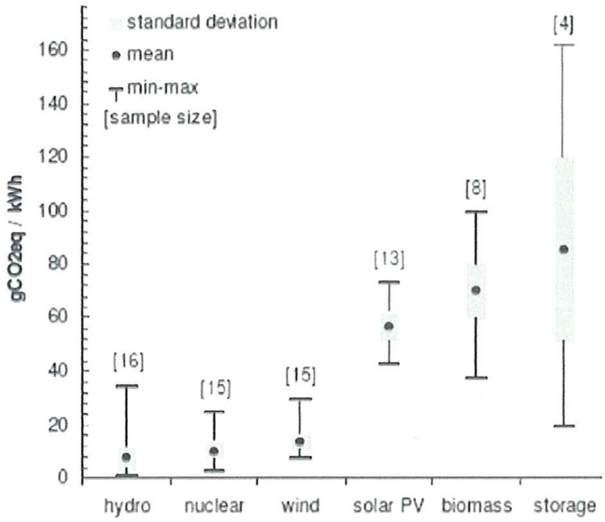
Hazards

Any good RMA application should come with an accurate oversight of on-site and off-site hazards. Furthermore, these hazards should be assessed during the life cycle of the project (i.e., from manufacture of solar panels, batteries, inverters, and transformers, through their operational use, and finally onto their disposal) with an outline of a) effects on water, soil and air, b) deleterious effects on flora, fauna, and human health, and c) hazard classifications for the activity that reflect real risks. Although an AEE (Assessment of Environmental Effects) report has been prepared, remarkably this contains no quantifiable measure of hazards. There are no HSNO classifications outlined in the RMA application, and no HSNO signage to protect the public, emergency workers, and the environment. Every farm at Brookside is obligated to provide HSNO signage, but because PV technology is purportedly "clean & green" the applicant has not bothered.

Perhaps we should begin by stating that GHG emissions during the life cycle of photovoltaic solar panels are considerably higher than for hydro-electric or wind generation (Fig. 1; Gibon *et al.* 2022); the entire land area used to produce a megawatt of PV electricity (2.6ha) is more than twice that of hydro-electric (Fig. 2; UNECE 2022; Aman *et al.* 2015), the 'levelized cost' of power generation is 3x the cost of hydroelectricity (Fig. 3; Aman 2015), and cancer rates are very high with PV power (Fig 4).



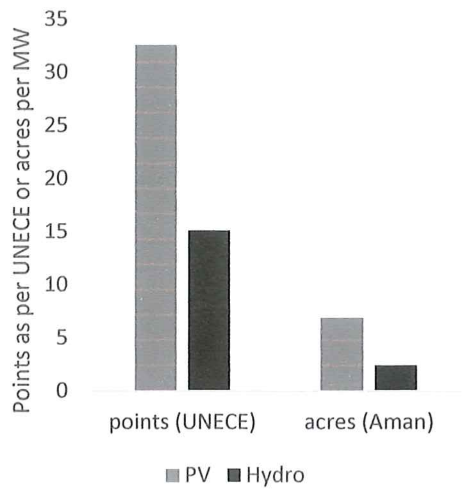
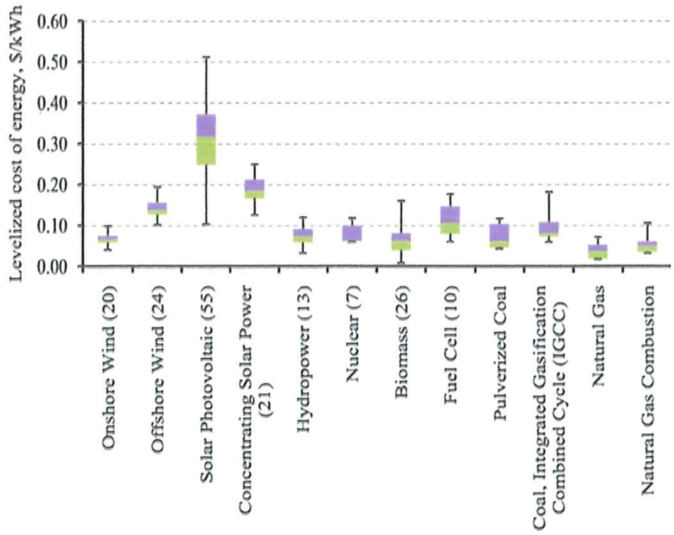


Fig. 1. Relative GHG emissions from power sources. Fig. 2. Land area for PV solar and hydroelectric



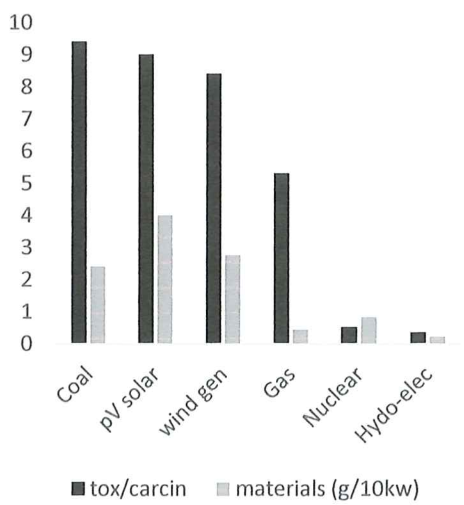
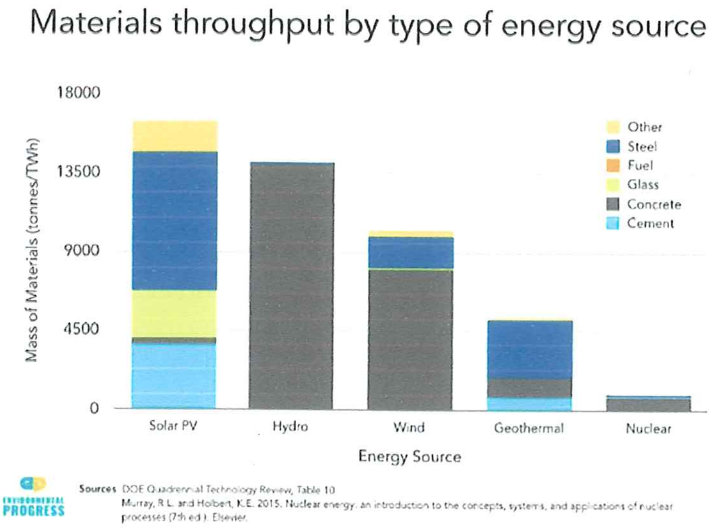


Figure 3. Relative costs per Kw of power. Figure 4. Cancer rates with power type & materials used

The high percentage of heavy metals, the use of per- and poly-fluoroalkyl substances (PFAS), as well as other hazardous materials in solar technologies relative to the kilowatts of power produced results in higher risks of target organ toxicity and carcinogenicity during the life cycle of photovoltaic panels than for all other methods of power generation. The risk from coal arises mainly from the airborne particulates produced when coal is combusted to produce steam.



