Fire Risk Mitigations & Commentary

Māniototo Plain Solar Farm

Prepared for Helios Energy Ltd
Prepared by Beca Ltd

2 July 2025

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Revision History

Revision Nº	Prepared By	Description	Date
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C	Hamish Denize & Dr Paul Horne	Record of risk mitigation decision outcomes	27/6/2025
D	Hamish Denize & Dr Paul Horne	Final Technical Report	27/6/2025
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Document Acceptance

Action	Name	Signed	Date
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Approved by	Mark Jacob		2/7/2025
on behalf of	Beca Ltd		

1 Introduction

Beca Limited (Beca) has been commissioned by Helios Energy Limited (Helios) to document the fire risk mitigations in relation to the Project, and comment on themes in regards to fire risk raised in a submission during the public notification period at 48 Ranfurly-Naseby Road, Naseby, Otago (referred to as 'the site').

1.1 Purpose

The purpose of this report is to provide:

- An overview of the solar farm components, with regards to combustibility and fire spread contribution.
- An overview of the fire risk mitigations to be implemented in detailed design, procurement and operational stages.
- Commentary regarding potential contamination of air, soil and groundwater, relative to the surrounding rural context.
- Response commentary on fire -risk themes raised in a submission in opposition (Submission 128, dated 19/12/2024).

1.2 Assumptions and Limitations

This report is based on a review of information provided to Beca by Helios. It is not possible to fully review all potential fire environmental risks associated with the operation of the site as it has not undergone detailed design and is not currently operational. Hence, the fire risk mitigations contained in this report are to be implemented by Helios (e.g. by corporate procedures) or implemented by other designers and must be confirmed prior to construction and commissioning of the facility.

The recommended fire risk mitigations have been made based on our experience and engineering judgement, customised for the site.

2 Overview of Electrical Component Fire Hazard

2.1 Electrical System Overview

For the purposes of discussing the ignition sources and fire hazards of the solar power system, a simple description of the system is presented. The components of the solar farm are described in detail within the existing resource consent application documentation ("Application for Resource Consent – Māniototo Plain Solar Farm" by The Property Group, dated 22 March 2024).

A high-level schematic of the photovoltaic (PV) system from PV module (solar panel) to national grid is shown in Figure 1 from Helios's briefing and as reported by The Property Group ("Application for Resource Consent - Māniatoto Plain Solar Farm", dated "Final – 22 March 2024"). For the purposes of electrical component fire hazard, the solar power system is divided into the following parts:

1. Solar photovoltaic (PV) modules/arrays – the "panels" themselves which are joined together to form arrays,
2. String Combiner (Monitoring) Boxes (SMBs) – which combine the outputs of multiple solar arrays into a single DC output
3. Inverters – convert DC to AC
4. Substation – steps up to grid voltage

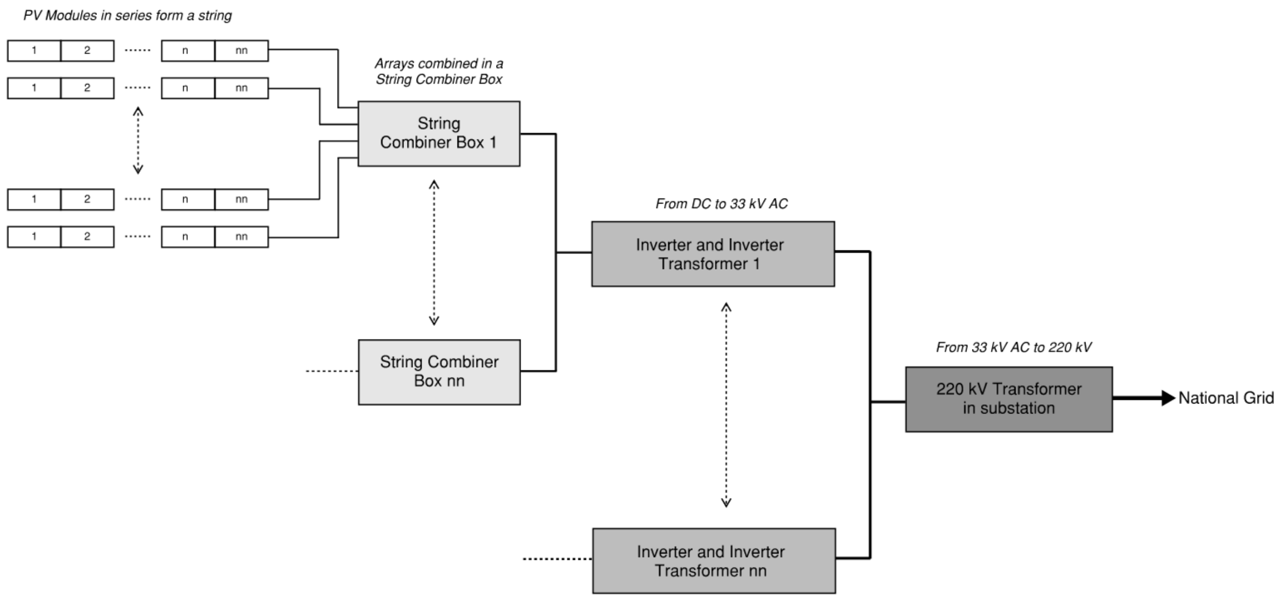

Figure 1: High-level schematic of proposed Naseby solar farm development (based on Helios's briefing and The Property Group's report)

2.1.1 Solar Photovoltaic Modules/Arrays

- The solar panels will be the Bi-facial type, meaning that both the top and bottom surfaces operate as PV panels. The panels will have toughened glass either side, 'sandwiching' the PV cells.
- Panels are mounted on galvanized steel frames, in a 'single axis tracker' formation to track the sun's changing angle throughout each day. Helios have clarified the type of tracking system which will be determined during the detailed design.
- Helios have confirmed PV modules will be certified to standards IEC 61730 and AS/NZS 5033 or equivalent international standards.
- Helios have informed that as part of this certification, PV modules will undergo thermal cycle and damp heat testing to demonstrate long term electrical and mechanical integrity, which reduces the likelihood of hot spots – a potential cause of ignition.
- Helios have stated that the toughened/tempered glass front layer of PV modules will be heat and impact-resistant, helping contain any internal failures.
- The modules will incorporate proper electrical connections and robust bypass diode design to mitigate overheating and arcing risks.

2.1.2 String Combiner (Monitoring) Box (SMB)

- Panels are wired to the SMBs via direct current (DC) cables. Arrays would be connected to each SMB. Cables from the panels to the SMBs are mounted on the underside of the panels (approx. 1.5m above ground).
- Helios have informed us that:
  - DC cables (IEC 62930 or equivalent) will be fire-resistant, UV-resistant, low smoke-emitting, and suitable for high-temperature outdoor environments.
  - Combiner boxes will be outdoor-rated (IP56+), UV-resistant, halogen-free, properly earthed, and ventilated to prevent condensation. They include surge protection, internal isolation, and covers over the live parts.
  - DC fuses/circuit breakers (IEC 60269-6 compliant) will be appropriately sized based on cable capacity and module short-circuit current.
  - DC isolators will be installed at inverters and combiner boxes, rated for full system voltage/current, externally operable, and clearly labelled for safe disconnection.

- Helios have confirmed that combiner boxes include voltage surge protection and internal isolation mechanism. Furthermore, they will be outdoor-rated (IP56+), UV-resistant, halogen-free, properly earthed, and ventilated to prevent condensation.

2.1.3 Inverters

- There are approximately 73 DC to AC inverters for the site.
- Cables from SMBs to the inverters are run underground.
- The inverters will be contained in prefabricated metal cabinets distributed within the site, away from shared boundaries.
- Each inverter cabinet will be approximately the size of a 20ft shipping container. The underlying ground will comprise compacted soil with gravel aggregate topping.
- The inverters themselves each contain an oil-filled transformer and electrical equipment.
- The inverters will comply with IEC 62109, standard for safety of power converters used in PV systems. IEC 62109-1 contains requirements for "Protection against fire hazard" (Clause 9.1) "to reduce the risk of ignition and the spread of flame, both within the equipment and to the outside, by the appropriate use of materials and components and by suitable construction".
- The inverters enclosures will be rated IP54 or higher, installed in ventilated locations.
- The inverters will be equipped with over-temperature and fault isolation protection.
- Transformers within the inverter skid enclosure will use low flammability dielectric fluid as electrical insulator if feasible.
- Helios have confirmed that the inverter skid includes thermal monitoring, ground fault detection system, over voltage detection, over current detection and circuit breakers. The circuit breakers would be configured to open if any anomaly is detected to prevent the fault from progressing and damaging the equipment.

2.1.4 Substation & Switchyard

A new substation is to be constructed within the site. The substation contains electrical equipment which carries the highest electrical energy loads, in particular the external national electricity grid step-up transformer and electrical switchgear.

