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Mahi Solar, LLC

BEFORE THE PLANNING COMMISSION
OF THE CITY AND COUNTY OF HONOLULU

In the Matter of the Application of MAHI SOLAR, LLC.	FILE NO. 2020/SUP-7 (FK) APPLICANT'S SECOND LIST OF EXHIBITS; EXHIBITS "37" – "44"; CERTIFICATE OF SERVICE

APPLICANT'S SECOND LIST OF EXHIBITS

Applicant Mahi Solar, LLC, a Delaware limited liability company ("Applicant"), by and through its attorneys, McCorriston Miller Mukai MacKinnon LLP, hereby submits its Second List of Exhibits; Exhibits "37" – "44", in support of the State Special Use Permit that was accepted by the Department of Planning and Permitting for processing on or around April 9, 2021. These exhibits may be used in support of Applicant's request for a State Special Use Permit. Applicant reserves all rights to identify additional fact witnesses and add rebuttal expert witnesses and exhibits.

LIST OF EXHIBITS

EXHIBIT NUMBER	DESCRIPTION
37	Testimony Letter, from Hawaii Agriculture Research Center to Commissioners and Land Use Commission re comments to SUP application No. 2020/SUP-7,
38	Letter, from Hartung Brothers, Inc. to Honolulu Planning Commission re SUP Application 2020/SUP-7
39	Letter dated June 17, 2021, from Law Tieng's Farm LLC to Honolulu Planning Commission in support of Mahi Solar project
40	Letter dated June 17, 2021, from Tony Law to Honolulu Planning Commission in support of Mahi Solar project
41	Letter dated June 17, 2021, from Manyvone Law to Honolulu Planning Commission in support of Mahi Solar project
42	Letter dated June 17, 2021, from Fat Law's Farm Inc. to Honolulu Planning Commission in support of Mahi Solar project
43	Planning Commission PowerPoint Presentation
44	Written Direct Testimony of Paul Matsuda (executed copy)

DATED: Honolulu, Hawai'i, JUN 21 2021.

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Attorneys for Applicant
MAHI SOLAR, LLC

BEFORE THE PLANNING COMMISSION
OF THE CITY AND COUNTY OF HONOLULU

In the Matter of the Application of MAHI SOLAR, LLC.	FILE NO. 2020/SUP-7 (FK) CERTIFICATE OF SERVICE

CERTIFICATE OF SERVICE

THE UNDERSIGNED HEREBY CERTIFIES that on this date, a true and correct copy of the aforementioned document was duly served upon the following by hand-delivery, addressed as set forth below:

PLANNING COMMISSION
Department of Planning and Permitting
City and County of Honolulu
650 South King Street, 7th Floor
Honolulu, Hawai'i 96813

DATED: Honolulu, Hawai'i, JUN 21 2021.

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Attorneys for Applicant
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Comments regarding SUP application No. 2020/SUP-7
Mahi Solar Project

Dear Commissioner Jonathan Likeke Scheuer, Chair
Commissioner Edmund Aczon, Vice Chair
Commissioner Nancy Cabral, Vice Chair
and other State of Hawaii Land Use Commissioners:

I am the Executive Director of the Hawaii Agriculture Research Center, Stephanie Whalen. I am currently out of the state but have asked Dora Nakafiji to read my comments. She brings the same passion for agriculture with a ton of energy experience in addition. She will be able to address any questions you may have regarding my comments on the subject of this meeting.

I want to start by saying how pleased the Hawaii Agriculture Research Center is to be a part of a solution orientated process. For too long agriculture and other sectors are pitted against one another in loud, noisy conflicting issues without mutual beneficial resolutions considered.

Agrivoltaics was conceived in the early 1980s. The pioneering scientists, A.Goetzberger and A. Zastrow recognized that both agriculture systems and solar arrays harvest energy from the sun. They reasoned that there would be benefits to both systems using the same land. Since then, many studies have validated their assumptions. This permit is about the solar sector and the agricultural sector working together to transfer this technology to Hawaii and help its 2 goals of food and energy self-sufficiency. While the state has classified about 2 million acres as agricultural land; it is clear that the best lands for food production are the same for power production: both use the power of the sun. To date the history of this dual use in Hawaii has produced nothing but controversy. For the first time here is an opportunity to move beyond conflict to a solution benefiting both sectors. But as with any challenging situation the resolution is in the details.

No doubt historically in these permit processes many promises are made only later to be broken often without recourse. I believe there is still a strong bias by all concerned to feel this is no different. To help alleviate that understandable reluctance it is HARC's goal to find additional funding both from the private and public sectors. It is committed to solutions to ensure its Agrivoltaic Research and Development Center will continue finding crops that are both efficient and economical under, beside and between the various PV panel types that exist now and in the future in Hawaii. It has reached out to the University of Hawaii to collaborate in this effort; it is applying to HEI for contributing funds and to the national energy and agricultural research funding sources; all to ensure the expansion and continuation of the program already initiated by Mahi Solar.

I do want to be clear here as folks often equate the word research to projects that do not produce near term results. This collaboration is about technology transfer not basic research. Technology transfer has been the culture of HARC, formerly the Hawaii Sugar Planters' Association, the research arm of the sugar industry. Its effectiveness for the industry speaks for itself. It helped keep a commodity product (high volume/low margin), sugar, situated 2500 miles from its nearest market and competing against over 140 lower cost countries in business for over 100 years. The key was technology transfer. Comb the globe for the latest and most efficient ideas and bring them to Hawaii to modify to its unique situations. The best example of that was drip irrigation for water use efficiency. An industry team went to Israel where this technology was being developed and brought it to the Hawaiian sugar industry. It is now the standard irrigation practice here for field crops. It was Hawaii's agricultural first huge step for water conservation. Agrivoltaics will be another step for water conservation in conjunction with solar panels. This is just one of the benefits agricultures will realize in this partnership. Both industries have proven benefits to realize with agrivoltaics.

Addressing the permit conditions:
A recent publication by A.S. Pascaris, C Schelly and J.M. Pearce, A First Investigation of Agriculture Sector Perspectives on the Opportunities and Barriers for Agrivoltaics (attached) concluded that there are some critical barriers to the use of this technology which can be addressed. The most important ones identified by farmers either actively using this technology or seriously considering it are long term land productivity, market potential, just compensation and system flexibility. These are important considerations when agreements/contracts are developed between the landowner, solar company, farmer, and regulatory agency. None are insurmountable but all necessarily need to be considered for this technology to transfer.

Defining the irrigation as specific to drip will reduce flexibility in the infrastructure design; do you really want to limit it?

Any agricultural plan needs to be flexible as crops and markets change throughout the years.
Rigid planning for decades is difficult to say the least.

Be mindful that some farmers will want to keep their production data confidential. Depending on number of farms; number of different crops, import or export all these factors can be important to a specific farm operation and how closely it wants to hold its data. Many small specialty crop farmers value their uniqueness for marketing purposes.

Trends may be more useful to determine if activities are increasing. It will be difficult to get 600+ acres into active agricultural production in a short time frame. I estimate 2 to 5 years. Which is really a guess. If you look at Hawaii in general over the past few years, the process has been slow and painful. The advantages of this proposal are affordable land, water and infrastructure and demonstrated crop production success. HARC's plan is to start with sheep and bees onto some of the poor crop areas that are sloped and rocky. That should be the easiest to move forward on as there is significant literature available for these and some sheep already are being used by other solar companies. The horticulture crops will depend on the work HARC is starting now and what it is able to do in the years leading up to and through construction completion. As I mentioned before it is collaborating with the University of Hawaii, is seeking additional funds to be able to put more effort into this area and demonstrate more crops. Some crop information is available in the literature but much of it is with different solar arrays and different environmental conditions.

In conclusion, this is a promising new approach to a tiring parade of controversies regarding the sustainability of agriculture and energy in Hawaii.

agronomy

MDPI

Article

A First Investigation of Agriculture Sector Perspectives on the Opportunities and Barriers for Agrivoltaics

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Abstract: Agrivoltaic systems are a strategic and innovative approach to combine solar photovoltaic (PV)-based renewable energy generation with agricultural production. Recognizing the fundamental importance of farmer adoption in the successful diffusion of the agrivoltaic innovation, this study investigates agriculture sector experts' perceptions on the opportunities and barriers to dual land-use systems. Using in-depth, semistructured interviews, this study conducts a first study to identify challenges to farmer adoption of agrivoltaics and address them by responding to societal concerns. Results indicate that participants see potential benefits for themselves in combined solar and agriculture technology. The identified barriers to adoption of agrivoltaics, however, include: (i) desired certainty of long-term land productivity, (ii) market potential, (iii) just compensation and (iv) a need for predesigned system flexibility to accommodate different scales, types of operations, and changing farming practices. The identified concerns in this study can be used to refine the technology to increase adoption among farmers and to translate the potential of agrivoltaics to address the competition for land between solar PV and agriculture into changes in solar siting, farming practice, and land-use decision-making.

Keywords: agrivoltaics; solar energy; agriculture; energy innovation; technology adoption; photovoltaics

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) Carbon and Other Biogeochemical Cycles report [1] reveals the predominant sources of anthropogenic greenhouse gas (GHG) emissions are the use of fossil fuels as sources of energy and land use changes, particularly agriculture. Agrivoltaics, the strategic codevelopment of land for both solar photovoltaic (PV) energy production and agriculture, can meet growing demands for energy and food simultaneously while reducing fossil fuel consumption [2–4]. Integrated energy and food systems have the potential to increase global land productivity by 35–73% [2] and to minimize agricultural displacement for energy production [5–7]. Agrivoltaic systems are a strategic and innovative approach to combine renewable energy with agricultural production, effectively addressing the predominant sources of anthropogenic GHG emissions as identified by the IPCC.

The viability of emerging agrivoltaic innovation has been investigated in various contexts. In conjunction with solar PV, there are emu farms in Australia [8] as well as sheep grazing [6,9,10] and pollinator-friendly sites proliferating in the U.S. (e.g., [11]). There is also the potential to use agrivoltaics with rabbits [12] and aquaponics (aquavoltaics) [13]. Experimental agrivoltaic research is occurring in diverse locations and climates. Examples include cultivation of corn and maize [14,15], lettuce [16,17], aloe vera [18], grapes [19], and wheat [20]. Mow [6] describes agrivoltaics as low-impact solar development that can alleviate agricultural displacement and assume varied designs: a solar-centric design that prioritizes solar output while growing low-lying vegetation; a vegetation-centric design that prioritizes crop production but incorporates solar panels and a colocation design that integrates both solar and agriculture for equal maximum dual output. Colocation designs have produced an estimated 3–8% per watt reduction in overall installation cost during site preparation due to cost reductions in land clearing and grubbing, soil stripping and compaction, grading and foundation for vertical supports, when compared to conventional solar industry development practices [6]. Further, Mavani et al. [4] found over a 30% increase in economic value for farms deploying such systems. Previous studies demonstrated that the dual-use of land for both PV and agriculture generates a mutually beneficial partnership that provides unique market opportunities to farmers and reduced operation and maintenance fees to solar developers, particularly in the case of grazing livestock [3,6,21–23].

The growing land footprint of solar PV presents social and spatial challenges, which are exacerbating the competition for land between agriculture versus energy production [5,23–25]. The U.S. Department of Energy Sunshot Vision Study forecasts that solar energy capacity will be nearly 329GW by 2030, which will necessitate approximately 1.8 million acres of land for ground-mounted systems [26]. Guerin [23] posits that the colocation of energy and agriculture will be stunted if there is absence of support from farmers and rural landowners, as the potential of agrivoltaic systems to address land-use competition will be contingent on farmer acceptance of agrivoltaics as a sociotechnological innovation. Brudermann et al. [27] found that PV adoption by farmers is primarily driven by environmental and economic considerations, which suggests factors that will be critical in agriculture sector decision-making concerning agrivoltaics.

Diffusion is a spatial and temporal phenomenon by which an innovation disseminates amongst adopters through a gradual process of filtering, tailoring and acceptance [28–30]. Rogers' [28] diffusion of innovations theory explains how and why some technological innovations are widely accepted while some are not, specifically referring to the adoption of an innovation by farmers over time in a rural diffusion model. The diffusion of innovations theory has been used to study diffusion of an innovation among physicians [31], among industrialized firms [32] and in terms of policy diffusion [33], among many other applications. Wilson & Grübler [34] applied the theory distinctly to energy innovations and described four phases of diffusion in which agrivoltaics can be categorized as existing in the first stage of an extended period of experimentation, learning, diversity of designs and small unit and industry-scale technologies. Grübler [30] warns that the existence of an innovation in itself does not promise proper diffusion, and while innovations have the capacity to induce change, it is the process of diffusion that realizes this potential as changes in social practice. By applying the diffusion of i theory to the agrivoltaic innovation, this study seeks to offer insight into potential refinements to the innovation of agrivoltaics in terms of its social acceptance to enable continued diffusion. This study uses Rogers' theory [28] as a practical framework for informing the diffusion of agrivoltaic innovation to discern the future potential and challenges for this technology to diffuse sufficiently to address energy and agricultural demands sustainably. While the technical viability of colocating solar PV and agriculture has been demonstrated [2,3,16,17], research in this field is incomplete with regard to placing the innovation within a social context to determine barriers to diffusion as perceived by industry experts.

