Authorization Dean Uchida, Director
Advertisement N/A
Public Hearing June 23, 2021

DEPARTMENT OF PLANNING AND PERMITTING
CITY AND COUNTY OF HONOLULU
650 SOUTH KING STREET, 7TH FLOOR • HONOLULU, HAWAII 96813
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21 JUN 21 P5:37
DEPT OF PLANNING AND PERMITTING
CITY & COUNTY OF HONOLULU

RICK BLANGIARDI
MAYOR

DEAN UCHIDA
DIRECTOR

DAWN TAKEUCHI APUNA
DEPUTY DIRECTOR

EUGENE H. TAKAHASHI
DEPUTY DIRECTOR

2020/SUP-7(FK)

June 21, 2021

MEMORANDUM

TO: Brian Lee, Chair
and Members of the Planning Commission

FROM: Franz Kraintz, Acting Branch Chief
Planning Division

SUBJECT: Special Use Permit (SUP) Petition File No. 2020/SUP-7
Mahi Solar, LLC for a 120-Megawatt Solar Energy Generation Facility plus a 480-Megawatt-Hour Battery Energy Storage System and ancillary support facilities (Project)
Honouliuli, Ewa District, Oahu
Tax Map Keys 9-2-001: 020 portion, 9-2-004: 003 portion, 9-2-004: 006 portion, 9-2-004: 010 portion, and 9-2-004: 012 portion

Attached are comments from agencies that arrived after the Director's Report was submitted to the Planning Commission on May 20, 2021. They include comments from the:

1. Board of Water Supply, City and County of Honolulu
2. Department of Emergency Management, City and County of Honolulu
3. State Historic Preservation Division, State Department of Land and Natural Resources
4. Department of Business, Economic Development, and Tourism, State of Hawaii
5. U. S. Fish and Wildlife Service
6. Hawaii Agriculture Research Center

In addition, written follow-up testimony was submitted by the:

1. State Energy Office, State of Hawaii
2. Department of Agriculture, State of Hawaii

Should you have any questions, please contact me at (808) 768-8046 or by email at fkraintz@honolulu.gov.

Enclosures

BOARD OF WATER SUPPLY

CITY AND COUNTY OF HONOLULU
630 SOUTH BERETANIA STREET
HONOLULU, HI 96843
www.boardofwatersupply.com

2021 JUN -1 PM 1:45
DEPT OF PLANNING AND PERMITTING
CITY & COUNTY OF HONOLULU

May 28, 2021

TO: RAYMOND YOUNG, ACTING COMMUNITY PLANNING BRANCH CHIEF
DEPARTMENT OF PLANNING AND PERMITTING

ATTN: FRANK KRAINTZ

FROM: ERNEST Y. W. LAU, P.E., MANAGER AND CHIEF ENGINEER

SUBJECT: YOUR MEMORANDUM DATED APRIL 9, 2021 ON THE APPLICATION FOR SPECIAL USE PERMIT (2020/SUP-7) FOR THE PROPOSED MAHI SOLAR PROJECT ON KUNIA ROAD IN EWA – TAX MAP KEY: 9-2-001: 020 (por.), 9-2-004: 003 (POR.), 9-2-004: 006 (POR.), 9-2-004: 010 (POR.), AND 9-2-004: 012 (POR.)

The Honolulu Board of Water Supply (BWS) does not have any water system located within the project area. All water services shall be provided by the private water system.

The project area is located in the BWS No Pass Zone where ground disposal of wastewater could detrimentally impact the underlying freshwater aquifer. BWS has several pumping stations downgradient of the project area. Best Management Practices (BMP) should be used to prevent the contamination of the underlying aquifer from the percolation of fertilizers, pesticides and herbicides.

If you have any questions, please contact Robert Chun, Project Review Branch of our Water Resources Division at 748-5443.

Kraintz, Franz

From: Jacinto-Kawabata, Marie
Sent: Thursday, June 10, 2021 2:45 PM
To: Kraintz, Franz
Subject: 2020/SUP-7 Mahi Solar Project

Mr. Kraintz,

Sorry for the late response. Director Toiya has no comments on Mahi Solar Project.

Mahalo,

Marie Jacinto-Kawabata
Clerk
City & County of Honolulu
Department of Emergency Management
808-723-8960

DAVID Y. IGE
GOVERNOR OF HAWAII

SUZANNE D. CASE
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

ROBERT K. MASUDA
FIRST DEPUTY

M. KALEO MANUEL
DEPUTY DIRECTOR - WATER

AQUATIC RESOURCES
BOATING AND OCEAN RECREATION
BUREAU OF CONVEYANCES
COMMISSION ON WATER RESOURCE MANAGEMENT
CONSERVATION AND COASTAL LANDS
CONSERVATION AND RESOURCES ENFORCEMENT
ENGINEERING
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
KAHOOLAWE ISLAND RESERVE COMMISSION
LAND
STATE PARKS

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES

STATE HISTORIC PRESERVATION DIVISION
KAKUHIHEWA BUILDING
601 KAMOKILA BLVD, STE 555
KAPOLEI, HAWAII 96707

TO: Public, Consulting Parties. Federal, State and City Agencies

FROM: Alan S. Downer, Administrator AD

RE: SHPD Migration of Submittals to the Hawaii Cultural Resource Information System (HICRIS)

DATE: November 30, 2020

Aloha,

The State of Hawaii Historic Preservation Division is in the process of moving to an online submission system. The Hawaii Cultural Resource Information System (HICRIS) will be the only way for SHPD to accept and process submittals. We are not accepting submissions currently, while we migrate the data from our existing systems to HICRIS. The transition period is from November 28 to December 16, 2020. Additional information on HICRIS and the launch date can be found on our website. http://dlnr.hawaii.gov/shpd/

Mahalo,

Alan Downer

Alan S. Downer, Administrator

Kraintz, Franz

From: Shiroma, Robin K <robin.k.shiroma@hawaii.gov>
Sent: Thursday, June 10, 2021 4:18 PM
To: Wong, Dina L
Cc: Kraintz, Franz; Hipolito, Ailene
Subject: RE: SUP Application No. 2020SUP-70 - Comments from HSEO
Attachments: DBEDTCommentsMahiSUP_2021-05-25_r .pdf

CAUTION: Email received from an EXTERNAL sender. Please confirm the content is safe prior to opening attachments or links.

Hi Dina,

Thank you for the email, apologies, for not attaching the letter. ☹ Please see attached.

Have a good weekend!

Thank you,

Robin Shiroma

Hawaii State Energy Office
235 S. Beretania St., 5th Fl.
Honolulu, HI 96813
Phone: (808) 587-3807

From: Wong, Dina L <dwong6@honolulu.gov>
Sent: Thursday, June 10, 2021 4:09 PM
To: Shiroma, Robin K <robin.k.shiroma@hawaii.gov>
Cc: Kraintz, Franz <fkraintz@honolulu.gov>; Hipolito, Ailene <ailene.hipolito@honolulu.gov>
Subject: [EXTERNAL] FW: SUP Application No. 2020SUP-70 - Comments from HSEO

Hello Robin:
The email below to Ray Young did not have the attachment. He is on leave for the remainder of June. Could you please resend with the attachment to me and those copied on this email?

Thank you,
Dina

From: Shiroma, Robin K [mailto:robin.k.shiroma@hawaii.gov]
Sent: Thursday, June 03, 2021 3:02 PM
To: Young, Raymond
Cc: Black, Cameron B; Kamaka, Ranette I; Fisher, Zenaida C
Subject: SUP Application No. 2020SUP-70

CAUTION: Email received from an EXTERNAL sender. Please confirm the content is safe prior to opening attachments or links.

