

Are Agrivoltaics HAIL?

Dr Andrew Pearson
Technical Director - Chemical Risk
Tonkin + Taylor

Agrivoltatics

- Co-located agriculture with solar energy production (solar photovoltaics)
- Stated to have benefits over standalone land use for either (Pandey et al., 2025), including:
 - water use efficiency
 - increased land use productivity
 - reduced land use conflict
 - increase social acceptability
- Identified as a pathway to fully renewable energy for NZ
- In drier NZ climates agrivoltaics could generate substantial financial benefits with minimal trade-offs to dry stock production (MPI, 2025)



Kohirā Solar Farm – Northland: Reproduced from <https://lodestoneenergy.co.nz/kaitaia/>



Operation vs manufacture/EOL



Image reproduced from IEA, 2022

Manufacture- HAIL status

- Likely captured as B1-B3 depending on the components being assembled
- PV manufacture can use hazardous chemicals (e.g. cadmium, phosphine, antimony, boron)
- Li battery may use VOCs, cobalt and nickel



Use – HAIL status

- Purist view -B4, however this is specifically focused on contaminating activities relating to fossil fuels and geothermal
- Currently B4 excludes hydro and wind due to absence of combustion and storage/use of chemicals, how does solar fit?



Image reproduced from US EPA, 2025

End of Life- HAIL status

- Likely captured as G3, 5 or 6
- Recognised that once panel integrity fails metals may leach out
- US EPA required TCLP testing and designates exceedances as hazardous waste
- Basel convention – E-waste
- Large amount of research on recycling/ safe disposal

Anatomy of a PV array

- Bifacial-monocrystalline silicon (c-Si):
 - Single silicon crystal layer laminated to glass sheets with ethylene vinyl acetate encapsulant
 - The encapsulant contains silver contact fingers and busbars in a contact grid
 - Cell made from c-Si wafers doped with boron or gallium (P-type cell) or phosphorus (N-type cell)
- Each module framed with extruded aluminium alloy and mounted on an array and piles of galvanised steel
- Cadmium telluride (CdTe) and copper indium gallium diselenide (CIGS) systems not currently in use