Research shows solar cells are at best only ever likely to be around 50% efficient at turning the sun's energy into electrical energy. The efficiency of commercial solar panels is shown in Figure 6.

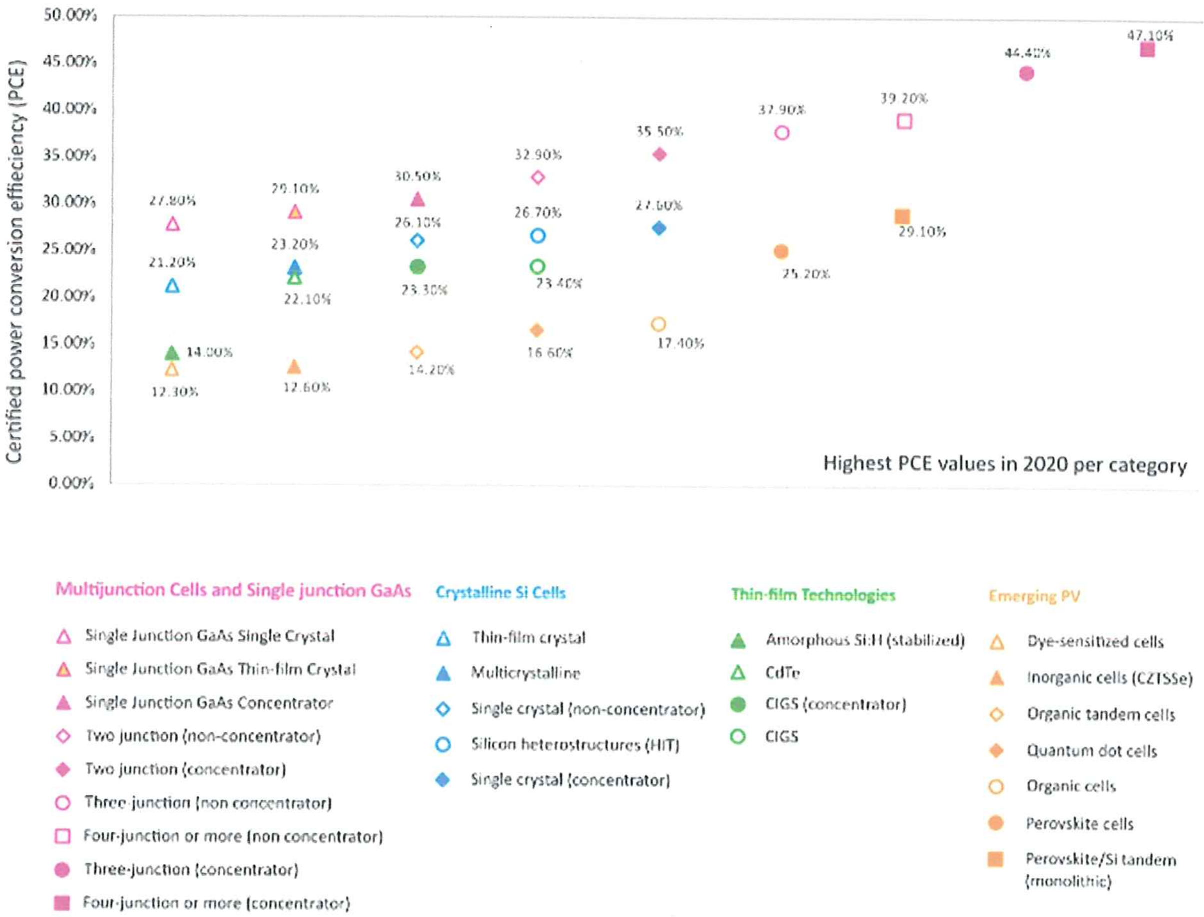


Figure 6. Best efficiency for a variety of new panels for photovoltaic energy (Buitrago *et al.* 2020).

Some materials included in different solar panels during manufacture are shown in Table 2.

CIS	CIGS	CZTS	GaAs	CdTe	Cu_2S	a-Si
Cadmium	Cadmium	Cadmium	Arsenic	Cadmium chloride	Ammonium chloride	Acetone
Copper	Copper	Copper	Arsine	Cadmium	Ammonium fluoroborate	Aluminum
Hydride gas	Gallium	Hydrogen selenide	Gallium	Molybdenum	Cadmium sulfide	Chloro-silanes
Hydrogen sulfide	Indium	Hydrogen sulfide	Hydrochloric acid	Nickel	Chromate coating	Diborane
Hydrogen selenide	Molybdenum	Molybdenum	Methane	Sulfur	Copper	Hydrochloric acid
Indium	Selenium	Selenium	Phosphine	Tellurium	Cuprous chloride	Hydrofluoric acid
Molybdenum	Zinc	Thiourea	Trichloroethylene	Thiourea	Gold	Hydrogen
Selenium		Tin	Triethyl gallium	Tin	Hydrochloric acid	Isopropanol
Zinc		Zinc	Trimethyl gallium		Hydrogen sulfide	Nitrogen
					Methanol	Phosphine
					Nickel	Phosphoric acid
					Nitrogen	Silane
					Polyvinyl butyral	Silicon tetrafluoride
					Silicon monoxide	Silicon
					Sodium chloride	Sodium hydroxide
					Tantalum pentoxide	Tin
					Zinc	
					Zinc fluoroborate	

Table 2.
Chemicals and materials involved in the manufacturing process of different thin film PV technology [

Some of the hazards of materials used to make solar panels are shown in Table 3.

Material	Source	DOT hazard classification	Critical effects
Arsenic	GaAs	Poison	Cancer, lung
Arsine	GaAs (CVD)	Highly toxic gas	Blood, kidney
Cadmium	CdTe, CdS, $CdCl_2$	Poison	Cancer, kidney, bone
Diborane	a-Si dopant	Flammable gas	Pulmonary
Diethyl silane	a-Si deposition	Flammable liquid	
Diethyl zinc		Pyrophoric liquid	
Dimethyl zinc		Spontaneously combustible	
Hydrochloric acid	a-Si, GaAs, Cu_2S/CdS	Corrosive material	
Hydrofluoric acid	a-Si	Corrosive material	
Hydrogen	a-Si	Flammable gas	Fire hazard
Hydrogen selenide	CIS	Highly toxic gas	Irritant
Hydrogen sulfide	CIS, Cu_2S/CdS	Flammable gas	Irritant, Fire hazard
Indium	CIS, CIGS	Not regulated	Pulmonary, bone
Methane	GaAs	Flammable gas	Fire hazard
Molybdenum hexafluoride		Toxic and corrosive gas	
Oxygen	x-Si	Gaseous oxidizer	
Phosphine	a-Si dopant	Highly toxic and pyrophoric gas	Irritant, fire hazard
Phosphorus oxychloride	x-Si	Corrosive material	Irritant, kidney
Selenium	CIS, CZTS	Poison	Irritant
Silane	a-Si deposition	Pyrophoric gas	Irritant, fire, explosion hazard
Silicon tetrafluoride	a-Si deposition	Toxic and corrosive gas	
Tellurium	CdTe	Not regulated	Cyanosis, liver
Tertiarybutyl arsine		Pyrophoric and highly toxic liquid	
Tertiarybutyl phosphine		Pyrophoric liquid	
Trimethyl aluminum		Pyrophoric liquid	
Trimethyl gallium	GaAs	Pyrophoric liquid	
Tungsten hexafluoride		Toxic and corrosive gas	

Table 3.

