Assessment of battery storage IPP/PPP schemes for the Pacific utilities

Report for the Pacific Power Association and the World Bank
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1 Introduction

The Pacific Power Association, in consultation with The World Bank, has identified the need to assess the battery storage deployment options with mobilising private sector funding to improve the utilisation of Variable Renewable Energy (VRE) sector in the region. Special emphasis has been put on assessing battery storage implementations under a Public-Private Partnership (PPP) scheme. This report has been developed as a part of the "Assessment of Variable Renewable Energy (VRE) Grid Integration and Evaluation of SCADA and EMS system design in the Pacific Island Counties" project.

The first section of the report provides a general overview of the PPP arrangements with a special focus on the Independent Power Producer (IPP) structure provided that this structure might be relevant for the commercial design of potential stand-alone battery storage implementations in the region. This section also provides an overview of the market and successful implementations of such schemes covering the most advanced markets such as the United States, Germany, Japan, United Kingdom and Australia. In addition, some applications by island nations have been also identified and assessed.

The second part of the report provides a qualitative assessment of setting up stand-alone battery storage projects under a PPP structure. The assessment is backed by the pros and cons for such an arrangement.

The third section of the report presents the methodology which has been used to assess a stand-alone battery storage project in the region. This covers the description of the working of the financial model, the main assumptions used and the outputs and main results. Two main options have been compared: PPP arrangement vs. public procurement. In addition, a number of different scenarios have been also analysed.

The fourth section of the report describes some high-level technical and commercial recommendation to be considered for a stand-alone battery storage procurement in the region. This is based on the analysis of actual procurements in other regions and recent developments of commercial terms in the advanced markets.

2 Review and assessment of relevant successful implementations of IPP/PPP schemes

2.1 Overview of PPP arrangements

Before looking at relevant stand-alone battery storage implementations worldwide it is important to have a brief overview of the generic PPP and IPP arrangements in the power sector. These arrangements present a framework that includes the private sector, but also engages the government/public sector to make sure that public sector objectives and social and environmental obligations are met.

A short definition of PPP and IPP may help guide the reader throughout the document at more ease.

Public Private Partnership: *A partnership in which the government transfers the exclusive rights to a private operator or investor to develop and/or operate an infrastructure facility under certain conditions for a fixed period of time. (Nathan Associates)*

Independent Power Producer: *A power project that mainly is privately developed, constructed, operated, and owned; has a significant proportion of private finance; and has a long-term power purchase agreements (PPA) with a utility or another off-taker. (www.powerengineering.com)*

The main factors which differentiate the PPP options are the scope, the ownership of the underlying asset, the duration, the operation and maintenance (O&M) responsibility, the capital investment, the commercial risk and the source of financing. The options for these factors define various public-private relationships which are summarised in the following figure.

	Service Contract	Management Contracts	Lease Contracts	Concessions	BOT
Scope	Multiple contracts for a variety of support services	Management of entire operation or a major component	Management, operations, and specific renewals	Operations, financing and execution of investments	Investment in and operation of a specific major component
Asset ownership	Public	Public	Public	Public/Private	Public/Private
Duration	1-3 years	2-5 years	10-15 years	25-30 years	Varies
O&M responsibility	Public	Private	Private	Private	Private
Capital investment	Public	Public	Public	Private	Private
Commercial risk	Public	Public	Shared	Private	Private
Mobilising investment finance	No	No	No	Yes	No

Figure 2-1: Main PPP structures[1]

A key feature of the build-operate-transfer (BOT) type of arrangements is that under these contracts the private sector provides the capital contribution and also operates the underlying assets.

The following figure sets out the basic delivery options through BOT-type of contracts and other arrangements.

	Own	Conceive	Design	Build	O&M	Financial Responsibility
Design-Bid-Build	Public	Public	Private by fee contract		Public	Public
Design-Build	Public	Public	Private by fee contract		Public	Public
Build-Operate-Transfer (BOT)	Public	Public	Private by fee contract			Public
Design-Build-Finance-Operate (DBFO)	Public	Public or Private	Private by fee contract			Public, Public/Private or Private
Build-Own-Operate (BOO)	Private	Public or Private	Private by contract (concession)			

Figure 2-2: Basic project delivery options[2]

In the case where the private sector invests into the project, the PPP contract allows this private project developer to recover its investment through user charges. The commercial arrangement in general is implementing one of the following types of offtake agreements:

[1] Public-Private Partnership Handbook, ADB, 2008
[2] Public-Private Partnership Handbook, ADB, 2008

1. Minimum level of off-take of electricity
2. Take-or-pay (ToP) agreement - whereby the electricity output of the project is purchased regardless of the demand
3. Capacity-based structure whereby the availability of the underlying asset is paid (availability payment) to recover the fixed costs and the required returns and consumption is a pass-through item.

The ToP agreement is the one usually implemented with respect to renewable energy assets as it is the least risky option from the investor's perspective.

2.1.1 The IPP structure

The Independent Power Producer (IPP) structure can be considered as a power-sector-specific variation of PPP. Under this arrangement the IPP is a private sector entity which usually finances, builds, owns and operates the power plant. IPPs are generally financed through project financing which is backed by a long-term off-take agreement.

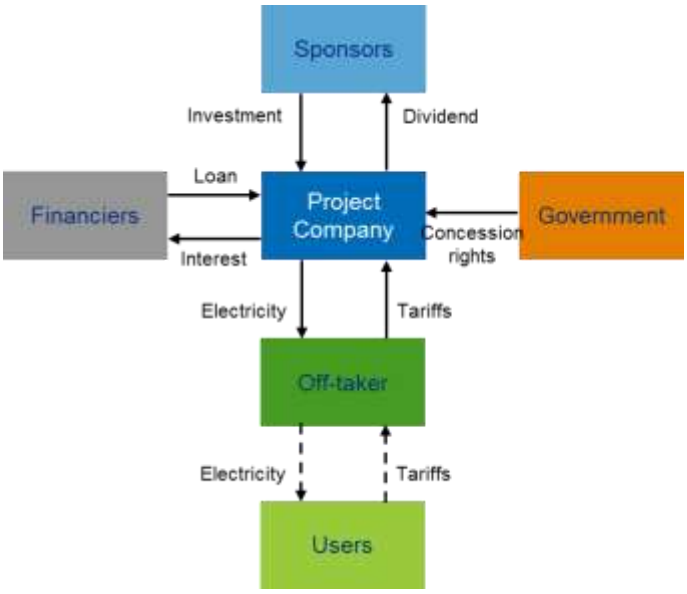

Figure 2-3: Example IPP structure

2.1.2 Main markets for integrated battery storage schemes

Deployment of large-scale battery storage can significantly enhance the utilisation of energy generation from renewable sources. One of the main consequences is the reduced or eliminated curtailment of renewable energy generation. Batteries can be used also to control the renewable generation plants' ramp rate and assist in frequency management. Therefore, there have been a growing number of combined renewable energy generation-battery storage scheme developments in the recent years with a common approach of a combined storage plus solar under long-term power purchase agreements (PPAs).

However, the deployment of stand-alone battery-based energy storage projects has been less wide-spread. Nevertheless, battery storage can contribute to defer transmission upgrades and can provide grid services, such as balancing short-term fluctuations in load, supply fast frequency response and voltage regulation. For this reason, electric utilities have started to implement battery systems for these purposes.

The main pioneer of deploying stand-alone battery storage is the United States where in some states electricity regulations are changing favourably for battery storage implementation. Another key market of utility-scale battery storage is Germany. In addition, Germany has an increasing amount of residential behind-the-meter small battery storage systems. In the United Kingdom, battery storage has taken part in the ancillary service market and some of the largest utilities have started to develop their own battery storage plants. Recently, Australia has also got itself on the map with large battery system installations alongside renewable energy plants[3].

Based on our desktop research and reaching out to industry players, it can be concluded that battery storage systems are most commonly installed together with generation units (renewable and/or thermal). Procurement of these systems mainly includes direct procurement by the utility or through IPPs. Stand-alone battery systems are rather uncommon and mainly happen on larger scale in the United States where utilities procure battery storage for balancing and ancillary services.

2.1.2.1 United States

To date, six states have already energy storage mandates and targets or have investigated closely the implementation of energy storage procurement targets: California, New York[4],Oregon, Massachusetts, Arizona[5] and Nevada[6].

Without any doubts, California, which kicked off its battery storage market by setting targets as early as in 2013[7] now has the largest energy storage market in the United States. These targets require the investor-owned utilities to procure 1.3GW of energy storage by 2020 and the state authorised an additional 500MW[8].

In 2013 the California Energy Commission (CPUC) directed California's three largest investor-owned electric utilities (IOUs) Southern California Edison (SCE), Pacific Gas and Electric (PG&E) and San Diego Gas and Electric (SDG&E) to procure grid-connected energy storage systems with 1,325MW by 2020[9]. This has been increased by a further 500MW in 2016[10]. The distribution of these obligations across the IOUs is the following:

- SCE: 580MW + 166.6MW
- PG&E: 580MW + 166.6MW
- SDG&E: 165MW + 166.6MW

The CPUC also directed California's publicly owned utilities (POUs) to adopt appropriate storage targets. The Los Angeles Department of Water & Power (LADWP) set its energy storage target at 178MW in 2017 from which already installed 22.6MW and plans to install another 20MW battery system at the Beacon Solar Plant in the Mojave Desert[11].

In line with its obligations, SCE initiated the procurement of about 400MW of energy storage projects[12], but not all moved forward. The main battery storage projects of SCE are the following:

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[3] https://www.smartenergy.org.au/sites/default/files/uploaded-content/field_f_content_file/australian_energy_storage_market_analysis_report_sep18_final.pdf
[4] https://electrek.co/2017/12/01/new-york-energy-storage-targets/
[5] https://www.scientificamerican.com/article/an-arizona-utility-is-betting-big-on-energy-storage/
[6] https://www.energy-storage.news/news/nevada-utilitys-100mw-plan-will-take-state-first-step-of-way-to-2030-storag
[7] https://www.greentechmedia.com/articles/read/california-sets-1-3gw-energy-storage-target-by-2020
[8] Integrated Energy Policy Report Update, California Energy Commission, 2018
[9] California Energy Commission – Tracking Progress, 2018 August
[10] https://www.sandiegouniontribune.com/business/energy-green/sd-fi-sdge-batterystorage-20180604-story.html
[11] California Energy Commission – Tracking Progress, 2018 August
[12] https://www.edison.com/home/innovation/energy-storage.html

Table 2-1: The main battery storage projects of SCE

Developer	Location	Rating (MW)	Capacity (MWh)	Compl. Date
Tesla[13]	Mira Loma	2 x 10	40	2017
esVolta[14] - Acorn I, II & III	Thousand Oaks	6.5	25	2020 est.
esVolta[15] - Wildcat	Palm Springs	31	12	2020 est.
esVolta - Millikan[16]	Irvine	2	9	2017
esVolta - Quarantina[17]	Santa Barbara	10	40	Unknown
GE – Hybrid EGT[18]	Norwalk and in Rancho Cucamonga	10	Unknown	2017
Quanta Technology[19]	Tehachapi	8	32	2015

The projects aim to provide incremental capacity at specifically selected areas on SCE's distribution network to enhance system reliability and to avoid expensive system upgrade investments to meet load growth. The project Mira Loma, Norwalk and in Rancho Cucamonga and Tehachapi are owned directly by SCE while the Acorn, Wildcat, Millikan and Quarantina projects are contracted under a build-own-operate structure. The Tehachapi project is a demonstration project to improve grid performance and wind integration at the Tehachapi Wind Resource Area[20].

In addition to the above, SCE launched in 2016 a pilot project of total 125MW to test if the growing demand of urban areas of Orange County can be met by clean energy[21]. This project consists contracted six developers to provide battery storage, demand response and solar-battery storage systems. These systems are the following:

[13] https://energized.edison.com/stories/innovative-battery-storage-facility-at-sces-mira-loma-substation-allows-for-more-renewables
[14] https://www.businesswire.com/news/home/20181015005312/en/esVolta-Selected-Energy-Storage-Projects-Totaling-38.5
[15] https://www.businesswire.com/news/home/20181015005312/en/esVolta-Selected-Energy-Storage-Projects-Totaling-38.5
[16] https://www.esvolta.com/millikan
[17] https://www.esvolta.com/quarantina
[18] https://energized.edison.com/stories/sce-unveils-worlds-first-low-emission-hybrid-battery-storage-gas-turbine-peaker-system
[19] https://www.energy.gov/sites/prod/files/Tehachapi.pdf
[20] https://www.energy.gov/sites/prod/files/Tehachapi.pdf
[21] https://energized.edison.com/stories/orange-county-pilot-tests-whether-clean-energy-resources-can-meet-major-metro-needs

Table 2-2: SCE Orange County pilot battery storage projects

Developer	Type	Rating (MW)	Term (years)
AMS	Demand Response from Energy Conservation and Battery Storage	40	15
Convergent	Battery storage	35	20
Hectate	Battery storage	15	10
NextEra	Battery storage	10	15
NextEra1	Demand Response from Energy Conservation and Battery Storage	10	15
NRG	Hybrid of Solar and Battery Storage	10	15
Swell	Demand Response from Battery Storage	5	15

PG&E aims to replace three of its peaker gas fired power plants by implementing four large battery storage systems[22].