Recognizing the fundamental importance of farmer adoption in the successful diffusion of agrivoltaics, this study investigates agriculture sector experts' perceptions on the opportunities and barriers to dual land-use agrivoltaic systems. Using in-depth, semistructured interviews, this study seeks to further the potential of agrivoltaics by identifying challenges to farmer adoption in an effort to address them by responding to societal concerns. In the following sections, the results are discussed, and conclusions are drawn on barriers to be overcome for agrivoltaic diffusion as identified by industry experts. The organization of the results and discussion are based on concepts from the diffusion of innovations theory [28], with a focus on relevant innovation characteristics (observability, relative advantage and compatibility), stages of the adoption process and categories of adopters. Finally, the implications of these findings for the future development of agrivoltaics and farmer adoption are considered.

2. Materials and Methods

This study investigates agriculture sector experts' perceptions of the opportunities and barriers to agrivoltaics using in-depth, semistructured interviews. Interview methodology is exploratory by nature and, most appropriately, collects and analyzes data about perceptions, opinions and attitudes of people [35]. Aimed at providing an inclusive and nuanced perspective of the phenomenon under study, interviews were employed to directly engage relevant informants related to agriculture and agrivoltaics.

Prior to commencement, this research obtained approval from Michigan Technological University's Institutional Human Subjects Review Board (code: 1524021-1) to ensure compliance with institutional ethics in human subjects research. The initial interview protocol can be found in Appendix A. Email was used to introduce the agrivoltaic concept and the study while inviting prospective participants to video conferencing discussions, which resulted in 10 online interviews lasting between 30 to 90 min. All participants provided informed consent for the recording of conversations, which were anonymized for the protection of their privacy. Data collection occurred between February and July 2020 until saturation was attained, known as the point when no new additional insight is derived from conversations with participants and stabilization of data patterns occur [36,37].

A total of 10 interviews were conducted with 11 agriculture sector professionals (one interview engaged two individuals simultaneously), including livestock and crop farmers, solar grazers (individuals who graze their livestock underneath solar panels) and an agriculture policy expert. Sampling for logical representativeness, variance, diversity, and relevance to agriculture, participants were pursued based on their potential to provide insight into the opportunities and barriers to agrivoltaics because they have direct experience in the agricultural sector. Both theoretical and snowball sampling methods are nonprobability techniques that were employed to construct a sample capable of representing a wide range of perceptions. Theoretical sampling intentionally captures individuals with certain characteristics [38,39], whereas snowball sampling progressively follows a chain of referrals from study participants to other potential contributors [40,41]. Table 1 details the sample of participants that was generated using these sampling methods, ranging in profession, geographic location and gender. While credible and valuable, samples constructed through nonprobability sampling do not lend themselves to generalization [42], nor are the findings generated through interview methodology suitable for statistical generalization or analysis. However, all of the themes discussed as findings were raised by the majority of participants and identify the primary opportunities and barriers to agrivoltaics according to this sample but cannot be quantified or suggested to represent a broader population. Therefore, the findings are not discussed quantitatively to steer clear from suggesting these results are statistically generalizable to the entire agriculture sector.

Table 1. Interview Participant Characteristics.

Profession	Geographic Region (United States)	Gender
Livestock farmer: 5	North East: 4	
Crop farmer: 1	South East: 1	Male: 5
Solar grazer: 4	Midwest: 5	Female: 6
Policy: 1	South West: 1	

Drawing from grounded theory methodology [41,43], data collection and data analysis occurred in parallel to strategically shape subsequent inquiry. Responses that emerged in initial interviews instructed the development of ensuing questions, allowing for gradual pursuit and refinement of relevant issues. Interview themes were generally organized around: (1) the participants' experience in agriculture and details of their current operation; (2) experience with and perceptions of agrivoltaics (e.g., attitudes, opinions, perceived opportunities and barriers); (3) willingness to engage in an agrivoltaic project (e.g., perceived benefits and challenges). Interview protocol matured over time to explicate what agriculture sector professionals perceived as relevant opportunities and barriers to agrivoltaic development.

All interviews were recorded, manually transcribed and analyzed using the qualitative data analysis program NVivo 12 Pro (QSR International, Melbourne, Australia) [44]. Data were studied on a line-by-line basis using a series of coding and analytic induction to explore relationships, patterns and processes. Line-by-line coding is the fundamental step in interview analysis that moves beyond concrete statements to make analytic interpretations [41]. Coding in grounded theory methodology helps anchor analysis to participants' perspectives, explore nuances of meaning, identify implicit and explicit issues, as well as cluster similarities and observe differences among responses [41]. As outlined by Znaniecki [45] and Robinson [46], analytic induction involves identifying patterns, themes and categories in qualitative data in preparation for comparison amongst the varied findings. Employing rigorous, iterative and comparative grounded theory techniques, analysis of these data has captured and condensed the most relevant opportunities and barriers to agrivoltaics according to this sample of agriculture sector professionals.

3. Results

This section organizes findings based on frequency and expressed magnitude of the barriers and opportunities to agrivoltaics as defined by study participants. Both direct quotations (italicized) and analysis of results are presented jointly. Sections 3.2 and 3.3 are aligned with three of the five innovation characteristics defined by Rogers' diffusion of innovations theory [28] (observability, relative advantage and compatibility), which were identified by participants as the most critical when considering the adoption of agrivoltaic technology. These results offer insights into the main challenges to farmer adoption of agrivoltaics and suggest opportunities for interested stakeholders to further diffuse this innovation. A discussion considering the implications of these results is followed in Sections 4 and 5.

3.1. Long-Term Land Productivity and Planning

The underlying fundamental challenge of agrivoltaic systems, as perceived by participants, concerns long-term land viability. Land viability is intrinsically proportionate to the livelihood of agriculturalists, as farmers explained that the quality of their land is of critical importance and cannot be compromised. Interviews with farmers revealed their temporal approach to decision-making as they prioritize the protection of long-term land viability above all. One farmer expressed this concern when considering the use of an agrivoltaic system:

> *I'm concerned too, if you're pouring a bunch of concrete and putting in permanent structures, what does this look like in the end of 20 or 30 years?*

Encompassed within concerns of long-term land viability are more nuanced challenges related to land productivity in the presence of permanent solar panel structures. Participants explained that in order to maintain their agricultural land status and thrive in their farming venture, land must stay actively agricultural. The challenge that permanent solar structures could potentially impose on land productivity was unsettling:

> *Given the permanency of all of the solar panels and the permanency of the size of the plot, maintaining it to be continually productive for the animals would be a challenge. One of the challenges that I foresee is learning how to get the production that you want navigating around all of those structures.*

When considering an agrivoltaic system, participants' concerns were largely technical and economic in nature, reflecting their dependence on land productivity. Considerations about long-term land use and farmland preservation constituted the basis for decision-making, suggesting that anything that jeopardizes land viability will not be tolerated by farmers. Thinking beyond protecting the soil itself, various participants expressed potential opportunities that agrivoltaic systems could bring to agriculturalists:

> *When we talk about farmland preservation, it's not just about preserving the physical ground, it's also about preserving the viability of the farm. If a farmer is going to go under because of lack of revenue, why wouldn't you want them to open up an additional revenue stream to be able to actually preserve that land?*

> *There's going to be ground that goes into the solar panels and I think the idea that here you can integrate mixed-use with this makes a lot of sense. I think you have to have the right farmers and the right producers that are committed to making some of these things work.*

Participants explained that long-term land viability and productivity implies required long-term planning. When discussing the prospect of engaging in an agrivoltaic project, participants proposed that incorporating some type of land-use agreement or long-term plan would relieve concerns around the future of their farm. Providing certainty of farmland preservation surfaced as a recurring consideration of agrivoltaic adoption, as articulated by one participant:

> *Restoring the land back to what it was having the right land agreements to where when that lease is up, they have to return it to prelease form.*

To address the need for long-term planning and prioritization of agricultural interests, agrivoltaic project contracts are widely used by current stakeholders. As described by interviewees who identify as solar grazers, agrivoltaic contracts provide certainty and prevent against loss for both parties involved. The temporal concerns of agriculturalists with regards to long-term land viability can be reassured by agreement and engagement on both sides, as a solar grazer explains:

> *You can't have any business planning when you have that degree of uncertainty. So, it was getting people to have contracts. What the contract did is give certainty to both sides. It meant the farmers could plan their businesses, because there is a whole bunch of this remote targeted grazing, there's tons of mechanics, tons of money, staffing, and planning around breeding schedules, you name it. And then on the other side you got people wanting to make sure that the insurance is okay, and that their wiring is going to be okay, and how they'll interface with all their service work, the whole picture. I just knew the contract was the first key to the puzzle.*

> *If you don't have a real contract and if you don't have someone really interested engaging in a 10-year kind of way on both sides, the whole thing is not going to work.*

The majority of participants communicated that to the extent that the solar infrastructure of an agrivoltaic project does not threaten long-term land productivity, there are opportunities for increased revenue to farmers and mutually beneficial land-use agreements. These interviews reveal that addressing concerns about the viability of land after project decommissioning and protecting the livelihoods of farmers will involve long-term planning and partnership between agriculture and solar industries. The establishment of agrivoltaic contracts has proven valuable to current solar grazers and provides a direct way to alleviate uncertainties in land-use planning.

3.2. Market (Un)certainty and Observability of Benefits

When considering barriers to farmer adoption of agrivoltaics, economic concerns were raised by participants only second to concerns described above regarding long-term planning for technical considerations. At a basic level, farming is a business, and is thus accompanied by a set of risks, uncertainties and investments. Participants explained that risk is especially unwelcome in the business of farming and that certainty in productivity and security in investment are vital. One participant articulated that the market unknowns are potentially more critical than the technical unknowns of agrivoltaics:

There's a lot of unknowns for the producer in this as well. Having established markets, alleviating some of the unknowns and the risks are probably as much of a piece of this as anything. So, sketching out the long-term financial return of like, "Here's what these markets look like for livestock production." And what the guaranteed revenue is for solar panels, for instance. In terms of just making it happen out there in the field, there's some requirements to make that happen, but they aren't insurmountable, I wouldn't imagine.

Others stressed the need for a secure market for an agrivoltaic system to be successful:

You would probably want to package it more as, "Do we have a food and farm system in place that allows somebody to have solar and grow these crops that are tolerant to that condition?" And then importantly, "Do we have a market to send that stuff to?" Because then all of a sudden it becomes this closed loop, kind of circular economy feel to it. But without that end market side of it, I think people would say, "That's great if you want to grow that stuff."

As long as the market is there, I would think a lot of these things could work.

As business owners, considerations of financial return and security in the marketplace are at the forefront of decision-making for farmers. For the majority of participants, the agrivoltaic innovation is unfamiliar and imposes constraints on business planning borne of unknowns and uncertainties. Building flexibility into the system to accommodate for changes in market conditions and farming practice could potentially alleviate some of the concern of uncertainty, as explained:

If we're looking at a 25-year kind of investment with the solar panels and when you're talking about integrating them within the livestock species too, that market for livestock might look totally different within 10 years. So, implementing some flexibility there that if we're not going to run rabbits, maybe we're running something else in there in 20 years. But having some flexibility in the system that you could respond to the livestock markets in there as well, I think is important.

Flexibility and adaptation to changing market conditions emerged as key elements to be incorporated into planning for an agrivoltaic system, highlighting again the temporal component to farmer decision-making and identifying concerns to be addressed for successful adoption. While the future unknowns of market acceptance of a product are difficult to ascertain, participants suggested that integrating flexibility into system design would reduce financial unease.

Coupled with concerns of a stable and reliable market for their product, were expectations for just compensation and tangible benefits from participation in an agrivoltaic project. When considering the adoption of the agrivoltaic innovation, participants also questioned if such an endeavor would be justified in terms of monetary gains. Participants perceived the adoption of such technology as an increased labor commitment and thus expected to reasonably gain from it. When asked if they would engage in an agrivoltaic project, one participant answered:

Essentially, they would have to pay me if they wanted me to be there because it's so much work to remediate soil and bring it up to a productive level, especially if this has been formally row cropped conventionally. So, it would really depend on what it had been earlier, how much I trusted the people who were starting this operation, and how much I felt that there would be ease of incorporating it into my schedule. I also think that it's not free pasture, you know what I mean? Even if they didn't charge me a single thing, there would be a lot of investment. So, I'd be going for like- I don't even know- I almost want to see like co-ownership, we own this land together, you get the profits from the solar and I get whatever everything else is. Or putting the solar panels on my own farm and then I get the revenue from the solar panels.