The substation concept designers (Beca) have been consulted and confirmed the substation will be designed to meet Transpower NZ's "Substation Fire Mitigation Design Standard" (Transpower reference TP.DS 61.06, October 2023). This standard has comprehensive fire risk mitigations and is summarized in Appendix B, which includes equipment spatial setbacks to boundaries, FENZ response/tactics, firefighting provisions and an Emergency Response Plan (ERP) with FENZ familiarisation.

There are hundreds of Transpower and utility substations located in NZ, of which many are in similar external rural contexts (such as the existing substation on Fennessy Road). This signals that when substations are designed in accordance with the Transpower standard, the fire risks are mitigated to a generally accepted level. Therefore, the substation is not discussed further in this report.

2.2 Fire Hazards of PV Modules

Refer to Section 2.1.1 for a description of the PV modules within the context of the solar farm.

The ignition source in PV modules (i.e. the panels) is the formation of so called "hotspots". A hotspot occurs when a solar cell (or group) is "forced into reverse bias and must dissipate power that can result in abnormally high cell temperatures in a restricted area of the surface" (Aram et al., 2021). Hotspots can originate due to partial shading, production flaws or damage to the cells. Bypass diodes are incorporated into modules to prevent hotspots developing – they allow electrical current to flow around groups of cells with a high resistance (e.g. as a result of shading) preventing resistance heating. It is also possible for a difference in module performance (a “mismatch”) to cause a reverse current to occur between whole PV modules resulting in power loss and hotspots.

A tracking system rotates the PV modules to follow the sun throughout the day to optimise output- from the PV system. Helios have stated the tracking system will be determined as part of detailed design. Without the details of the tracking system, we are unable to comment on the degree of fire risk from the tracking system.

The main materials of PV modules are glass, silicon solar cells, the aluminium frame, copper wiring and EVA encapsulant. The proposed PV modules are bifacial i.e. there are cells and glass on both sides forming a ‘sandwich’ between toughened glass. This is different to mono-facial panels which have a plastic backing sheet. This backing sheet, which is not in the proposed panels, is the “most flammable component and has the potential to exacerbate the spread of fire” (Pester et al., 2017). The EVA encapsulant is the main combustible component in the bifacial PV modules – however is very thin and sandwiched between the glass.

2.3 Fire Hazards of Electrical System Components

A 2018 study by the Building Research Establishment (BRE) on “Fire and PV Systems” investigated historic incidents and incidents that occurred during the study. They found “80 potential PV related fire incidents, representing approximately 0.01% of the current number of PV installations installed in the UK” (Coonick, 2018). 47 of these events occurred during the course of the study (July 2015 to February 2018) and 33 events were historical events before the study occurred. PV systems were identified to have caused the fire in 58 (72.5%) of these incidents, the cause was unable to be determined in six incidents and the remaining fires spread to the PV system from other ignition sources.

Of the 80 incidents the BRE Study investigated, six fire incidents occurred in solar farms and the remaining occurred in PV installations fixed to buildings (domestic and non-domestic). “Anecdotal evidence indicates that more solar farm incidents would have occurred that were not reported because the Operation and Maintenance companies, usually on rapid response service level agreements, tend to deal with issues as they arise and buildings and people are often not affected” (Coonick, 2018). These six identified solar farm incidents are detailed in Table 1. Most of the fires were classified as localised fires which “caused some damage to areas around the point of origin, mainly affecting the PV system component, but did not spread beyond that…” and one incident was a thermal event consisting of “components that over-heated, often observed to be smouldering or producing smoke, but did not develop into fires”.

Table 1: Solar farm fire incidents reported in BRE study (Coonick, 2018)

Site Type	Cause of fire attributed to PV system?	Severity	PV components involved	Most likely root cause
Solar Farm	Yes	Localised	Unknown	Unknown
Solar Farm	Unknown	Localised	Unknown	Unknown
Solar Farm	Yes	Localised	Inverter	Unknown
Solar Farm	Yes	Localised	Inverter	Faulty product
Solar Farm	Yes	Thermal event	DC Connectors	Poor installation
Solar Farm	Yes	Localised	DC Combiner Box	Poor installation

A literature review as part of the same BRE Study identified that arc faults “undoubtedly represent the greatest fire hazard in PV systems” (Pester et al., 2017). Arc faults are “where current flows across an air gap by ionising the air.” Arcs in AC systems tend to self-extinguish as the voltage alternates many times per second, whereas the voltage in DC systems is continuous, maintaining the arc once established. Arcs are frequently preceded by ground faults “so it is important to detect as they arise and take appropriate action.”

The BRE Study identified certain PV components that if incorrectly selected, installed or contain flaws are common locations of electrical arcs, and potentially therefore fires:

- PV modules and their junction boxes
- DC Connectors,
- DC Isolators,
- Inverters,

This aligned with PV incident data which found 75% of fires occurred in DC isolators, DC connectors and inverters (Coonick, 2018). The study also investigated the most likely root cause of fires that started in the PV system – 36% were attributed to poor installation practice, 10% to design errors and 5% to faulty products. The cause of the remaining 50% was unable to be determined (Coonick, 2018).

This review of available information suggests the occurrence of fires in solar farm arrays is low but cannot be entirely ruled out. Therefore, additional mitigations are discussed in the following sections to address these scenarios.

3 Fire Risk Mitigations

The fire risk mitigations for the site have been categorised into the following 5 sub-sections:

1. Management plans that include fire risk mitigations
2. Detection, FENZ Notification, Access and Fire Fighting
3. Solar Farm Components
4. Vegetation
5. Boundary System

3.1 Management Plans That Include Fire Risk Mitigations

Fire Risk Mitigations proposed by Helios

1. Management plans:
    a. General Construction Management Plan **(CMP)**, incorporating a Construction Fire Risk Management Plan (**CFRMP**);
    b. Landscape Management Plan (**LMP**);
    c. Operational Management Plan (**OMP**);
    d. Emergency Response Plan (**ERP**).

2. All management plans are prepared by a suitably qualified and experienced person, and be complied with.

3. The OMP must be reviewed annually from the date the Solar Farm becomes operational (unless Council waived). Any amendment arising out of this review must be incorporated into the OMP.

4. The CMP must locate notice boards that clearly identify the name, telephone number and address for service of the construction site manager.

5. Two copies of the ERP must be stored on site in a prominent 'Emergency Information Cabinet' located directly adjacent to the site's main entry point(s).

CFRMP

6. Prior to construction, the following matters must be addressed in the CFRMP:
    a. Identify any foreseeable on-site and off-site fire events and other emergency risks that could occur at the facility during construction (e.g. fires involving solar panels, bushfires in the immediate vicinity or potential hazardous materials incidents);
    b. Identify appropriate fire risk control measures to safely mitigate the identified risks;
    c. Prioritise what fire risk mitigations should be sequenced early into the construction works, including consideration of site access for emergency vehicles, internal access tracks and fire water tanks.
7. As part of the CFRMP, a "construction stage" ERP must be developed in consultation with FENZ. The following matters must be addressed in the "construction stage" ERP:
    a. Identify any foreseeable on-site and off-site fire events and other emergency risks that could occur at the facility during construction (e.g. fires involving solar panels, bushfires in the immediate vicinity or potential hazardous materials incidents);
    b. Provide details of appropriate risk control measures to be implemented to safely mitigate potential risks to the health and safety of firefighters and other first responders (including electrical hazards) from the events identified in subsection (a) above. Such measures should include:

Fire Risk Mitigations proposed by Helios

i. The level of personal protective clothing required to be worn;
ii. The minimum level of respiratory protection required and decontamination procedures;
iii. Minimum evacuation zone distances taking into consideration a range of potential fire events and weather conditions; and
iv. A safe method of shutting down and isolating the photovoltaic system (either in its entirety or partially, as determined by the risk assessment).

c. Other risk control measures that may need to be implemented in a fire emergency due to any unique hazards specific to the site;
d. Include a procedure for a site representative to be available to attend whenever Fire and Emergency New Zealand are alerted to a fire at the site.

OMP

8. Prior to the commencement of the Solar Farm operations, the following matters must be addressed in the OMP:
   a. Contact details of the local Site Representative on a 24 hour, 7 days a week basis;
   b. Fire water storage tank checks;
   c. Seasonal grass height requirements in accordance with Section 3.4.4;
   d. Access track maintenance;
   e. Weed maintenance;
   f. Boundary vegetation treatment maintenance;
   g. Panel and infrastructure maintenance and cleaning, including monitoring for panel damage and integrity;
   h. Emergency events and site remediation in the event of contaminant discharge (e.g. fire or oil spill);
   i. A reinstatement procedure after any electrical equipment is damaged by an emergency event or natural disaster.