Hazard classification of chemicals typically used in PV module manufacturing [31, 32].

Many of the materials used in manufacture of photovoltaic solar panels are both toxic and carcinogenic (Table 2), and/or very hazardous to human health (Table 3). All heavy metals used in solar technologies are persistent in the environment and do not readily degrade by natural processes to harmless end-products. Furthermore, most of the materials used in photovoltaic technologies are 'forever chemicals', and many of these persist in the food web and finish as residues in animals (with impacts on animal welfare) or in apex predators like humans (with impacts on their health). The potential for utility-scale photovoltaic facilities to affect the health and well-being of people is significant (Table 3).

The extensive list of hazardous materials shown is exacerbated when the hazards caused by fire are added. The particulate matter in smoke (heavy metal halides such as PbI_2, metal oxides, silica dust, hydrofluoric acid and phosphoric acid (from combustion of per- and poly-fluoroalkyl substances (PFAS) in circuit boards (Yin et al. , electrical wiring or materials in batteries), arsenic trioxide, hydrogen cyanide and carbon monoxide make firefighting very dangerous. In the event of an on-site fire locals downwind must be evacuated and firefighters must wear pressurized breathing apparatus.

We can see from figures 4 & 5 and Tables 2 & 3 that solar generation of electricity is unequivocally the most hazardous form of power generation for human health and the environment, but it has somehow got labelled as "clean-and-green". It is a misnomer that we hope empirical data presented throughout this dissertation and the 'food-web' dossier will dispel.

Hazards exist on-site in the form of:

a) Heavy metals in solar panels. These are leached from panels either damaged by hail, wind, lightening or during normal weathering processes as panels delaminate.
b) Per- and poly-fluoroalkyl substances (PFAS) and titanium dioxide that form part of ASC (Anti Soil Coatings), ARC (Anti Reflective Coatings), washing agents to clean panels, circuit boards, or coatings on electrical wire. These substances are especially toxic in the aquatic system, are carcinogenic (cause breast cancer, testicular cancer, kidney cancer), affect target organs (thyroid, heart with increased cholesterol, lungs if dust is inhaled, and they bioaccumulate in the liver causing liver disease); they are a reproductive inhibitor (lowered fertility, increased miscarriage, lowered birthweights, lowered head circumference of baby at birth, cause obesity in offspring, cause pregnancy induced hypertension/pre-eclampsia, and result in inflammatory bowel disease). Leachates of PFAS onto soils accumulate and are taken up by domestic livestock and/or crops subsequently grown on the site (see Fenton *et al*. 2021 for details of risks, and the 'food-web' dossier for exposures). The widespread presence of PFAs in the food chain has been reported in Africa (SSebugere *et al*. 2020), Europe (EEC 2021) and America (Penland *et al*. 2020).
c) Particulates in smoke from an on-site fire are highly toxic if inhaled by firefighters and the public.
d) Leachates fall onto soils as panels deteriorate through weather events (viz. hail, lightening, wind damage, heavy rain etc) where they accumulate and then enter the food web through the grazing of livestock or harvesting of grain / vegetables (especially root vegetables, herbs, and brassicas), and within honey and fruits (see 'food-web' dossier for empirical data).
e) Uncontained high voltage electricity will exist on site in the event of a flood or fire.

Hazards exist off-site in the form of:

a) Residues of heavy metals and PFAS are removed off site by livestock that have grazed at the USSP-facility.

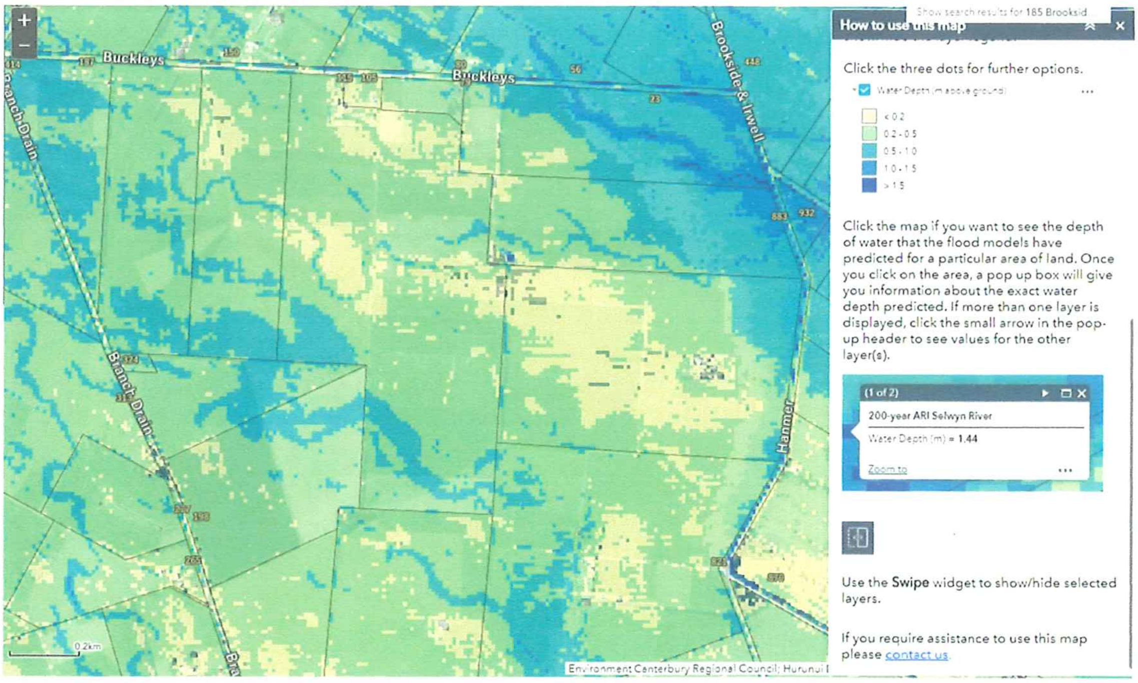
b) Produce (fruits, vegetables, honey, and hay) that has been harvested from the USSP facility and is then on-sold to the public.
c) Airborne particulates that have been carried off-site by the wind (e.g., in a fire, or in dust).
d) Hazardous materials ingested by insects and birds and then carried offsite (e.g., residues in nectar carried to a hive, birds eat fruits such as blackberry & briar containing high levels of metal halides and PFAS).
e) Toxic substances ingested by small vertebrates (rats, mice, stoats, rabbits, hares, hedgehogs, mustelids, cats) will be subsequently carried away onto surrounding properties.
f) Soluble forms of heavy metals and PFAS that are washed off-site during heavy rain and enter surrounding properties or drains and creeks containing surface water and are then washed down into Lake Ellesmere.