Table 2-3: The main battery storage projects of PG&E

Developer	Location	Rating (MW)	Capacity (MWh)	Compl. Date
Vistra[23]	Moss Landing	300	1,200	2020 est.
esVolta - Hummingbird[24]	Coyote Valley	75	300	2020 est.
mNOC[25]	Various	10	40	2019 est.
Tesla (only EPC)	Moss Landing	182.5	730	2020 est.

The commercial structure of the Moss Landing Project PG&E entered in a 20-year resource adequacy contract with Vistra. This contract with a bankable off-taker allows Vistra to develop and finance the project and to provide ancillary services and sell the surplus on the wholesale market unlocking additional revenue streams[26].

The Hummingbird project developed, financed and owned by esVolta has been awarded a 15-year reliability-must-run (RMR) type of contract by PG&E[27].

The 10MW / 40MWh mNOC AERS Energy Storage project would be developed and owned by a subsidiary of Mirconoc. The project is an aggregation of distribution-connected, behind the meter batteries which has been awarded a 10-years contract[28].

The 182.5MW / 730MWh project would be owned by PG&E and would be implemented by Tesla under an engineering, procurement, and construction (EPC) contract. The system when completed will be the

22 https://www.greentechmedia.com/articles/read/pge-proposes-worlds-biggest-batteries-to-replace-south-bay-gas-plants#gs.46djmt
23 https://www.prnewswire.com/news-releases/vistra-energy-to-develop-300-megawatt-battery-storage-project-in-california-300674786.html
24 https://www.esvolta.com/hummingbird
25 http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M240/K050/240050937.PDF
26 https://investor.vistraenergy.com/investor-relations/news/press-release-details/2018/Vistra-Energy-to-Develop-300-Megawatt-Battery-Storage-Project-in-California/default.aspx
27 https://www.esvolta.com/hummingbird
28 https://www.utilitydive.com/news/pge-to-replace-3-gas-plants-with-worlds-biggest-battery-projects/526991/

largest battery storage system in the world[29]. According to the plans, the system would address local capacity requirements and would participate in the California Independent System Operator (CAISO) markets, providing energy and ancillary services[30].

The above projects, however, may need to be scrapped due to the potential bankruptcy of PG&E which filed for bankruptcy earlier this year[31]. It is not clear at the moment how these projects can move forward with this unfavourable development.

SDG&E has got more than 125MW energy storage and 83.5MW is under procurement at the moment. This portfolio consists of the following projects[32]:

Table 2-4: The main battery storage projects of SDG&E

Developer	Location	Project size	Capacity	Compl. Date
Fluence Energy	Fallbrook	40MW	160MWh	2021 est.
Renewable Energy Systems (RES) America	San Diego	30MW	120MWh	2019 est.
Powin Energy (esVolta)	Escondido	6.5MW	26MWh	2021 est.
Advanced Microgrid Solutions (AMS)	San Juan Capistrano	4MW	16MWh	2019 est.
Enel Green Power	Poway	3MW	12MWh	2021 est.

Besides California, New York is the other leader of implementing battery storage in the United States. The state set a target of 1,500MW energy storage target by 2025 and a 3,500MW target by 2030[33]. To support to reach these targets the New York State Energy Research and Development Authority (NYSREDA) developed the New York State Energy Storage Roadmap in 2018. The Roadmap defines the main areas to focus including the necessary regulatory changes and authorising $350 million in bridge incentives and reallocation $52.9 million in Regional Greenhouse Gas Initiative (RGGI) to reach the set goals. Key element of this to direct the state's six IOUs to procure a minimum of 350MW energy storage systems under a competitive tender process. Projects however are yet to materialise. To date the largest project in the state is the 20MW KCE NY 1 in Saratoga which has been developed by Key Capture Energy and NEC Energy Solutions[34].

Oregon followed California with its own target and required its utilities, Portland General Electric (PGE) and PacifiCorp (PC), to submit proposals to procure storage systems of 5MWh or higher[35]. PGE already proposed a project with a total capacity of 39MW[36] while PC only identified two pilot projects with an aggregate capacity of 4MW / 11MWh[37] which is yet to move forward as it has not been proven to be cost effective at the moment.

[29] https://interestingengineering.com/california-set-to-build-the-worlds-largest-battery-system
[30] http://investor.pgecorp.com/news-events/press-releases/press-release-details/2018/PGE-Proposes-Four-New-Cost-effective-Energy-Storage-Projects-to-CPUC/default.aspx
[31] https://uk.reuters.com/article/uk-pg-e-us-storage/pge-bankruptcy-threatens-major-battery-storage-project-idUKKCN1R32OG
[32] https://www.utilitydive.com/news/sdge-approved-for-5-storage-projects-totaling-334-mwh/525425/
[33] https://www.nyserda.ny.gov/All%20Programs/Programs/Energy%20Storage/Achieving%20NY%20Energy%20Goals/The%20New%20York%20State%20Energy%20Storage%20Roadmap
[34] https://www.keycaptureenergy.com/kce-ny-1-breaks-ground-on-20-mw/
[35] https://www.powermag.com/new-york-city-sets-ambitious-citywide-energy-storage-target/
[36] https://www.energy-storage.news/news/portland-general-electric-to-invest-up-to-100-million-for-39mw-of-energy-st
[37] https://www.utilitydive.com/news/pacific-power-analysis-shows-storage-pilot-projects-currently-uneconomic/522065/

Massachusetts has also taken significant measures to adapt battery storage in its power system. As part of this, the Department of Energy Resources (DOER) set a 200MWh energy storage target by 2020 for the electric distribution companies of the state[38]. It was also the first state which made battery storage eligible for Energy Efficiency Incentives[39].

The following table summarises the main ongoing projects in Massachusetts.

Table 2-5: The main battery storage projects in Massachusetts

Developer	Location	Project size	Capacity	Compl. Date
Eversource Energy	Martha's Vineyard Phase 1[40]	4.9MW	20MWh	2020 est.
Eversource Energy	Martha's Vineyard Phase 2[41]	9.8MW	64MWh	2023 est.
Eversource Energy	Provincetown	25MW	38MWh	Unknown
Green Charge (ENGIE Group)	Mt. Tom	3MW	6MWh	Operational[42]
Tesla	Nantucket	6MW	48MWh	2019 est.

The project at the vineyard was designed to reduce the use of the diesel generators on the island and defer the expansion of the grid via an additional undersea cable. The project would also improve the utilisation of the existing solar power plants owned by IPPs and support the integration of additional renewable energy sources. The Provincetown project will serve as a backup generation for four towns in case of a power outage on the system[43].

The battery storage at Mt. Tom is used to optimise the production of the adjacent solar plant and to reduce utility capacity costs for Holyoke Gas & Electric (HG&E). The storage was built and now is operated by Green Charge (now ENGIE Storage Services) under a 20-year commercial agreement[44].

Nantucket is an island and a popular tourist spot which hosts 10,000 year-round residents with a 50,000 summertime population[45]. The island currently is supplied by a 3MW close-to-end-of-lifetime diesel generator and two undersea cables. The island's utility National Grid decided to install a large battery storage system which, along with the planned upgrade of the diesel generator to 10MW, will defer the installation of a third undersea cable and secure the uninterruptable power supply.

In addition to the above larger projects $20 million in grants were awarded to 26 small scale battery storages under the state's Advancing Commonwealth Energy Storage (ACES) programme[46]. These projects represent a total size of 32MW and a total capacity of 85MWh[47].

[38] https://www.mass.gov/service-details/energy-storage-target
[39] https://www.renewableenergyworld.com/ugc/articles/2019/02/01/massachusetts-becomes-first-in-the-nation-to-make-battery-storage-eligible-for-energy-efficiency-inc.html
[40] https://www.eversource.com/content/nh/about/projects-infrastructure/projects/martha's-vineyard-energy-storage-project
[41] https://www.eversource.com/content/nh/about/projects-infrastructure/projects/martha's-vineyard-energy-storage-project
[42] https://www.marketwatch.com/press-release/engie-na-unveils-largest-energy-storage-system-in-massachusetts-in-cooperation-with-holyoke-gas-electric-2018-09-25
[43] https://microgridknowledge.com/energy-storage-marthas-vineyard/
[44] https://www.businesswire.com/news/home/20171004005416/en/ENGIE-North-America-Announces-Largest-Utility-Scale-Energy
[45] https://www.utilitydive.com/news/there-once-was-an-energy-storage-system-on-nantucket/513650/
[46] https://www.utilitydive.com/news/6-months-after-target-adoption-massachusetts-sees-energy-storage-growth-c/515353/
[47] https://files.masscec.com/ACES%20Project%20Details.pdf

Arizona has also significant ambitions regarding battery storage deployment set out in the state's Energy Modernisation Plan[48]. The Plan aims to pursue a target of 3,000MW energy storage deployment by 2030 from electrochemical, mechanical, thermal, and gravitational technologies. The state's largest IOU Arizona Public Service Electric Company (APS) has plans to deploy 850MW battery storage by 2025. This includes the addition of 200MW battery storage for existing solar plants, 500MW new battery storage under APS ownership and contracting 150MW of third-party owned systems[49]. The 500MW systems will be generally co-developed with solar projects. The 150MW / 600MWh battery storage capacity will help APS to meet demand in peak periods substituting peaking gas fired power plants. Out of the total 150MW, 100MW was awarded to AES and 50MW to Invenergy.

The state's other large utility Tucson Electric Power (TEP) has been leading the development of energy storage systems not only on the state level, but also nation wise. TEP added two 10MW of battery storage systems to its grid in 2017 alone[50] to maintain grid reliability during peak periods and to improve renewable energy generation utilisation. One project was implemented by NextEra Energy Resources and the other one is E.ON Climate & Renewables. The projects were developed under 10-year contracts with performance guarantees by the developers[51].

The first stand-alone battery storage of the state will be deployed by Salt River Project (SRP) a Tempe-based not-for-profit public power utility which is largest electricity provider in the greater Phoenix metropolitan area. This 10MW / 40MWh project will be developed by Fluence, a Siemens and AES company, under a 20-year and will be charged by an SRP distribution substation[52].

Nevada has been behind the five other states above regarding deployment of battery storage. The Public Utilities Commission of Nevada (PUCN) however have commissioned an economic study in 2018 to investigate the potentials of battery storage and whether setting mandatory targets for the utilities would be in the public interest[53]. Despite the fact that there have been no mandatory targets set by the authorities yet, one of the state's utilities NV Energy announced recently it has contracted the procurement of more than 1GW of solar projects and 100MW of battery storage[54]. These storage capacities though seem not to be stand-alone systems but would be integrated with the solar power plants. Some stand-alone battery storage systems in Nevada are planned but are yet to be implemented.

For the applicability of battery-storage implementation under PPP-type of arrangements on PIC Islands, solutions on United States island territories have been also analysed. More specifically, recent developments in the battery storage area in Puerto Rico and Hawaii have been assessed below.

Puerto Rico which is prone to tropical storms and was devastated by Hurricane Maria in September 2017, is considering improving the electricity network resilience by creating mini-grids and deploying energy storages. To facilitate it, the Puerto Rico Electric Power Authority (PREPA) engaged Siemens to prepare a new integrated resource plan (IRP) for the island covering the period of 2019-2038. The first four years of the plan includes a potential deployment of between 440MW and 900MW of energy storage systems.

Following a study on potential procurement of battery storage systems under a PPP arrangement published by the Puerto Rico Public-Private Partnerships Authority (PRPPPA), together with PREPA a request for proposal was issued to (RfP) short-listed firms AES, Fluence and Tesla55. The scope included deployment of a portfolio of one or more energy storage systems at PREPA substations with a capacity between 10MW and 40MW and with one to four hours of discharge capacity.

The contractors need to provide the financing, the design, engineering, and construction services, the operation, maintenance, the necessary ongoing capital improvement, warranties, training, and support. Under this 10- to 30-year term PPP arrangement, the selected contractor would also own the assets

[48] https://www.azcc.gov/commissioners/atobin/letters/energyplan.asp
[49] https://www.greentechmedia.com/articles/read/aps-battery-storage-solar-2025#gs.6w3yud
[50] https://www.tep.com/news/tep-ranks-among-nations-top-utilities-for-expanding-energy-storage/
[51] https://www.tep.com/news/tep-enhances-service-reliability-with-new-developing-energy-storage-systems/
[52] https://srpnet.com/newsroom/releases/053018.aspx
[53] https://www.energy-storage.news/news/energy-storage-procurement-targets-could-work-for-nevada-pucn-commissioned
[54] https://www.nvenergy.com/about-nvenergy/news/news-releases/nv-energy-announces-largest-clean-energy-investment-in-nevadas-history
[55] http://newenergyevents.com/puerto-rico-issues-energy-storage-rfps-to-shortlisted-firms/

providing the committed capacity[56] while PREPA will control the system and be responsible for the energy needed to charge the batteries.

Recently, Hawaii has approved seven new solar-plus-battery projects adding a total 1048MWh of storage to the grid. Table 2-6 to

Table 2-8 list the battery storage projects in Hawaii.