When judging the adoption of agrivoltaic innovation, participants expressed critical valuations of its worth and asserted that observable and substantial benefits would have to be derived in order for them to commit. Of the 10 farmers interviewed, four were already engaging with the technology and five others said they would get involved if they would derive more benefit than cost from it. Thus, the vast majority (nine of 10) of the farmers interviewed were open to using or already using agrivoltaics. Improving the agrivoltaic innovation to increase diffusion to these interested farmers will require establishment of just compensation for farmers, as explained by two solar grazers:

> *The biggest misconception to clear up immediately when people start thinking about this is that it can be anything like free grass. Because there's so much commitment on my end, and the cost of setting up all that equipment is very high. The time and labor of going there and servicing the sheep is a big commitment.*

> *I'm really trying to get out of is the idea that the farmer should be doing all this work for free. The solar firms are making—maybe not tons of money—but reasonable amounts of money off these investments. For them, they need to know that the performance guarantee is there, the sun has to shine on their panels, there shouldn't be interference with that. They need that steady assurance. And the farmers need to get paid for recognizing that there is a performance guarantee to meet.*

Participants explained that their willingness to be involved with the agrivoltaic innovation would be contingent on the near-term observability of direct benefits to them and the long-term certainty and security in the marketplace for their product. Observability is an innovation characteristic explained by Rogers (1962) that concerns the degree to which the results of an innovation are visible to potential adopters. When assessing their potential adoption of agrivoltaics, agriculture sector experts framed their considerations in terms of direct and tangible benefits, suggesting that observability of benefits is a characteristic of the agrivoltaic innovation that is of decisive importance to adopters. As discussed by participants in Section 3.1, agrivoltaic contracts are currently recognizing the rights and duties of involved parties, and provide opportunity to establish legitimate, mutually beneficial partnerships. With nine of 10 farmers inclined to partake in an agrivoltaic partnership, the above concerns about economic uncertainty and gains are active considerations for all involved stakeholders in project development.

Relative Advantage

The degree to which agrivoltaics are perceived by participants to be advantageous to current practice was identified as important when considering adoption. While participants expressed that financial compensation for farmers is both necessary and attractive, they also spoke of other benefits they anticipate as a result of engaging with the agrivoltaic technology. Participants discussed potential marketing advantages:

> *It's got a great story; it's got a wonderful marketing edge from that perspective. So, your advantage is a great story to tell from a marketing standpoint.*

> *I think that's where you have a very unfair advantage for whoever would be doing this rabbit production, you might be getting paid for land maintenance and then have rabbits for free. So, your profitability could be way up or your price could be way lower because you wouldn't have land expenses. There's a lot of opportunity to create some advantage from a production standpoint. From that perspective they may sell better or have an [edge] in the marketplace because of that aspect.*

Another participant expressed other technical synergies when grazing animals underneath solar panels:

> *I think it sounds like a great idea. It sounds like a great way to maintain, and not have to mow. I can see the panels providing shade and protection from the rain in a way that seems very valuable.*

Perceiving a multitude of potential benefits, participants speculated how the adoption of the agrivoltaic innovation could provide them benefits and competitive advantages in the marketplace. Foreseeing a unique opportunity to derive a revenue stream from land maintenance, some participants postulated that there were economic gains associated with combined solar and agriculture systems. Rogers' (1962) innovation characteristic, relative advantage, explains that innovations that are perceived to be superior to business as usual have higher potential for adoption. Participants described the relative advantage of agrivoltaics worthwhile, and thus identified this innovation characteristic as critical when considering the adoption of the innovation, suggesting that if an agrivoltaic system could provide an advantage to a farmer, the likelihood of adoption would be greater.

3.3. Compatibility with Current Practice

A considerable opportunity for farmers in agrivoltaic projects is the potential for integration of the innovation into their current practice. Participants expressed disinterest in increased complications in their business, and rather actively seek ways to reduce labor through harnessing the synergies of innovative practices. The ease of integration and compatibility of solar with current production was frequently considered amongst participants, highlighting the opportunity to plan overlapping operations to increase farmer acceptance. The attractiveness of agrivoltaic integration was explained by two participants:

> *Most of my exposure to this is from sheep, and I think that it's a great idea. For my own particular system, it would definitely reduce the amount of labor for one aspect of the system, which is moving the fencing. So, I'm all for it. I think it'd be a really nice mesh.*

> *Alternative energy is expensive to people like us. But it's something that I guess, if it could be integrated into something I'm already doing and could potentially help protect the animals, or do whatever, and then also run the homestead, it's just another perk of having something like that. It's another reason to have it besides just having the electricity.*

As elucidated by participants, compatibility of the agrivoltaic innovation with current practice could reduce labor and create an incentive to engage in the technology. When considering the value of agrivoltaics to them personally, farmers offered calculated and context-dependent perspectives, making judgments on the benefits in terms of their own operation rather than speaking generally about dual-use solar systems. Speaking from a place of personal considerations and interests, participants revealed that there is a context-dependent nature of success for agrivoltaic projects. Reflecting their own practices, one participant stated:

> *I've also heard them say in meetings the fact that we're going to farm soybeans underneath solar panels, which is just asinine. Like, it's not going to happen. The size of our equipment doesn't permit that kind of thing. Putting livestock under, kind of a grazing operation, seems to make sense.*

Compatibility with current practice not only includes size of equipment, but also scale of the farming operation, as explained by one participant:

> *The work that would be involved with that, I think, or potentially having to hire someone to manage them, it would decrease our profit so much that it wouldn't make sense. I could see how that would be to someone's benefit though, but not at our scale.*

To justify the labor involved in engaging in an agrivoltaic project, farmers evaluated their own enterprise by mentally applying the innovation and determining the potential compatibilities. As suggested by participants, the benefits of agrivoltaics are noteworthy, but will only be fully realized if there is ease of integration into their current farming practice. Compatibility is an innovation characteristic defined by Rogers (1962) that explains the degree to which an innovation is perceived to be consistent with needs, norms and sociocultural values is decisive to potential adopters. The theme of compatibility among most participants was viewed as an opportunity rather than a barrier for agrivoltaics, suggesting that the innovation's context-dependent nature provides flexibility and potential to leverage the solar system to derive synergistic benefits to compliment current farming practices.

4. Discussion: The Opportunities & Barriers for Agrivoltaic Diffusion

This research provides insight from the agricultural sector into the challenges and opportunities for farmer adoption of the agrivoltaic innovation. Results indicate that participants see potential benefits for themselves in combined solar and agriculture technology and identify barriers to adoption including desired certainty of long-term land productivity, market potential and just compensation, as well as the need for predesigned system flexibility to accommodate different scales of operation and adjustment to changing farming practice. The findings suggest that these barriers to adoption are not insurmountable and can be sufficiently addressed through prudent planning and mutually beneficial land agreements between solar and agriculture sector actors. Table 2 below organizes the identified barriers and opportunities to address them. All of the participants of this study assented to agrivoltaics as a synergistic and innovative approach to combined land-uses, while nine of the 10 participants who are currently active farmers stated they would engage in the use of a dual-use system given the discussed concerns are considered (four of the nine already are). Interviews with industry professionals informed the current state of diffusion of the agrivoltaic innovation and identified opportunities to further stimulate farmer adoption of the technology. These findings may be used to translate the potential of agrivoltaics to address the competition for land between solar PV and agriculture into changes in solar siting, farming practice and land-use decision-making.

Table 2. Barriers, opportunities, and directions for future work regarding the diffusion of agrivoltaics.

Barrier	Opportunity	Future Work
End-of-life impacts from solar infrastructure	-Driven piles (constructed of galvanized steel I-beams, channel-shaped steel or posts), helical piles (galvanized steel posts with split discs welded to the bottom at an angle) and ground screws (galvanized steel posts with welded or machined threads) can be removed and recycled [47,48]. -Photovoltaic (PV) racking can be put on removeable ballasted foundations or skids of precast or poured-in-place concrete ballasts to minimize land disturbances [47]. -Impacts from modules such as leaching of trace metals [49–51] and compromised future agricultural productivity [52] have been proven highly unlikely. -Contracted agreements that establish plans to return land back to prelease form after decommissioning of solar system.	-Empirical research investigating the magnitude of long-term impacts of solar infrastructure on land (e.g., [53]), soil, and pasture-grass productivity.
Permanent structures interfering with agricultural production and future farming practice	-A variety of plants have proven to maintain higher soil moisture, greater water efficiency, and experience increase in late season biomass underneath PV panels [54]. -Improvements in water productivity and additional shading are projected to increase crop production in arid regions experiencing climate change [55]. -Semitransparent PV [56] (Thompson et al., 2020) or vertical bifacial PV [57]. -Raised racking systems provide clearance for agricultural equipment, which could allow for nearly any crop to be used in agrivoltaic production [58]. -Design flexible open source racking systems [59,60] that have adjustable panel height, tilt angle and spacing [61], as well as a combination of permanent and portable fencing. -East-west tracking array configurations allow optimal conditions for plant growth when compared to conventional south-facing designs [62].	-Empirical research aimed at understanding the implications of solar PV infrastructure on perennial pasture grass maintenance. -Optimized agrivoltaic PV -Cost-benefit analysis of open source PV racking systems designed with adjustable panel height, tilt angle and spacing. -Cost-benefit analysis of permanent and portable fencing for animal grazing agrivoltaics.

Table 2. *Cont.*

Barrier	Opportunity	Future Work
Uncertainties in operation and business planning	-Legitimate partnerships and contracts that establish up-front costs and compensation for both parties -Local government policy aimed at supporting development of solar PV [63,64] -Education and outreach from PV industry to farming industry to reduce barriers to knowledge and increase trust.	-Policy research focused on market mechanisms to incentivize agrivoltaic systems for both solar and agriculture sector. -Increased efforts from university extension programs to increase information sharing and partnership between energy and agriculture.

4.1. *Diffusing the Agrivoltaic Innovation—Where Are We Now?*

The diffusion of innovations theory [28] identifies five stages in the process of technology adoption. Participants of this study predominantly fell into the decision or evaluation stage of adoption, which is understood as the stage in which an individual mentally applies an innovation to their present and perceived future circumstances to arrive at a decision to try it or not. Beyond the initial knowledge or interest stages of Rogers' adoption model [28], the majority of participants (six of 11) considered their potential adoption of agrivoltaics beneficial but dependent on factors related to context. Speaking from a place of receptivity, these participants saw value in the innovation and felt inclined to engage with it, while voicing a few concerns about compatibility with their practice and uncertainties about long-term land productivity. Four of the 11 participants were already functioning in the confirmation or adoption stage of the adoption process, making full use of the innovation. Based on these findings, it is observed that the current state of the diffusion of agrivoltaics is advancing towards wider implementation and has surpassed initial phases of information gathering and persuasion. Participants in the decision or evaluation stage of adoption identified barriers to their engagement with agrivoltaics, giving interested stakeholders the ability to directly respond to these concerns by improving the technology to enable further diffusion.

Further, most participants of this study were early majority adopters, characterized by wanting proven and reliable applications, reference from trusted peers and being prudent in financial risk and uncertainty. Rogers [28] asserts that an innovation must meet the needs of all categories of adopters, making clear in the context of agrivoltaic adoption where efforts should be focused to successfully move early majority adopters into acceptance of the innovation. Technological diffusion is a process of filtering, tailoring and accepting [30], and the identified concerns of the agriculture sector professionals in this study can be used to tailor or refine the technology to increase adoption among farmers. The following section will elaborate upon the critical characteristics of agrivoltaic systems as identified by participants and suggest recommendations for improvement with the intention of facilitating accelerated diffusion.

4.2. *Diffusing the Agrivoltaic Innovation—What Needs to Happen?*

Rogers [28] posited that there are five distinct innovation characteristics that help explain why some innovations are widely accepted and some are not. Understanding the characteristics of the agrivoltaic innovation is valuable for interested stakeholders when assessing areas for improvement and pursuing further acceptance of the technology. The results of this study identify the most critical characteristics of agrivoltaics and point to opportunities to directly respond to farmers concerns.

Of these five characteristics, observability of benefits, relative advantage and compatibility with current practice were identified by participants as the most critical when considering their personal adoption of the agrivoltaic technology. What this means for further diffusion is that the solar industry actors involved in the development of agrivoltaic systems must devise mutually beneficial land agreements with farmers that establish compensation for their labor, articulate plans for land restoration after the decommissioning of the system and be sensitive to contextual differences among agriculturalists by designing a system that is flexible enough to meet the needs of the current and future users. Participants in this study saw immediate value in personal adoption of the technology but sought long-term security in terms of farmland preservation and financial return.

There are a handful of practical actions to be taken to enable further diffusion of agrivoltaics. Table 2 presents a summary of the identified barriers, existing opportunities to overcome them and directions for future work. First, the establishment of agrivoltaic contracts has proven valuable to current solar grazers. Robust and forward-thinking land use agreements will provide a direct way to alleviate uncertainties in land-use planning and secure compensation for farmer's labor. Second, system designers need to integrate flexibility in design by accommodating current land practices and allowing for future changes. Concerns about market uncertainty and rigid systems can be addressed by crafting a combined solar and agricultural project that is adaptable to changing market and farming conditions. Third, agrivoltaics systems should be designed with compatibility in mind. By strategically harnessing the synergy of compatibility with current practice, these results suggest that farmers would be more inclined to engage with a project if it generated advantages in their operation. Being sensible in scaling a system to current practice, rather than creating increased labor burden on farmers, will increase the likelihood of their participation with the technology.

