Hawaii's Innovative New PPA Structure for Hybrid Solar PV and Energy Storage Projects

Nicholas W Miller
HickoryLedge LLC
Delmar, NY United States
nicholas.miller@hickoryledge.com

***Abstract*— Many operating power systems around the world, including most island systems are *not* full ISO type markets, and depend on a variety of power purchase agreements (PPAs) as the contractual mechanism for supply of power from variable energy resources (VERs), such as solar PV and wind, to the grid.**

VER PPAs are typically long-term agreements, with contractual spans of 20 years being common. PPAs need to respect the diverse interests of all the involved parties, and as such there is a complex balance between the grid operator, the government, the generation owner/investor, and the end-user/ratepayer community. Traditional PPAs based on energy delivered to the grid have serious deficiencies when VERs become a major contributor to the overall energy supply of a host power system.

The key stakeholders in the State of Hawai'i have introduced an exciting and fundamentally altered PPA structure that represents a departure from traditional energy (MWh) based PPAs.

The new structure is essentially a contract for service: revenue is based on providing capital equipment with specified performance characteristics coupled with demonstrated (and policed) proof that equipment is able to provide specific functions when called upon. The contract structure provides substantial benefits for all key stakeholders:

- **For Investors: the PPA provides higher financial certainty, putting the onus on the owner in attributes over which they have control.**

- **For the host grid operators: the PPA provides the operational flexibility required to meet economic and reliability constraints, including a spectrum of grid services. This is critical for operation when VERs represent the majority (or even 100%) of the instantaneous power needs of the grid. The structure avoids the necessity to determine, *a priori*, the exact nature and price of grid services as the system evolves.**

- **For the end-user/ratepayers: The risk premium built into typical energy PPAs is reduced and reflected in the prices of the power used. The grid is operated at best balance of economy, environmental objectives and reliability; even when the grid infrastructure, generation mix and load behavior changes over the life of the PPA. Innovative system operations are rewarded, with accompanying economies benefiting ratepayers**

The arrangement can be superior for systems in which VERs are a major source of energy, especially for island systems. The paper discusses the motivation and general structure of the new PPAs, addressing risk allocation and management elements built into the documents.

Keywords-Island power systems, hybrid plants, solar, PPAs, contracts)

I. INTRODUCTION

A. Power Systems in Hawai'i

There are six main islands in the state (there are over 100 islands), from oldest to youngest, Kaua'i, Oahu, Molokai, Lanai, Maui and Hawai'i (the Big Island). They contain the majority of the population and economic activity of the state. Each of these are electrically isolated, i.e. none of them are interconnected by AC or DC to neighbors today. Interconnection between some or all of the main islands has been considered at various times, but such interconnection has not yet passed the economic, societal and environmental hurdles necessary to proceed. One factor is that being volcanic (and in the middle of the Pacific Ocean), the depth of channels between most of the islands is huge.

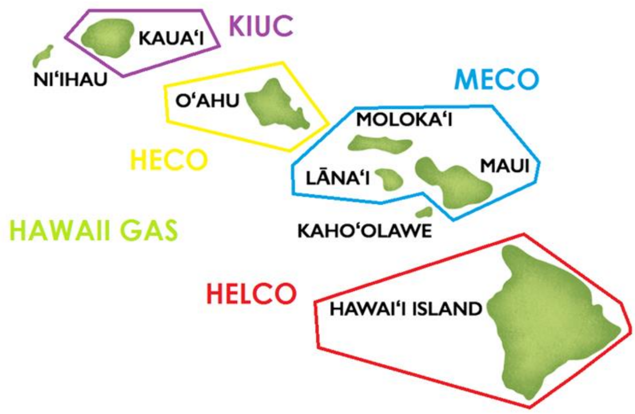

Figure 1. State of Hawai'i with Electric Service Companies [1]

This paper is the sole product of the author, and is not official or sanctioned by the State of Hawai'i or any other parties.