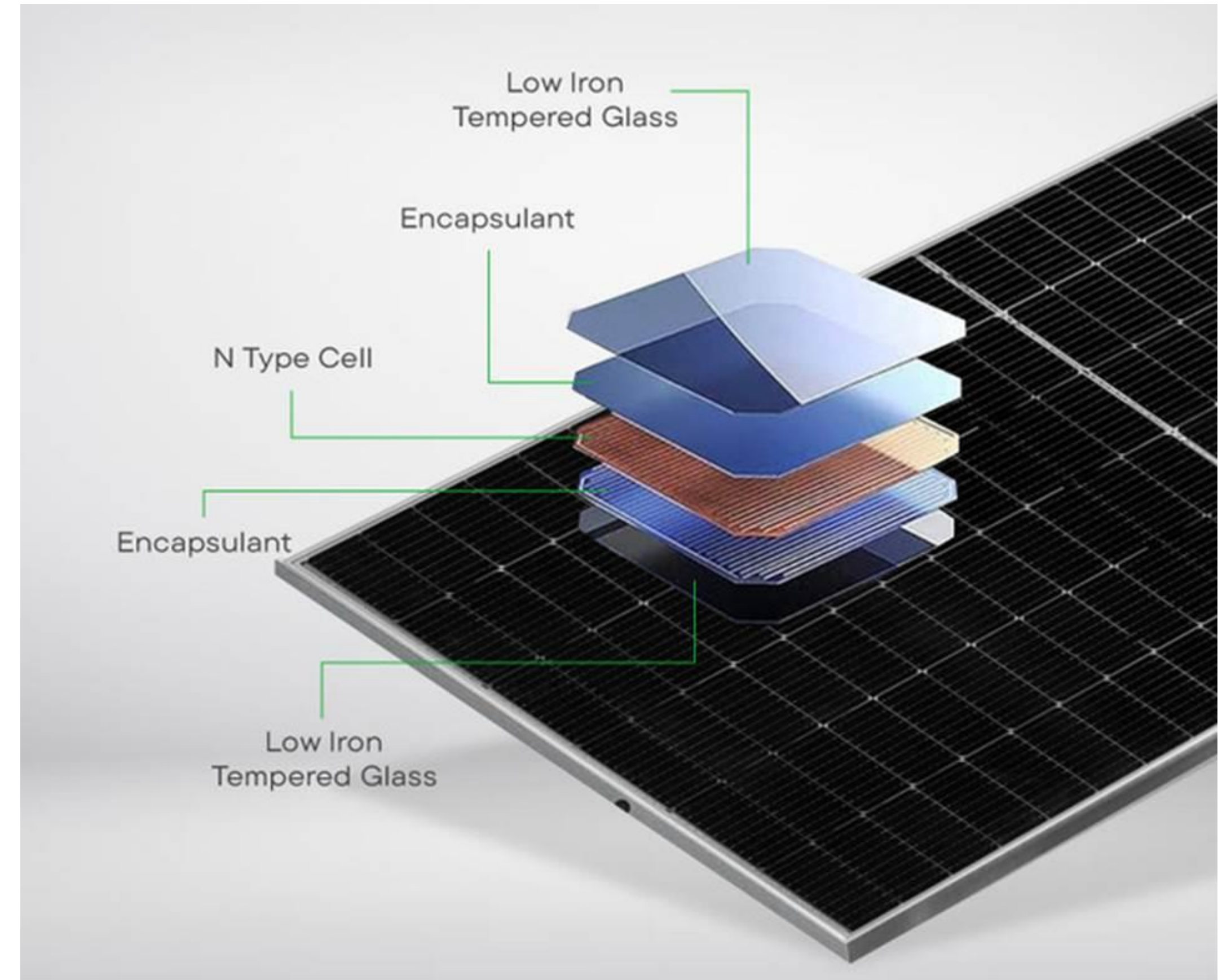


Image reproduced from Nover et al., 2021



Contaminant sources

Cell

- Si - inert, doping chemicals present as minor impurities
- Framework and electrical components may contain metals
 - 5 cm² c-Si module pieces: Al 167 mg; Cu 254 mg; Pb 16.7 mg (Novar et al., 2021).
- Tempered glass may have ZnO and SiO antireflective coatings
- Plastic componentry and cabling may contain plasticisers and flame retardants