The potential for increased utilization of the agrivoltaic technology is ripe. While previous research has demonstrated its technical viability, this study recognizes that technology innovations exist within a social context and thus depend upon social acceptance and adoption. It is concluded that continued farmer adoption of agrivoltaics is likely, yet contingent on observable benefits in farming practice and assurance of financial gain. Future research should investigate how perceptions vary across geographic regions and agriculture professions (i.e., animal versus crop farming) to study the unique opportunities and barriers for agrivoltaics in the context of local climate and agricultural practice. Increased education and outreach concerning the end-of-life impacts, negligible effects of solar PV on agricultural productivity and potential for agrivoltaic systems to protect crop production during climate change, is necessary to inform and stimulate further farmer adoption. Empirical experimental research should investigate the long-term impacts of solar PV infrastructure on perennial pasture grasses to better understand the possible effects of agrivoltaic systems on future grazing productivity. Economic cost-benefit analysis will be valuable for quantifying the potential cost disadvantages of designing flexible PV arrays that can be adjusted to accommodate different panel heights and spacing requirements. Future policy research can investigate the role of market mechanisms, such as incentives, in prompting further development of agrivoltaics. Based on these findings, policy makers should consider implementing financial instruments that stimulate both solar and agriculture sector adoption of the technology, while building flexibility into such policies to allow diverse, innovative and contextually appropriate system designs. To do this, agrivoltaic proponents can model their efforts on the successful diffusion of wind farm/solar farm integration that focuses on local support [65,66]. Previous research examining diffusion of solar as an innovation among residential adopters highlighted the role of communities of information sharing for promoting adoption [67]. The study presented here is unique in examining the diffusion of agrivoltaic solar innovation as a community level consideration, but also demonstrates how diffusion of innovation can occur within a social context. Moving forward, placing the agrivoltaic technology in a social context will be essential to identify the barriers to its diffusion and will offer relevant solutions to increase its adoption.

5. Conclusions

Agrivoltaic systems are a strategic and innovative approach to combine renewable energy with agricultural production. Recognizing the fundamental importance of farmer adoption in the successful diffusion of agrivoltaics, this study investigates agriculture sector experts' perceptions on the opportunities and barriers to dual land-use systems. Results indicate that participants saw potential benefits for themselves in combined solar and agriculture technology and identified barriers to adoption including desired certainty of long-term land productivity, market potential and just compensation, as well as the need for predesigned system flexibility to accommodate different scales and types of operations and adjustment to changing farming practice. The identified concerns of the agriculture sector professionals in this study can be used to refine the technology to increase adoption among farmers and to translate the potential of agrivoltaics to address the competition for land between solar PV and agriculture into changes in solar siting, farming practice and land-use decision-making. Ultimately, building integrated energy and food systems can increase global land productivity, minimize agricultural displacement and reduce greenhouse gas emissions from fossil fuels. Informed and concerted efforts at enabling further diffusion of this innovation are imperative for meeting growing demands for energy and food simultaneously.

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Appendix A

Initial interview protocol as approved by IRB

1. Please tell me about your experience as a farmer.
    a. What is your geographic location?
    b. How long have you been doing it?
2. Who [markets, restaurants] are your biggest customers?
    a. How do you go about opening new accounts with potential customers?
    b. What is your greatest barrier to gaining access to new markets/customers?
3. How large is your operation? Would you consider it small-medium-large?
4. Are you familiar with both crop and animal farmers that incorporate solar panels on their land?
    a. If so, what are your thoughts on this?
5. Would you ever consider embracing the mixed-use of solar on your farm to harness co-benefits of solar energy generation and agricultural production?
    a. If so, why?
        i. What is your minimum acceptable rate of return?
    b. It not, why?
        i. What type of barriers are there?

6. Would you consider renting land on a prefenced solar-farm meant for agricultural production?
    a. If so, why?
        i. What is your minimum acceptable rate of return?
    b. It not, why?
        i. What type of barriers are there?
7. What is needed to make a mixed-use solar farm more attractive to you?
8. A new study that is sponsored by the D.O.E. has shown an opportunity to incorporate rabbit farming with solar photovoltaic farms that make electricity. This study has shown substantial economic opportunity from this mixed-use scheme: upwards of 24% increase in site revenue. Now I would like to ask you specifically about mixed-use solar involving farmed meat rabbits.
    a. What do you think are the biggest opportunities for this kind of mixed-use solar development?
    b. What do you think are the biggest barriers for this kind of mixed -use solar development?
9. Do you anticipate solar farm pasture-raised livestock selling for a premium or increasing sales?
10. Is there anything else you would like to tell me about your perspectives of mixed-use solar PV development?
11. Do you have suggestions of other experienced farmers I should speak with?

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66. Groth, T.M.; Vogt, C.A. Rural wind farm development: Social, environmental and economic features important to local residents. *Renew. Energy* **2014**, *63*, 1–8. [CrossRef]
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Honolulu Planning Commission
650 South King Street, 7th Floor
Honolulu, HI 96813

Dear Commissioners:

As one of the landowners at the Mahi Solar project site, we have been working with Longroad Energy and are fully supportive of this project, which will provide clean energy and encourage local agriculture. We are currently negotiating agreements that will provide long-term use of portions of our land for the duration of the project's operation. These agreements will be executed in the next several months and will require that Mahi Solar posts financial security to ensure that sufficient funds are available to decommission the project after operation, remove all equipment and restore our property to its current condition. Thank you for your consideration.

Sincerely,

Daniel J. Hartung
President, Hartung Brothers, Inc.
Sole Member of Hartung Brothers Hawaii, LLC

LAW TIENG'S FARM LLC
HAWAII

TEL:808·282·0787 FAX:808·688·2015
CELL:808·864·1008

P.O.BOX 970935 WAIPAHU HI. 96797
e-mail: thomas@ltffarm.com

June 17, 2021

Honolulu Planning Commission
650 South King Street, 7th Floor
Honolulu, HI 96813

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Mahalo,

TONY LAW
P.O. BOX 155
Kunia, Hi 96759

June 17, 2021

Honolulu Planning Commission
650 South King Street, 7th Floor
Honolulu, HI 96813

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Mahalo,

Tony Law

MANYVONE LAW
P.O. BOX 155
Kunia, Hi 96759

June 17, 2021

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Honolulu, HI 96813

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Mahalo,

Hawaii Fresh Herbs
FAT LAW'S FARM INC.
P o box 970188
Waipahu hi 96797
Ph (808)485-7488 fax (808)681-6889

June 17, 2021

Honolulu Planning Commission
650 South King Street, 7th Floor
Honolulu, HI 96813

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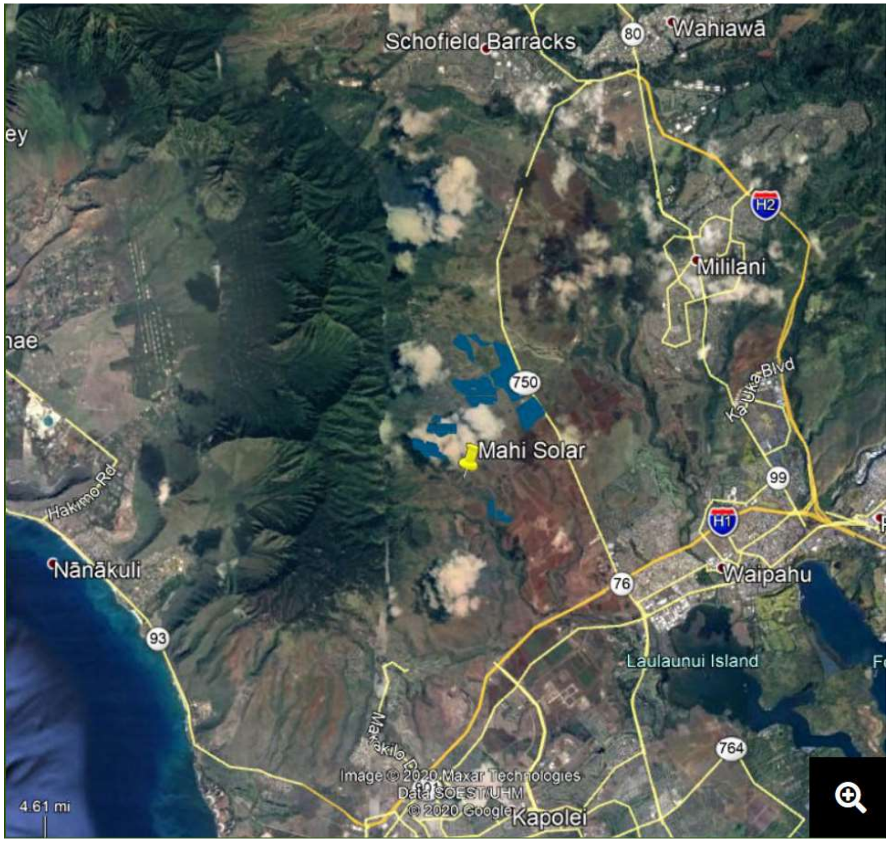
Mahalo,

Exhibit 43

Transition to Clean Energy

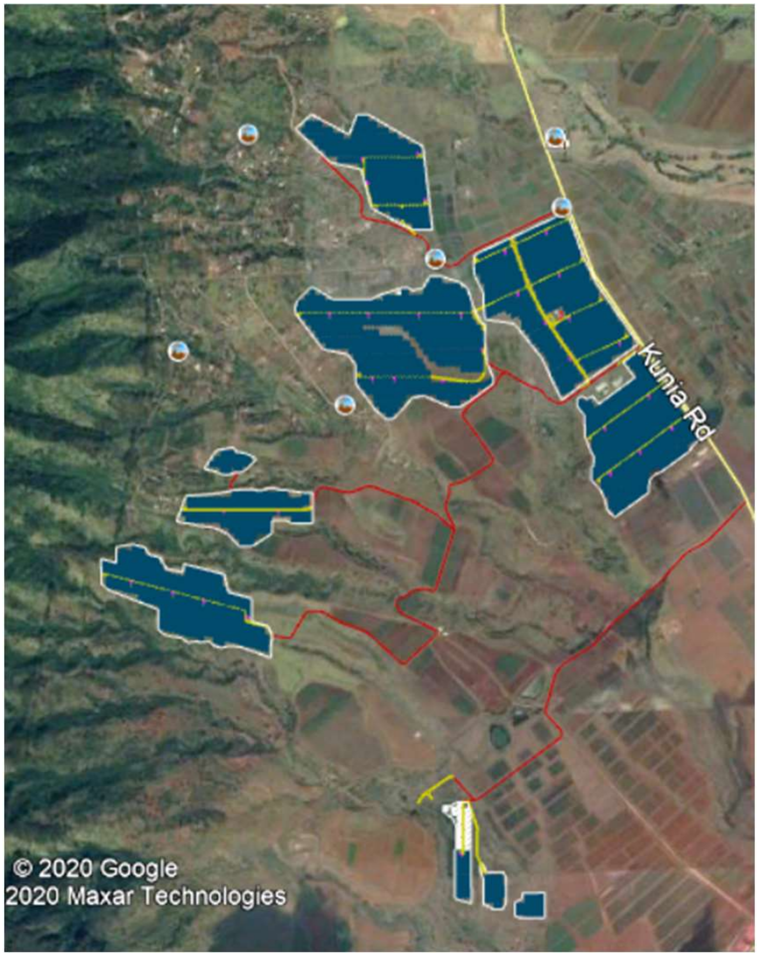
- Hawaii has set a goal of generating 100% of electricity from renewable energy
- Replace coal-burning power plant in 2022 and all oil-burning generation by 2045
- Hawaiian Electric RFP in 2019 selected 8 solar/battery projects on Oahu
- **Mahi Solar** was selected as the largest project (3% of 100%) w/lowest priced energy – Approved PPA with HECO
- Most projects online by end of 2023
- Energy coming to your home will be cleaner and cost less



longroad ENERGY

Mahi Solar Project in Kunia

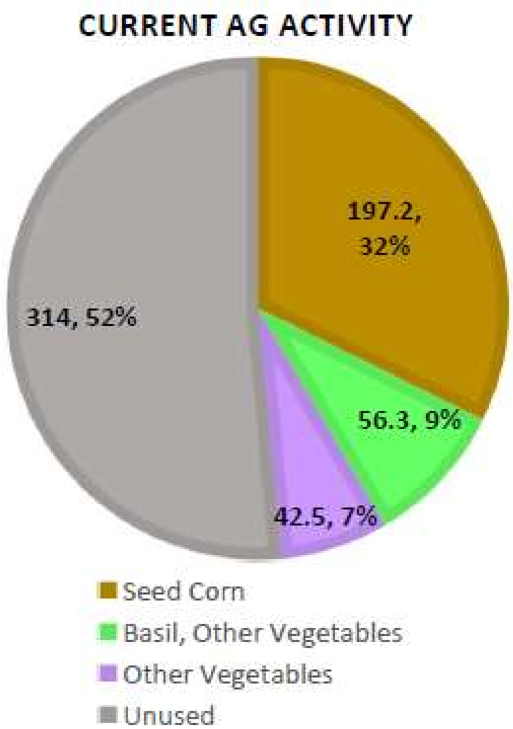
- 120 MW – enough power for ~37,000 homes
- West of Kunia Road, mauka of Royal Kunia, downhill from Kunia Loa Ridge Farmlands
- 480 MWh of batteries to store solar energy in the day & power the grid at night
- Connects to existing 138 kV power lines
- Solar will occupy up to 620 acres; about half is being farmed in seed corn or veg crops
- Farmers will continue farming their best land, while leasing the less productive areas