Hello Mr. Young,

On behalf of Director Mike McCartney, please see the attached comments for the Mahi Solar Project.

Thank you,

Robin Shiroma

Hawaii State Energy Office
235 S. Beretania St., 5th Fl.
Honolulu, HI 96813
Phone: (808) 587-3807

DAVID Y. IGE
GOVERNOR

MIKE MCCARTNEY
DIRECTOR

CHUNG I. CHANG
DEPUTY DIRECTOR

DEPARTMENT OF BUSINESS, ECONOMIC DEVELOPMENT & TOURISM

No. 1 Capitol District Building, 250 South Hotel Street, 5th Floor, Honolulu, Hawaii 96813
Mailing Address: P.O. Box 2359, Honolulu, Hawaii 96804
Web site: dbedt.hawaii.gov

Telephone: (808) 586-2355
Fax: (808) 586-2377

May 25, 2021

Via email: rcsyoung@honolulu.gov
Mr. Raymond Young
Acting Branch Chief
City and County of Honolulu
Department of Planning and Permitting, Community Planning Branch

Dear Mr. Young:

Subject: DBEDT Comments on Special Use Permit (SUP) Application No. 2020/SUP-7
Mahi Solar Project
Tax Map Keys 9-2-001: 020 portion, 9-2-004:003 portion,
9-2-004:006 portion, 9-2-004:010 portion, and 9-2-004:012 portion,
Honouliuli, ʻEwa, Oʻahu

The Hawaiʻi Department of Business, Economic Development & Tourism (DBEDT) offers the following comments on the Special Use Permit (SUP) Application for the Mahi Solar Project (Project) proposed by project developer Longroad Energy (Mahi Solar, LLC) on 620 acres across five (5) different parcels in Kunia, Oʻahu. The Project would be a 120-megawatt (MW) alternating current solar photovoltaic (PV) project with a 120 MW/480 megawatt-hour battery energy storage system consisting of approximately 362,000 ground-mounted PV modules mounted on 4,300 single-axis trackers, thirty-two four MW inverters, an overhead 34 kilovolt (kV) collector line, a 34.5/138 kV substation, and possibly an additional 138 kV collector line.

DBEDT is Hawaiʻi's resource center for economic and statistical data, business development opportunities, energy and conservation information, and foreign trade advantages. DBEDT's mission continues to be achieving a Hawaiʻi economy that embraces innovation and is globally competitive, dynamic and productive, providing opportunities for all Hawaiʻi's citizens. Through its attached agencies, DBEDT fosters planned community development, creates affordable workforce housing units in high-quality living environments, and promotes innovation sector job growth. As DBEDT and its attached agencies represent a variety of State interests and duties, DBEDT encourages the Department of Planning and Permitting and the Hawaiʻi Land Use Commission (LUC) to take a holistic view when considering the subject SUP. DBEDT acknowledges comments may be submitted separately by its attached agencies such as the Hawaiʻi Office of Planning and Hawaiʻi State Energy Office.

The State of Hawaiʻi's heavy reliance on imported food and energy makes it vulnerable to major disruptions beyond its control. The judicious planning and use of Hawaiʻi's limited land resources is necessary to achieve food and energy security. According to the Hawai'i Department of Agriculture (DOA), the majority of the land area under the project site contains some of the State's most potentially productive soils for intensive agricultural production. Accordingly, DBEDT recommends the LUC consider the recommendations provided by DOA regarding water demand information, the inclusion of the soft hose irrigation system, fencing, clarity on the linking and implementation of all three phases of the Project's Agricultural Plan, agreements in place with slaughter facilities, and the Project's overall commitment to long-term, economically viable, and productive agriculture.

Looking at the socio-economic impacts, the SUP states the Project would save O'ahu electricity consumers $175 million over its 25-year lifespan. Longroad estimates the Project would create more than 200 jobs during construction and another 2-3 long-term positions during operations.[1] These are tangible benefits of the Project in addition to the indirect economic impacts caused by the estimated ratepayer's savings and spending from the jobs created. Socio-economic impacts are only part of the over impact the Project would have on O'ahu's greater population.

Should you have any questions regarding these comments, please feel free to contact me at 586-2355.

With aloha,

Mike McCartney

Mike McCartney

[1] https://www.longroadenergy.com/mahi/

Kraintz, Franz

From: Salbosa, Lasha-lynn H <lasha-lynn_salbosa@fws.gov>
Sent: Wednesday, June 16, 2021 3:20 PM
To: Kraintz, Franz
Subject: FW: [EXTERNAL] Mahi Solar Project - Kunia, Honouliuli, Ewa District, Oahu, Hawaii
Attachments: City, State, and Federal Agency RFC memo.doc; Project Summary for Mailout.docx

CAUTION: Email received from an EXTERNAL sender. Please confirm the content is safe prior to opening attachments or links.

Aloha Franz,

Thank you for your email below. The USFWS has reviewed the State of Hawai'i Special Use Permit (SUP) Application proposal for the Mahi Solar Project. We do not have any additional comments other than what is presented in sections 4.4.1 and 4.4.3 of the proposal.

Thank you,
Lasha

Lasha-Lynn Salbosa, Renewable Energy Program/HCP Coordinator
U.S. Fish and Wildlife Service, Ecological Services
Pacific Islands Fish and Wildlife Office
300 Ala Moana Blvd Rm 3-122
Honolulu, HI 96850
808-792-9442 office (*calls forwarded to mobile.)
808-792-9580 fax

INTERIOR REGION 12 • Pacific Islands
American Samoa, Guam, Hawai'i, Northern Mariana Islands

From: Kraintz, Franz <fkraintz@honolulu.gov>
Sent: Monday, May 10, 2021 10:15 AM
To: PIFWO_Admin, FW1 <pifwo_admin@fws.gov>
Subject: [EXTERNAL] Mahi Solar Project - Kunia, Honouliuli, Ewa District, Oahu, Hawaii

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

Aloha

In review of our document analyzing the Mahi Solar Project, a 120MW solar generating facility and a 480 MW BESS about 2 miles north of H-1, I noticed that our request for comments to the US Department of the Interior went to the Water Resources Division and not the Fish and Wildlife Service. Attached please find more information for the project. Come to find out the primary contact, Becca Frager, is no longer with the USFWS.

Unfortunately, the comment period on the Special Use Permit (SUP) for this project ends today, Monday the 10th. However, we do have the USFWS general comments on the biological resources in the area from the AES EIS completed last July. While these comments give us a general idea of USFWS concerns, you may still want to provide a response directly regarding this proposal and we can include them with our presentation to the Planning Commission at the public hearing scheduled June 23, 2021.

Let me know if you have any further questions or comments. Mahalo.

Franz Kraintz, AICP
Urban Planner
Community Planning Branch
Planning Division
Department of Planning and Permitting
City and County of Honolulu
650 S. King Street, 7th Floor
Honolulu, Hawaii 96813
(808) 768-8046
fkraintz@honolulu.gov
www.honoluludpp.org

Hawaii Agriculture Research Center
P.O. Box 100, Kunia, HI 96759
Ph: 808-621-1350
www.harc-hspa.com

HARC

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

Alexis S. Pascaris [1,*], Chelsea Schelly [1] and Joshua M. Pearce [2,3,4]

1 Department of Social Sciences, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931, USA; cschelly@mtu.edu
2 Department of Materials Science and Engineering, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931, USA; pearce@mtu.edu
3 Department of Electrical & Computer Engineering, Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931, USA
4 School of Electrical Engineering, Aalto University, Aalto, 02150 Espoo, Finland
* Correspondence: aspascar@mtu.edu; Tel.: 906-487-2113

Received: 21 October 2020; Accepted: 24 November 2020; Published: 28 November 2020

check for updates

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 Crop farmer: 1 Solar grazer: 4 Policy: 1	North East: 4 South East: 1 Midwest: 5 South West: 1	Male: 5 Female: 6

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?

