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Comments on 2.1 and 2.2

Additional submitted attachment is included below.

Comment on Initiative 2.1: Deploy Thin Film and Tandem Material PV Cells.

Overall, the initiative provides value, but the wording could be improved. Some specific notes/comments include:
Please be careful with "thin-film" terminology: The statement "Meanwhile, thin-film technologies have shown increasing laboratory performance, but have not achieved the manufacturing scale needed to demonstrate their potential cost advantages" neglects consideration of CdTe, which has demonstrated > GW/y manufacturing scale and documentable cost advantage and CIGS, which has reached ~ GW/y manufacturing scale, but has not demonstrated adequate cost/performance advantage.
Indeed, the status of the various thin-film and tandem technologies is highly variable and the research that will be most beneficial also will be highly variable.

Reliability testing: Focus on field testing is an excellent strategy for CEC to complement larger programs that are putting substantial funding into laboratory (materials) studies. However, to accomplish the goals of addressing *failure mechanisms and durability*, a **coordinated accelerated stress and field testing** program is likely to be most effective. Perhaps the CEC goal is to do field testing when accelerated stress testing already demonstrates durability? In my opinion, the size (cost) of field testing should be scaled to reflect the durability demonstrated by accelerated stress testing (for a completely new product, only deploy very small coupons; move to testing multiple kWs only after baseline accelerated tests can be passed).

Performance testing: Field testing will be especially valuable for thin-film and tandem products for evaluating performance in addition to failure and durability. Three types of performance issues should be included in the **Metrics and/or Performance Indicators**:
• **Transients**: Any cell type that exhibits transients in performance such as light-induced degradation needs to be characterized both to predict electricity production and to enable business transactions: if the manufacturer measures 100 W, but it changes to 90 W one day and 110 W another, how do we verify that 100 W modules were delivered?
• **Temperature effects**: The operating temperature and temperature coefficients can make a substantial difference in electricity generation, especially for higher band gap materials and when subband gap reflection enables the module to reject infrared light that is not used by the cell instead of turning it into heat. Reduced operating temperature not only increases operational efficiency, but can slow many degradation mechanisms and can reduce local heating, which is especially useful when solar panels are mounted on roofs in hot locations. (During the winter, it could be an advantage for the panels to get hot and heat the house.)
• **Spectral sensitivities**: Series connected tandem cells may change in efficiency as the spectrum changes (bluer spectrum on a clear day at noon and redder spectrum on a hazy day and/or at sunset). Many papers have been published on this topic, but the effect can depend on radiative transfer with in the tandem and should be verified for a specific cell type with field data. *Performance testing should be done side-by-side with silicon or other thin-film to compare the effects of variable weather*.
To successfully attract a manufacturer to California, you will need to offer significant funding, I think.

Comments on Initiative 2.2: Reduce Capital Costs of PV by Improving Cell Recycling

Recycling may be a good choice for public investment because businesses are unlikely to invest until government policy and business climate require it. However, I'm having difficulty envisioning how the results of this at this time will make a difference. The description does not discuss the need to partner the technology development with policy/business implementation. One very nice recent study (https://doi.org/10.1016/j.rser.2019.04.020) concludes that glass recycling of solar panels is already feasible but has not been done because the "required volume of modules is not sufficient."

Is the goal to reduce the tons of material going into landfills or reduce the hazardous waste? First Solar already offers recycling for their modules. They were forced to create the capability for business reasons because of the hazard associated with the CdTe. On the other hand, for the glass and aluminum recycling, my impression is that technology has already been demonstrated, but that the demand has not yet developed to make it a viable business without government support. Will an incremental improvement in the technology change that picture? Or, if the module volume became significant, would it quickly become a big business and then the companies would be ready to improve the technology as it moves to higher volume?

In Japan, they have made significant progress in recovering the aluminum and glass using approaches such as:
https://asia.nikkei.com/Business/Biotechnology/Japanese-companies-work-on-ways-to-recycle-a-mountain-of-solar-panels

So, my hesitancy about this initiative is that I'm not sure that it is the right time/type.
I'm quite confident that recycling of solar panels will become available when the business climate becomes appropriate. This initiative may be successful in bringing that day closer, but the focus on technology with little mention of policy and business challenges leaves me questioning. The companies that already have functioning hardware as in this exhibition: https://www.batteryjapan.jp/en-gb/visit/feature14-tokyo.html are unlikely to propose. The California groups that you may fund may have difficulty in catching up with what is already available, so at the end, California will learn a little, but may not manage to achieve lower costs. One possibility could be to purchase hardware from one of the companies at the above link and gain experience with it by tapping into the small existing waste stream. This could be a useful way to get a local company to get their feet wet with PV recycling business, but the "buy in California" requirement might make it challenging to purchase the hardware from the Japanese (or European) companies. Nevertheless, I think California could benefit from something like https://www.livingcircular.veolia.com/en/industry/first-recycling-plant-europe-solar-panels. Some research should be part of the proposal to benchmark the project (cost & fraction recycled), but the end result would be an operating PV recycling plant in California.