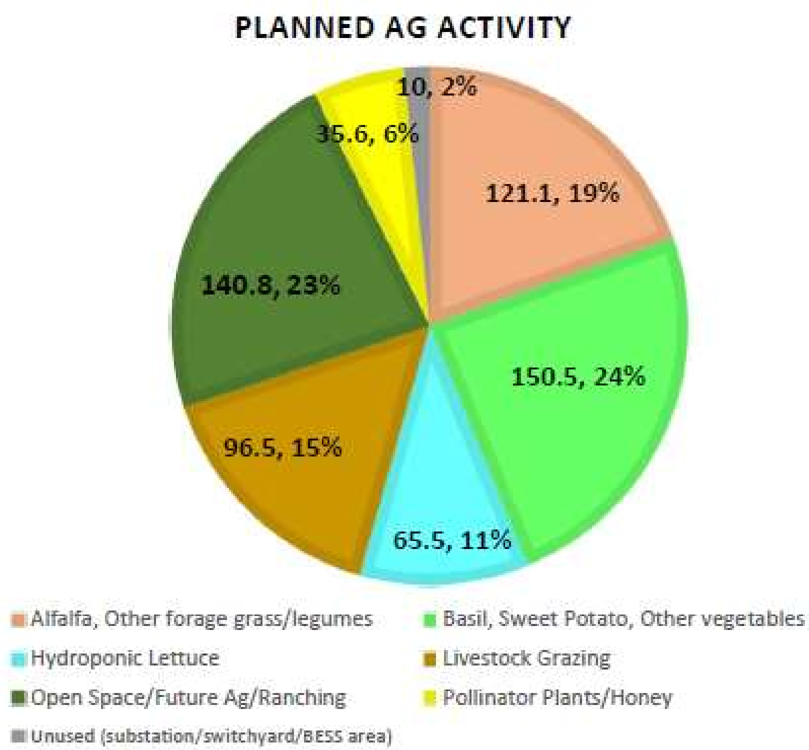


longroad ENERGY

Energy and Agriculture

Most of the Mahi Solar project area will be used for solar AND agriculture

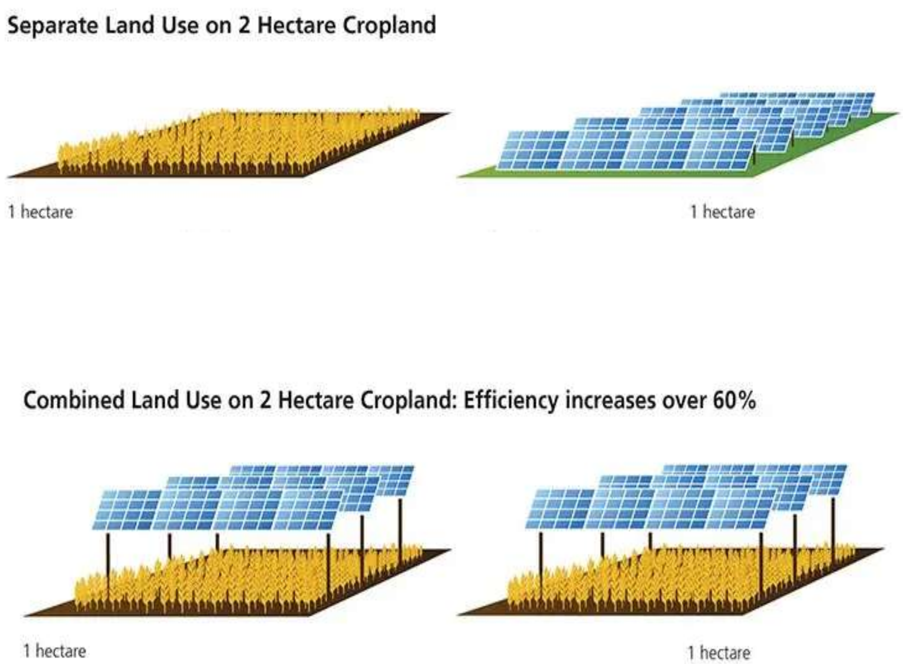




longroad ENERGY

Finding New Agricultural Uses

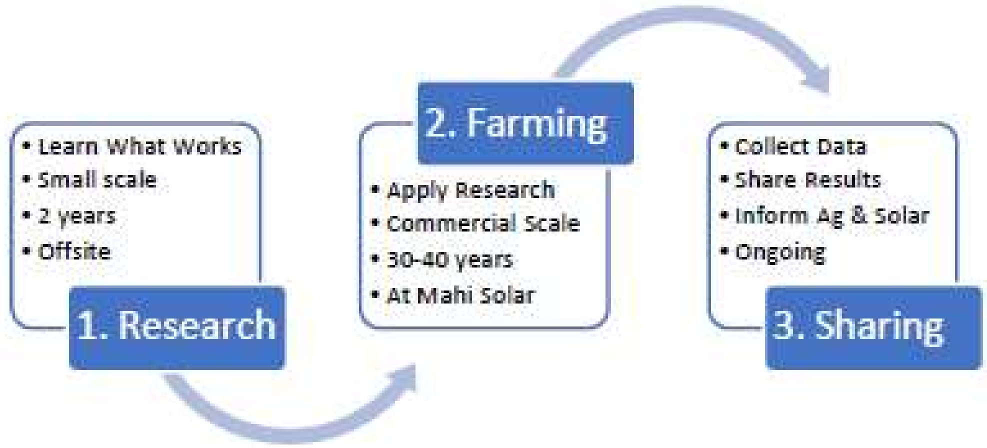
Helping farmers & ranchers find what grows best under/around solar panels



Mahi Solar is a Lab for Co-Use of Land

Investing in Research & Farming to find better ways to share land for both uses

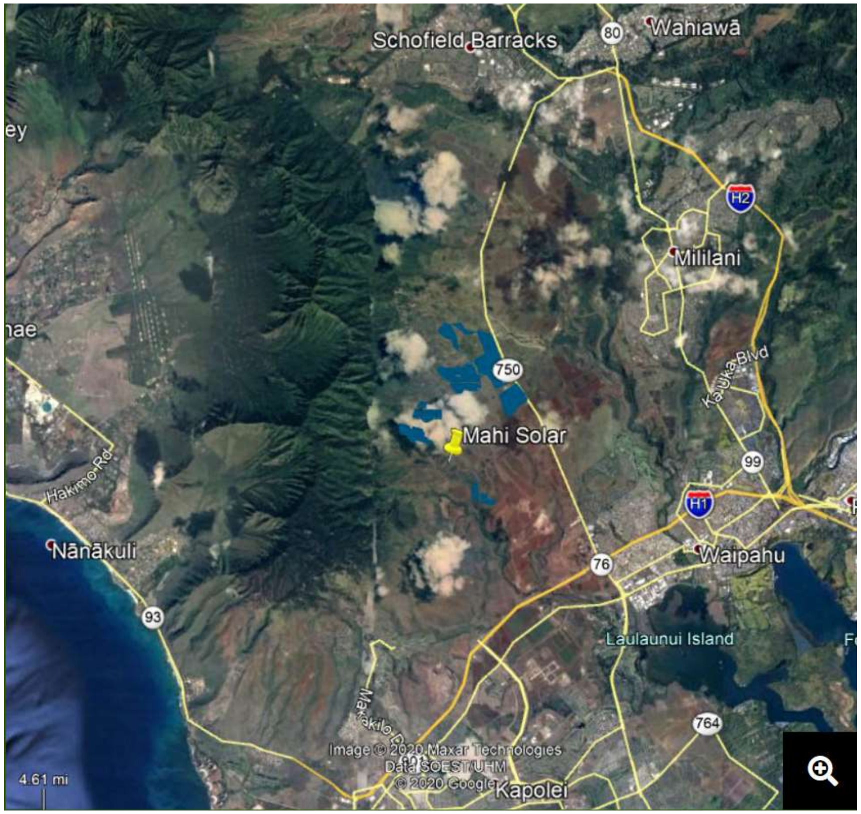
1. Hawaii Agricultural Research Center (HARC) will study what grows well under solar panels.
2. Local farmers grow crops, livestock. Mahi Solar will provide land and water and start-up funding.
3. Share research with other farmers and solar companies, to find more ways to co-locate farming and clean energy on the same land.



Community Outreach

Mahi Solar has engaged with community members all around the project

- Online community meetings
- Neighborhood Board meetings
- Community Associations
- Nonprofit farming organizations
- Cultural practitioners
- Government agencies & representatives



longroad ENERGY

Hawai‘i Revised Statutes (HRS), Chapter 205

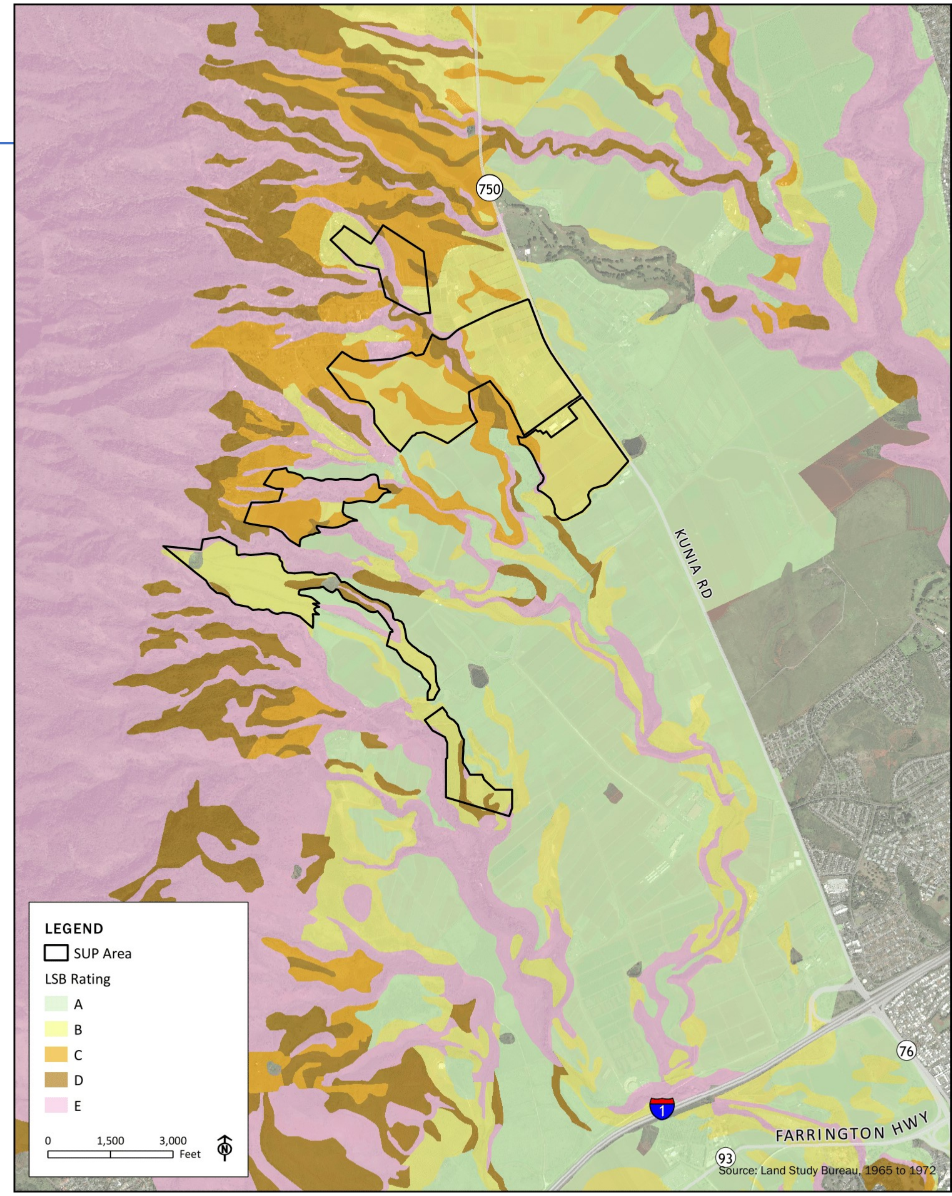
§205-4.5 Permissible uses within the agricultural districts. (a) Within the agricultural district, all lands with soil classified by the land study bureau's detailed land classification as overall (master) productivity rating class A or B shall be restricted to the following permitted uses:

(20) Solar energy facilities that do not occupy more than ten per cent of the acreage of the parcel, or twenty acres of land, whichever is lesser; provided that this use shall not be permitted on lands with soil classified by the land study bureau's detailed land classification as overall (master) productivity rating class A.

(21) Solar energy facilities on lands with soil classified by the land study bureau’s detailed land classification as overall (master) productivity rating B or C for which a special use permit is granted pursuant to section 205-6.

