Hawai'i Powered

Integrated Grid Planning Stakeholder Technical Working Group

November 29, 2022

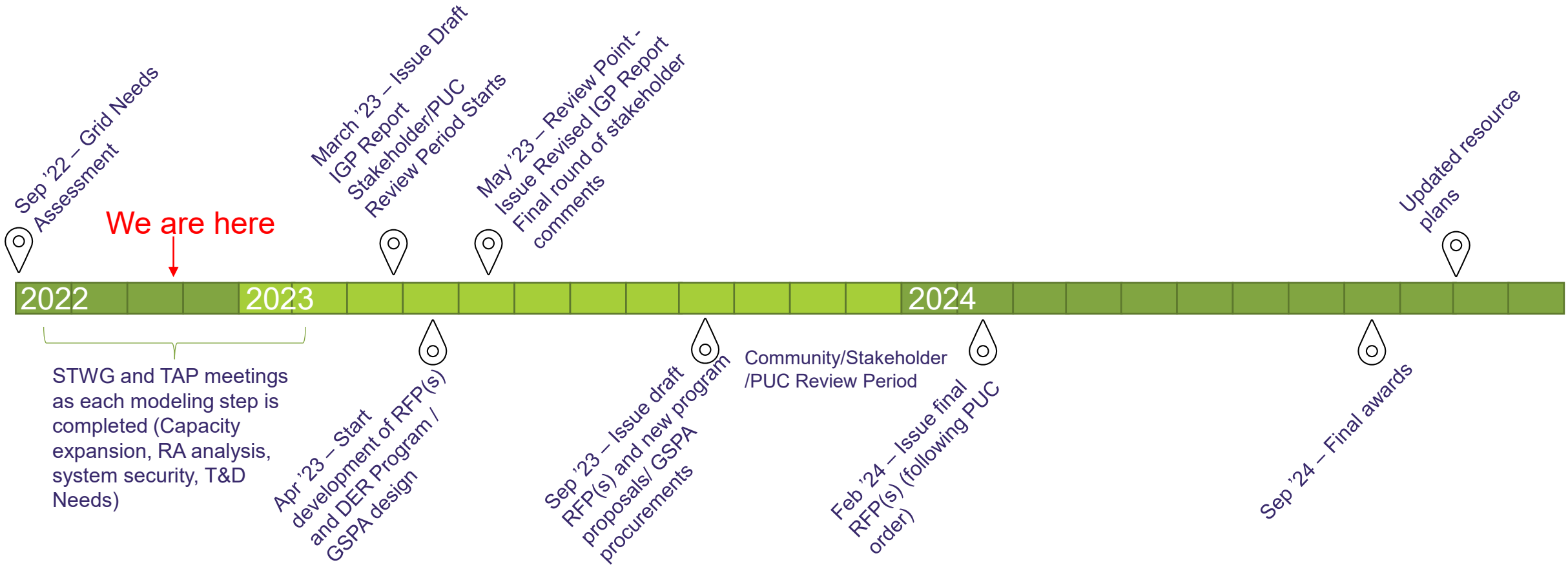
Hawaiian Electric

Agenda

- High level overview of Preliminary RESOLVE Modeling Results
- Next steps of analysis

This deck includes information and data as a result of the first step in the IGP grid needs assessment. These initial results include the scenarios and sensitivities based on the approved Inputs & Assumptions and Grid Needs Assessment Methodology. The first step includes RESOLVE results only, the next steps in the process will include resource adequacy and system security steps. After this meeting, please take time to review the deck and send any feedback or comments as discussed later in the presentation.

Updated Proposed Schedule for First IGP Cycle



- Schedule subject to change based on PUC guidance and orders, and stakeholder engagement and review process, and as we learn through the first IGP cycle

Grid Needs Assessment Schedule

IGP Task/Step	Start	Finish
Grid Needs Assessment		
Preliminary RESOLVE and PLEXOS Prod Sim Base case results	9/1/2022	10/31/2022
STWG Meeting	11/29/2022	
Joint Stakeholder Council & TAP Meeting	11/30/2022	
All TAP Meeting	12/1/2022	
Transmission – System Security Methodology TAP Meeting	11/1/2022	
Transmission Needs – System Security (steady-state)	11/1/2022	2/28/2023
Transmission Needs – System Security Analysis (dynamic/stability)	11/1/2022	2/28/2023
TAP/STWG – Transmission Needs	TBD	
Distribution Grid Needs	9/1/2022	10/31/2022
TAP/STWG – Distribution Needs	TBD – Nov 2022	
Finalize Distribution Grid Needs	12/1/2022	1/31/2023
Preliminary RESOLVE results for remaining cases and probabilistic resource adequacy on Base case	10/31/2022	12/26/2022
TAP/STWG Meetings – Model iterations discussion	TBD – Feb 2023	(Also as needed)
PLEXOS modeling iterations based on System Security Analysis	2/21/2023	3/14/2023
Resilience Needs	10/1/2023	1/31/2023
Stakeholder Council Meeting	TBD	

Transmission Needs analysis based on RESOLVE Plans have started

Preliminary Distribution Needs have been completed – Results to be presented at future STWG

Resource Adequacy Analysis (Base case) to begin soon

We will seek comment on RESOLVE plans prior to start of RA analysis

High Level Overview of Preliminary RESOLVE Results

Stage 3 Grid Needs Assessment Provides a Foundation

The grid needs assessments conducted in support of the Stage 3 RFP provided the groundwork for IGP

- Utilized the IGP assumptions and processes to identify proxy resources for near-term grid needs
- On O‘ahu and Maui, RESOLVE resource plans were validated with probabilistic resource adequacy analysis based on best practices endorsed by the TAP

IGP builds upon this work to identify longer term grid needs including renewables located in potential future Renewable Energy Zones

Updates Made Since the GNA Filings

Several updates were made since the Stage 3 RFP grid needs assessments were filed:

- Placeholder resources were included for the Stage 3 RFP capacity and energy
- The RESOLVE models underwent an ERM calibration where resource plans were evaluated at incremental ERM targets and verified by a probabilistic resource adequacy analysis. RESOLVE ERM targets were updated to use the percentage that yielded a reliable resource plan where LOLE <0.1. A probabilistic resource adequacy back check will still be conducted once the base case is finalized.
- Additional RESOLVE sensitivities were conducted, as discussed with stakeholders and identified in the Grid Needs Assessment Methodology

Modeling Scenarios

Modeling Case	Purpose	DER Forecast	EV Forecast	EE Forecast	Non-DER/EV TOU Forecast	EV Load Shape	Fuel Price Forecast	Resource Potential
Base_EELayer	Reference Case	Base Forecast	Base Forecast	Base Forecast	Base Forecast	Managed EV Charging	Base Forecast	NREL Alt-1
LC_EELayer	Understand the impact of limited availability of land for future solar, onshore wind, and biomass development.	Base Forecast	Base Forecast	Base Forecast	Base Forecast	Managed EV Charging	Base Forecast	**Land Constrained Resource Potential**
High_Load	Understand the impact of customer adoption of technologies for DER, electric vehicles, energy efficiency, and time-of-use rates that lead to higher loads.	**Low Forecast**	**High Forecast**	**Low Forecast**	**Low Forecast**	**Unmanaged EV Charging**	Base Forecast	NREL Alt-1
Low_Load	Understand the impact of customer adoption of technologies for DER, electric vehicles, energy efficiency, and time-of-use rates that leads to lower loads.	**High Forecast**	**Low Forecast**	**High Forecast**	**High Forecast**	Managed EV Charging	Base Forecast	NREL Alt-1
Faster_Tech	Understand the impact of faster customer adoption of DER, EV, and EE.	**High Forecast**	**High Forecast**	**High Forecast**	**High Forecast**	Managed EV Charging	Base Forecast	NREL Alt-1
Unmanaged_EV	Understand the value of managed EV charging relative to unmanaged.	Base Forecast	Base Forecast	Base Forecast	Base Forecast	**Unmanaged EV Charging**	Base Forecast	NREL Alt-1
DER_Freeze	Understand the value of the distributed PV and BESS uptake in the Base forecast. Informative for program design and solution sourcing.	**DER Freeze**	Base Forecast	Base Forecast	Base Forecast	Managed EV Charging	Base Forecast	NREL Alt-1
EV_Freeze	Understand the value of the electric vehicles uptake in the Base forecast. Informative for program design and solution sourcing.	Base Forecast	**EV Freeze**	Base Forecast	Base Forecast	Managed EV Charging	Base Forecast	NREL Alt-1
HighFuel_RetOpt	Understand the impact of higher fuel prices on the resource plan while allowing existing firm unit to be retired by the model	Base Forecast	Base Forecast	Base Forecast	Base Forecast	Managed EV Charging	**EIA High Fuel Price Forecast**	NREL Alt-1
Base_EEResource	Understand the value of the energy efficiency as a resource. Informative for program design and solution sourcing.	Base Forecast	Base Forecast	**EE Freeze + EE Supply Curves**	Base Forecast	Managed EV Charging	Base Forecast	NREL Alt-1

Summary of Preliminary Results

O'ahu

O'ahu – ERM Calibration July 2022 GNA

RESOLVE Resource Selection					
Year 2030	**Base.v3_ 0ERM**	**Base.v3_ 10ERM**	**Base.v3_ 20ERM**	**Base.v3_ 30ERM**	**LC.v3_ 10ERM**
Existing firm HDC (%)	72.37	72.37	72.37	72.37	72.37
New firm HDC (%)	97.4	97.4	97.4	97.4	97.4
ERM Requirement (%)	0	10	20	30	10
New Firm (selected by RESOLVE, MW)	213	300	408	521	342
Existing Firm (MW)	967	967	967	967	967
Standalone PV (MW)	0	0	0	0	0
Paired PV (Hybrid Solar, MW)	1,741	1,594	1,556	1,401	270
Onshore Wind (MW)	163	163	163	163	0
Offshore Wind (MW)	0	0	0	0	0
Standalone Storage (MW / MWH)	75 / 140	61 / 115	64 / 122	67 / 127	14 / 26
Paired Storage (MW / MWH)	1,741 / 5,613	1,594 / 4,770	1,556 / 4,502	1401 / 3,639	270 / 270

PLEXOS Probabilistic RA			
Year 2029	**Base_300_1600PVB_Mar22Out**	**Base_300_270PVB_0Wnd_Mar22Out**	**Base_400_270PVB_0Wnd_Mar22Out**
Existing firm HDC (%)	N/A	N/A	N/A
New firm HDC (%)	N/A	N/A	N/A
ERM Requirement (%)	N/A	N/A	N/A
New Firm (selected by RESOLVE, MW)	300	300	400
Existing Firm (MW)	970	970	970
Standalone PV (MW)	0	0	0
Paired PV (Hybrid Solar, MW)	1,600	270	270
Onshore Wind (MW)	163	0	0
Offshore Wind (MW)	0	0	0
Standalone Storage (MW / MWH)	Aggregated with Paired Storage	Aggregated with Paired Storage	Aggregated with Paired Storage
Paired Storage (MW / MWH)	1,887 / 5,339	557 / 1,349	557 / 1,349
LOLE (Days / Year)	0.01	0.66	0.04

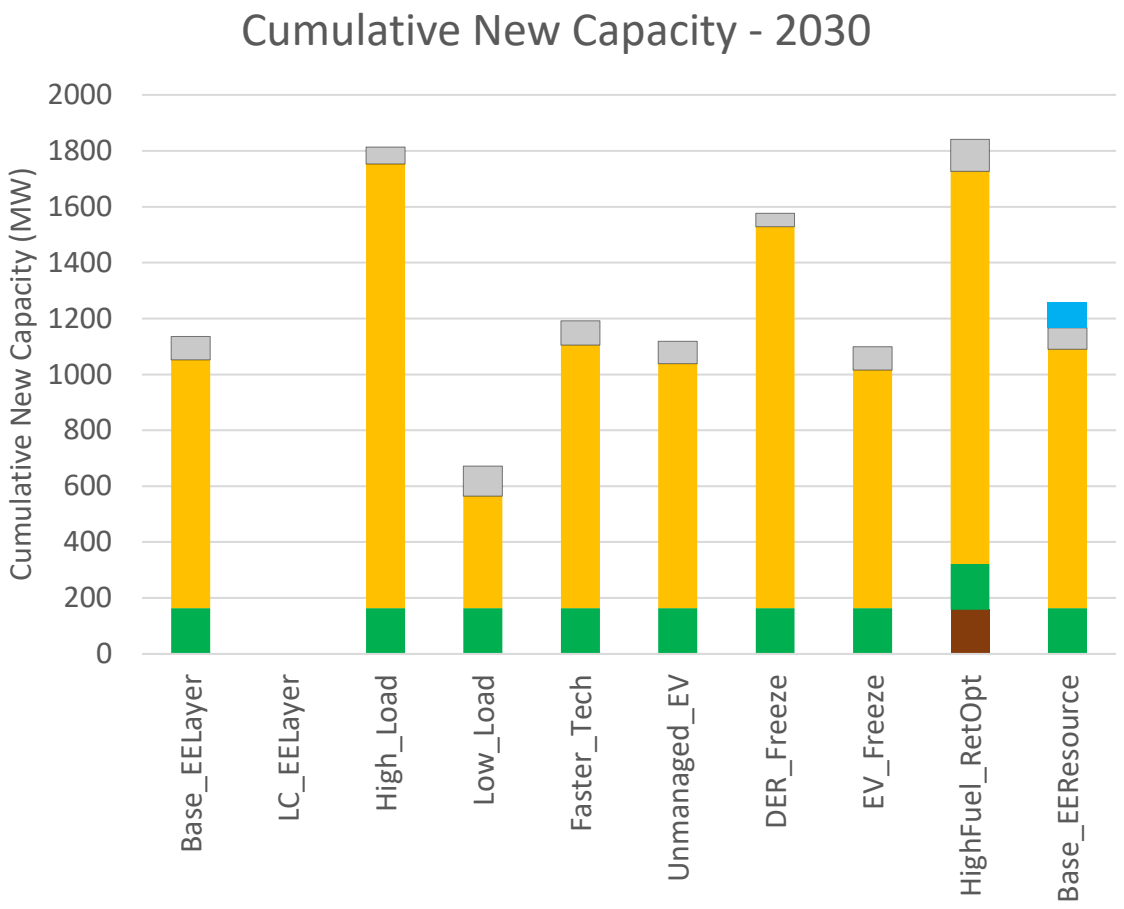
- The probabilistic analyses in the O'ahu GNA showed that 300 MW of new firm generation can achieve an LOLE < 0.1 days/year in the Base case. However, in a Land Constrained case where only 270MW of future paired PV can be built, more than 300 MW may be needed.
- 10% ERM target was based on Base.v3_10ERM and LC.v3_10ERM, which both showed at least 300 MW of new firm generation built.

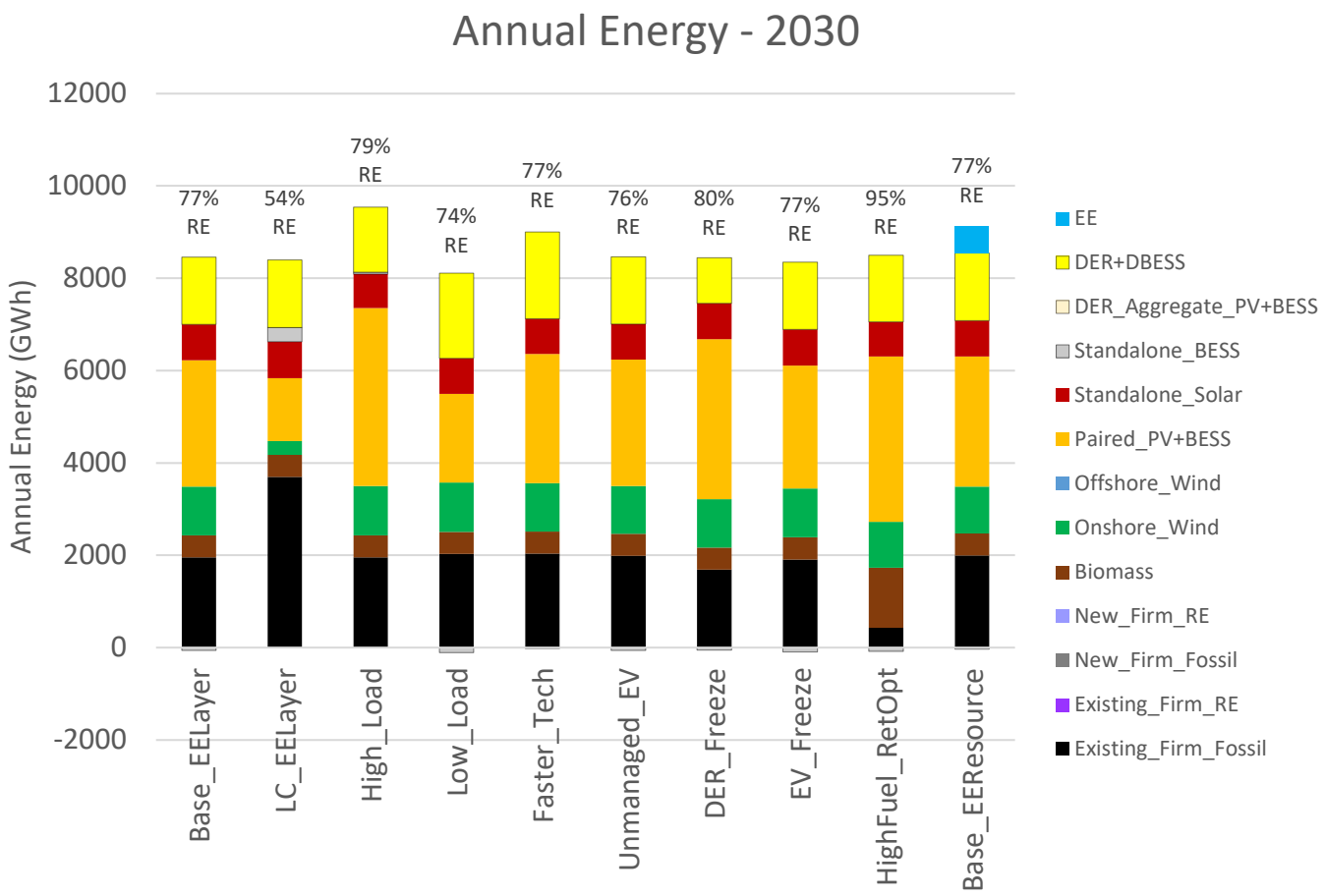
O'ahu – Key Observations

- The Base, High Load, Low Load, and Faster Tech cases build the same resources (paired PV, onshore wind, offshore wind, standalone BESS) in different amounts. The High Load case also builds Biomass whereas the other two cases do not.
- The Unmanaged EV has a negligible (but higher) NPV compared to the Base case and builds more utility scale standalone PV and no Biomass.
  - Only the shape is different, not the annual load.
  - The unmanaged EV builds more firm renewables and less variable renewables and storage to meet ERM criteria.
- The DER Freeze case has a higher NPV due to decreased DER resources and the EV Freeze has a lower NPV due to decreased load to serve.
  - DER Freeze built more utility scale paired PV.
  - EV Freeze built less utility scale paired PV and more standalone PV.
- Using the high fuel price forecast and allowing RESOLVE to optimize the removal of existing firm generation, RESOLVE decides to remove approximately 833 MW of firm capacity while building 158 MW of Biomass by 2030.
  - Based on the ERM calibration this should yield an LOLE of around 0.22 days/year.
- When energy efficiency was modeled as a selectable resource, RESOLVE selected less EE supply curves than the base EE forecast. The energy efficiency shape as a resource was less peak focused compared to the base forecast.

O'ahu– 2030

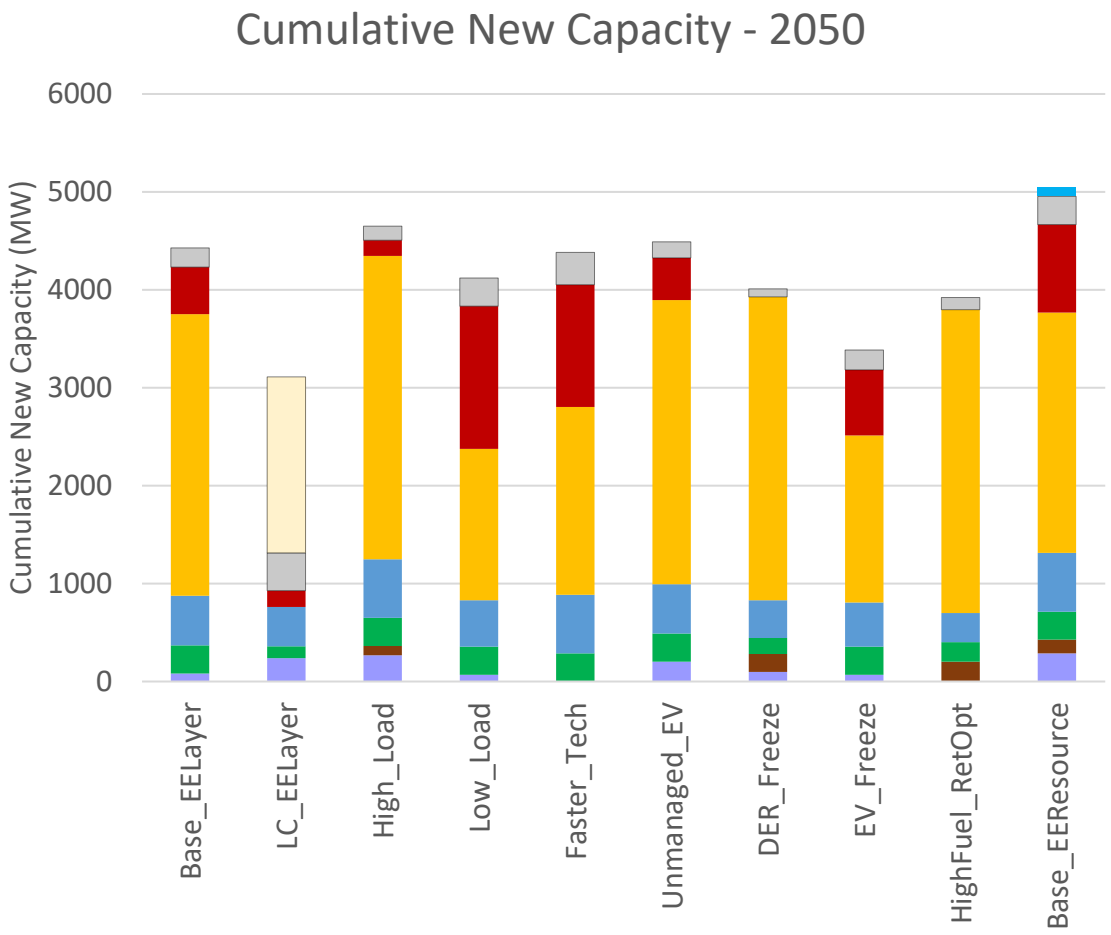
Planned Stage 3 resources
450 MW Paired PV+BESS installed in 2027
300 MW Firm RE installed in 2029
208 MW Firm RE installed in 2033

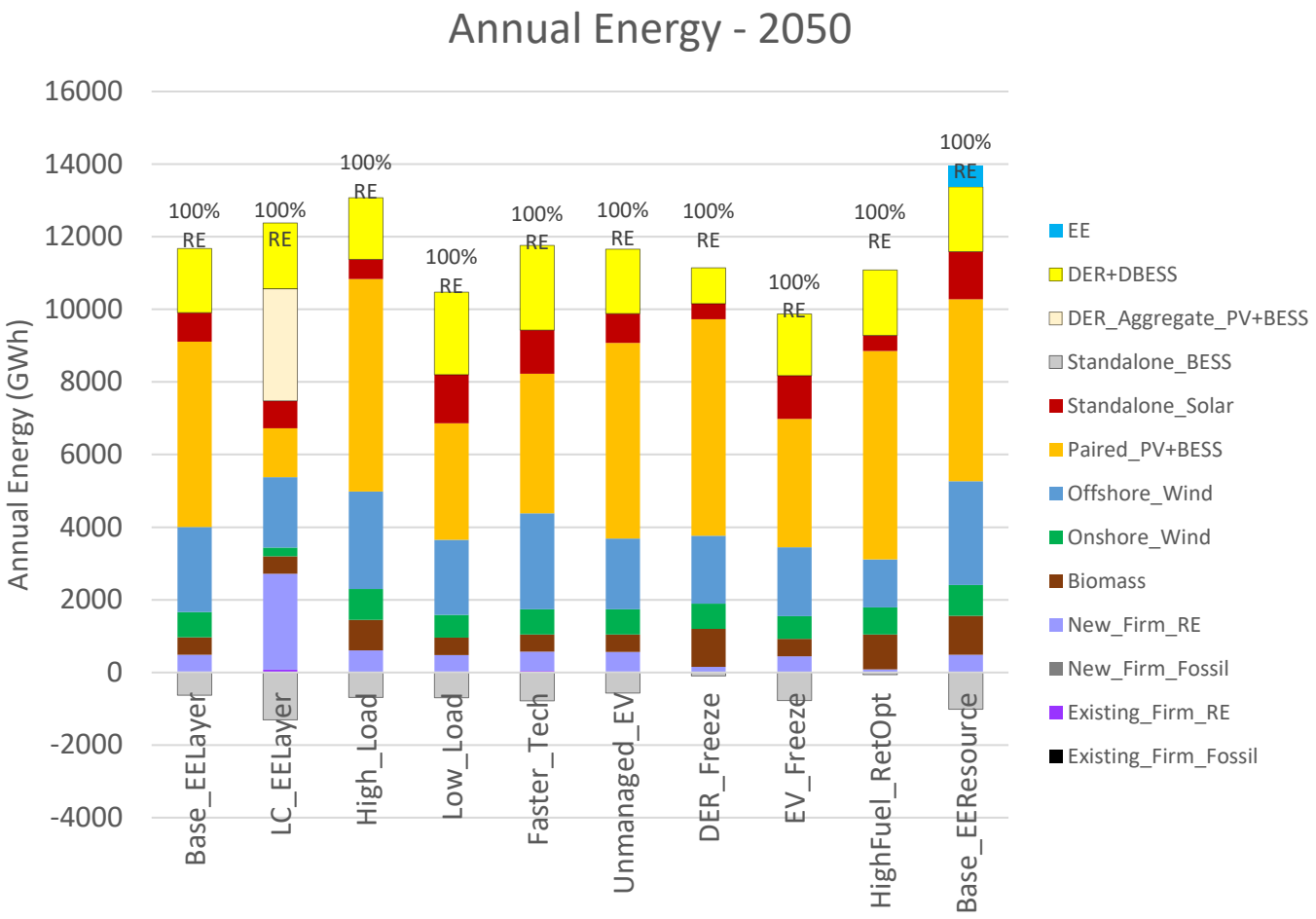




In the Land Constrained (LC_EELayer) case, it is assumed that the Stage 3 resources use all available potential and is unable to build any utility scale PV and onshore wind.

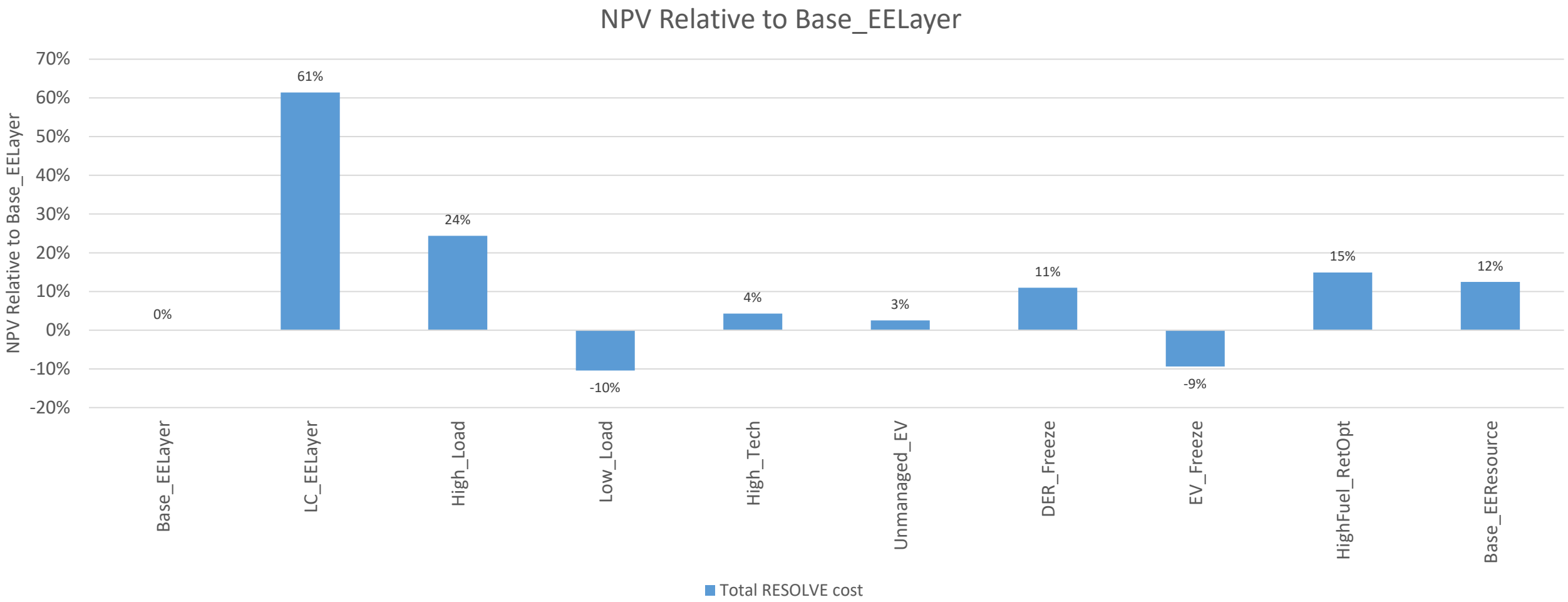
O'ahu– 2050





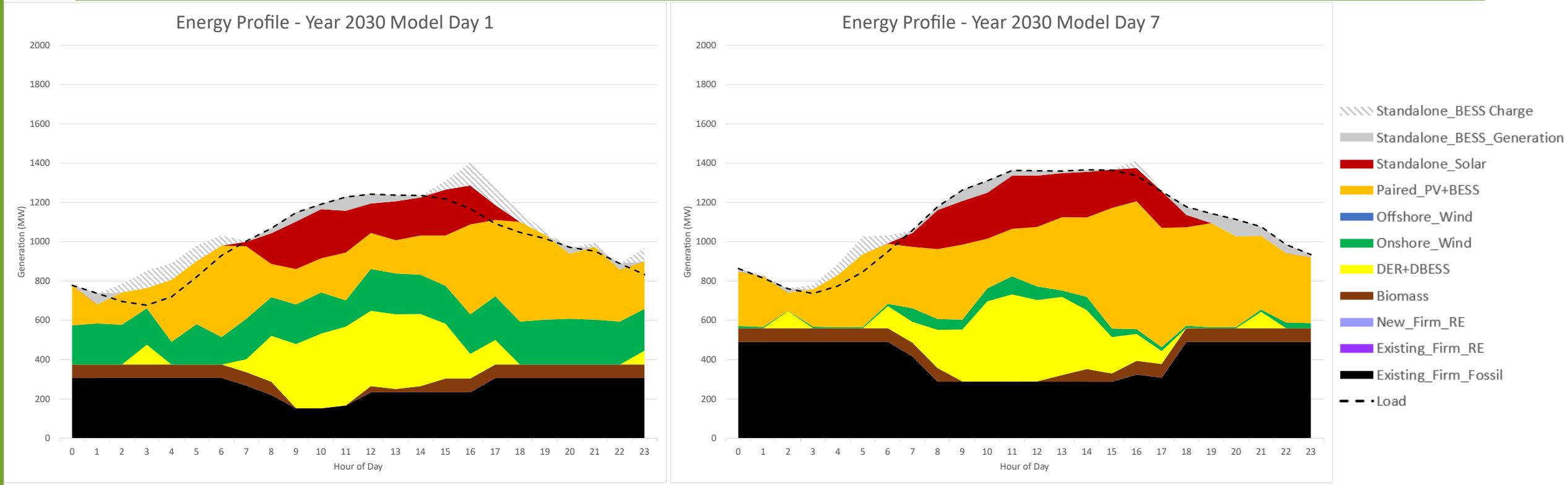
Biomass is consistently built across the high load, DER freeze, High Fuel and EE as a Resource cases.

O'ahu – NPV



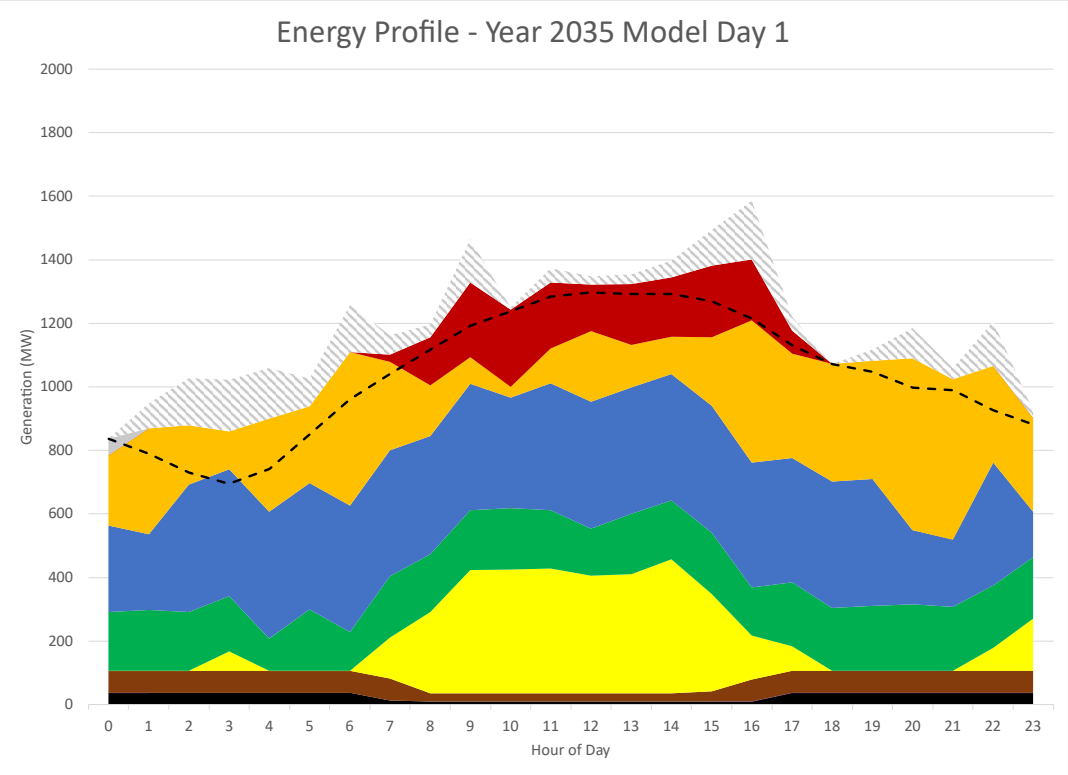
Net present value (NPV) of each modeling scenario from 2029 to 2050 relative to the base scenario.

