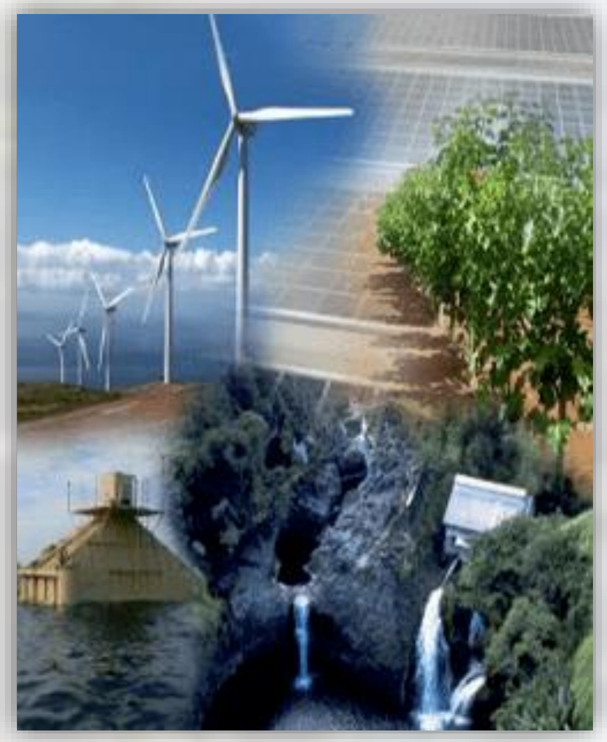
World Bank Sponsored Project Report

Developing Renewable Energy Storage System for the Pacific Island Countries



GridSTART

Hawaiʻi Natural Energy Institute | University of Hawaiʻi

Grid System Technologies Advanced Research Team

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HNEI
Hawaiʻi Natural Energy Institute
University of Hawaiʻi at Mānoa

University of Hawaiʻi
Mānoa

Pacific Islands Climate Collaborative 2023 Forum

Virtually presented on March 8, 2023
Honolulu, Hawaii

Island Power Systems are Unique

Reliance on Imported Diesel for Generation

Often leading to high electricity rates (>40cents/ kWh), price volatility, higher emission rates, etc.

Contingency Events are More Severe

Islands tend to have fewer synchronous generators online and are susceptible to outages and grid stability risk

Isolated Grids

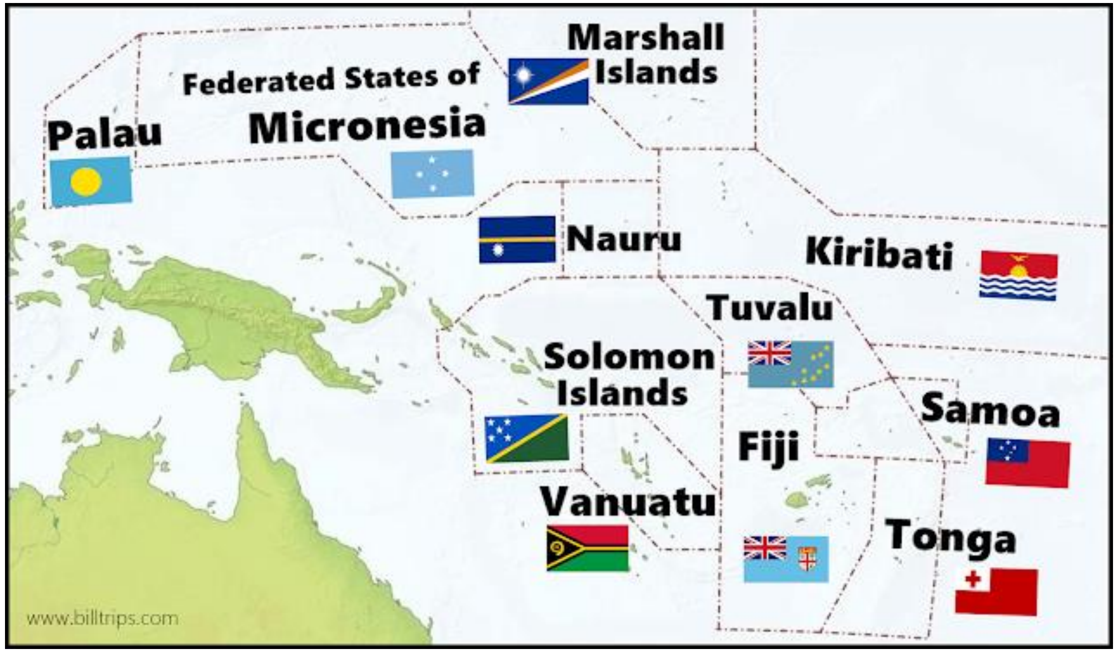
Islands cannot rely on neighboring electric systems during emergency events for grid support

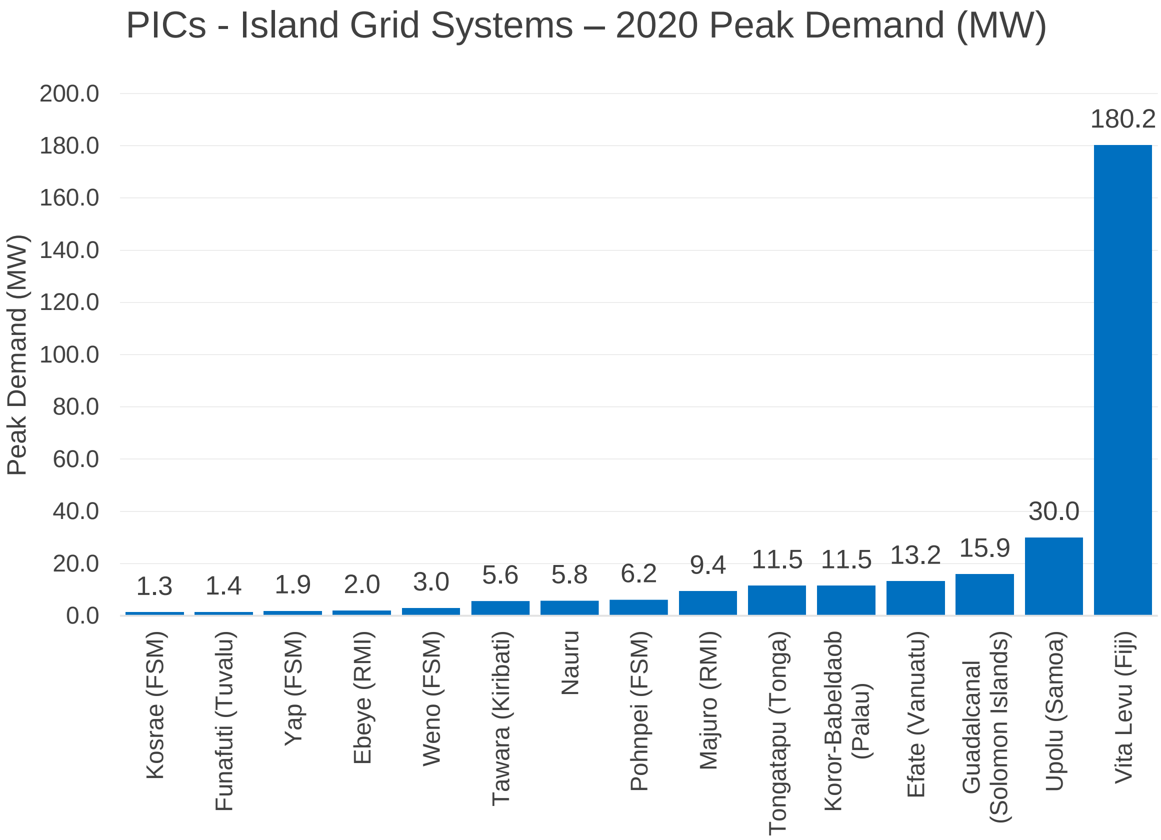
Limited Sources of Renewable Energy Generation