EMP

9. Prior to the commencement of the Solar Farm, an “operational” ERP must be prepared in consultation with FENZ. The following matters must be addressed in the “operational” ERP:

   a. Identify any foreseeable on-site and off-site fire events and other emergency risks that could occur at the facility (e.g. fires involving solar panel arrays, bushfires in the immediate vicinity or potential hazardous materials incidents);
   b. Provide details of appropriate risk control measures to be implemented to safely mitigate potential risks to the health and safety of firefighters and other first responders (including electrical hazards) from the events identified in subsection (a) above. Such measures should include:
      i. The level of personal protective clothing required to be worn;
      ii. The minimum level of respiratory protection required and decontamination procedures;
      iii. Minimum evacuation zone distances taking into consideration a range of potential fire events and weather conditions;
      iv. A safe method of shutting down and isolating the photovoltaic system (either in its entirety or partially, as determined by the risk assessment).
   c. Other risk control measures that may need to be implemented in a fire emergency due to any unique hazards specific to the site; and
   d. Include a procedure for a site representative to be available to attend whenever FENZ are alerted to a fire at the site.

3.2 Detection, FENZ Notification, Access and Fire Fighting

Fire Risk Mitigations Proposed by Helios
1. Prior to the Solar Farm becoming operational, the operator must offer to undertake an onsite meeting with FENZ and if agreed, undertake the site visit to familiarise emergency crews with the site and the ERP.
2. During the operation of the Solar Farm, the following equipment must be monitored at all times by a remote central control room for the purposes of monitoring equipment faults and potential fires: a. Key electrical system infrastructure; b. Fault monitoring detection system(s); and c. CCTV system(s) that covers the components of the Solar Farm within the screen planting. **Note from Helios:** *The O&M contractor is responsible for the ongoing operation and maintenance of the solar farm, which includes both proactive preventative maintenance and timely resolution of issues as they arise. A Supervisory Control and Data Acquisition (SCADA) system, which is essentially a centralised computer-based system used to monitor and control key equipment in real time, will play a vital role in the management of the solar farm. SCADA system communicates with key equipment and automatically generates alarms to alert operators when a fault is detected, allowing for prompt and effective response.*
3. During the operation of the Solar Farm, all Buildings on the site must be monitored at all times by an automatic fire detection and alarm system incorporating automatic notification to FENZ. a. Site Administration Building with SCADA (approx. 70m^2) b. The substation switch-room buildings' (approx. 12m^2) c. Any sheds containing maintenance equipment or parts (Sheds to be determined in detailed design)
4. Each fire water storage tank installed must be exclusive for firefighting purposes and filled following its installation and then refilled after each subsequent take of water has ceased.
5. Each fire water storage tank must be fitted with a highly visible float indicator so each tank's water level is easily observed.
6. Prior to construction the Consent Holder must submit to the Council's Group Manager Planning and Environment, detailed design drawings showing the following: a. The LDP identifying final location of all internal roads; b. Detailed design of all site access tracks demonstrating compliance with FENZ "Emergency Vehicle Access" (F5-02-GD, 10 December 2021), applicable for an Aerial Appliance. The access tracks must be gravel and of minimum 4m width and able to withstand a laden weight of up to 25 tonnes, with multiple axles spaced at no less than 2.5m centres and each carrying 8.2 tonnes. c. Size and location of fire water tanks including hard stands capable of accommodating a fire appliance. d. Details of fire water tanks including appropriate couplings in accordance with the New Zealand Fire Service Fire Fighting Water Supplies Code of Practice SNZ PAS 4509:2008; ***Note:*** *New Zealand Fire Service Fire Fighting Water Supplies Code of Practice SNZ PAS 4509:2008 applies only to the type of coupling at each water tank. The purpose is to provide Water Tanker*

Fire Risk Mitigations Proposed by Helios
(not Aerial Appliance) access and manoeuvring and therefore, in accordance with FENZ advice, an Aerial Appliance has been referenced to ensure suitable access and turning radius is provided for Water Tankers. This access condition does not apply to manoeuvring around water tanks and their associated hardstand areas.

3.3 Solar Farm Components

Fire Risk Mitigations proposed by Helios	
1.	Helios will procure and install all key equipment, including photovoltaic (PV) modules and inverters, from globally recognized Tier 1 manufacturers with a proven track record of safety, long-term operational reliability, and compliance with relevant industry standards on comparable utility-scale solar projects. All PV modules installed shall conform to international standards, including IEC 61730 and AS/NZS 5033 or their equivalent. Inverters shall comply with IEC 62109 or an equivalent international standard.
2.	Helios will engage a highly reputable and recognised Engineering, Procurement and Construction (EPC) contractor with a proven track record in large-scale infrastructure delivery to deliver the project.
3.	All panels are to be the bifacial type.
4.	The substation will be designed and operated to meet Transpower's "Substation Fire Mitigation Design Standard" (Transpower Reference TP.DS 61.06).
5.	Construction and operational (not visiting) vehicles, excluding motorbikes and quadbikes, entering the site must be equipped with fire extinguishers, of size and type in accordance with NZS4503 or as recommended by FENZ. ***Note:*** *It is expected that operational vehicles which are able to carry a fire extinguisher will do so, including cars, utes, vans, trucks and tractors which have an enclosed cab. It is not practical, and therefore not required, to carry fire extinguishers on smaller vehicles such as motorbikes, quadbikes or side-by-sides. Where fire extinguishers are carried, these are expected to be hand-held and generally expected to be the dry-powder type (Class ABE) which are versatile in responding to most types of fires.*
6.	Site buildings must be equipped with fire extinguishers, of size and type in accordance with NZS4503. a. Site Administration Building (approx. 70m^2) b. The substation switch-room buildings' (approx. 12m^2) c. Any sheds containing maintenance equipment (sheds to be determined in detailed design)
7.	At least 10 working days prior to the operation of the Solar Farm, the Consent Holder must provide Council with written verification from a suitably qualified and experienced engineer confirming that the installed panels have been designed and installed in accordance with good engineering practice and in accordance with the conditions of this resource consent.

3.4 Vegetation

Fire Risk Mitigations proposed by Helios
1. The landscaping undertaken must be in accordance with the Landscape Design Package (**LDP**) prepared by Boffa Miskell (date & rev.).
2. Retained existing trees must be regularly maintained to remove dead branches and maintain height and width.
3. The LDP and LMP must include: a. Vegetation within the site must include trees and shrubs that are classified by Fire and Emergency New Zealand (**FENZ**) as “very low” or “low” for no less than 70% of plants, as “low-moderate” or “moderate” for up to 20% of plants and as “high” for up 10%. Plants classified with flammability of “Moderate” or greater shall be spaced at their expected mature height. b. Details of a maintenance programme including: i. maintenance of maximum shrub height, with trees being managed so they can grow to their full mature height; ii. maintenance cuttings must be removed from the confines of the Solar Farm site.
4. Once the Solar Farm is operational, the Consent Holder must ensure that all grass on the site is maintained to reduce grass fire risk, ensure that all grass on the site is maintained at a reasonably practicable height during the summer months.

3.5 Boundary System

Fire Risk Mitigations proposed by Helios

1. The system includes perimeter gravel access tracks (generally 4 m wide), with gaps between panels and access tracks and screen plantings where practicable.
2. OMP incorporating maintenance of access tracks and screen plantings.
3. Grass height (see Section 3.4)

4 Fire Contamination Commentary

The following is a simplified commentary regarding potential contamination of air, soil and groundwater, relative to the surrounding rural context. Fires are emergency events that fall well outside normal operations, causing unwanted damage and disruption that require repair and result in downtime. Therefore, like all asset owners, it is in the best interests of the solar farm owner to avoid fires which are unwanted events.

Products of all fires are toxic to some degree. The common products of combustion are water vapour, carbon (soot), carbon monoxide and carbon dioxide. There are numerous other products of combustion that depend on the type of fuel and the fuel-air ratio. Burning plastic produces “dirtier” smoke, with a range of toxins not typically present from a vegetation fire.

In the existing rural context, a range of fires are possible including vehicle (e.g. ute, tractor), building (e.g. house or farm shed) and wildfires involving grass or tree fuels. A tractor or vehicle fire would also have additional, more harmful toxic smoke produced from the presence of polyurethane seating and rubber tyres, which generates large quantities of isocyanates and hydrogen cyanide which are at the higher end of the smoke toxicity spectrum. Building fires involve plastics contained in couches, furnishings, contents, wiring, and parts of cladding in houses are all made of plastics. Building fires also burn with insufficient air for complete combustion; this results in a more toxic smoke than when the same fuels are burnt with plentiful oxygen. Higher levels of soot, more carbon monoxide and hydrogen cyanide will be produced from a house fire than would be expected from a free-burning external vegetation fire.

Within the solar farm, the largest potential fire (greatest heat release rate) would be from the vegetation fire contribution (e.g. grass fire, screen planting, shelter belts). This is because vegetation forms the most abundant and continuous fuel in the closest proximity to any solar farm ignition source. A range of controls on vegetation have been proposed for the solar farm (see Section 3) including grass height management and boundary vegetation selection. Compare this to the surrounding risk context where on adjacent property where similar controls are not required. There is greater potential for larger fire outside the solar farm resulting in more smoke being produced when compared to a fire within the solar farm.