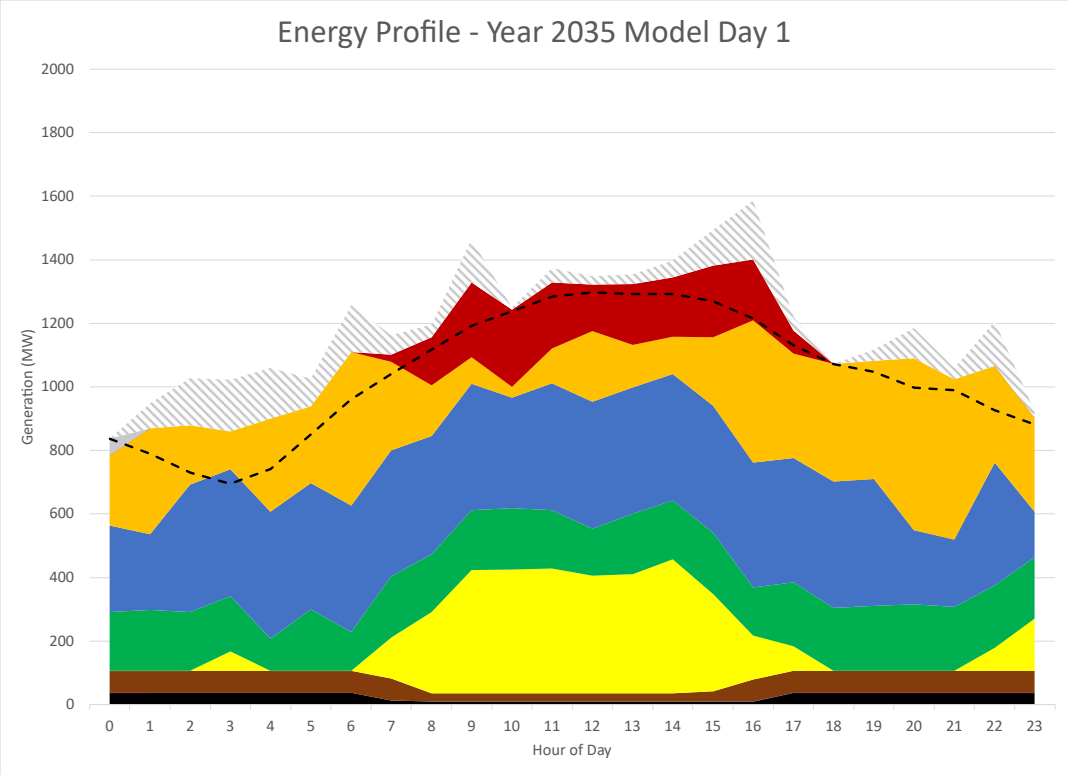
O'ahu – Base – 2030



Left: Energy generated on a typical day in 2030 base scenario and most typical day in the model
Right: Energy generated on a day with low renewable resource availability assuming 2030 base scenario

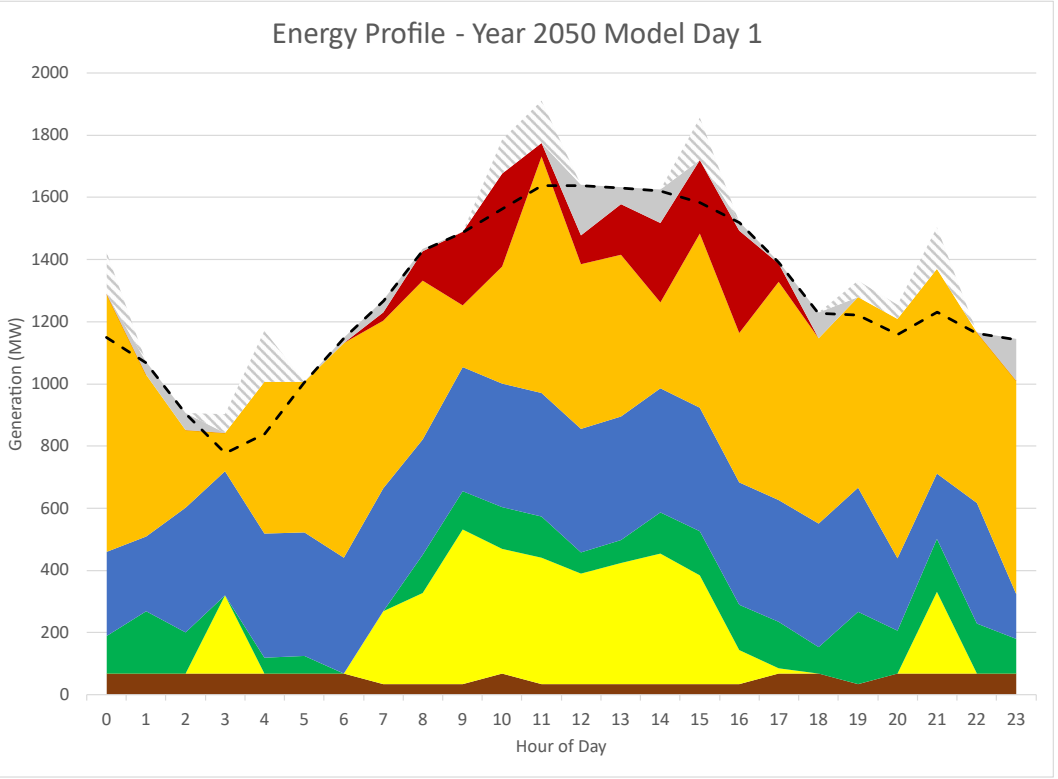
O'ahu – Base – 2035

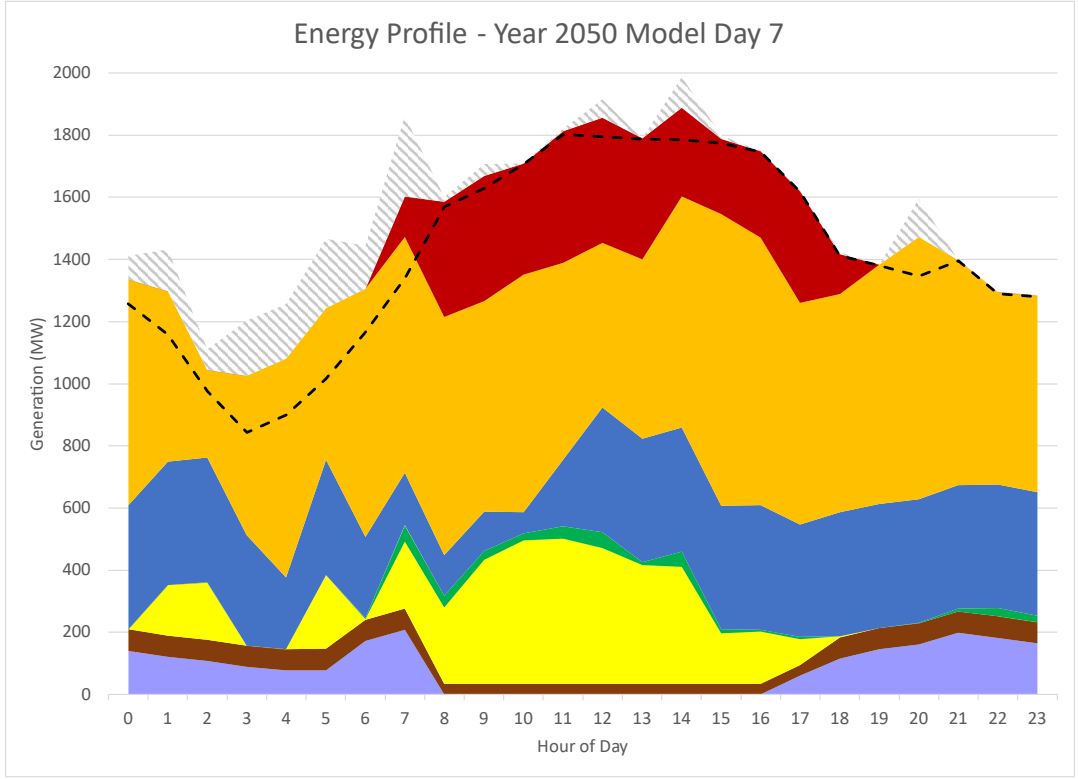




- Standalone_BESS Charge
- Standalone_BESS_Generation
- Standalone_Solar
- Paired_PV+BESS
- Offshore_Wind
- Onshore_Wind
- DER+DBESS
- Biomass
- New_Firm_RE
- Existing_Firm_RE
- Existing_Firm_Fossil
- Load

O'ahu – Base – 2050

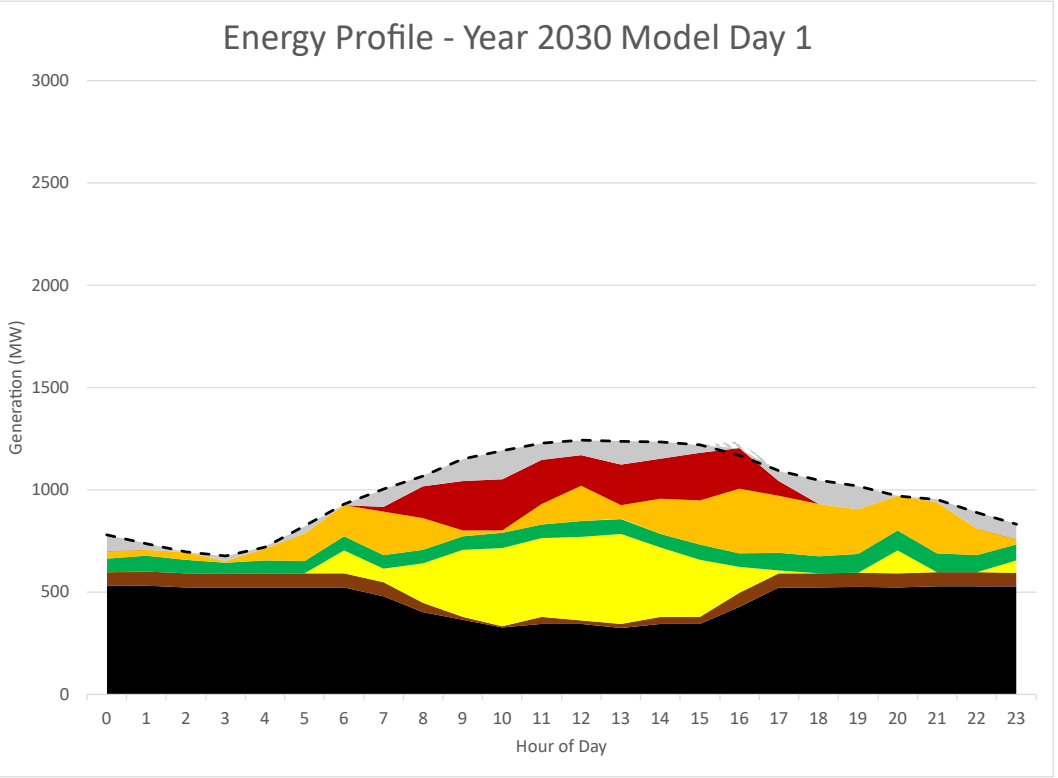


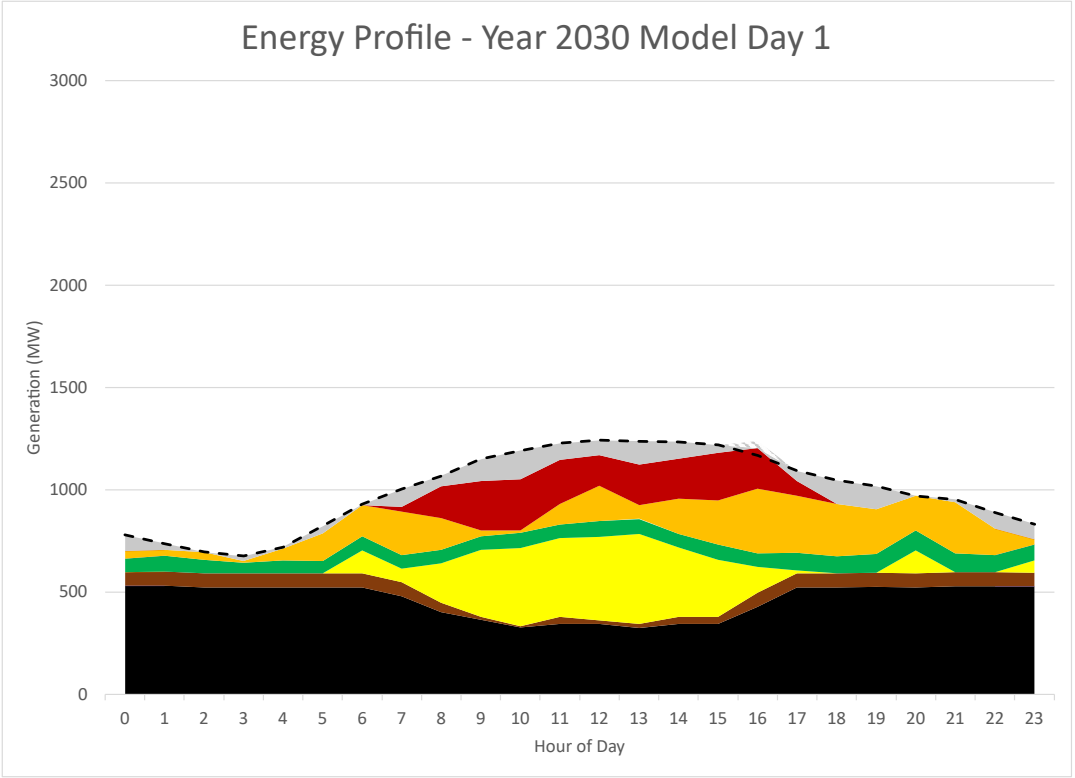


Standalone_BESS Charge
Standalone_BESS_Generation
Standalone_Solar
Paired_PV+BESS
Offshore_Wind
Onshore_Wind
DER+DBESS
Biomass
New_Firm_RE
Existing_Firm_RE
Existing_Firm_Fossil
Load

As EV loads continue to ramp up, the effect of managed charging becomes more apparent with higher midday loads.

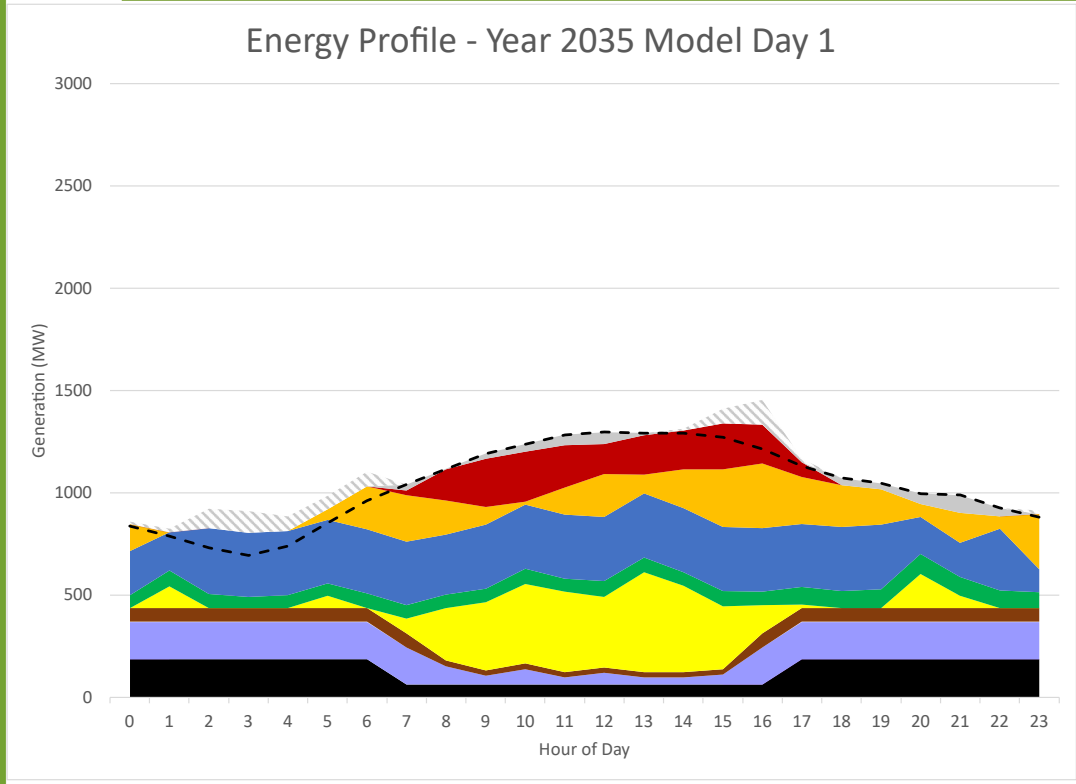
O'ahu – Land Constrained – 2030

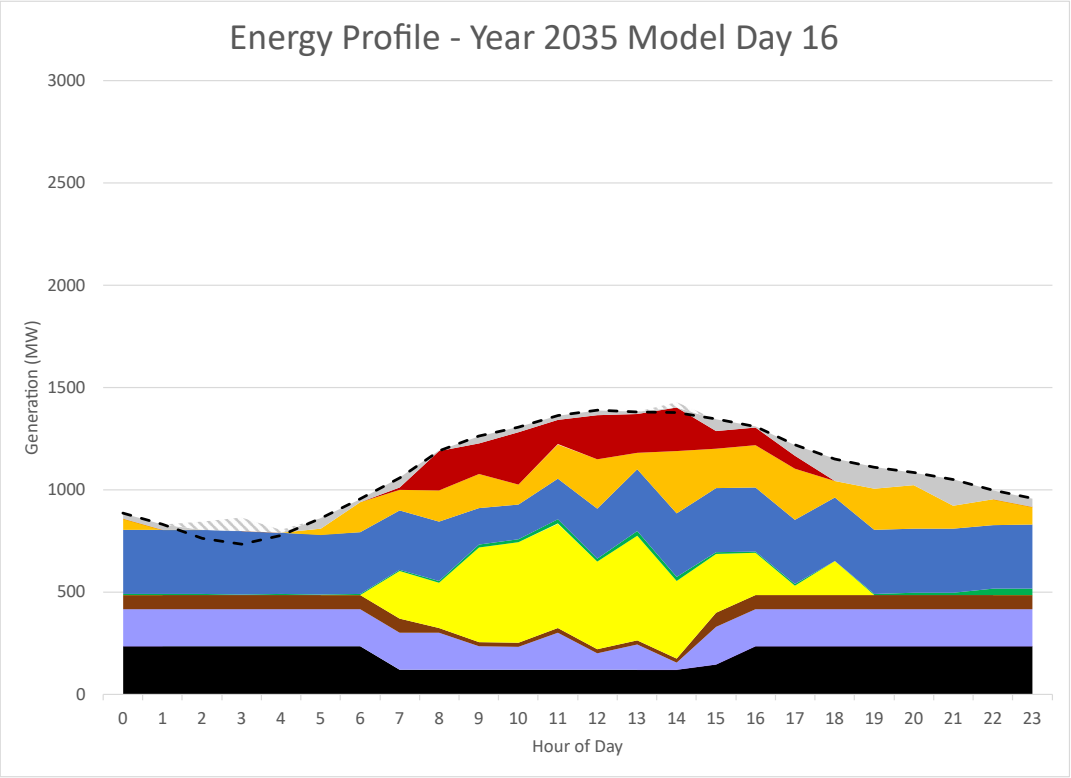




Left: Energy generated on a typical day in 2030 Land Constrained scenario and most typical day in the model
Right: Energy generated on a day with low renewable resource availability assuming 2030 Land Constrained scenario

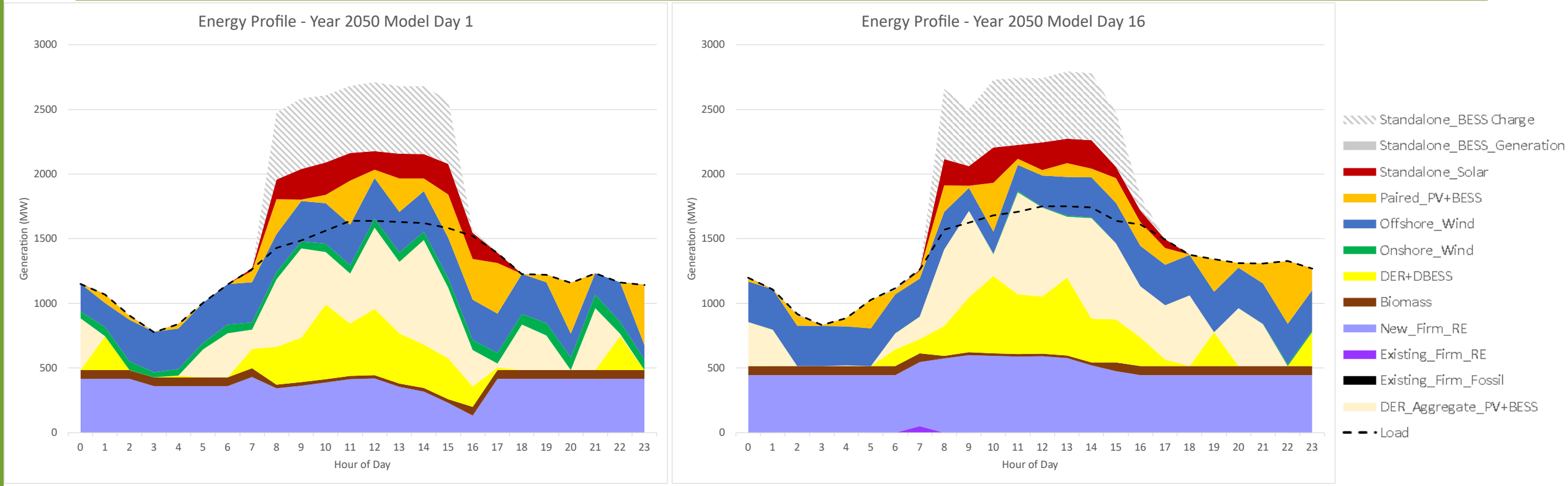
O'ahu – Land Constrained – 2035





Standalone_BESS Charge
Standalone_BESS_Generation
Standalone_Solar
Paired_PV+BESS
Offshore_Wind
Onshore_Wind
DER+DBESS
Biomass
New_Firm_RE
Existing_Firm_RE
Existing_Firm_Fossil
DER_Aggregate_PV+BESS
Load

O'ahu – Land Constrained – 2050



Higher utilization of firm renewables shown here due to the lower resource potential for PV and onshore wind in the Land Constrained case.

Summary of Preliminary Results

Hawai'i Island

Hawai'i Island – ERM Calibration

Year 2029	Base 0% ERM	Base 10% ERM	Base 15% ERM	Base 20% ERM	Base 25% ERM	Base 30% ERM
Existing firm HDC (%)	82.1	82.1	82.1	82.1	82.1	82.1
New firm HDC (%)	97.4	97.4	97.4	97.4	97.4	97.4
ERM Requirement (%)	0	10	15	20	25	30
New Firm (selected by RESOLVE, MW)	0	5	12	21	29	37
Modified Firm* (input into PLEXOS, MW)	0	0	0	0	48	48
Existing Firm (MW)	143	143	143	143	143	143
Standalone PV (MW)	145	145	145	145	145	145
Paired PV (Hybrid Solar, MW)	87	132	135	136	137	137
Hydro (MW)	17	17	17	17	17	17
Onshore Wind (MW)	89	87	86	86	86	86
Standalone Storage (MW / MWH)	7 / 12	9 / 20	9 / 21	9 / 21	9 / 21	9 / 21
Paired Storage (MW / MWH)	87 / 344	132 / 397	135 / 397	136 / 398	137 / 399	137 / 400
LOLE (Days / Year)	---	0.716	0.700	0.672	0.024	---

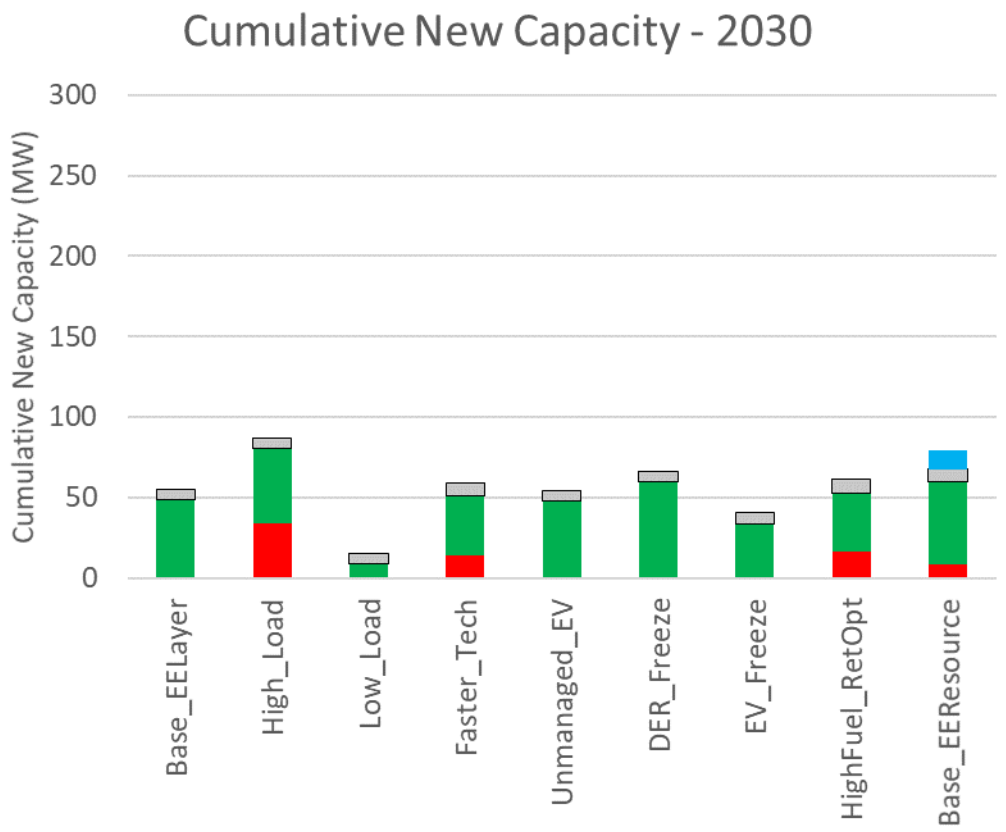
- 25% ERM target shows an LOLE under 0.1 days/year
- *New firm resource capacities selected by RESOLVE were rounded to the nearest resource block size in the PLEXOS probabilistic analysis.

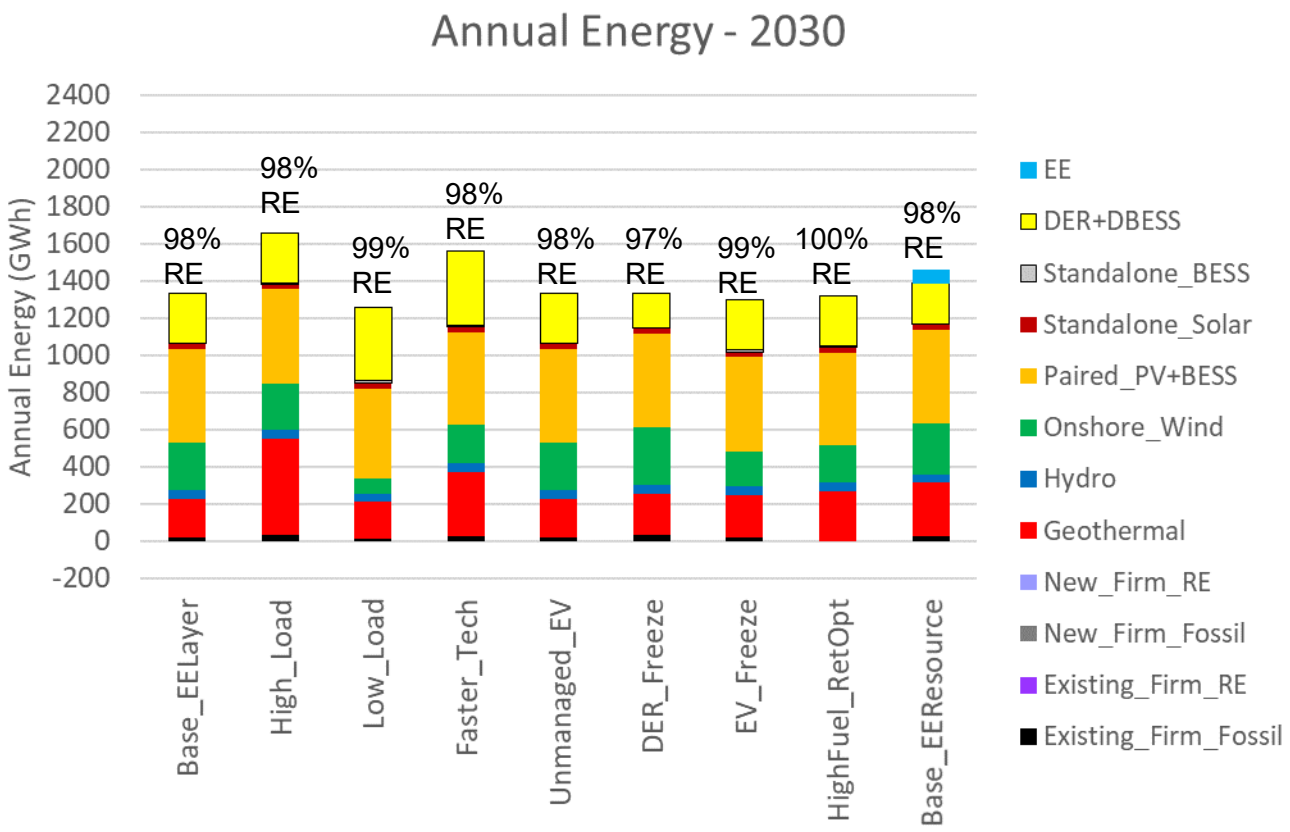
Hawai'i Island – Key Observations

- The Base, High Load, Low Load, and Faster Tech cases build the same resources (onshore wind and standalone BESS) in different amounts.
  - Firm thermal resources, including geothermal, are selected in the Base, Faster Tech, and High Load cases.
  - Paired PV is selected in the Base and High Load cases.
- The difference in buildout and NPV between the managed and unmanaged EV charging is negligible.
  - Only the shape is different, not the annual load.
- The DER Freeze case has a higher NPV due to decreased DER resources and the EV Freeze case has a lower NPV due to decreased load to serve.
  - DER Freeze built more utility scale renewables but same resource types as the Base case.
  - EV Freeze built only onshore wind and in lesser amounts than the Base case.
- Using the high fuel price forecast and allowing RESOLVE to optimize the removal of existing firm generation, RESOLVE decides to remove approximately 54 MW of existing firm generation.
  - Based on previous work done on resource adequacy, the remaining firm generation should produce a LOLE that is less than 0.1 days/year.
- When EE was modeled as a selectable resource, RESOLVE selects less EE supply curves than base EE forecast. The energy efficiency shape as a resource was less peaked focused compared to the base forecast.