Firm Renewable Resources are not always available – leading to high penetration levels of variable renewable energy (VRE) sources

Pacific Island Countries (PICs) Grid Systems

Evaluated fifteen (15) island grid systems across 11 PICs





Annual peak demand between 1.3 MW to 180.2 MW

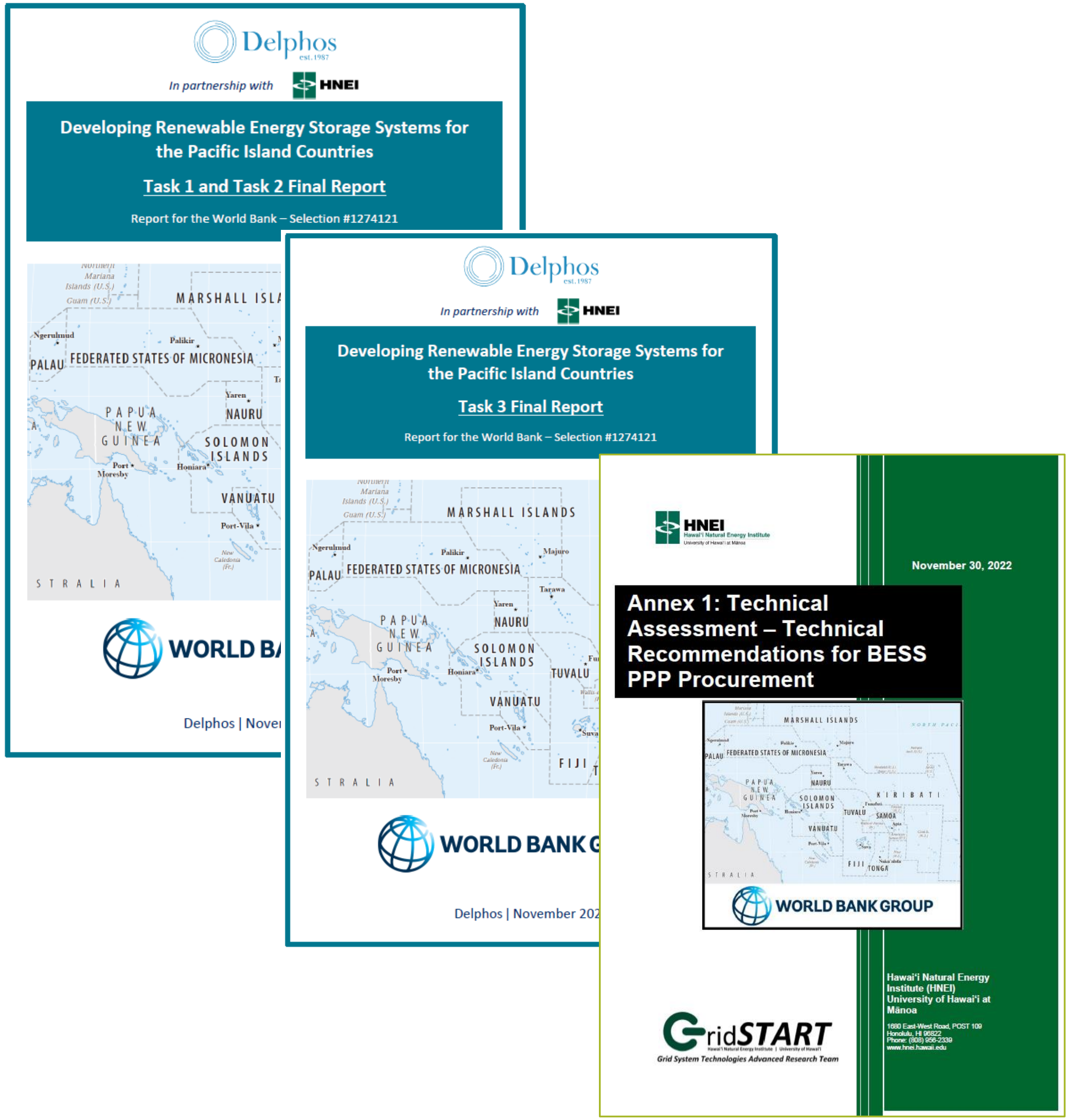
Final Reports - Delivered Nov 2022

The Study was comprised of three tasks:

- Task 1: Policy and Technical Recommendations. Recommend PPP structures for BESS acquisition that are appropriate to the region and the individual PICs, as well as related policy changes and other interventions to facilitate such structures. A technical assessment of PIC BESS needs will inform the recommendations of PPP structures.
- Task 2: Regional Strategy on Auction Arrangements. Develop a regional strategy for BESS procurement and PPP structuring, including guidance on tendering.
- Task 3: Design detailed BESS development roadmaps for three specific countries: Federated States of Micronesia, Republic of Marshall Islands, and Tuvalu.
- HNEI produced an annex to the reports detailing the technical BESS needs assessment that formed the basis for the PPP structure recommendations and roadmaps developed in the three tasks.

The reports can be found in the google drive link below.

https://drive.google.com/drive/folders/1HtuRk7OGhS36gBozbhEPtg4zIA6pU4Tg?usp=share_link



Battery Energy Storage Systems (BESS) Use Cases for PICs

- Batteries can be used in a wide range of applications.
- Use cases depend on system characteristics, resource mix, and regulatory structure.

Energy & Capacity	Ancillary Services	Transmission Services	Distribution Services	End Use Applications
Energy Time-shifting (Arbitrage)	Fast Frequency Response	Transmission Upgrade Deferral ✗	Distribution Upgrade Deferral	Power Quality
Firm Capacity	Regulation	Transmission Congestion Relief ✗	Distribution Voltage Support	Reliability & Resilience
	Ramping Reserves		Distribution Loss Reduction	Demand Change Management ✗
	Spinning Reserves			Time of Use & Realtime Pricing ✗
	Non-Spinning Reserves			
	Voltage Support			
	Black Start			