The physical remoteness and lack of indigenous fossil fuels (beyond some moderate scale biofuel systems) has resulted in electricity prices that are relatively high compared to the large US mainland grids. Import of fossil fuels, including coal, diesel and fuel oil is expensive. The islands have some good wind and solar resources, and the State of Hawai'i has been at the policy forefront of decarbonization efforts. The three medium sized islands, Maui, Kaua'i and Hawai'i have all managed to accommodate substantial fractions of wind and solar PV generation, often eclipsing levels of instantaneous penetration reached by mainland systems. Kaua'i, which is run by a local cooperative, KIUC that is administratively separate from the other islands, now often runs at 100% renewables, with many hours of extremely high instantaneous penetration of solar PV [2].
The islands of Maui and Hawai'i have vertically integrated operations by fully owned subsidiaries of Hawaiian Electric Company (HECO), with peak loads on the order of 200MW. Recent solar PV plus energy storage projects on those islands are the subject of this paper, but their experience is highly relevant to similar systems around the world.

B. The granularity problem

Operation of relatively small, isolated systems introduces some unique challenges. One aspect that makes both operations and market-based solutions to them problematic is that the relative size of central station generating resources tend to be quite large. On the three biggest (electrically) islands, Oahu, Maui and Hawai'i, that are on the order of ten (relatively small) utility-scale power plants available for operation, of which a very few are the most economic and run on most days. Unlike large systems, the act of committing even a single additional unit and respecting its minimum power limits can substantively impact generation balance. Bringing on a fossil plant to provide essential reliability services or in anticipation of sunset or a wind drop can often lead to curtailment of the solar or wind generation to "make room" for the added plant. The granularity of these systems makes many competitive market constructs intractable. Open, liquid and transparent bidding and clearing mechanisms that work in a large ISO are nearly impossible. As is often the case on island systems, a more traditional vertically integrated and highly regulated approach is used in the state. Market competition is introduced at the procurement planning stage, with independent participants competitively bidding on specific tenders for new resources, under the watchful gaze of the state regulator (i.e. the public utilities commission, "PUC"). The interests of stakeholders in managing cost while maintaining reliability depends on the host system receiving attractive bids.

II. THE RISK PROFILE

A. Managing Conventional Risks

Traditional power purchase agreements that are the primary outcome of such tenders center on offered energy prices. That is, prospective new entrants interested in building wind or solar generation in this environment, offer in an energy price (in \$/MWh) over a specified term (often 20 years) that will meet their return on investment objective based on the projected energy production for a facility. The bidder includes their monetization of their risks in their price.

Developers are accustomed to monetizing the risks associated with (1) uncertainties in projected production that are driven by a degree of uncertainty in future weather (totally outside of the investors control) and (2) equipment performance/availability (a risk over which the investor and owner has significant control). The bidder includes this monetization in their proposed PPA price. This approach has served the industry well.

B. Curtailment Risk is Different

Curtailment risk is not a new worry for developers. Even in large systems, transmission congestion and other factors can contribute to some risk of curtailment. In large systems, developers may avoid some locations because of undue curtailment risk. But the granular nature of these small systems makes the risk of curtailment more systemic, in that the risk applies regardless of the exact location on the grid. But more important, the curtailment risk may be vastly more difficult to quantify. Specific system performance, including the need to curtail due to overproduction or conflicts with essential reliability services, will depend the entire resource portfolio of the system. Addition or retirement of a single resource can radically alter curtailment risk.

PPAs in these granular (usually island) power systems that try to project curtailment risk have not served well. Consider the following illustrative scenario:

A wind project is proposed on an island system that has a small number of fossil generators that are to be displaced when there is available wind power, and when system operation allows decommitment of some of the fossil generation. However, it is anticipated that minimum load constraints will result in conditions that require some curtailment.

Projections over the life of the PPA, based on the estimated weather, system load growth, anticipated service life of the rest of the generation portfolio, the known grid constraints, etc. result in an estimate that 10% of the possible production from the wind plant will need to be curtailed.