Table 2-6:Projects on O'ahu

Project	Status	Rating (MW)	Capacity (MWh)
Campbell Industrial Park Storage BESS	Construction starts Oct 2019	100	100
AES West Oahu Solar/BESS	Operational	~12.5[57]	50
Mililani I BESS	Approved	Unknown	156
Waiawa Solar BESS	Approved	Unknown	144
Ho'ohana Solar I BESS	Approved	Unknown	208
West Loch Storage	Construction starts Oct 2019	20	80

Table 2-7: Projects on Hawai'i Island

Project	Status	Rating (MW)	Capacity (MWh)
Hale Kuawehi Solar LLC BESS	Approved[60]	Unknown	120
AES Waikoloa Solar LLC BESS	Approved[60]	Unknown	120

[56] http://www.p3.pr.gov/assets/dc-study-utility-scale-energy-storage-systems.pdf%20
[57] https://energy.ehawaii.gov/epd/public/energy-project-details.html?rid=177--310d42690926589

Table 2-8: Projects on Maui

Project	Status	Rating (MW)	Capacity (MWh)
Kaheawa Wind II BESS	Operational	10	20
Wailea Substation BESS		1	1
Lana'I Sustainability Reach	Operational	1	0.5
Kuihelani Solar/BESS	Approved	~62[58]	240
Auwahi Wind/BESS	Operational	11	4.4
Paeahu Solar/BESS	Under Development		60
Moloka'I New Energy Partners BESS	Under Development	2	15
Moloka'I BESS		1	0.397

The Hawaiian Electric Company is the utility that supplies about 95% of the electricity in the state. It enters into long-term PPAs with renewable energy generators which includes battery operators. These PPAs vary are in the region of 20-25 years. After reviewing all the projects in the state, no information about payments for ancillary services has been found in the public domain. Equally, there is no evidence that there is scope for arbitrage (wholesale energy price trading), which is unsurprising given the small size of the grid. At present, the mechanism through which renewable energy projects paired with batteries are being subsidised is Federal Investment Tax Credit, which amounts to 30% of the value of the project, which is significant government support. However, there is no evidence about further partnerships with public organisations [59] [60].

Out of the listed projects, three stand-alone battery storage installations have been identified. These are

- Campbell Industrial Park BESS

[58] https://energy.ehawaii.gov/epd/public/energy-project-details.html?rid=16f--7a8669ae32df7ff
[59] https://energy.ehawaii.gov/epd/public/energy-projects-map.html
[60] https://www.hawaiianelectric.com/clean-energy-hawaii/clean-energy-facts/about-our-fuel-mix

- Wailea Substation BESS
- Moloka'i BESS

Wailea and Moloka'i are installed in substations and are used to provide grid stability [61] [62]. The Campbell Industrial Park BESS is a good large-scale battery example from Hawaii that is stand-alone and not paired with a renewable energy installation. The project is a stand-alone battery storage that is expected to offset generation from conventional sources and provide contingency reserve. The project is expected to pay off the required investment on its own through network service cost savings. The project seems to be also unsubsidised[63] [64].

2.1.2.2 Germany

Over the last 25 years, more than 1.7 million solar power installations with an overall capacity of 45GWp were installed in Germany. These installations create a good basis for the implementation of small-scale battery storage systems. On average, when combined with solar power, batteries can increase the utilisation of PV-generated electricity from 35% to 70%[65]. This, in addition to the falling costs of batteries and regional incentives, makes investment in battery storage more attractive than ever. It is attracting attention in the German power market, but for large, not only for small-scale installations, combined with power plants.

Indeed, large-scale stand-alone battery storage systems are also being deployed all over Germany. Their fast response times help stabilise the grid frequency and provide more control in balancing large amounts of energy. The total power capacity provided by large-scale systems in Germany in 2012 was 26MW. In 2017, the cumulative power capacity was 6.5 times larger with 172MW and 14 times larger in 2018 with 371MW[66]. The number of projects is rapidly increasing mainly because of public and private initiatives cooperating on the development of this technology. Numerous pilot projects have been successful in improving the reliability of transmission networks over the last few years, which further supports the momentum of the technology implementation.

In addition to providing frequency balancing services such as Enhanced Frequency Response (EFR), battery storage applications also include uninterrupted power supply and black start capabilities. These combinations of services provide operators with a set of different revenue streams ensuring the viability of the system. Below is a list of a few successful stand-alone large-scale projects implemented in the country:

Table 2-9: The main battery storage projects in Germany

Developer	Location	Project MW	Completion Date	Main Services Provided
Enspire ME	Jardelund	48MW	2018	Supply
Enel Green Power & Leclanché	Cremzow	22MW	2018	EFR, Black start
Steag	Various sites	90MW (6x15MW)	2017	EFR, Supply
Eins Energie in Sachsen	Chemnitz	10MW	2017	EFR, Supply

61 https://www.hnei.hawaii.edu/sites/www.hnei.hawaii.edu/files/HEET%2010%20Grid%20Scale%20Storage.pdf
62 http://hiveenergyinternational.com/wp-content/uploads/2018/12/Hive_presentation_03.pdf
63 https://www.hawaiianelectric.com/hawaiian-electric-plans-major-energy-storage-projects
64 https://www.energy-storage.news/news/hawaii-electric-announces-120mw-of-grid-balancing-renewables-integrating-li
65 https://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/Downloads/GTAI/Fact-sheets/Energy-environmental/fact-sheet-energy-storage-market-germany-en.pdf?v=6.com
66 https://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/Downloads/GTAI/Fact-sheets/Energy-environmental/fact-sheet-energy-storage-market-germany-en.pdf?v=6.com

One of Germany's largest battery storage facilities was constructed in 2018 in Jardelund. The project was developed by Enspire ME, a joint venture formed between Enerco, a Dutch developer, and Japan's Mitsubishi. Jardelund is a key location in Germany as it is a nexus for offshore wind energy transmission and where other storage technologies are not suitable. The facility is located next to a substation and will maximize its efficiency while storing surplus energy from local wind farms. The facility's power and energy capacities are 48MW and 50MWh and it has a 15-year warranty[67].

In 2018, the 22MW facility in Cremzow was completed. Leclanché, a provider of energy storage systems based in Switzerland, is the engineering, procurement and construction contractor of the project. With an initial €17 million investment, Enel Green Power Germany, a subsidiary of the Italian Enel Group dedicated to the development and operation of renewables, owns 90% of the project and Enertag, a German renewable energy company owns the remaining 10%. The facility provides EFR services that allow control of the grid frequency and is capable of backing up the renewable energy system in case a black start is necessary. This project was a clear demonstration that battery energy systems are profitable without the need for subsidies. In addition, the possibility of integrating Enertag's wind farms' energy surplus to the facility is currently being studied[68].

In 2017, Steag, a major German utility, completed a project that consists of six 15MW storage systems deployed in six different cities in Germany. The investment of US$100 million was made by Steag, without any public funding. Nidec ASI was commissioned to supply and install the batteries that have a total combined capacity of more than 120MWh and could theoretically provide power for 300,000 homes for one hour[69]. The purpose of this project was to help Steag stabilise the grid via frequency regulation and voltage control[70].

Another project is a 10MW/16MWh battery storage plant built by Belectric for Eins Energie in Sachsen, a local German energy utility. The project cost €10 million and was funded by the state, with the help of the European Regional Development Fund, a fund allocated by the European Union, that contributed with €1 million[71]. The facility will mainly provide EFR and power supply services.

2.1.2.3 Japan

Japan is experiencing a growing demand for battery storage technologies, however at this stage this is predominantly at domestic level. The generous feed-it tariff regime that began in 2009 is beginning to expire in 2019, which means that domestic renewable energy producers will need to focus on consuming their electricity rather than exporting it to the grid[72]. There are also a number of larger scale battery storage projects operated predominantly by utility companies[73]. However, these batteries are not independently operated and are not part of a PPP. The reason for this is that Japan has only started to liberalise its electricity market using a similar structure to the one in the UK, with the reform due to be completed by 2020, including the introduction of a capacity and a real-time electricity exchange market[74]. Once the entire market is liberalised and the country's entire volume of electricity is traded on the market, and additionally there is a capacity market and ancillary services market, stand-alone energy storage facilities could become commercially viable.

2.1.2.4 United Kingdom

In a report released by the All-Party Parliamentary Group (APPG) and written by the Renewable Energy Association (REA), it is mentioned that despite a low battery storage capacity of 0.06GW in 2016, the deployment of battery storage in the UK could reach up to 12GW by 2021[75]. This increase in capacity is not only explained by falling battery prices, but also because of the realisation that battery storage

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[67] https://greycellsenergy.com/examples/enspire-mes-jardelund-battery-storage-plant/
[68] https://www.evwind.es/2019/05/16/enel-green-power-enertrag-leclanche-inaugurate-22-mw-cremzow-battery-energy-storage-system-in-germany/67226
[69] http://www.steag-grossbatterie-system.com/en/index.html
[70] https://www.energy-storage.news/news/steag-inaugurates-us100-million-largest-of-its-kind-energy-storage-system
[71] https://renews.biz/36014/saxony-angle-for-belectric-battery/
[72] https://www.energy-storage.news/news/home-solar-plus-storage-technology-enables-tokyo-electric-powers-smart-tari
[73] https://www.eubusinessinjapan.eu/sites/default/files/energy_storage_landscape_in_japan.pdf
[74] https://solar-media.s3.amazonaws.com/assets/Pubs/Global%20Energy%20Storage%20Opportunity%202018/Global%20Energy%20Storage%20Opportunity%202018%2005.06.pdf?utm_source=ESN_resource+page
[75] https://www.r-e-a.net/news/mps-foresee-massive-subsidy-free-deployment-of-12gw-battery-storage-as-possible-with-favourable-poli

technology is going to play a critical role in balancing the grid, especially due to the increasing share of renewables in the energy mix (30% in 2017).

Since battery storage is a rather new technology, there are issues preventing its growth. Electricity markets in the UK were designed well before these technologies existed, and as a result, it turns out that storage providers have strong disadvantages that prevent them from successfully participating in these markets. One of these disadvantages is that storage providers are taxed both when electricity is used to charge the batteries, and when the electricity is released into the grid

However, this did not prevent investors from being attracted by the technology. For instance, one of UK's largest stand-alone battery storage projects consists of a 49MW/24.5MWh lithium ion facility in Roosecote, which received a 15-year Capacity Market contract[76]. The construction was completed by Centrica in December 2018 and the facility is now able to provide a sub-second response to demand fluctuations and holds enough power to meet the needs of around 50,000 homes[77].

In 2016, the National Grid, the British network operator, launched its first EFR tender. Out of the 64 pre-selected projects, only 8 of them were selected to receive 4-year long EFR contracts[78]. Contracts of short periods have brought bidders to consider other revenue streams, such as the Capacity Market and balancing services, amongst others, to ensure the viability of the projects. In 2018, the Port of Tyne's 35MW battery storage project was the last of these 8 projects to be successfully completed[79].

The Port of Tyne's 35MW battery storage facility was developed and completed by Renewable Energy Systems Limited (RES). UK-based infrastructure investor Foresight Group purchased it in 2017 and RES remains the operator of the system. The project is comprised of eight battery containers functioning as a single unit with a primary function to provide frequency response balancing services through the EFR contract[80] and provide available capacity to the National Grid, through a 12-year capacity market contract[81].

Similarly, The Renewables Infrastructure Group (TRIG) acquired a 20MW energy storage project in Broxburn, Scotland in 2017 which was also developed, constructed and operated by RES[82]. The project has a 15-year lifetime and provide grid balancing services, such as EFR, through a four-year bilateral agreement with the National Grid and associated availability payments[83].

National Grid's 2016 EFR tender left over 1.2 GW of unsuccessful EFR battery storage capacity without support. The market is clearly booming and will require more clarity in the future if sector momentum will be maintained. Future policy direction will be key in this matter, but in the meantime, battery storage projects which are combined with existing solar and wind farms are helping to bring battery prices down without policy support[84].

2.1.2.5 Australia

Currently Australian storage projects generate revenue through wholesale energy price trading (arbitrage) or through payments for ancillary services. Private sector investors require stable and predictable cashflow in order to justify their investment and currently this commercial environment cannot provide sufficient certainty of income. As a result, purely private investment in such projects becomes difficult to attract and developers rely on incentives and subsidies from the government[85]. Another consequence of this is that stand-alone battery systems are not yet widespread, but instead battery storage usually accompanies renewable energy projects.