The applicant has supplied **<u>no details</u>** of the panels, batteries, transformers, and inverters that will be used at Brookside. Therefore, some of the materials listed above will not apply.

Because the applicant has not supplied critical information, the parties to a 'limited notification' can only provide a generalized overview of critical hazards.

Flood plain.

According to the Council District Plan, the proposed development of solar arrays is located on a flood plain. Fortunately, in recent years the Selwyn has burst its banks at places where water has gone down the Irwell River and then onto land alongside the Brookside-Irwell Road (this has happened 6 times in the past 35 years since 1987 so is not uncommon). However, if water comes over the stop-banks further upstream, then Stage 1 of the proposed development near the substation is under 0.6–1.5m of water (Fig. 6). In 1992 the land used in stage 1 of the project was seen to be flooded by 2-3 foot of water following heavy rain and has ponded there in recent storms. Given the increased rain events New Zealand is experiencing it is almost inevitable that Stage 1 of the development will be repeatedly flooded. The risk of electrical arcing into floodwaters is quite high. Inevitably there will be multiple flood events at the proposed site during a 35-year period.



Water and electricity are not a good mix, particularly at inverters, transformers, around battery storage, and outlets from solar panels. There are likely to be electrical shorts and live wires, with panels continuing to generate lethal amounts of electricity into a flooded area (viz. solar panels cannot simply be turned off like other power sources). Should solar arrays even be located on a flood plain?

Fire

Any form of high-power electrical equipment, including a solar power plant, presents a risk for starting a fire. The cables and connectors going into a solar panel are a common place for fires to start. Fires at a solar farm can also start within the DC combiner boxes or inverters, which manage and convert the electricity to alternating current. Furthermore, within 5-years of the commencement of project development, the RMA-application indicates batteries will also be installed on-site. Batteries have a history of catching fire. Batteries for energy storage are typically cooled by fans, but when there are failures in the system or there are electrical shorts, they too are likely to ignite. Batteries burn very hot (>1000^{0}C) and are notoriously difficult to extinguish.

The soils at Brookside are a clay loam. With irrigation the soils are very productive. However, without irrigation spring growth rapidly transcends into rank dry matter as plants go to seed. Sheep routinely eat succulent short-sward grasses but will not touch dry rank weeds, grasses and pasture that has gone to seed. The same happens in autumn following autumnal rains. This will inevitably create a plethora of dry matter that is source of fuel for a fire at the facility.

The risks from fire at the proposed USSP site at Brookside are much greater than on surrounding farmland. Surface coatings on solar panels, coatings on wires, solar panels, and batteries in a fire all burn at "normal" combustion temperatures. Solar panels and other electrical equipment release toxic lead particulates, assorted metal halides, hydrofluoric acid, phosphoric acid, hydrogen fluoride, carbon monoxide, hydrogen cyanide, arsenic trioxide, silica dust, and polyfluoroalkyl particulates in smoke. These substances are all highly toxic if inhaled. Firefighters must wear pressurized breathing apparatus to combat the health risks that smoke presents. Residents downwind of the fire must be evacuated because of the risks to their health. These fire hazards alone should negate the establishment of solar arrays at Brookside.

When a lithium-ion battery goes on fire the consequences are dire. The solvents used in the electrolyte in LI cells are normally hydrocarbon based; ethylene carbonate (C3H4O3) and diethyl carbonate (C5H10O3) are commonly used solvents. In a fire, depending on the available oxygen, they will typically evolve into carbon monoxide (CO), carbon dioxide (CO2) and water (H2O). However, there are far more potent constituent parts in an LI cell. The lithium salt commonly used in the electrolyte is lithium hexafluorophosphate (LiPF6), the binder commonly used for the electrodes is polyvinylidene fluoride or PVdF (C2H2F2). Both of these compounds contain fluorine. As the electrolyte breaks down, phosphorous pentafluoride (PF5) is released, this combines with water released during combustion of the solvents, to evolve phosphoryl fluoride (POF3) and hydrogen fluoride (HF), both of which hydrolyse rapidly with water to form phosphoric acid and hydrofluoric acid respectively (Larsson, Andersson, Blomqvist & Mellander, 2017). Phosphoric acid and hydrofluoric acid in smoke represent extremely hazardous substances when inhaled. In some countries USSP storage batteries are not permitted within several kilometres of a town.

Banks of solar panels damaged by fire continue to produce sufficient electricity for it to be lethal to emergency workers. The panels only stop generating electricity when solar panels are either covered by tarpaulins or a black foam (this is being developed in the UK and America to cope with emergencies at USSP-facilities). The uncontrollable production of lethal amounts of electricity produces a significant risk to emergency workers on site.

Following fire damage, the laminate that prevents leakage from panels is gone. This sort of scenario has been simulated with leakage of

Leachates

Dozens of studies have now been completed on leachates from solar panels and their impacts on soils, vegetation, and aquatic environments. Because we do not know the specifics of the solar panels that are to be used, a generalized overview of recent research on leakage of toxic substances onto soils is provided.

Although perovskite solar cells (PSCs) are efficient (26-29% efficiency) and may at some time in the future better encapsulate hazardous materials (e.g., Vidal *et al.* 2021), there is currently extensive leakage of many substances from them onto soils. Currently, the most deployed solar panels are crystalline silicon pVs (either mono-, multi-Si or ∂-Si) that represent around 95% of market share. In many instances it is difficult to detect differences in rates of leakage of toxic materials from these silicon solar panels onto pasture. Some studies use acid rain as opposed to pH-neutral water, other studies wash panels with either high temperature water >60C, water at 20C, or low temp water (0C), some studies focus on damaged panels (from hail, lightening, wind) and some studies simulate torrential rain as exposed to light rain. What is presented is thought to represent typical leakage with 'normal' weathering of commonly used solar panels.