Two PPAs structures might ensue. "Take-or-pay" PPAs require that the host utility pays for all the power that might have been produced, regardless of whether it is accepted by the grid. Alternatively, if the plant assumes the delivery risk, they must price it into their bid. To a first approximation, the rational PPA bid (in \$/MWh) for the project will need to be about 10% higher, since the capital cost must be recovered over fewer MWh. Other competing projects are subject to similar risk, and a PPA is awarded with the risk premium included.

This arrangement results in several perverse outcomes, depending on the PPAs structure:

- The host utility has less incentive to find ways to reduce curtailment, because the wind power is "over-priced" by 10%.
- With "take-or-pay" PPAs, the host (and ratepayers) assume the risk of curtailment, without the other flexibility that would accompany full control of the plants.

- Without take-or-pay, the resource owner realizes a windfall due to the higher PPA price if the curtailment is reduced.

The resource owner is still exposed to substantial risk should the curtailment be even worse than estimated.

- The host utility is unnecessarily constrained in dispatch and use of the resource for essential reliability services rather than just energy.
- The host utility is unnecessarily constrained in planning or accommodating new resources or changes in their network that might affect the projected curtailment of current or future projects.

These outcomes can be a concern even in large systems, but for relatively small isolated systems with high shared of VERs, these perverse outcomes can be fatal for the various stakeholders. Overall, the arrangement can be characterized as misallocation of risk. When viewed that way, it is useful to examine which risks are within the control of the project and which are not. Table 1 parses the key risks into two groups – those largely under the control of the developer/owner and those outside of their control.

This parsing of risk gives rise to a new contractual structure, one that places the competitive onus on developers to focus on risks for which they have control. Other risks, and the accompanying benefits of assuming those risks, accrue to the buyer – i.e. the grid operator.

TABLE I. RISK CONTROL FOR PROJECT DEVELOPERS AND OWNERS

Under Control of Project (owner/investor)	Not Under Control of Project
Quality (buy good equipment; design and install properly)	Insolation or wind (some years are more sunny or windy than others)
Suitability/Compliance (buy, design, install equipment that can do what the PPA requires it be capable of doing)	Curtailment (the grid may or may not be able to accept the project's power at any given time)
Maintenance (take care of the project so that it is capable of delivering power and other required services when it is possible and needed)	Dispatch (when and if the grid operator wants the available power from the project; dispatch constrained to provide other essential reliability services, like primary frequency response)
Capital and Fixed Operating Costs (buy cost effective equipment; train and invest in service staff and equipment to manage costs)	Variable costs with dispatch and commitment (losses, loss-of-life associated with project producing energy and supplying grid services)

III. A NEW CONTRACTUAL PARADIGM

The new contract paradigm for PPAs of combined solar plus battery power plants is essentially a service contract, rather than an energy PPA contract. The basic structure of the contract is an agreement that the developer will build and maintain a facility with a specified set of performance characteristics, and allow the host grid operator to operate the plant at their discretion within bounds negotiated in the contract. In return for building and taking care of the facility, the developer/owner receives a fixed annual revenue stream, independent of the energy delivered to the grid.

The economic line-of-sight becomes clear and simple: the developer knows their upfront capital costs and has good information on which to estimate on-going costs to maintain the facility at a level that meets their contractual obligations. The developer can accept a lower revenue stream than a traditional PPA because the risks are reduced and under their control. The developer/owner is obligated and policed to make sure that they build a plant that meets all of the specifications provided by the host utility, and that they maintain the plant and equipment so that it can always provide the services for which it is contracted. Thus, at the heart, the plant must be able to provide the power that the sun (or wind) make possible, the battery must have the capacity and performance specified, and the overall system must respond to commands from the grid operator within the bounds specified. Failure to do so results in an economic penalty – i.e. reduced payments. But, if it is not sunny, or if the grid doesn't want to accept the plant's MW, there is no penalty. The grid operator can use the entire facility to the holistic benefit of the system. The flexibility of this arrangement allows for the grid to grow and change; allows for operations to evolve, to get smarter, cheaper, cleaner; allows for the facility to be used differently over its life for the benefit of the ratepayers; innovation by the host grid operator and planners is rewarded as they have the latitude to use the resource differently as circumstances, priorities and understanding evolve.