Hawai'i Island – 2030

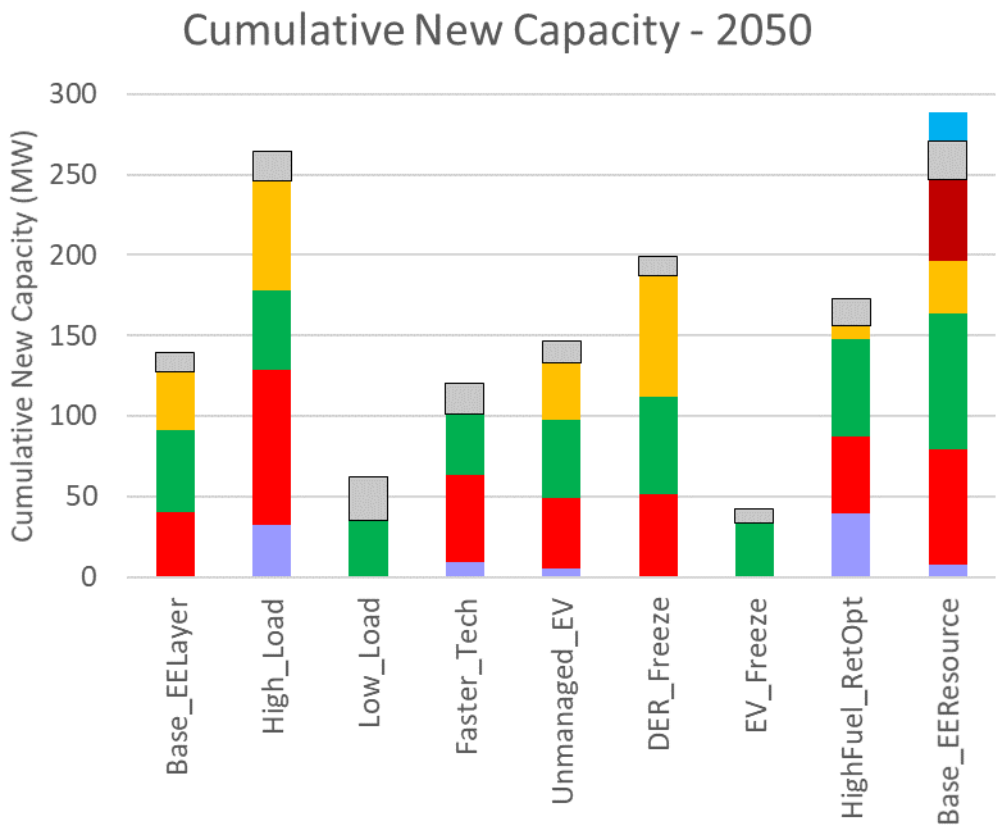
Planned Stage 3 resources
(140 MW Paired PV+BESS) installed in 2030

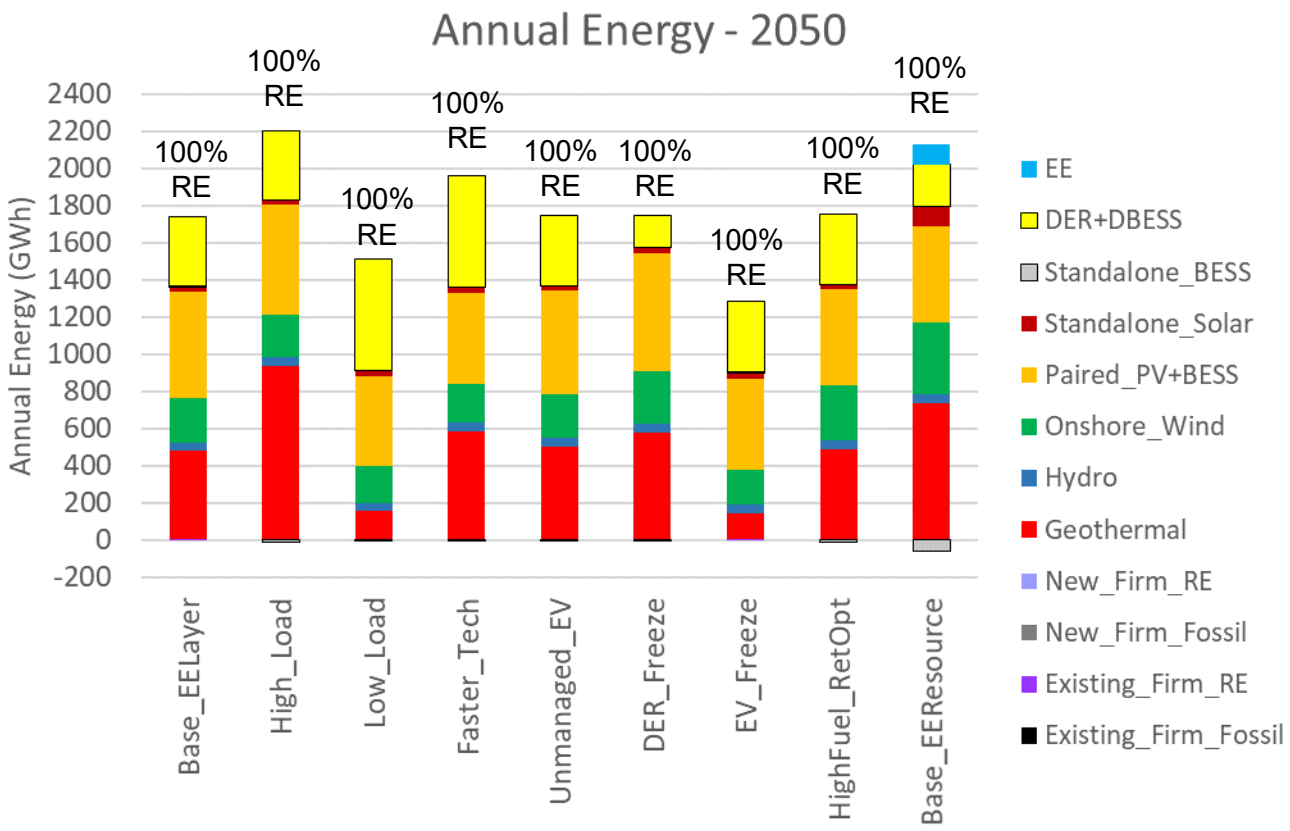




Resource selection is consistent across the cases and achieves nearly 100% renewable energy early in the planning horizon.

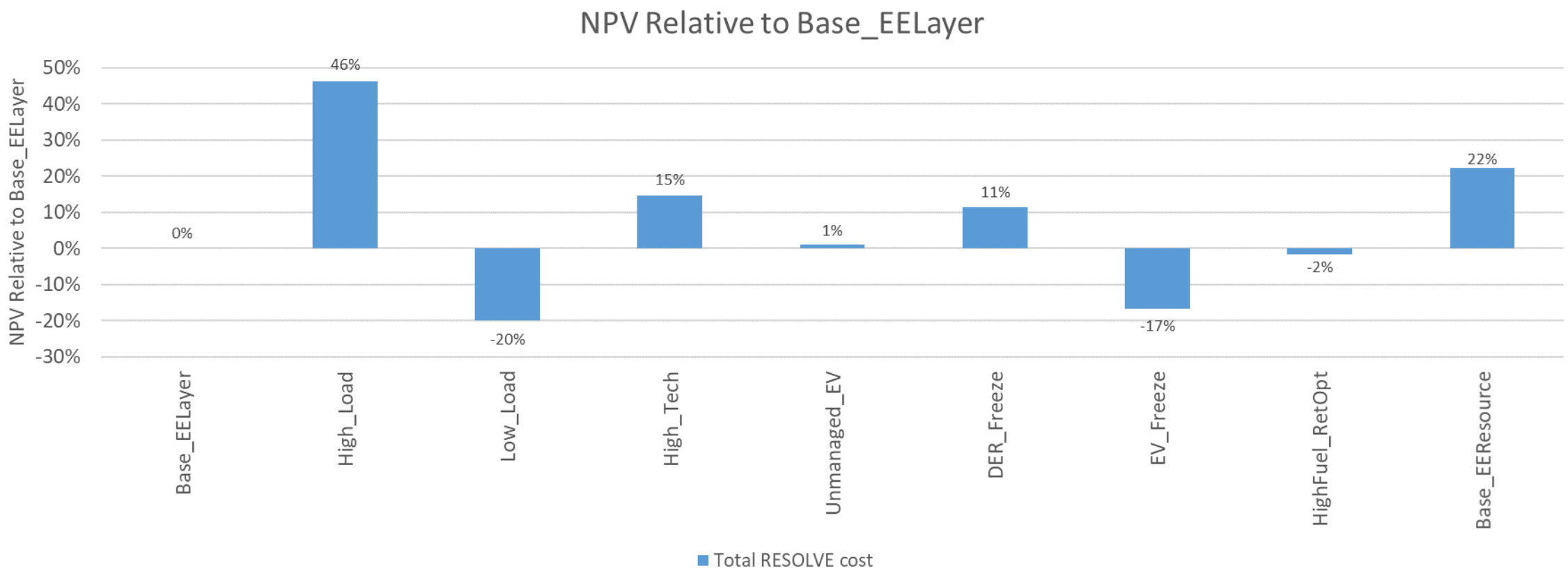
Hawai'i Island – 2050





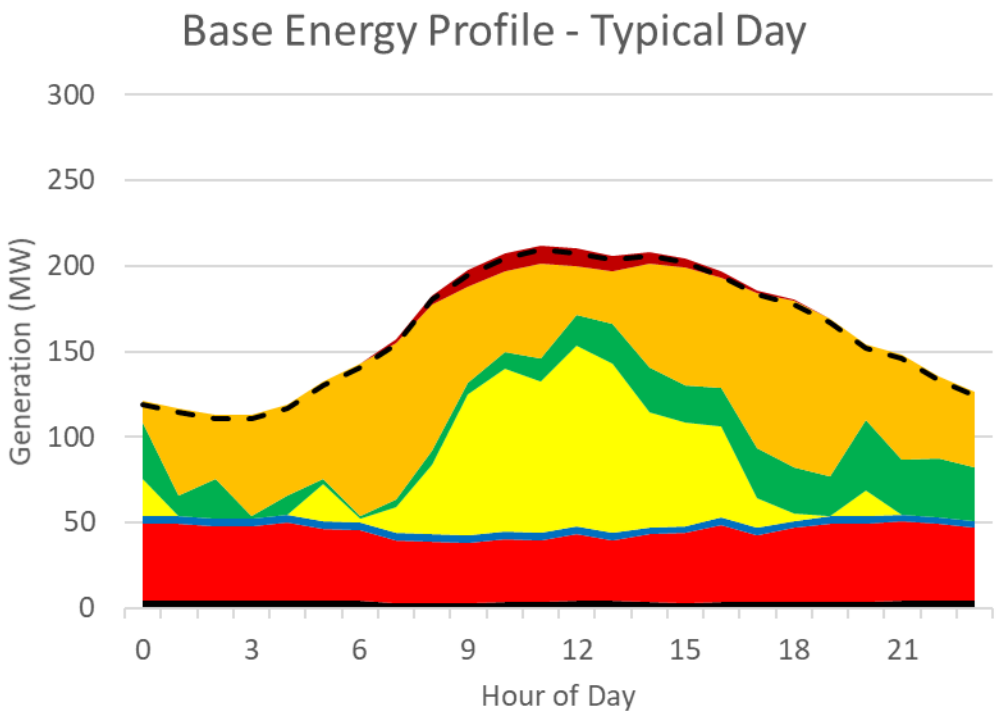
As loads increase through the planning horizon, there is some variation observed in the resource mix; however, 100% renewable energy is still maintained with low utilization of conventional thermal resources on biofuel (light purple).

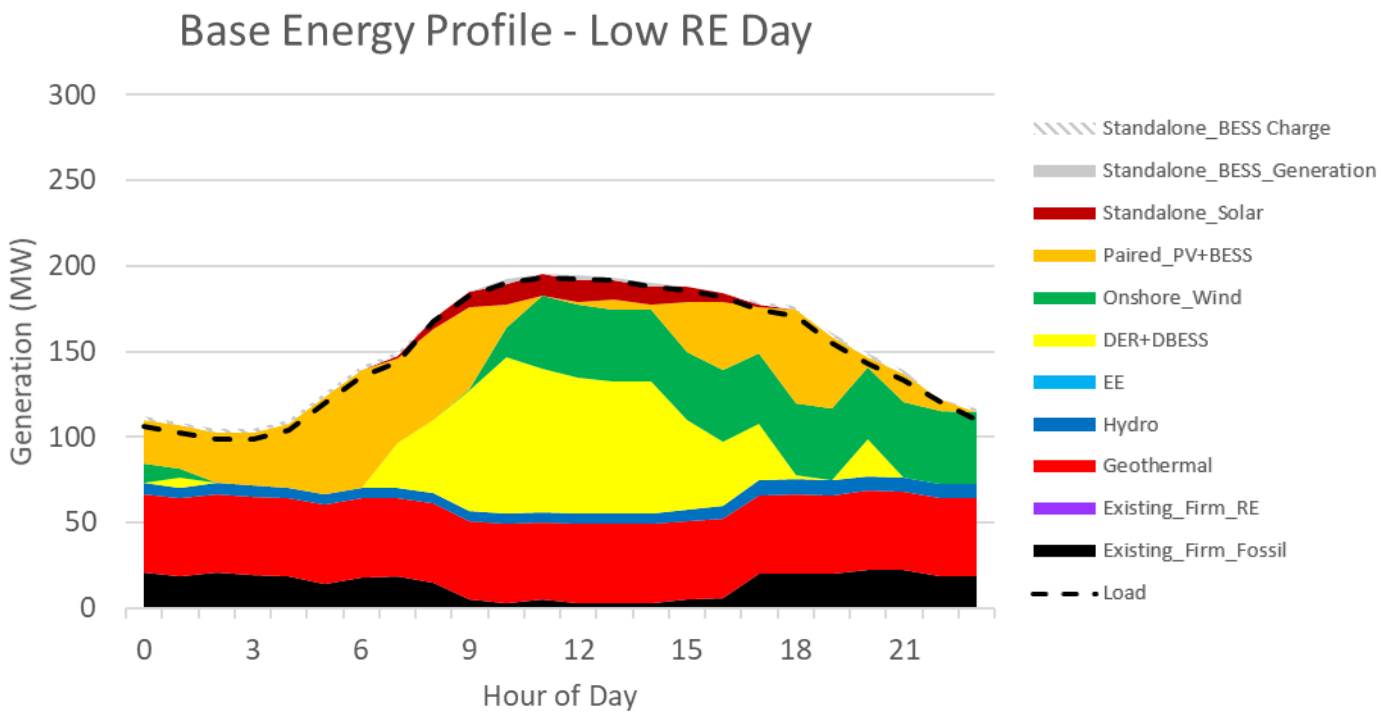
Hawai'i Island – NPV



Net present value (NPV) of each modeling scenario from 2029 to 2050 relative to the base scenario.

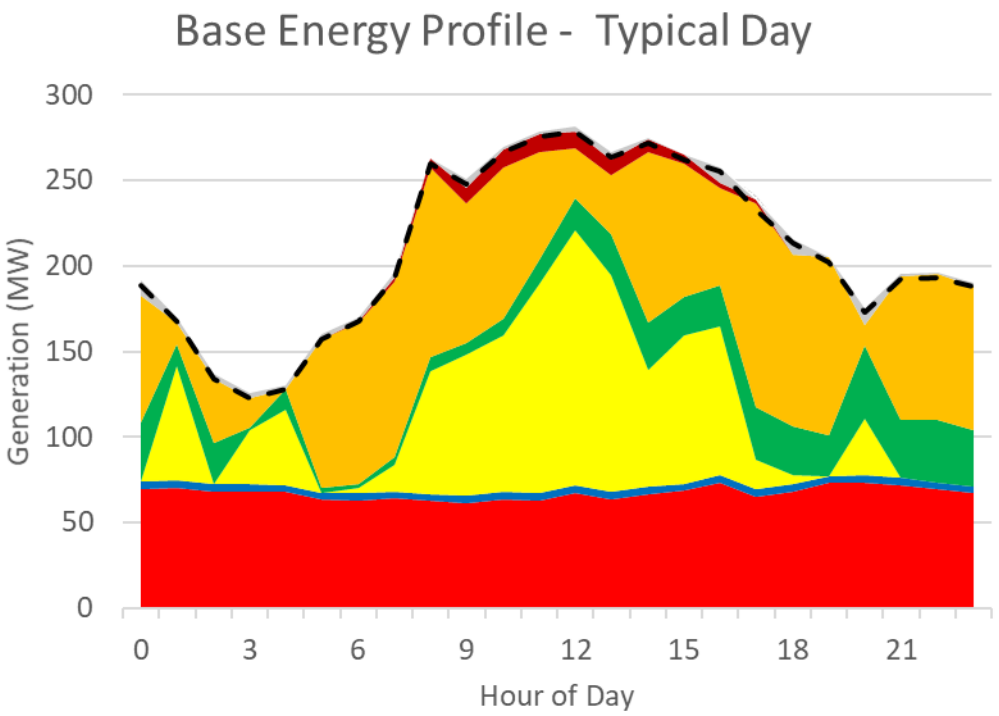
Hawai'i Island – Base – 2030

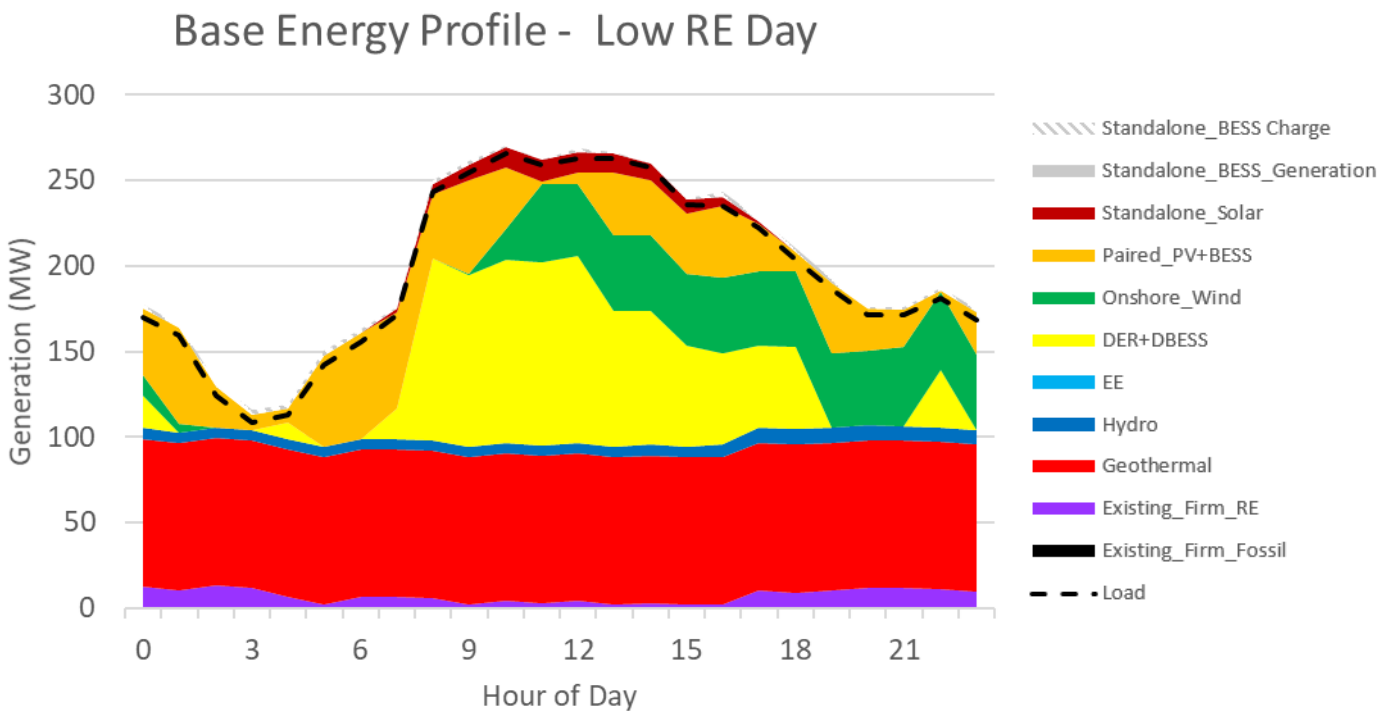




Left: Energy generated on a typical day assuming 2030 base case and most typical day in the model
Right: Energy generated on a day with low renewable resource availability assuming 2030 base case

Hawai'i Island – Base – 2050





As EV loads continue to ramp up, the effect of managed charging becomes more apparent with higher midday loads.

Summary of Preliminary Results

Maui

Maui – ERM Calibration July 2022 GNA

RESOLVE Resource Selection				
Year 2030	10% ERM, Thermal HDC	15% ERM, Thermal HDC	20% ERM, Thermal HDC	30% ERM, Thermal HDC
Existing firm HDC (%)	89.72%	89.72%	89.72%	89.72%
New firm HDC (%)	97.4%	97.4%	97.4%	97.4%
ERM Requirement (%)	10%	15%	20%	30%
New Firm (selected by RESOLVE, MW)	0	4	12	26
Existing Firm (MW)	126	126	126	126
Paired PV (MW)	14	17	18	25
Onshore Wind (MW)	64	62	62	60
Paired Storage (MW / MWh)	14 / 14	17 / 17	18 / 18	25 / 25

PLEXOS Probabilistic RA			
Year 2030	Base, No ICE	Base w/ 9 MW ICE	Base w/ 18 MW ICE
Existing firm HDC (%)	N/A	N/A	N/A
New firm HDC (%)	N/A	N/A	N/A
ERM Requirement (%)	N/A	N/A	N/A
New Firm (selected by RESOLVE, MW)	0	9	18
Existing Firm (MW)	126	126	126
Paired PV (MW)	22	22	22
Onshore Wind (MW)	60	60	60
Paired Storage (MW / MWh)	22 / 22	22 / 22	22 / 22
LOLE (Days / Year)	0.14	0.04	0.0

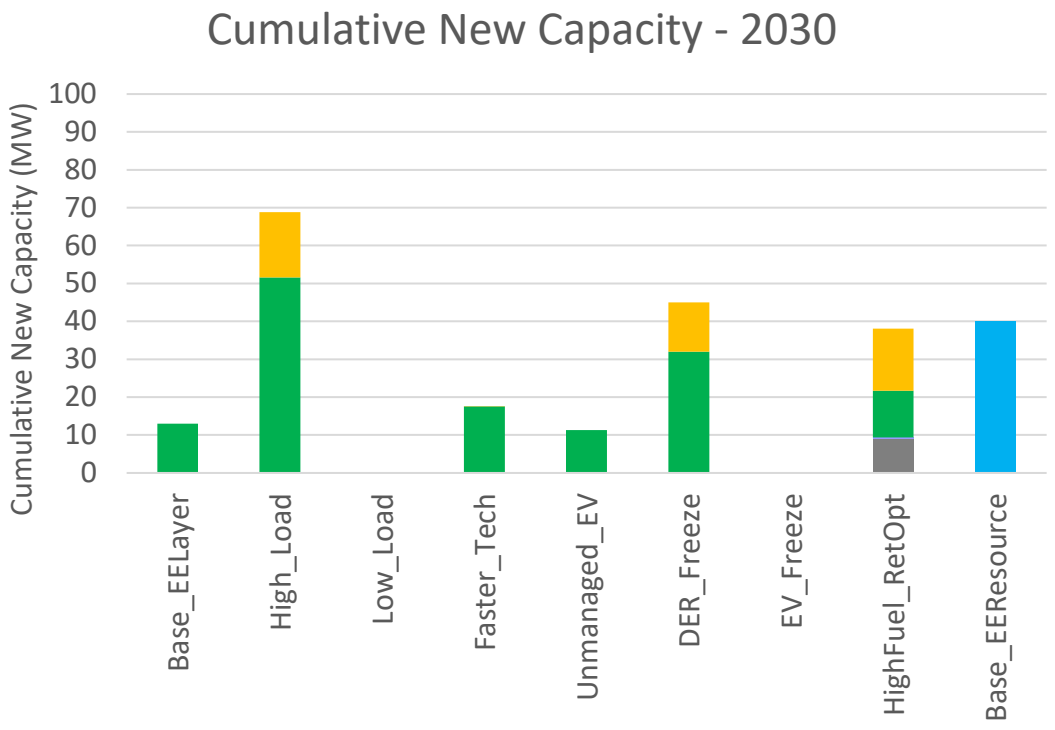
- The probabilistic analyses in the Maui GNA showed that 9 MW of new firm generation can achieve an LOLE < 0.1 days/year.
- The 15% ERM target RESOLVE case had a similar amount of new resources between the probabilistic RA cases, Base w/ No ICE and Base w/ 9 MW ICE.

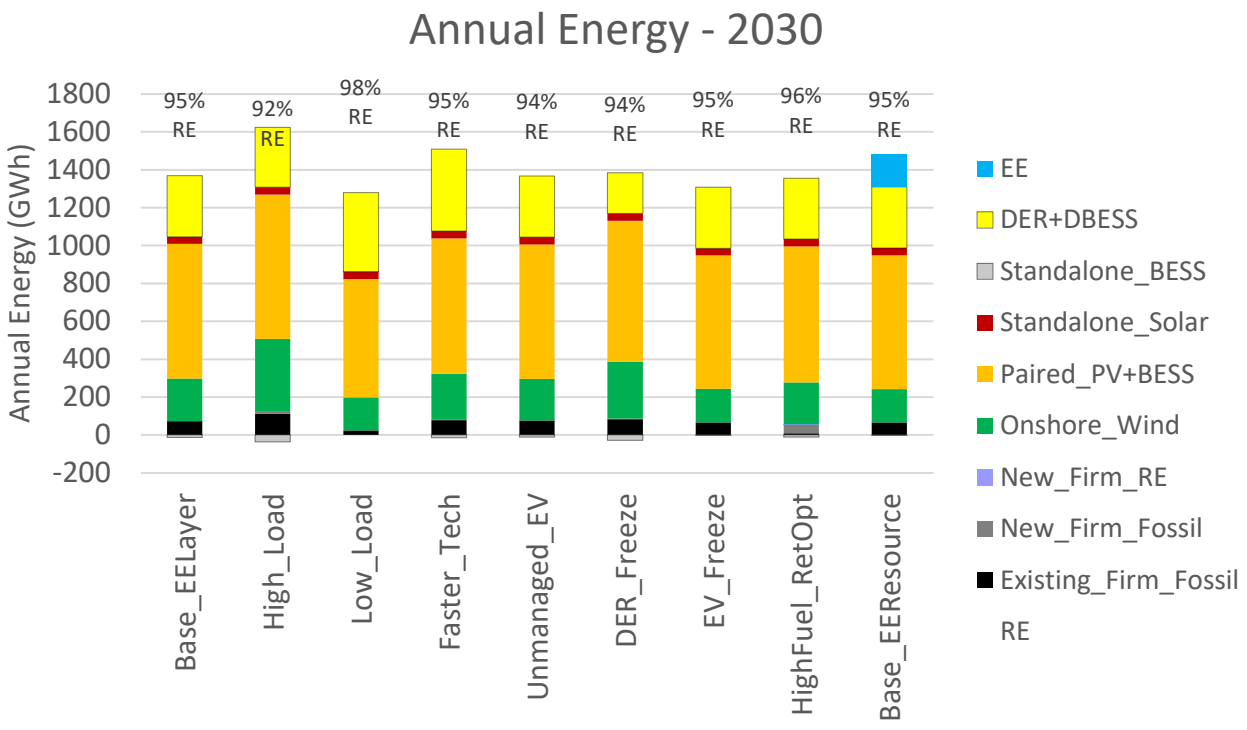
Maui – Key Observations

- The Base, High Load, and Faster Tech cases select the same resources in different amounts (wind followed by paired PV). In the later years of the High Load case, firm resources are selected.
- In the low load case, the resources selected by RESOLVE starts with adding wind followed by standalone solar.
- The Unmanaged EV has a negligible difference in NPV compared to the Base case and builds more wind.
- The DER Freeze case has a higher NPV due to decreased DER resources and the EV Freeze has a lower NPV due to decreased load to serve.
  - DER Freeze built more utility scale paired PV.
  - EV Freeze built less utility scale paired PV and more standalone PV.
- Using the high fuel price forecast and allowing RESOLVE to optimize the removal of existing firm generation, RESOLVE decides to remove approximately 54 MW of firm capacity.
  - Based on the ERM calibration this should yield a LOLE of around 0.14 days/year.
- When energy efficiency was modeled as a selectable resource, RESOLVE selected more EE supply curves than the base EE forecast. The energy efficiency shape as a resource was similar to the base forecast.

Maui – 2030

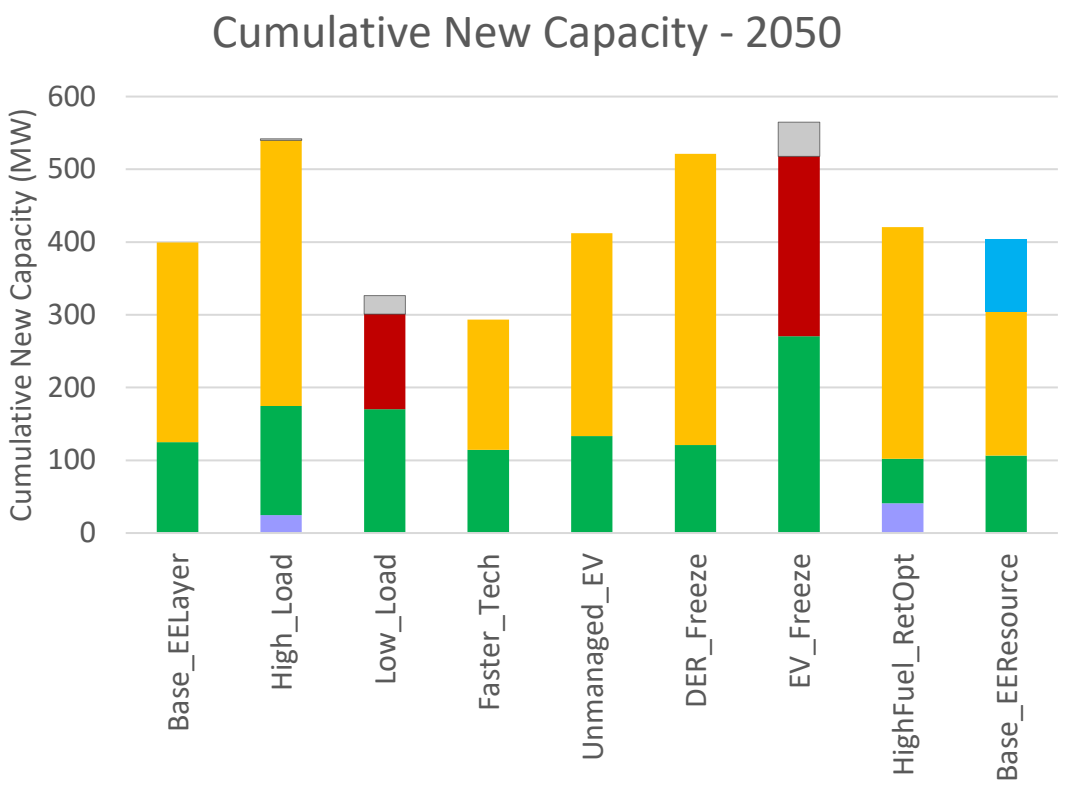
Planned Stage 3 resources
171 MW Paired PV+BESS
36 MW Firm installed in 2027

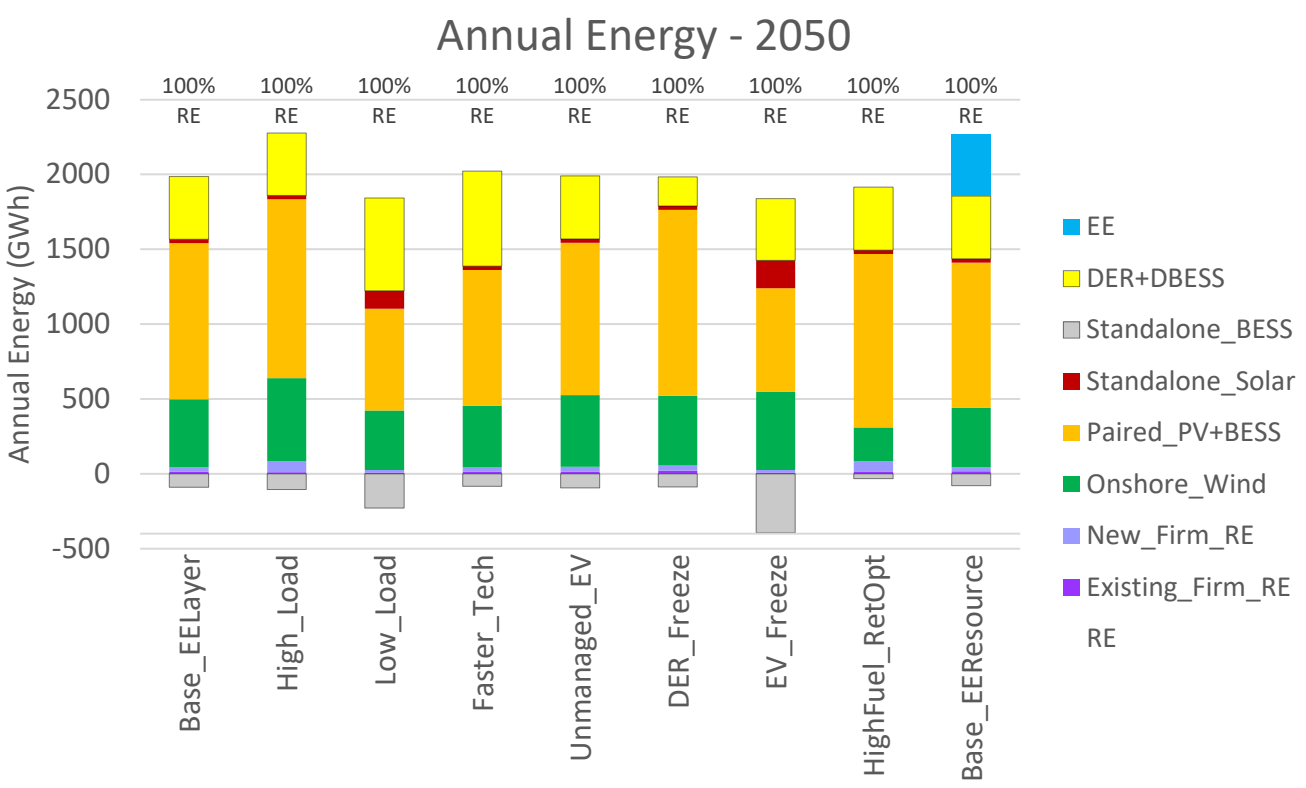




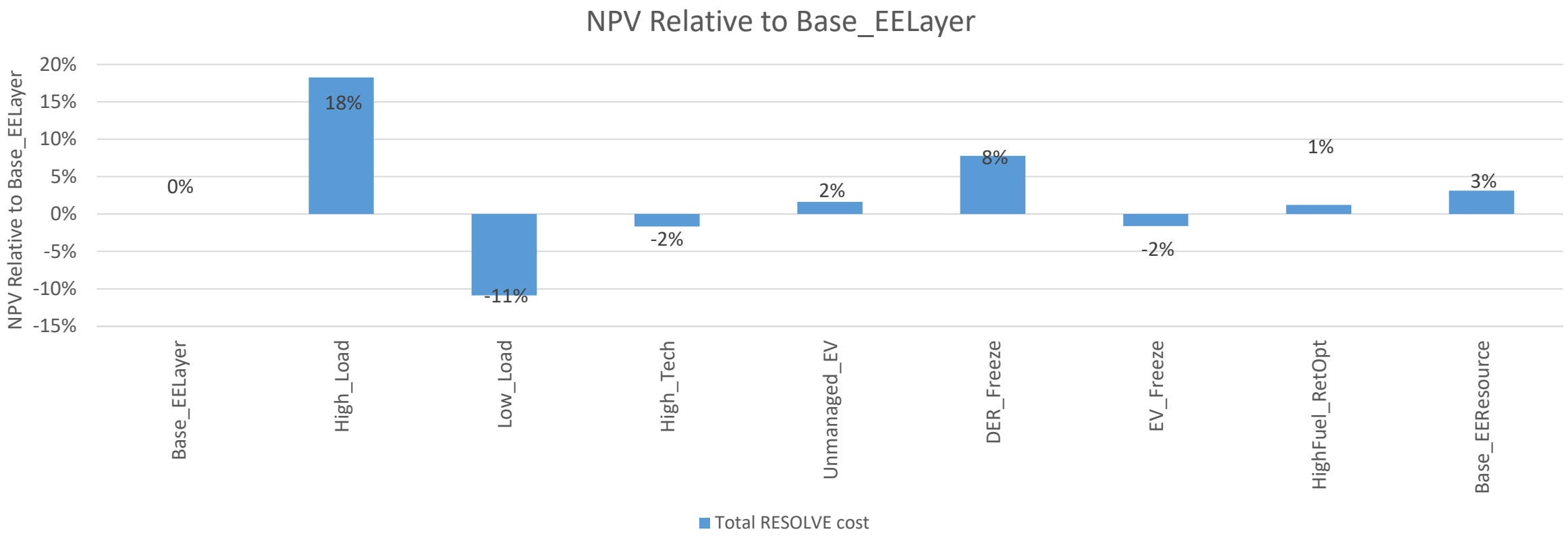
Onshore wind is selected across the base and higher load cases. Only in cases where the loads are lower (Low Load, EV Freeze) was no wind selected.