References

1. Ciais, P.; Sabine, C.; Bala, G.; Bopp, L.; Brovkin, V.; Canadell, J.; Chhabra, A.; DeFries, R.; Galloway, J.; Heimann, M.; et al. Carbon and Other Biogeochemical Cycles. In *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P.M., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2013.
2. Dupraz, C.; Marrou, H.; Talbot, G.; Dufour, L.; Nogier, A.; Ferard, Y. Combining solar photovoltaic panels and food crops for optimising land use: Towards new agrivoltaic schemes. *Renew. Energy* **2011**, *36*, 2725–2732. [CrossRef]
3. Dinesh, H.; Pearce, J.M. The potential of agrivoltaic systems. *Renew. Sustain. Energy Rev.* **2016**, *54*, 299–308. [CrossRef]
4. Mavani, D.D.; Chauhan, P.M.; Joshi, V. Beauty of Agrivoltaic System regarding double utilizati on of same piece of land for Generation of Electricity & Food Production. *Int. J. Sci. Eng. Res.* **2019**, *10*.
5. Calvert, K.; Mabee, W. More solar farms or more bioenergy crops? Mapping and assessing potential land-use conflicts among renewable energy technologies in eastern Ontario, Canada. *Appl. Geogr.* **2015**, *56*, 209–221. [CrossRef]
6. Mow, B. Solar Sheep and Voltaic Veggies: Uniting Solar Power and Agriculture|State, Local, and Tribal Governments|NREL [WWW Document], n.d. URL. 2018. Available online: https://www.nrel.gov/state-local-tribal/blog/posts/solar-sheep-and-voltaic-veggies-uniting-solar-power-and-agriculture.html (accessed on 2 July 2020).
7. Adeh, E.H.; Good, S.P.; Calaf, M.; Higgins, C.W. Solar PV Power Potential is Greatest Over Croplands. *Sci. Rep.* **2019**, *9*, 11442. [CrossRef]
8. Renewable Energy World (REW). Getting Out of the Weeds: How to Control Vegetative Growth under Solar Arrays. 2014. Available online: https://www.renewableenergyworld.com/articles/2014/07/weed-control-at-solar-installations-what-works-best.html (accessed on 7 February 2020).
9. Ouzts, E. Farmers, Experts: Solar and Agriculture 'Complementary, not Competing' in North Carolina [WWW Document]. Energy News Network. 2017. Available online: https://energynews.us/2017/08/28/southeast/farmers-experts-solar-and-agriculture-complementary-not-competing-in-north-carolina/ (accessed on 2 July 2020).
10. Andrew, A.C. *Lamb Growth and Pasture Production in Agrivoltaic Production System*; Oregon State University: Corvallis, OR, USA, 2020.

11. Dunbar, E. Pollinator-Friendly Solar Energy Becomes the Norm in Minnesota. 2019. Available online: https://www.mprnews.org/story/2019/06/20/pollinatorfriendly-solar-energy-becomes-the-norm-in-minnesota (accessed on 23 September 2020).
12. Lytle, W.; Meyer, T.K.; Tanikella, N.G.; Burnham, L.; Engel, J.; Schelly, C.; Pearce, J.M. Conceptual Design and Rationale for a New Agrivoltaics Concept: Pastured-Raised Rabbits and Solar Farming. *J. Clean. Prod.* **2020**, 124476. [CrossRef]
13. Pringle, A.M.; Handler, R.M.; Pearce, J.M. Aquavoltaics: Synergies for dual use of water area for solar photovoltaic electricity generation and aquaculture. *Renew. Sustain. Energy Rev.* **2017**, *80*, 572–584. [CrossRef]
14. Amaducci, S.; Yin, X.; Colauzzi, M. Agrivoltaic systems to optimize land use for electric energy production. *Appl. Energy* **2018**, *220*, 545–561. [CrossRef]
15. Sekiyama, T.; Nagashima, A. Solar Sharing for Both Food and Clean Energy Production: Performance of Agrivoltaic Systems for Corn, A Typical Shade-Intolerant Crop. *Environments* **2019**, *6*, 65. [CrossRef]
16. Marrou, H.; Wery, J.; Dufour, L.; Dupraz, C. Productivity and radiation use efficiency of lettuces grown in the partial shade of photovoltaic panels. *Eur. J. Agron.* **2013**, *44*, 54–66. [CrossRef]
17. Elamri, Y.; Cheviron, B.; Lopez, J.M.; Dejean, C.; Belaud, G. Water budget and crop modelling for agrivoltaic systems: Application to irrigated lettuces. *Agric. Water Manag.* **2018**, *208*, 440–453. [CrossRef]
18. Ravi, S.; Macknick, J.; Lobell, D.; Field, C.; Ganesan, K.; Jain, R.; Elchinger, M.; Stoltenberg, B. Colocation opportunities for large solar infrastructures and agriculture in drylands. *Appl. Energy* **2016**, *165*, 383–392. [CrossRef]
19. Malu, P.R.; Sharma, U.S.; Pearce, J.M. Agrivoltaic potential on grape farms in India. *Sustain. Energy Technol. Assess.* **2017**, *23*, 104–110. [CrossRef]
20. Marrou, H.; Guilioni, L.; Dufour, L.; Dupraz, C.; Wéry, J. Microclimate under agrivoltaic systems: Is crop growth rate affected in the partial shade of solar panels? *Agric. For. Meteorol.* **2013**, *177*, 117–132. [CrossRef]
21. Santra, P.; Pande, P.C.; Kumar, S.; Mishra, D.; Singh, R.K. Agri-voltaics or Solar farming-the Concept of Integrating Solar PV Based Electricity Generation and Crop Production in a Single Land use System. *Int. J. Renew. Energy Res.* **2017**, *7*, 694–699.
22. Barron-Gafford, G.A.; Pavao-Zuckerman, M.A.; Minor, R.L.; Sutter, L.F.; Barnett-Moreno, I.; Blackett, D.T.; Thompson, M.; Dimond, K.; Gerlak, A.K.; Nabhan, G.P.; et al. Agrivoltaics provide mutual benefits across the food–energy–water nexus in drylands. *Nat. Sustain.* **2019**, *2*, 848–855. [CrossRef]
23. Guerin, T.F. Impacts and opportunities from large-scale solar photovoltaic (PV) electricity generation on agricultural production. *Environ. Qual. Manag.* **2019**. [CrossRef]
24. Nonhebel, S. Renewable energy and food supply: Will there be enough land? *Renew. Sustain. Energy Rev.* **2005**, *9*, 191–201. [CrossRef]
25. Marcheggiani, E.; Gulinck, H.; Galli, A. Detection of Fast Landscape Changes- The Case of Solar Modules on Agricultural Land. In *International Conference on Computational Science and Its Applications*; Springer: Berlin/Heidelberg, Germany, 2013; pp. 315–327.
26. U.S. Department of Energy (DOE). *SunShot Vision Study (Rep.)*. Available online: https://www.energy.gov/sites/prod/files/2014/01/f7/47927.pdf (accessed on 24 February 2020).
27. Brudermann, T.; Reinsberger, K.; Orthofer, A.; Kislinger, M.; Posch, A. Photovoltaics in agriculture: A case study on decision making of farmers. *Energy Policy* **2013**, *61*, 96–103. [CrossRef]
28. Rogers, E. *Diffusion of Innovations*, 1st ed.; Free Press: New York, NY, USA, 1962.
29. Robertson, T.S. The process of innovation and the diffusion of innovation. *J. Mark.* **1967**, *31*, 14–19. [CrossRef]
30. Grübler, A. Time for a change: On the patterns of diffusion of innovation. *Daedalus* **1996**, *125*, 19–42.
31. Coleman, J.; Katz, E.; Menzel, H. The diffusion of an innovation among physicians. *Sociometry* **1957**, *20*, 253–270.
32. Mansfield, E. Technical change and the rate of imitation. *Econom. J. Econom. Soc.* **1961**, *29*, 741–766. [CrossRef]
33. Shipan, C.R.; Volden, C. The mechanisms of policy diffusion. *Am. J. Political Sci.* **2008**, *52*, 840–857. [CrossRef]
34. Wilson, C.; Grübler, A. Lessons from the History of Technological Change for Clean Energy Scenarios and Policies. In *Natural Resources Forum*; Blackwell Publishing Ltd.: Oxford, UK, 2011; Volume 35, pp. 165–184.
35. Goetz, J.P.; LeCompte, M.D. *Ethnography and Qualitative Design in Educational Research*; Academic Press: New York, NY, USA, 1984.
36. Strauss, A.; Corbin, J. *Basics of Qualitative Research-Grounded Theory Procedures and Techniques*; Sage Publications: Newbury Park, CA, USA, 1990.