The largest potential fire in solar farm electrical components would involve the largest fuel packages (excluding substation) - the inverters, which are approximately the size of a shipping container. These contain electrical switchgear, an oil filled transformer, other combustibles and plastics such as cable insulation. The fire fuel type (electrical components, plastics and petroleum derived oils/fuel), materials and quantities are similar to that of many tractors, vehicles and small farm buildings which are already present in the existing rural context. So overall, the smoke toxicity from an inverter fire can be considered to be similar to a tractor, vehicle or small farm building fire

PV modules cover the majority of the solar farm. This solar farm will use bi-facial PV modules which have toughened glass on both sides, sandwiching the silicon cells inside, which is bonded together with an encapsulant. The panels have a plastic connector box and cabling underneath, similar in diameter to a household extension cord. Glass is non-combustible as are the metal frames that support them. Bifacial panels have little that can burn compared to mono-facial panels which have a plastic backing.

Products of combustion from the fire can be transported in water away from the fire site. This can be water from firefighting or from rain. This is equally true for fire events outside and within the solar farm. The toxicity of fire products in water follows the same concepts outlined previously for airborne fire products. Water applied in firefighting is for the purpose of extinguishing the fire so that the source of the toxic products is terminated. Remediation after a fire event is covered in the OMP plan (see Section 3).

Similarly, contamination of the soil around a fire is possible (e.g. ash). This applies to fire events outside and within the solar farm. The toxicity of fire products on the soil follows the same concepts outlined previously for airborne fire products. Post fire remediation, including of any contaminated ground concentrated around burnt components, will be part of the OMP (see Section 3).

The toxicity of a solar farm fire is too difficult to predict with any real certainty, given it is totally dependent on what is on fire. It could involve electrical components (e.g. inverters), vegetation or both. However, given the electrical components are dispersed and/or spaced, and the fuel source is predominantly hydrocarbons, toxicity levels from a burning electrical component could be expected to be similar or less to that which would be produced from a vehicle, tractor, house or farm building fire in the surrounding rural context. Furthermore, the solar farm contains fire risk mitigations (e.g. monitoring, on-site firefighting water and access, OMP and ERP plans, etc), which may not be present on the surrounding rural context.

5 Submission 128 Summary

Submission 128 raises several concerns around fire risk in relation to Helios's application. A summary response to the submission is provided below.

While a range of statistics of fires involving PV systems are presented in Submission 128, only those relevant to the proposed project should be considered. That is ground-mounted, grid-scale solar installations with modern equipment and systems that include risk mitigation measures.

Submission 128 expresses concerns about potential contamination from fire.

All fires produce toxic products which can be dispersed through air, by water and over the ground. This is includes tractor, ute, or house fires in the surrounding risk context and potential fires in the solar farm. The proposed solar farm contains mitigations (see Section 3) which facilitate better firefighting intervention reducing effects of fire (e.g. firefighting access and on-site water).

Submission 128 identifies that it is possible for solar farms to present an increased fire risk.

Risk is defined as a combination of probability and consequences. The range of mitigations presented in Section 3 of this report reduce both the probability and consequence components of risk. The probability component is reduced by factors such as compliance with relevant standards, quality of installation and ongoing maintenance and monitoring. The consequence component is reduced through measures intended to limit fire spread beyond the original source and facilitating firefighting intervention, should a fire occur.

Refer to Appendix A for more detailed commentary on this submission.

6 References

- Coonick, C. (2018). *Fire and Solar PV Systems—Investigations and Evidence* (Nos. P100874-1004 Issue 2.5). BRE National Solar Centre.
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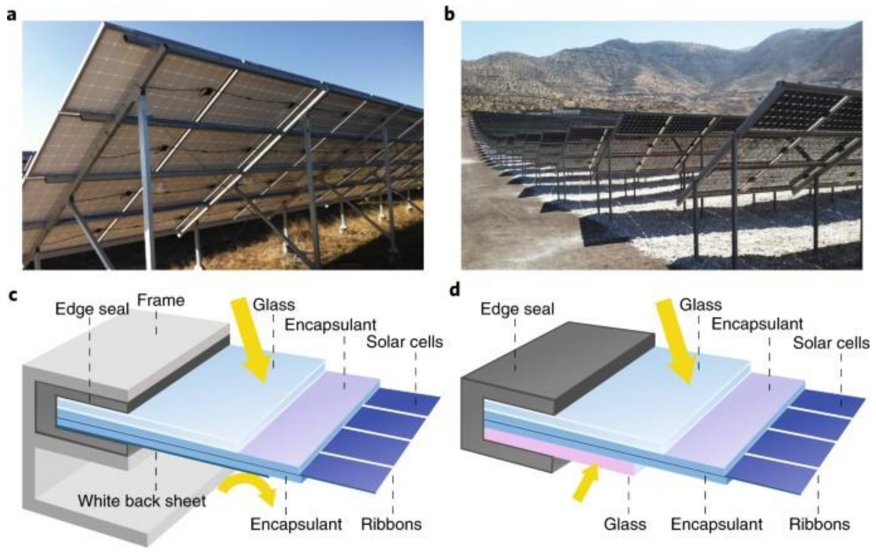
Appendix A – Submission 128 with Commentary

This appendix offers commentary to the points raised in Submission 128.

Submission 128 (dated 19/12/2024)	Beca Commentary
On page 438 Helios make the bold, and completely unsupportable claim that *"There is no increased risk of fire with a solar farm. Solar panels are not flammable. The components are encapsulated in glass and cannot support a fire. All major electrical components such as inverters and transformers will be containerised. Electrical wiring from panels to inverters is undergrounded".* I start with this paragraph simply because it encapsulates, within 47 words, so many gross oversimplifications, misrepresentations of fact and unsupportable assertions that I consider it a very good guide to the value of the application as a whole.	It is understandable how the original statement extracted from the resource consent may be construed as an oversimplification. The additional information discussed in the body of this report intends, in part to address this by clarifying the proposed mitigations and how they relate to the concerns raised.
From the top, there is a demonstrably increased risk of fire associated with a solar farm. This installation involves over one million electrical connections for the panels alone and thousands of kilometres of interconnecting wire suspended over a fuel load that has increased flammability due to the increase in local temperature that the panels themselves create. Simply enormous amounts of energy flow through those conductors. In the event of a failure of any component associated with the panels the energy likely cannot be removed from that system because, ultimately, that energy is the sun - and you cannot turn off the sun.	Solar farms can present elevated fire risks compared to existing rural context where some fire risks are already accepted e.g. vehicle, house or vegetation fire. The mitigation measures (see Section 3; e.g. vegetation controls and firefighting features) mitigate these elevated fire risks. The MPI Project "Putting the Farm in to Solar Farm" found that "soil volumetric water content to 5 cm depth was generally higher in the array compared to the controls" outside the solar array. A higher soil moisture content results in a greater moisture content and reduced flammability of grass.
Solar panels are flammable, they are generally not "encapsulated in glass" (a bi-facial panel might be, but there is no indication from Helios about the type or flammability class of the panels they intend to use, and bi-facial panels are unlikely to be employed). A small percentage of panels are "double glass" but, as with so many elements of this installation, the applicant has provided no information about the panels they intend to use. I can find no data that suggest double glass panels have a lower risk of being the point of inception for a fire than any other type. To a very high degree, the most common encapsulant on solar panels is not glass, but EVA film, an extremely flammable polymer. This paper: https://epublications.marquette.edu/cgi/viewcontent.cgi?article=1086Ccontext=chem_fac , which outlines the researchers attempts to overcome the obvious problems associated with the use of EVA, contains these words "The ease of ignition and subsequent flaming combustion with the release of large volumes of toxic smoke prohibit the application of EVA-based materials in high temperature service environments." Even if the panels proposed for use here were "encapsulated in glass", that encapsulation is extremely unlikely to survive a fire of any significant size - which may be initiated in any one of the, literally, millions of electrical components that make up the installation. There exists an IEC standard (IEC 61730-2) that divides PV panels into one of three categories according to their propensity to spread a fire once they are ignited. Those categories are: Flame spread should not exceed: Class A – 1.82 m, Class B – 2.40 m, C Class C – 3.90 m under defined test conditions. We are not told what category of panels Helios intends to employ.	Helios have clarified use of bifacial panels throughout the solar farm. Monofacial panels use a plastic backing (left in image below) which can contribute significantly to the total combustible fuel and a also presents a combustible surface for flame spread. Without the plastic backing, bifacial panels are a considerably lower fire risk that monofacial panels.  *Illustration of monofacial (left) vs bifacial (right) - (Kopecek & Libal, 2018)* Encapsulants are required for electrical insulation, mechanical support, physical insulation for the cells and protection from moisture and dirt, enhancing the operational stability of the cells and facilitating lamination to the glass substrates. Encapsulants are typically about 7% by mass of the panel (range from 4-11%) (European Commission. Joint Research Centre., 2016; Mulazzani et al., 2022). The majority of the panel mass is glass and the