Mounting frames and piles

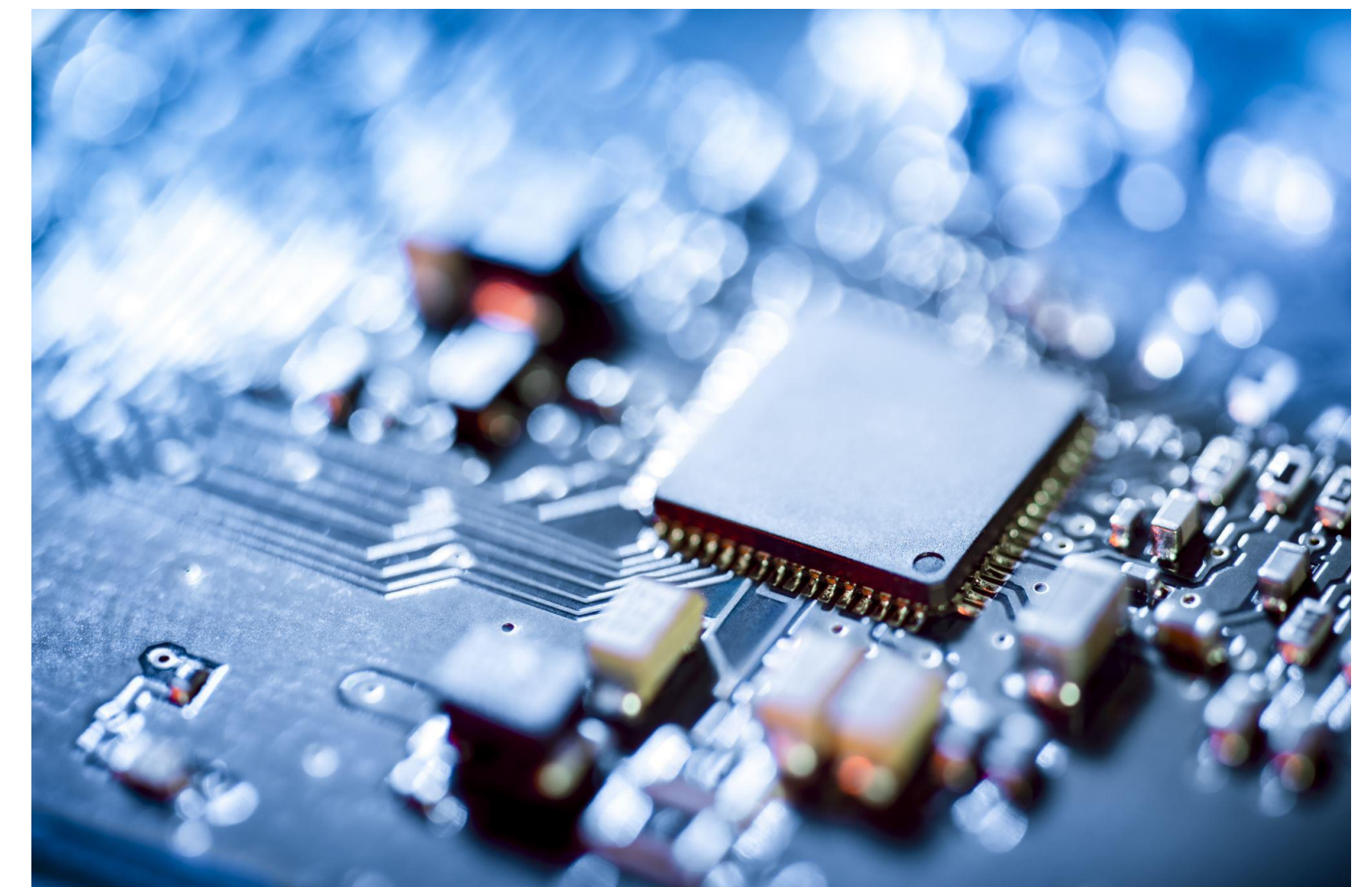