37. Fusch, P.I.; Ness, L.R. Are we there yet? Data saturation in qualitative research. *Qual. Rep.* **2015**, *20*, 1408.
38. Corbin, J.; Strauss, A. Theoretical sampling. In *Basics of Qualitative Research*; SAGE Publications: Thousand Oaks, CA, USA, 2008.
39. Lindlof, T.R.; Taylor, B.C. Sensemaking: Qualitative data analysis and interpretation. *Qual. Commun. Res. Methods* **2011**, *3*, 241–281.
40. Biernacki, P.; Waldorf, D. Snowball sampling: Problems and techniques of chain referral sampling. *Sociol. Methods Res.* **1981**, *10*, 141–163. [CrossRef]
41. Charmaz, K. *Constructing Grounded Theory*; SAGE Publications: Thousand Oaks, CA, USA, 2014.
42. Bhattacherjee, A. *Social Science Research: Principles, Methods, and Practices*; Open University Press: Tampa Bay, FL, USA, 2012.
43. Charmaz, K.; Belgrave, L.L. Grounded Theory. In *The Blackwell Encyclopedia of Sociology*; Blackwell Publications: Malden, MA, USA, 2007.
44. Unlock Insights in Your Data with Powerful Analysis. QSR International. NVivo (Version 12.0 Pro) [Computer Software]. Available online: https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home (accessed on 11 May 2020).
45. Znaniecki, F. *The Method of Sociology*; SAGE Publications: Thousand Oaks, CA, USA, 1934.
46. Robinson, W.S. The logical structure of analytic induction. *Am. Sociol. Rev.* **1951**, *16*, 812–818. [CrossRef]
47. Lorenz, E. Types of PV Racking Ground Mounts. 2016. Available online: https://www.cedgreentech.com/article/types-pv-racking-ground-mounts (accessed on 14 October 2020).
48. Turney, D.; Fthenakis, V. Environmental impacts from the installation and operation of large-scale solar power plants. *Renew. Sustain. Energy Rev.* **2011**, *15*, 3261–3270. [CrossRef]
49. Fthenakis, V. *Could CdTe PV Modules Pollute the Environment?* National Photovoltaic Environmental Health and Safety Assistance Center, Brookhaven National Laboratory: Upton, NY, USA, 2002.
50. *Potential Health and Environmental Impacts Associated with the Manufacture and Use of Photovoltaic Cells*; EPRI: Palo Alto, CA, USA; California Energy Commission: Sacramento, CA, USA, 2003.
51. NC Clean Energy Technology Center. Balancing Agricultural Productivity with Ground-Based Solar Photovoltaic (PV) Development. 2017. Available online: https://energizeohio.osu.edu/sites/energizeohio/files/imce/Handout_Balancing-Ag-and-Solar-final-version-update.pdf (accessed on 14 October 2020).
52. Armstrong, A.; Ostle, N.; Whitaker, J. Solar Park Microclimate and Vegetation Management Effects on Grassland Carbon Cycling. *Environ. Res. Lett.* **2016**, *11*, 074016. [CrossRef]
53. Hernandez, R.R.; Hoffacker, M.K.; Murphy-Mariscal, M.L.; Wu, G.C.; Allen, M.F. Solar energy development impacts on land cover change and protected areas. *Proc. Natl. Acad. Sci. USA* **2015**, *112*, 13579–13584. [CrossRef] [PubMed]
54. Hassanpour Adeh, E.; Selker, J.S.; Higgins, C.W. Remarkable agrivoltaic influence on soil moisture, micrometeorology and water-use efficiency. *PLoS ONE* **2018**, *13*, e0203256. [CrossRef] [PubMed]
55. Weselek, A.; Ehmann, A.; Zikeli, S.; Lewandowski, I.; Schindele, S.; Högy, P. Agrophotovoltaic systems: Applications, challenges, and opportunities. A review. *Agron. Sustain. Dev.* **2019**, *39*, 25. [CrossRef]
56. Thompson, E.; Bombelli, E.L.; Simon, S.; Watson, H.; Everard, A.; Schievano, A.; Bocchi, S.; Zand Fard, N.; Howe, C.J.; Bombelli, P. Tinted semi-transparent solar panels for agrivoltaic installation. *Adv. Energy Mater.* **2020**, *10*, 1614–6840. [CrossRef]
57. Riaz, M.H.; Younas, R.; Imran, H.; Alam, M.A.; Butt, N.Z. Module Technology for Agrivoltaics: Vertical Bifacial vs. Tilted Monofacial Farms. *arXiv* **2019**, arXiv:1910.01076.
58. REM TEC (Revolution Energy Maker TEC). 2017. Available online: http://www.remtec.energy/en/#agrovoltaico; https://www.youtube.com/watch?v=gmbfb4vZOuQ (accessed on 14 October 2020).
59. Buitenhuis, A.J.; Pearce, J.M. Open-source development of solar photovoltaic technology. *Energy Sustain. Dev.* **2012**, *16*, 379–388. [CrossRef]
60. Wittbrodt, B.; Pearce, J.M. 3-D printing solar photovoltaic racking in developing world. *Energy Sustain. Dev.* **2017**, *36*, 1–5. [CrossRef]
61. Denholm, P.; Margolis, R.M. *Impacts of Array Configuration on Land-Use Requirements for Large-Scale Photovoltaic Deployment in the United States (No. NREL/CP-670-42971)*; National Renewable Energy Lab (NREL): Golden, CO, USA, 2008.