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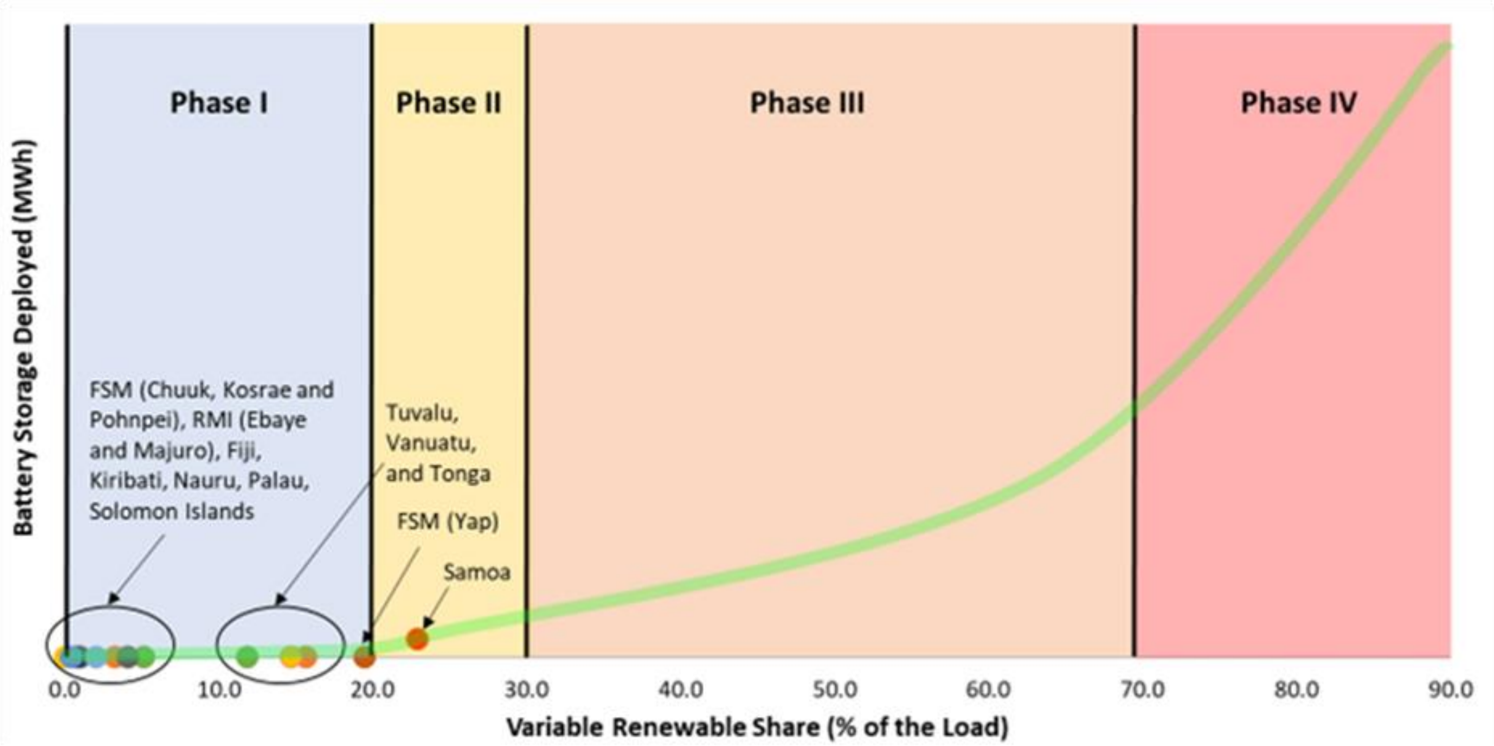
Four Phases of BESS Deployment on Island Power Systems



As VRE (i.e. **wind and solar**) increases, the value and need for storage increases – but not linearly

Phase I: Grid services and renewable enablement

Phase II: Capacity deferral and/or fossil retirement

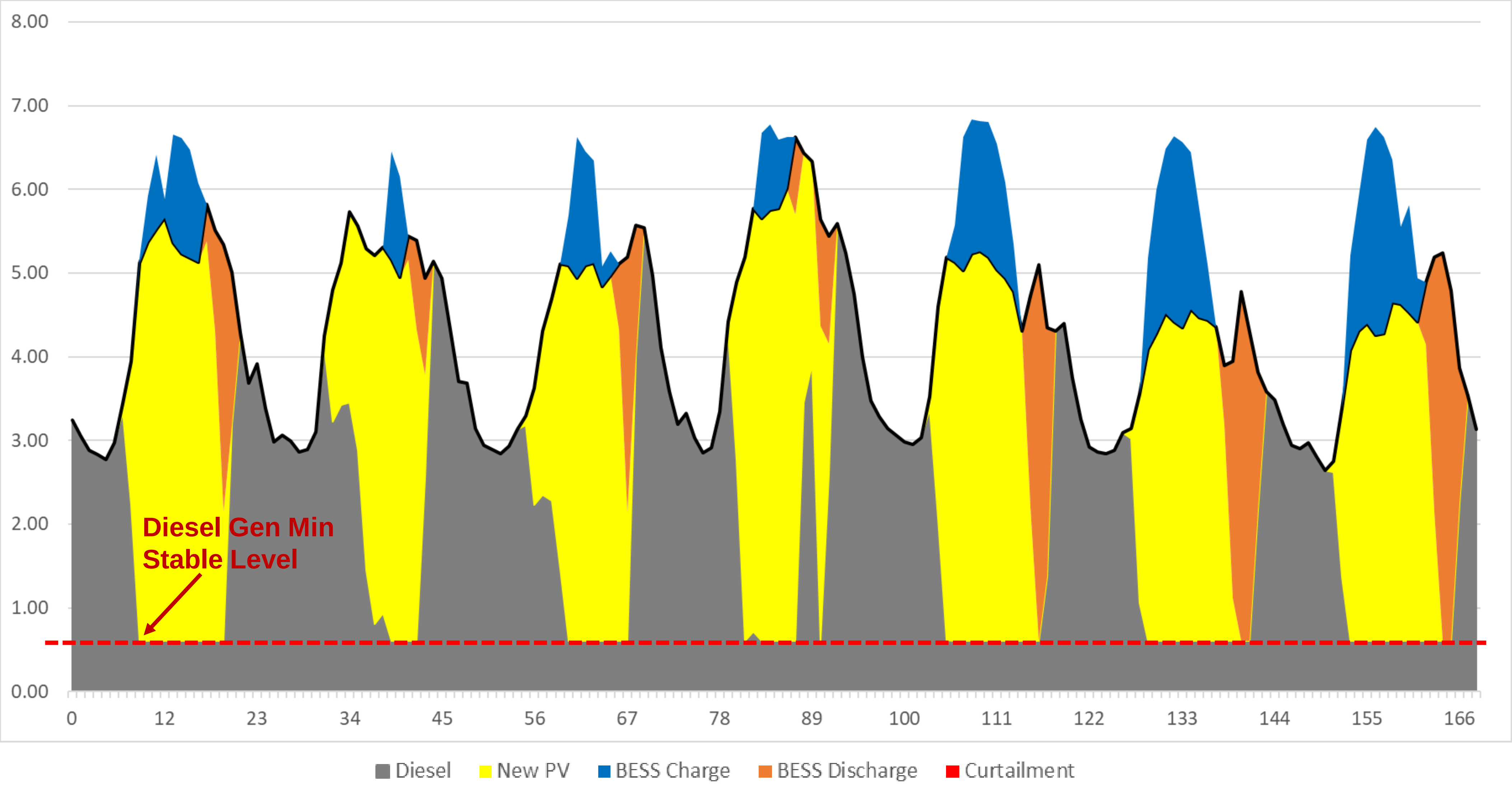
Phase III: Energy shifting and curtailment mitigation