Maui – 2050


Cumulative New Capacity - 2050
Cumulative New Capacity (MW)
600
500
400
300
200
100
0
Base_EELayer
High_Load
Low_Load
Faster_Tech
Unmanaged_EV
DER_Freeze
EV_Freeze
HighFuel_RetOpt
Base_EEResource

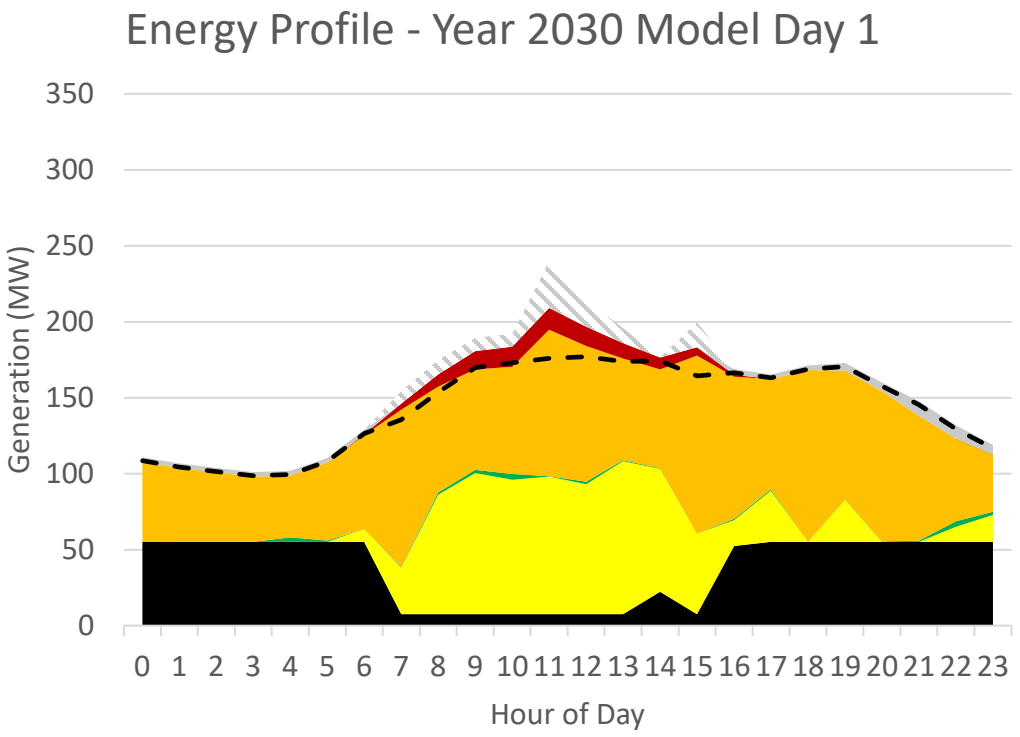

Annual Energy - 2050
Annual Energy (GWh)
2500
2000
1500
1000
500
0
-500
100% RE
Base_EELayer
High_Load
Low_Load
Faster_Tech
Unmanaged_EV
DER_Freeze
EV_Freeze
HighFuel_RetOpt
Base_EEResource
EE
DER+DBESS
Standalone_BESS
Standalone_Solar
Paired_PV+BESS
Onshore_Wind
New_Firm_RE
Existing_Firm_RE
RE

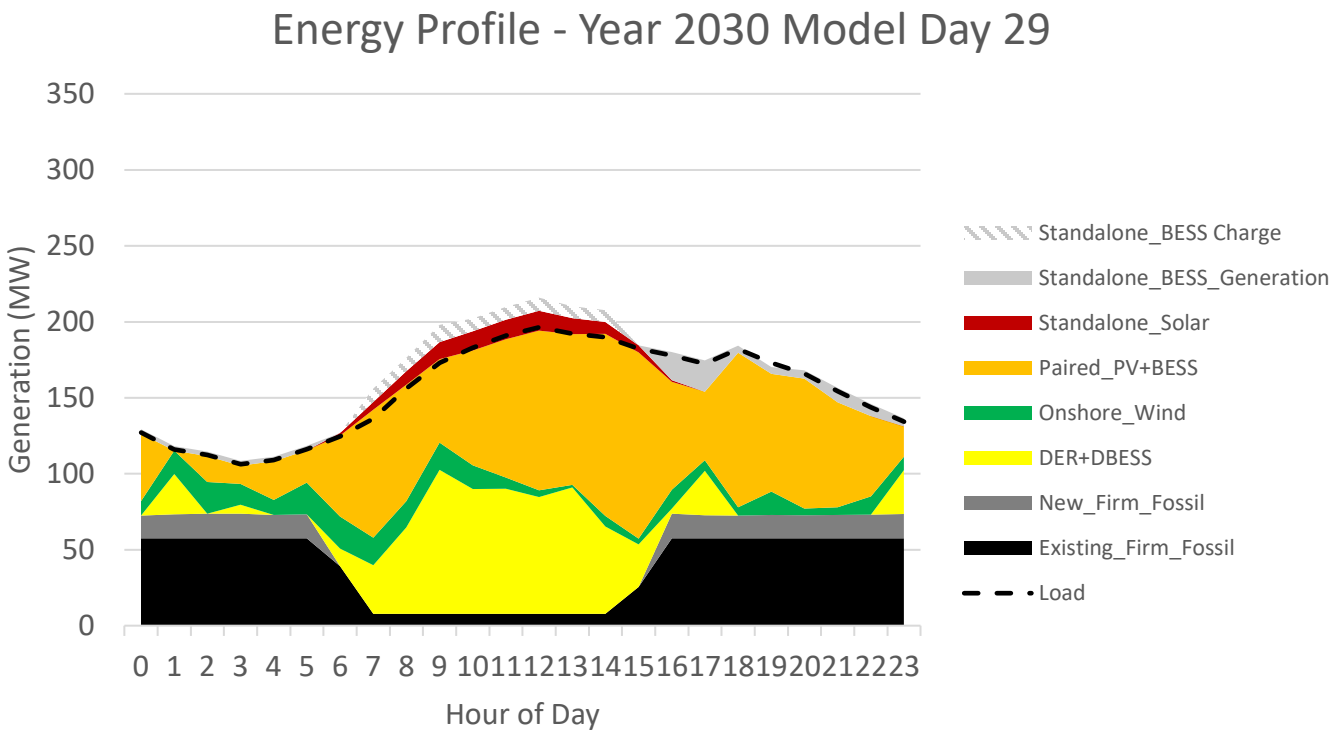
Maui – NPV



Net present value (NPV) of each modeling scenario from 2029 to 2050 relative to the base scenario.

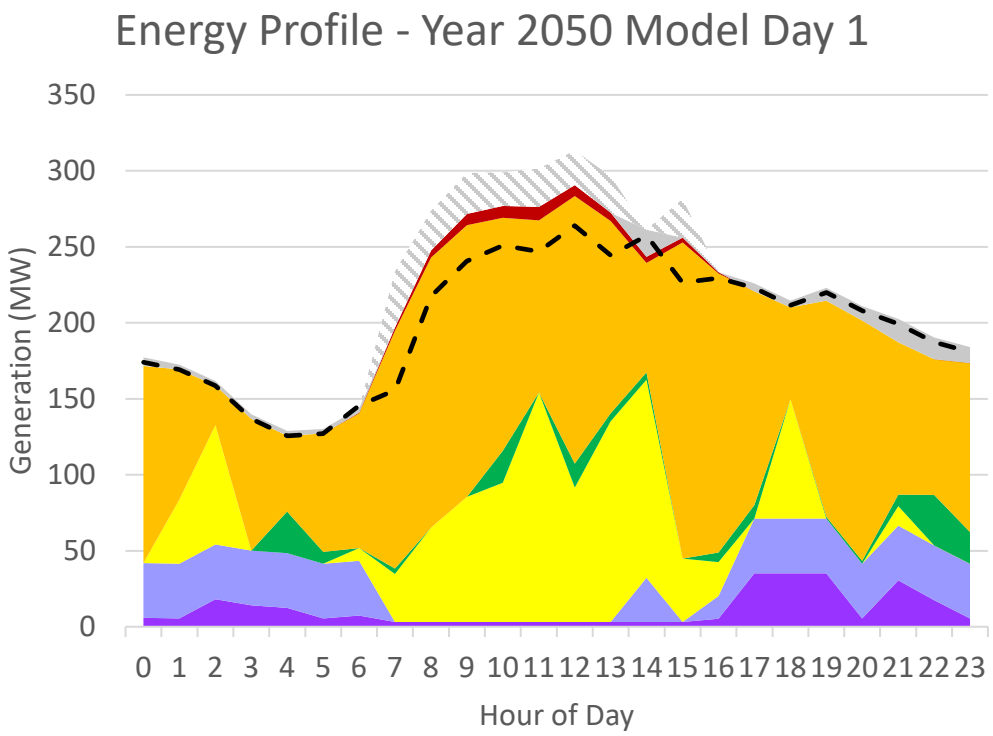
Maui – Base – 2030

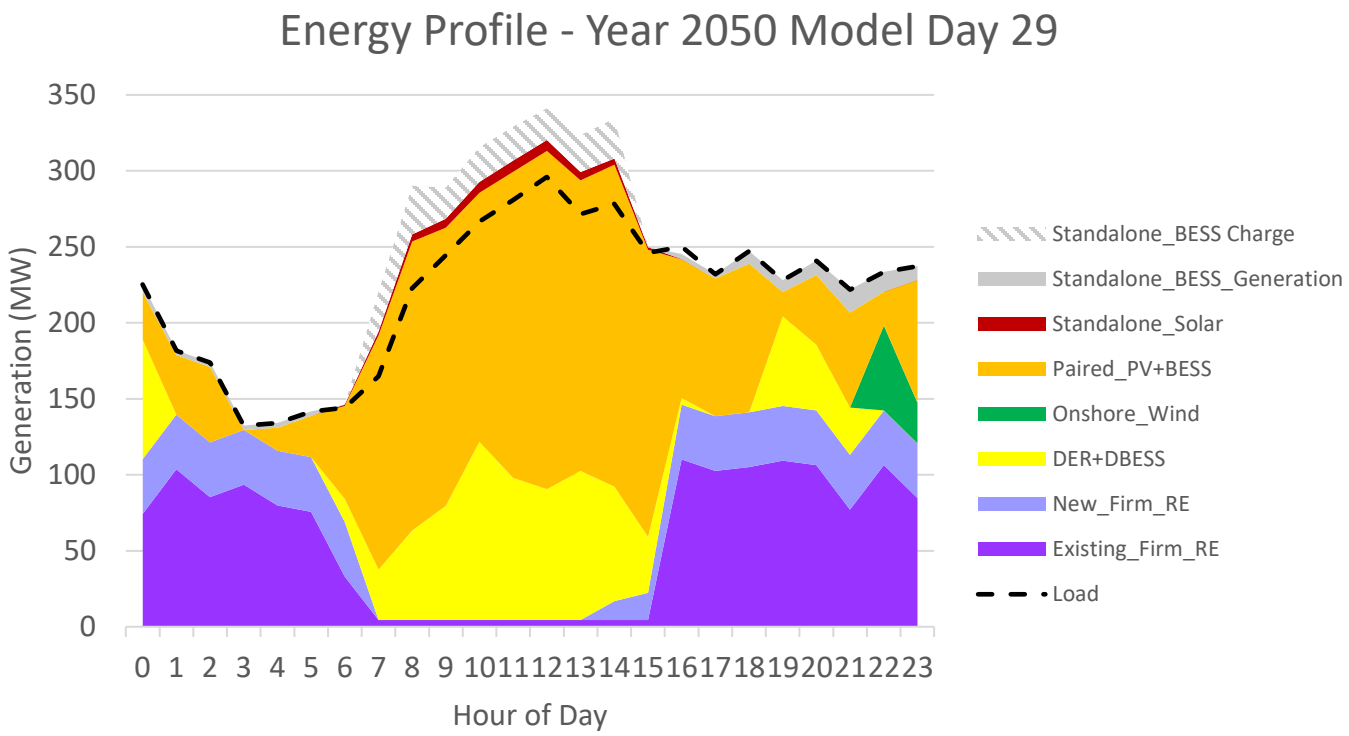




Left: Energy generated on a typical day assuming 2030 base case and most typical day in the model
Right: Energy generated on a day with low renewable resource availability assuming 2030 base case

Maui – Base – 2050





As EV loads continue to ramp up, the effect of managed charging becomes more apparent with higher midday loads.

Summary of Preliminary Results

Lānaʻi

Lānaʻi – ERM Calibration

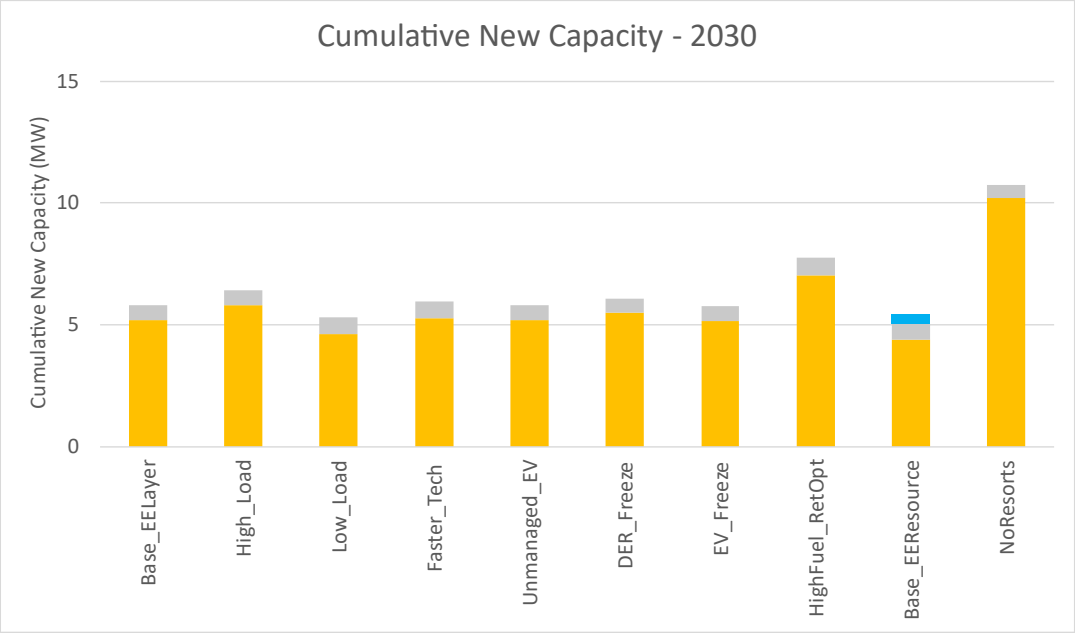
Year 2030	Base 0% ERM	Base 30% ERM	Base 45% ERM	Base 60% ERM
Existing firm HDC (%)	89.72	89.72	89.72	89.72
New firm HDC (%)	96.1	96.1	96.1	96.1
ERM Requirement (%)	0	30	45	60
New Firm* (input into PLEXOS)	2-0.97MW unit	4-0.97MW unit	5-0.97MW unit	5-0.97MW unit
Existing Firm (MW)	0	0	0	0
Standalone PV (MW)	0	0	0	0
Paired PV (Hybrid Solar, MW)	22.6	22.0	22.0	21.9
Onshore Wind (MW)	0	0	0	0
Standalone Storage (MW / MWH)	0.7 / 1.2	0.7 / 1.2	0.7 / 1.2	0.7 / 1.2
Paired Storage (MW / MWH)	22.6 / 70.0	22.0 / 69.4	22.0 / 69.4	21.9 / 69.3
LOLE (Days / Year)	12.69	0.32	0.04	0.04

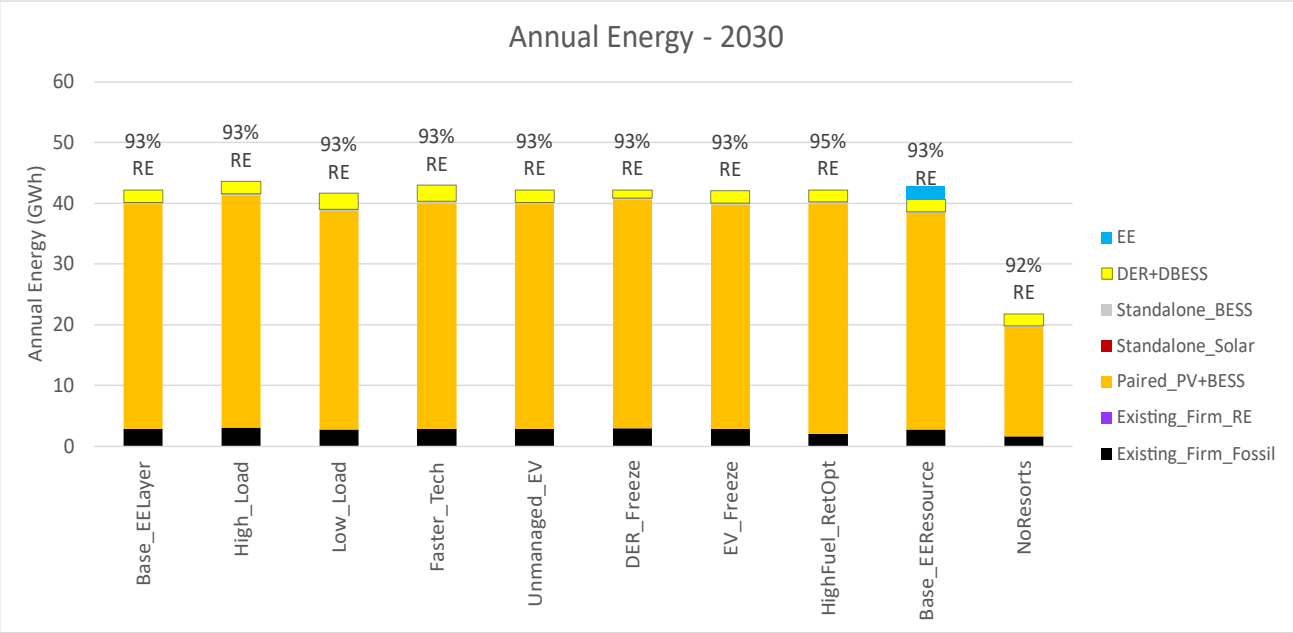
- 45% ERM target has an LOLE < 0.1 days/year.
- * New firm resource capacities selected by RESOLVE were rounded to the nearest resource block size in the PLEXOS probabilistic analysis.

Lānaʻi – Key Observations

- In the base, high load, low load, and faster tech cases, the types of resources selected by RESOLVE remain the same (Paired PV and Standalone BESS); only the amount changes.
- The difference in buildout and NPV between the managed and unmanaged EV charging is negligible.
  - Only the shape is different, not the annual load.
- The DER Freeze case has a higher NPV due to decreased DER resources and the EV Freeze has a lower NPV due to decreased load to serve.
  - DER Freeze built more paired PV.
  - EV Freeze case built less paired PV.
- Using the high fuel price forecast and allowing RESOLVE to optimize the removal of existing firm generation, RESOLVE decides to remove approximately 5.5 MW of existing firm generation.
  - Based on previous work done on resource adequacy, the remaining firm generation should produce a LOLE that is less than 0.1 days/year.
- When energy efficiency was modeled as a selectable resource, RESOLVE selected more EE supply curves than the EE forecast. The energy efficiency shape as a resource was similar to the base forecast.
- There is an additional sensitivity for Lana'i that examines a scenario with the resorts going off-grid. The scenario removes the paired PV placeholder for the CBRE RFP renewable energy target of 35.8 GWh and allows RESOLVE to re-optimize the resource selection.

Lānaʻi – 2030

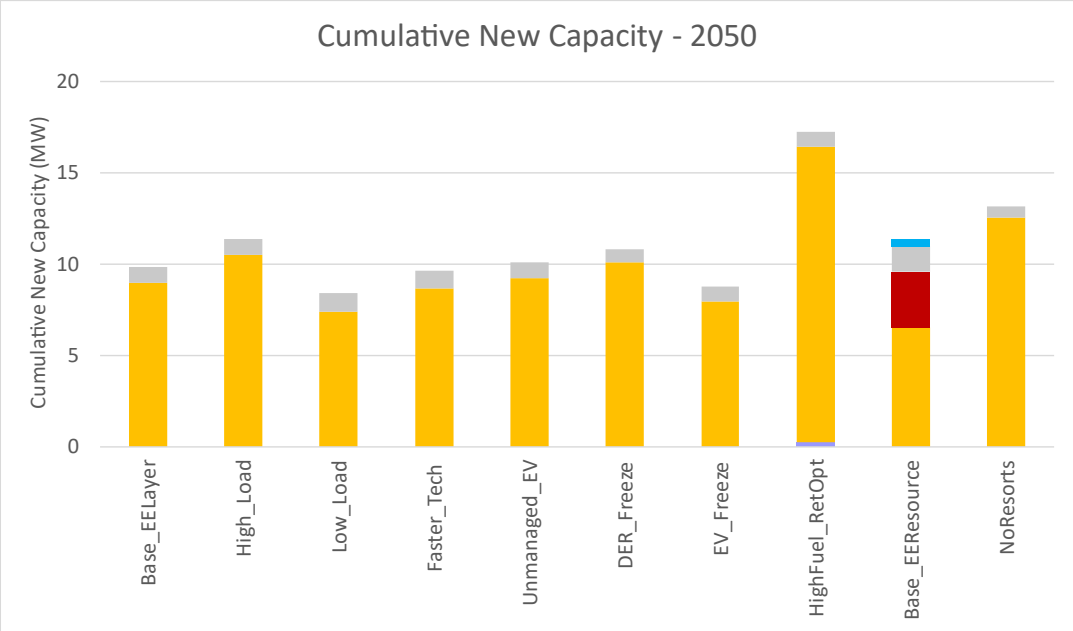


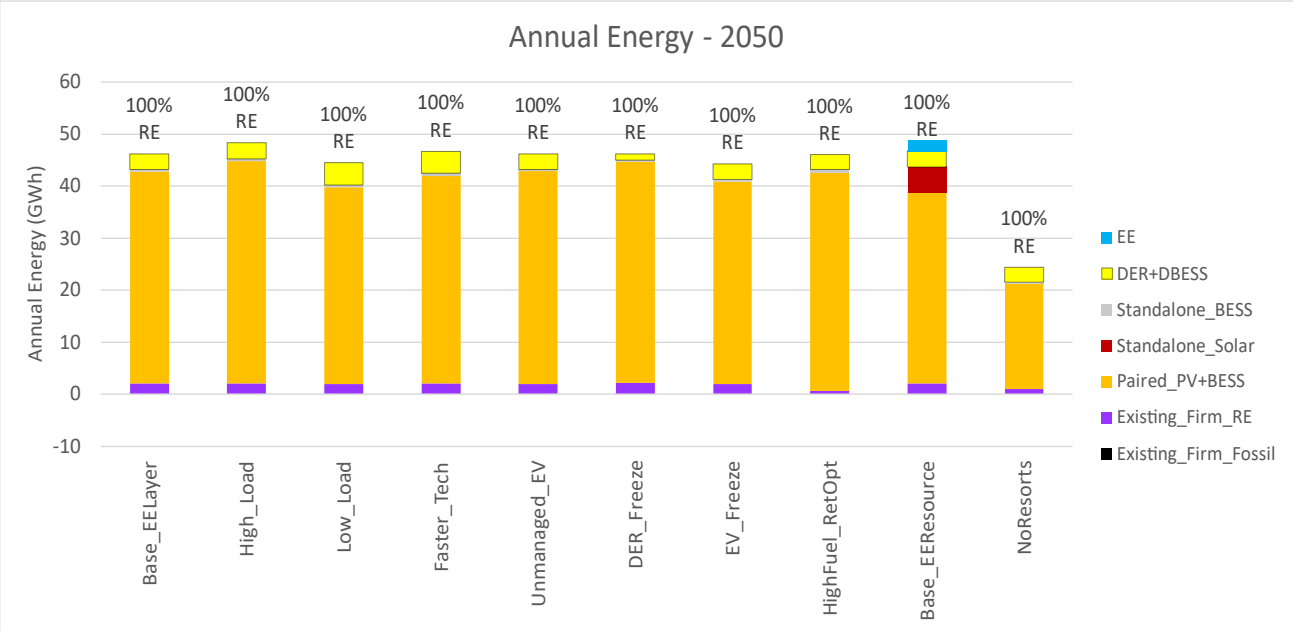


No Resorts case assumes the resorts go off-grid and the CBRE RFP placeholder is removed. This allows the additional resources to be selected although the annual load is roughly half of the Base case.

In all cases, the paired PV is consistently selected.

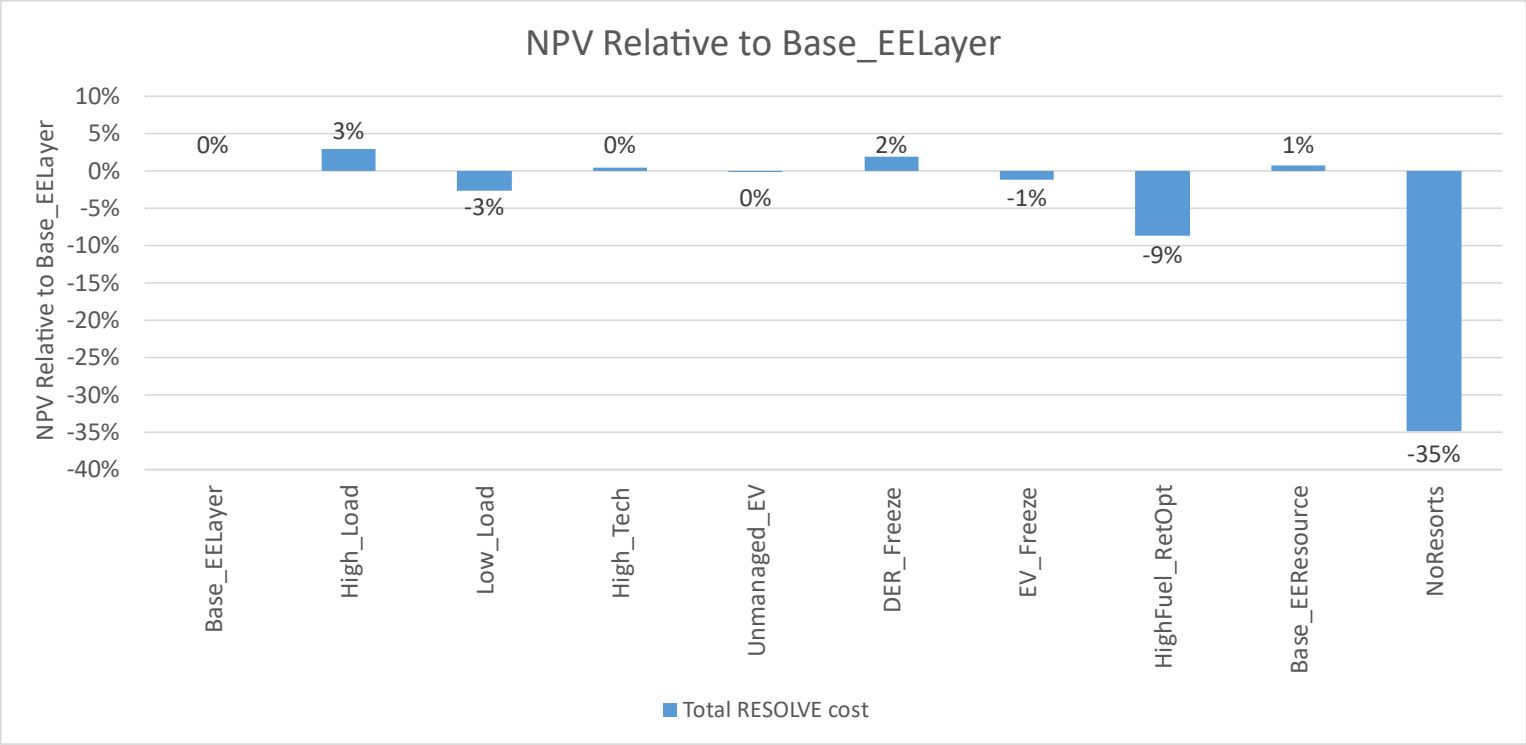
Lānaʻi – 2050





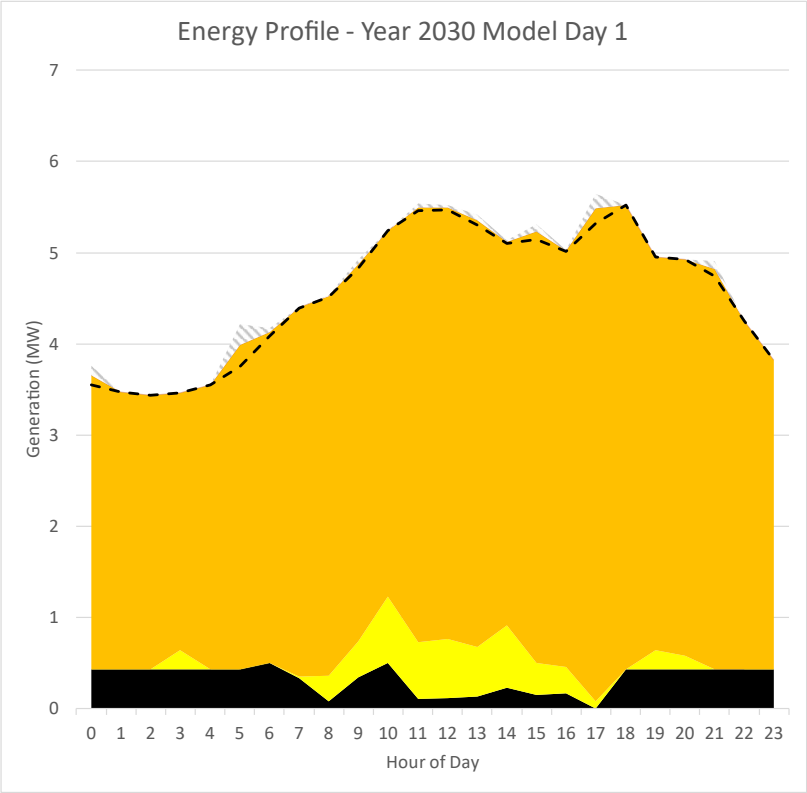
Resource selection is still consistent across the cases with paired PV being predominantly selected. In the EE supply curve case, standalone PV is also selected.

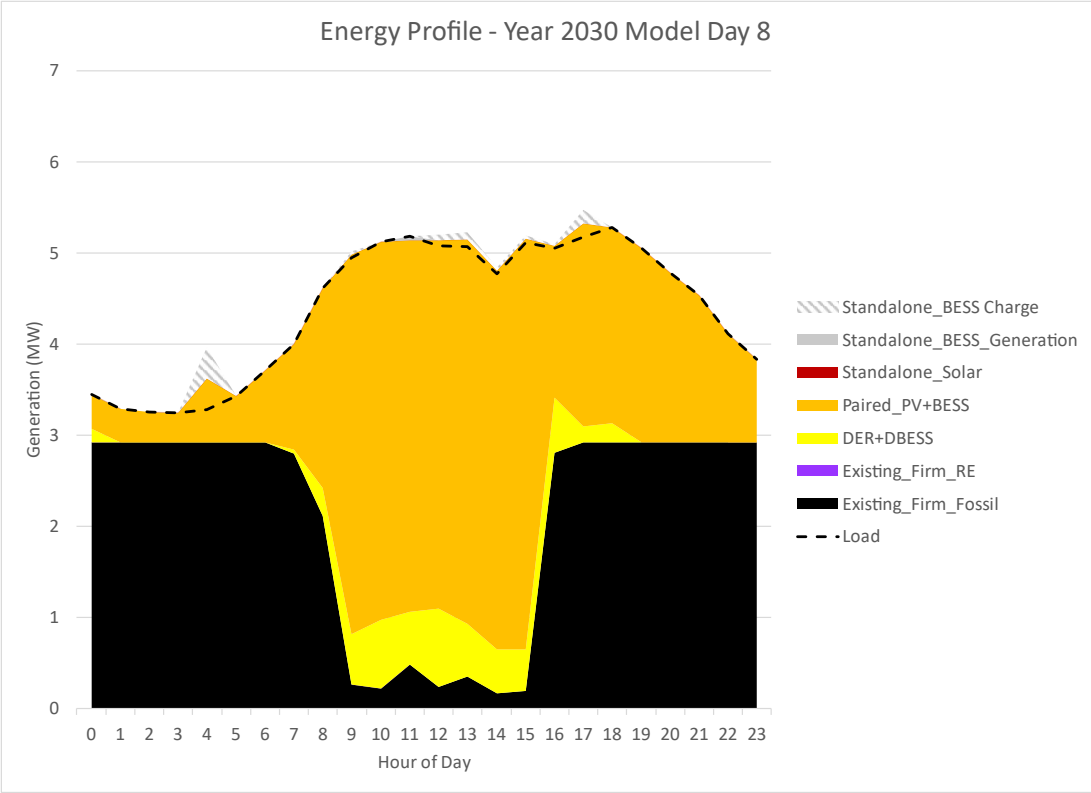
Lānaʻi – NPV



Net present value (NPV) of each modeling scenario from 2029 to 2050 relative to the base scenario.