62. Perna, A.; Grubbs, E.K.; Agrawal, R.; Bermel, P. Design Considerations for Agrophotovoltaic Systems: Maintaining PV Area with Increased Crop Yield. In Proceedings of the 2019 IEEE 46th Photovoltaic Specialists Conference (PVSC), Chicago, IL, USA, 19 June 2019; pp. 0668–0672.
63. Prehoda, E.; Pearce, J.M.; Schelly, C. Policies to overcome barriers for renewable energy distributed generation: A Case study of utility structure and regulatory regimes in Michigan. *Energies* **2019**, *12*, 674. [CrossRef]
64. Corwin, S.; Johnson, T.L. The role of local governments in the development of China's solar photovoltaic industry. *Energy Policy* **2019**, *130*, 283–293. [CrossRef]
65. Mulvaney, K.K.; Woodson, P.; Prokopy, L.S. A tale of three counties: Understanding wind development in the rural Midwestern United States. *Energy Policy* **2013**, *56*, 322–330. [CrossRef]
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]
67. Schelly, C. Residential solar electricity adoption: What motivates, and what matters? A case study of early adopters. *Energy Res. Soc. Sci.* **2014**, *2*, 183–191. [CrossRef]

Kraintz, Franz

From:	Black, Cameron B <cameron.b.black@hawaii.gov>
Sent:	Thursday, June 17, 2021 11:08 AM
To:	Kraintz, Franz
Cc:	Schafer, Monique M; Taylor, Mark J; Young, Raymond
Subject:	HSEO Letter - Mahi Solar
Attachments:	HSEO Comments Mahi Solar SUP _2021-06-16.pdf

Franz,

FYI. Please find attached a letter from our office to the Planning Commission for the Mahi Solar project. It's similar to the letter we sent DPP a while back.

We also plan to testify verbally at the Planning Commission meeting next week about Oʻahu's energy situation, specifically the retirement of the AES coal plant in September 2022 and the planned retirement of the Waiʻau 3 and 4 units in 2024, and how this project would impact that situation. We did something similar at last Thursday's LUC hearing for the AES West Oʻahu SUP.

Thanks,

Cam

Cameron Black
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June 16, 2021

Via email: info@honoluludpp.org
Mr. Brian Lee, Chair
City and County of Honolulu
Department of Planning and Permitting
Planning Commission

Subject: Hawaiʻi State Energy Office Comments on Special Use Permit (SUP) Application No. 2020/SUP-7
Mahi Solar Project
Tax Map Keys 9-2-001: 020 portion, 9-2-004:003 portion, 9-2-004:006 portion, 9-2-004:010 portion, and 9-2-004:012 portion, Honouliuli, ʻEwa, Oʻahu

Dear Chair Lee and Members of the Planning Commission:

The Hawaiʻi State Energy Office (HSEO) offers the following comments on the Special Use Permit (SUP) Application for the Mahi Solar Project (Project) proposed by project developer Longroad Energy (Mahi Solar, LLC) on 620 acres across five (5) different parcels in Kunia, Oʻahu. The Project would be a 120-megawatt (MW) alternating current solar photovoltaic (PV) project with a 120 MW/480 megawatt-hour battery energy storage system consisting of approximately 362,000 ground-mounted PV modules mounted on 4,300 single-axis trackers, thirty-two four-MW inverters, an overhead 34 kilovolt (kV) collector line, a 34.5/138 kV substation, and possibly an additional 138 kV collector line. HSEO is supportive of the renewable energy, electricity cost savings, grid-stabilization, and greenhouse gas (GHG) emission reduction benefits from the Project. HSEO appreciates many topics are evaluated as part of the SUP, but focuses its comments on the stakeholder engagement and energy aspects of the Project.

HSEO's comments are guided by its statutory purpose under Hawaiʻi Revised Statutes §196-71 and its mission to promote energy efficiency, renewable energy, and clean transportation to help achieve a resilient, clean energy, and ultimately carbon negative economy. As an island community currently dependent on imported fossil fuels for over 60% of its electrical power, Hawaiʻi is particularly vulnerable to fuel and energy supply disruptions, unpredictable fuel cost fluctuations, unintended fuel releases impacting both marine and terrestrial environments, and the many impacts associated with climate change. That is why Hawaiʻi's 100% renewable energy goal is critical to the health, safety, affordability, and well-being of Hawaiʻi's residents. It is important that reaching 100% renewable energy generation by 2045 be done in a manner that prioritizes the health, safety, and well-being of Hawaiʻi's residents, natural resources, culture, and environment.

The Project is currently the largest solar plus storage project being proposed in Hawaiʻi and will be capable of generating 271,525 MWh annually; an estimated 4% of Oʻahu's annual electricity needs[1] and the equivalent power for 37,000 Oʻahu homes a year. It would provide much needed renewable energy to help replace the 12-16% of Oʻahu's electricity generation that will be lost upon the planned retirement of Oʻahu's 180 MW coal power plant on September 1, 2022.[2] When the coal plant retires, the energy that cannot be conserved or replaced by renewables will come from other fossil fuel sources, further underscoring the importance of developing renewable energy and storage projects in a timely manner. Currently, the guaranteed commercial operation date for the Project is December 31, 2023, however, on May 28, 2021, Longroad informed the Hawaiʻi Public Utilities Commission (PUC) of its plan to accelerate the Project schedule to achieve an earlier guaranteed commercial operations date of September 30, 2023, and possibly a commercial operations date as early as July 31, 2023. With this accelerated schedule, the Project could help minimize the potential for a period of tight generation reserves for Oʻahu's electric grid from July to October 2023 as projected by the Hawaiʻi Natural Energy Institute.[3] In addition to the retirement of the coal plant, Hawaiian Electric is also planning to retire its combined 92.6 MW Waiʻau 3 and 4 fossil fuel power generators in 2024. The Project would also enable the retirement of these units.

Mahi Solar would sell power from the Project to Hawaiian Electric at a fixed unit price of $0.097 per kilowatt-hour under a 25-year power purchase agreement (PPA) approved by the PUC on December 30, 2020.[4] Per the PPA application, Hawaiian Electric estimates the Project could save typical residential customers consuming 500 kilowatt-hours per month approximately $1.38 per month on average for the term of the PPA. The SUP states that over its 25-year lifetime the Project would avoid the consumption of 18 million gallons of oil per year, thus saving Oʻahu consumers an estimated $175 million over the project lifetime based on future oil price projections.[5]

According to the U.S. Environmental Protection Agency's Greenhouse Gas Equivalencies Calculator, displacement from the Project's annual generating capacity of

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[1] 271,525 is 4.39% of 6,183,093, the amount of electricity in MWh sold to Hawaiian Electric customers in 2020.
[2] The power purchase agreement between Hawaiian Electric and coal plant operator, AES, expires on September 1, 2022. Under state law (Act 23, 2020), all coal burning for electricity must cease by December 31, 2022.
[3] Grid Planning for a Modern Power System in Hawaiʻi, March 15, 2021, PUC Docket No. 2021-0024; https://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A21C23B41114D03112
[4] Hawaiian Electric Company, PUC Filing Docket No. 2020-0140 For Approval of Power Purchase Agreement for Renewable Dispatchable Generation with Mahi Solar, LLC.
https://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A20L30B45115B00135
[5] Oil prices are projected to rise (United State Energy Information Administration https://www.eia.gov/outlooks/steo/report/prices.php); HSEO has calculated that if oil prices over the project lifetime are similar to actual historical Oahu oil prices over the past 15 years, savings would be $389 million over the lifetime of the project.

271,525 MWh would be equivalent to reducing carbon dioxide emissions by 192,425 metric tons annually, or taking approximately 41,840 average passenger vehicles off the road for one year.[6]

The SUP identifies the following community and stakeholder engagement activities that have been conducted or will be conducted by Mahi Solar for the Project:

- Virtual public meetings for the Project on July 15, 2020, and October 29, 2020.
- Meetings with various State and City & County of Honolulu agencies in 2020.
- Ongoing outreach with key community stakeholders through presentations to organizations such as Kunia Ridge Farmlands.
- One-on-one interviews with cultural practitioners from the region.
- Presentations are planned for the two neighborhood Boards in the Project area: Waipahu (No. 22) and Mililani-Waipiʻo-Melemanu (No. 25).