In a market where prices experience a significant surge during peak demand, batteries could be used to limit those surges by providing the extra capacity, while generating profit by buying energy cheaply and selling it at higher prices. Having the extra capacity would also reduce the price fluctuations in the market. For this revenue stream, a liberalised electricity market structure (such as the Australian one)

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[76] https://www.current-news.co.uk/news/centrica-celebrates-completion-of-49mw-roosecote-battery
[77] https://www.centrica.com/news/centrica-start-construction-new-battery-storage-facility-roosecote
[78] https://home.kpmg/content/dam/kpmg/uk/pdf/2016/10/kpmg-efr-tender-market-briefing-updated.pdf
[79] https://www.energy-storage.news/news/edfs-completed-49mw-battery-system-brings-nearly-all-efr-projects-over-the
[80] https://www.powerinfotoday.com/Hydroelectric/res-sells-35mw-battery-storage-facility-at-port-of-tyne-to-foresight/
[81] http://www.windpower-international.com/features/featureadvanced-battery-storage-for-uks-national-grid-6125469/
[82] https://www.powerinfotoday.com/Hydroelectric/trig-acquires-20mw-broxburn-energy-storage-project-from-res/
[83] https://theenergyst.com/res-sells-20mw-efr-battery-storage-project-to-infrastructure-investment-group-trig/
[84] https://home.kpmg/content/dam/kpmg/uk/pdf/2016/10/kpmg-efr-tender-market-briefing-updated.pdf
[85] https://www.pwc.com.au/infrastructure/pwc-energy-storage-financing-speed-humps.pdf

with fluctuating prices should be in place. The second revenue stream is ancillary services (i.e. frequency response). Again, this revenue stream could only exist in a liberalised market where such services are monetised. And finally, the level of government support should be adjusted based on the ability of such projects to generate revenue on their own.

As a consequence of rapidly falling battery storage prices, the rates at which batteries are being deployed in Australia have significantly increased. As already mentioned, due to the limited scope for energy storage projects to generate revenue on their own, the prevailing configuration for storage technology is collocation with renewable energy generators. Table 2-10 lists the completed projects that use batteries as energy storage alongside renewables.

Table 2-10: Completed renewables projects that feature battery storage[3]

Project	Type	Rating (MW)	Capacity (MWh)
Coober Pedy	Hybrid off-grid	1	0.5
DeGrussa Copper Mine	Solar + battery	4	5.6
Flinders Island	Solar + wind + storage	1.1	0.3
Hornsdale Power Reserve	Wind + battery	100	129
Jemalong CSP Pilot	Solar Thermal	1.1	
King Island	Hybrid off-grid	3	1.6
Lakeland Solar and Storage	Solar + battery	1.4	5.3

The common feature between all of these projects is that all of them have benefited from a grant from the Australian Renewable Energy Agency (ARENA). The grant value differs from case to case and its main goal is to leverage private investment by making the project more economically viable.

To give a better overview of the projects listed in Table 2-10, the commercial arrangements of each of them have been explored in more detail. The Coober Pedy Renewable Diesel Hybrid project is a 1MW solar, 4MW wind and a 1MW/0.5MWh battery storage facility that operates in conjunction with adjacent 3.9MW diesel generation. The project aims to achieve the highest penetration of renewable energy in Australia by reaching around 70%. The project was partially funded by the ARENA, which has enabled it to go forward. The total project value is A$38.86m, A$18.41m of which has been supplied by ARENA (47.4% funding). The lead organisation on the project is Energy Developments Ltd (EDL)[86]. The purpose of installing the battery is to increase the penetration of renewable energy, thus helping to displace a larger proportion of the diesel generated electricity. The project has been developed in an off-grid location, which increases the replicability of its concept in islands and islanded communities.

Hornsdale Power Reserve is where the well-known 100MW/129MWh Tesla battery was installed. It is collocated with a wind farm and provides arbitrage and frequency response among other services. The battery is operated by the French company Neoen[87]. In 2018 the project generated A$29m in revenue[88] - a third of its reported capital investment of A$90m[89]. While the project's technical aspects have been widely publicised, information about financial arrangements is scarce.

[86] https://arena.gov.au/projects/coober-pedy-renewable-diesel-hybrid/
[87] https://hornsdalepowerreserve.com.au/
[88] https://reneweconomy.com.au/tesla-big-battery-pulled-in-29-million-in-revenue-in-2018-2018/
[89] https://reneweconomy.com.au/revealed-true-cost-of-tesla-big-battery-and-its-government-contract-66888/

The DeGrussa Copper Mine project is another off-grid project that combines solar with storage in order to offset diesel generation. The storage system is a 4MW/5.6MWh battery that aims to increase renewable energy penetration. ARENA has provided A$20.9m out of the total A$39.47m value of the project – a 53% share funding. The project is owned by the French company Neoen[90].

Another similar off-grid project that is capable of displacing 60% of annual diesel generation is the Flinders Island Hybrid Energy Hub[91]. The project cost is A$13.38m, A$5.5m (41.1%) of which came from ARENA. The project was developed by Hydro Tasmania[92].

King Island Renewable Energy Integration Project is another example of partially ARENA funded off-grid hybrid system. The level of support from ARENA is 33.3% (A$6.08m out of A$18.25m). The lead organisation in the project is Hydro Tasmania[93].

The Jemalong CSP Pilot is a 6MW(th) concentrated solar thermal power plant with a three hour storage capacity. The venture has attracted funding from a number of partners, leveraged by a A$9.89 grant from ARENA. The total value of the project is A$23.71 which translates to a 41.7% grant contribution.

Further example of funding leveraged by ARENA for off-grid renewables and storage project is the Lakeland Solar and Storage project. The grant proportion in this project is 41% - A$17.41m out of a total of A$42.50.

Apart from Hornsdale Power Reserve, all of the listed projects are located in off-grid locations. In such micro grid arrangements there is no market for ancillary services, hence the scope for revenue generation from storage facilities is even more limited and storage has been used exclusively as a supplementary technology for renewable energy generators and to offset diesel generation.

Table 2-11 lists known standalone battery projects in Australia. Most have not yet been completed.

Table 2-11: Stand-alone battery projects in Australia[94]

Project	Status	Rating (MW)	Capacity (MWh)
Alice Springs BESS	Construction	5	3.3
Battery Demonstration Systems Adelaide	Tendered	Unknown	Unknown
Carnarvon	Construction	2	2
Dalrymple	Contracted	30	8
Darwin/Katherine	Call for EoI	25-45	12.5
Snowtown	SA Gov grant approved	21	26
Thomastown	Completed	1	1
Vic battery Ballarat	Committed	30	30
Vic Battery Gannawarra	Committed	25	50
Whyalla Steel	Proposed	100	100

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90 https://arena.gov.au/projects/degrussa-solar-project/
91 https://www.hydro.com.au/clean-energy/hybrid-energy-solutions/success-stories/flinders-island
92 https://arena.gov.au/projects/flinders-island-hybrid-energy-hub/

93 https://arena.gov.au/projects/king-island-renewable-energy-integration-project/
94 https://www.smartenergy.org.au/sites/default/files/uploaded-content/field_f_content_file/australian_energy_storage_market_analysis_report_sep18_final.pdf

The rarity of operational battery storage projects in comparison with combined renewables/storage projects could be interpreted as evidence that such undertakings are only just becoming commercially viable or are only viable in certain circumstances. There are a number of projects that are currently under development, which could mean either that they are being developed in an environment where they could be profitable on their own or that there is readiness on the side of government institutions to provide support.

There is limited publicly available information about any of the ongoing projects as some of them are still at an early stage.

The Alice Springs BESS is a 5MW/3.3MWh grid connected battery. The initial investment in the project is $8.3m, with a projected simple payback time of four to five years. The battery is expected to aid the penetration of solar energy in the area, which is already high on residential properties[95], as well as providing grid stability. The project is being undertaken by Territory Generation (a government owned corporation[96]) without private sector partners.

A better example of private investment in battery storage leveraged by public support is the 30MW Dalrymple battery west of Adelaide. The cost of the project is A$30m, A$12m of which is provided by ARENA. In South Australia approximately 40% of the electricity comes from wind. There are no coal power plants and peak demand is met by gas-fired power plants, which comes at a higher price. As with other similar projects, the battery will provide ancillary services and grid stability, while also smoothening the output of renewable energy generators and accumulate revenue through arbitrage[97].

A similar funding arrangement is in place for the Ballarat Energy Storage System ($35.1m) and Gannawarra Energy Storage System (A$34.27m) projects. Each will receive A$25m from ARENA and the Victoria Government – funding amounting to around 70% of the value of the project. The leading organisations are Spotless Sustainability Services for Ballarat and Edify Energy for Gannawarra. This is yet another instance of government funding for a storage project, which would pay the required remaining investment through grid services and arbitrage[98] [99].

2.1.2.6 Rest of the World

Apart from the locations already explored in this section, there are a number of examples from the rest of the world of battery energy storage facilities supporting renewables. This technology is particularly well suited to small islands where conventional electricity generation takes the form of diesel generators which are polluting and expensive to operate. As previously discussed, batteries have positive effects on the penetration of renewables, grid stability and security, costs and the environment. Examples of such projects are:

- The Caribbean island of Bonaire, where a 6MW battery is charged through wind and solar power [100].
- The Caribbean island of Saba, where a 2.3MW battery performs a similar function and offsets the consumption of around 300 litres of diesel an hour [101].
- The French island of Martinique installed a 5MW/5MWh battery[102].
- A 7.5MWh battery on the island of Corsica to provide solar smoothing and peak dispatch[103].

There are limited details about the commercial arrangements in these examples, however some conclusions could be drawn. Battery storage seems to be very well suited to islanded communities without connection to a mainland grid. Storage is competitive with electricity from diesel generators even when the environmental benefits are neglected, so it brings down cost for such locations. Additionally, it balances the grid and provides extra security. Energy storage is a justified investment in

95 https://reneweconomy.com.au/northern-territory-unveils-first-grid-scale-battery-in-solar-capital-alice-springs-79369/
96 http://territorygeneration.com.au/
97 https://arena.gov.au/blog/southaustraliabattery/
98 https://arena.gov.au/projects/ballarat-energy-storage-system/
99 https://arena.gov.au/projects/gannawarra-energy-storage-system/
100 https://cleantechnica.com/2019/01/25/caribbean-island-bonaire-balances-solar-wind-diesel-with-storage/
101 https://www.energy-storage.news/news/2.3mwh-battery-saves-300-litres-of-diesel-an-hour-on-dutch-caribbean-island
102 https://www.energy-storage.news/news/nidec-asi-to-supply-complete-5mw-5mwh-system-to-martinique-wind-farm
103

the cases where the electricity is supplied by renewable energy sources such as solar and wind, which at present offer a very competitive prices per unit of energy. The common feature between the given examples is that they are located in places with extremely good renewable energy resource (in this case – solar).

2.2 Pros and cons in utilising PPP scheme for battery development in the Pacific region

The power systems of the Pacific Island countries (PIC) face several challenges. Without the adequate support to maintain system stability and frequency such smaller scale power systems can have grid stability issues. The Provision of spinning reserve in small diesel-based systems is normally not cost-effective. In addition, generation capacities on these networks often do not have the appropriate control systems in place to manage behaviour during disturbances. At present, most generation is diesel-based (i.e. fossil fuel) which requires expensive shipping and exposes the utility organisations to the volatile market prices of these fuels. Increasing solar PV implementation around the Pacific is helping to reduce dependence on fossil fuel. However, solar PV normally cannot provide continuous system stability due to its intermittency and daytime availability. Careful implementation of battery storage in PIC can improve the situation; nevertheless, the procurement method can have a significant impact on the outcomes. The advantages and disadvantages of utilising a PPP scheme in PIC are summarised below.

A key element of deploying battery storage systems is the selection of the appropriate battery **technology**. The field of battery storage is developing, new technologies are emerging and prices are falling. While the changes in the industry are attracting interest, they create challenges for users in selecting the technology and technical requirements which optimises their current and future needs of their systems. There is no simple single solution which always works. The thorough assessment of the local technical requirements and circumstances is essential and although battery storage can not only enhance the reliability and resilience of the grid, it normally also increases the complexity of control of the system. Therefore, the integration of batteries into small power systems in remote areas requires robust methods to ensure proper long-term performance and minimal system disruption during the implementation.

Considering the above challenges, one key argument in support for the potential involvement of the private sector in the battery storage implementation on PICs is the technical expertise which is required to maintain and operate these systems. Most PICs have limited technical **capability** and therefore outside expertise is usually required to assist in the analysis, selection and implementation of battery storage projects. Further, maintenance is a crucial activity to ensure the maximal utilisation of the assets. Although battery systems and electronic controls are usually known to be very reliable if correctly selected, installed and commissioned, high-level expertise is sometimes necessary for fault finding. Even remote support from suppliers, via the internet may not be adequate to enable repairs or module replacements and recommissioning. In addition, hard-to-get-to Pacific locations present challenges for quick access even from Pacific-rim countries such as Australia, New Zealand and South East Asia.

However, a private sector partner can assist in these critical tasks leveraging their specialised knowledge in the field, providing that they employ suitable expertise. As most, if not all, battery installations in the Pacific would be relatively small in comparison to those in locations like the US and Australia, battery installations would normally be unmanned. Unmanned batteries would need periodic checking and responses to alarm conditions, but generally would need very little personnel input. Consequently, it would not be cost-effective for battery providing organisations to employ full-time personnel on each island. So a PPP arrangements would most likely include ongoing training of local personnel and support to the utility or customer. In this case the PIC utilities would benefit from this potential **technical knowledge transfer** which would gradually and organically enhance the technical capability of their staff.

PIC governments and public utilities typically lack the necessary capacity to build infrastructure and also maintain complex equipment. Private sector operators enter into a PPP arrangement to maximise profits which are usually generated by increased efficiency and providing infrastructure services meeting with minimum performance standards. PPP could therefore enhance efficiency in procurement and maintenance through innovation and private sector experience reducing the investment and the operating costs of the projects. In addition, an experienced private sector partner could lower risk and increase bankability of the project. The **reduced risk** could be reflected in lower financing costs.