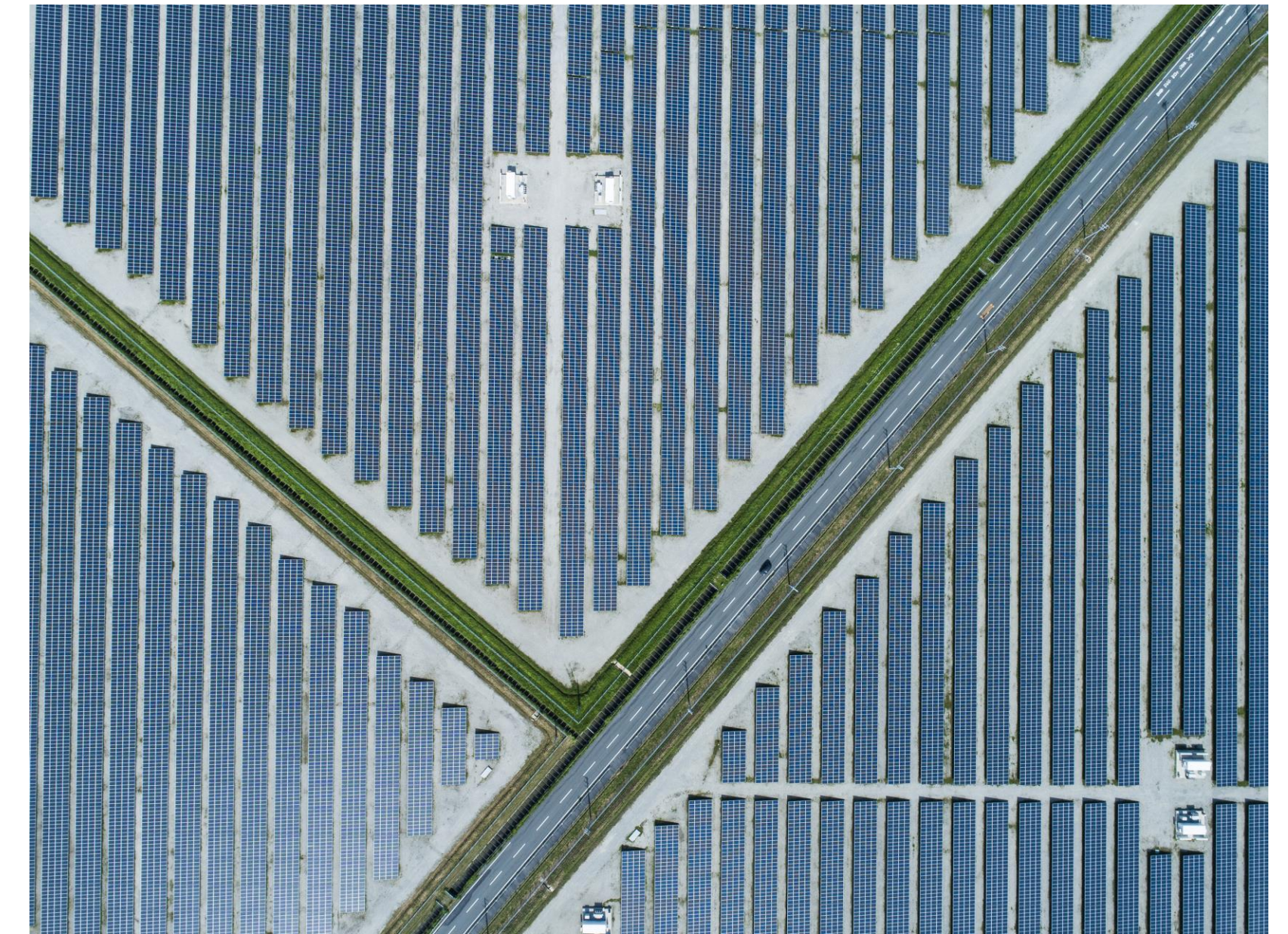
- Zinc as a sacrificial galvanic coating