All heavy metals used in the different types of solar panels (Pb, Ag, Pt, Ge, Te, In, As, Si, Sn, Se, Mo, Mg, Cd, Zn, Zr, Ga, Au, Al, Fe, Cu, Ti, etc) and PFAS are leached onto soils. The coatings on solar panels (ASC or ARC coatings) also degrade at a steady rate to accumulate on soils. They are "forever chemicals" that either persist in soils or persist in the food chain. The only way they are removed from site is if they are taken up by plants (e.g., Tangahu *et al.* 2011 showed all are absorbed by roots albeit at different rates) which are then eaten by livestock. Once ingested some leachates bioaccumulate in animal livers, kidneys, brains, or contaminate meat and milk; they are harvested by bees in the form of the pollen and nectar or are washed into drains and surface waters (where they are extremely hazardous to aquatic life). At Brookside with clay-loam soils only a portion of leachates are likely to be leached into shallow groundwaters (c. 2m BGL) with many of the others washed into stream water. In some studies, the heavy metals and PFAS in soils have exceeded environment standards set by the EPA. Su et al. (2020) for example found leachates of Pb^{2+} at USSP facilities that exceeded the hazardous waste limit of 5mg/L in soils; and he also measured high levels of soluble Pb^{2+} salts that were leached into surface waters. Other forms of Pb^{2+} are insoluble and remain in soils unless taken up by plant roots. Panthi *et al.* (2021) found leachates of lead from panels as high as 6.6 mg/Kg in soils. There are a multitude of studies on lead leaching from damaged solar panels or electrical solders (a worst-case scenario), leaching during acid rains (2nd worst scenario), leaching at high temperatures (e.g., in a desert environment), leaching within the freeze-thaw process (<0C), and leaching in torrential rains. All solar panels leach lead, aluminium, and other metal cations onto soils over their lifetime as a result of weather events, and damage to solar panels (see Lu *et al.* 2022 for a summary). Leachates progressively accumulate in soils at USSP-facilities over time. The effects of Pb^{2+} on soils are profound, so this has been the focus of research.

The combustion of solar panels releases lead as either PbO/PbO_2 or PbI_2 into the air at around 0.3 μg/m^3. A solar panel on a house roof can release around 20g of lead into the air in a fire, so a USSP-facility fire that affects all panels will release hundreds of kilograms of lead in smoke. The destruction of panels by fire of course frees up further lead and other metal halides in damaged electrical circuitry for release into soils. In addition to lead there are other toxic heavy metals (listed above) and their metabolites in fire that are highly toxic, particulates of PFAS in smoke that are highly toxic, and the derivatives from oxidation and/or hydrolysis (e.g., hydrofluoric acid; Yin *et al.* 2018 and phosphoric acid) that are also extremely toxic. As outlined in the original submission, inhaled air containing >30ppm HF or HF in the form of hydrofluoric acid is fatal. Inhalation of other materials (HCN, AsO_3, $H3PO_4$, etc) may also be fatal, or for survivors that are sub-lethally poisoned they cause multiple foci of target organ toxicity within the body (especially the lungs). These materials from a fire (e.g., hydrofluoric acid) in aquatic ecosystems are lethal to all aquatic organisms. The amounts of toxic metal halides, metal oxides, fluoride derivatives, hydrofluoric acid, and other assorted toxicants produced in a fire are very hazardous to the endangered mudfish (*Neochadda apoda*) that reside in surface waters along Buckleys Road and Caldwells Road. These contaminants would wash all the way down into Lake Ellesmere and further damage the ecosystem that exists there.

The effects of leachates on soils are profound. All metal iodides (e.g., CuI, PbI_2, AgI, Zn) have antimicrobial effects (Awed *et al.* 2021), with AgI so effective at controlling micro-organisms it is used as a sterilant in industry. Some soil organisms are very susceptible to PbI_2 with *Vibrio fischeri, Pseudomonas putida* and earthworms all impacted by lead leachates (Wang *et al.* 2020). Silver (AgI) at high concentrations is a soil sterilant (i.e., kills everything). Soils subjected to 10 years of leachates from USSP-facilities had changed pH, were compacted, aggregated, had poor water dissipation during rainfall, and had a poor carbon-nitrogen balance (Choi *et al.* 2020).

Some plants (e.g., *Arabidopsis thaliana*) will not grow in soils within a USSP-facility that contains iodide ions (Hunter *et al.* 2022), while the growth of other plants (e.g., clover) is suppressed, and rates of nitrogen fixation are impeded (50% lower in one study). In contrast, some hardy grasses are unaffected by metal halides. In general, excessive accumulation of metal halides (including lead) in plant tissue is toxic to most plants, it leads to decreasing rates of seed germination as concentrations of Pb^{2+} leachates increase, root elongation happens, there is decreased plant biomass, inhibition of chlorophyll biosynthesis, changed mineral nutrition and enzymatic reactions (e.g., less nitrogen fixation), as well as several other physiological effects that are all impacted by Pb (*see* Pourrut *et al.* 2011 for detailed analysis). The susceptibility and uptake of metal halides by plants varies considerably. Mint grown in non-contaminated soils outside contained 9.3-15.2, 2.8-3.9, and 7.5-8.4 mg/kg of Pb in roots, stems and leaves; whereas mint grown in soils contaminated by $MAPbI_3$ and PbI_2 at long-established USSP-facilities contained 3401-4896 mg/kg in roots, 179-240 mg/kg in stems, and 385-427 mg/kg in leaves; concentrations well above (i.e., 40x) the accepted levels for agriculture of 10mg/kg in dried herbs (WHO). Research showed uptakes of Pb by blackberries grown in contaminated soils were 29x the accepted WHO limits, so consumers that ate 100g of berries a week were at risk of lead poisoning and expected nephrotoxicity associated with elevated Pb in the diet. So, what are the implications when a USSP-facility is established on ryegrass/clover pasture? Surprisingly, this has not been evaluated, but high levels of zinc, copper and nickel applied as sewage sludge to ryegrass/clover pastures reduced nitrogen fixation by clovers, the metal halides reduced both clover and ryegrass growth, and there were significantly elevated levels of heavy metals in foliage (Sanders *et al.* 1986).

Aquatic organisms

Finally, there are risks to aquatic organisms. The many metal halides, and especially Pb^{2+}, Ag^{+}, Cr, Cd, Cu, Al as common USSP leachates are toxic to organisms that live in surface waters (all the above are classified as 9.1A substances). Silica from glass in solar panels embeds itself in the gills of fish and has an EC_{50} of 12-93 mg/L in water (Book *et al.* 2019, Book & Bachhaus 2021) depending on particle size (the small particulates as leached from panels are the most hazardous). Many of the PFAS and derivatives of PFAS from combustion are also toxic to fish, many of the iodides are toxic to fish, and finally many substances with hydrogenated fluorides (from burning PFAS) are toxic to aquatic organisms. If we focus on lead, then the leachates from solar panels were 0.28-4.37 mg/L at solar facilities, and the EC_{50} for fish embryos containing these leachates was 26% at 7 days, and the EC_{50} for water fleas was >50% (so both trigger a HSNO classification of 9.1A). Kwak et al. found that PbI2-treated zebrafish and Japanese medaka exhibited multiple adverse effects (e.g., growth reduction, tail malformation, spine deformity, haemostasis, and oedema deformation in organs) with increasing PbI2 exposure concentration from 1 to 20 mg /L. Bae et al. compared the toxicity of perovskite MAPbI3 to four species, where the order of their ecotoxicity *was D. magna>D. rerio>C. elegans>C. riparius.* Based on *C. elegans* in 72 h reproduction, the mean EC50 values were 0.59, 5.05, 2.65, and 4.30 mg/L for Pb2þ, PbI2, PbO, and PSC, respectively. Liu et al. reported that *S. obliquus* growth was remarkably inhibited when the initial MAPbI3 leachate level (CPL) was above 40 mg/L; and when the CPL was over 5 mg/L, and the survival of *D. magna* was notably threatened. The 72 h EC_{50} of *Scenedesmus obliquus* (phytoplankton) was calculated as 37.21 mg/L, and the 24 h LC_{50} of $Ch_3NH_3PbI_3$ from solar panels to *D. magna (*water flea*)* adults and neonates were calculated as 37.53 and 18.55 mg/L respectively (Liu *et al.* 2021). All this research suggests that leached Pb at USSP-facilities induces high toxicity to aquatic organisms even at low concentrations. The aquatic toxicity of other substances like hydrofluoric acid, phosphoric acid, hydrogen cyanide, hydrogen fluoride, other metal halides, etc from fire and combustion products at solar farms are all listed with a 9.1A hazard classifications (i.e., they are all highly toxic to fish).