Land Study Bureau (LSB)

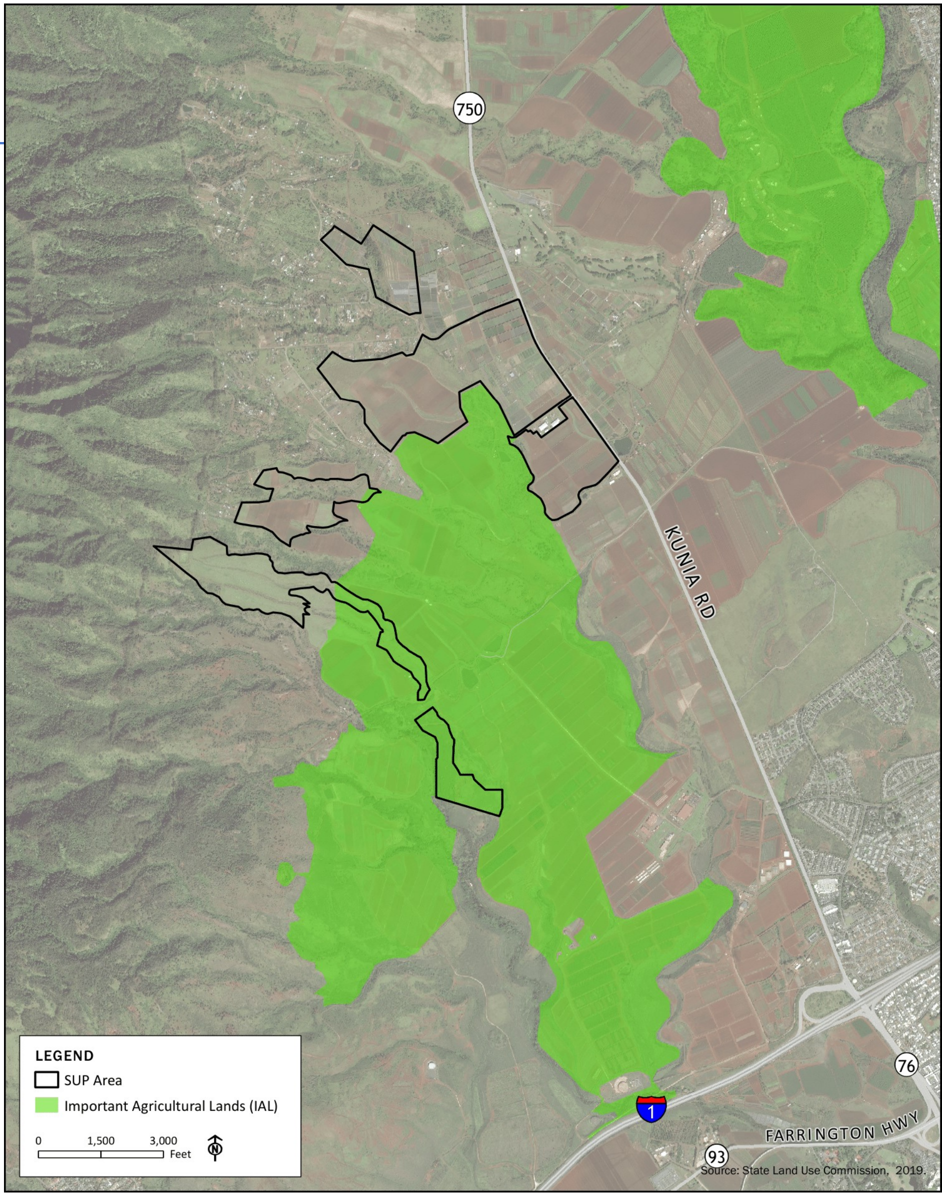
Table 4.1: Land Study Bureau (LSB) Soil Class by Area	
LSB Class	Acres
A	0
B	399.8
C	115.6
D	36.8
E	61.9
Unclassified	5.9
Total Area (acres):	**620**



longroad ENERGY

Important Agricultural Lands (IAL)

- 69.5 acres designated as IAL



Site Studies & Permits

Studies:

- Traffic study
- Reflectivity analysis
- Geotechnical investigations
- Boundary & topo survey
- Archaeological assessment
- Analysis of cultural practices
- Biological assessment
- Hydrology analysis
- Visual simulations

Permits:

- Special Use Permit
- Conditional Use Permit (Minor)
- SHPD Concurrence
- Grading Permits
- Building Permits

Mahi Solar

Kunia Road
(1.2 Miles Away)

longroad ENERGY

G70

February 24 , 2021

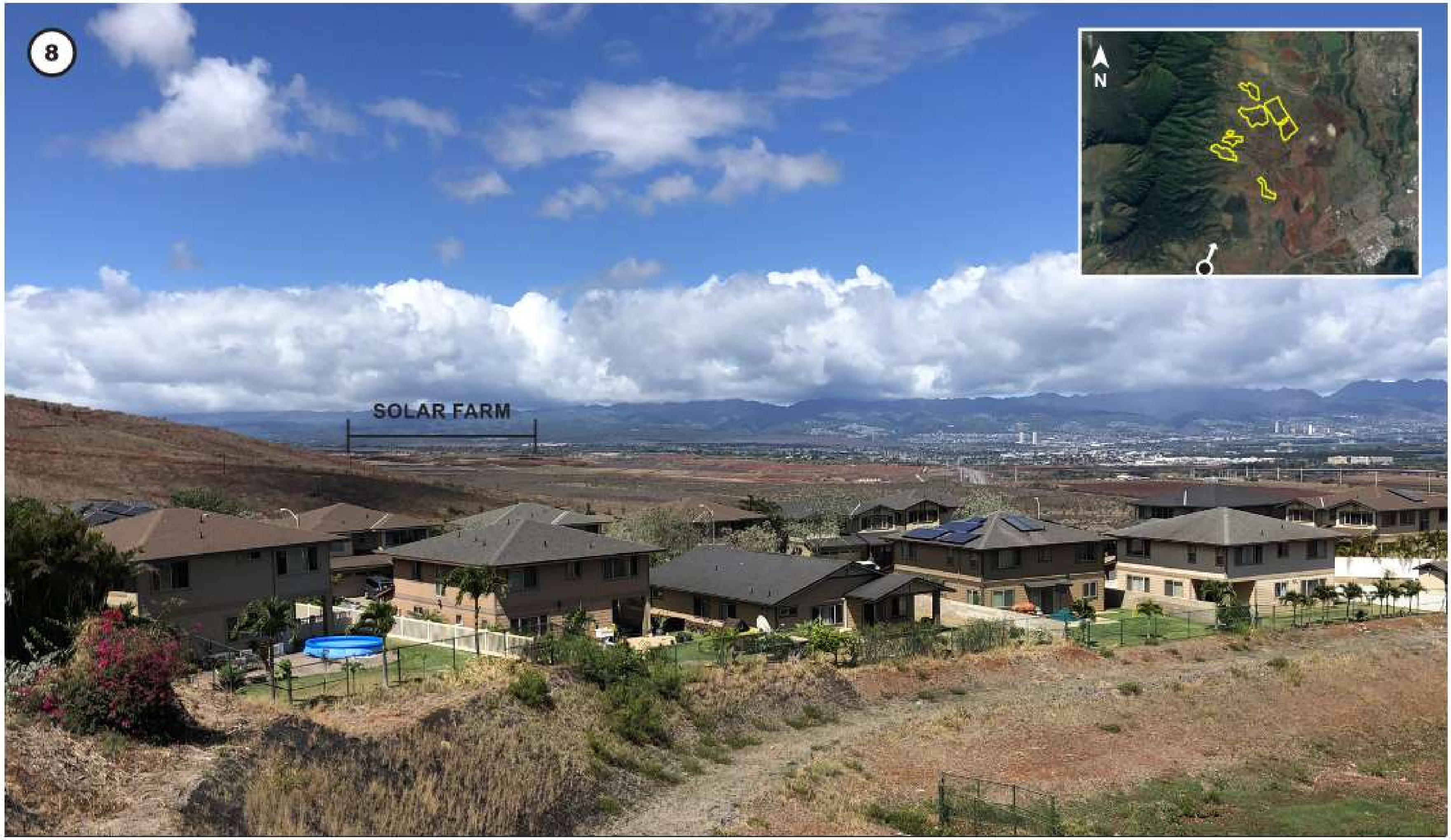
Mahi Solar

Kunia Road
(0.2 Miles Away)

longroad ENERGY

G70

February 24 , 2021



Mahi Solar

Makakilo Drive
(2.3 Miles Away)

longroad ENERGY

G70

February 24 , 2021

Mahi Solar

Niu Street, Mililani
(2.0 Miles Away)

longroad ENERGY

G70

February 24 , 2021

Mahi Solar

Kunia Road and Pālāwai Road
(0.1 Miles Away)

