may lead to challenges with post-construction runoff, even with properly designed and constructed ESC measures in place. The positive impact of a fully vegetated site with properly engineered and constructed SWM measures in controlling runoff and suspended solids movement cannot be overstated. Therefore stripping of vegetation should be avoided wherever possible, and where vegetation must be stripped, the installation of appropriately sized retention/settlement ponds prior to stripping must be considered.

Monitoring

At many sites in Ontario, monitoring of runoff is required under the REA. Typically, total suspended solids (TSS) are required to be tested at locations where water flows off-site. Depending on the discharge location and receiving body, different requirements may apply. In some cases, a fixed limit of 25 mg/L for TSS for water leaving the site (regardless of receiver) may apply. In other cases, TSS in runoff may be limited to a factor increase in turbidity or TSS concentration relative to upstream levels of these parameters.

It should be noted that TSS is not the only compound/contaminant that should be monitored. Depending on the former use of the site, other nutrients (phosphorus, nitrogen etc.) may be present and require testing. Site-specific monitoring criteria should be established.

In all cases where TSS monitoring is conducted, it should be accompanied by a Contingency Plan that provides the Operations and Maintenance staff with a procedure in order to address TSS concerns, should they arise.

Remediation

Following completion of a solar farm, remediation may be required to prevent turbid runoff from leaving the site. This may require new SWM and ESC measures, combined with concerted efforts to revegetate sites. In some cases, new or additional retention ponds may need to be installed and active pumping and water control may be required. Other remediation efforts may include:

- Construction of additional piping (culverts, storm sewer) to direct runoff across roads or into storm sewer networks;
- Paving of low level crossings to prevent erosion / granular washouts;
- Addition of topsoil and seeding;
- Placement of erosion control blankets on steep slopes to prevent erosion;
- Application of hydroseed with tackifier to prevent erosion on steep slopes;
- Construction of flow dissipation or flow spreading devices;
- Construction of dry and wet retention ponds;
- Construction of infiltration trenches;
- Placement of fill in low-lying areas to promote positive drainage;
- Construction of roads and roadside ditches to provide safe passage and convey runoff;
- Reconstruction of roadside ditches to ensure subgrade is drained;
- Relocation of arrays of panels;
- Re-alignment of ditches and movement of discharge points from the site;
- Reconnecting existing tile drains destroyed during construction;
- Placing berms to limit adjacent floodwater from entering the site;
- Removing berms to limit concentration of runoff within a site; and
- Use of flocculants to control TSS in runoff water.

Lessons Learned

The identification and correction of issues related to SWM and ESC at solar projects provides a number of "lessons learned" which can be applied to new and existing projects to prevent issues in the future. The following recommendations are presented.

Site selection:

- Exercise caution with sites adjacent to sensitive surface water receptors (e.g. cold water streams);
- Avoid sites that may be within a floodplain (limits the ability to grade, may result in seasonal flooding);
- Avoid sites with shallow bedrock (if grading is anticipated);
- Avoid ecologically sensitive lands (rare vegetation or species at risk);
- Conduct advanced planning on the front end (advanced biological surveys); and
- Conduct pre-condition surveys – these are essential to ensure the concerns of neighbouring landowners and municipalities may be adequately addressed.

- Ensure that the design team (electrical design, civil, structural, etc.) communicate to ensure that the design meets all needs, including prevention of erosion and sediment transport;
- Effectively plan the location of SWM measures (e.g. a pond must be located downstream of the development; a pond on top of a hill is not much use);
- Ensure that the design is conservative with respect to runoff potential;
- Provide a reasonable degree of redundancy in designing SWM and ESC measures;
- Ensure that stormwater management design criteria from the MOECC are followed;
- Execute reasonable engineering judgment with respect to the solar farm design; it is not an urban development, municipal road or provincial highway. It should not be designed as such, but it does require a level of sophistication with respect to the collecting and conveying of runoff;
- Review the stormwater design in the context of different storm events (4-hour Chicago storm, 12- and 24-hour SCS storm events); in a number of situations, given the rural nature of most sites, the peak flows may be as a result of the shorter duration events but the SWM measures (ponds) will need to be sized for the volume of the longer events (24-hour);
- Ensure the design takes construction over winter months into account;
- Ensure the design uses "bare soils" calculations to account for runoff during construction;
- Ensure sufficient geotechnical data are available, including depth to groundwater and percolation rates (if designing infiltration trenches);
- Review the designs with operations and maintenance staff to ensure the farms are accessible and operational;
- Provide guidelines to the contractor regarding staging of works to be completed on site;
- Design robust temporary ESC measures that include quantity management and which require continued use and maintenance after commercial operation of the site if it is not fully re-vegetated;
- Emphasize that permanent SWM and ESC measures are based on a fully vegetated site; and
- Ensure the design takes into account the laydown areas and specifically the fuel tanks and refuelling stations to ensure they are in a location which will is not prone to flooding or ponding runoff.

[redacted]

- Develop a spill containment and response plan prior to the start of construction;
- Ensure placement of all temporary SWM and ESC measures prior to any construction; ensure regular maintenance of these measures during construction and through to full re-vegetation of the site;
- Ensure regular site inspections (especially during, or immediately after, storm or rapid thaw events) are completed by a civil engineering consultant to review construction, SWM and ESC measures;
- Ensure additional materials for ESC are on site, especially over winter months;
- Ensure contractor implements staged construction process;
- Minimize the removal of vegetation (and topsoil) prior to construction, especially over winter months;
- Provide sufficient detail on the plans to permit a contractor to construct the farm;
- Minimize construction truck traffic, especially over bare soils; and
- Do not construct during inclement weather or during spring thaw (if possible).

Monitoring:

- The vegetation, stormwater management features and outlets of the sites should be monitored throughout the life of the project;
- If TSS/turbidity monitoring are conducted, ensure that a Contingency Plan is prepared and is implemented, if exceedances of limits are observed;
- At a minimum, bi-annual inspections should be performed and the frequency should be increased if issues arise; and

Owner and Operation and Maintenance staff should contact appropriate consultants in the event that issues arise so that a suitable solution may be developed.

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