In addition, environmental impacts of solar farms on natural flora and fauna are substantial (refer dossier on 'food-web", Hernandez *et al.* 2014).

ARC and ASC coatings

These materials are added to solar panels to primarily improve energy uptake from sunlight. They prevent sunlight either dissipating or being reflected back from where it came. Once again, we have no idea what will be in use by the applicant because that is not detailed in the application. Most ARC (anti-reflective coatings) and ASC (anti-soil coatings) are made from a composite of SiO_2. MgF_2, TiO_2, Si_3N_4, ZrO_2, and PFAS (Sarkin *et al.* 2020). These materials are frequently leached onto soils and enter the food chain where all substances are toxic to fish.

PFAS

As a group per- and poly-fluoroalkyl substances (PFAS) are used extensively in electrical components, wire insulation, circuit boards, and films. They are "forever chemicals" that bio-accumulate in ecosystems affecting many animals, birds, and fish. Extensive studies have been done in Africa (Ssebugere *et al.* 2020), Europe (EEC 2022), and America (Penland *et al.* 2020) that demonstrate PFAS have entered every corner of the food web and are a serious health risk to humans and wildlife. PFAS are responsible for a range of health effects including poor AGPAR scores, smaller head circumference, shorter body frame, and smaller chest circumference at birth, cancer, liver damage, decreased fertility, immune deficiencies, elevated cholesterol, heart disease, and increased risk of asthma and thyroid disease (see EEC 2022). These substances are also known to compromise the efficacy of vaccines administered against either viruses or bacterial infections.

Silicon compounds

The glass for solar panels is made from high-grade silicon. The most common leachates from solar panels during leaching trials are Si, Pb, Al, As (arsenic), and Ni (Panthi *et al.* 2020); with fine silica dust always recorded as a significant leachate. Breathing in very small ("respirable") crystalline silica particles that are carried in wind, causes multiple diseases, including silicosis, an incurable lung disease that leads to disability and death. Respirable crystalline silica also causes lung cancer, chronic obstructive pulmonary disease (COPD), and kidney disease. Silica leached from glass is toxic to fish when washed into drains and creeks because they accumulate in gills. EC_{50} values are dependent on particle size, but range between 12 and 93 mg/L (Book *et al.* 2019). The silica washed off site into surface water has a hazard rating of either 9.1B or 9.1C depending on particle size.

Unbelievably, with all these toxic substances in soils that are taken up by plants, proponents of solar farms advocate grazing livestock, or the planting of high nectar-producing species for bees at USSP facilities (BRE 2014). Little thought has been given to contamination of meat, animal by-products (especially livers, kidneys, and brains where residues bioaccumulate), the effects on milk, honey, fruits, and vegetables. When 81.4% of New Zealand's exports are agricultural produce or fibre that can potentially be contaminated by heavy metals and polyfluoroalkyl substances at solar farms, then **MPI should be evaluating risks <u>before</u> the use of solar energy becomes widespread.** I cannot find a comprehensive study that has assessed the risks of toxic residues in the food-chain at long-established USSP facilities (i.e., where leachates are high), but as an example of the risks from Pb^{2+} we can cite the example of heifers exposed to lead intoxication in Australia. Around 2000 12–15 month old heifers were placed in a paddock with a dump containing burned electrical waste and lead-acid batteries; blood testing showed 70% of the heifers (n=1408) had not been exposed, had no lead in the blood, and so were drafted off, but of the remainder exposed to lead (n=685) 6.6% died of lead poisoning (i.e., 45/685) 18-491 days after exposure; 117 of survivors had lead levels above the maximum permitted blood level of 0.24 μmol/l and 85 had very high lead levels >0.7 μmol/l. Of the animals with high levels of Pb^{2+} in the brain, 18 months later when they were slaughtered residues in brain tissue were 0.7 mg/kg (viz. well above permissible levels), 0.24 mg/kg in liver (around MAL's), and 0.01 mg/kg in muscle (Scrivens *et al.* 2023). For these animals there were huge issues with animal welfare, and in my opinion, they should have all been euthanized immediately. In short, lead at USSP-facilities is a contaminant of animal feeds (grasses and clovers), a possible contaminant of nectar in flowers, is likely to create residues in food for export, and may eventually pose a serious public health risk. We can see from the Scrivens study that heavy metals like Pb^{2+} persist in animals for >18 months, so repeated grazing causes them to bioaccumulate in tissues.

So why do people talk glibly about running stock under solar farms? Studies have been done on lambs grazing under solar arrays shortly after USSP-facilities were established (i.e., negligible accumulation of leachates). One of these studies 0-1 year after establishment of solar arrays demonstrated herbage production was down 38%, but lambs grew at the same rates as lambs on open pasture (Andrew *et al.* 2021). Remarkably there was no histology of key tissues (liver, brain, kidneys) at the time of slaughter, and no toxicology done on tissues. In another study (not reported by advocates of solar farms), they were having difficulties in re-establishing pasture 10 years after the solar farm was established (which is not surprising because Pb^{2+} impedes germination), biomass production was low, there were issues with dust on solar panels, soils were compacted, problems existed with soil flocculation, and water dissipation was poor because soil particulates were aggregated as clods (Choi *et al.* 2020). Clearly a longitudinal study is required with replicated measures of soil quality, soil organisms, grass growth, leachates in herbage, and leachates in the liver, kidney, and brain tissue of animals that are kept on-site at the USSP facility.