Phase IV: Long duration energy shifting for deep decarbonization

#	Island	2020 Peak (MW)	2020 RE %	2020 VRE %
	Group 1 (0 - 5 MW)			
1	Kosrae (FSM)	1.3	3.2	3.2
2	Funafuti (Tuvalu)	1.4	15.7	15.7
3	Yap (FSM)	1.9	19.5	19.5
4	Ebeye (RMI)	2.0	0.0	0.0
5	Weno (FSM)	3.0	5.1	5.1
	Group 2 (5 - 7 MW)			
6	Tawara (Kiribati)	5.6	6.8	6.8
7	Nauru	5.8	7.7	7.7
8	Pohnpei (FSM)***	6.2	4.1	4.1
	Group 3 (9 - 16 MW)			
9	Majuro (RMI)	9.4	0.8	0.8
10	Tongatapu (Tonga)	11.5	11.8	11.8
11	Koror (Palau)	11.5	2.0	2.0
12	Efate (Vanuatu)	13.2	14.7	14.7
13	Solomon Islands	15.9	1.7	1.7
	Group 4			
14	Samoa*	30.0	44.4	**23.0**
	Group 5			
15	Fiji	180.2	64.2**	0.4**

** In 2020, Samoa had approximately 8 MW / 13.7 MWh of installed BESS*
*** 57% of Fiji's electricity was provided by hydropower dams (firm power)*

Managing Excess Energy Curtailment of VRE Production in PICs – A strong case for BESS deployment



BESS Assessment for the PICs

Group	2025 RE Target	2030 RE Target	2035 RE Target
Group 1	30%	50%	70%
Group 2	30%	50%	70%
Group 3	30%	50%	70%
Group 4	60%	80%	90%
Group 5	75%	85%	95%

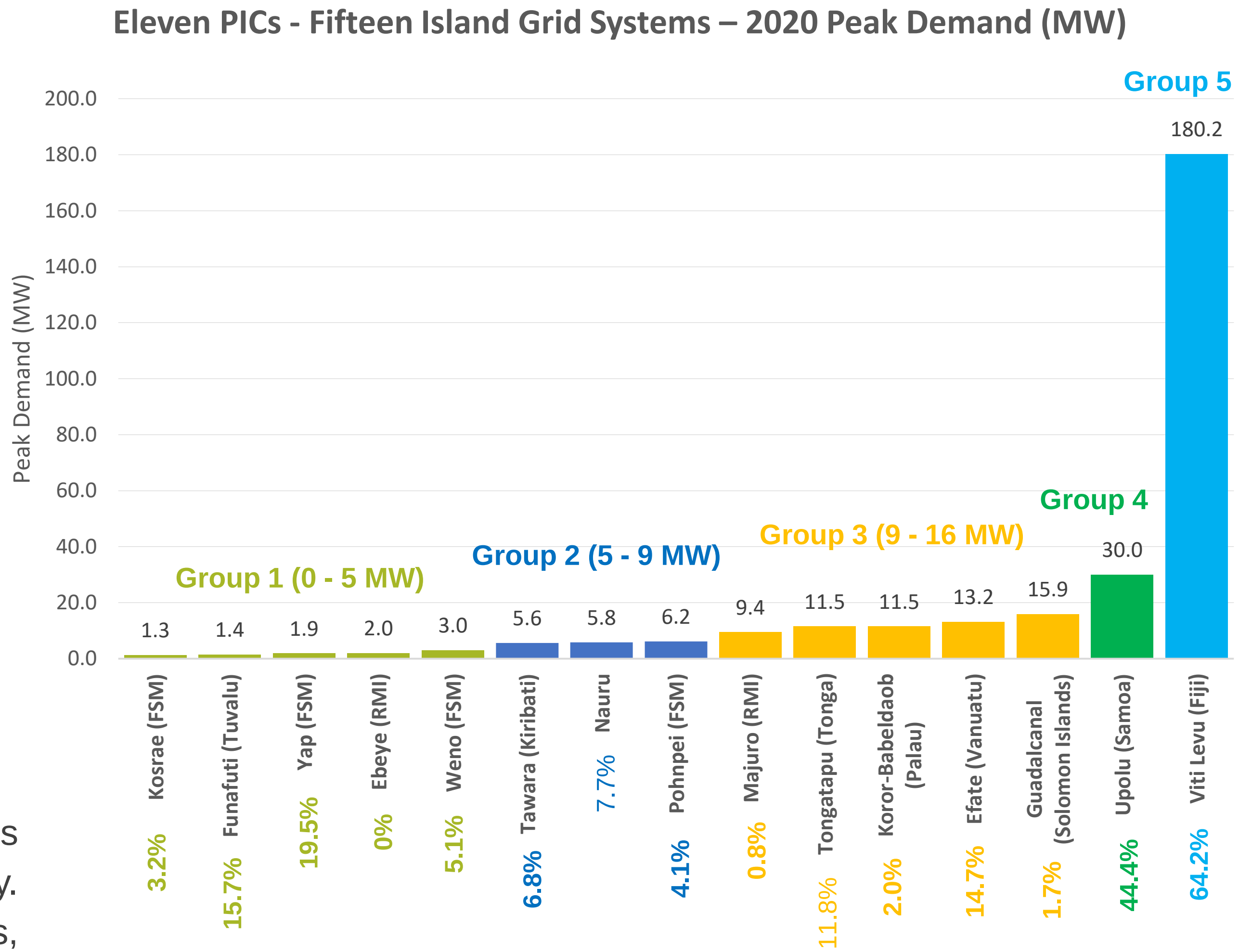
HNEI evaluated different durations of BESS in future years to meet the RE targets.

Future RE Resources

Case 1: Incremental Solar (100%)

Case 2: Incremental Solar-Wind (50%-50%)

Electric systems in the PICs vary greatly in size. Different sized grids have different constraints and needs and must be modeled differently. Thus, the main PIC grids were modeled in five different groups, based on peak demand.



HNEI Spreadsheet-Based Model for the PICs

3-HOUR BESS

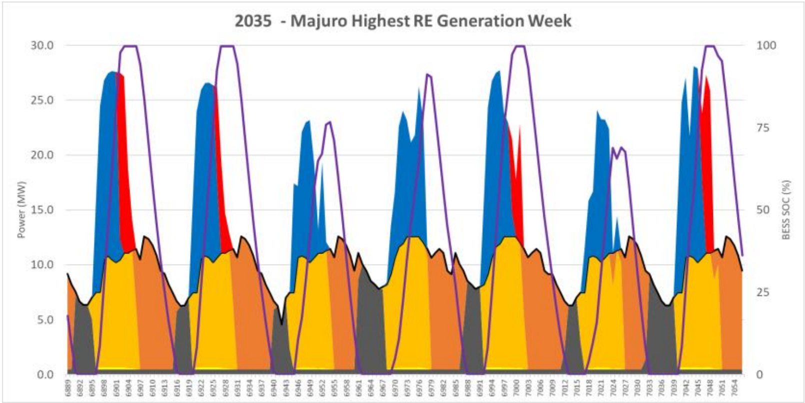
INPUT PARAMETERS

Capacity		
Pmin Diesel	0.45	MW
New Wind	0.0	MW
New Solar	31.6	MW
Storage (MWh)	94.8	MWh
BESS Inverter (MW)	31.6	MW
BESS Duration (hrs)	3.0	hours
Initial BESS SOC	0.0	%
Min BESS SOC	0.0	%
Max BESS Inverter Output	100.0	%

OUTPUT

Energy	MWh	%
Diesel	26,217	29.9%
New Wind	(0)	0.0%
New Solar	60,977	69.5%
2020 RE	496	0.6%
Total Load	87,690	100.0%
RE%		70.1%