A. The Hawai'I PPAs

As noted in the introduction, the State of Hawai'i covers multiple islands. The projects discussed here are on the islands on Maui and Hawai'i, which have in the past few years launched aggressive renewable energy plans. The two islands had a substantial amount of wind and solar PV generation in operation as of the initiation of this phase, circa 2017. The ability of the two island grids to accommodate the variability of the resources by operating mechanisms familiar to the renewable energy integration community had already been exhausted to an appreciable extent. In particular, and familiar to many systems with high solar growth, they saw growing urgency to have resources that could help meet their version of the evening "duck curve". Consequently, the tenders for new resources included energy storage that can be discharged during the post-sunset evening peak, as a key portion of their portfolio strategy. There are six projects (in this first tranche), with a combination of solar PV arrays "paired" (using the Hawai'i PUC language) with battery energy storage systems (BESS).

B. Disclaimer

While the contracts and the PUC proceedings are well written, and generally understandable, the nature of the documents (public filings and contracts) leads to language that is difficult to assimilate for the more casual reader. To that end, the author has attempted to give "vernacular" interpretations of the intent. These are written from my perspective (as a "student"), and are intended to help the reader divine the participants' and document's intent. They are the author's interpretation, and are not in any fashion official views. Nor are they a substitute for the more precise language of the actual documents, which the interested reader is encouraged to review.

C. The project(s)

The commission approved six projects, totaling 247MW of solar PV and 988MWh of energy storage, with costs that range from $0.08 to $0.10/MWh. These are average costs assuming full production and dispatch of the project output. Much of the language used here is from public documents [3]. Most of the quotes, prices, costs and other quantitative specifics are from that specific project, but are representative of the six projects.

The subject project is a 39MW PV array paired with a 39MW/156MWh of battery energy storage system (BESS). The PV and BESS are at a single integrated site, with a single point-of-interconnection (POI), PPA, and owner. This is a hybrid plant in the current lexicon of US power industry. The project occupies 144 acres (58Ha) of agricultural land on the island of Oahu, state of Hawai'i, United States. The land use power density of the project is about 3.5ac/MW or 1.5Ha/MW. The PPA (as discussed in this paper) with Hawaiian Electric Company (HECO) works out to $88/MWh.

The project is expected to result in rate savings for HECO ratepayers. Over its 20-year life it is anticipated to save over 1 million barrels of ultra-low sulfur diesel. Over 500 tons of coal and over 11,000 barrels of diesel, will be saved. Green house gas (GHG) reductions are anticipated to be about 400,000 metric tons.

D. The view from the regulator

The host utility and the regulator spent considerable effort on crafting the new PPA structure. The public docket includes language that gives insight into the thinking of the regulator. Where the statements have been particularly clear and illuminating, direct quotes (from [3]) are given.

The regulator and host utility recognized the need for a new arrangement, having learned that the older PPA contractual provisions, including seniority curtailment and evergreen terms, were particularly undesirable due to their impacts on curtailment of renewable energy. The project avoids "*complicated pricing mechanisms to guarantee financial recovery..*"

In the view of the regulator, this is "*a new model PPA*", that "*…provides a contractual vehicle to integrate more renewable energy, provide flexibility on the [HECO] Companies' grids, and address financing risks previously associated with curtailment.*" As described above, the PPA provides "the lump sum payment is made in exchange for the right to dispatch the [project's] energy production."