To me, all this is analogous with a problem of brodifacoum (and other 2nd generation anticoagulants) in the food chain that I worked on for 6-years with Dr. Charles Eason, until eventually brodifacoum was banned on the DoC estate. Toxic materials that persist in the food-chain kill non-target species by primary poisoning, secondary poisoning, and tertiary poisoning; they affect animal health and animal welfare in sub-lethally poisoned animals through target organ toxicity; they reduce fertility and the viability of offspring, they reduce food availability in the food web; and they impede the cognitive abilities of those animals affected. For brodifacoum the rhetoric used by the pest control industry was "hey, this stuff is great for exterminating possums and rats"; however, over the course of time it was established accidental poisoning was killing short-tailed bats, long-tailed bats, NZ falcon, harrier hawks, black-backed gulls, red-billed gulls, kea, kaka, weka, etc, etc, and it was found at toxic levels in the livers of wild pigs; thus, it impacted the food web at all levels (including pig hunters that ate the livers of wild game). For USSP-facilities we repeatedly hear "it's clean and green and produces cost-effective electricity"; however, it has already been established that leachates degrade soils and soil organisms, affect vegetative growth on contaminated soils, are readily taken up by many plants and subsequently ingested by livestock, are taken into flowers where residues are harvested by bees; the ecotoxicology of USSP leachates on aquatic ecosystems is dire with most fish affected; leachates have target organ toxicity on terrestrial vertebrates creating issues with animal welfare; and residues from this electronics industry eventually appear at the top of the food-chain within humans (e.g., Saha *et al.* 2021, Parvez *et al.* 2021). We have demonstrated above that e-waste, e-contaminants, and e-leachates at a proposed Brookside USSP facility will contaminate soils, water, and air. Comprehensive papers by Saha *et al.* (2021) and Parvez *et al.* (2021) demonstrate how e-waste affects human health. The ramifications of USSP-facilities are just emerging and will eventually cast a huge shadow over the technology; so, will their use eventually be restricted just as the use of brodifacoum has been restricted? In the meantime good soils like those at Brookside are being contaminated, soil organisms and soil structures are being destroyed, aquatic organisms like those in the surface waters along Buckley's Road and Caldwells Road will be impacted by run-off of leachates, bees and invertebrates are impacted by residues and electromagnetic fields, livestock will inevitably harbour increasing amounts of residues, toxic levels of metal halides will be harvested from some plants and fruits at long-established USSP-facilities, and the locals at Brookside may bioaccumulate residues of metal halides and PFAS from the meat and vegetables they eat. Someone must undertake a long-term study monitoring the long-term consequences of sub-chronic doses of leachates in the food web at USSP facilities, the histology and toxicology of vertebrates and invertebrates eating food from USSP sites, and the fate of residues entering the food web. <u>This is critical for New Zealand's economy.</u>

Airborne particulates in a fire

Of course, it all gets horrendously worse in the event of a fire. In a fire Pb in solar panels is released as particulates in smoke at concentrations of around 0.3 $\mu g/m^3$ so instead of small sub-chronic exposures to e-waste, then suddenly inhaled smoke represents a sub-acute or acute dose of toxic substances. Some solar panels release combustibles (e.g., hydrogen) in a fire which fuels the blaze, while other materials in coatings get burned to highly toxic substances like hydrofluoric acid (Yin *et al.* 2018). The list of toxic substances and health effects because of sublethal poisoning by airborne e-waste are multi-factorial; hydrofluoric acid in smoke causes severe burning in the lungs with pneumonia, hydrofluoric acid is lethal at concentrations >30ppm; inhaled PbO and PbI_2 cause serious neurological effects, kidney damage and anaemia; inhaled polyfluoroalkyl particulates have multiple effects on health as outlined above; arsenic in fires is released as a white cloud of highly toxic arsenic trioxide; PFAS oxidize into dangerous chemicals or are inhaled as fine particulates within smoke; and so the list goes on and on.

Studies measuring combustion products from 2 types of solar panels (Liao *et al.* 2020, and Aram *et al* 2021) measured the usual CO in smoke as well as a range of other toxic substances that included sulphur dioxide, hydrogen fluoride, hydrogen cyanide, arsenic trioxide, and a plethora of volatile organic compounds.

A survey in Italy showed 1600 fire incidents at USSP-facilities up until 2014 (Cancelliere 2014). This would suggest they don't just happen once in a blue moon. Fires at a USSP-facility are very, very dangerous to the local community. This risk alone should preclude the siting of a USSP-facility at Brookside. Further reviews of

We sought advice from FENZ regarding fire plans at the proposed Brookside USSP facility, and up until 20th January 2023 they had not been consulted (see Appendix 1)

Decommissioning and Recycling issues.

Overview

The project has a 35-year lifespan, yet the average lifespan of solar panels is only around 20 years. Furthermore, throughout the lifespan of solar panels the electricity output diminishes year-on-year (viz. around 1-1.5% *per annum*). By 20 years disposal of panels is imminent. Solar panels contain PFAS (per- and poly-fluoroalkyl substances) which are toxic if inhaled or ingested, they contain toxic heavy metals (all have target organ toxicity above listed LOAEL's (lowest observed adverse effect levels) for hazardous waste), silica dust, and other leachates that contaminate soils and drinking water. Solar panels are not readily recyclable, and because of the hazardous substances within, they cannot be disposed of in landfills. Where unlawful disposal has taken place PFAs, and toxic contaminants have been found in water and the food web. The landfilling of a small 5-megawatt solar plant for example, resulted in air, soil, and surface water pb^{2+} concentrations of 0.2 $\mu g/m^3$, 100mg/kg and 15 $\mu g/mL$ respectively. Solar energy requires massive battery storage. Batteries also cannot be recycled or placed in landfills. PFA substances constitute a large group of man-made chemicals used for manufacturing industrial and consumer products, particularly in the electronics industry, that produce leachates found in drinking water. A review of hazards (Dubey *et al.* 2012) suggests problematical waste disposal and resulting target organ effects would classify them 6.8b and carcinogenicity would rank them 2b. PFAs can accumulate in both the environment and human body over time. Solar panels are identified by the Europe and America as repositories of materials that should not be dumped in landfills. The EPA has cited landfills as a repository of polyfluoroalkyl substances — a group of man-made chemicals that never decompose and cause cancer.

Is there cogent and established plan for getting rid of the solar panels, batteries, and/or dealing with any potential leaching of hazardous materials into the ground and watersheds within the RMA application? These are not small issues. Who pays for this? It will be both expensive, time-consuming and create both environmental and human health risks.

Evidence from cross-sectional, case-control, and longitudinal studies show that co-occurrence of PFAS, metal halides, and other e-waste as toxicants in body fluids and the organs of humans act synergistically with other substances to cause several serious health disorders (Garg *et al.* 2020). Based on holistic analyses, PFAS from solar panels significantly contribute to e-waste pollution, which needs immediate attention from policymakers.

Adverse effects of potential pollutants present in e-waste.