	MWh	%
Curtailment	3,032.59	4.7%
		% of Available RE



PV Needed: 31.6 MW

BESS: 31.6 MW/ 94.8 MWh

Curtailment: 4.7%

4-HOUR BESS

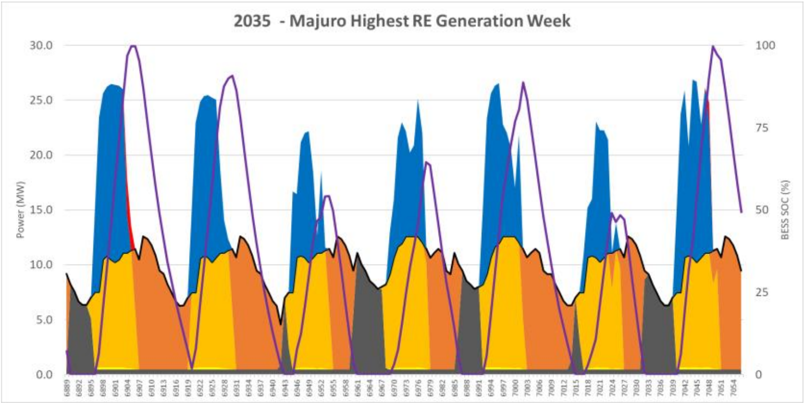
INPUT PARAMETERS

Capacity		
Pmin Diesel	0.45	MW
New Wind	0.0	MW
New Solar	30.2	MW
Storage (MWh)	120.8	MWh
BESS Inverter (MW)	30.2	MW
BESS Duration (hrs)	4.0	hours
Initial BESS SOC	0.0	%
Min BESS SOC	0.0	%
Max BESS Inverter Output	100.0	%

OUTPUT

Energy	MWh	%
Diesel	26,326	30.0%
New Wind	(0)	0.0%
New Solar	60,860	69.4%
2020 RE	496	0.6%
Total Load	87,682	100.0%
RE%		70.0%

	MWh	%
Curtailment	313.87	0.5%
		% of Available RE



PV Needed: 30.2 MW

BESS: 30.2 MW/ 120.8 MWh

Curtailment: 0.5%

5-HOUR BESS

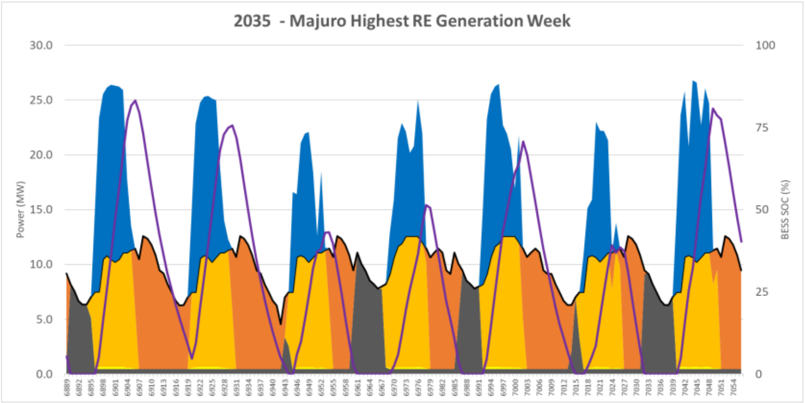
INPUT PARAMETERS

Capacity		
Pmin Diesel	0.45	MW
New Wind	0.0	MW
New Solar	30.1	MW
Storage (MWh)	150.5	MWh
BESS Inverter (MW)	30.1	MW
BESS Duration (hrs)	5.0	hours
Initial BESS SOC	0.0	%
Min BESS SOC	0.0	%
Max BESS Inverter Output	100.0	%

OUTPUT

Energy	MWh	%
Diesel	26,225	29.9%
New Wind	(0)	0.0%
New Solar	60,960	69.5%
2020 RE	496	0.6%
Total Load	87,681	100.0%
RE%		70.1%

	MWh	%
Curtailment	11.59	0.0%
		% of Available RE



PV Needed: 30.1 MW

BESS: 30.1 MW/ 150.5 MWh

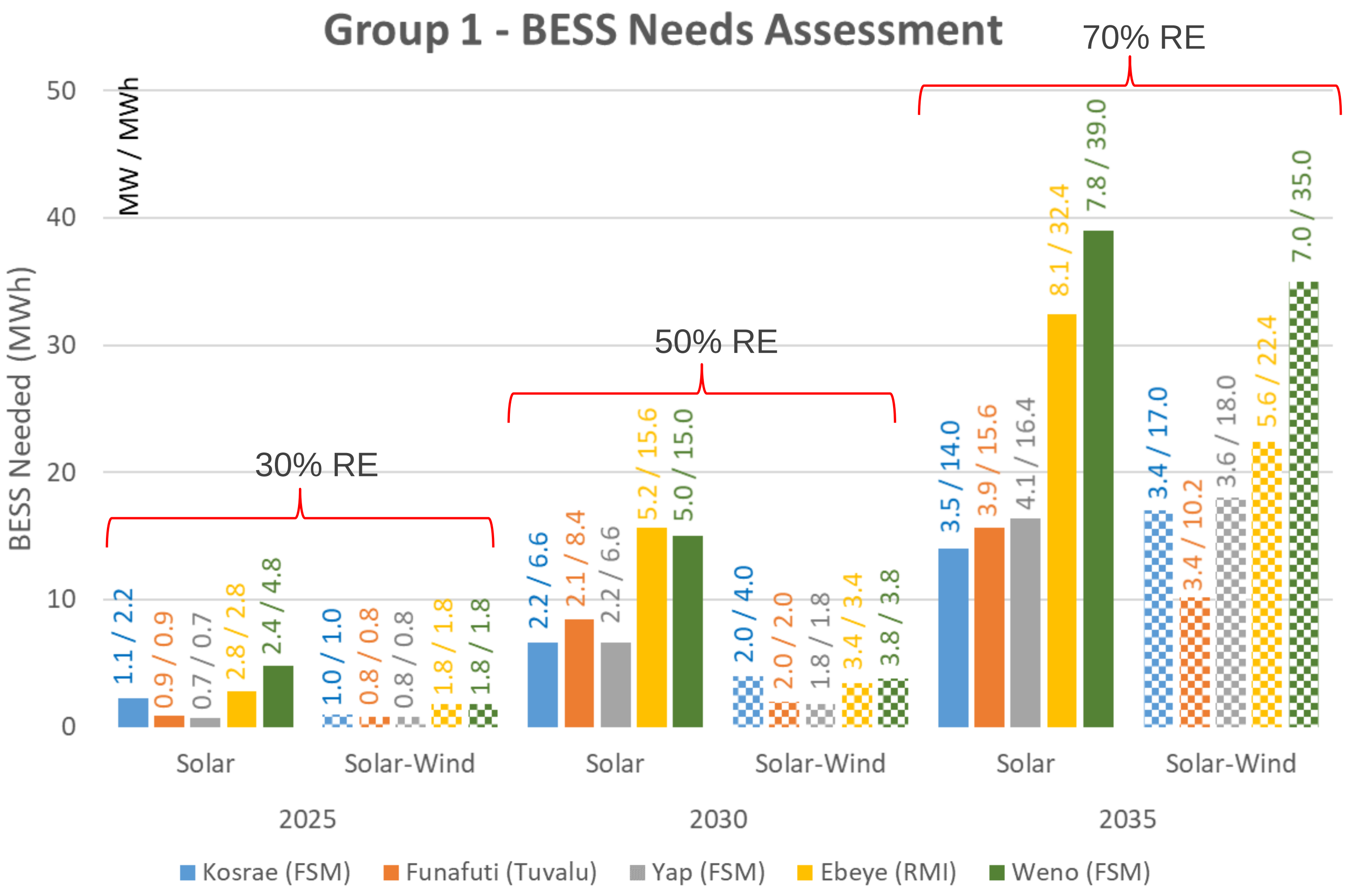
Curtailment: 0.0%

Diesel | Total Existing RE | New Solar | BESS Discharge | Load | BESS Charge | Curtailment | BESS SOC