The SUP states the following issues and concerns were most prevalent during the past outreach and includes the mitigation measures proposed by Mahi Solar for each:

- Loss of agricultural land.
- Concerns about the viability of co-location of solar panels with plants or crops.
- Potential impacts to the ʻelepaio, pueo, and Hawaiian hoary bat due to the Project's proximity to their habitats.
- Loss of access to cultural resources and impacts to historic sites.
- Use of equipment made outside the United States.
- Glare from the panels and the possibility of an associated heat island effect.
- Decommissioning and disposal of the Project materials (panels, inverters, transformers etc.) upon the end of the Project lifetime.
- Stormwater runoff due to the impervious surface of the panels and impacts to city and county stormwater fees.
- Impacts to views and public view planes.
- General interest in the Project's renewable energy contribution.

HSEO encourages Mahi Solar to continue its stakeholder engagement and agency consultation to address these impacts, continue to develop appropriate mitigation measures, and identify any other community concerns. Every project has some degree of impacts and only through close coordination with community members and stakeholders can the impacts be mitigated or minimized to an acceptable degree.

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[6] United States Environmental Protection Agency, Greenhouse Gas Equivalencies Calculator, 2021 https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

Finally, HSEO believes this is a critical project for our energy transformation given its role related to ending the use of coal in Hawaiʻi. We hope this project receives your approval, and we request that the Planning Commission make a timely decision so that all involved can integrate your decision into how we move forward.

Thank you for the opportunity to provide these comments. If you have any questions, please feel free to contact me at scott.glenn@hawaii.gov.

Sincerely,

Scott J. Glenn

Scott J. Glenn
Chief Energy Officer

DAVID Y. IGE
Governor

JOSH GREEN
Lt. Governor

PHYLLIS SHIMABUKURO-GEISER
Chairperson, Board of Agriculture

MORRIS M. ATTA
Deputy to the Chairperson

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TESTIMONY OF PHYLLIS SHIMABUKURO-GEISER
CHAIRPERSON, BOARD OF AGRICULTURE
STATE OF HAWAII

BEFORE THE PLANNING COMMISSION
CITY AND COUNTY OF HONOLULU
WEDNESDAY, JUNE 23, 2021

REMOTE MEETING
1:30 p.m.

EWA DISTRICT – STATE SPECIAL USE PERMIT (SUP) – 2020/SUP-7 (FK)
MAHI SOLAR, LLC

Chairperson Lee and Members of the Commission:

Thank you for the opportunity to testify on this important matter. On May 14, 2021, the Department of Agriculture (Department) sent a letter to the City Department of Planning and Permitting containing our comments and recommendations on the Mahi Solar State Special Use Permit (SUP). We have attached our letter to this written testimony. Earl Yamamoto, Planner with the Department is attending the meeting remotely and is available for questions.

In summary, the Department stands on its letter of May 14, 2021 in its entirety. We would add that "B" rated agricultural lands comprise 65 percent of the Mahi Solar project area that is split into five areas within the most highly productive agricultural area on Oahu that we refer to as the Kunia corridor. We have summarized the recommendations and other statements made in the letter as follows (additional underscoring made for emphasis):

The Department's concluding statement on the Mahi Solar State Special Use Permit application is as follows:

"The Department strongly encourages Mahi Solar to fulfill its commitments and assertions and go beyond the minimum statutory requirement of making the project site available for agricultural activities at a lease rate that is at least 50 percent below the fair market rent for comparable properties. The Department believes that research alone is not a satisfactory outcome, nor is sheep used only for weed control. The majority of the land area under the project site contains some of the State's most potentially productive soils for intensive agricultural production. The Department expects the research to be done by HARC along with the field trials with interested farmers to result in intensive agricultural activity on the project site."

"Irrigation water

The availability of sufficient irrigation water when needed is fundamental to ensuring maximal agricultural productivity for conventional soil-based agricultural production. This is particularly critical during the dry and windy summer months experienced in the area and for crops such as alfalfa.

. . . .

The Department strongly recommends that data and information on maximum water demand, sources, storage, pumping, delivery, and year round availability to all five project areas be developed prior to Phase Two of the Agricultural Plan described in Appendix C. Further, this data and information should be provided to agricultural operators interested in the project site or specific project areas for agricultural production including livestock, hydroponic, and aquaponic."

"Solar panel coverage by project area

There will be a net area of 147 acres of solar panel coverage on the project site (Application, page 3-7).. . . .

The Agricultural Plan, research, and field testing should include the soft hose irrigation system being proposed for future agricultural activities that may occur under and adjacent to the solar panel arrays."

"Fencing

Fencing is important to discourage trespassing and crop or animal theft and to keep livestock from dislocation.

. . . .

The extent and type of fencing and gating to be in place prior to full operation of the solar energy facility should reflect the needs of the anticipated agricultural activities and not just providing security for the solar energy facility."

"Mahi Solar Agricultural Plan

The proposed agricultural plan would utilize 610 of the 620-acre project. Of the 610 acres, 488.9 acres will be cultivated in crops and used for livestock grazing and bee keeping. (Application, pages 3-10 to -11) Department staff notes that livestock grazing and crop cultivation are not compatible in the same area if they are not effectively separated. The aforementioned proposed fencing can contain livestock under the solar panels to do weed control but that will likely preclude the cultivation of in-ground crops within the same area. Further, as noted on page 3 of this letter, irrigation water in sufficient quantity and availability on demand is fundamental to any crop or livestock operation. There is scant mention of irrigation water and no mention of water for livestock in the Application and Appendix C (Mahi Solar: Agricultural Plan), although water infrastructure is planned for all project areas (Appendix C, Table 1, page 7)

The Agricultural Plan has three phases –
Phase One is two years of research to be done by the Hawaii Agriculture Research Center (HARC) that will include field trials of identified crops at the Clearway solar facility just south of Mililani Town. Conventional and hydroponic cultivation will be used for crops such as lettuce, basil, and alfalfa and other legumes and grasses for livestock forage. The field trials are to determine what crops can be productively grown with what practices under and between solar panels. (Appendix C, pages 19-21)

Phase Two occurs after Mahi Solar is in operation, they "will make available" 610 of the 620-acre project site "to local farmers to grow agricultural products at a commercial scale." (Application, page 3-12). Department staff find this phase confusing as the Application further states that Mahi Solar will coordinate with local farmers and ranchers, along with HARC and local experts "to propose agrivoltaic projects that they believe will be successful". (Application, page 3-12) This differs considerably from the description of Phase Two further on in the Application - "As each new agricultural use is tested at the project site in research trials or grown in the solar fields by farmers, HARC and Mahi Solar will gather data and evaluate the results. This will help farmers and ranchers learn and modify their work, in an iterative process." (Application, page 5-2) Similarly, the linkage between Phase One and Two is made in the Agricultural Plan (Appendix C, page 5), where land and water will be provided to farmers and ranchers to grow out these crops (from Phase One) at commercial scale. This is more in line with the description of Phase Two in the Agricultural Plan (Appendix C, pages 22-26) Mahi Solar needs to make consistent its intention to link the research in Phase One and its application by farmers and ranchers in Phase Two.

Phase Three is the sharing of data collected on agrivoltaic farming.

The Department supports proof-of-concept as the best way to determine the suitability of the to-be-determined agricultural activities to be researched and field trialed by HARC and interested farming operations at the Clearway Mililani solar facility.