Toxicants	Existence in e-waste	Health effects	References
Halogenated compounds			
PCBs	Condenser, Transformer, adhesive in plastics, old fluorescent lighting fixtures.	Cancer, immune system disorder, endocrine system damage	Loganathan and Masunaga (2015), Omondi et al. (2015), Xu et al. (2015a,b), Kaifie et al. (2020) and Gaum et al. (2021)
TBBA,PBB,PBDE	Fire retardants for plastics, insulation in cables	Impaired memory functions and learning in foetus, endocrine system disorder	Xu et al. (2015a,b), Jarema et al. (2015), Wang et al. (2020b) and Arvaniti and Kalantzi (2021).
PVC	Cable Insulation	Cancer, birth defects, diabetes, learning and developmental delays, endometriosis and immune system abnormalities	Liebers et al. (2006) and Boyle et al. (2020).
Heavy metals and other metals			
Antimony (Sb)	Fire retardants, plastics	Inflammation of lungs, chronic bronchitis and chronic emphysema	Cooper and Harrison (2009), Boreiko and Rossman (2020) and Jiang et al. (2021).
Arsenic (As)	Semiconductors, LED, IC, Solar cells	Damages digestive system, skin problem, lung cancer	Kapp (2016) and Sharma et al. (2020)
Barium (Ba)	Getters in spark plugs, CRT, fluorescent lamps	brain swelling, muscle weakness	Oskarsson (2015) and Peana et al. (2021)
Beryllium (Be)	Circuit boards, mother boards, connecters	Carcinogenic, causes lung cancer	Edmunds (2011) and Adanu et al. (2020)
Chromium (Cr)	Anticorrosion coating, data tapes, Floppy discs, dyes, pigments	Irritation to eyes, skins and mucous membrane, causes bronchitis, kidney and liver damage	Shanker and Venkateswarlu (2011) and Kuntawee et al. (2020)
Cadmium (Cd)	Batteries, solders, CRTs, infrared detectors, Chips, Toner ink, photocopy machines, mobile phones	Fever, headache, sweating and muscular pain, long exposure may lead to lung cancer, kidney damage, lower cognitive skill in children.	Zheng et al. (2008), Li et al. (2008), Zhang et al. (2014) and Ebrahimi et al. (2020)
Copper(Cu)	Television, DVDs, cables and wires	Hampers the liver function, nausea, diarrhoea, chest pain	Danzeisen et al. (2007), Taylor et al. (2020)
Lead (Pb)	Batteries, CRTs, cables and wires	Asthma and decline in immune response, lower cognitive skill in children, learning capabilities	Li et al. (2008), Zheng et al. (2008) and Sharma et al. (2020)
Lithium (Li)	Mobile, photographic equipments, video equipments, batteries	It can pass in infant through mother milk and makes adverse effects on health	Hendricks et al. (2015)
Mercury (Hg)	Sensors, monitors, PCBs, Cathodes, Fluorescent lamps, LCDs, batteries in clock and pocket computers	Bioaccumulation causes brain and liver damage, respiratory and skin disorders	Kim et al. (2016)
Nickel (Ni)	Rechargeable Ni-Cd batteries, electron gun in CRTs	Allergy to skin, lung infection, behavioral disorders, and cancer	Kuntawee et al. (2020)
Selenium (Se)	Photoelectric Cells, photocopier machines	Selenosis, the major sign includes hair loss, nail brittleness	Hefnawy and Tortora-Perez (2010)
Silver (Ag)	Capacitors, switches, batteries	Stomach discomfort, kidney damage, brain damage	Gaillet and Rouanet (2015) and Nayek et al. (2021)

Table 4. **Adverse effects from the most persistent electronic substances disposed of at landfills and when leached into the environment (from Saha *et al.* 2021).**

Summary

Although hydro-electric generation is the most cost-effective and safest form of power generation, this unfortunately got privatised. Privatisation and the sale of publicly owned electric utilities for $4.8 billion has resulted in the hydro-electric amenity declining from 75% of electricity production to 57% of power within the national grid. This devaluation of the hydro-electric asset has happened because private investors have pocketed $8.7 billion in dividend payments from their investment during the period 2014-2022 without reinvesting one cent of that money back into further electricity generation.

Overpriced electricity means avaricious investors are now flooding the market with utility-scale solar power (USSP) that provide an expected return on investment of 10-20% *per annum*. The investors carry no responsibility for the liabilities they impose on the land (this report), leachates in vegetation (this report, see 'food-web' dossier), the welfare of animals that graze under solar panels (this report), impacts on aquatic ecosystems (this report), the health and welfare of people (all reports including this report), and the effects on the nation's economy (see cost-benefits report); those things can only be appropriately managed by the board or individual assessing the RMA application. The prospective hazards at Brookside outlined in this summary are not only totally unacceptable to the local community, but outside the bounds of personal health and safety, environmental safety, and the minimization of impacts on ecosystems as described in the RMA 1991. There is a real risk of contamination of food both for domestic consumption and export.

In this report we have demonstrated that hazard classifications are likely to be:

- Impacts on soils would rate hazards as 9.2B
- Impacts on soil organisms would rate hazards as 9.2B
- Impacts of uptake of leachates into vegetation would rate toxic hazards as 6.1D
- The potential impacts from secondary poisoning of livestock rate hazards as 9.3D
- The impacts on adjacent aquatic ecosystems would rate hazards as 9.1B
- The risks of fire at the facility list it as a class 4.1.2 hazard (i.e., it requires a fire plan)
- The impacts of inhalation of combustion products at a fire may impose hazards that rate smoke toxicity as 6.1D, carcinogenicity as 6.7B, eye irritation 6.4A, skin irritation 6.3B, and risk to target organs as 6.9B
- Lithium-ion batteries are currently a class 9 dangerous goods that in a fire produce toxic substances with a likely hazard rating of 8.2A, 6.7B and 6.9A (actual ratings depend on apparatus and the leachates they produce).
- There is a high risk of discharges of lethal amounts of on-site electricity into flood waters or fire damage to racks of solar panels that will similarly discharge electricity.

SIGNAGE MUST APPROPRIATELY REPRESENT HAZARDS

It should be reiterated once again, the applicant has not indicated what equipment will be used on site (which is atypical for a RMA application), so we cannot specifically provide hazards for their equipment. The simulated hazards from research papers and reports do not portend that USSP-facilities will ever provide a completely safe form of electricity generation; particularly when arrays of solar panels are placed on fertile soils, and in the heart of a rural community.

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Appendix 1.

Hello Mark,

Thanks for sending this through – this is a rather large development.. I have checked both our engineering files and SMS and we have nothing on this development.

From a fire engineering perspective as it's not a building its not our focus however the operation aspects are acknowledged. I have also spoken with our wildfire team who echoed the comments over how important the land management is to manage the overall fire risk of the site. I would also be requesting information on the emergency procedures as to how to isolate portions of the site in the event of a fire within or threatening the site.

I have also copied in Mike Gaskin for any Fire Risk Management advice he can offer.

Kind regards

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From: Mark Lowry <markjlowry@gmail.com>
Sent: Tuesday, 17 January 2023 12:14 pm
To: Richards, Paul <Paul.Richards@fireandemergency.nz>
Subject: Fwd: solar

Hi Paul

Thanks for your time on the phone yesterday, very much appreciated

Thought i'd send you the link to the consent request for the Solar Farm in question

Some of it may interest you

The site address for this proposal is 150 Buckleys Rd and 821 Hanmer Drain Rd, RD2 Leeston

Refer RC225180 – KeaX Limited documents (23 in total)

Selwyn District Council - Limited Notified Resource Consents

Happy to receive a phone call from you or an email if you have any correspondence you're happy to share re the Solar Farm

Kind regards

Mark Lowry

027 3734590