Investment on battery storage systems is capital intensive, so a PPP delivery option, which requires the private sector contractor to finance the system would **decrease the initial funding** required from the utilities. Often the PIC utilities rely on significant public and donor funding and a PPP option with private financing may save of these funds which could be allocated for other purposes.

Table 2-12: Main pros and cons of utilising PPP in battery storage deployment

Pros	Cons
Reduced costs through innovation and private sector experience	Potential low competition may drive up costs
Lower initial funding from the public sector overcoming capital constraints	Higher return requirements of the private sector
Technical knowledge transfer from the private sector to the public sector	
Lower technical responsibility and possibly lower technical staffing requirements for the utility	More commercial administration requirements for the utility
Risk mitigation by allocating to the party best able to manage them	High transaction costs

A well-designed PPP scheme could improve the mitigation of the project risks if risks and responsibilities are allocated to the party best able to manage them.

The main risks can be included in two categories:

(i) Implementation risks and

(ii) Operation and maintenance risks

Implementation risks include risks related to technology selection and procurement, permitting, financing and construction. It is important that the utility engages adequate expertise to assess technical and commercial requirements to analyse the utility's circumstances and define key technical and commercial criteria, as there are risks of stranded assets if they are not fully fit for purpose. The private sector partner should select the most suitable solution ensuring that the system meets minimal technical specifications and also the private sector is best positioned to procure the technology leveraging its experience and relationship with the technology providers.

In a PPP arrangement with private sector financing, the financing risk obviously sits with the private sector partner. The construction risk is mitigated by selecting an experienced, credit-worthy construction contractor and it is covered by the private sector. This commercial structure includes liquidated damages payable from the contractor to the project company to cover any losses which arises from completion delay. The risk of failure of completion of any required ancillary infrastructure which is required to be able to operate the battery storage system in full capacity, for example, interconnection to the local network, is usually borne by the public sector utility under a PPP framework.

Operation and maintenance risks are mitigated by selecting an experienced operator with a strong track record of operating assets of a similar nature and size and borne by the private sector. These long-term contracts usually include liquidated damages in the case of the committed performance levels not being met.

Nevertheless, utilising PPP schemes may have negative implications as well which need to be understood. Under a PPP arrangement the private sector seeks compensation for its services through fees which cover their costs and provide an appropriate return on investment. In general, the required rate of return of the private sector is higher than that of the public sector, which on its own may make the projects more expensive. When determining the return on a project, this should be assessed in conjunction with the potential savings on costs as described above.

If a long-term PPP contractual arrangement is preferred providing relatively low returns for the investor, there is a risk that a smaller number of firms respond to the request for tender, than in the case of a procurement-only option by the public sector utility. In this case the downside of a PPP scheme would be the decreased cost efficiency due to the low level of competition.

2.3 Cash flow scenarios for a sample battery project

2.3.1 Introduction

The analysis, based on previous work for Kosrae, to assess the economic viability of a sample battery project based on a best practice financial model was undertaken. This was tailored to the project scenarios defined by the project delivery options (PPP case and public owned case).

2.3.2 Methodology

To forecast key elements of the economic feasibility assessment, a flexible MS-Excel based financial model (the Model) has been developed covering a time horizon of 20 years of operation for an illustrative project in Kosrae. To compare the two options, the PPP case and public owned case, the Levelised Cost of Storage (LCOS) approach has been applied. The LCOS is calculated as follows:

$$LCOS = \frac{\sum_{t=1}^{n} \frac{I_t + M_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Where:

I_t = Investment expenditures in the year t;

M_t = Operations and maintenance expenditures in the year t;

E_t = Energy generation in the year t

r = discount rate (rate of return); and

n = economic lifetime of the plant

The Model first solves for the levelised $/MWh off-take price that results in a levered Internal Rate of Return (IRR) equal to the assumed cost of equity. The calculated off-take price then is used as payments from the public sector perspective. This cash flow stream is then used to calculate the LCOS of the PPP structure. This option is compared to a traditional public procurement when the PIC utility purchases the system with a significant upfront cash outflow and pays an O&M fee to a contractor during the lifetime of the system. This cash flow is used to calculate the LCOS under a public procurement option.

As a first step, the main assumptions have been set and the outputs have been modelled for the two main options (‘Base case’). The next step was undertaking a sensitivity analysis which is a powerful tool to assess the impact of possible future events (e.g. change in the key assumptions) on the projects’ results (LCOS) as they do not try to show one exact picture of the future, but rather a range of outcomes. The generic process of the sensitivity/scenario analysis is set out in the chart below.

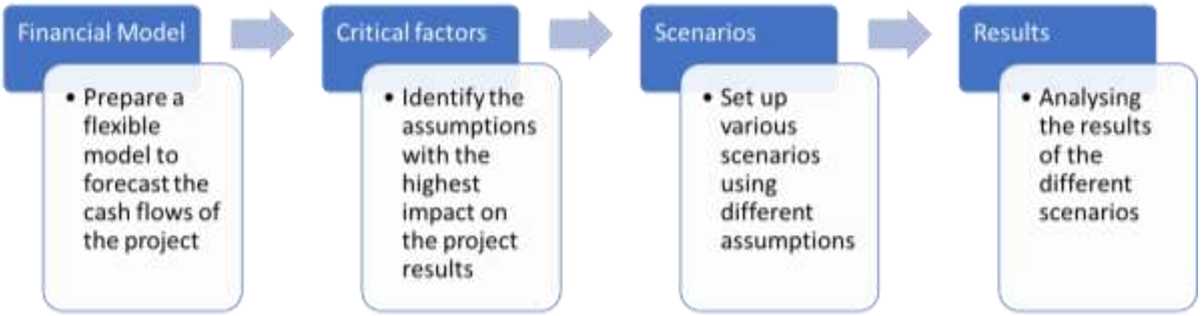

Figure 2-4: Sensitivity analysis process

For this, critical factors have been identified, which might have significant impact on the financial performance of the project if they develop unplanned and possible values of these critical factors have been determined (sensitivities) to indicate the unplanned development of external and internal circumstances.

2.3.3 Main assumptions of the Model

2.3.3.1 Options modelled

The modelled options are the following:

- Option 1: The battery storage system is procured under a PPP scheme.
- Option 2: The battery storage system is procured by the public sector (the PIC Utility).

2.3.3.2 Common assumptions

During the preparation of the Model, a number of assumptions have been made for the 'Option 1' and 'Option 2'. Some of them are related to the project timeline:

Table 2-13: Project timeline assumptions

Section	Timeline
Model start date	1 January 2020
Procurement and construction	1 January 2020 – 31 December 2020
Operational period	1 January 2021 – 31 December 2040 (20 years)

Other main assumptions are related to the environment of the project in both options.

Table 2-14: Project main assumptions

Description	Assumption	Source	Further details
Capacity	1.25MW	Ricardo Kosrae report	Draft Interim Report and Model for Kosrae Utilities Authority (Kosrae)
Duration	4 hours	Ricardo	Draft Interim Report and Model for Kosrae Utilities Authority (Kosrae)
Average depth of discharge	50%	Ricardo	The depth of discharge could vary greatly from day to day. 90% discharge would be maximum, but not often reached, while 80% would be a typical depth. If the batteries are used for frequency control and/or just to shave peaks, depth of discharge might be much less than 80%. For the purposes of this evaluation 50% depth of discharge has been used as average.
Annual system degradation	~0.5% p.a.	Ricardo	About 5% degradation has been assumed over 10 years.
Initial round trip efficiency	90%	Ricardo	Typically, the batteries' round-trip efficiency can be greater than 90% at the beginning of life of the batteries, but will gradually reduce over the 10 years, so using an average 90% seems to be sensible.
Round-trip efficiency degradation	0.5% p.a.	Ricardo	The round-trip efficiency degradation will be small, e.g. 0.5% or lower.

Description	Assumption	Source	Further details
International inflation (US PPI)	2.76%	U.S. Bureau of Labor Statistics 2019 February release	Used for the escalation of foreign cost components (e.g. fixed O&M costs).
Depreciation	10% per annum	Ricardo	Straight line inflation over the 10 years of useful time. Financing costs are included in the asset base.
Land rental cost	Nil	Ricardo	It was assumed that land has been granted to the project at zero cost.
Site rehabilitation at the end of useful life	Nil	Ricardo	It was assumed that rehabilitation cost will be offset by residual value of assets.
Gearing	80% debt and 20% equity	Ricardo	
Risk free rate	2.57%[104]	Ricardo	20 Year Treasury Rate
Country default spread	5.08%	Damodoran Country Default Spreads and Risk Premiums[105]	The figure of the Cook Islands has been used
Company default spread	4.25%	Damodoran[106] Company default spread	The default spread is defined based on the times interest earned (TIE) ratio of the project company
Interest	12%	Ricardo	In general, if the company has no rating, an indicative pre-tax cost of debt can be used as proxy for interest and calculated as a sum of the risk-free rate, the country default spread and the company default spread. In this case it equals to 11.90% and rounded up to 12%.
Debt tenor	9 years	Ricardo	To be equal with the lifetime of the main underlying components using a 1 year tail.
Corporate tax	25.5%[107]	Deloitte	

[104] Yahoo Finance, 24 May 2019
[105] http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/ctryprem.html
[106] Damodaran, 2002
[107] https://www2.deloitte.com/content/dam/Deloitte/cn/Documents/international-business-support/deloitte-cn-ibs-micronesia-tax-invest-en-2013.PDF

Description	Assumption	Source	Further details
Market risk premium	5.96%	Damodoran Country Default Spreads and Risk Premiums[108]	Over risk free rate for mature markets
Unlevered industry beta	0.52	Global power industry beta by NYU Stern/Damadoran	
Required return on equity (private partner)	~13.5%	Ricardo	Applied according to the corporate finance principles. Required equity return (cost of equity) has been estimated based on the capital asset pricing model (CAPM) principles.
Discount rate for LCOS calculation	10.00%	Ricardo	

2.3.3.3 Option 1 main assumptions – PPP scheme

The assumed contractual arrangement in the option is that the private contractor designs, finances, builds, operates and maintains the energy storage system and delivers electric capacity and energy storage under a long-term PPA. The agreement requires the private contractor to guarantee specified levels of capacity, energy and availability.

Table 2-15: Option 1 specific main assumptions

Description	Assumption	Source	Further details
Capital costs	US$ 2,000 per kW	Ricardo	Draft Interim Report and Model for Kosrae Utilities Authority (Kosrae)
Annual operating and maintenance costs	US$ 6.75 per kW	Ricardo	US$ 7.5 per kW was decreased with the assumed profit margin of the O&M contractor. The value was taken from the Draft Interim Report and Model for Kosrae Utilities Authority (Kosrae) and escalated with US PPI throughout the project lifetime.
Replacement time of major components	10 years after COD	Ricardo	

[108] http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/ctryprem.html

Description	Assumption	Source	Further details
Replacement value of major components	US1.838 million	Ricardo	It is assumed that 80% of the original hardware would need to be replaced. The original project cost split: 70% hardware (including shipping) and 30% site works, buildings and commissioning. The initial value has been escalated with the US PPI.

2.3.3.4 Option 2 main assumptions – Public procurement (utility)

Option 2 assumes that the battery storage system is procured directly by the utility.

Table 2-16: Option 2 specific main assumptions

Description	Assumption	Source	Further details
Capital costs	US$ 2,000 per kW	Ricardo	Draft Interim Report and Model for Kosrae Utilities Authority (Kosrae)
Annual operating and maintenance costs	US$ 7.5 per kW	Ricardo	The value was taken from the Draft Interim Report and Model for Kosrae Utilities Authority (Kosrae) and escalated with US PPI throughout the project lifetime.
Replacement time of major components	10 years after COD	Ricardo	
Replacement value of major components	US1.838 million	Ricardo	It is assumed that 80% of the original hardware would need to be replaced. The original project cost split: 70% hardware (including shipping) and 30% site works, buildings and commissioning. The initial value has been escalated with the US PPI.

2.3.4 Summary

The main results of the Model have been calculated with a cash flow analysis for the useful lifetime (20 years). Based on the financing need of the development and the construction phase and estimated cash flow of the operating phase, we have calculated the flat off-take price at which the required return on equity of the Private Partner equals with the IRR if the project will be carried out as planned ('Base case'). The resulted off-take price can be considered as payments from the public sector perspective under the PPP option. These payments have been used to calculate the LCOS under this option. The base case LCOS for the public procurement option has been calculated based on the cash flows of the initial investment and the annual O&M expenses. The main outputs of the model are set out in Table 2-17.

The results show that under the 'Base case' scenario the public procurement option seems to be more favourable from the PIC Utility stand point as the LCOS is lower in this option. In the 'Base case' the Model produces an LCOS of 516.42 US$/MWh for Option 1 and 452.05 US$/MWh for Option 2 at the10% discount rate.

It should be noted that the same capital expenditure assumption has been used for both options in the base case. However, some historical evidence shows that in general there is often significant cost overruns on projects under public procurement versus private procurement[109]. This information has been used to set up the various sensitivity tests.