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	metal frame. The toughened glass of bifacial panels is non-combustible so inherently resists fire, and acts as a physical barrier separating the fuel from the oxygen required for combustion. Helios have clarified that the PV modules will be certified to IEC 61730 and AS/NZS 5033 or equivalent international standards. Helios have clarified the selected PV modules will meet Class C fire requirements of IEC 61730.
In my view, Helios's claim extends beyond the disingenuous into the realms of the deceitful. Solar panels are not some benign, foolproof, rock-like component that perform in a foolproof way due to some inherently safe characteristic. They are one part of a system that envelopes literally millions of potential points of failure, a system which is designed to transmit large quantities of a potentially lethal form of energy. Simply by confining their comments to the solar panels themselves – and not the system as a whole – Helios have sought to sustain the unsustainable, the idea that a system containing millions of discrete electrical connections, spaced evenly across a fuel load that has been dried by the increased ambient temperatures created by the installation itself, that is transmitting huge amounts of energy, at potentially dangerous voltages, somehow adds no risk of fire. The idea is inconceivable. PV panels present many challenges at the design and construction phase, not the least of which is the fact that, unlike almost all other forms of generation, you can not turn off the generator – you cannot switch off the sun. This characteristic alone leads to a plethora of problems for PV installs. Once a fire has initiated within a panel, or within its surroundings, damage to the insulation of the conductors that link the panels together is almost assured. Damaged insulation will often lead to arcing that is likely to persist – because the source of energy, the sun, can not be switched off and it is extremely unlikely that any protection devices will be available to disconnect the failure point from the rest of any given solar string. It's important to understand that Utility scale solar does not run at 12 Volts, nor 24V. With large solar installations there is a massive economic driver to use the highest available voltage in an installation. While each panel may only produce a few tens of Volts, those panels are connected in series to produce hundreds and - sometimes - over a thousand Volts. That increase in Voltage comes with an increase in risk. Insulation levels of every part of every component become critical to the safety of the installation as a whole. Those elevated Voltages also pose a risk to life for anyone engaged in containing a fire once it starts. We are not dealing with ten or fifteen PV panels placed on a roof and producing a few tens of Volts. Here we are dealing with a totally different proposition. With increased scale comes increased risk, with massively increased scale comes massively increased risk. Damaged interconnecting string conductors present two additional challenges to fire prevention and remediation. Water, used during firefighting operations may in fact contribute to the fire through increased, unintended, current flow and subsequent arcing. Damaged conductors will continue to feed into a short circuit until the sun goes down -unless that circuit is protected by an effective means of disconnection - which is extremely unlikely for a single string. Re-ignition of the fire from such an arc is a very real possibility. With DC current there is no zero-crossing point, once an arc is established the arc will likely self-sustain. In AC systems, an event may cause an arc to form, but the voltage of the system drops to zero 100 times a second and if the event that caused the arc to initiate is no longer present then there is a chance for the arc to extinguish.	Ignition scenarios come from the whole PV system not just the degree of flammability of the PV modules (as evidence by the cited research on historical PV system fires). Consequently, the solar farm installation inherently presents a greater likelihood of a fire starting when compared to an open field. However, risk is defined as a combination of probability (the likelihood element) and consequence. The range of mitigations presented in the body of this report intend to reduce both. Probability is mitigated by factors such as compliance with relevant standards, quality of installation or ongoing maintenance and monitoring. Consequence mitigated through measures intended to limit fire spread beyond the original source and facilitating intervention to deal with a fire, should one occur. With regards to the specific comment on firefighting operations, the response to specific incidents is always scenario specific and made by the officer-in-charge after dynamic risk assessments. Firefighting operations do not typically begin on solar farms without a person from the facility who can inform firefighters of and resolve electrical hazards. As already included in the proposed mitigations, an emergency response plan will be developed for the site in consultation with FENZ. This will address firefighter safety and protocols to manage the electrical risk.

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To illustrate just how much effort has gone into attempting to mitigate the risks presented by solar panels themselves, as opposed to the BoS, I list below the standards referenced by IEC 61730-1:2023, a standard which specifies and describes the fundamental construction requirements for photovoltaic (PV) modules. *IEC 60216-1, Electrical insulating materials – Thermal endurance properties – Part 1: Ageing procedures and evaluation of test results* *IEC 60216-2, Electrical insulating materials – Thermal endurance properties – Part 2: Determination of thermal endurance properties of electrical insulating materials – Choice of test criteria* *IEC 60216-5, Electrical insulating materials – Thermal endurance properties – Part 5: Determination of relative temperature index (RTE) of an insulating material* *IEC 60243-1:2013, Electric strength of insulating materials – Test methods – Part 1: Tests at power frequencies* *IEC 60243-2:2013, Electric strength of insulating materials – Test methods – Part 2: Additional requirements for tests using direct voltage* *IEC 60269-6, Low-voltage fuses – Part C: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems* *IEC 60364-7-712, Low voltage electrical installations – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems* *IEC 60417, Graphical symbols for use on equipment, available at https://www.graphical-symbols.info/equipment* *IEC 60529S, Degrees of protection provided by enclosures (IP code)* *IEC 60664-1:2020, Insulation coordination for equipment within low-voltage systems – Part 1:Principles, requirements and tests* *IEC 60695-11-10, Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods* *IEC TS 6 0904-1-2, Photovoltaic devices – Part 1-2: Measurement of current-voltage characteristics of bifacial photovoltaic (PV) devices* *IEC 60950-1:2005, Information technology equipment – Safety – Part 1: General requirements* *IEC 61032:1SS7, Protection of persons and equipment by enclosures – Probes for verification* *IEC 61140, Protection against electric shock – Common aspects for installation and equipment* *IEC 61215 (all parts), Terrestrial photovoltaic (PV) modules – Design qualification and type approval* *IEC 61730-2, Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing* *IEC TS 6183C, Solar photovoltaic energy systems – Terms, definitions and symbols* *IEC 62548, Photovoltaic (PV) arrays – Design requirements* *IEC 62788-1 (all parts), Measurement procedures for materials used in photovoltaic modules –*	Helios have clarified that the PV modules will be certified to IEC 61730 and AS/NZS 5033 or equivalent international standards.

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IEC 61730-1:2023 ED3 *https://standards.iteh.ai/catalog/standards/sist/5eef43fe-Cc78-41aa-ScfS-b8ae88fdf715/iec-61730-1-2023-ed3* *IEC 62788-1-2, Measurement procedures for materials used in photovoltaic modules – Part 1-2: Encapsulants – Measurement of volume resistivity of photovoltaic encapsulants and other polymeric materials* *IEC TS 62788-2, Measurement procedures for materials used in photovoltaic modules – Part 2: Polymeric materials – Frontsheets and backsheets* *IEC 62788-2-1, Measurement procedures for materials used in photovoltaic modules – Part 2-1: Polymeric materials – Frontsheets and backsheets – Safety requirements* *IEC 627S0:2020, Junction boxes for photovoltaic modules – Safety requirements and tests* *IEC 62852, Connectors for DC-application in photovoltaic systems – Safety requirements and tests* *IEC 62S30, Electric cables for photovoltaic systems with a voltage rating of 1,5 kV DC* *IEC TS 63126, Guidelines for qualifying PV modules, components and materials for operation at high temperatures* *IEC TR 63225, Incompatibility of connectors for DC-application in photovoltaic systems* *ISO 1456, Metallic and other inorganic coatings – Electrodeposited coatings of nickel, nickel plus chromium, copper plus nickel and of copper plus nickel plus chromium* *ISO 1461, Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods* *ISO 2081, Metallic and other inorganic coatings – Electroplated coatings of zinc with supplementary treatments on iron or steel* *ISO 2093, Electroplated coatings of tin – Specification and test methods* *ISO 7010, Graphical symbols – Safety colours and safety signs – Registered safety signs, available at https://www.iso.org/obp* *ISO 9224:2012, Corrosion of metals and alloys – Corrosivity of atmospheres – Guiding values for the corrosivity categories* *EN 50618, Electric cables for photovoltaic systems* *UL 746B, Standard for Polymeric Materials – Long Term Property Evaluations* *IEC/IEEE 82079-1, Preparation of information for use (instructions for use) of products – Part 1:Principles and general requirements.* That list should provide some idea of the complexity involved in the construction of PV Panels.	