Power Conversion Unit

- General construction material (e.g. steel, Cu, Al) and electronics (transistors, integrated circuits etc.) (Dodd et al., 2020)

Battery energy storage units

- LiFeP-based anode, graphite cathode, LiF₆ in methyl ethyl carbonate and/or ethylene carbonate as the electrolyte
- Structural components : binders, separators, current collectors (typically Cu+Al), valves, gaskets, washer and membranes (Rensmo et al., 2023; ZVEI, 2023)



Panel leaching with rain/simulated rain

- Most studies on EOL (e.g. milled, cut or crushed panels). However metal releases still low:
 - Ag: 0.0005 mg/L, Cu: 0.01 mg/L and Pb: 0.002-0.04 mg/L (Al, Cd, Cr, Zn all ND) for 225 cm² cut panels 18 hours (Sharma et al., 2021)
 - 5 cm² module pieces 1.5 years soaking: Al <0.5 mg/L, Pb 0.02 mg/L (Nover et al., 2021)
 - By DOM crushed panels decreased in Pb, unchanged in Al, increased in Sb; Tamaro et al., 2016)
- International Energy Agency (2020) risk assessment of broken panels in operation:
 - 70 Ha, annual breakage of 0.04%, leaching lead at 0.069 mg/L
 - Estimated exposures many magnitudes below water/soil/air screening criteria