Estimated BESS Needed in the PICs to meet 2030 RE target

Country	Island Grid	2020 Peak Demand (MW)	2020 RE Penetration (%)	2030 RE Penetration Target (%)	Est. BESS Needed by 2030 BESS (MW / MWh) Duration (H)	
					Case 1	Case 2
FSM	Chuuk	3.0	5.1	50.0	5.0 / 15.0 (3H)	3.8 / 3.8 (1H)
	Kosrae	1.3	3.2		2.2 / 6.6 (3H)	2.0 / 4.0 (2H)
	Pohnpei	6.2	4.1		9.2 / 18.4 (2H)	6.4 / 6.4 (1H)
	Yap	1.9	19.5		2.2 / 6.6 (3H)	1.8 / 1.8 (1H)
RMI	Ebeye	2.0	-	50.0	5.2 / 15.6 (3H)	3.4 / 3.4 (1H)
	Majuro	9.4	0.8		20.0 / 40.0 (2H)	13.4 / 13.4 (1H)
Tuvalu	Funafuti	1.4	15.7	50.0	2.1 / 8.4 (4H)	2.0 / 2.0 (1H)
Fiji	Viti Levu	180.2	64.2	85.0	213 / 426 (2H)	180 / 360 (2H)
Kiribati	Tarawa	5.6	6.8	50.0	7.9 / 15.8 (2H)	7.8 / 7.8 (1H)
Nauru	Nauru	5.8	7.7	50.0	9.3 / 18.6 (2H)	10.0 / 10.0 (1H)
Palau	Koror	11.5	2.0	50.0	27.1 / 54.2 (2H)	23.0 / 23.0 (1H)
Samoa	Upolu	30.0	44.4	80.0	51 / 255 (5H)	42 / 126 (4H)
Solomon Islands	Guadalcanal	15.9	1.7	50.0	37.5 / 75.0 (2H)	37.6 / 37.6 (1H)
Tonga	Tongatapu	11.5	11.8	50.0	19.4 / 38.8 (2H)	14.6 / 14.6 (1H)
Vanuatu	Efate	13.2	14.7	50.0	13.8 / 27.6 (2H)	9.0 / 9.0 (1H)

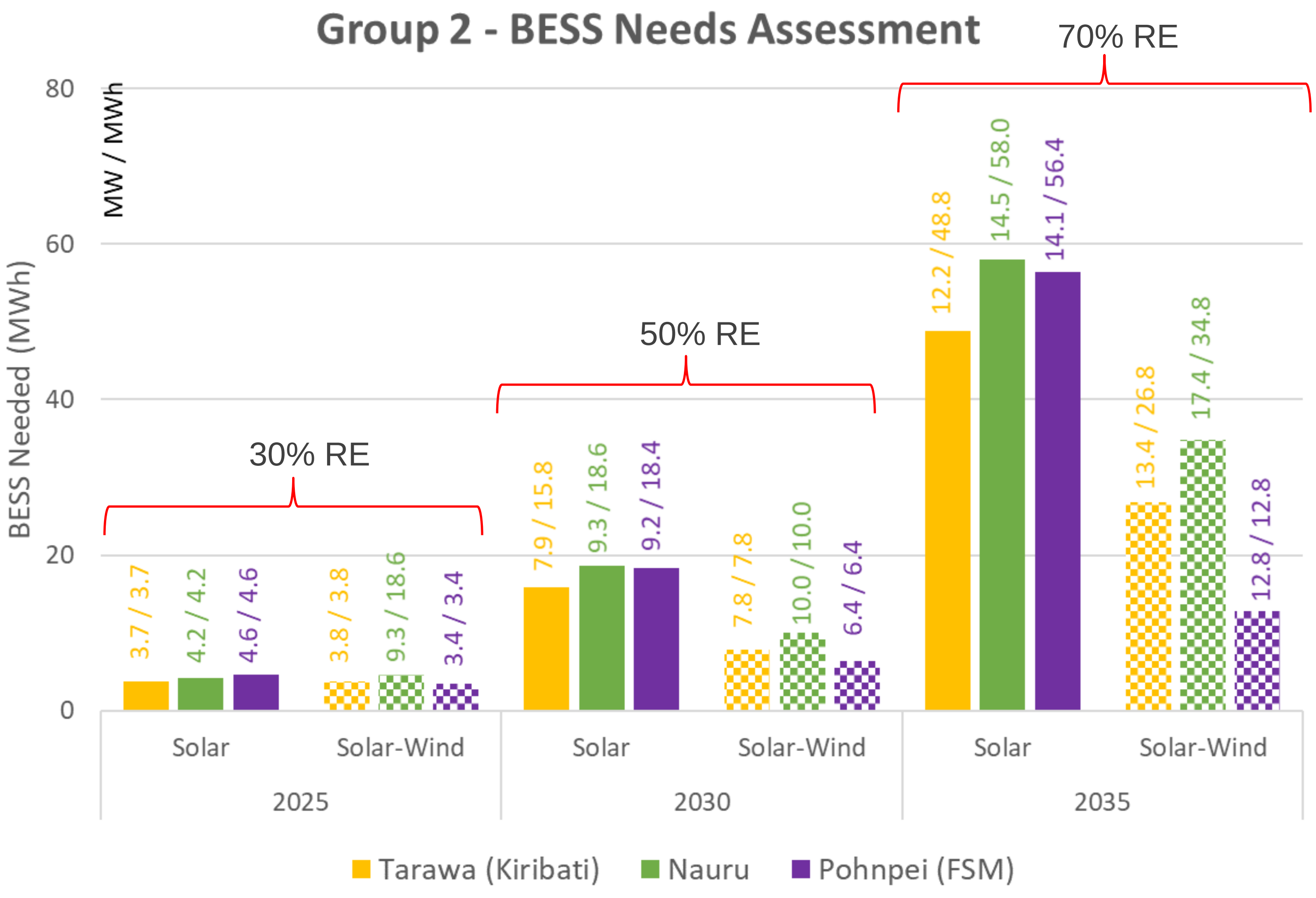
BESS Needs Assessment for Group 1 (0 to 5 MW)



Solar and Wind Capacity Factors (CF)

Island	2020 RE (%)	Solar CF (%)	Wind CF (%)
Kosrae (FSM)	3.2	23.0	29.0
Funafuti (Tuvalu)	15.7	24.6	31.7
Yap (FSM)	19.5	24.5	39.6
Ebeye (RMI)	0.0	24.6	51.8
Weno (FSM)	5.1	23.8	38.2