The request for proposals *"was specifically designed to include the following characteristics: technology agnostic, not specifying a maximum size requirement, allowing projects to be sited a developer-defined sites, and allowing for variations with proposals*". The host utility is looking forward to the control and optionality that the arrangement provides. The document states: "*according to HECO: The key benefit of the [project] … is that the Company (i.e. grid operator) will be able to utilize attributes of the [project]*"

E. The view from planning

As always in vertically integrated systems, issuing calls for tender, requires a degree of definition for the bidders. Normally, this is the domain of utility planning, and is likely to be the outcome of some type of "integrated grid planning" process. In this structure, the specification of needs covers not only energy but capacity and several services, all of which are bundled together in the project to be delivered. That puts additional onus on the planning process to examine each feature both individually and holistically, while attempting to look into an often highly uncertain future. Requirements that follow a "low regrets" planning approach, i.e. one in which required functionality provides benefits over a wide range of credible future scenarios, tends to serve the process best. This can be heavy lifting for the planning organization, and requires careful oversight by the regulator.

F. Performance Obligations: Risk Management for the Host (power buyer)

Since the contract does not pay for energy delivered, the contract must be highly precise in defining what constitutes satisfactory delivery of the contracted services. The buyers' recourse included penalties broadly grouped as "liquidated damages", for such failures as:

- Lower than expected availability
- Lower than expected efficiency
- Lower than expected storage capacity of the BESS
- Various schedule infractions related to date of commercial operations

Such elements make qualitative sense, but for monetary penalties, precise measures are needed. To that end, the contract includes a number of "*Performance Metrics*", specifically (and carefully) designed for this contract structure. They include:

- PV Availability. PV Equivalent Availability Factor ("EAF ")
- PV Efficiency. The guaranteed performance Ration ("GPR").
- BESS Capacity This confirms its ability to discharge as defined
- BESS Availability. The BESS EAF.

No attempt is given in this paper to show the details of how each of these (and other) metrics are calculated. They are carefully outlined in the public documents. Any new system considering adopting this contract structure might to do well to start with these metrics, and, if necessary, customize them to the specifics of their system and regulatory regime. The point is that monitoring and measuring how well the project is performing is *absolutely foundational* to this new PPA arrangement. Details matter. In the view of the regulator: "*… these performance metrics will collectively…assure that ratepayers are not paying ...if the systems do not meet their expected capability*"

G. Safeguards: Risk management for the Developer (plant owner)

Of course, the contract needs to protect the seller as well. As noted above, the PPA arrangement avoids "*complicated pricing mechanisms to guarantee financial recovery*..." This is at the core of the benefits for the developer/investor. There are many details that are addressed in the contract, including:

- Detailed specification of acceptance tests.
- Provision for the installation to be sold.
- Provision for delays, etc. related to other permitting and administrative delays outside of the developer's control.
- Provision for bankruptcy.
- Provisions for adjustments related to "as built".
- Provision for failure and mandated removal of equipment.
- Monthly reporting.

Generally, there are lots of details about mandatory reporting; provision for policing reporting; penalties for poor, inaccurate reporting.

It is worth noting that multiple independent parties bid on these projects, which is *prima facie* evidence that the general structure is acceptable to prospective investors.

H. *Determining if the price is fair*

To make certain that the interests of the ratepayers and other stakeholder are primary, awards must be "fair". Arguably, holding an open procurement process with multiple independent bidders should satisfy this need. But, being new ground, the commission felt that the competitive bidding was not a substitute for their "*review of evidence*" to make sure the PPA should be approved. The proceedings document considerable debate, with the requirement to show deep details of pricing being fiercely contested, since the bid should be sufficient. The counter argument is that there is a public interest in making sure the price is reasonable. Similar debates can be expected in other places. Ultimately, a considerable level of documentation on how prices were arrived at was provided by the bidders.

One step towards monitoring the business processes was a "*commission appointed Independent Observer (IO)*". Among the functions of the IO are monitoring the independence of the bidders. Considerable effort was expended to ensure that no collusion occurred. There was also a lot of debate about the 20-year term of the contracts. The core of the debate being summed up as "*long terms arguably stifle innovation.*"

The benchmarking of prices, including calculation of an effective $/MWH price for reference, is highly valuable for broader communication with stakeholders. Further, it allows comparison of projects of different rating. This allows the bidders themselves to determine the best rating for the specifics of their site, while making meaningful comparisons straightforward for making awards. The final equivalent PPA price of this projects drives home how effective this approach is: the prices (~$90/MWh) where spectacularly good (for 2019) for Hawai'i (or any remote, island system). (Remember, this is solar PV *plus 4 hours of fully rated battery energy storage*).