(a)			
	Al	Pb	Sb
Law limit (µg/L)	200/1000	10/100	5
C1	355.7 (274.5)	105.3 (19.6)	** (0.6)
C2	557.6 (208.2)	485.7 (185.6)	4.5 (*)
C3	211.8 (221.2)	61375.0 (36228.0)	** (*)
C4	160.0 (184.3)	57187.5 (48631.0)	** (*)
C5	406.3 (22.5)	971.9 (34.2)	** (2.2)
C6	176.5 (17.3)	547.9 (134.8)	** (*)
C7	303.13 (25.3)	475.0 (45.6)	** (0.6)
C8	315.27 (124.2)	334.2 (57.8)	** (*)
C9	199.03 (100.40)	14.4 (5.1)	** (*)
C10	281.96 (294.40)	6.4 (5.9)	3.2 (*)
C11	450 (465.1)	39.7 (27.5)	3.8 (*)
C12	207.68 (25.5)	156.2 (78.1)	** (*)
C13	422.5 (34.4)	259.4 (38.5)	** (*)
C14	496.3 (21.5)	90.6 (7.7)	7.5 (3.7)
C15	106.3 (12.1)	296.9 (11.0)	6.5 (2.5)
C16	677.7 (491.5)	** (2.0)	9.6 (4.7)
C17	160.84 (38.0)	5.0 (2.9)	** (*)
C18	250.13 (209.3)	3.2 (1.1)	13.2 (11.2)
C19	1320.6 (86.9)	403.1 (25.4)	20.1 (13.2)
C20	489.0 (489.9)	80.5 (27.3)	13.8 (10.5)
C21	109.44 (110.8)	8.9 (1.1)	3.6 (2.1)
C22	420.0 (449.3)	34.4 (17.6)	5.6 (2.4)
C23	218.8 (81.2)	7.5 (1.3)	5.6 (3.1)
C24	305.0 (306.1)	6.9 (3.0)	4.3 (*)
C25	395.0 (417.8)	39.5 (4.0)	3.3 (1.5)
C26	299.5 (254.4)	** (2.8)	7.0 (3.8)

Element leaching from 0.5-3 cm² crushed c-Si modules into neutral lab water over 24 hours, reported as unfiltered and 0.45 µm filtered (value in brackets). C1-C5 manufactured in 1980s, C7-C15: 1990s; C16-C18- 2000s and C19-C26 2010s. Adapted from Tamaro et al., 2016



Field testing- NZ study (unpublished-Henderson & Dalley, 2024)

- Canterbury soil under 9.5 yr old panels. Study of soil chemistry, pasture composition/chemistry, lame lamb autopsy
- Compared to nearby pasture control site (no info on comparability of stocking/ fertilizer, how close to other land uses etc.)
- Control substantially higher Olsen-P, lower nitrate-N; pH, CEC and OM all slightly lower under panels
- Soil
 - Al: Control: 15.5±0.3 g/kg, Panels: 16.3±0.3 g/kg (GNS, 2022 regional median: 20 g/kg)
- Ryegrass (not stated if washed before testing)
 - Al: Control 22 mg/kg, Panels: 49.5 mg/kg,
- Lamb (states cause of death likely infection): Liver Al: 1.1 mg/kg (NZTDS max 3.1 mg/kg); Kidney: Al 3.4 mg/kg

Health Effects

Just as the health of the lamb has been impacted by consuming vegetation growing under solar panels, so too will the health of people by consuming contaminated fruit, berries, foliar plants (brassicas, lettuce), and especially root crops grown in soils containing leachates. It is now well established that changes in heavy metals (especially P, Al, Mn, Cd, Cu, Mg, Fe, Pb, Ca) are implicated in the rise of Alzheimer's disease and other related brain disorders (e.g., Bakulski *et al.* 2020). The agrivoltaics proposed at Brookside and other sites with poorly drained

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Other field testing and PFAS