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Quantifying the degree of risk from fire within PV installations is complicated by the lack of compulsory reporting of such events and by the lack of a suitable database for the collection of such data, nevertheless, some research is available. In the paper "Worldwide scientific landscape on fires in photovoltaic" [1] the authors say *"There is a lack of comprehensive data on fires caused by PV installations, which are usually classified as 'other' incidents. As a reference, a frequency analysis shows 0.283 fires per MW installed, or 28.3 fires per GW installed (Ong et al., 2022)"* They go further and agree with my own analysis of solar based fire risks precisely *"Potential fire hazards in PV systems are a critical concern that requires thorough analysis and mitigation strategies (Juarez-Lopez et al., 2023). Extinguishing a fire in a photovoltaic electrical installation is a challenging task. This is due to the unique characteristic of photovoltaic modules, which continue to produce energy despite the presence of fire. It is important to note that electricity continues to ffow through the installation, even during a fire. For instance, the cables of a photovoltaic installation can carry up to 1500V of direct current. In other words, water alone cannot extinguish a fire as it poses an added danger of electrocution."* [1]	These quotes are taken from a paper documenting an analysis of keywords (which are chosen by paper authors) found in the publications using a search query "Fire" and "Photovoltaic" or "PV". This paper does not study or investigate the findings of the publications, nor was there any filtering of the returned publications for quality etc. The paper by Ong et al is entitled "Fault Tree Analysis of Fires on Rooftops with Photovoltaic Systems". This is based on rooftop PV installations not ground-mounted PV installations. The authors actually report "An annual fire incident frequency of 0.0293 fires per MW is calculated" (not 0.283 as stated in the submission). Refer image below from Ong Report. They conclude "it was found that arcing is the major contributor of fire events, which arise from poor-quality products, planning and installation errors, component damages during transportation, operation errors, lack of regular inspection and maintenance, as well as weathering effects." A commercial solar farm offers far greater opportunity to control these key variables and many of these have been included in the mitigation measures in Section 3. From Ong et al (2023): contributor in 17% of the PV-related fires. Finally, the quantitative analysis established an annual fire incident frequency of 0.0293 fires per MW. The results enable estimation of the number of fire incidents linked to the installed Ong et al also conclude "… an increased focus on mitigating the consequences in case of ignition might be the most effective way to reduce the overall fire-related risk of building applied PV installations." The mitigations in Section 3 contain some measures to reduce the risk of ignition.
In an issue of Solar titled "A Review of Photovoltaic Module Failure and Degradation Mechanisms: Causes and Detection Techniques" [2] The authors state: *"Furthermore, some PV failures, such as cell cracks, propagate rapidly [33,34]; if undetected, they will cause a significant cost loss that may reach up to 10 times the equipment cost [38]. This is because some undetected failures may lead to fire and catastrophic damage to the entire PV system [33]. For instance, critical degradation in some PV modules in an array system leads to mismatch, increasing the PV module's temperature and subsequently leading to fire [40,41]. Critical degradation in PV modules was also highlighted as initiating fire in a research project based in Germany [33]. Fire can also be caused by hotspot failure, primarily driven by other failure mechanisms that elevate the operating temperature to a hazardous level, and eventually cause a fire [42,43]. There have been 80 fire incidents involving PVs in the United Kingdom alone [44].* While many of the listed failures are for rooftop mounted solar, the underlying systems and components, particularly the panels, share many characteristics with utility scale installs. Image 1 (below) is taken from this paper [2] and shows a hot spot created by an internal fault in the panel.	The submission correctly notes PV modules are not impervious to being ignition sources. Helios have since clarified that the panels will be bifacial (enclosed within two glass layers) and will comply with IEC 61730 so have been tested under the suite of circumstances the submission mentioned previously. Furthermore, the measures developed in Section 3 reduce the fire risks resulting from any ignition. Note that only 6 of the 80 PV fires in the BRE study occurred in solar farms, the other 74 occurred in building-mounted PV systems. BRE reports that of the 80 fire events studied zero fatalities occurred in fire caused by the PV systems and that three fatalities occurred in fires not caused by the PV system (see Table 3 of the BRE Report). Furthermore, these fatalities relate to PV installations on roofs of buildings, not ground-mounted installations where there are no occupants. Of the 80 fire events that the BRE studied, there were 9 counts injuries/psychological trauma in fires caused by PV systems. From the BRE Report:

Injuries / fatalities	Fire caused by PV	Fire not caused by PV	Cause unknown	*Total*
Injuries / psychological trauma	9[8]	1[9]	0	*10*
Fatalities	0	3[10]	0	*3*
Total	*9*	*4*	*0*	***13***

Table 3: Numbers of casualties recorded in all incidents

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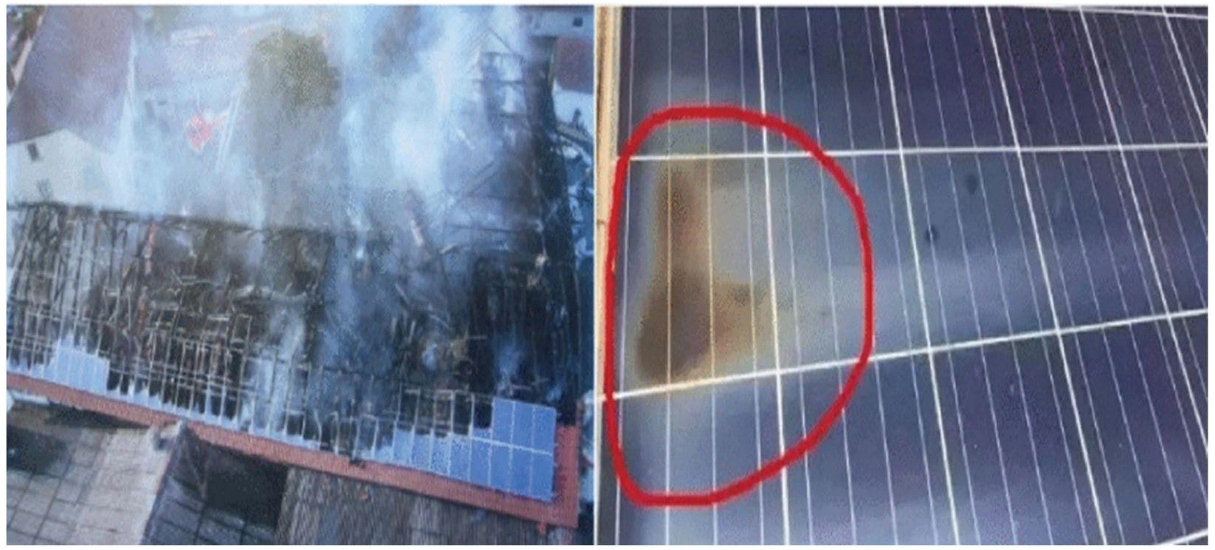 *Image 1 Fire initiated by a hotspot in a PV panel* In the same paper [2], the authors say: *"The fire caused by PV failures not only results in power reduction and cost losses, but it may sadly lead to fatalities; twenty-two casualties related to fire incidents stemming from PV failures were reported in the UK by BRE National Solar Centre."*	
The report quoted above [3] identified 63 components that could be labelled with accuracy as the cause of the PV fires. Of those 65 components, three can fairly be said to be indistinguishable from the same components used at utility scale – DC connector, DC cables and the PV panels themselves. Of those components 12 connector failures, 5 cable failures and five failures of the PV modules themselves are listed.	The BRE study identifies six different types of PV components involved in fires: DC isolators, DC connectors, DC cables, Inverters, PV modules, DC combiner box and an additional unidentified components category. The statistic for the location of the origin of the fire does not reflect the root cause of the fire. For example, in the case of DC isolators (implicated in a third of cases) the common root causes were poorly designed or constructed products, incorrectly specified DC isolators and poor installation practice. A commercial solar farm offers far greater opportunity to control these key variables and Helios have stated they will use whitelisted Tier 1 suppliers and specialist installers. These statistics illustrate that the likelihood of fire is not the same for all components. Furthermore, the majority of these statistics are from building PV installations not utility ground-mounted installations where the risks are substantially different and have been mitigated by the suite of measures listed in Section 3.
TUV, an internationally renowned and respected test and verification authority [4] in their paper Assessing Fire Risks in Photovoltaic Systems and Developing Safety concepts for Risk Minimization say this specifically about the flammability of glass/glass panels: *"In other words, under relatively low stress, e.g. with a smaller electric arc turned off by an arc detector, no independent spread of fire occurred on these specimens. On the other hand, once a full-scale fire develops in a PV module, it can continue burning and thereby spread the fire to other elements. This is also the case with glass-glass modules."*	In this quote the report authors are summarizing a series of experiments that were undertaken. These experiments investigated panel behaviour in a "roof fire" scenario which does not occur for ground-mounted PV modules. The authors also state "Owing to the lack of a backsheet, the glass-glass module (CdTe) exhibits significantly better properties of fire behavior compared with the two other modules." Helios is proposing bifacial glass-glass PV modules. DC arcing is sustained so can pose higher risk than AC arcing. This cannot be entirely prevented but mitigation measures such as those developed in Section 3, including the IEC 61730 or AS/NZS 5033 compliant PV modules