The proposed agricultural activities (Appendix C, Figure 4, page 6) shows about 41 percent (250 acres) of the 610 acres available for agricultural uses may be in directly edible commodities such as honey, vegetable, sweet potatoes, and hydroponic lettuce. Another 19 percent (121 acres) will be in livestock grazing, presumably sheep, as cattle and goats are not mentioned.

Oahu Grazers has expressed interest in using a few hundred acres of the project site as additional pasture land for their sheep (500 head) and maybe calves. This operation already runs sheep on existing solar energy facilities on Oahu.

With respect to the market for sheep and lambs, the Department understands that Oahu's primary livestock slaughter facility has expressed reluctance to offer services to hogs. The Department is not aware that this reluctance also applies to sheep and lambs. The Department recommends Oahu Grazers to confirm their agreement(s) with their slaughter facilities.

While sales of sheep/lamb is not required by State law (Section 205-4.5(21), HRS), it is the generation of revenue by agricultural operators selling their agricultural products such as vegetables, melons, fruits, honey, and so forth that will ensure continued agricultural activity. This is why the Department focuses on the application's references and commitments to infrastructure, research, and field trials that affect agricultural operators and the establishment and continuation of their agricultural activities.

The Department has read the HARC Solar White Paper (Appendix B within Appendix C "Agricultural Plan") and has every confidence that this venerable Hawaii agricultural institution will follow through on their commitments to the best of their ability and produce data and information that will help those agricultural operators who are committed to the project site be economically viable."

This concludes our presentation. Thank you for the opportunity to testify on this important permit application.

Attachment (1)

DAVID Y. IGE
Governor

JOSH GREEN
Lt. Governor

PHYLLIS SHIMABUKURO-GEISER
Chairperson, Board of Agriculture

MORRIS M. ATTA
Deputy to the Chairperson

State of Hawaii
DEPARTMENT OF AGRICULTURE
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May 14, 2021

Mr. Dean Uchida, Director
Department of Planning and Permitting
City and County of Honolulu
650 South King Street 7th Floor
Honolulu, Hawaii 96813

Dear Mr. Uchida:

Subject: Special Use Permit (SUP) Application No. 2020/SUP-7
Mahi Solar Project
TMK: 9-2-01: por. 20, 9-2-04: por. 03, 9-2-04: por. 06, 9-2-04: por. 10, and 9-2-04: por. 12
Honouliuli, Ewa, Oahu
Area: 620 acres of 2,952.3 gross acres

The Department of Agriculture (Department) has reviewed the SUP application and offers the following comments and recommendations.

Background

The 620-acre project site consists of five project areas located to the west of Kunia Road . (Application, Figure 2.2, page 2-4; and Appendix B, Figures 2 through 6, unpaginated)

Project Area	Project Area Acreage	Landowner	Historic Agricultural Use
1	21.5	Hartung Bros. Hawaii	irrigated sugar
1, 2A, 2B, 2C, and 3	240.1	Hartung Bros. Hawaii	Irrigated sugar
3	12.1	Hartung Bros. Hawaii	Unirrigated pine
4A, 4B, and 4C	305.6	Fat Law's Farm	Unirrigated pine
5	40.7	Monsanto Technology	Irrigated sugar

Planning and zoning status
All project areas are in the State Agricultural District, within the Agriculture and Preservation Area of the Central Oahu Sustainable Communities Plan and the Ewa Development Plan, and zoned AG-1 (Restricted Agricultural).

Soil index classifications
The soils and historic agricultural uses on the five project areas reflect the availability of irrigation. Irrigated sugarcane was grown makai of the Waiahole Ditch and unirrigated pineapple grown mauka of the Waiahole Ditch. About 400 acres (65 percent) of the project site has "B"-rated soils according to the Land Study Bureau's (LSB) Overall Productivity Rating. "C"-rated soils comprise 115 acres (18 percent), and "D" and "E" soil are 69 acres (11 percent). (Application, Figure 4.2, page 4-5) A cursory review of the project site using the original LSB maps (147, 162, 163, 177) shows that the unirrigated "B", "C", and "D" rated soils would have had their Overall Productivity Ratings improved to "A", "B", and "C", respectively, if irrigation had been available for these soils at the time of the study.

The Agricultural Lands of Importance to the State of Hawaii (ALISH) system classifies the former unirrigated pineapple lands in project areas 4A, 4B, and 4C as mostly "Unique" agricultural lands and "Other Important" agricultural lands in the more sloped areas. "Prime" agricultural lands are found in the project areas makai of the Waiahole Ditch. (Application, Figure 4.3, page 4-8)

The Soil Survey Geographic Database (SSURGO) of the Natural Resource Conservation Service, U. S. Department of Agriculture describes slight to moderately sloped topography for the majority of the project areas with the exception of the southwestern most section of project area 1 and the easternmost section of 2A and 2C. (Application, Figure 4.1, page 4-2) Despite the slope, Appendix B, Figure 2 (unpaginated) indicates installation of solar panel arrays in these three areas.

Designated and proposed Important Agricultural Land status
About 69.5 acres of the 620-acre project site are designated as Important Agricultural Lands (IAL) (Application, Figure 4.4, page 4-10). On page 5-20 of the Application, 85 acres is identified as designated IAL. Assuming the 69.5 acres as the correct acreage, their location and current use are as follows:
29.3 acres in project area 1 (Hartung Bros., unspecified total acreage) and not in agricultural use, and
40.2 acres in project area 5 (Monsanto, total acreage of 40.7) and not in agricultural use.

About 305.6 acres of the 620-acre project site is recommended by the City and County of Honolulu for IAL designation (Application, Figure 4.5, page 4-11). Their location and current use are as follows:
305.6 acres in project area 4 (A, B, and C, Fat Law's Farm) of which about 99 acres is in basil and other vegetables (Application, Figure 3.1, page 3-10), about 200 acres in seed corn, and 51.7 acres located in the gap between 4A and 4B are not in agricultural use. (Application, page 4-9).

Current agricultural use
Of the 620 acres in the project site, 314 acres are currently not in agricultural production. The 306 acres in agricultural production is comprised of seed corn (197 acres), basil and other vegetables (56 acres), and other vegetables (43 acres). (Application, Figure 3.1, page 3-10; Appendix C, Mahi Solar Agricultural Plan, Figure 8, Current Agricultural Activity Map, page 8) The food crops are found in project areas 4B and 4C (Fat Law's Farm) along Kunia Road. (Application, page 3-9)

Irrigation water
The availability of sufficient irrigation water when needed is fundamental to ensuring maximal agricultural productivity for conventional soil-based agricultural production. This is particularly critical during the dry and windy summer months experienced in the area and for crops such as alfalfa. The Kunia Water Association (KWA) provides water service to the project site pursuant to KWA's "lease agreements for the property" (Application, page 6-1) but it is unclear if water will be available to each of the project areas to meet projected needs. The current agricultural activity map (Appendix C, page 23) indicate that irrigation water of unknown quantity is supplied to project areas 2B, 2C, 3, 4A, 4B and 4C.for seed corn and basil/other vegetables. Crop irrigation for future agricultural uses will be done by soft hoses (*usually as part of a traveling sprinkler or cable-tow system*) and drip feeder line (*typically drip tape*) (Appendix C, page 39). The Application states that the Agribusiness Development Corporation (ADC) is proposing improvements to the Waiahole Ditch, however "all proposed construction for Mahi Solar project will take place outside of the ADC's proposed improvement areas". (Application, page 6-2)

Department staff notes that Fat Law's Farms has a permit from the Commission on Water Resource Management (CWRM) allowing the withdrawal of up to 0.551 million gallons per day from the Waiahole Ditch to irrigate 329 acres of diversified agriculture, the area of which encompasses all of project areas 4A, 4B, and 4C. Use of the water by parties other than the permittee and the crops that may be irrigated may require

CWRM approval. The cost of water from the KWA ranges from $1.47 to $2.04 per thousand gallons. In comparison, Waiahole Ditch water is noted to be $0.517 (now, $0.87) per thousand gallons for agricultural usage.