longroad ENERGY

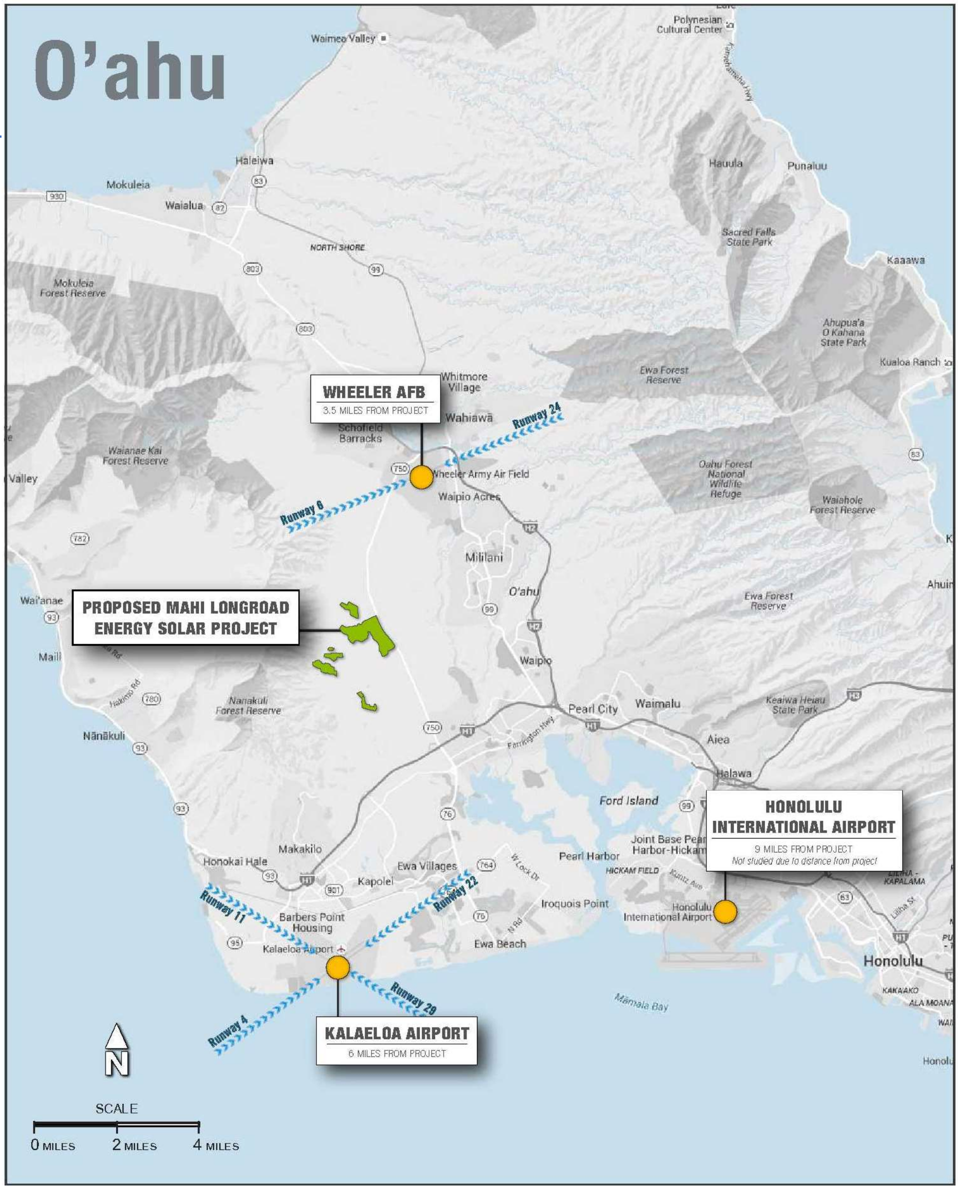
G70

February 24, 2021

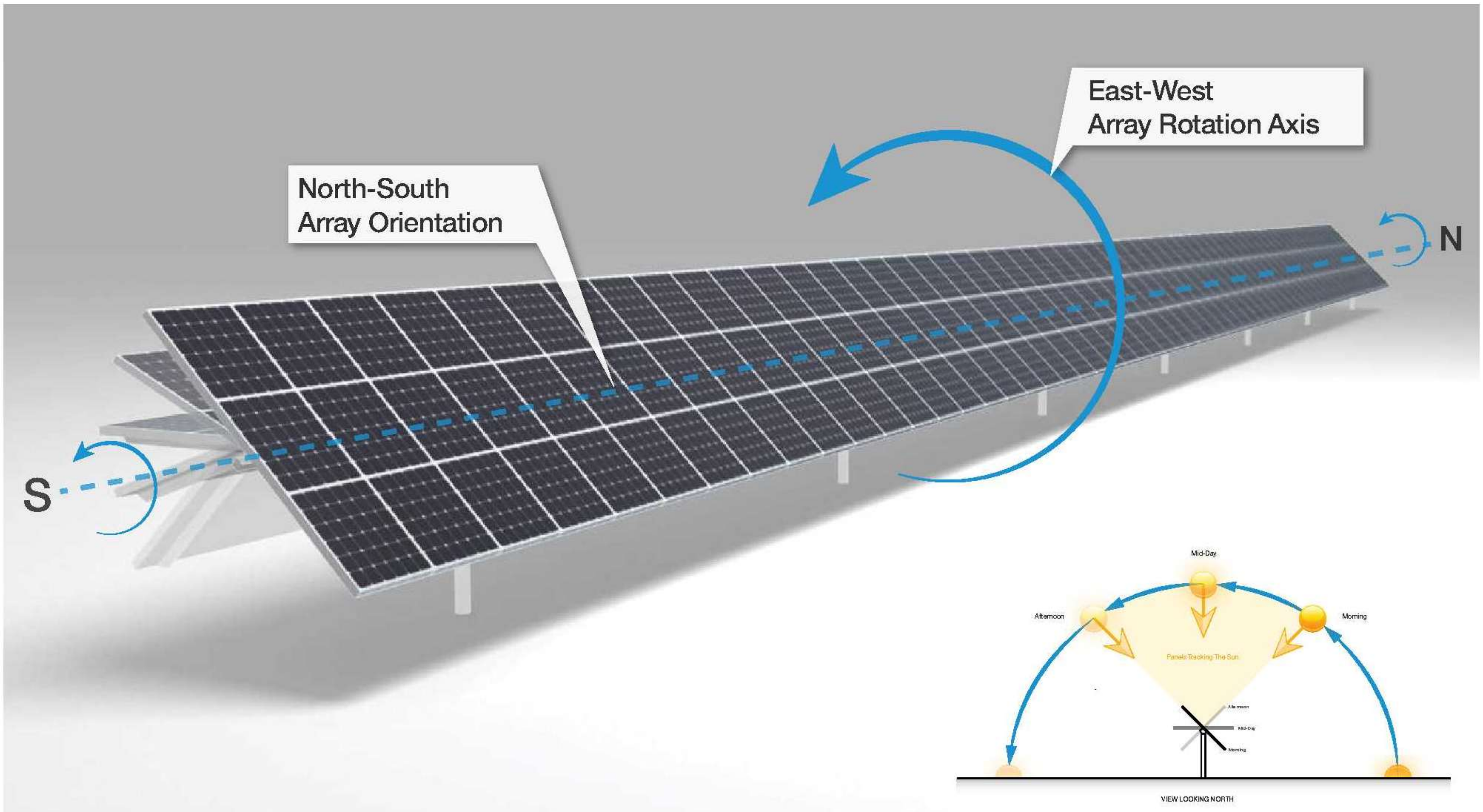
Glint & Glare Study

Sensitive Viewer Sites:

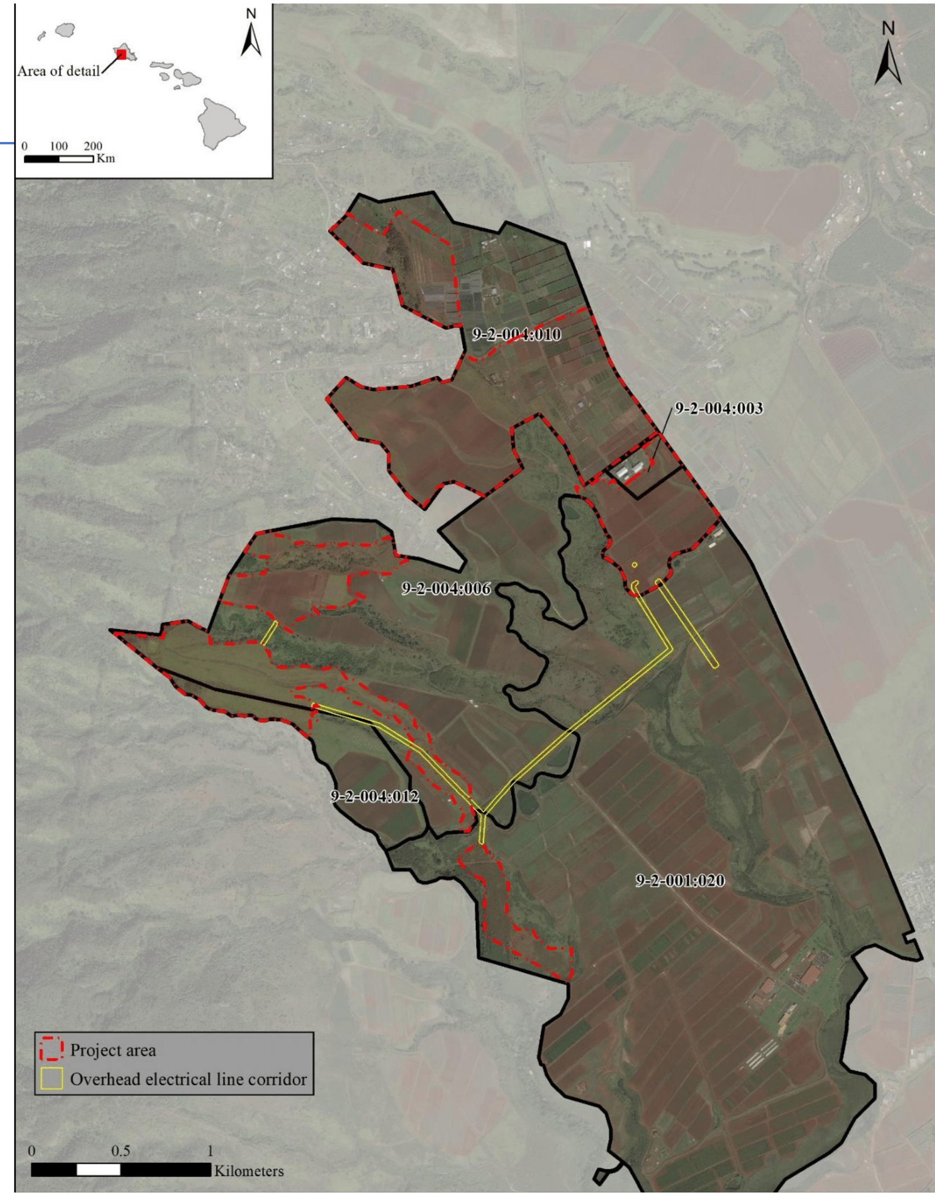
- Wheeler Air Force Base
- Honolulu International Airport
- Kalaeloa Airport



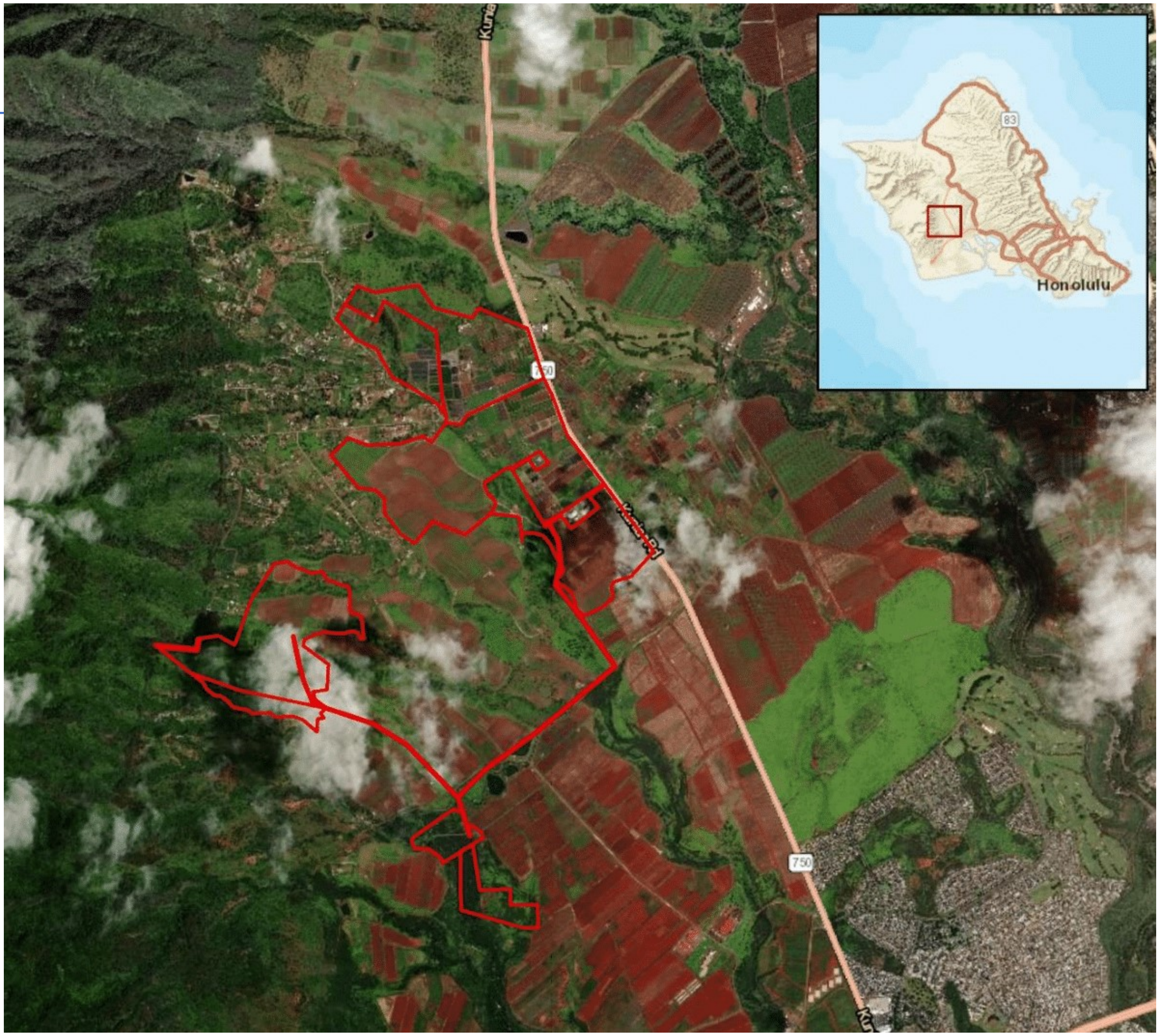
longroad ENERGY


East-West
Array Rotation Axis
North-South
Array Orientation
N
S
Mid-Day
Afternoon
Morning
Panels Tracking The Sun
VIEW LOOKING NORTH

Archaeological Assessment Study Area



Biological Resources Study Area



WRITTEN DIRECT TESTIMONY OF PAUL T. MATSUDA, P.E.
(Civil Engineering)

1. <u>Please state your name and business address for the record.</u>

Paul T. Matsuda, 111 S. King Street, Suite 170, Honolulu, Hawaiʻi 96813

2. <u>What is your current occupation?</u>

I am a Principal and the Director of Civil Engineering at Group 70 International, Inc.

3. <u>How long have you worked as a civil engineer?</u>

Over 28 years.

4. <u>Did you provide a copy of your resume for these proceedings?</u>

Yes, a copy of my resume was provided as ***Exhibit 17***.

5. <u>Please briefly describe your educational background.</u>

I have a Bachelor of Science in Civil Engineering from the University of Washington. I am a licensed professional civil engineer in Hawaiʻi, Oregon, and Washington. I am also a U.S. Green Building Council LEED accredited professional.

6. <u>To what professional organizations do you belong?</u>

I am a member of the American Society of Civil Engineers, Hawaiʻi Section; the American Council of Engineering Companies Hawaiʻi, the American Water Works Association, Hawaiʻi Section; and the U.S. Green Building Council, Hawaiʻi Chapter. I served as a board member and Building Committee Chair for Honolulu Habitat for Humanity and was awarded the Fran Brossy Lifetime Achievement Award in 2011. I am also a member of Pacific Business News' Forty under 40 Class of 2009.

7. <u>Do you specialize in any particular Area?</u>

I specialize in civil engineering, primarily site development, transportation, and utility infrastructure projects.

8. <u>Have you ever been qualified as an expert witness in civil engineering before the Planning Commission, Lane Use Commission, or in any other proceeding?</u>

Yes. I was qualified as an expert witness in land and use planning before the State of Hawaiʻi Land Use Commission in October 2014 for a 50-megawatt ("***MW***") utility scale solar project on Oahu.

9. What is your role in the proposed Mahi Solar Project (the "*Project*")?

I am the civil engineering designer of record for the project.

10. Describe the details of the proposed Project.

The 620-acre Project is projected to generate a total of 120 MW of energy, which is enough to power approximately 37,000 Oʻahu homes or 4 percent of the island's electricity annually and the project is estimated to avert the consumption of 11,111,800 barrels of oil and save Oʻahu consumers $175 million over a 25-year lifespan.

11. Briefly describe the proposed location of the Project.

The project is located in on five portions of TMKs (1) 9-2-001:020 and (1) 9-2-004: 003, 006, 010, and 012 in Kunia, Oʻahu, Hawaiʻi and totals approximately 620 acres. The site will be developed in five areas identified as Areas 1, 2, 3, 4A, 4B, 4C, and 5, across the five TMK parcels. The site lies within the traditional moku of ʻEwa and the ahupuaʻa of Honouliuli.