Other field testing

- Transects (0 -30 m) away from 5 year old c-Si arrays(Robinson and Meindl, 2019)
 - Ba, Se, Li and Sr highest near the array– attributed to cement around the piles,
 - All other metals unchanged or increased with distance
- Testing in agricultural fields adjacent to and distant to c-Si solar arrays (Yousef et al., 2024)
 - No consistent metal elevation near vs far

PFAS

- Fluoropolymers are widespread in society, no indication they are a PFAS concern
- “Although fluoropolymers are technically PFAS they are not high up the level of concern relatively speaking”
- Nain & Anctil (2025) identified that there was no evidence that PFAS based anti-soil layers, such as trichloro(1H,1H,2H,2H-perfluorooctyl) silane had made it into commercial cells

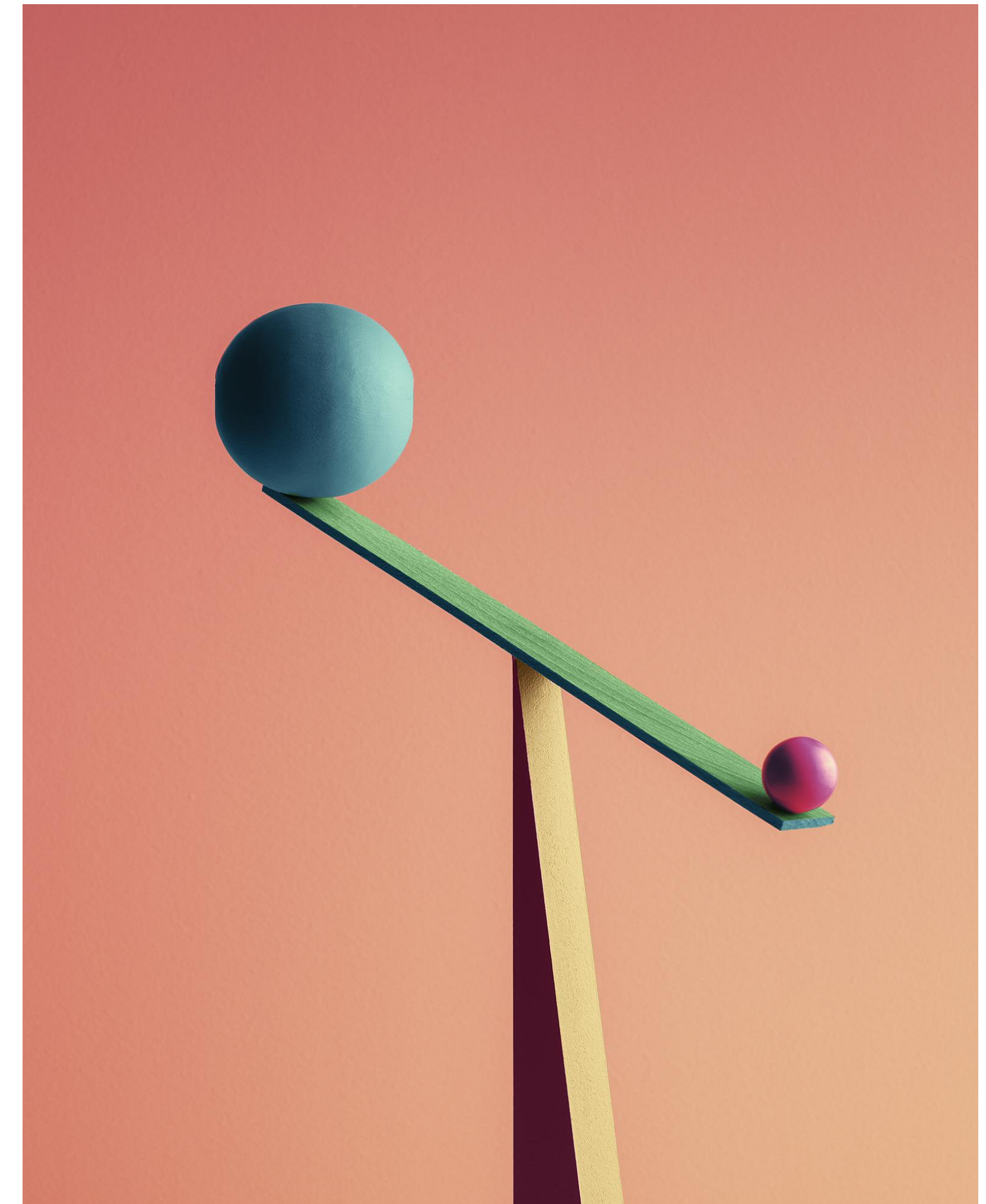


The stadium will be covered, with much of the roof made of a clear material called Ethylene Tetrafluoroethylene (ETFE), that will let natural light shine through to support turf growth:
<https://www.newsline.ccc.govt.nz/news/story/watch-latest-look-inside-new-stadium>



Risk assessment

- No identified international regulations for Agrivoltaics as a contaminant risk
- Panels are sealed, contaminant leaching will be negligible. Broken panels will be identified and replaced in site maintenance
- Batteries, PCUs and Cables sealed and will stop operating if water ingress. Most sites have a Li-battery fire control plan requiring maintaining system.
- US EPA” *“It is important to note that solar panels are safe during use. While solar panels may contain small amounts of toxic metals like cadmium, silver, or lead, working solar panels do not leach those toxic metals. They have a strong encapsulant that prevents leaching. “*
- Array mounts and piles will leach Zn from the sacrificial galvanising
- For an array using 20*Z1200 c-post piles (2000 x 150 x 70 x 14 mm and 3.5 mm thick) a maximum of 58 mg/kg Zn could accumulate in the array footprint
- With gaps for spacing, access and ancillaries unlikely Zn concentrations would achieve Eco-SGV (95 % LOP Sensitive soils: 180mg/kg).
- Zn additions common in agriculture(e.g. Zinc Sulphate Monohydrate fertilizer, Zn excretion from Facial eczema prophylaxis).