Appendix C (pages 25-26) state that the area to be provided with water infrastructure will increase from the current 262 acres to 442 acres of the of the project site but does not provide further details.

Mean annual rainfall is about 30 inches with January being the wettest month at 4.8 inches. (Application, page 4-1)

The Department strongly recommends that data and information on maximum water demand, sources, storage, pumping, delivery, and year round availability to all five project areas be developed prior to Phase Two of the Agricultural Plan described in Appendix C. Further, this data and information should be provided to agricultural operators interested in the project site or specific project areas for agricultural production including livestock, hydroponic, and aquaponic.

Solar panel coverage by project area

There will be a net area of 147 acres of solar panel coverage on the project site (Application, page 3-7). Department staff was unable to find a breakdown of this area by project area. From Appendix B (Site Plan and Drawings, Prepared by Revamp Engineers and Walters, Kimura, Motoda, Inc. February 2021, Figures 2-5, unpaginated) nearly all of project areas 4A and 4B, and most of 4C (all Fat Law's Farm) will be covered by solar panels. There is a gap between 4A and 4B (described as 51.7 acres in Application, page 4-9) that may be used for "solar panels and/or farming/ranching." Department staff roughly estimates solar panel coverage as follows:
Nearly all of project area 3 (Hartung Bros.) will be under solar panels.
About 70% of project area 5 (Monsanto) will be under solar panels.
About 50% of project area 1 (Hartung Bros.) in the far western portion of the area will be covered by solar panels and the remainder that may be used for "solar panels and/or farming/ranching."
About 60% of project areas 2A, 2B, and 2C (Hartung Bros.) will be under solar panels and the remainder may be used for "solar panels and/or ranching."

The solar arrays will be six- to eight-feet off the ground when panels are zero degrees tilt (parallel to the ground) At maximum rotation (50 degrees tilt) the arrays will have the lowest edge of the solar panels one- to three-feet off the ground. There will be nine-foot spacing between adjacent arrays of panels at zero degrees tilt. (Application, page

3-4; Appendix B, "Site Plan and Drawings...", Figure 7, unpaginated; and Appendix C, "Agricultural Plan", pages 15-16)

The Agricultural Plan, research, and field testing should include the soft hose irrigation system being proposed for future agricultural activities that may occur under and adjacent to the solar panel arrays.

Fencing
Fencing is important to discourage trespassing and crop or animal theft and to keep livestock from dislocation.
Department staff notes that there will be fencing on the perimeters of the solar paneled areas, however the "solar panels and/or ranching" areas appear to not be fenced. (Appendix B: Site Plan and Drawings, Prepared by Revamp Engineers and Walters, Kimura, Motoda, Inc. February 2021, Figures 2-5)

The extent and type of fencing and gating to be in place prior to full operation of the solar energy facility should reflect the needs of the anticipated agricultural activities and not just providing security for the solar energy facility.

Mahi Solar Agricultural Plan
The proposed agricultural plan would utilize 610 of the 620-acre project. Of the 610 acres, 488.9 acres will be cultivated in crops and used for livestock grazing and bee keeping. (Application, pages 3-10 to -11) Department staff notes that livestock grazing and crop cultivation are not compatible in the same area if they are not effectively separated. The aforementioned proposed fencing can contain livestock under the solar panels to do weed control but that will likely preclude the cultivation of in-ground crops within the same area. Further, as noted on page 3 of this letter, irrigation water in sufficient quantity and availability on demand is fundamental to any crop or livestock operation. There is scant mention of irrigation water and no mention of water for livestock in the Application and Appendix C (Mahi Solar: Agricultural Plan), although water infrastructure is planned for all project areas (Appendix C, Table 1, page 7)

The Agricultural Plan has three phases –
Phase One is two years of research to be done by the Hawaii Agriculture Research Center (HARC) that will include field trials of identified crops at the Clearway solar facility just south of Mililani Town. Conventional and hydroponic cultivation will be used for crops such as lettuce, basil, and alfalfa and other legumes and grasses for livestock forage. The field trials are to determine what crops can be productively grown with what practices under and between solar panels. (Appendix C, pages 19-21)

Phase Two occurs atter Mahi Solar is in operation, they "will make available" 610 of the 620-acre project site "to local farmers to grow agricultural products at a commercial scale." (Application, page 3-12). Department staff find this phase confusing as the Application further states that Mahi Solar will coordinate with local farmers and ranchers, along with HARC and local experts "to propose agrivoltaic projects that they believe will be successful". (Application, page 3-12) This differs considerably from the description of Phase Two further on in the Application - "As each new agricultural use is tested at the project site in research trials or grown in the solar fields by farmers, HARC and Mahi Solar will gather data and evaluate the results. This will help farmers and ranchers learn and modify their work, in an iterative process." (Application, page 5-2) Similarly, the linkage between Phase One and Two is made in the Agricultural Plan (Appendix C, page 5), where land and water will be provided to farmers and ranchers to grow out these crops (from Phase One) at commercial scale. This is more in line with the description of Phase Two in the Agricultural Plan (Appendix C, pages 22-26) Mahi Solar needs to make consistent its intention to link the research in Phase One and its application by farmers and ranchers in Phase Two.

Phase Three is the sharing of data collected on agrivoltaic farming.

The Department supports proof-of-concept as the best way to determine the suitability of the to-be-determined agricultural activities to be researched and field trialed by HARC and interested farming operations at the Clearway Mililani solar facility.

The proposed agricultural activities (Appendix C, Figure 4, page 6) shows about 41 percent (250 acres) of the 610 acres available for agricultural uses may be in directly edible commodities such as honey, vegetable, sweet potatoes, and hydroponic lettuce. Another 19 percent (121 acres) will be in livestock grazing, presumably sheep, as cattle and goats are not mentioned.

Oahu Grazers has expressed interest in using a few hundred acres of the project site as additional pasture land for their sheep (500 head) and maybe calves. This operation already runs sheep on existing solar energy facilities on Oahu.

With respect to the market for sheep and lambs, the Department understands that Oahu's primary livestock slaughter facility has expressed reluctance to offer services to hogs. The Department is not aware that this reluctance also applies to sheep and lambs. The Department recommends Oahu Grazers to confirm their agreement(s) with their slaughter facilities.

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Conclusion
The Department strongly encourages Mahi Solar to fulfill its commitments and assertions and go beyond the minimum statutory requirement of making the project site available for agricultural activities at a lease rate that is at least 50 percent below the fair market rent for comparable properties. The Department believes that research alone is not a satisfactory outcome, nor is sheep used only for weed control. The majority of the land area under the project site contains some of the State's most potentially productive soils for intensive agricultural production. The Department expects the research to be done by HARC along with the field trials with interested farmers to result in intensive agricultural activity on the project site.

Thank you for the opportunity to provide our input on this very important application. Should you have any questions, please contact Earl Yamamoto at 973-9466 or email at earl.j.yamamoto@hawaii.gov.

Sincerely,

Phyllis Shimabukuro-Geiser

Phyllis Shimabukuro-Geiser
Chairperson, Board of Agriculture

c: Office of Planning
Land Use Commission