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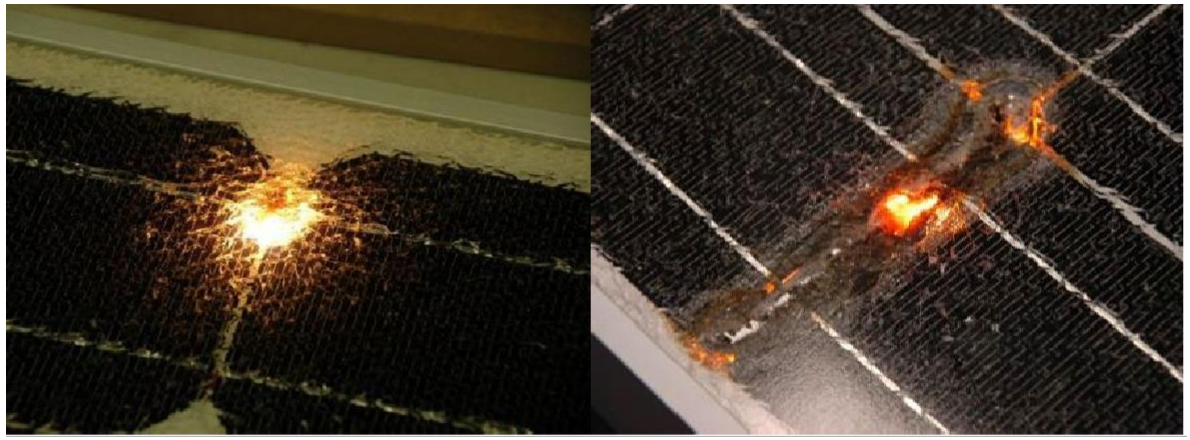
TUV undertook a wide range of tests that quantified the relative risk of failure presented by individual elements of solar panels, the toxic residue left in firefighting water, the level of toxic fumes generated by a solar panel fire, the risk to life through electrical hazards to first responders and any other factors – all things which, according to the applicant, do not exist.  *Image 2 Testing by TUV showing hot spotting within a solar panel caused by an electrical fault* TUV say: *"Past discussions on fire hazards from PV systems have focused on the supposedly more critical DC currents. Owing to the numerous electrical connections, the many components exposed to weather and the self-stabilization of any electric arcs given the current source characteristic of the solar cells, the risk of fire emergence in the PV generator sector is estimated to be significantly higher than in the AC part."* TUV also conducted experiments which looked at the behaviour of arcs formed when a soldered junction within a solar panel failed. Individual modules are soldered to a common bus within each panel. The Naseby proposal involves many millions (best guess tens of millions) of such connections. They found: *"Electric arcs were then ignited that generated temperatures far above the melting temperature (600°C) of (e.g.) thermally pre-stressed glass (Figure 3-42). The front glass and the photoactive silicon layers melted and formed burning droplets The electric arc will continue burning until sufficient voltage for maintaining it is no longer available. This situation can be attained by turning off the voltage or by increasing the distance between the electric arc contacts. If this distance is so large that the available voltage no longer suffices, the electric arc will extinguish itself. This time can be very long, however (several minutes).* *The electric arc burns not only at the direct contacts of the cell, but it can also continue burning between the cells. The electric arc will then move back and forth between the cells. Owing to the large amount of available material, the contacts will burn down only slightly. In the lab experiments the electric arc was always extinguished by turning off the voltage. The electric arc burning the longest was turned off after 16 minutes. During this time the electric arc moved several times from one cell side to the other.*	and the emergency response plan developed in consultation with FENZ which covers how they will respond to a fire on the site, mitigate the elevated fire risks raised by the submitter.

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Until the electric arc was extinguished, it emitted a great deal of heat, greatly damaging the surrounding module materials. The latter also burned, but after a period of time extinguished themselves after the electric arc was turned off. Until then, the flames were intensively blazing from the underside of the module, however. In cases of very long-burning electric arcs the temperatures increase until the glass melts (1,000°C to 1,500°C) and liquid silicon drips down from the module."	
As would be expected given the results from there flammability testing, TUV also carefully measured the toxic gas emission, level of toxic residue and toxic components in water used to extinguish the fires. The data varies substantially by panel type and is best read in full however their conclusion is fairly simple to understand: *"Depending on the technology, the fire residue from PV modules can contain concentrations of lead or cadmium that can create critical levels of contamination in the soil. Professional disposal of fire residue and, if necessary, soil replacement are therefore urgently recommended."* Water use to quench the fires contained significant levels of lead, but not above regulatory levels, however the measured cadmium concentration in the quench water indicates possibly critical soil contamination from CdTe modules The burning panels generated large amounts of smoke, which produce obvious problems, but were relatively free of contaminants.	A fire involving PV components, like any fire involving plastics and electrical components (e.g. tractor, ute, house, etc) will release toxic combustion products and particulates in the plume as well as residues which may be transported in firefighting water. The proposed measures in Section 3 include firefighting features (access, water etc) which allow firefighters to extinguish the fire quickly and so terminate the production of particulates and products of combustion. These measures also contain a requirement for the OMP to document remediation after a fire event.
According to a report by FireTrace International: [4] *"Statistics from the Australian PV Institute show that PV installations in the country increased from around 7.3GW in January 2018 to more than 20.7GW in December 2020.C However, while the increase in PV installations in Australia during the period was less than three-fold, data from Fire and Rescue New South Wales (NSW) showed that there was a six-fold increase in the number of solar fires attended by firefighters in the period 2018 to 2020, according to reports in 2020, Fire and Rescue (NSW) attended 133 solar fires, compared to 22 in 2018."* That report also lists some interesting statistics from the TÜV: *With regard to the data that is actually available, the US Department of Energy's Solar Energy Technologies Office has cited a study conducted by European testing and certification company TÜV Rheinland – entitled 'Assessing Fire Risks in Photovoltaic Systems and Developing Safety Concepts for Risk Minimization' – which found that, in approximately half of 430 cases of fire or heat damage in PV systems, the PV system itself was considered the "cause or probable cause.*	The FireTrace document summarises findings from other research including the BRE and TUV research reports already referenced, rather than presenting new research. The statistic on increase in solar fires comes from an article entitled "'The irony's not lost on me': Solar panel safety device led to 500 per cent rise in rooftop fires", indicating that these statistics relate more to rooftop PV installations which have less control and more firefighting challenges compared to the ground-mounted PV modules proposed. The TUV report found 430 historical accounts of fire in PV solar systems. However, fire was attributable to the PV system in only 210 cases. In the remaining 220 cases, the cause of fire was external to the PV system. In 28% of these cases only the component was damaged and in 34% the PV system was damaged but the building was not classified as damaged. The authors report that 24% of incidents occurred on open-space (ground-mounted) PV systems "based on 139 incidents of damage". The mitigations developed in Section 3 contain measures such as vegetation control and access tracks, which mitigate against the fire risks identified by the submitter and allow for easier firefighting intervention than on building rooftops.
Solar installers, especially at utility scale often hype the capability of arc detection systems. Such systems seek to identify a developing (or developed) arc in an electrical system and to shut that system down before significant damage can be done. Similar systems are used in electricity distribution to identify and eliminate the risk from fallen power lines. The working principle is that an arc has a specific "signature" that it imposes on the system as a detectable waveform. There are significant problems with this approach however, as highlighted by the TÜV:	There is no single, entirely reliable method of arc detection. However, the authors of the report go on to summarise that "electric arc detectors can add to safety in especially hazardous situations". Monitoring of arcs, output metadata, temperature and of other sensors across solar farm components are key to identifying situations that may eventually lead to ignition and fires. This monitoring allows the O&M contractor to intervene earlier.