Table 2-17: Financial modelling results – LCOS (US$ per MWh)

	PPP - Base case	PIC Procm't - Base case
LCOS	516.42	452.05

2.3.5 Sensitivity

In order to test the robustness of the LCOS results for each of the options and to show the impact of the changes a number of sensitivity tests have been performed on the financial model outputs. We have run the following sensitivity testing:

- PPP case with 10% interest rate
- PPP case with 8% interest rate
- PPP case with 15% required return
- PPP case with 10% required return
- Public (PIC Utility) procurement with Capital expenditure + 10%
- Public (PIC Utility) procurement with Capital expenditure + 20%
- Public (PIC Utility) procurement with O&M cost + 10%
- Public (PIC Utility) procurement with O&M cost + 20%
- Public (PIC Utility) procurement with Capital expenditure + 20% and O&M cost + 20%

We have chosen these elements to sensitise as these have been identified as key driving factors behind the financial viability of the project. The results of this sensitivity testing are shown in Table 2-18.

Table 2-18: Sensitivity analysis

Sensitivity	LCOS (US$ / MWh)
PPP case with 10% interest rate	487.49
PPP case with 8% interest rate	459.79
PPP case with 15% required return	527.98

[109] Determinants of Cost Overruns in Public Procurement of Infrastructure: Roads and Railways, Ram Singh, 2016

PPP case with 10% required return	489.12
Public (PIC Utility) procurement with Capital expenditure + 10%	495.9
Public (PIC Utility) procurement with Capital expenditure + 20%	539.75
Public (PIC Utility) procurement with O&M cost + 10%	453.40
Public (PIC Utility) procurement with O&M cost + 20%	454.75
Public (PIC Utility) procurement with Capital expenditure + 20% and O&M cost + 20%	542.46

From assessing the 'Base case' results and the sensitivity analysis it can be concluded that the capital cost overrun has the largest impact on the LCOS in case of the Public procurement option whilst the interest rate and the required return have significant impact on the PPP option.

The graphical representation of the LCOS for each option is shown on the charts below.

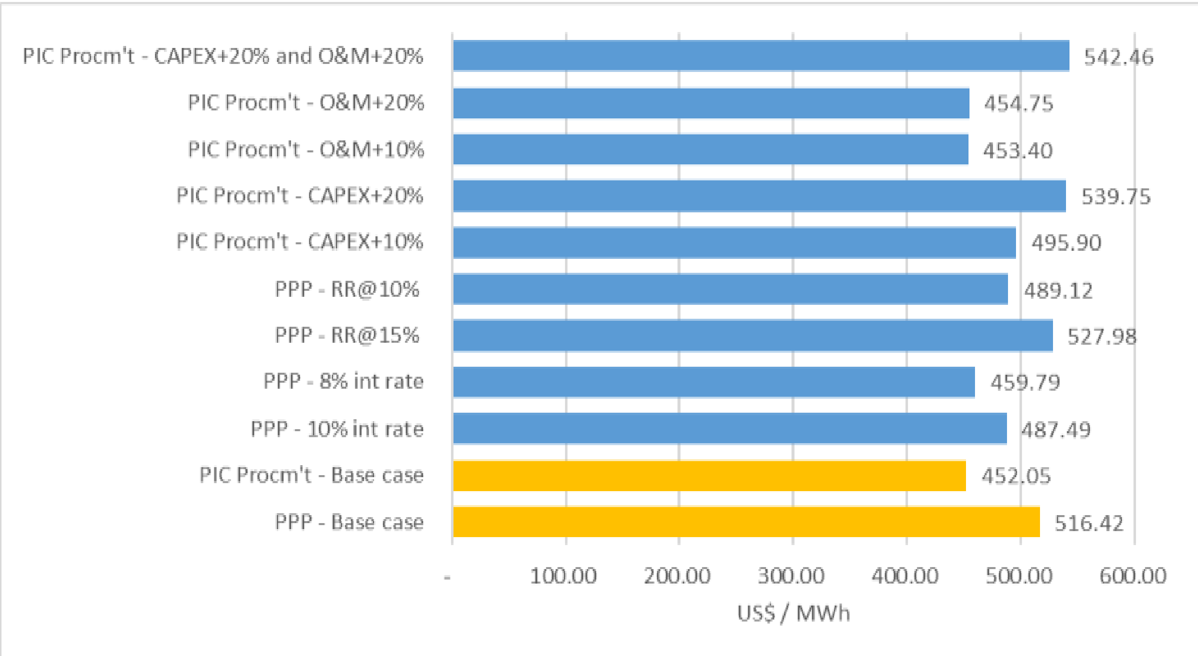

Figure 2-5: Scenario summary for LCOS in both options

Another representation of the results of the scenario analysis is presented on the following chart.

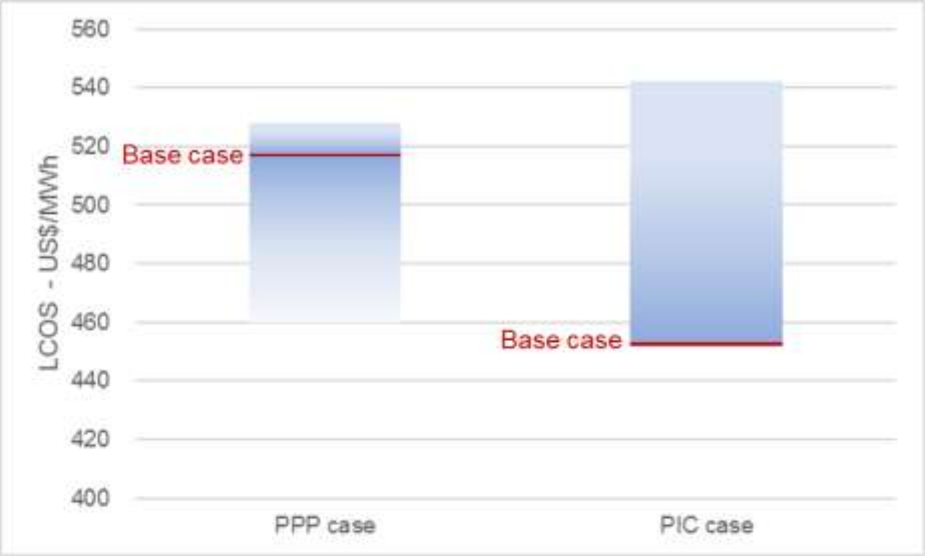

Figure 2-6: Distribution of LCOS across different scenarios

The chart shows that even though the Public procurement option produces a lower LCOS in Base case, the broad range of values across the different scenarios suggests higher level of associated risks under this delivery option. In addition, it seems to be more likely that the LCOS is improving under the PPP option in other scenarios whereas the Base case provides the lowest value in case of the Public procurement.

2.4 Recommendation of technical requirements and commercial conditions for the request-for-proposal and service agreement in a PPP battery project for the Pacific utilities

2.4.1 Potential PPP structure

The battery storage projects in general are output focused providing the required power capacity, are scalable and can respond in a short period of time. The battery can be either located 'behind the meter' as part of a generation plus storage system smoothing generation output or providing back-up power. It can also be located 'in front of the meter', providing electricity grid services with a set of different revenue streams. Even though in the context of this report we specifically focus on the 'front of the meter' situation, it can be assumed that it could share land rights, permits, grid connection arrangements and meters with exiting generation project.

In some cases, **retrofitting** of the battery storage at an existing site where financing is already in place may be an option. In this case, the review of the terms of the existing financing documentation and undertaking an additional due diligence would be required. Such financing mechanisms are still in nascent stage and yet to become standard market practices.

The following section provides more insights on who would be the potential players in a PPP structure and what kind of arrangements would commercially be viable.

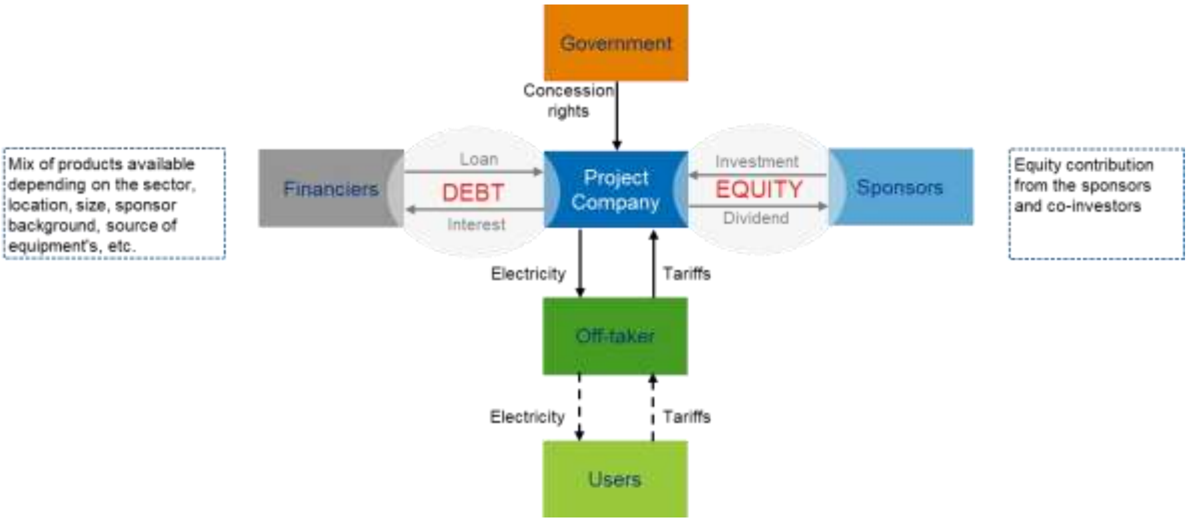

Figure 2-7: Project Structure and Sources of Finance

Figure 2-7 gives a general overview of the equity and debt arrangements in a Project. The potential providers of the needed equity and debt and their main characteristics are listed below.

Sources of Equity in a PPP Battery Storage Project

Industrial Investors (i.e. Utility, EPC/O&M Contractors, Equipment Suppliers, Battery Manufacturers)

- Industrial expertise
- Variable investment horizon
- Secure scope of work
- Want the flexibility to stack revenues

Financial Investors (Bond holder (Hotels, Large Island Industries), Infrastructure or Pension Funds)

- Limited industrial expertise
- May be short-midterm minded but will want to see a longer -term base contract revenue-stream to underpin the debt repayment.
- Realize return
- Low risk

Sources of Debt in a PPP Battery Storage Project

- Commercial Bank Loan
- Multilateral Agencies and Export Credit Agencies
- Bonds (could provide attractive alternative for refinancing/retrofitting scenario)

Possible PPP structures and agreements for the Pacific Islands

Based on the review and assessment of the implementation of successful battery storage schemes, the most common structure is where the contractor arranges the funding (both investment and raising financing), designs and builds the scheme and provides the operation and maintenance services. The high-level structure is set out on the following chart.

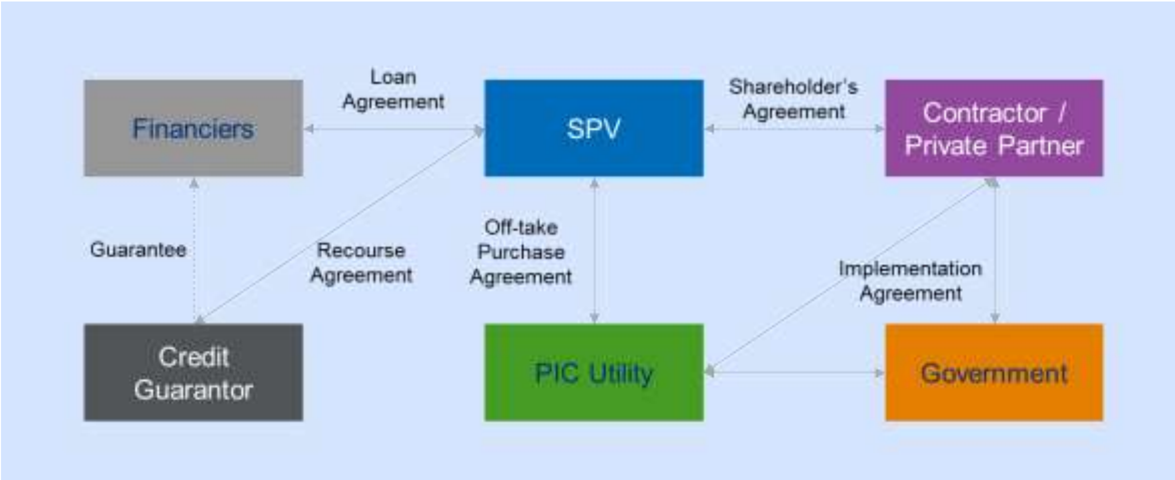

Figure 2-8: High-level PPP structure of a battery storage implementation scheme

Build-Operate-Transfer (BOT) arrangements, and Design-Build-Operate (DBO) arrangement

For this, the most suitable arrangements seem to be the concessions, the Build-Operate-Transfer (BOT) arrangements, and Design-Build-Operate (DBO) arrangements. Under this arrangement, the contractor finances, designs, builds, operates and maintains the energy storage system and delivers the electric capacity and energy storage. The structure of this delivery option is such that the SPV provides the required capacity under the defined technical and commercial parameters and the PIC Utility pays capacity payments to cover the investment, the interest and the loan payback, the required return and the O&M costs of the contractor.