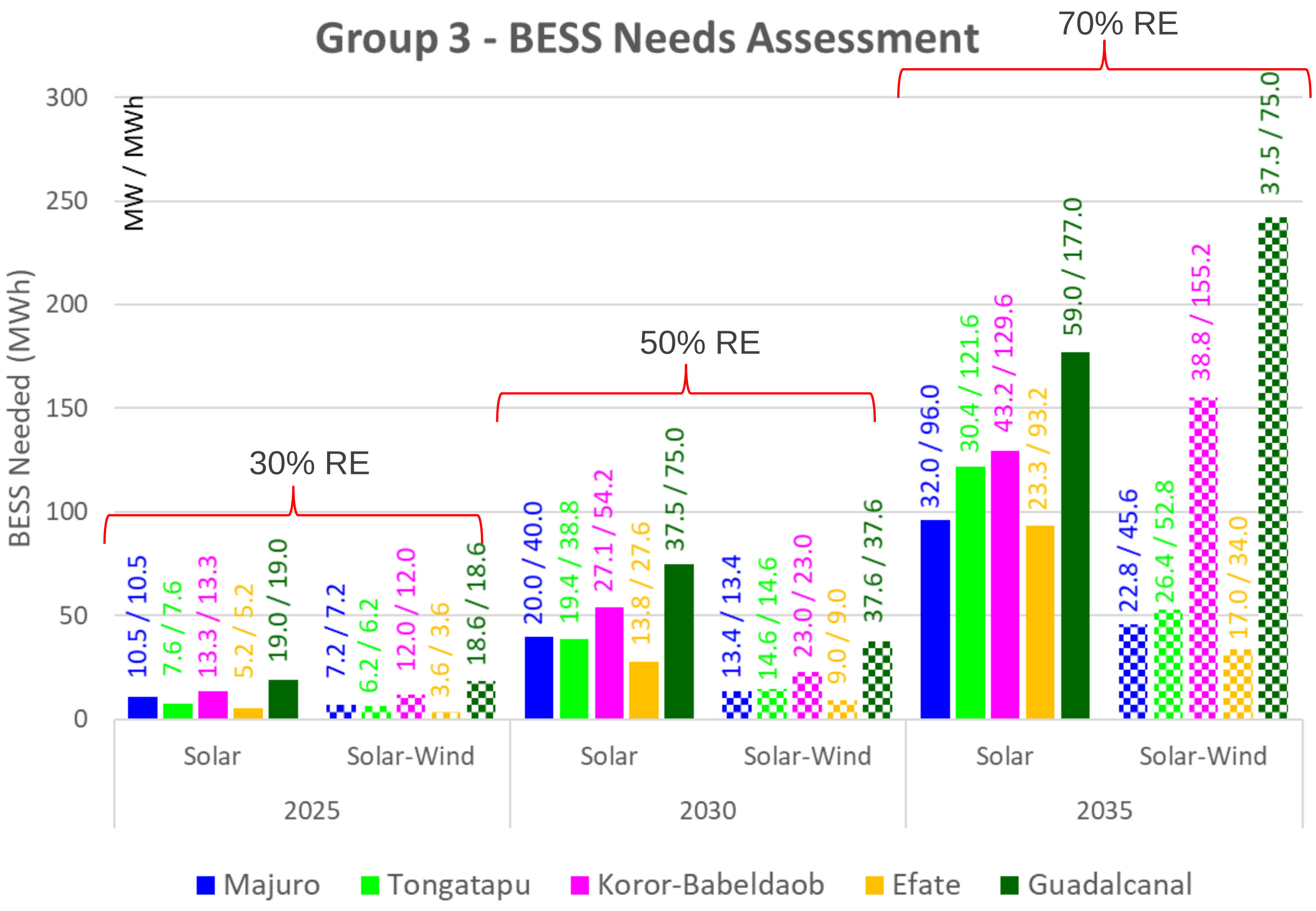
BESS Needs Assessment for Group 2 (5 to 7 MW)



Solar and Wind Capacity Factors (CF)

Island	2020 RE (%)	Solar CF (%)	Wind CF (%)
Tarawa (Kiribati)	6.8	28.0	26.9
Nauru	7.7	27.6	21.8
Pohnpei (FSM)	4.1	28.2	48.9

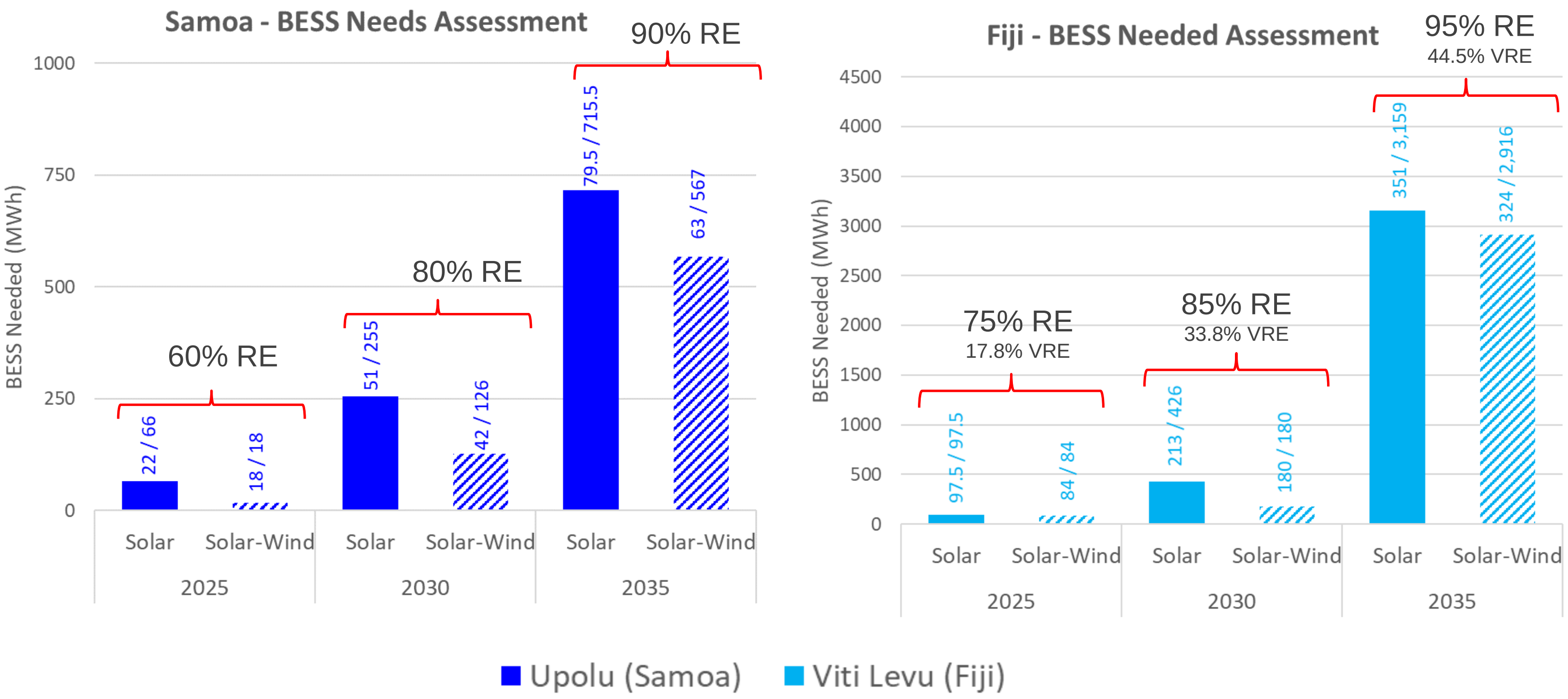
BESS Needs Assessment for Group 3 (9 to 16 MW)