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(an electric arc detector is)"moreover useful only if it can be assumed to reliably detect electric arcs. Electric arcs in modules produce different noise patterns than those in serial terminals. Different cable lengths greatly differ in their dampening of electric arc signatures. Interference from inverters, switching transients, or coupled radio signals can mask or overlay the noise coming from the electric arc. *Only very robust detection algorithms tested on different systems can ensure real added utility here."*	Helios have stated an arc flash study will be conducted during the detailed design phase to assess the associated risks within both AC and DC system components. The design will incorporate appropriate control measures to manage the identified arc flash hazards.
A web article from CoverNote [5], a New Zealand Insurance Industry online magazine also quoted from the FireTrace paper: *"However, in many emerging industries, risks are often harder to measure, leading to exposures and losses. One such industry is solar energy, which has been growing rapidly in recent years due to the shift to renewable energy.* *A recent report by Firetrace International found that the solar industry is potentially underestimating the risk of fire at solar farms, partly due to a shortage of data on solar farm fires. The report also said that research into the issue has given rise to suspicions that fires at solar farms have been under-reported.* *"To be clear, fire risk is present across all utility scale, high voltage, renewable energy from wind to solar to battery storage systems," Ross Paznokas, global business development manager, clean energy at Firetrace International, told Corporate Risk and Insurance. "Fire risks cannot be totally engineered out.* *"With the expected exponential growth of renewable energy as well as aging infrastructure, the number of fire occurrences will only increase. One thing that operators tend to overlook is addressing these fire risks with fire mitigation strategies. Often, owners will simply rely on their insurance provider to cover a loss, if that does occur, rather than implementing the likes of fire suppression technology."* *According to Paznokas, solar asset owners and major OEMs are reluctant to discuss or publicly acknowledge a loss attributable to fire. This means that there is a lack of data and definitive case studies to draw insights from.* *With regard to data that is actually available, Paznokas said that the US Department of Energy's Solar Energy Technologies Office cited a study conducted by European testing and certification company TÜV Rheinland, titled Assessing Fire Risks in Photovoltaic Systems and Developing Safety Concepts for Risk Minimization. The study found that in approximately half of 430 cases of fire or heat damage in photovoltaic (PV) systems, the PV system itself was considered the "cause or probable cause."*	This CoverNote article also summarises previously published research including the already cited TUV research which has already been covered.

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 *Image 3: 150MVA 33/220KV transformer* Helios claims that "*All major electrical components such as inverters and transformers will be containerised".* The reality is shown in *image 2*. Helios plan to install two 150MVA 33/220KV transformers as part of their build, according to Helios, those transformers hold 107,600L of transformer oil, a little over half the capacity I would have guessed. I say "according to Helios" because the company gives no clue in their application as to the manufacturer or transformer type in use - and I suspect that the quoted volume is simply a number pulled out of the air by the applicant and their consultants. One thing that I can almost guarantee however is that they will not be specified as filled with FR3 class (reduced flammability) oil. These transformers are likely to weigh 230 tonnes each. These components, the largest single components on site, will not and cannot be containerised. Nor will the outdoor bus of the substation, with its many exposed conductors and connections, be containerised. Containerisation is, in any case, no guarantee of protection from the risk of fire in the event of an electrical failure. A good example of this concept is a BESS unit – which is containerised but fitted with pressure relief / blast vents and /or active ventilation systems to reduce the risk of explosion, vents which allow the release of flammable (and often burning) gasses into the surrounding environment. Indeed, the 150MVA transformers themselves will each be fitted with an overpressure release device which is designed to vent gasses in the same way.	The specific equipment in the substation, such as these large transformers, will be determined during the detailed design of the substation. Substation design must comply with a number of standards, including the Transpower DS 61.06 Substation Fire Mitigation Design Standard. This design standard covers fire emergency response, outdoor equipment (separation, passive protection, suppression systems for outdoor transformers, cables and wiring), buildings, cabling, mechanical services, lighting and earthing, and good housekeeping practices. Refer to the separate section of this report which addresses the substation.

Submission 128 (dated 19/12/2024)	Beca Commentary
Containerisation may contain the fire for some defined amount of time, or it might seek to limit the spread of fire to one element of plant, but only when specifically designed for that purpose - and the effectiveness of that design is never guaranteed. Invertors are containerised primarily as an aid to transport and installation. They are also usually fitted with forced ventilation, certainly the case here since their cooling systems are listed by the applicant as a potential source of noise pollution. I have not yet seen an inverter that purports to have a container with a fire rating – although they may exist. To say that a given piece of equipment is containerised is meaningless without data on both the equipment and the container. We are given no such data; the comment therefore is meaningless as well as demonstrably untrue.	

B

Appendix B – Transpower's Substation Fire Mitigation Design Standard

Appendix B ‑ Summary of Substation Fire Mitigation Design Standard

Helios have confirmed that the substation design will meet Transpower NZ's "Substation Fire Mitigation Design Standard" (Transpower reference TP.DS 61.06). Beca contacted Transpower and obtained a copy of the current TP.DS 61.06 standard (dated October 2023).

The various fire risks and mitigations which the Transpower standard addresses is summarised below:

- *This design standard has been developed by Transpower and represents international practice and customisation for the New Zealand power system and environment.*
- *It is not practical to eliminate the possibility of a fire completely, so measures to mitigate the potential consequences of a fire are important to managing fire risk.*
- *Transpower's approach to substation fire mitigation is to incorporate a mix of passive fire protection, fire detection, active fire protection, good housekeeping, and documentation of requirements, as appropriate into all substations.*
- *Transpower's approach to substation fire mitigation is essentially around the following:*

  a. Providing resilience to ensure the safe and reliable transmission of electricity

  b. Keeping workers safe when they are on site

  c. Minimising the risk of consequential damage to the surrounding environment.

- *The purpose of this standard is to outline design requirements and guidance to achieve consistent and appropriate fire mitigation practices at Transpower substations.*
- *Some of the key Safety by Design considerations for substation fire mitigation related to our critical risks are:*

  a. Conscious consideration of the possible effects of any fire during the initial design stages when the site layout is being determined or altered.

  b. Procurement of assets with low combustibility and low toxic smoke.

  c. Ensuring that plant items which can provide a fuel or energy source are either avoided or are suitably located/separated. An example of this is the placement of assets with the highest fire risks downwind of the site's prevailing winds to minimise damage caused by the transfer of fire plumes, high temperatures, smoke and soot.

  d. Ensuring that designs include appropriate emergency egress, access routes and assembly points.

  e. Fire stopping of penetrations (cables, metal pipes, plastic ducts etc.) that pass through firecell boundaries (where firecells are deemed to be required).

  f. Fire stopping of cables leading into buildings or passing nearby oil bunding around transformers, to mitigate fire spreading from the switchyard to buildings (and vice versa) via cable insulation. Fire stopping of power cables from transformers can be achieved by direct burying or sand filling of a length of the cable trough. This needs to be balanced with any reduction in cable rating incurred due to the enclosure of the cables.

  g. Ensuring accessibility to inspect and maintain equipment without creating undue risk to personnel (e.g. avoiding locating fire suppression system cylinders down in cable basements which can require careful manoeuvring over/around power cables and under cable trays etc.).

  h. Ensuring that any cable ducts into the bund are fire resistant and terminated no lower than the top of the bund wall.

  i. Ensuring that LV cable fire stops in cable troughs are reinstated after any cable maintenance, addition, or removal, throughout the life of the facility.

j. Ensuring there are no possible burning oil paths from bunds that could spread fire (e.g. through leaks of inadequately rated or poor condition bund walls or non- bunded/sealed ducts/pipes leading directly into buildings).

k. Where diesel generators are permanently installed at a site, they must be located where a fire in the generator or its fuel storage facility, will not affect other primary/secondary plant or buildings.

l. Placement of assets inside buildings such that emergency egress is not blocked or impeded.

m. Placement of outdoor assets to facilitate fire-fighting efforts and not block access for appliances (FENZ vehicles).

n. Avoidance of installing batteries, LVAC switchboards or any other electrical equipment inside cable basements.

o. Specification of Low Smoke Zero Halogen (LSZH) cables to significantly reduce the amount of toxic and corrosive gas emitted during combustion compared to PVC insulation.

p. Consideration in the design of the fire temperatures, heat release rates, fire durations, and smoke damage that could be expected in the event of a fire occurring.

q. Allowance in the design for separation between cable types (e.g. power and low voltage cables) and separation of cable containment systems (e.g. avoidance of stacking multiple cable trays in close proximity).

The Transpower standard addresses FENZ emergency response criteria and practices, including:

- FENZ response times
- the local brigade capability (eg: mix FENZ equipment and volunteers Vs professional)
- tactics and logistics to be considered and documented in a site Emergency Response Plan (ERP) and practiced with FENZ during site familiarisation activities
- site access, trafficable and manoeuvring accessway design (widths, weights and turning radius etc)
- hardstanding area size and manoeuvring areas
- hose run distances
- water supply provisions

The Transpower standard addresses outdoor equipment design criteria, with other fire risk mitigation factors including:

- transformer minimum safe separation distances to other substation equipment, to buildings and to property boundaries, determined from the electrical equipment size and oil capacity
- transformer bunding requirements with fire stopping drainage to oil interception facilities

The Transpower standard provides an *"…overview of Transpower's approach to managing fire risks for its substation buildings. It is the intention that the user will supplement this general philosophy with the requirements specific to their particular application…The general philosophy is as follows:*

- *Risks associated with origin fire scenarios (i.e. fires started within the building) are primarily managed by having:*
    - *A SCADA-connected fire alarm system inclusive of a fire panel, manual call points, detectors and alerting devices.*
    - *An active suppression system that is connected to, and triggered automatically by, the fire panel. Dry Sprinkler Powder Aerosol (DSPA) systems are the Transpower standard for active suppression.*
    - *Portable fire extinguishers at appropriate locations.*
      Appropriate exit routes, emergency lighting and exit signage for personnel to escape."