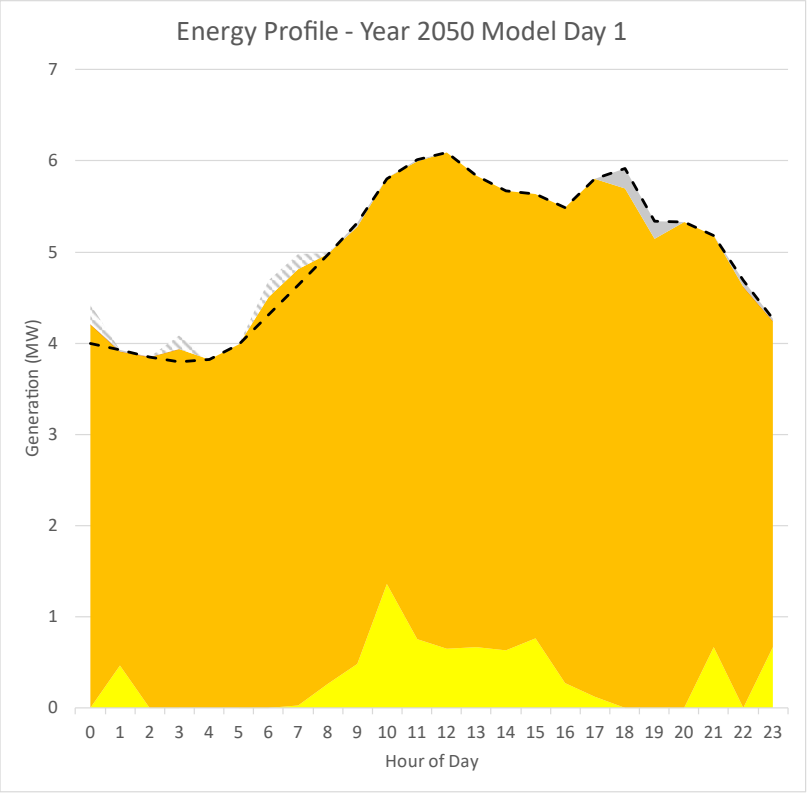
Lānaʻi – Base – 2030

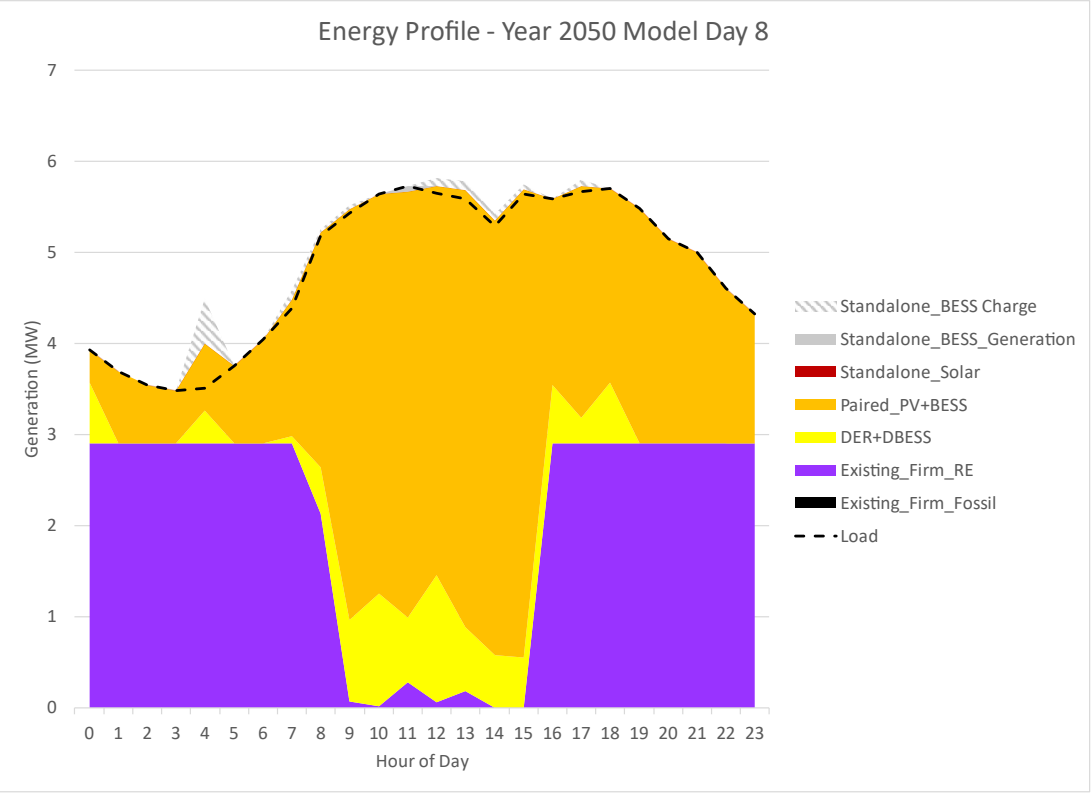




Left: Energy generated on a typical day assuming 2030 base case
Right: Energy generated on a day with low renewable resource availability assuming 2030 base case

Lānaʻi – Base – 2050





The effect of managed charging is more subtle due to the lower uptake of electric vehicles compared to other islands.

Summary of Preliminary Results

Moloka'i

Moloka'i – ERM Calibration

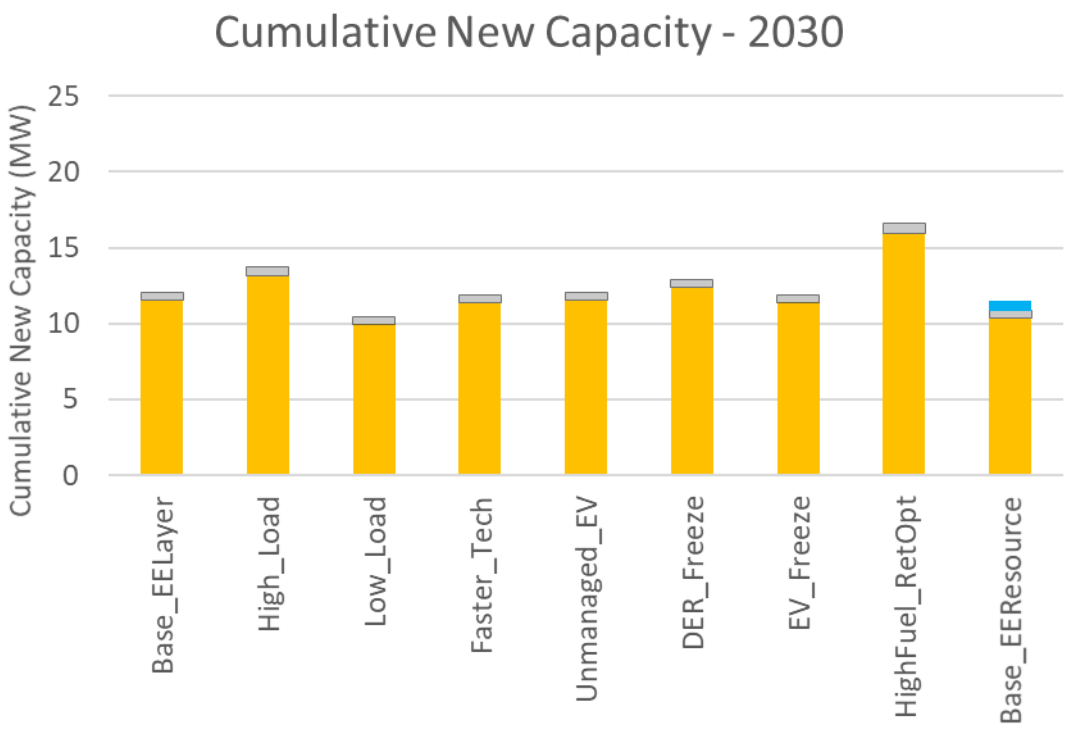
Year 2030	Base 0% ERM	Base 30% ERM	Base 45% ERM	Base 60% ERM
Existing firm HDC (%)	89.72	89.72	89.72	89.72
New firm HDC (%)	96.1	96.1	96.1	96.1
ERM Requirement (%)	0	30	45	60
New Firm* (input into PLEXOS)	3-0.97MW unit	3-0.97MW unit	4-0.97MW unit	5-0.97MW unit
Existing Firm (MW)	0	0	0	0
Standalone PV (MW)	0	0	0	0
Paired PV (Hybrid Solar, MW)	13.4	14.4	13.9	13.5
Onshore Wind (MW)	0	0	0	0
Standalone Storage (MW / MWH)	0.6 / 1.5	0.5 / 1.0	0.5 / 1.0	0.5 / 1.0
Paired Storage (MW / MWH)	13.4 / 33.4	14.4 / 37.0	13.9 / 35.6	13.5 / 34.9
LOLE (Days / Year)	0.436	0.392	0.008	0.000

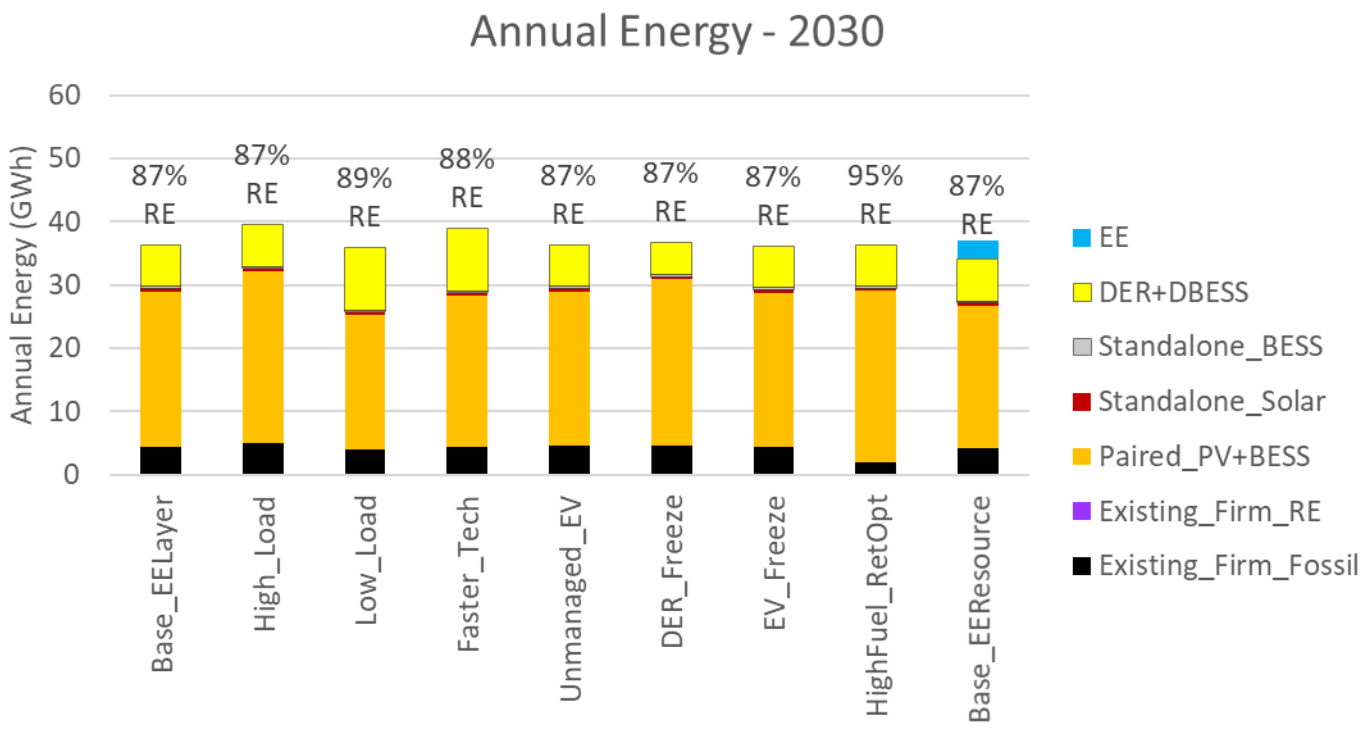
- 45% ERM target has an LOLE < 0.1 days/year.
- * New firm resource capacities selected by RESOLVE were rounded to the nearest resource block size in the PLEXOS probabilistic analysis.

Moloka'i – Key Observations

- In the base, high load, low load, and faster tech cases, the types of resources selected by RESOLVE remain the same (Paired PV and Standalone BESS); only the amount changes.
- The difference in buildout and NPV between the managed and unmanaged EV charging is negligible.
  - Only the shape is different, not the annual load.
- The DER Freeze case has a higher NPV due to decreased DER resources and the EV Freeze has a lower NPV due to decreased load to serve.
  - DER Freeze built more paired PV.
  - EV Freeze case built less paired PV.
- Using the high fuel price forecast and allowing RESOLVE to optimize the removal of existing firm generation, RESOLVE decides to remove approximately 10.4MW of existing firm generation.
  - Based on previous work done on resource adequacy, the remaining firm generation should produce a LOLE that is less than 0.1 days/year.
- When energy efficiency was modeled as a selectable resource, RESOLVE selected more EE supply curves than the base forecast. The energy efficiency shape as a resource was flatter in the midday compared to the base forecast.

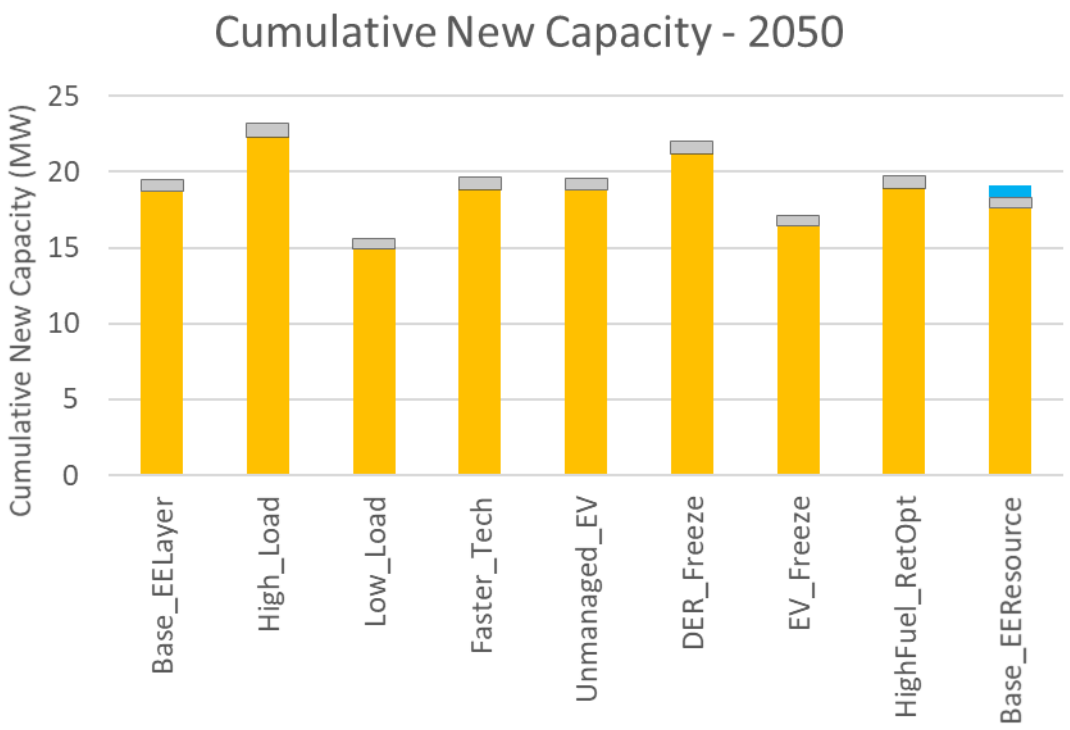
Moloka'i – 2030

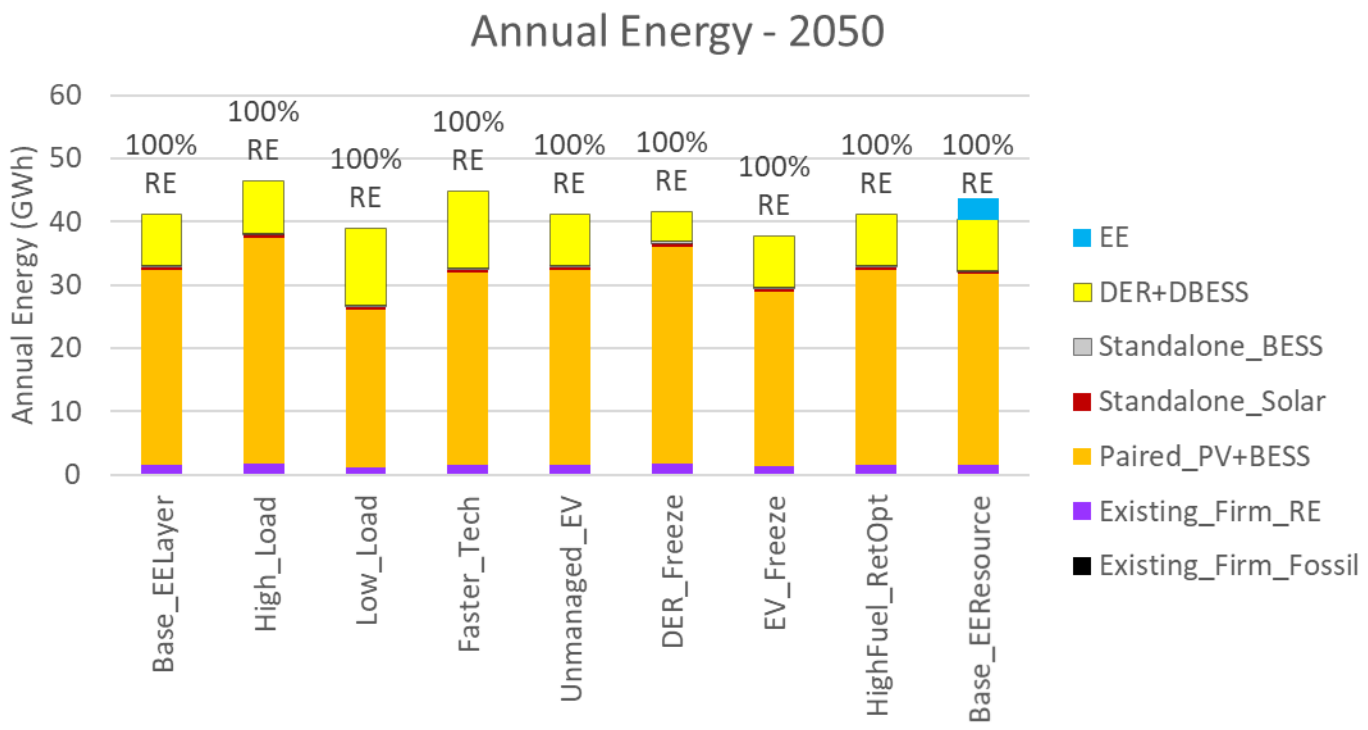




Paired PV is consistently selected across the cases.

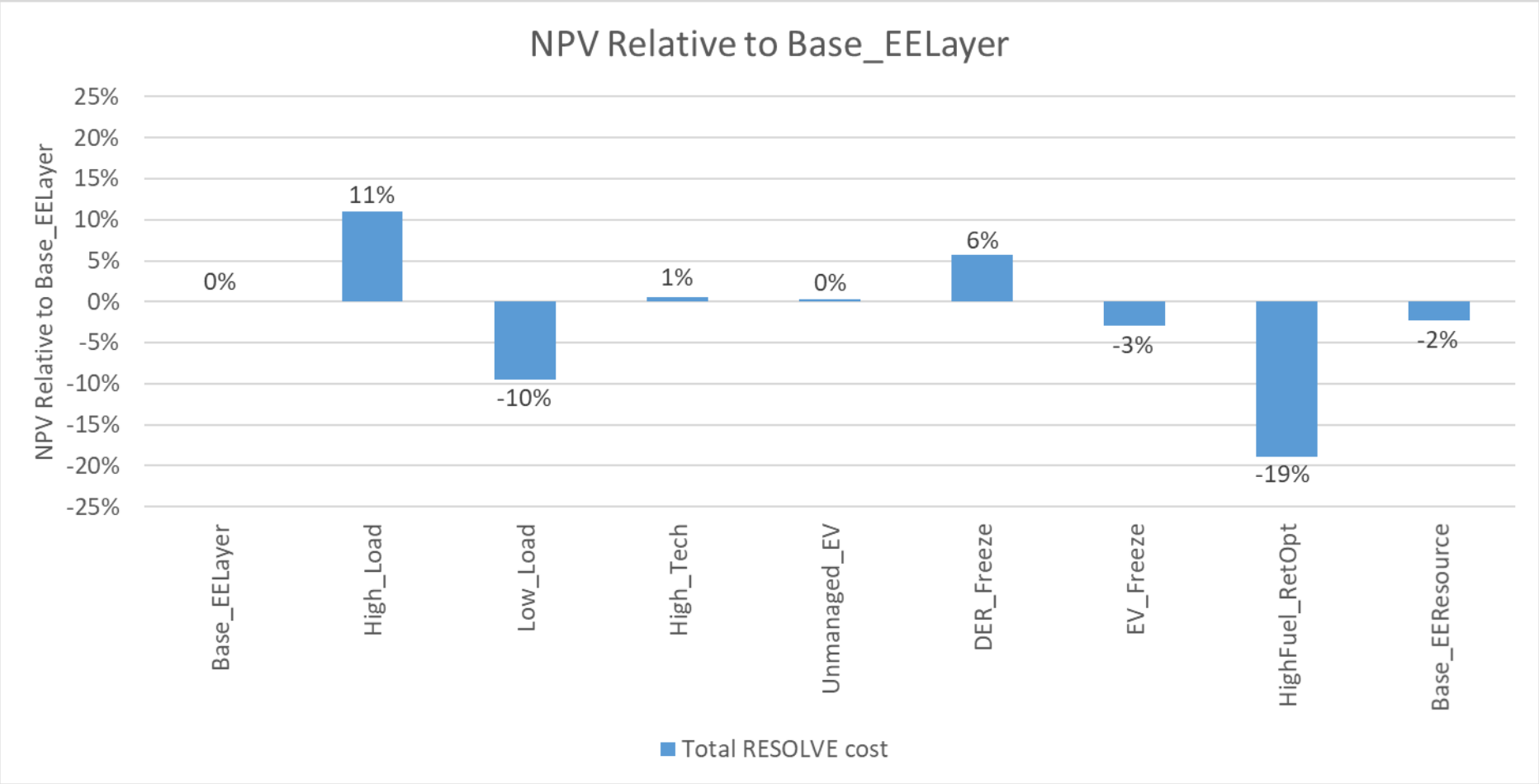
Moloka'i – 2050





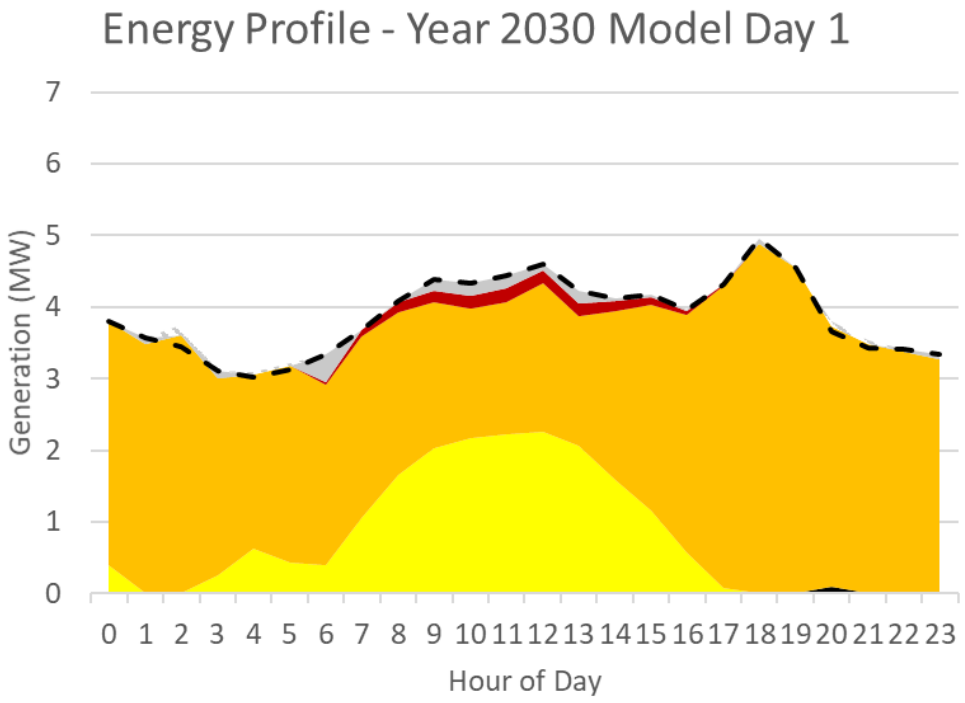
Paired PV is consistently selected across the cases.

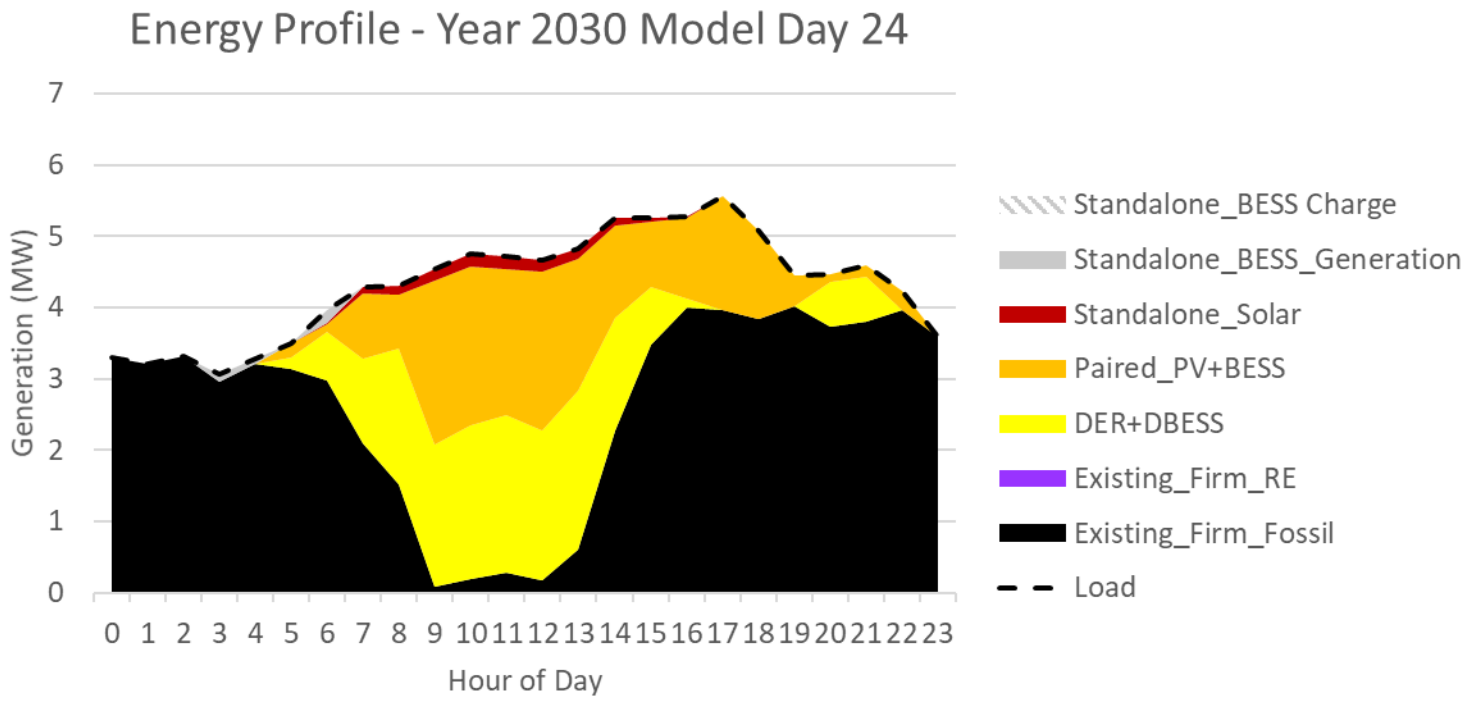
Moloka'i – NPV



Net present value (NPV) of each modeling scenario from 2029 to 2050 relative to the base scenario.

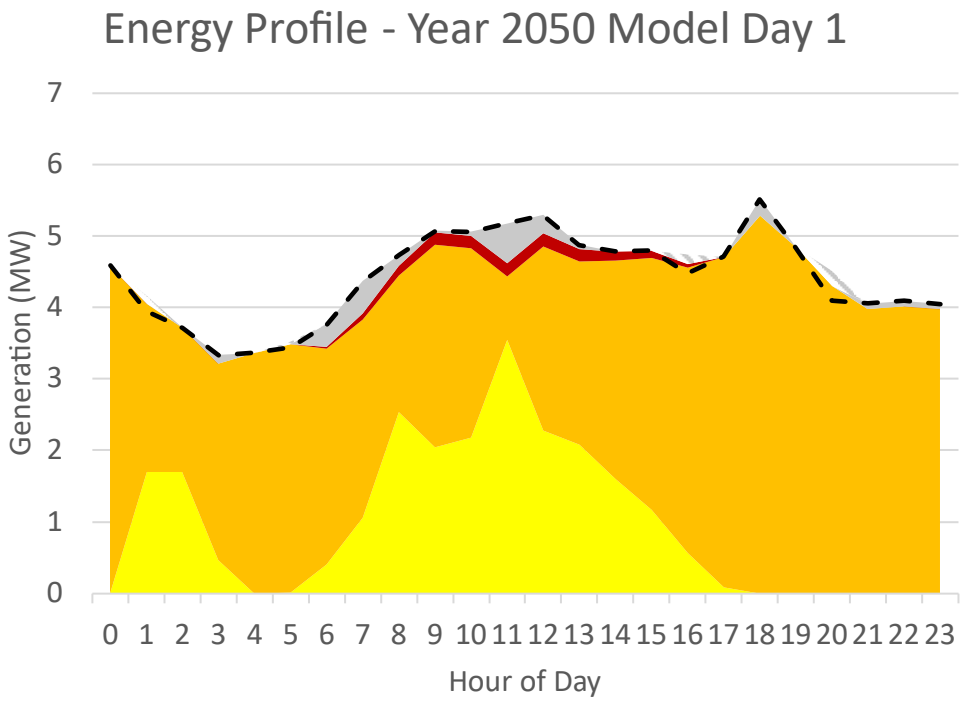
Moloka'i – Base – 2030

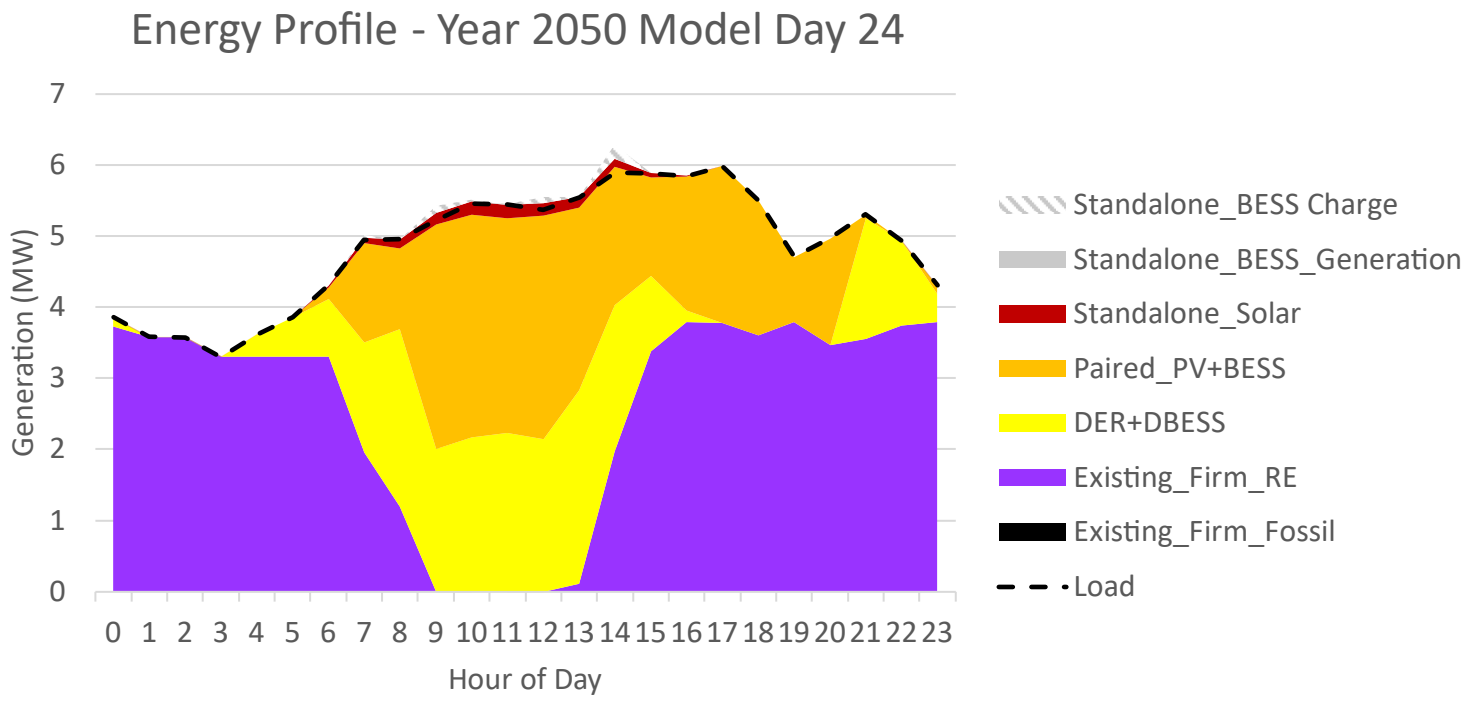




Left: Energy generated on a typical day assuming 2030 base case
Right: Energy generated on a day with low renewable resource availability assuming 2030 base case

Moloka'i – Base – 2050





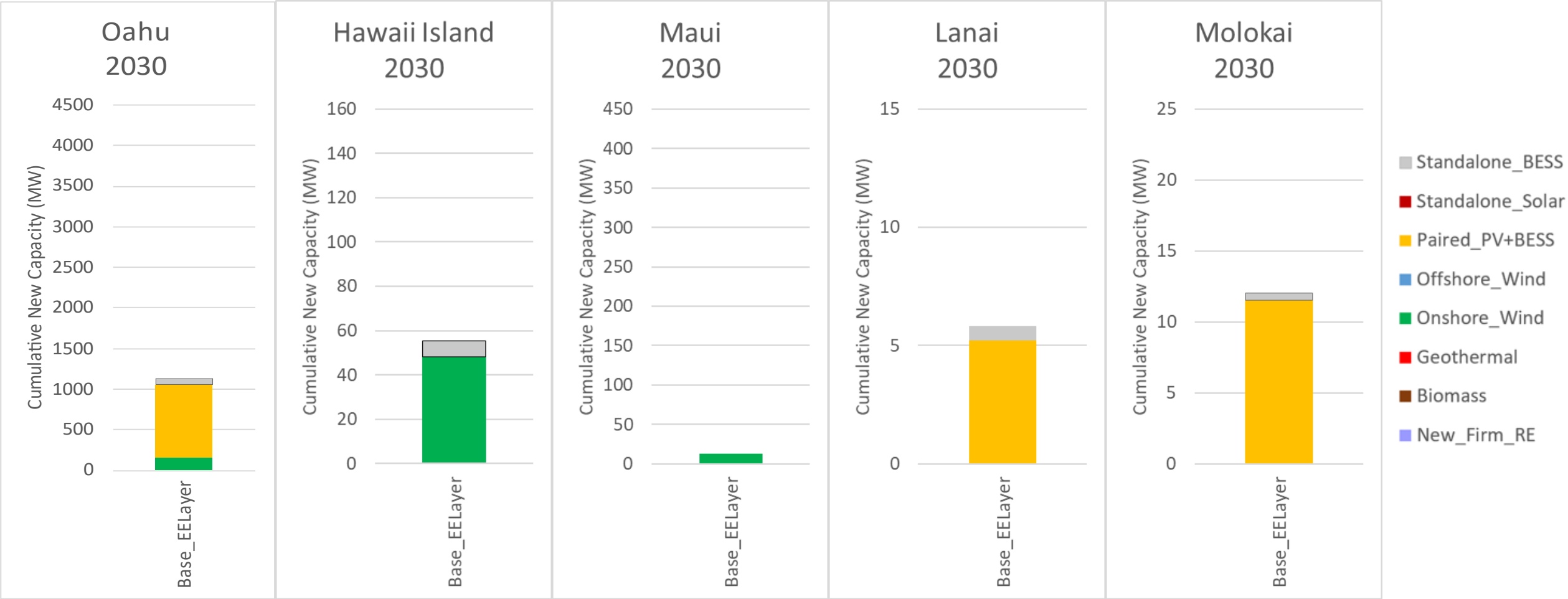
The effect of managed charging is more subtle due to the lower uptake of electric vehicles compared to other islands.