Solar and Wind Capacity Factors (CF)

Island	2020 RE (%)	Solar CF (%)	Wind CF (%)
Majuro (RMI)	0.8	23.1	44.2
Tongatapu (Tonga)	11.8	24.3	35.8
Koror (Palau)	2.0	23.1	28.6
Efate (Vanuatu)	14.7	24.3	47.0
Guadalcanal (Solomon Islands)	1.7	18.9	19.3

BESS Needs Assessment for Groups 4 and 5



Solar and Wind Capacity Factors (CF)

Island	2020 RE (%)	Solar CF (%)	Wind CF (%)
Upolu (Samoa)	44.4*	24.3	35.8
Viti Levu (Fiji)	64.2**	22.3	31.4

* In 2020, Samoa had about 8 MW / 13.7 MWh of BESS
** 57% of Fiji's electricity in 2020 was provided by firm hydropower; Fiji's VRE(%) in 2020 was 0.4%

<u>100% RE:</u>

- 79 MW of new PV
- 79 /15,010 (MW/MWh) of BESS (190-hours or storage)

- 36 MW of new PV
- 36 MW of new Wind
- 72 /6,480 (MW/MWh) of BESS (90-hours or storage

<u>100% RE:</u>

- 350 MW of new PV
- 350/42,000 (MW/MWh) of BESS (120-hours or storage)

- 150 MW of new PV
- 150 MW of new Wind
- 300/48,000 (MW/MWh) of BESS (160-hours or storage)

Mahalo!

(Thank you)

HNEI
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University of Hawai'i at Mānoa

For more information, contact:

GridSTART
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Grid System Technologies Advanced Research Team

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Grid System Technologies Advanced Research Team

Leon R. Roose

Chief Technologist

Mr. Roose is a tenured faculty member of the Hawaii Natural Energy Institute (HNEI), University of Hawaii, where he formed and leads Grid***START*** (Grid System Technologies Advanced Research Team), a research team focused on the integration and analysis of energy technologies and power systems, including smart grid and micro grid applications.

He served in numerous leadership roles at the Hawaiian Electric Company for 19 years prior including management of renewable energy planning and integration, generation resource planning and competitive procurement, negotiation of all power purchase agreements for the utility, transmission and distribution system planning, smart grid planning and projects, system relaying and protection, and fuel purchase and supply to utility generating plants. He is a licensed attorney, worked in private law practice in Hawaii and was formerly Associate General Counsel at Hawaiian Electric. He holds a B.S. in Electrical Engineering and a J.D. from the University of Hawaii.

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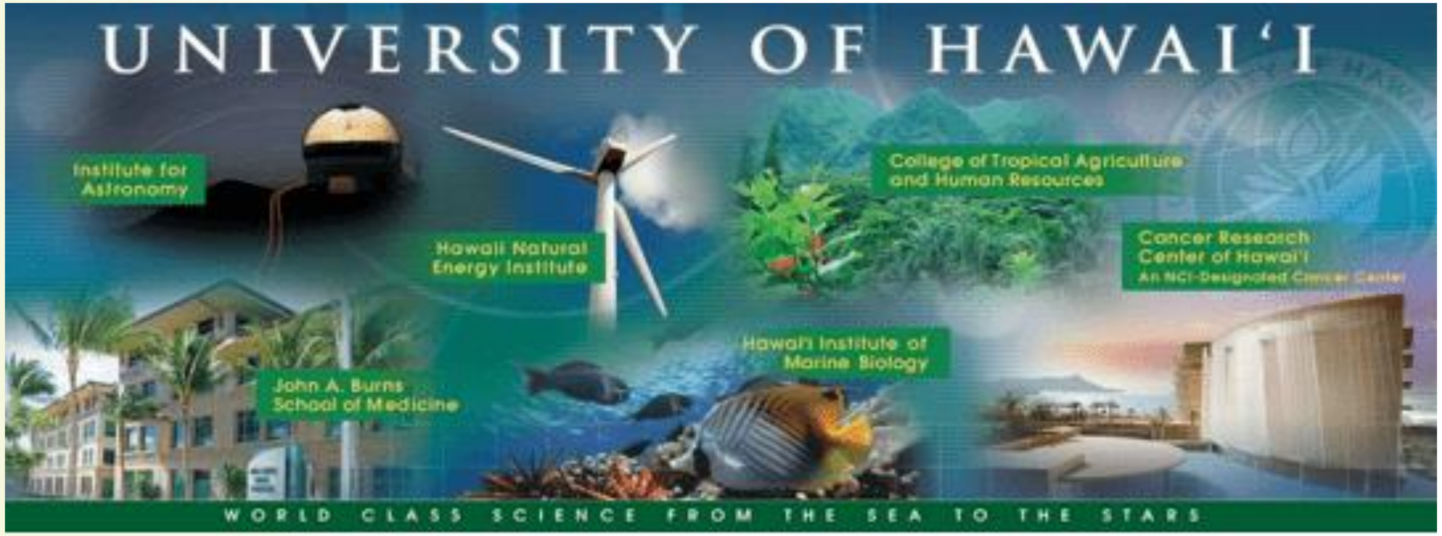

- Established in 1907
- Statewide system with 3 universities & 7 community colleges
- Over 50,000 students
- Manoa is the largest and main research campus
  - 14,000 undergraduate students
  - 6,000 graduate students

- ***School of Ocean and Earth Science and Technology*** is the largest research unit on the Manoa campus

~$100 million extramural funding per year

Hawaii Natural Energy Institute (HNEI)

University of Hawaiʻi at Mānoa

Organized Research Unit in School of Ocean and Earth Science and Technology
Founded in 1974, established in Hawaiʻi statute in 2007 (HRS 304A-1891)

- Conduct RDT&E to accelerate and facilitate the use of resilient alternative energy technologies and reduce Hawaii's dependence on fossil fuels.
- Diverse staff includes engineers, scientists, lawyers; students and postdoctoral fellows; visiting scholars

Areas of Interest

- **Grid Integration (Grid*START*)**
- **Policy and Innovation**
- **Alternative Fuels**
- **Electrochemical Power Systems**
- **Renewable Power Generation**
- **Building Efficiency**
- **Transportation**

Core Functions

- **State Energy Policy Support**
- **Research & Development**
- **Testing and Evaluation**
- **Analysis**
- **Workforce Development**

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Grid System Technologies Advanced Research Team

Established to develop and test advanced grid architectures, new technologies and methods for effective integration of renewable energy resources, power system optimization and resilience, and enabling policies

- Serves to integrate into the operating power grid other HNEI technology areas: energy efficiency, renewable power generation, biomass and biofuels, fuel cells and hydrogen
- Strong and growing partnerships with Hawaiʻi, national and international organizations including Asia-Pacific nations

Lead for many public-private demonstration projects

Expertise & Focus:

- *Energy Policy and Regulation*
- *Renewable Energy Grid Integration*
- *Smart Grid Planning & Technologies*
- *Power Systems Planning*
- *RE Resource Procurement*
- *Power Systems Operation*
- *Power Systems Engineering and Standards*
- *Communications Design and Testing*
- *Project Management and Execution*