Build-own-operate-transfer (BOOT) arrangement

An alternative option to the above IPP type structure could be a build-own-operate-transfer (BOOT) type of arrangement where the ownership of the battery storage system is transferred to the PIC Utility after a certain period of time. In case of battery storage systems, as their economic lifetime is around 10 years, the transfer seems to be logical between 5 and 10 years following the commencement of the operation. This arrangement may only be working if the necessary O&M knowledge is successfully transferred to the PIC Utility.

The loan agreement includes the terms and conditions under which the project is financed by the debt providers. The implementation agreement provides the framework of the cooperation between the parties and sets out the main principles of the PPP arrangement in place. The project's bankability and financing viability can be improved by including some sort of **credit guarantee** in the structure. Such guarantees would provide risk mitigation related to obligations of governments and state-owned utilities to the private investor. The cost of a guarantee may be offset by the reduced required return of the private sector and the decreased interest rates. Suitable guarantees may be provided by multilateral donor organisations such as the World Bank or the Asian Development Bank and would cover the following risks[110]:

- Contractual risk
- Regulatory risk
- Currency risk
- Political risk

Risk mitigation measures will help the financing costs. One important measure is to achieve 10-15 years warranty agreements from the battery manufacturers. Also, the maintenance agreement of the unmanned battery system could include a knowledge transfer/training part. Knowledge Sharing Plan (KSP) – administered by the Pacific Power Association - across the Pacific Islands could act as a platform of sharing lessons learned and helping the market develop new business models for PPP battery storage projects in the region.

Project Bond as form of mean to raise money from local entities

To enhance the project's returns and hence the attractiveness from private sector perspective, a World Bank backed special project **bond** could be issued with lower interest rate than that of the debt financing. The buyers of this battery storage project bond could be the larger electricity consumers on the island, such as hotel facilities and fisheries, which would benefit form a more reliable electricity supply. This Bond could even be converted into equity (Convertible Bond) at the end of the financing period (or maybe even just an initial period of the project finance to ease burden of high upfront costs and could equal warranty time) and act as an incentive of having ownership of the asset. This gives opportunity for project finance structuring.

In general, the off-take agreement of battery storage projects may take one of the following types:

- tolling agreement
- the capacity sales agreement or
- the hybrid PPA[111].

The tolling agreement provides the off-taker with capacity and energy generated by the battery storage system. The project owner maintains the technical operational control over the system. The off-taker has full control over charging and discharging the systems within the agreed technical limitations and parameters. Also, the off-taker is responsible for purchasing the energy needed to charge the battery. The project sponsor is compensated with fixed capacity payments for providing the availability of the battery's capacity and potentially with variable energy payments to cover the costs of the actual dispatches initiated by the off-taker.

Under the capacity sales agreement only capacity payment is paid to the seller for the available capacity and no energy payment is charged. The agreement allows the seller to sell the other products of the battery to third parties. Usually, the seller maintains both the operational and the dispatch control of the battery storage system.

Under hybrid PPAs the combined products of a usually renewable generation with an integrated battery storage system is sold. One form is take-or-pay type of agreement and another form provides the off-taker control over dispatch.

[110] https://www.worldbank.org/en/programs/guarantees-program
[111] http://s3.amazonaws.com/cdn.orrick.com/files/Insights/Orrick-Energy-Storage-Update-2018.pdf

Build-Lease-Return / (optional) Transfer can address the challenges related to lack of experience

Given the fact that the main challenges of the PIC utilities are the lack of experience with battery storage systems and that the scale may be too small to attract interest from the private sector or it would make such implementation too expensive, as an alternative to purchasing the assets, rental can be also an option. Some suppliers (e.g. Aggreko) provide small battery rental services which could be also considered as an alternative. For example, the offering of Aggreko[112] includes systems with a size of 1MW and duration of 30-60 minutes. The service covers the integration and operation and management of the battery and the term can be also flexible spanning from a couple of months to years.

Aggregated PPP auction arrangement in multiple countries/islands

Economies of scale could be utilised if the service is procured aggregating the needs of multiple PICs, however harmonisation of the different requirements may cause difficulties and delays in the process. In addition, typically, these services don't include the ownership transfer of the asset and therefore would not cover the knowledge transfer aspect. This term may need to be explored by approaching service providers directly.

2.4.2 Technical requirement recommendations

2.4.2.1 Battery storage system technical requirements

Table 19 defines requirements for battery storage systems and their associated infrastructure. It should be noted that although there are requirements common to all systems and locations, most aspects need to be properly researched and engineered to match local requirements, power system details including demand, demand growth, the grid configuration, renewables intermittency and other factors.

Table 2-19– Technical requirements for battery storage systems

	Topic	Requirements to be considered	Notes
1	Batteries	• Lithium-ion phosphate or other lithium-ion chemistries • Minimum battery life 10 years under normal use	Battery chemistry and cell type to be proven in at least 10 years' service in similar applications
2	Battery ratings	• kW (MW) and kWh (MWh) ratings to be determined for each site • Specified nominal battery ratings to be available throughout battery life • High charge/discharge cycle efficiencies required	Technical analysis of site and power system requirements required
3	Battery system	• Battery mounting system to be permanent and corrosion protected • Battery room layout to be fully accessible for personnel movement and emergency exit without obstruction • Interconnections and terminations to be accessible for easy maintenance and disconnection • Electrical protection by MCBs or fuses to prevent battery short circuit or cable meltdown • Charge and discharge current metering • Energy output metering	

[112] https://www.aggreko.com/en/products/hybrid-power-plants

	Topic	Requirements to be considered	Notes
4	Battery management	• Battery monitoring system • Cell monitoring • Battery condition alarms • Battery overcurrent to be limited to avoid combustion	
5	Battery enclosure	• Permanent building preferred • Alternatively factory-built enclosure with permanent corrosion-proof cladding and roofing • Floor level to be minimum 1 metre above finished ground level or high flood level, whichever is highest • Cyclone proof • Vermin proof • Seismic considerations • Internal low energy switched lighting • Fire alarms and fire protection • High quality doors, locks, fittings and fixtures • Low maintenance • Cooling system and ventilation to prevent rain and dust entry • Cooling system to be low maintenance, have redundancy and failure remote alarms • Minimum 30 year life • Safety and emergency exit signage	Shipping containers show rust within 2 or 3 years, even with marine-grade surface coatings
6	Control system and communications	To be determined for each site and to take account of relevant power system requirements including: • Existing power station controls • SCADA requirements • Solar PV and/or other renewables intermittency • Standardisation • Maintenance support	
7	Energy storage kW (or MW) rating	To be determined for each site	Technical analysis required. Battery and inverter capacities to be considered.
8	Energy storage kWh (or MWh) rating	To be determined for each site	Technical analysis required. Battery nominal capacity and discharge rate determines rating.
9	Inverters & inverter/chargers	• Established technology and proven design • Fail-safe • Reliability MTBF • Suitable for tropical environments • Cooling • Harmonics limitation • Adjustable power factor controls • Frequency control/grid forming and grid following features • Facilities for external control and alarms • Ready repairs' support from Pacific rim countries	

	Topic	Requirements to be considered	Notes
		• Maintenance support • Remote technical support availability	
10	Standards and codes	• For most Pacific Islands, Australian, New Zealand or European standards • For Federated States of Micronesia, US or above standards	
11	Power system connection	• In most PICs likely to be either 11kV 3 phase 50Hz or 13.8kV 3phase 60Hz • LV switchgear and HV switchgear required • Cabling to depend on site and Employer requirements	
12	Documentation and drawings	• All to be in English • Hard copies and soft copies • Clearly written • To cover As-Built details, operation and maintenance • To be reviewed and approved by Employer	
13	Shipping and storage	• Refrigerated container • Temperature recording from factory onwards	
14	Installation, testing and commissioning	• Must be checked • Test certificates needed • Full commissioning tests required	
15	On-site operation and maintenance training and support	• Attendance on site of the contractor's personnel should be available after commissioning for a defined period	

2.4.2.2 Commentary on battery storage system technical requirements

Item numbers refer to various aspects of the items in table 19.

1 & 2 Battery ratings: Currently available lithium-ion cells gradually lose capacity during their life of around 10 years. Some batteries may have a life considerably longer than 10 years but there are many factors involved in battery life, including depth of discharge, number of cycles, quality of manufacture etc. It is advisable to determine the kWh ratings required at end of life. Good quality batteries can have charge/discharge efficiencies greater than 90%.

Analysis of system load growth, load flows and system stability over a full range of likely conditions should be performed to establish battery and renewables size requirements and constraints.

3 & 4 Battery system: The battery system should be in a well laid-out room with ample space for access and personnel movement. There are potential fire risks with rapid fire acceleration for lithium-ion batteries and clear access to enable personnel escape under fire conditions is essential. For very large battery systems (MWh), separate buildings or fire compartments within buildings should be considered.

Also, electrical protection with good circuit LV design is necessary to avoid the possibility of short circuits and/or excessive battery discharge currents that can trigger fires.

5 Battery enclosure: Pacific Island locations provide aggressive environments for buildings and metalwork and most have experienced severe storm and/or cyclone conditions, storm surges and rainwater flooding. It is essential that the floor level of battery enclosures is well clear of likely water

level rises and the enclosures should be designed and constructed to withstand category 5 storm conditions without damage, including damage from flying debris. Some islands, e.g. in Vanuatu, are subject to regular significant seismic events.

6 Control system and communications: Detailed investigation of existing power station controls, facilities for generator control, interfacing and level of automation is required. Some Pacific islands already have existing control systems associated with generator management and renewables control, so the introduction of any new system may need detailed engineering.

7 & 8 kW and kWh ratings: Each rating should be determined after detailed technical analysis of the power system, existing and likely future renewables and whether the battery system will be used for frequency control only, peak lopping or a significant amount of energy storage, e.g. to reduce diesel consumption overnight or during daytime as well.

9 Inverters and inverter/chargers: Various configurations of inverters and chargers may be available at the time of tendering and each manufacturer may provide different features compared with another manufacturer. Main characteristics required should be defined in tender documents, but detailed requirements resulting from power system technical analysis should also be taken into account.

10 & 11 Standards and power system connection: Battery and systems are relatively new technology and the development of international standards has tended to lag behind battery and inverter developments. Prior to tendering, assessment of available latest international standards should be undertaken. Power system connections should be defined by the utility and should take account of site conditions, electrical protection on the network and at power stations. Some protection coordination studies may be required.

12 Documentation and drawings: It is even more important in the Pacific islands to ensure that adequate documentation is available, due to the remote locations and travel time for support and repair personnel from Pacific-rim countries. Documentation should be clear and easily referenced, as English is not necessarily the first language for power utility personnel on many islands.

13 Shipping and storage: Lithium-ion batteries can degrade if stored and/or operated at high temperatures, so it is important that they are kept within temperature limits at all times.

14 Installation, testing and commissioning: The Employer (usually the utility or utility's representative) should ensure that all features of the installation are to a high standard and that the contractors make no shortcuts to testing or commissioning. Tests should cover a full range of expected operating conditions and may also need to be performed in accordance with applicable standards or codes.

Tests should be recorded on calibrated instruments and witnessed by the Employer.

15 On-site operation and maintenance training and support: It is important that the contractor's technical specialist remains on site for a defined period, e.g. 2 weeks, for the training of Employers' staff and to deal with any technical or operational teething problems.

2.4.3 Commercial condition recommendations

If potential interest is identified from the private sector to participate in such PPP schemes, the underlying services should be carefully procured in a transparent manner based on the specific requirements of the system (technology compatibility, specified selection criteria of technology type and consortium members, timely delivery, pricing sustainability, etc.) avoiding unsolicited proposals to create competition and maximise value for money.

2.4.3.1 Main responsibilities of the project sponsor

In general, the contractor should take full responsibility to operate and maintain the energy storage system and should be required to guarantee specified levels of capacity, energy and availability which are translated into a Power Purchase Agreement. More specifically the scope should include all engineering, design, finance, procurement of equipment and materials, permitting, construction, installation, interconnection, commissioning, performance verification and long-term operation and maintenance for the duration of the agreement.

The private partner as specialist in the field and being owner of the project should be required to obtain all permits (environmental, building, transportation, etc.). The permitting requirements should be shared in detail by the PIC procurer and if the battery system project is implemented on the premises of the utility, support in obtaining the site-specific consents should be provided to the private partner.

To make sure that the potential bidders have the financing and fund-raising capacity, it is recommended to request information on the project finance structure. This might require the bidders to reveal their project finance assumptions, including the terms of the debt financing, level of own capital injection, etc. Any commitments from a financier or bank should be also presented to back the proposal.

2.4.3.2 Agreement type and revenue stream

In case of non-utility owned projects, it is crucial to have a long-term off-take agreement which ensures the financial viability through a steady revenue stream. To provide adequate cash flow levels, the agreement should include a regular, preferably monthly, payments to the contractor (SPV).

The power grids in the PIC are typically small and simple and operated by an incumbent utility. There are no power markets and the power systems have no or very limited other players. In addition, the power generation facilities are often also owned by the incumbent utility.

Considering the above, for a storage energy system in the PIC the **tolling type of off-take agreement** seems to be the most suitable. Under this agreement, monthly capacity payments would not only provide adequate income to cover investment, fixed costs and required return for the private partner, but would also ensure that the frequent cash inflow maintains a sufficient cash position necessary for the project to be bankable.