Preliminary Base Case

Summary – Base Case

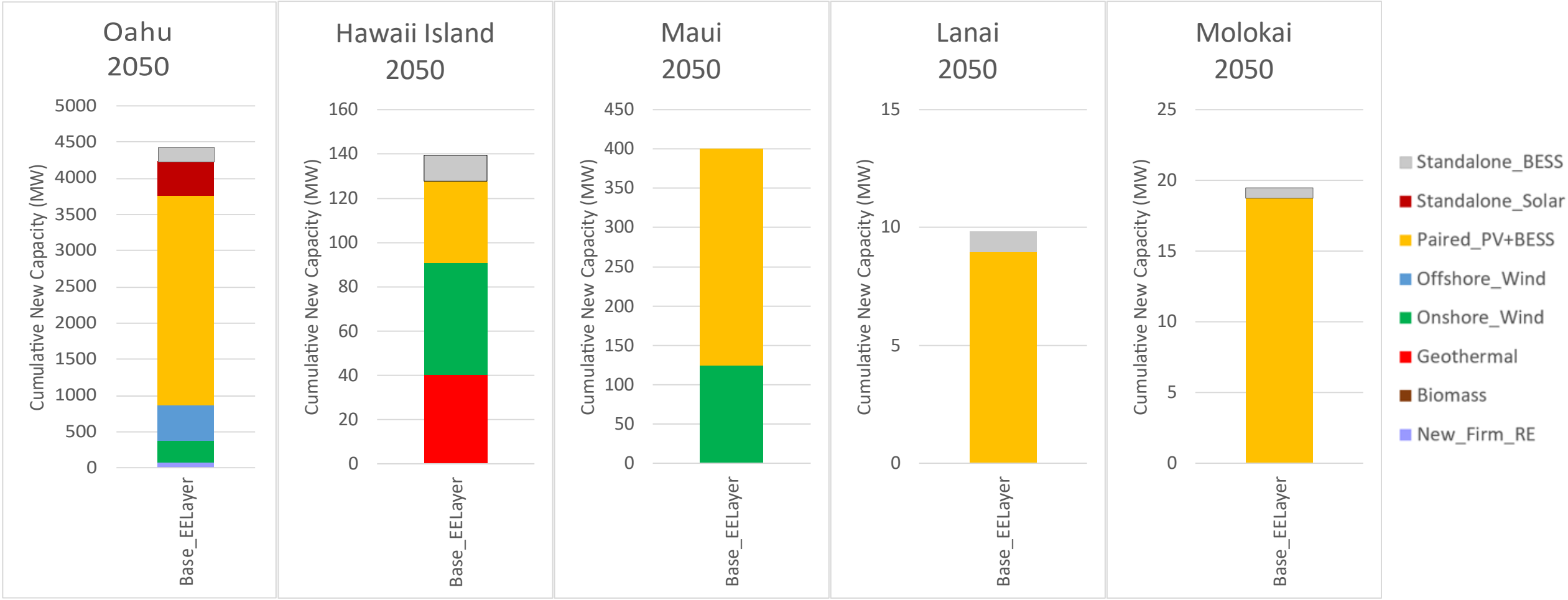
- O'ahu builds similar amounts of PV+BESS by 2030 compared to the July 2022 O'ahu GNA when including the amount of renewable energy scoped for the Stage 3 RFP
- Maui and Hawaiʻi Island continue to build wind due to its low resource cost
- Maui, Hawaiʻi Island, Lānaʻi, and Molokaʻi reach nearly 100% RPS by 2030

Base Case Summary : Cumulative New Capacity – 2030



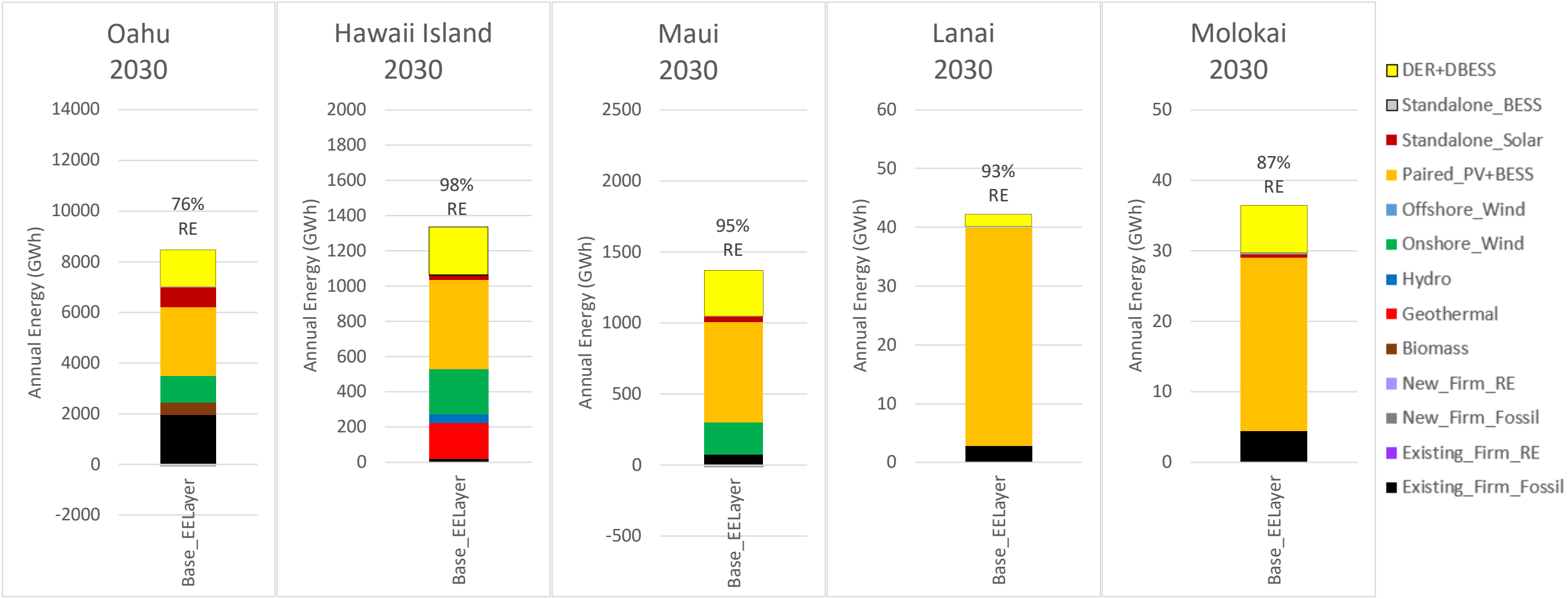
- By 2030, variable renewables and storage are consistently built across the islands.

Base Case Summary: Cumulative New Capacity – 2050



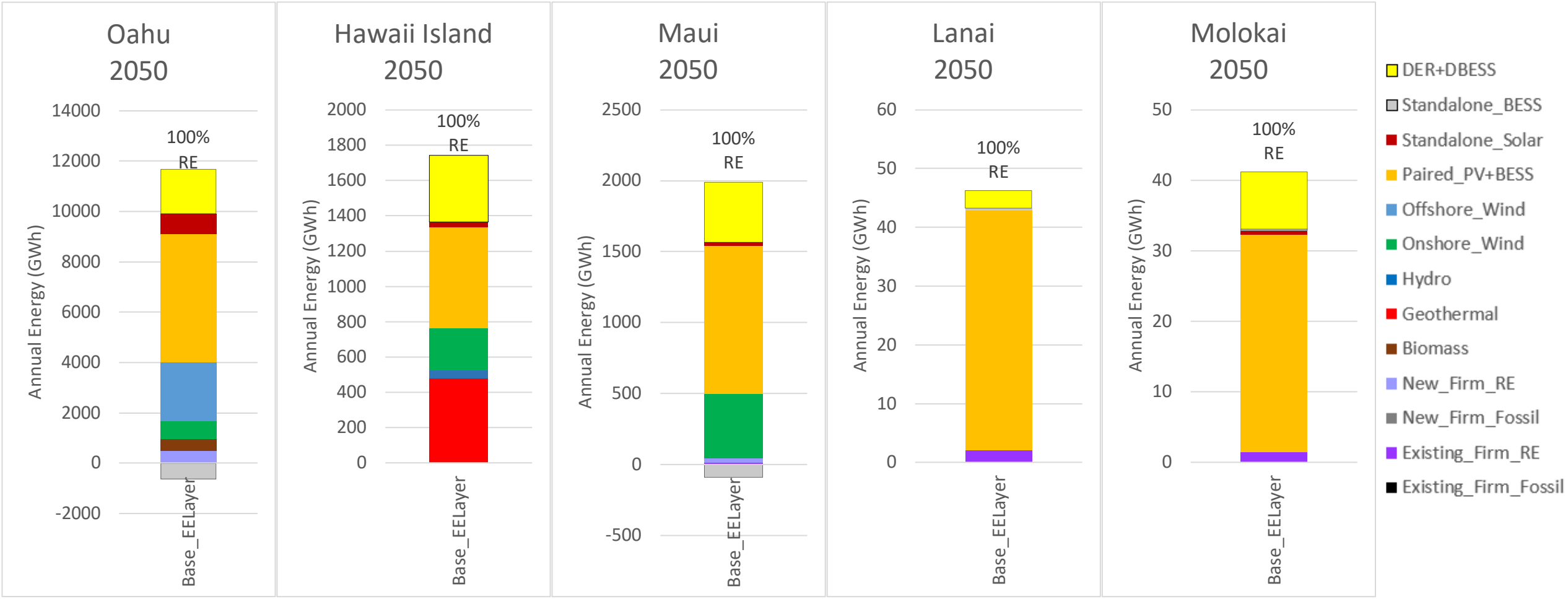
- By 2050, additional variable renewables and storage continue to be built. On O‘ahu and Hawai‘i Island, firm renewables are also selected.

Base Case Summary: Annual Energy – 2030



- By 2030, PV is the predominant renewable energy resource across all islands.

Base Case Summary: Annual Energy – 2050



- By 2050, PV continues to be the predominant renewable resource but a portion of future load will be met by firm renewables.

Preliminary DER Freeze Sensitivity

Summary – DER Freeze

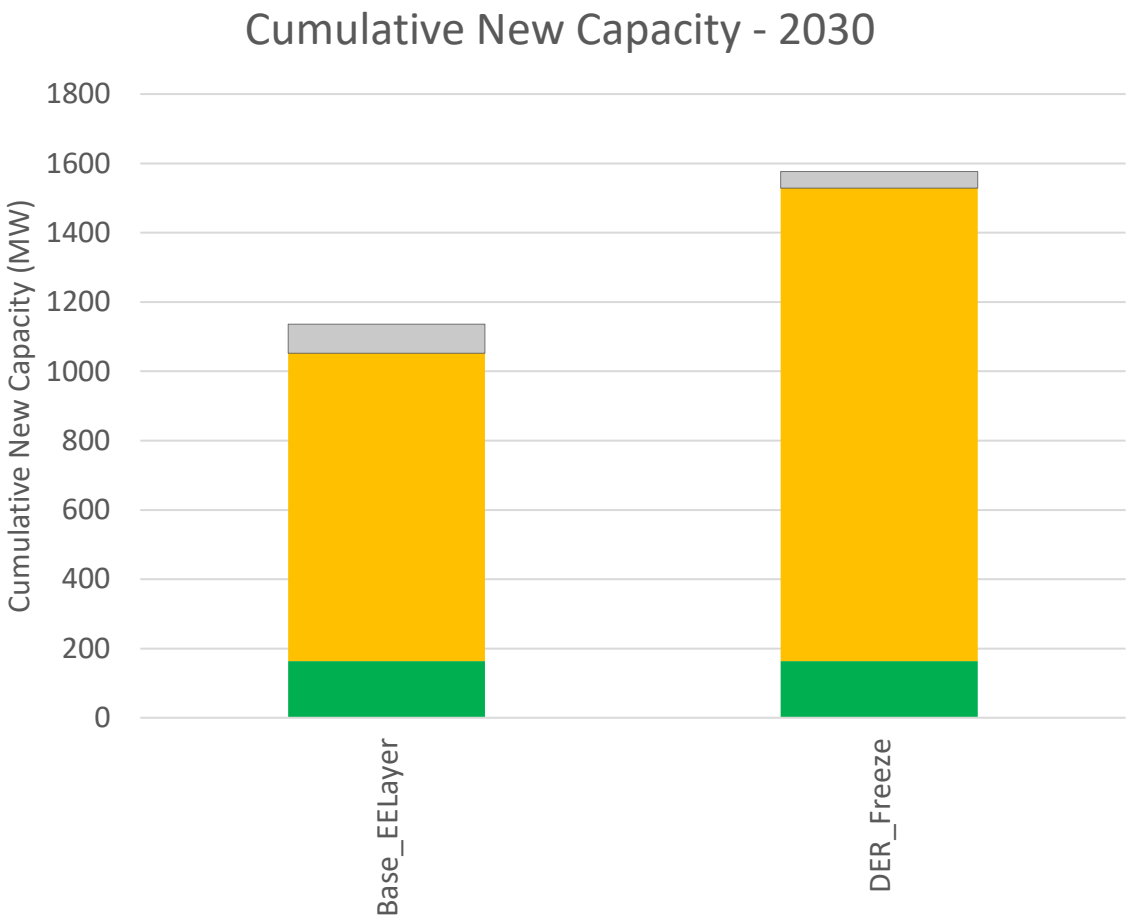
As shown in the summary table on the next slide, the avoided cost of the DER forecast in 2030 is low because of the availability of low cost, grid-scale renewables that can be built in the absence of the forecasted DER.

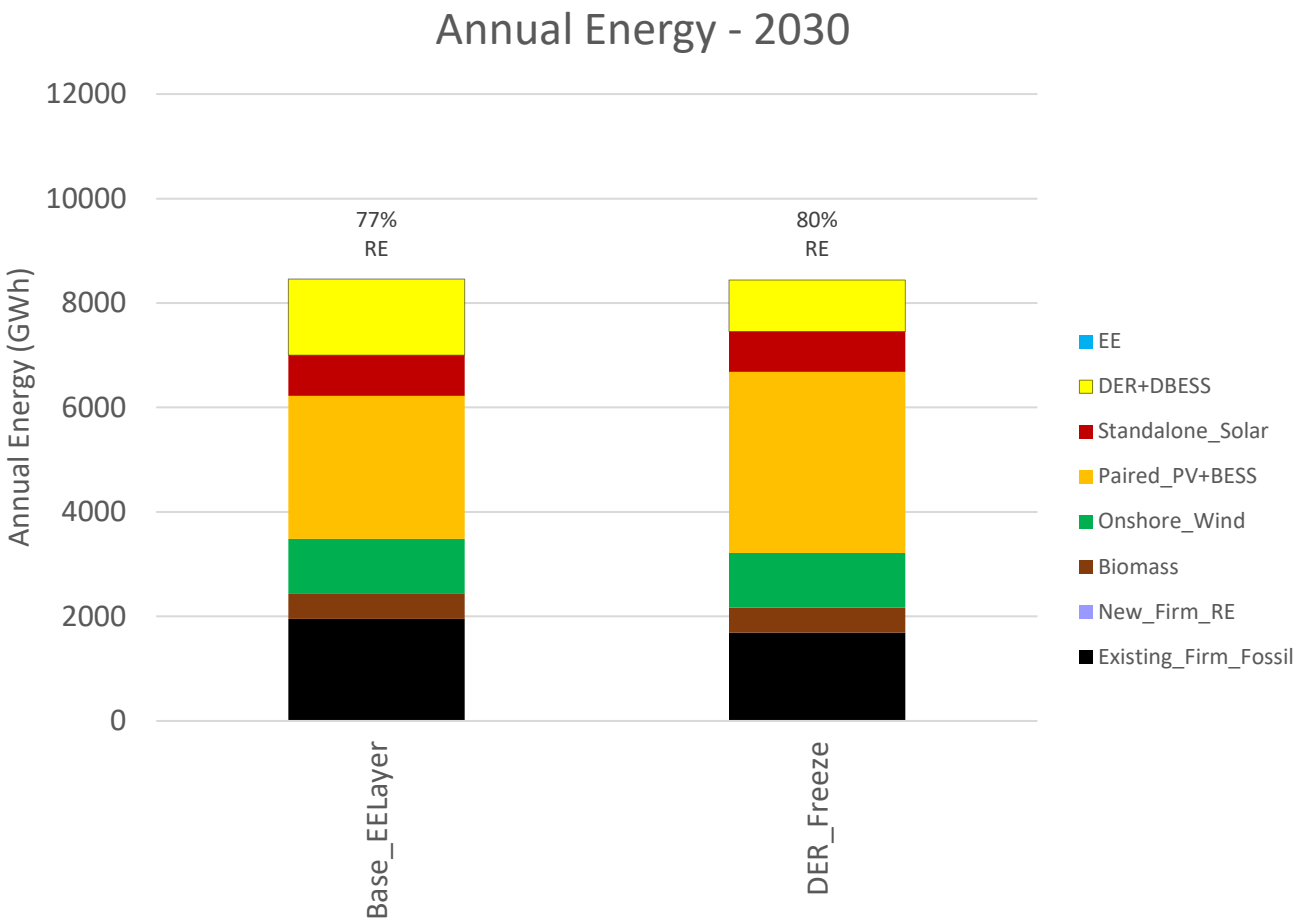
This avoided cost ($, cents/kWh) can inform either the total program cap ($) or compensation rate to be applied to new DER in order to break even with a resource plan where the DER uptake is “frozen”.

DER Freeze

Year 2030	Incremental DER Addition After 2020 Relative to Freeze Case			Incremental Cost Relative to Base Case for Year 2030 (2018$ MM) (Freeze minus Base)	Incremental Distributed PV Generation (MWh) (Base minus Freeze)	Avoided Cost of the DER Forecast in 2030 (cents/kWh)
	Distributed PV Capacity (MW)	Distributed BESS Capacity (MW)	Distributed BESS Energy (MWh)			
O'ahu	268	111	267.1	23.4	486,442	4.8
Hawai'i Island	52	22	58	6.3	88,137	7.1
Maui	64	52	138	14	112,940	12.4
Lana'i	0.5	0.3	0.8	0.05	838	6.0
Moloka'i	1.0	0.8	2.1	0.2	1,523	13.1

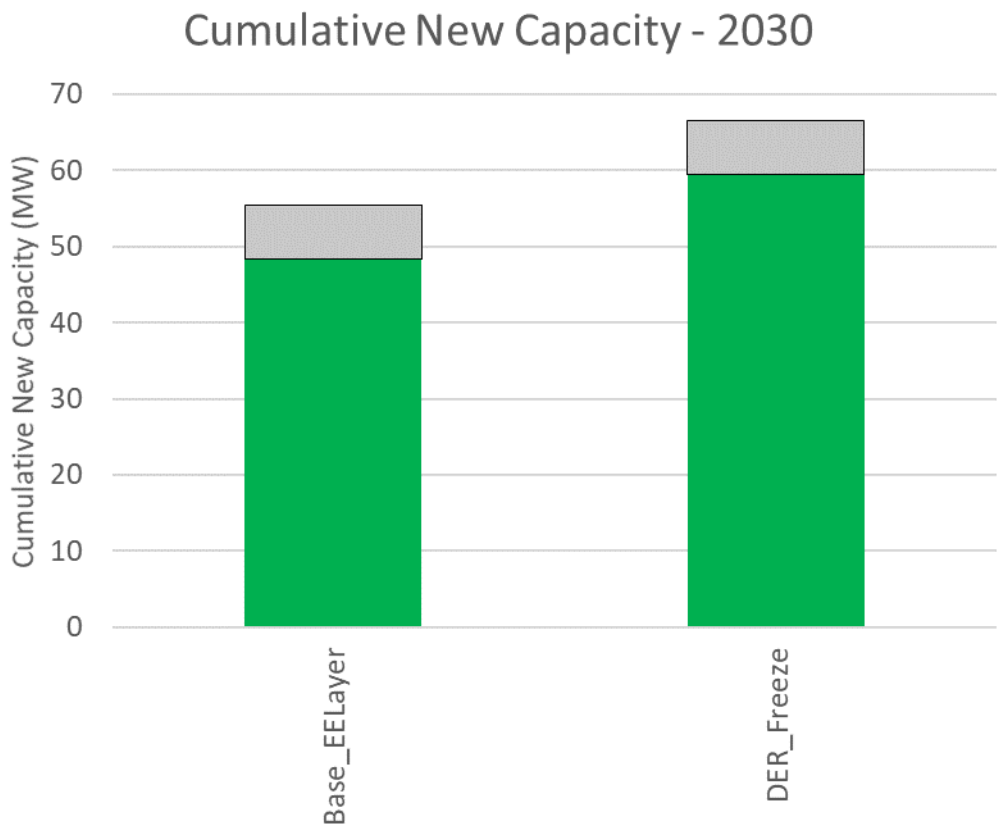
O'ahu – DER Freeze – 2030

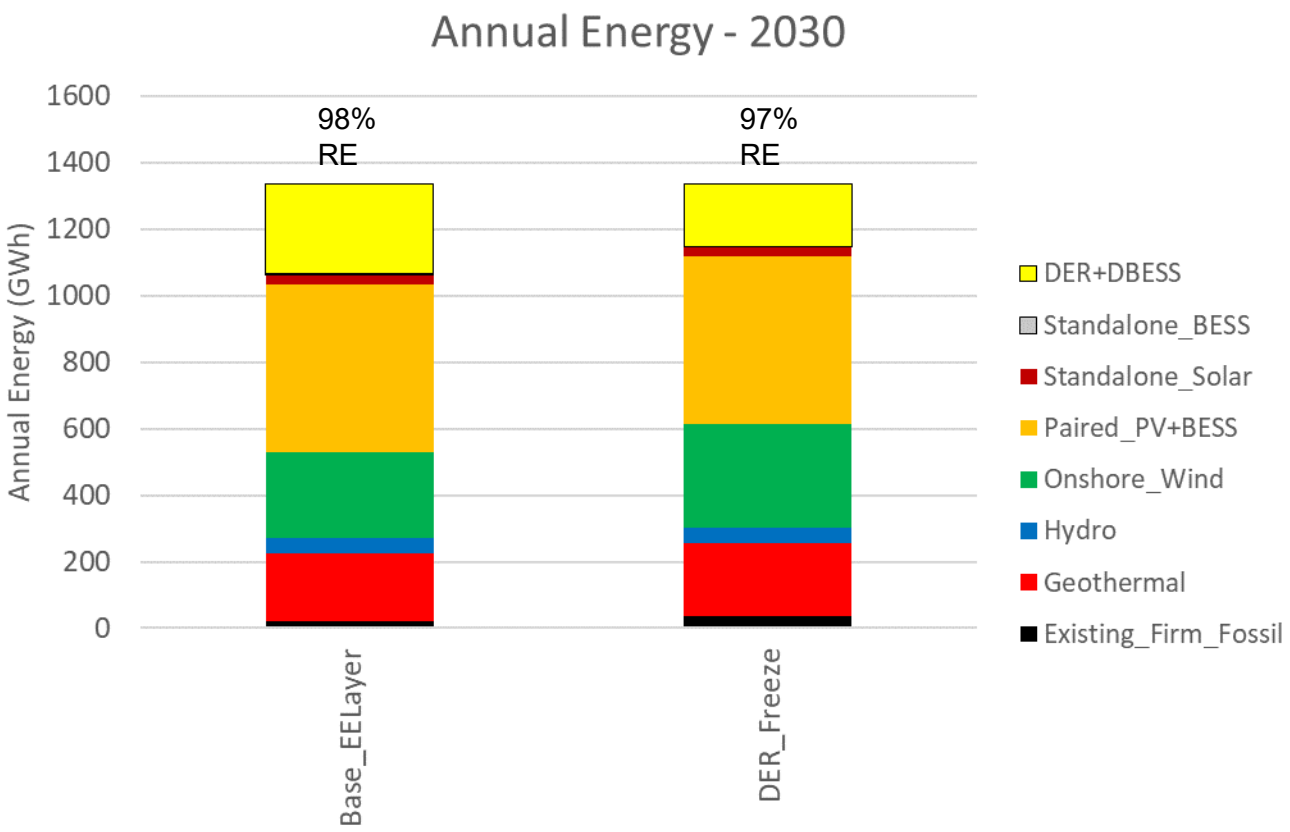




- On O‘ahu, additional paired PV is added in the absence of the forecasted DER.

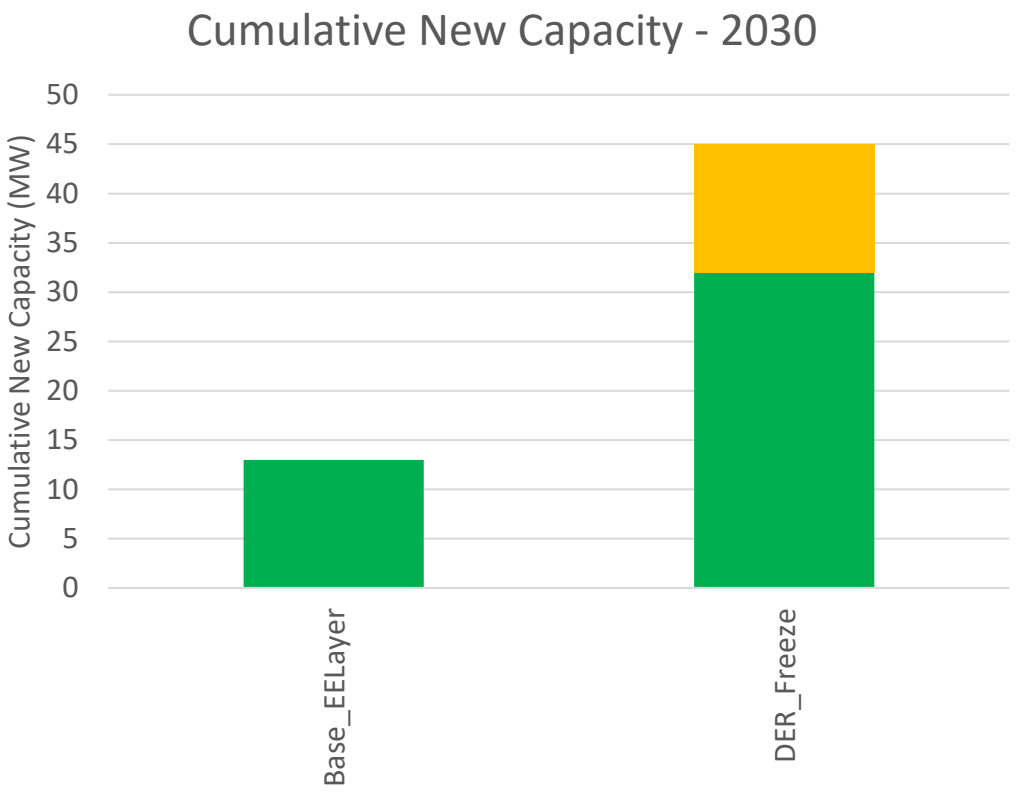
Hawai'i – DER Freeze – 2030

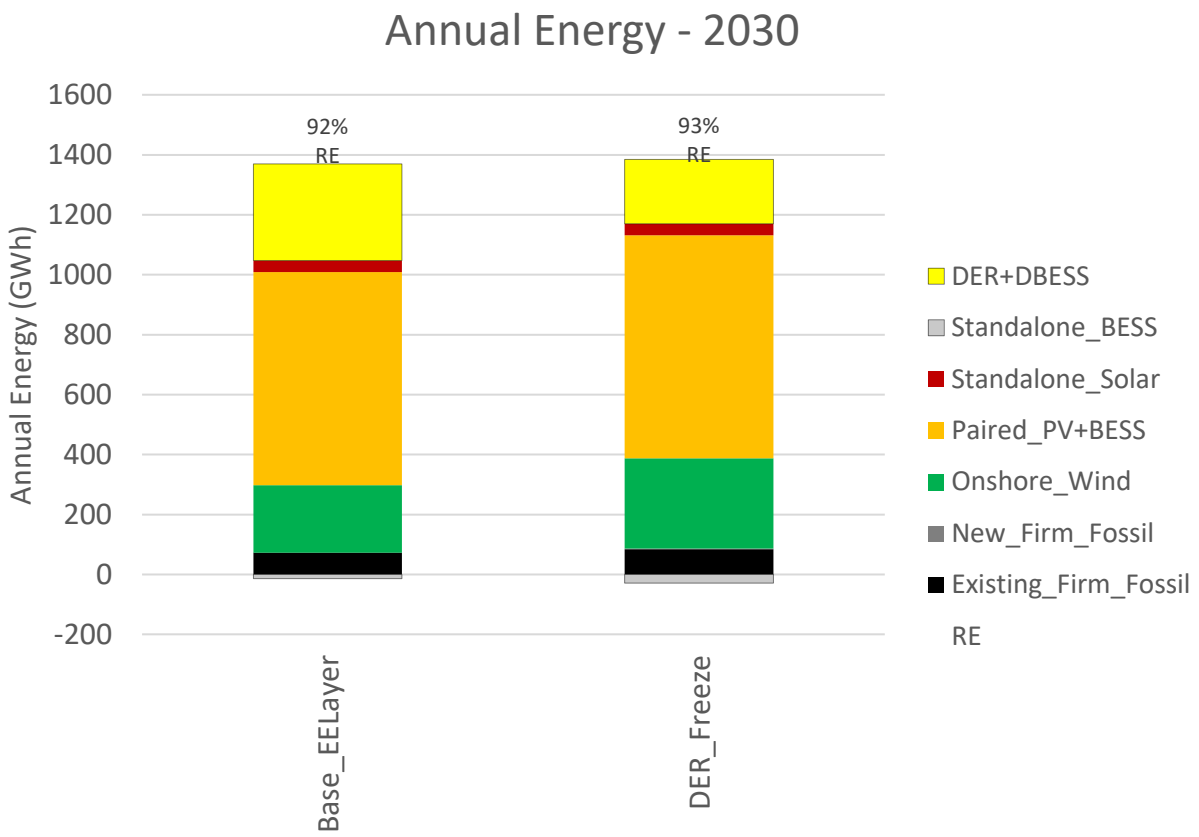




- On Hawai'i Island, additional wind is added in the absence of the forecasted DER.