Other major metallic agricultural infrastructure



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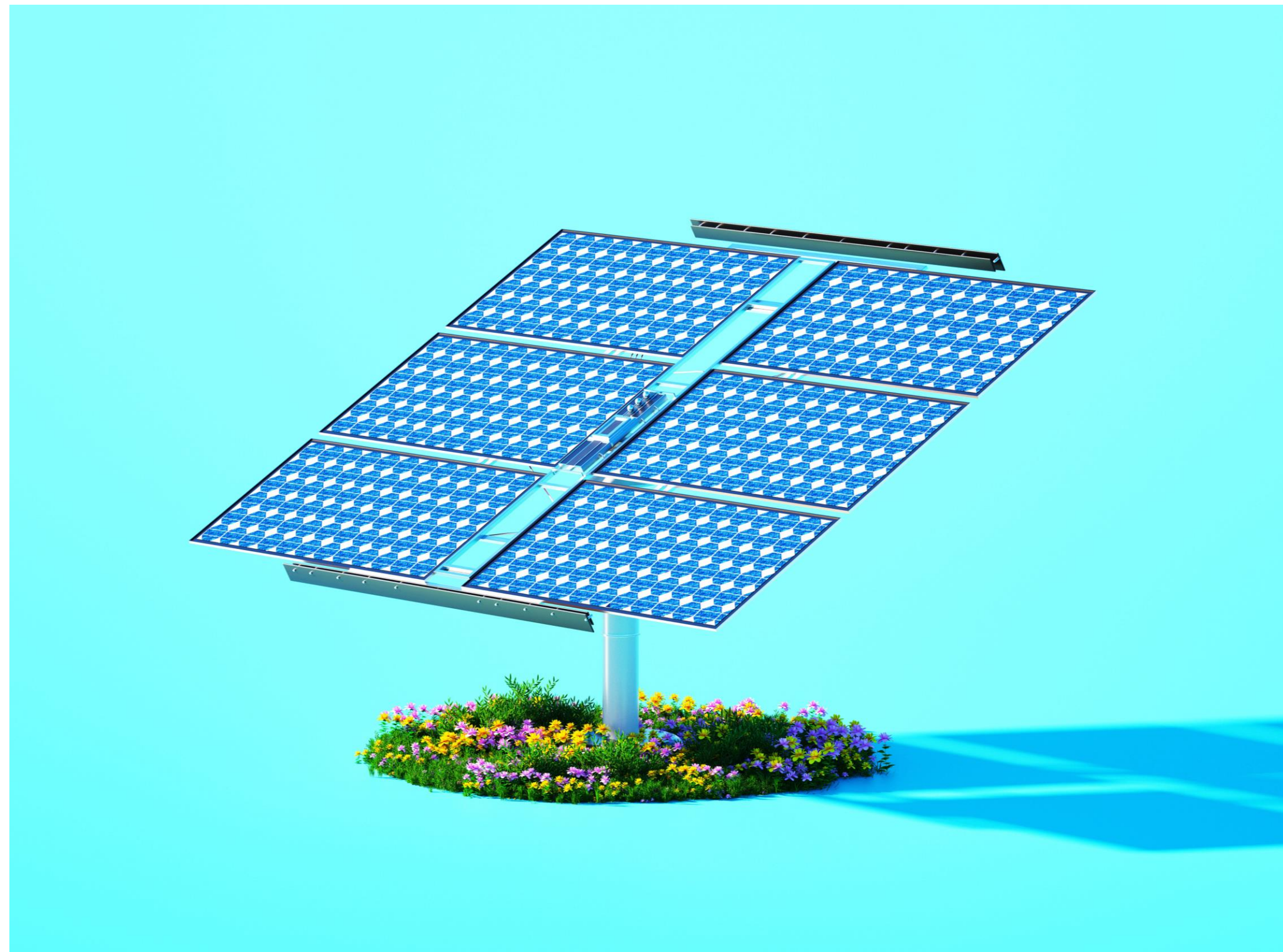


Regulatory interpretation

- Review of EPA documentation for Fast track consents upto mid 2025. Different levels of consideration over risks of panel contamination:
- **Carterton Solar Farm:** *“The panels are closed, sealed systems that do not result in the discharge of any contaminants to the ground”*
- **Marion Solar Farm:** *“....accepts that the solar panel units are closed systems and are brought on to the Site complete and finds that any adverse effects associated with this activity would be minor and do not stand against a grant of consent for the Project.”*
- **Ōpunakē Solar Farm :** *“STDC expects soil monitoring to be carried out, prior to establishment, during the project and following the decommissioning of the project to ensure adequate soil health is enhanced throughout the lifetime of the project..... There is concern that no supporting assessment is given regarding leachate from solar panels should they be damaged or as they degrade. “*
- **Tauhei Solar Farm, Rangiriri Solar Farm.** No conditions of consent related to the management of operational contamination risks on the Site
- **Ōpunakē Solar Farm (2), Waerenga Solar Farm:** Neither the applicant, nor parties invited to comment, nor decision making panel raised concern associated with contamination from panels or infrastructure.



Are Agrivoltaics HAIL (B4)?



- Contaminant sources are present in panels, mounts and ancillary infrastructure, but in a maintained sealed system will not leach
- Other contaminant sources don't differ from those in other societal/agricultural infrastructure (e.g. galvanised steel, fluoropolymers)
- No other country identifies agrivoltaics as a contaminating activity
- Of B4 HAIL examples, Solar aligns better with Wind than Fossil fuel or Geothermal (e.g. no combustion, no storage of chemicals)
- **No current convincing reason for agrivoltaics to be considered HAIL**
- Benefit in a nationally coordinated approach to avoid regulatory inconsistency and support transition to renewable energy





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