2.4.3.3 Pricing

To be able to consider multiple options, one or more proposed tariff schedules should be indicated. Creative pricing proposals should be encouraged, but at least a flat and escalating tariff options should be provided.

If the pricing involves escalation or an index, the escalation terms or specific index should be clearly stated. The currency of the tariff should be also stated and for comparison purposes one single currency is recommended to be used (e.g. U.S. dollars).

It is recommended that the total costs for the proposed system and services is presented by the bidder including cost breakdown for components, subcontracting, etc. This should cover any replacement needed to meet project life cycle. In addition, levelised cost of energy (LCOE) should be also provided for life of project. Any exclusions and all assumptions and risk of cost overruns should be listed by the bidder.

2.4.3.4 Project commencement

The project timeline and completion deadline should be clearly described. The private partner should be required to provide energy storage equipment of the required capacity and duration at the point of the defined interconnection, no later than the set commencement date. If the project needs to be implemented in phases this should be also clarified in the RfP and set out in the agreement conditions.

2.4.3.5 Term

The starting and ending dates of energy delivery should be indicated along with any flexibility in those dates and any significant contingencies that may affect them.

Some battery systems can be considered a power source with a long useful lifetime as individual batteries can often be replaced, and the battery system can carry on. It is important that the technical criteria and performance guarantees are well designed and met by the system throughout the entire term of the agreement.

2.4.3.6 Control of dispatch

Another important battery-specific commercial consideration is the control of the dispatch of the system. This section in the agreement needs to cover the decisions on the management of charging: timing, quantities, source, etc. The roles of the seller and the off-taker in managing discharging / dispatches needs to be formed in a way that suits best with the characteristics of the power systems in the PIC and the purpose of the battery system project. For example, the utility may want to reduce the energy costs during peak-hours or use it for demand response[113], therefore it may need to have full control to dispatch the energy storage system and should provide all of the energy to charge the system. The storage should provide all uses of its capacity.

Under a tolling type of off-take agreement, the PIC Utility would have full control of the battery storage system, while being responsible for the energy required for charging.

2.4.3.7 Warranty and guarantees

The warranty periods for various parts of the proposed solution (main equipment, the other components and the workmanship) should be clearly defined. The warranty inclusions and exclusions should be specified and any replacement schedules to be included. A timespan of warranty and any limitations should be also spelled out.

It should be also determined what the penalty is in the case of non-performance when the system fails to meet with the required and agreed technical criteria. The conditions under these criteria to be met, should be precisely described to avoid any misinterpretations. The capacity payments may be subject to reduction for decreases in capacity, availability or efficiency of the project.

Key input for this set of criteria are the requirements of the manufacturer. It is important that the party which exercises the control rights, dispatches the system within these parameters (e.g. minimum and maximum amount of cycles per day). Operating outside of these parameters might significantly affect the performance and the warranty of the system.

In addition, the availability of warranty support for hardware and software, including location of nearest service technicians, and expected maximum time from warranty call to a technician's arrival on site should be also described in detail. The latter has especially high importance in this case provided the remote nature of the PIC islands.

2.4.3.8 Knowledge transfer

The private partner should deliver a comprehensive safety and operation manual for the project. Additional post-handover services should include the provision of a comprehensive on-site safety and operation training for the PIC Utility staff and potentially to its contractors. To ensure a long-term benefit for the PIC Utility, this task should include assistance in O&M and capacity building which may be in the form of a remote support arrangement supplemented by periodic visits by the private partner staff. The private partner may also assist in identifying the key PIC Utility personnel for the training enrolments.

2.4.3.9 Reserve accounts

If the term of the agreement is longer than the battery storage system's useful lifetime without replacing some of the elements, and the scope of the agreement includes these replacements, one of the most significant risks of the project is funding the equipment replacement and maintenance over time. To ensure that the adequate funding is available when needed regular payments to a capital replacement reserve account would be recommended.

[113] https://www.projectfinance.law/media/1601/pfn_1017.pdf

Annex 1 – Cash flows of the implementation options

	Model period beginning				**01 Jan 20**	**01 Jan 21**	**01 Jan 22**	**01 Jan 23**	**01 Jan 24**	**01 Jan 25**	**01 Jan 26**	**01 Jan 27**	**01 Jan 28**	**01 Jan 29**	**01 Jan 30**	**01 Jan 31**	**01 Jan 32**	**01 Jan 33**	**01 Jan 34**	**01 Jan 35**	**01 Jan 36**	**01 Jan 37**	**01 Jan 38**	**01 Jan 39**	**01 Jan 40**
	Model period ending				**31 Dec 20**	**31 Dec 21**	**31 Dec 22**	**31 Dec 23**	**31 Dec 24**	**31 Dec 25**	**31 Dec 26**	**31 Dec 27**	**31 Dec 28**	**31 Dec 29**	**31 Dec 30**	**31 Dec 31**	**31 Dec 32**	**31 Dec 33**	**31 Dec 34**	**31 Dec 35**	**31 Dec 36**	**31 Dec 37**	**31 Dec 38**	**31 Dec 39**	**31 Dec 40**
	Project phase				Construction	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation
	Financial year ending				2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
	Model column counter	**Constant**	**Unit**	**Total**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
PRIVATE SECTOR																									
	Total revenue	-	US$ 000's	- -	-	428	426	424	422	419	417	415	413	411	428	426	424	422	419	417	415	413	411	409	407
	O&M contractor cost	-	US$ 000's	- -	-	8.7	8.9	9.2	9.4	9.7	9.9	10.2	10.5	10.8	11.1	11.4	11.7	12.0	12.4	12.7	13.0	13.4	13.8	14.2	14.5
	EBITDA		**US$ 000's**		**-**	**419.3**	**416.9**	**414.6**	**412.2**	**409.8**	**407.5**	**405.1**	**402.7**	**400.4**	**416.9**	**414.5**	**412.0**	**409.6**	**407.1**	**404.7**	**402.3**	**399.8**	**397.4**	**394.9**	**392.5**
less	Accounting Depreciation	-	US$ 000's	4,338 -	-	250	250	250	251	250	250	250	251	250	432	184	184	184	184	184	184	184	184	183	-
	EBIT		**US$ 000's**		**-**	**169.3**	**166.9**	**164.6**	**161.5**	**159.8**	**157.5**	**155.1**	**152.0**	**150.4**	**(15.5)**	**230.6**	**227.7**	**225.8**	**223.3**	**220.9**	**217.9**	**216.0**	**213.6**	**212.1**	**392.5**
less	Interest expense	-	US$ 000's	- -	-	240	224	206	185	162	137	108	76	40	-	176	165	151	136	119	101	80	56	30	-
less	Income tax expense	-	US$ 000's	353 -	-	-	-	-	-	-	-	-	-	13	-	9	16	19	22	26	30	34	40	46	100
	Net Income		**US$ 000's**		**-**	**(70.7)**	**(56.8)**	**(41.0)**	**(23.7)**	**(2.6)**	**20.6**	**46.9**	**75.9**	**97.6**	**(15.5)**	**45.0**	**47.4**	**55.9**	**65.3**	**76.0**	**87.8**	**102.0**	**117.8**	**136.4**	**292.8**
plus	Accounting Depreciation	-	US$ 000's	4,338 -	-	250	250	250	251	250	250	250	251	250	432	184	184	184	184	184	184	184	184	183	-
less	Total investment costs	-	US$ 000's	4,338 -	2,500	-	-	-	-	-	-	-	-	-	1,838	-	-	-	-	-	-	-	-	-	-
plus	Debt drawdown	-	US$ 000's	- -	2,000	-	-	-	-	-	-	-	-	-	1,470	-	-	-	-	-	-	-	-	-	-
less	Debt payback	-	US$ 000's	- -	-	135	152	170	190	213	239	267	299	335	-	100	111	125	140	157	175	196	220	246	-
	After tax levered cash flow		**US$ 000's**		**(500.0)**	**44.0**	**41.6**	**39.2**	**36.8**	**34.5**	**32.1**	**29.7**	**27.4**	**12.5**	**49.3**	**129.3**	**120.3**	**114.9**	**109.3**	**103.2**	**96.7**	**89.4**	**81.6**	**72.8**	**292.8**

Model period beginning				**01 Jan 20**	**01 Jan 21**	**01 Jan 22**	**01 Jan 23**	**01 Jan 24**	**01 Jan 25**	**01 Jan 26**	**01 Jan 27**	**01 Jan 28**	**01 Jan 29**	**01 Jan 30**	**01 Jan 31**	**01 Jan 32**	**01 Jan 33**	**01 Jan 34**	**01 Jan 35**	**01 Jan 36**	**01 Jan 37**	**01 Jan 38**	**01 Jan 39**	**01 Jan 40**
Model period ending				**31 Dec 20**	**31 Dec 21**	**31 Dec 22**	**31 Dec 23**	**31 Dec 24**	**31 Dec 25**	**31 Dec 26**	**31 Dec 27**	**31 Dec 28**	**31 Dec 29**	**31 Dec 30**	**31 Dec 31**	**31 Dec 32**	**31 Dec 33**	**31 Dec 34**	**31 Dec 35**	**31 Dec 36**	**31 Dec 37**	**31 Dec 38**	**31 Dec 39**	**31 Dec 40**
Project phase				Construction	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation
Financial year ending				2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Model column counter	**Constant**	**Unit**	**Total**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
PUBLIC SECTOR - PUBLIC PROCUREMENT																								
Total investment costs	-	US$ 000's	4,338 -	2,500	-	-	-	-	-	-	-	-	-	1,838	-	-	-	-	-	-	-	-	-	-
Total fixed O&M	-	US$ 000's	- -	-	11.6	11.9	12.2	12.5	12.9	13.2	13.6	14.0	14.4	14.8	15.2	15.6	16.0	16.5	16.9	17.4	17.9	18.4	18.9	19.4
Total costs		US$ 000's		2,500.0	11.6	11.9	12.2	12.5	12.9	13.2	13.6	14.0	14.4	1,852.9	15.2	15.6	16.0	16.5	16.9	17.4	17.9	18.4	18.9	19.4
Total energy supply	-	MWh	- -	-	875	871	866	862	858	853	849	845	841	875	871	866	862	858	853	849	845	841	836	832
WACC discount factor	-	factor	- -	1.000	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.467	0.424	0.386	0.350	0.319	0.290	0.263	0.239	0.218	0.198	0.180	0.164	0.149
Discounted total costs		US$ 000's	3,327	2,500	11	10	9	9	8	7	7	7	6	714	5	5	5	4	4	4	4	3	3	3
Discounted energy supply		MWh	7,317	-	795	720	651	589	533	482	436	394	356	337	305	276	250	226	204	185	167	151	137	124
LCOS	454.75	US$ / MWh																						

Model period beginning				**01 Jan 20**	**01 Jan 21**	**01 Jan 22**	**01 Jan 23**	**01 Jan 24**	**01 Jan 25**	**01 Jan 26**	**01 Jan 27**	**01 Jan 28**	**01 Jan 29**	**01 Jan 30**
Model period ending				**31 Dec 20**	**31 Dec 21**	**31 Dec 22**	**31 Dec 23**	**31 Dec 24**	**31 Dec 25**	**31 Dec 26**	**31 Dec 27**	**31 Dec 28**	**31 Dec 29**	**31 Dec 30**
Project phase				Construction	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation
Financial year ending				2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Model column counter	**Constant**	**Unit**	**Total**	1	2	3	4	5	6	7	8	9	10	11
PUBLIC SECTOR - PPP														
Payments to the Private Partner		US$ 000's	8,368	-	428	426	424	422	419	417	415	413	411	428
Total energy supply	-	MWh	- -	-	875	871	866	862	858	853	849	845	841	875
WACC discount factor	-	factor	- -	1.000	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.467	0.424	0.386
Discounted total costs		US$ 000's	3,579	-	389	352	318	288	260	236	213	193	174	165
Discounted energy supply		MWh	7,317	-	795	720	651	589	533	482	436	394	356	337
LCOS	489.12	US$ / MWh												

Model period beginning	**01 Jan 31**	**01 Jan 32**	**01 Jan 33**	**01 Jan 34**	**01 Jan 35**	**01 Jan 36**	**01 Jan 37**	**01 Jan 38**	**01 Jan 39**	**01 Jan 40**
Model period ending	**31 Dec 31**	**31 Dec 32**	**31 Dec 33**	**31 Dec 34**	**31 Dec 35**	**31 Dec 36**	**31 Dec 37**	**31 Dec 38**	**31 Dec 39**	**31 Dec 40**
Project phase	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation	Operation
Financial year ending	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Model column counter	12	13	14	15	16	17	18	19	20	21
PUBLIC SECTOR - PPP										
Payments to the Private Partner	426	424	422	419	417	415	413	411	409	407
Total energy supply	871	866	862	858	853	849	845	841	836	832
WACC discount factor	0.350	0.319	0.290	0.263	0.239	0.218	0.198	0.180	0.164	0.149
Discounted total costs	149	135	122	110	100	90	82	74	67	61
Discounted energy supply	305	276	250	226	204	185	167	151	137	124
LCOS										

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