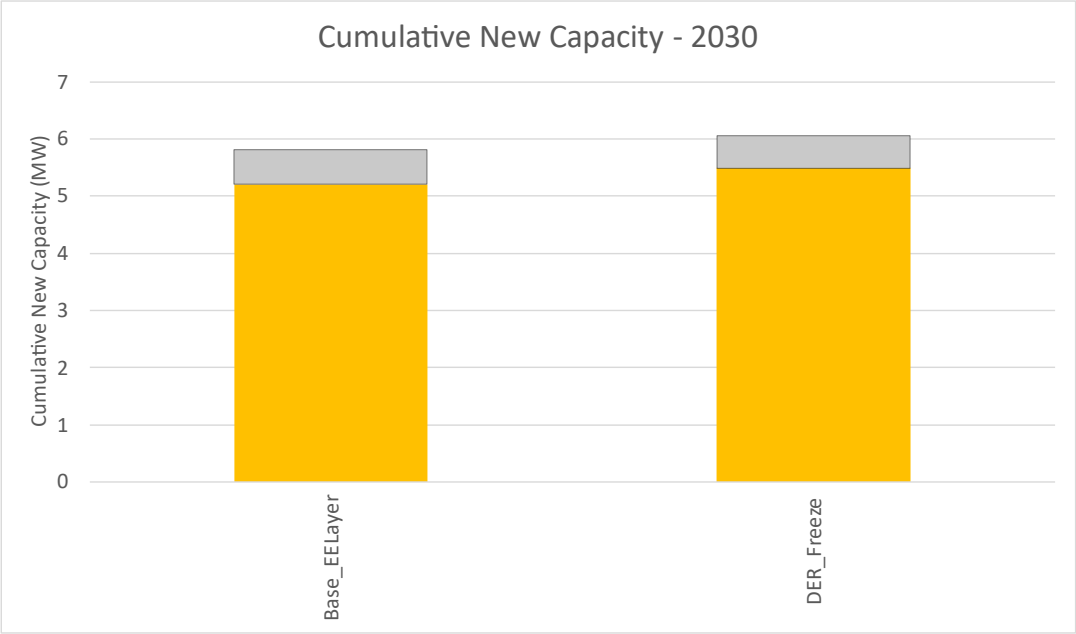
Maui – DER Freeze – 2030

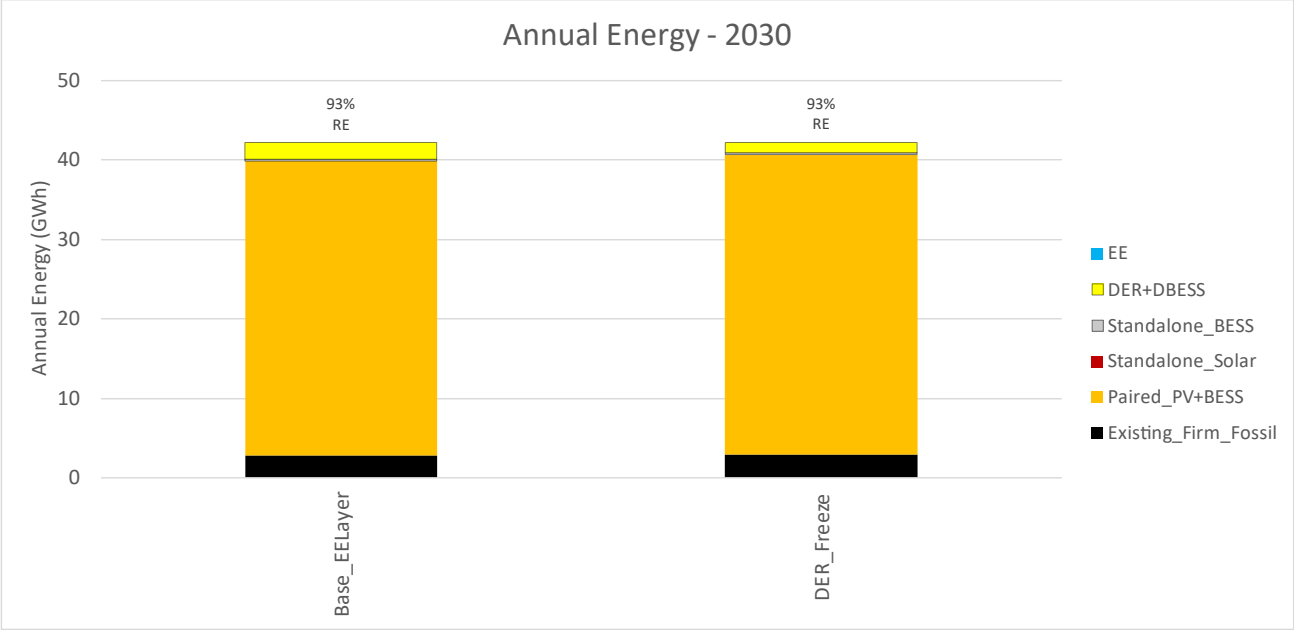




- On Maui, additional wind and paired PV is added in the absence of the DER forecast.

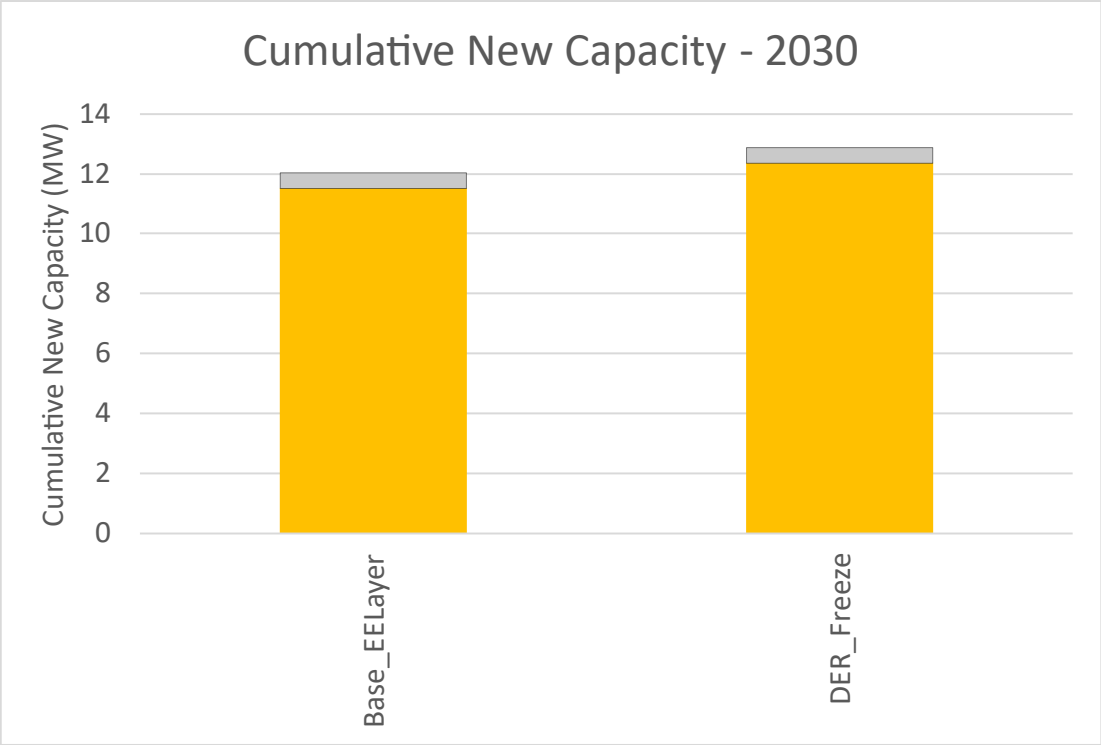
Lānaʻi – DER Freeze – 2030

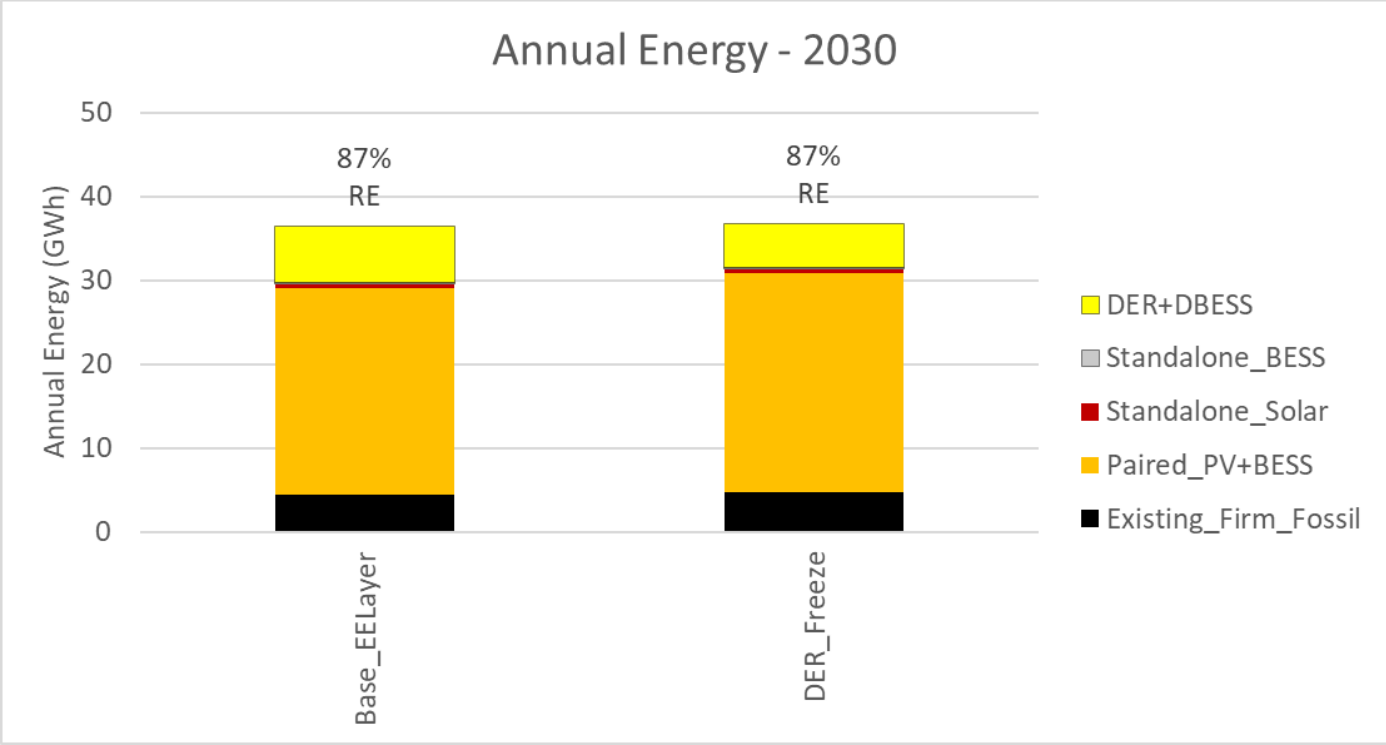




- On Lānaʻi, additional paired PV is added in the absence of the forecasted DER.

Moloka'i – DER Freeze – 2030





- On Moloka‘i, additional paired PV is added in the absence of the forecasted DER.

Preliminary High Fuel Price Retirement Optimization Sensitivity

Summary High Fuel Price Forecast Retirement Optimization

- As shown on the summary table on the next slide, when RESOLVE is allowed to retire firm thermal units under the high fuel price forecast, a significant amount of capacity is retired on each island.
- Compared to a probabilistic RA case with a similar portfolio of resources, RESOLVE may have over retired, under built the portfolio on O‘ahu and Maui due to LOLE higher than 0.1.
- The retirements that were selected in this exercise are dependent upon the capacity of the replacement resources that are also selected by RESOLVE. On O‘ahu, new firm capacity is provided by a future biomass resource in addition to large amounts of PV+BESS that will require REZ.

O'ahu – High Fuel Price Retirement Optimization

High Fuel Price with Retirement	
Year 2030	**HighFuel_RetOpt**
Existing firm HDC (%)	72.37
New firm HDC (%)	97.4
ERM Requirement (%)	10
New Firm (selected by RESOLVE, MW)	158
Existing Firm (MW)	915*
Standalone PV (MW)	398
Paired PV (Hybrid Solar, MW)	2,136
Onshore Wind (MW)	163
Offshore Wind (MW)	0
Standalone Storage (MW/MWH)	299 / 780
Paired Storage (MW/MWH)	2,136 / 6,038

Year 2030	HighFuel_RetOpt
Cumulative Capacity Removed from Service (MW)	833

PLEXOS Probabilistic RA			
Year 2029	**Base_150_1600PVB_Mar22Out**	**Base_300_270PVB_0Wnd_Mar22Out**	**Base_400_270PVB_0Wnd_Mar22Out**
Existing firm HDC (%)	N/A	N/A	N/A
New firm HDC (%)	N/A	N/A	N/A
ERM Requirement (%)	N/A	N/A	N/A
New Firm (selected by RESOLVE, MW)	150	300	400
Existing Firm (MW)	970	970	970
Standalone PV (MW)	0	0	0
Paired PV (Hybrid Solar, MW)	1,600	270	270
Onshore Wind (MW)	163	0	0
Offshore Wind (MW)	0	0	0
Standalone Storage (MW/MWH)	Aggregated with Paired Storage	Aggregated with Paired Storage	Aggregated with Paired Storage
Paired Storage (MW/MWH)	1,887 / 5,339	557 / 1,349	557 / 1,349
LOLE (Days/Year)	0.22	0.66	0.04

*Includes S3 firm renewable RFP placeholder

Hawai'i Island – High Fuel Price Retirement Optimization

High Fuel Price with Retirement	
Year 2029	HighFuel_RetOpt
Existing firm HDC (%)	82.1
New firm HDC (%)	97.4
ERM Requirement (%)	25
New Firm (selected by RESOLVE, MW)	16
Modified Firm* (input into PLEXOS, MW)	---
Existing Firm (MW)	174
Standalone PV (MW)	145
Paired PV (Hybrid Solar, MW)	85
Hydro (MW)	18
Onshore Wind (MW)	47
Standalone Storage (MW/MWH)	9 / 17
Paired Storage (MW/MWH)	85 / 340

Year 2029	HighFuel_RetOpt
Cumulative Capacity Removed from Service (MW)	54

PLEXOS Probabilistic RA		
Year 2029	Base 20% ERM	Base 25% ERM
Existing firm HDC (%)	N/A	N/A
New firm HDC (%)	N/A	N/A
ERM Requirement (%)	20	25
New Firm (selected by RESOLVE, MW)	21	29
Modified Firm* (input into PLEXOS, MW)	0	48
Existing Firm (MW)	143	143
Standalone PV (MW)	145	145
Paired PV (Hybrid Solar, MW))	136	137
Hydro (MW)	17	17
Onshore Wind (MW)	86	86
Standalone Storage (MW/MWH)	9 / 21	9 / 21
Paired Storage (MW/MWH)	136 / 398	137 / 399
LOLE (Days/Yr)	0.672	0.024

Maui – High Fuel Price Retirement Optimization

High Fuel Price with Retirement	
Year 2030	HighFuel_RetOpt
Existing firm HDC (%)	89.72
New firm HDC (%)	97.4
ERM Requirement (%)	30
New Firm (selected by RESOLVE, MW)	9.32
Existing Firm (MW)	100.21
Paired PV (MW)	347
Onshore Wind (MW)	54.4
Paired Storage (MW/MWh)	381 / 1430

PLEXOS Probabilistic RA			
Year 2030	Base, No ICE	Base w/ 9 MW ICE	Base w/ 18 MW ICE
Existing firm HDC (%)	N/A	N/A	N/A
New firm HDC (%)	N/A	N/A	N/A
ERM Requirement (%)	N/A	N/A	N/A
New Firm (selected by RESOLVE, MW)	0	9	18
Existing Firm (MW)	126	126	126
Paired PV (MW)	22	22	22
Onshore Wind (MW)	60	60	60
Paired Storage (MW / MWh)	22 / 22	22 / 22	22 / 22
LOLE (Days / Year)	0.14	0.04	0.0

Year 2030	HighFuel_RetOpt
Cumulative Capacity Removed from Service (MW)	54.31

Lānaʻi – High Fuel Price Retirement Optimization

Year 2030	HighFuel_RetOpt
Existing firm HDC (%)	89.72
New firm HDC (%)	96.1
ERM Requirement (%)	45
New Firm* (input into PLEXOS, MW)	0
Existing Firm (MW)	4.9
Standalone PV (MW)	0
Paired PV (Hybrid Solar, MW)	22.8
Onshore Wind (MW)	0
Standalone Storage (MW/MWH)	0.8 / 1.4
Paired Storage (MW/MWH)	22.8 / 70.3

Year 2030	Base 0% ERM	Base 30% ERM	Base 45% ERM	Base 60% ERM
Existing firm HDC (%)	89.72	89.72	89.72	89.72
New firm HDC (%)	96.1	96.1	96.1	96.1
ERM Requirement (%)	0	30	45	60
New Firm* (input into PLEXOS)	2-0.97 MW unit	4-0.97 MW unit	5-0.97 MW unit	5-0.97 MW unit
Existing Firm (MW)	0	0	0	0
Standalone PV (MW)	0	0	0	0
Paired PV (Hybrid Solar, MW)	22.6	22.0	22.0	21.9
Onshore Wind (MW)	0	0	0	0
Standalone Storage (MW/MWH)	0.7 / 1.2	0.7 / 1.2	0.7 / 1.2	0.7 / 1.2
Paired Storage (MW/MWH)	22.6 / 70.0	22.0 / 69.4	22.0 / 69.4	21.9 / 69.3
LOLE (Days/Yr)	12.69	0.32	0.04	0.04

Year 2030	HighFuel_RetOpt
Cumulative Capacity Removed from Service (MW)	5.5 MW

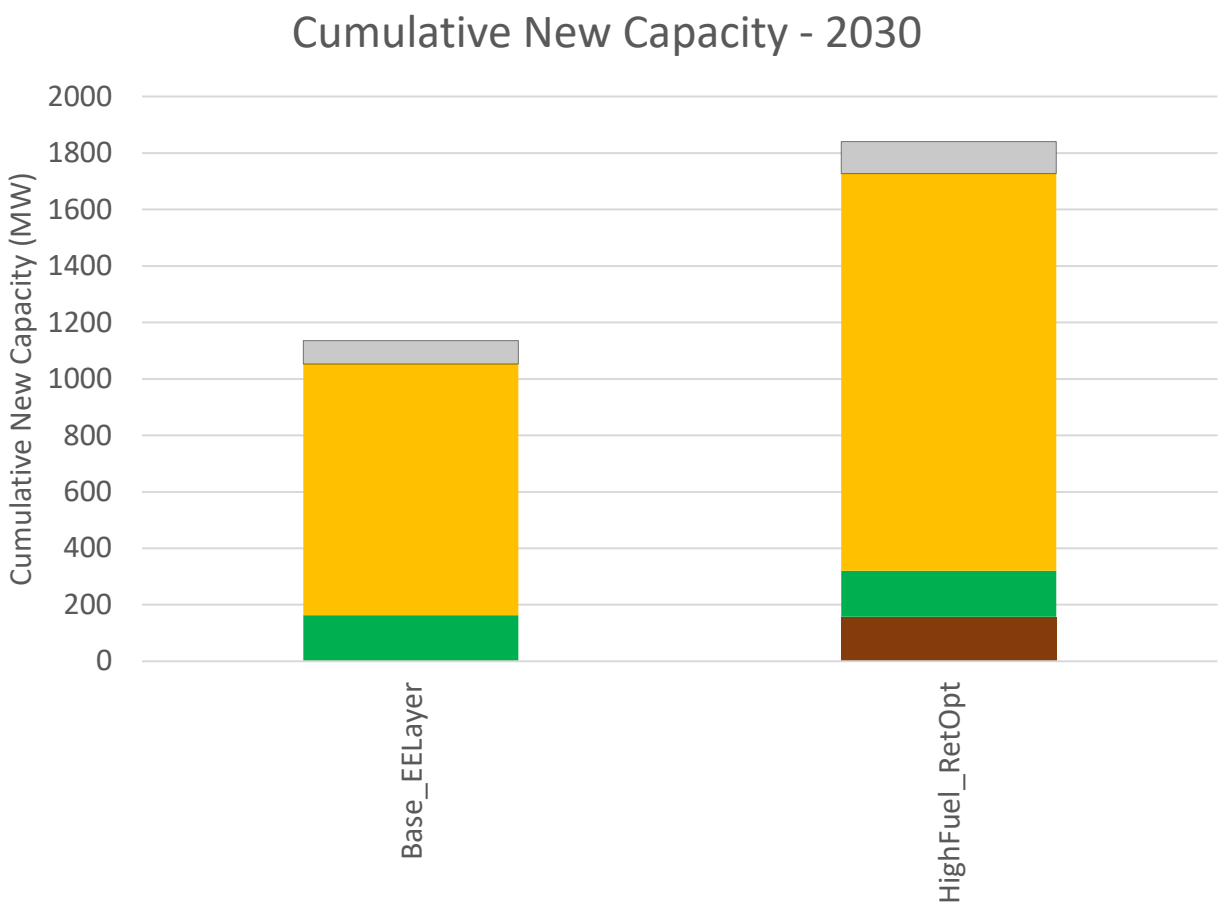
Moloka'i – High Fuel Price Retirement Optimization

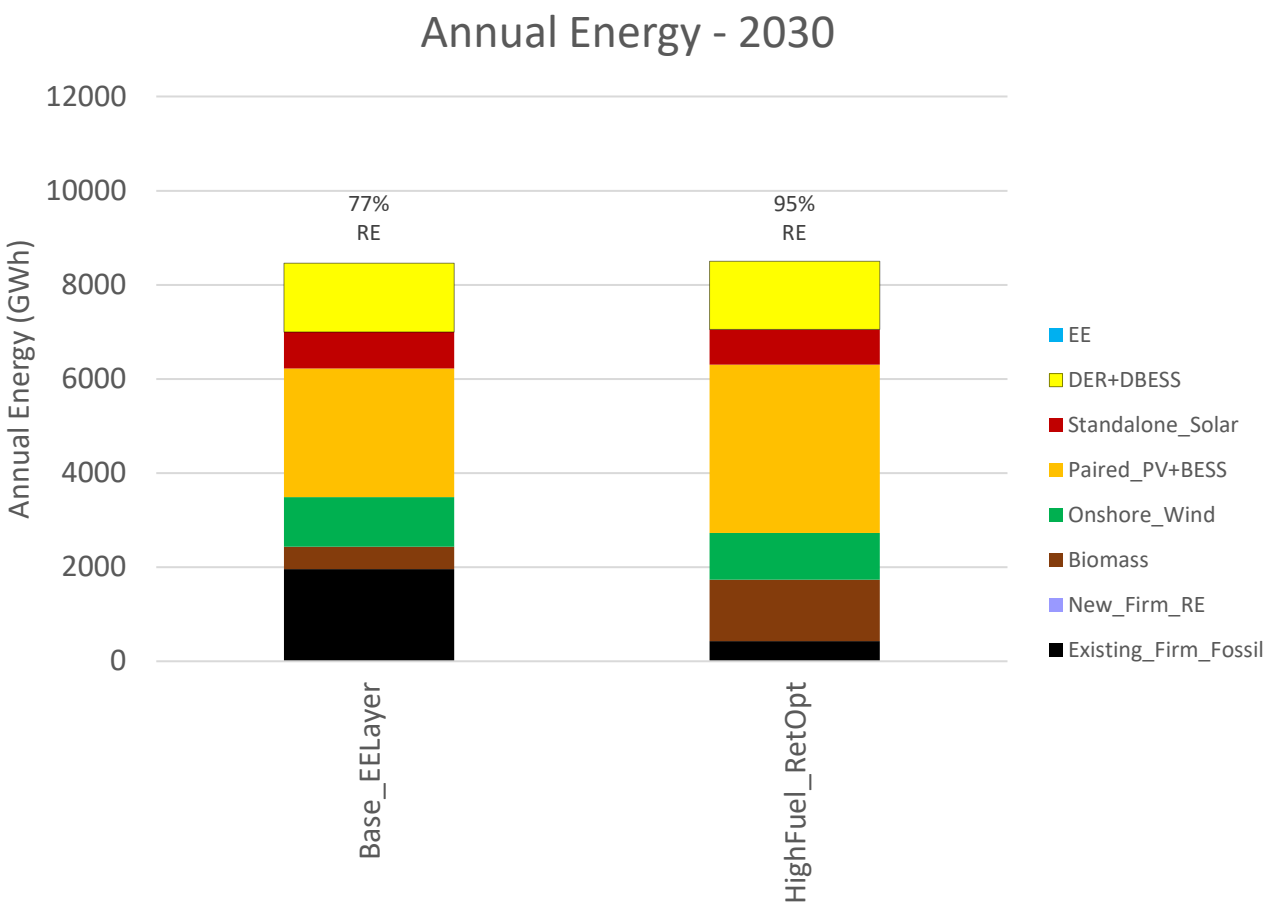
Year 2030	HighFuel_RetOpt
Existing firm HDC (%)	89.72
New firm HDC (%)	96.1
ERM Requirement (%)	45
New Firm* (input into PLEXOS, MW)	0
Existing Firm (MW)	5-0.97 MW unit
Standalone PV (MW)	0.25
Paired PV (Hybrid Solar, MW)	18.7
Onshore Wind (MW)	0
Standalone Storage (MW/MWH)	0.7 / 1.2
Paired Storage (MW/MWH)	18.7 / 51

Year 2030	Base 0% ERM	Base 30% ERM	Base 45% ERM	Base 60% ERM
Existing firm HDC (%)	89.72	89.72	89.72	89.72
New firm HDC (%)	96.1	96.1	96.1	96.1
ERM Requirement (%)	0	30	45	60
New Firm* (input into PLEXOS)	3-0.97 MW unit	3-0.97 MW unit	4-0.97 MW unit	5-0.97 MW unit
Existing Firm (MW)	0	0	0	0
Standalone PV (MW)	0	0	0	0
Paired PV (Hybrid Solar, MW)	13.4	14.4	13.9	13.5
Onshore Wind (MW)	0	0	0	0
Standalone Storage (MW/MWH)	0.6 / 1.5	0.5 / 1.0	0.5 / 1.0	0.5 / 1.0
Paired Storage (MW/MWH)	13.4 / 33.4	14.4 / 37.0	13.9 / 35.6	13.5 / 34.9
LOLE (Days/Yr)	0.436	0.392	0.008	0.000

Year 2030	HighFuel_RetOpt
Cumulative Capacity Removed from Service (MW)	10.4

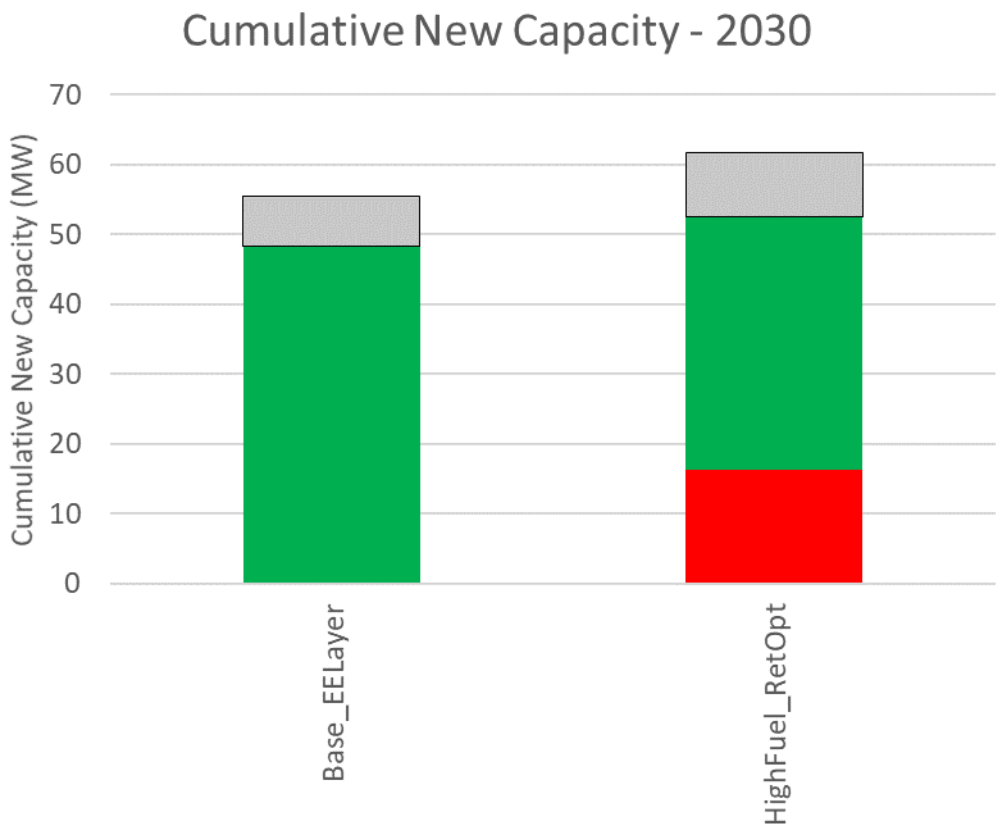
O'ahu – High Fuel Price w/Retirement Optimization – 2030

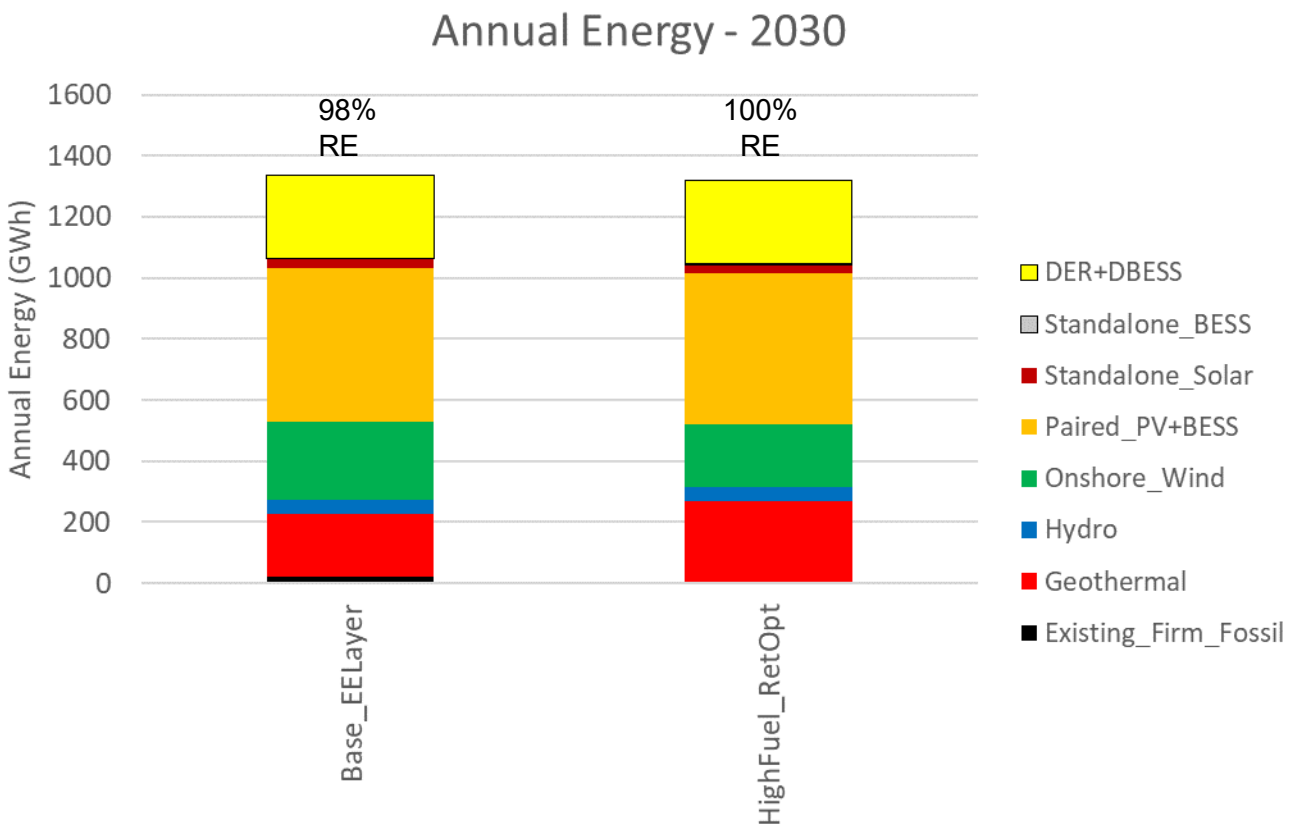




- On O‘ahu, biomass and paired PV are added when existing firm units are allowed to retire.