As a general observation, as the number of independent bidders increase for specific tenders, the presumption that the bids are honestly representative of the costs and give a fair return on investment rises. Experience will help as well. Systems (and countries) trying this structure out for the first time may wish to take the cautious approached used in Hawai'i.

I. *Assuring the value is realized*

One other important aspect for ensuring customer/ratepayer value is in how the grid operator ultimately utilizes these systems. This is a risk that is ultimately borne by the customer, but is out of their control. For example, if the operator does not decommit excess units, or fails to dispatch/utilize the hybrid projects to their potential, then customers are paying a fixed payment for the project but also paying for the conventional fossil units that remain online.

This contract structure is very helpful in assigning risk to developers that they can effectively manage. However, the end result of these contracts also shifts risks onto customers, over which they have little control. Mitigation of this risk requires that the PUC and stakeholders remain engaged and help the utility get the most out of these very advanced and highly capable hybrid projects.

J. *Complications of the Energy Investment Tax Credit*

The US Energy Investment Tax Cried (ITC) adds complexity. The contract obliges operation such that the terms of the ITC are satisfied, allowing the investors to realize the tax benefit. It basically prevents the host grid from charging the battery with power taken off the grid. Violating those terms can have significant economic consequences for the plant owner. In the next stage of projects, some provision has been made in which it some violation the terms is allowed, with appropriate compensation, in return for higher benefit to the grid. These refinements will almost certainly continue. This complexity is illuminating, in the sense that externalities such as tax rules, government energy policies and programs, can impact this new arrangement in which operations control is passed to the buyer. It is almost inevitable that future projects in any jurisdiction will need to address the particular constraints of that location and project.

IV. CONCLUSIONS

- **This is revolutionary**. The constraints of old energy based PPAs become crippling in smaller systems with high penetration of VERs. Hawai'i in many regards is leading the world in decarbonization. It has arrived at this structure as a creative way to manage many of the problems that every islanded system will face as they add more wind and solar generation.

- **This is cost effective.** The PPAs are highly competitive. At about $90/MWh in 2019, for PV plus 4 hours of fully rated battery storage, on a small island in the middle of the Pacific Ocean, these prices eclipse most other alternatives.

- **This is efficient.** The project and contractual structure provide the host grid with energy, capacity and grid services bundled together in a nice package that facilitates licensing and procurement.

- **This is real.** These projects are in the engineering and construction stage (as of the time of writing this paper), and are scheduled to be in commercial operation by the end of 2022. Any arguments that island systems can not economically meet the majority of their electric power needs with variable renewables *now* will not stand up to this real world experience.

References

[1] https://energy.hawaii.gov/developer-investor/utility-resources#gallery

[2] Kaua'I Island Utility Cooperative; https://website.kiuc.coop/renewablesJ. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[3] Docket No. 2018-0434. "in the matter of the Application of Hawaiian Electric Company, Inc. for the Approval of Power Purchase Agreement for Renewable Dispatchable Generation with Mililani I Solar, LLC." Decision and Order No. 36232 Filed March 25, 2019.

V. Biography

Nicholas W. Miller is a Principal with HickoryLedge LLC, in New York State. He holds B.S. and M.Eng., Electric Power Engineering, Rensselaer Polytechnic Institute, Troy, New York. Mr. Miller recently retired as Senior Technical Director, Energy Consulting, GE Power after 3/8 century of experience and research on bulk power systems. He has lectured on Wind and Solar Power integration to governments and institutions in more than three dozen countries. He currently provides consulting expertise to a variety of private and public institutions on topics of grid integration of renewable resources. He holds twenty US patents for wind, solar, and grid technologies, is a Fellow of IEEE, a NY PE, a Distinguished Member of CIGRE, has authored over 150 technical papers and articles, and is the recipient of several power industry awards.