The project is situated on lands designed as Agricultural by the State of Hawaiʻi Land Use Commission.

12. How is the Project area zoned?

The project area is zoned as AG-1 Restricted Agricultural District by the City and County of Honolulu's Land Use Ordinance and is planned for "Agriculture Preservation" uses within both the City and County of Honolulu Central Oʻahu Sustainable Communities Plan and Ewa Development Plan.

13. Does the Project's propose use of the agricultural zoned lands for the solar farm an allowable use?

Yes, it would be an allowable use with approval of the State of Hawaii Special Use Permit and City and County of Honolulu (minor).

14. What are the past and current uses of the property?

The property was historically used for the commercial agriculture that included sugarcane and pineapple.

Today, the project site currently consists of actively farmed areas, undeveloped and fallow agricultural land, and overgrown vegetation.

15. What are the anticipated permits and approvals required for this Project?

For the State of Hawaiʻi the following permits are required: (i) SUP; (ii) National Pollutant Discharge Elimination System Permit, Form C for Construction Activities; (iii) Community Noise Permit; and (iv) Historic Preservation Review.

For the City and County of Honolulu the following permits are required: (i) Conditional Use Permit Minor for Utility Installation, Type B; (ii) Zoning Waiver Permit; (iii) Building Permit; (iv) Grading, Grubbing and Stockpiling Permit; and (v) Erosion and Sediment Control Plan, Storm Water Pollution Prevention Plan, Post-Construction Best Management Practices Plan.

16. What are the flood zones of the property?

The property is located in Flood Zone D, areas undetermined flood hazard.

17. Are wastewater facilities required for this Project?

No wastewater facilities are required as occupied facilities will not be located on the site.

18. How is water provided to the Project area?

Kunia Water Association provides agricultural water service to the site and surrounding agricultural lands.

19. Are domestic and fire protection water service required for the Project area?

No because the facility is unmanned and there are no occupied buildings planned for the project.

20. Will the on-site water demand be minimal?

Onsite water demand is anticipated to be minimal and limited to a drip irrigation system or the use of water trucks to provide start up irrigation for screening plants and will be designed into the solar farm to ensure compatibility with the operation and maintenance activities.

21. What is the storm drainage system in the Project area?

There is no City and County of Honolulu storm drainage system in the project vicinity. State of Hawaii storm drainage systems in the vicinity are limited to concrete culverts crossing Kunia Road. There is no subsurface drainage system on the project property.

Existing drainage infrastructure on the property is comprised of agricultural drainage ways and culverts that convey water from mauka areas through the property and to downstream properties and across Kunia Road. Stormwater eventually flows into the various tributaries of Honouliuli Stream.

22. Will water resources be affected by the project design?

No adverse effect to water resources, including Honouliuli Stream or its tributaries is anticipated.

23. How will stormwater runoff be addressed?

Stormwater runoff will be appropriately addressed through design features that incorporate temporary erosion controls and post-construction BMPs to minimize the quantity and water quality impacts of the runoff.

24. How will BMP's be identified?

In compliance with DOH's NPDES permit and DPP's Water Quality Rules, BMPs will be identified as part of a Temporary Erosion and Sediment Control Plan and Permanent Post-Construction BMP Plan.

25. Is the stormwater runoff expected to be minimal?

Yes, given the relatively short duration of construction and with the implementation of BMP's, the potential for sedimentation or increased pollutants in stormwater runoff is expected to be minimal.

26. Will the construction and operation of the project generate a significant amount of waste?

No.

27. How will the Project be developed?

The project will be developed as a Utility Installation, Type B and will provide 120 MW of solar electricity and 480 Megawatt-hours ("***MWh***") of battery storage.

28. Please explain the Project Components.

The project includes ground-mounted, single-axis tracking photovoltaic ("***PV***") arrays, a 480 MWh BESS, and a 34.5 kilovolt ("***kV***")/138 kV substation. The project will interconnect through a new 138 kV switchyard, also called a "switching station" adjacent to the existing Kahe-Waiau 138 kV transmission circuit west of Kunia Road. The 138kV transmission line is not currently serving other renewable projects, and no additional easements or rights of way are required.

29. Please explain the type of solar panels that will be installed.

Each panel is approximately 48 inches wide and 79 inches long, dark in color, and stands approximately 6 to 8 feet above ground level when flat (0-degree tilt). At maximum rotation or 50-degree tilt, the height of the panel reaches approximately 9 to 12 feet high and is approximately 1 to 3 feet off of the ground. Each PV panel is made up of thin-film Cadmium Telluride ("***CdTe***") semiconductor cells or equivalent. The cells are linked together and function as a single unit.

30. How will the solar panels be installed?

The PV panels will be installed on single-axis trackers aligned north-south which will vary in length. The trackers will rotate the panels to follow the sun during the day to maximize solar exposure to the face of the module. Trackers are supported by steel pile foundations at intervals. The PV panels may be mounted in either a portrait or landscape orientation, in single or double combination. Based on the preliminary design criteria for the project, there will be approximately one foundation for every eight-to-ten panels. Foundation spacing will be dependent upon the final chosen panel orientation. The array will have approximately 370,000 ground mounted PV panels, for a combined capacity of 120MW (AC).

31. Please explain how the panels will be mounted.

PV panels will be mounted on a rack with steel and aluminum construction and will be designed with a wind resistance to meet wind loading requirements per the adopted building code. There will be an approximately 9-foot-wide aisle between adjacent arrays of panels when they are in the horizontal position or 0-degree tilt.

32. How will the panels be connected?

The project's PV panels will be connected in series, referred to as a "string". The maximum string size is limited by a maximum system voltage of 1,500 volts direct current ("***VDC***"). For this project's design, a string is a DC circuit of approximately 6 panels each. Each string is connected to a combiner box with a fused disconnect. Typically, a group of approximately 16-30 strings will be connected at the combiner boxes and are limited by the 400A fuse size. A group of approximately 20-30 combiner boxes are connected via DC feeders into a DC/alternating current ("***AC***") inverter which connects to the AC power system.

33. What does the AC power system consist of?

The AC power system consists of pad-mounted equipment, including the inverters, step up transformer and communication equipment, which increases the power from 400-600 volts to a medium voltage of approximately 34.5 kV. Each pad will tie into the 34.5 kV collector system which terminates at the high-voltage AC substation, whereby the voltage will be increased to 138 kV.

34. **<u>Will the substation connect to a switchyard?</u>**

Yes, the substation connects to a new adjacent 138 kV switchyard. The new 138 kV switchyard will connect to the existing HECO utility line at the property.

35. **<u>Do the inverters contain a safety protocol?</u>**

Yes, the inverters contain a safety protocol that automatically shuts off the PV facilities in the event the HECO grid loses power. This prevents adverse effects on grid operation, and electricity from leaving the PV facilities and injuring utility line workers who may be working on a nearby power line.

36. **<u>What protective devises and safety protocols will be implemented at the PV facility?</u>**

The PV facility will integrate protective devices for safe operation, and a Supervisory Control and Data Acquisition ("***SCADA***") which includes a central system controller, generating station protocols, and sensors to perform plant control and system operation. The SCADA system will allow for remote monitoring and control of select facility functions.

37. **<u>Will the PV systems be interconnected with a substation?</u>**

Yes, the PV systems will be interconnected with a substation located in Area 3 at the southwest corner of the project area.

38. **<u>When will electrical power be produced?</u>**

Electrical power from the PV system will be produced during daylight hours.

39. **<u>Where will electrical power be stored?</u>**

Power from the PV system may be stored in the BESS and may be discharged from the BESS at any time of day or night.

40. **<u>Where will the BESS be located?</u>**

The BESS will be located in Area 3 of the Project.

41. **<u>Please explain the BESS system.</u>**

The BESS system provides a four-hour discharge duration and storage capacity of 120 MW/480 MWh. The BESS consists of lithium-ion battery cells that are connected in series into a battery module or array. The battery modules are typically stacked and connected into vertical racks containing several modules. The racks are then collected via cables and fed into DC to AC converters that feeds into the Battery Energy Storage inverter. The battery energy storage transformer steps up the voltage from the BESS inverter from 400–600V to 34.5kV. The battery energy system will typically come equipped with controls and communications systems that integrate into the plant's SCADA, including a battery management system to monitor battery state of health and operations. The battery racks will be stored in cabinets/enclosures and laid on top of a gravel pad. The enclosures will contain an internal thermal management system and/or HVAC units to support battery temperature management. The battery enclosures are also rated for outdoor use. Each BESS container is approximately 15 feet high.

42. <u>What type of operational support facilities will the project consist of?</u>

The operational support facilities will consist of an outdoor electrical substation, switchyard, and two control enclosures. The support facilities will be located in Area 3.

43. <u>What will be the medium voltage AC output from the solar project?</u>

At the substation, the medium voltage AC output from the solar project 138 kV and interconnected to the new HECO-owned switchyard.

44. <u>Please explain the control enclosures.</u>

There will be two control enclosures, each with an area of approximately 798 square feet, and a height of approximately 13 feet. The control enclosures will house the PV and BESS plant control systems, HECO remote terminal units, communications equipment, and relays and meters. Within the control enclosures, there will be a small battery system to serve as a back-up power system for data collection.

45. <u>Please explain an inverter station.</u>

The project will also include 32 PV inverter stations. The inverter stations will be located within the PV solar array field and include inverters and medium voltage transformers. Inverters rated at 3.95-4.2 MW-AC will be used to convert the DC electricity from the PV modules to AC. The AC electricity will be stepped up with a medium voltage transformer at the inverter station and connected to the substation by an underground or overhead medium voltage line.

46. <u>What is the total building area for the facilities and equipment at the project site?</u>

The total building area or lot coverage of the facilities and equipment at the project site will be approximately 6,495,188 square feet (approximately 149.1acres).

47. Are the structures and equipment governed by AG-1 Restricted Agricultural District development requirements?

Yes, the structures and equipment will be governed by AG-1 Restricted Agricultural District development requirements such as lot coverage, setbacks, and height restrictions.

48. How will the project be integrated into HECO's grid?

The project will be interconnected to HECO's Kahe-Waiau 138 kV transmission circuit located west of Kunia Road. The medium voltage collection system will transmit generation from the solar array inverters to the BESS and substation along overhead lines to be installed as part of the project.

49. How will the collector lines be installed?

The collector lines will be installed on new wooden structures along existing roadways, where required to comply with existing land use regulations, and then will cross the existing 138 kV lines underground to the BESS yard and project substation.

50. How will the BESS and substation be connected to the HECO switchyard?

The BESS and substation will be connected to the HECO-owned switchyard via an overhead bus structure. A short extension of the adjacent Kahe-Waiau circuit will extend both transmission lines into a proposed ring bus in the switchyard.

51. Will the Kahe-Waiau circuit be the primary Point of Interconnection ("*POI*")?

The Kahe-Waiau circuit is expected to be the primary POI since the 138 kV line located in the vicinity can accommodate the full output of the project without requiring a more elaborate interconnection scheme.

52. Is an alternative generation tie line ("*gen-tie*") route being considered for the Project?

Yes, at the request of HECO, an alternative gen-tie route and substation/switchyard/ BESS location is being considered for the project. The alternative would require the substation and BESS yard to be relocated to the southwest corner of Area 3. The same number of panels would be included in the project and shifted from Area 3 to Area 5. The alternative route would interconnect to a HECO switchyard proposed at the Hoʻohana Solar project site, located directly across Kunia Road to the southeast of the project.

53. Are gen-tie poles permitted use within the AG-1 Restricted Agricultural Zoning District?

Yes, gen-tie poles permitted use within the AG-1 Restricted Agricultural Zoning District

54. **<u>Is the design of the site, structures and fire access for the project based on applicable requirements of the State of Hawaii Fire Code.</u>**

Yes. Appropriate clear areas are incorporated throughout the site. Fencing will be provided around the perimeter of the PV panel areas, at the project substation, HECO switchyard, and BESS area. Batteries will be installed in self-contained enclosures that are constructed across an open-air gravel pad. The self-contained enclosures are remotely monitored and are intended to contain/suppress fires with no active fire response necessary from the Honolulu Fire Department ("***HFD***"). Coordination with the HFD will occur throughout the project design and permit process to ensure adequate access and fire code requirements are met.

55. **<u>Will the Project area need to be cleared and graded?</u>**

Minimal clearing and grading will need to be done in the project area for the access roads and leveling of uneven terrain.

56. **<u>Describe the landscaping proposed for the project site.</u>**

Minimal landscaping will be done with primary concentration on the eastern boundary of the project site along Kunia Road. Landscaping will include plants suitable for the Kunia climate and will include native Hawaiian or Polynesian-introduced species.

57. **<u>What type of irrigation system will be used?</u>**

A drip irrigation system or watering via water trucks will be used to irrigate the required screening plants thereby minimizing runoff and soil erosion as low volumes of water will be directed at individual plants near the soil surface.

Respectfully submitted,

[signature]

PAUL T. MATSUDA, P.E.

DATED: Honolulu, Hawaiʻi, June 21, 2021.