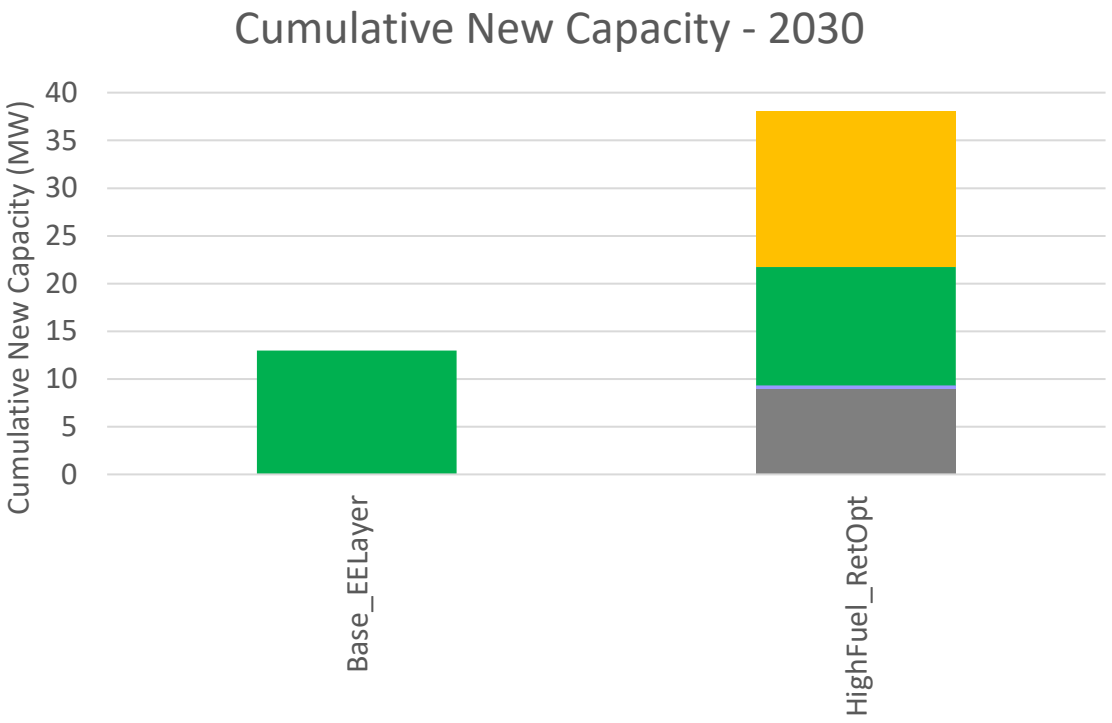
Hawai'i – High Fuel Price w/Retirement Optimization – 2030

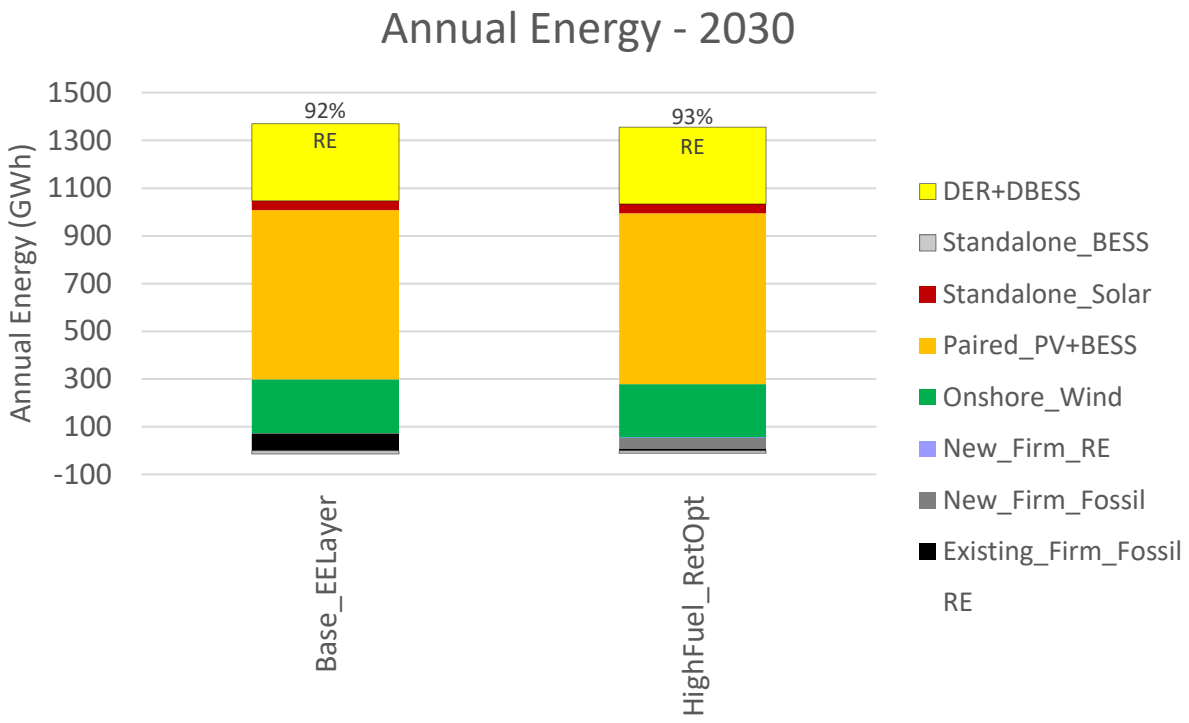




- On Hawai'i Island, additional geothermal and standalone BESS are added when existing firm units are allowed to retire.

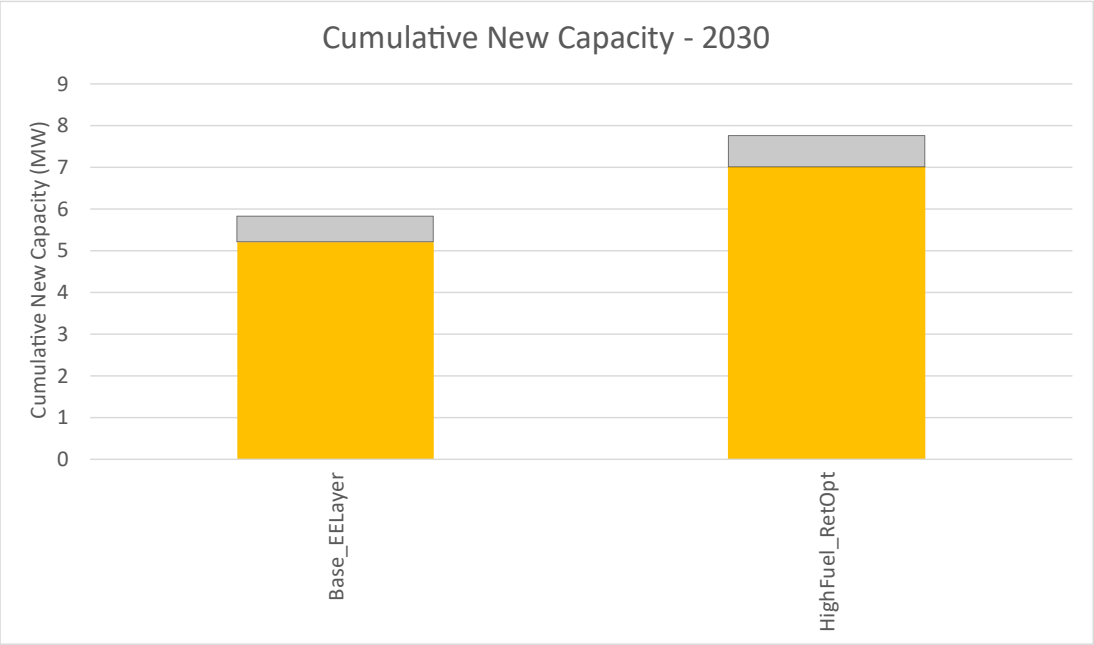
Maui – High Fuel Price w/Retirement Optimization – 2030

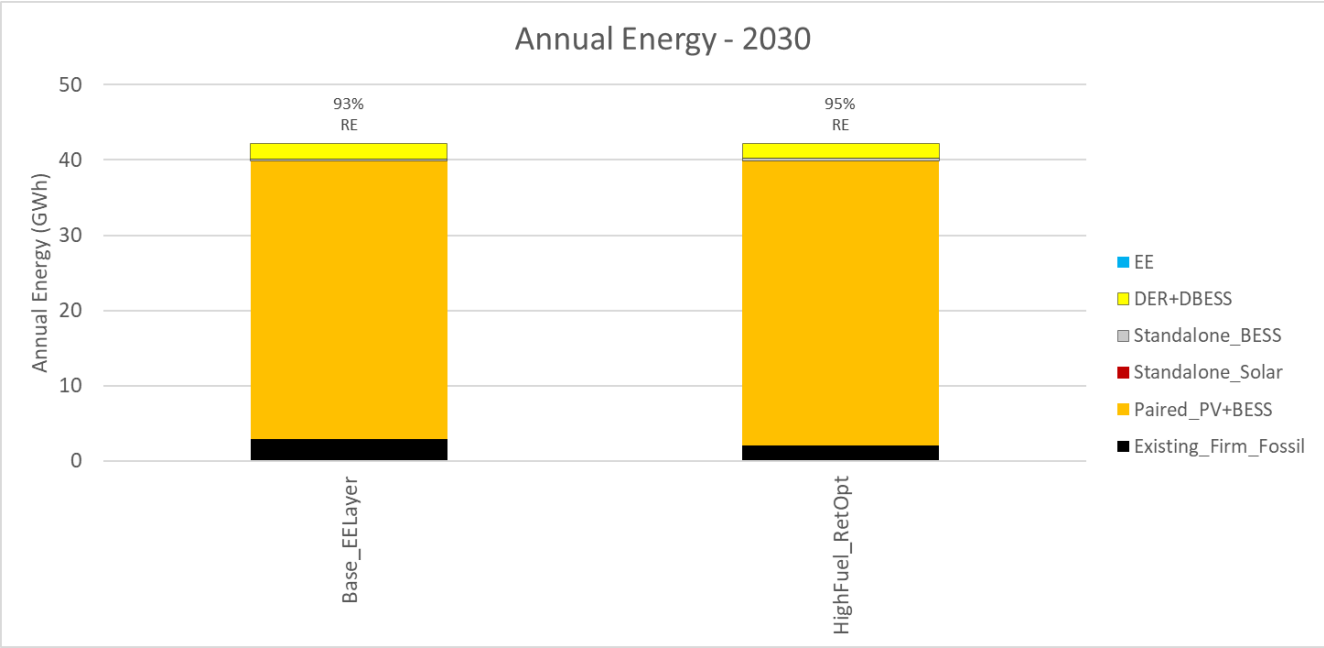




- On Maui, paired PV and new firm resources are added when existing firm units are allowed to retire.

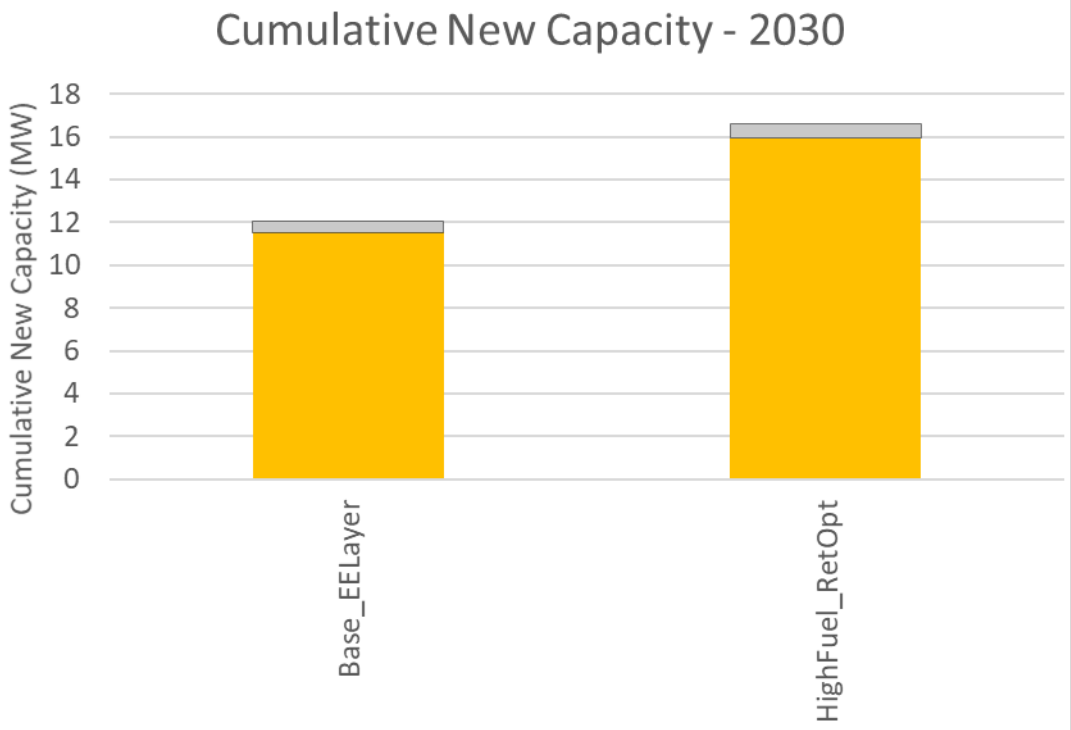
Lānaʻi – High Fuel Price w/Retirement Optimization – 2030

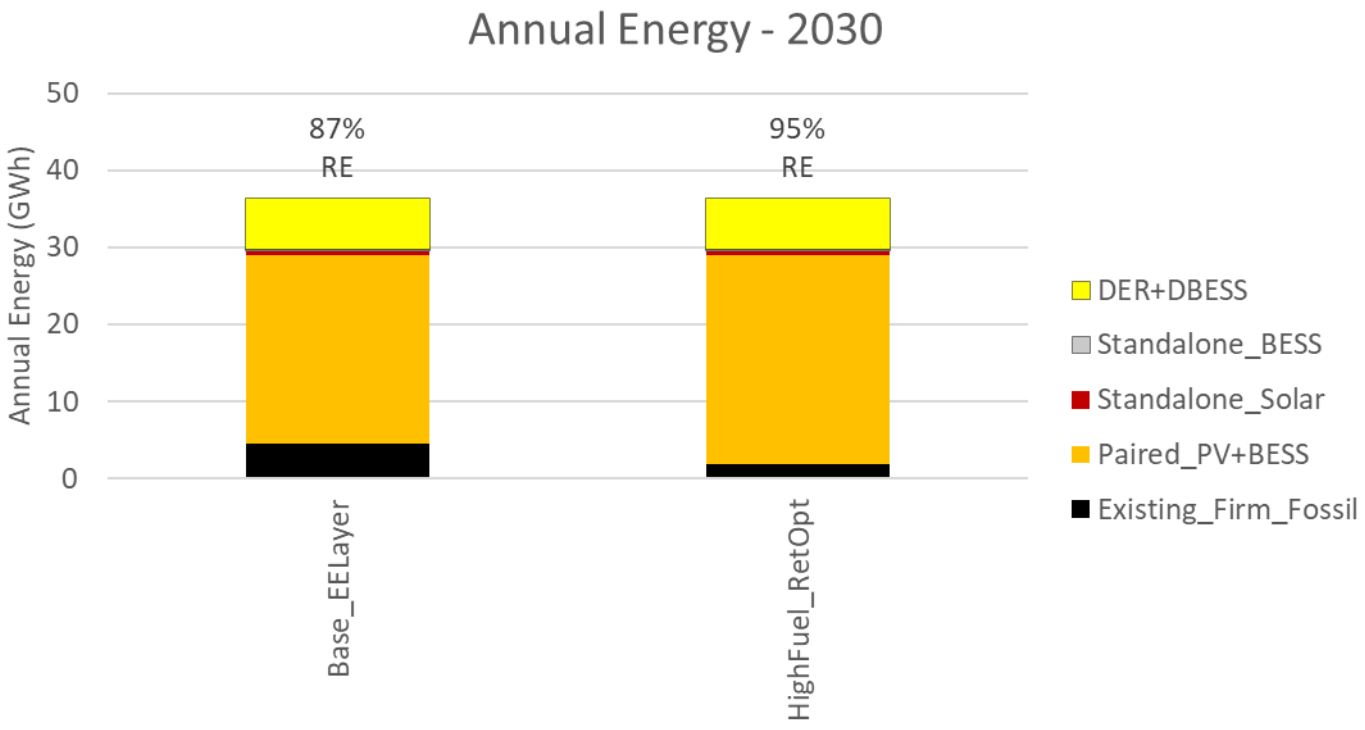




- On Lānaʻi, additional paired PV is added when existing firm units are allowed to retire.

Moloka'i – High Fuel Price w/Retirement Optimization – 2030





- On Moloka‘i, additional paired PV is added when existing firm units are allowed to retire.

Preliminary EE as a Resource Sensitivity

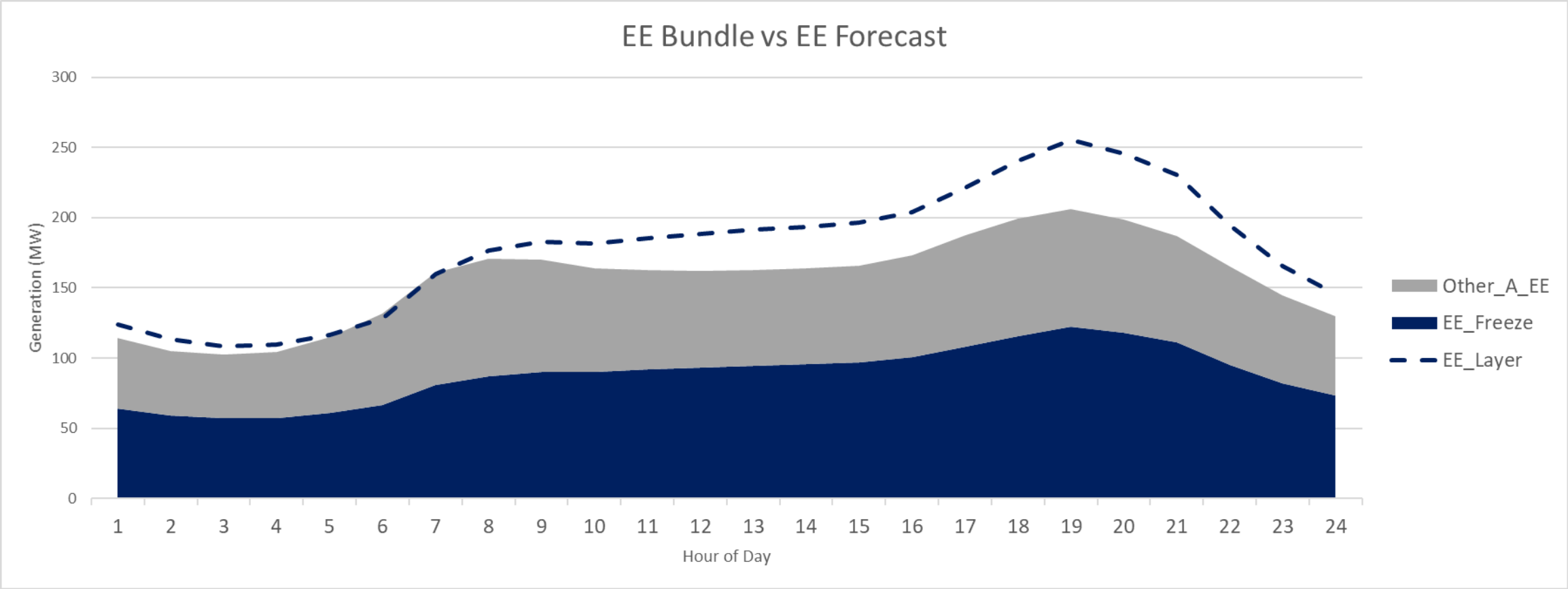
Summary – Energy Efficiency Supply Curves

- On O‘ahu and Hawai‘i Island, less energy efficiency is selected as a resource than the Base forecast.
- On Maui, Moloka‘i, and Lāna‘i, more energy efficiency is selected as a resource than the Base forecast.
- Measures that were identified as cost effective in AEG’s Market Potential Study were selected by RESOLVE (A, B supply curves).
- O‘ahu, Hawai‘i Island, and Lāna‘i preferred the Other, non-peak focused supply curves.
- Maui and Moloka‘i added Peak focused supply curves in addition to the Other supply curves.

EE Comparison

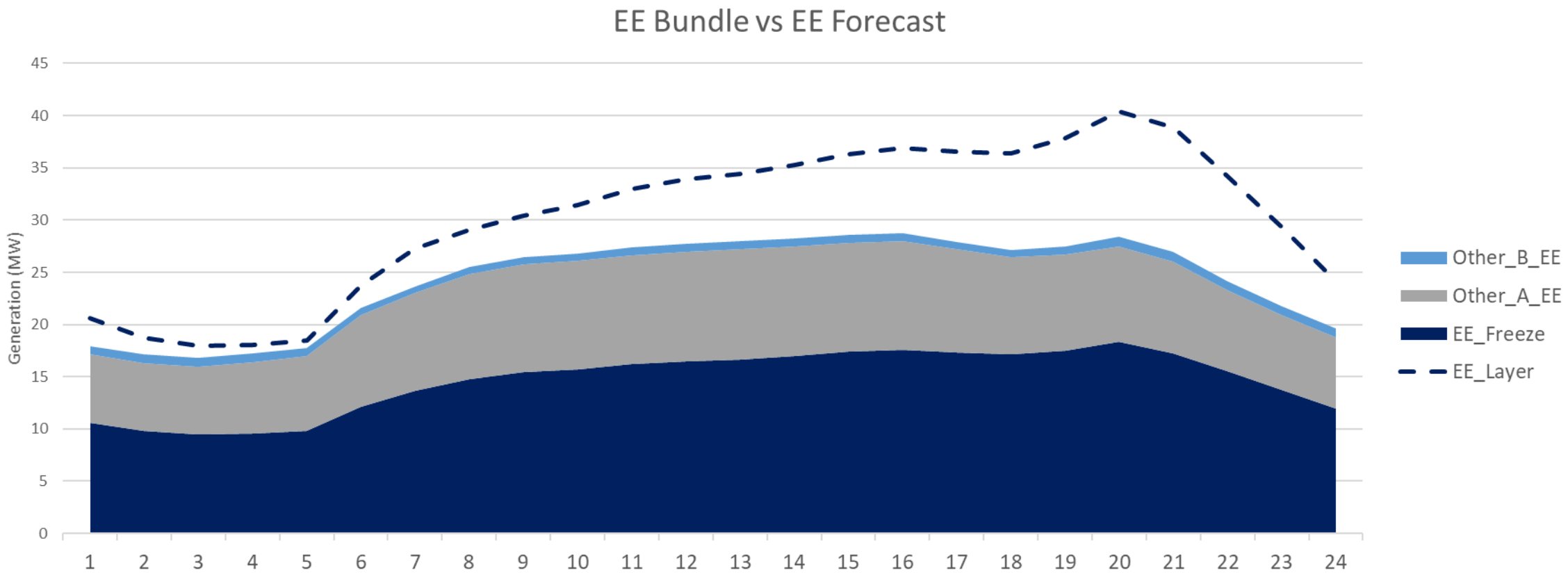
Year 2030 (GWh)	Energy Efficiency Base Forecast Layer	Energy Efficiency Selected as a Resource (Difference from Base Forecast)
O'ahu	1,418	1,309 (-109, -8%)
Hawai'i Island	250	197 (-52, -21%)
Maui	239	290 (+50, +21%)
Lana'i	1.3	2.8 (+1.5, +115%)
Moloka'i	1.4	2.9 (+1.5, +107%)

O'ahu – EE Shape Comparison – 2030



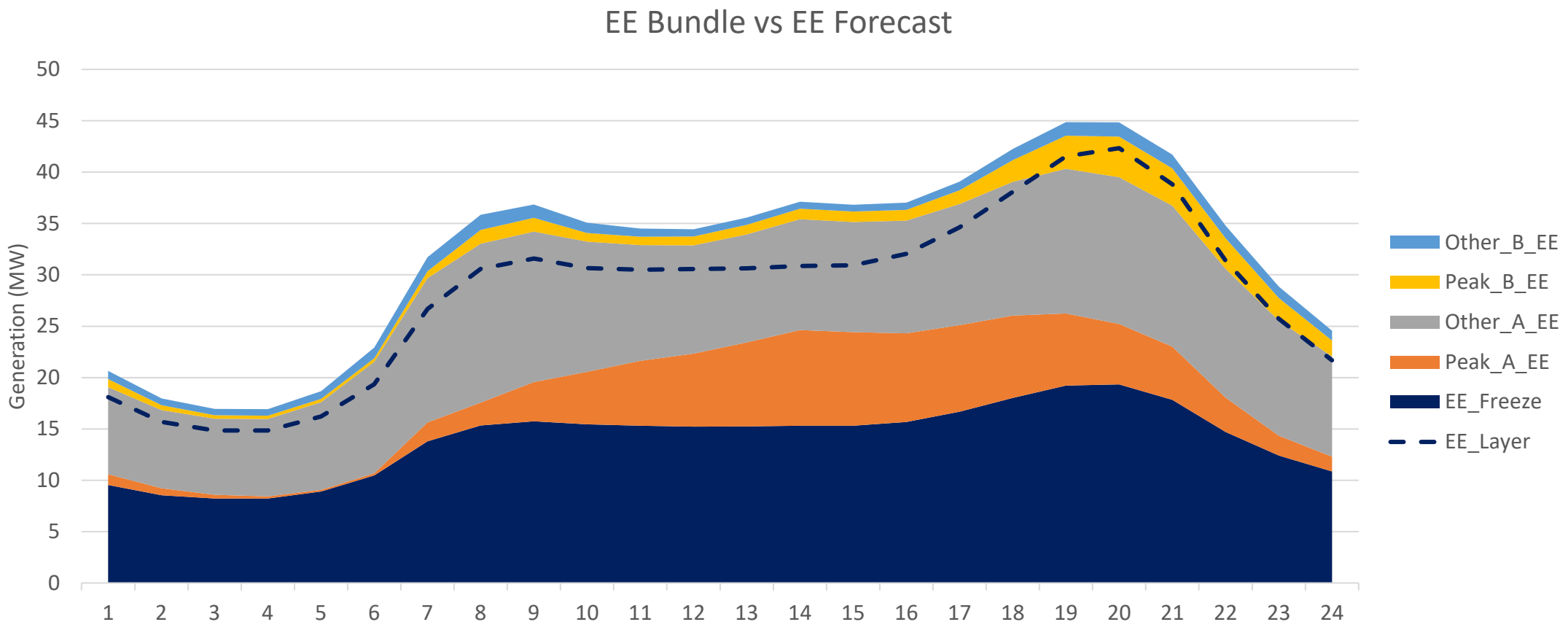
- Selected energy efficiency was less than assumed in the base forecast

Hawai'i – EE Shape Comparison – 2030



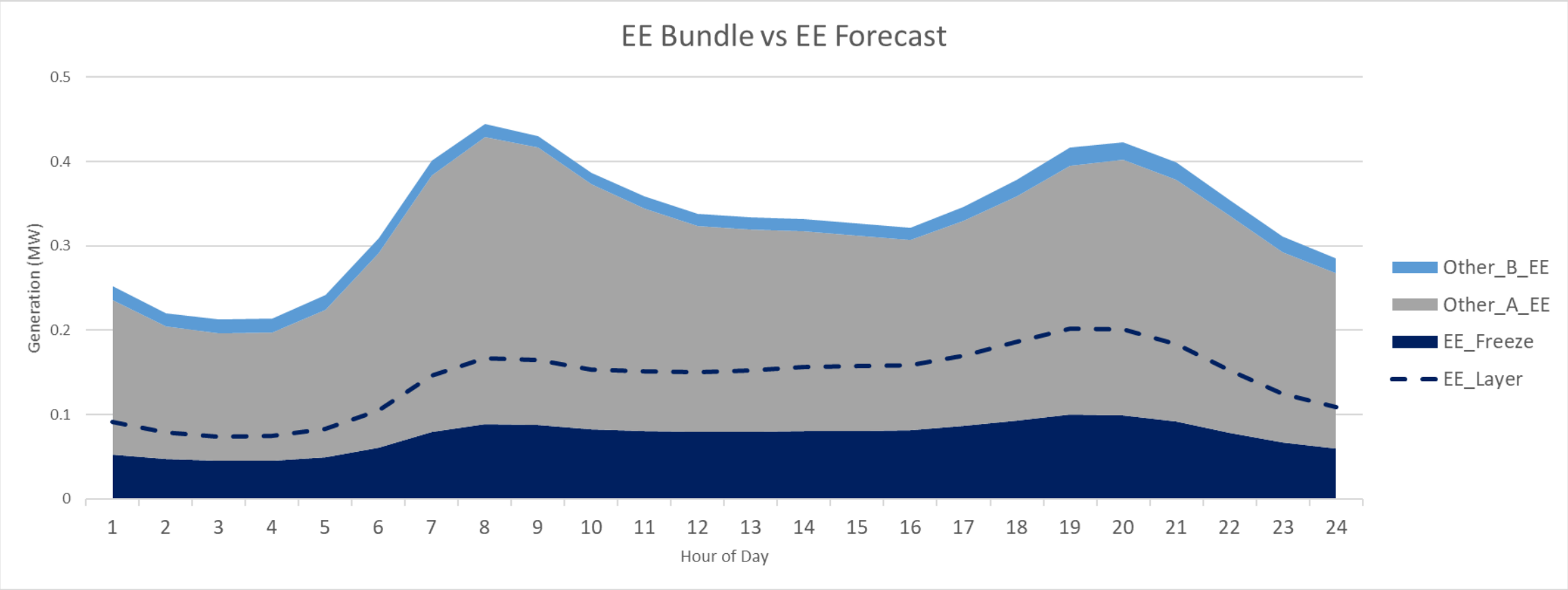
- Selected energy efficiency was less than assumed in the base forecast

Maui – EE Shape Comparison – 2030



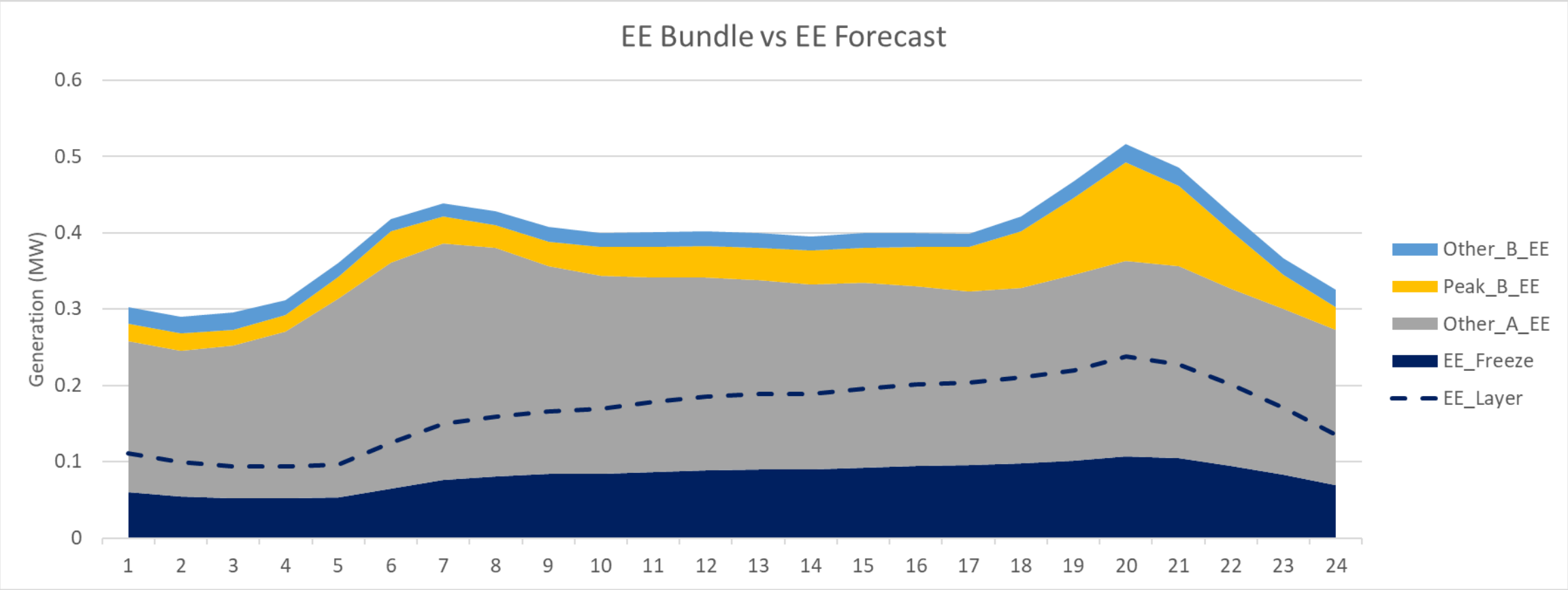
- Selected energy efficiency was more than assumed in the base forecast

Lana'i – EE Shape Comparison – 2030



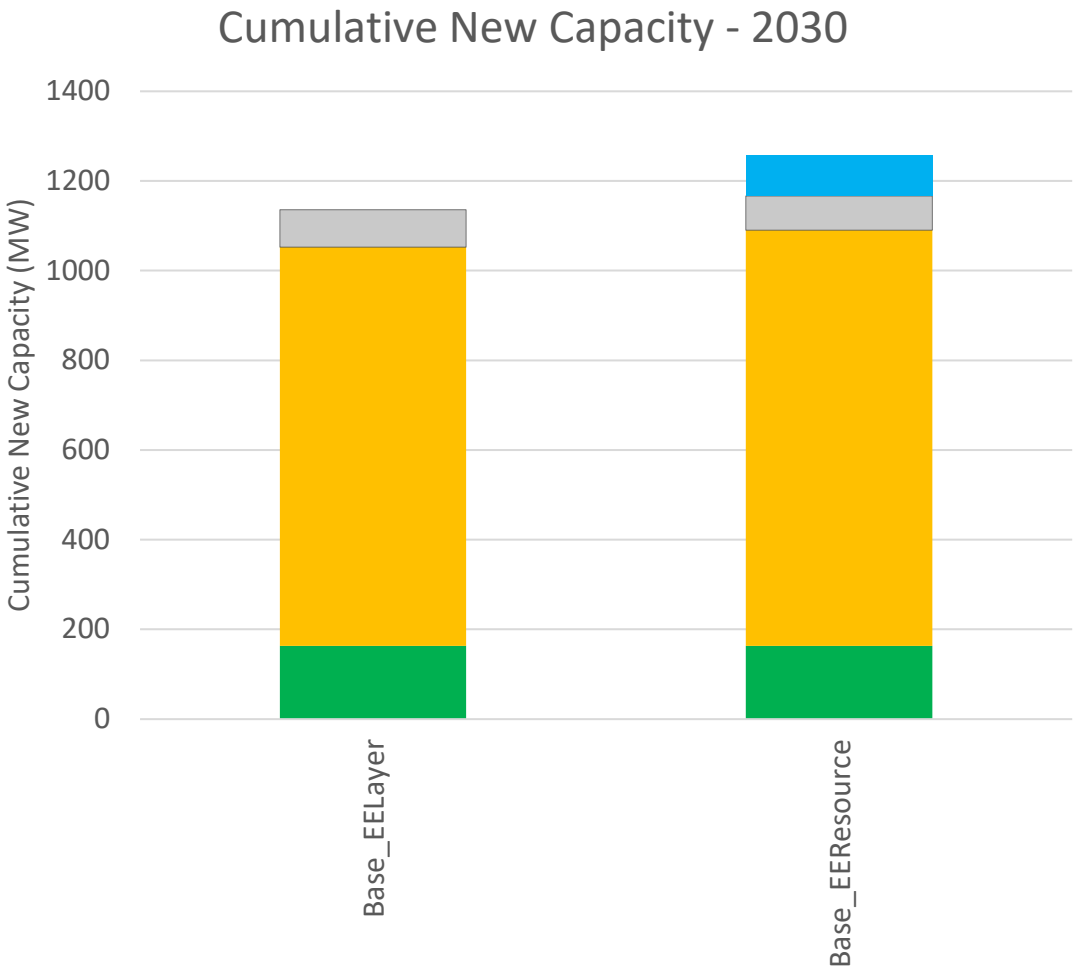
- Selected energy efficiency was more than assumed in the base forecast

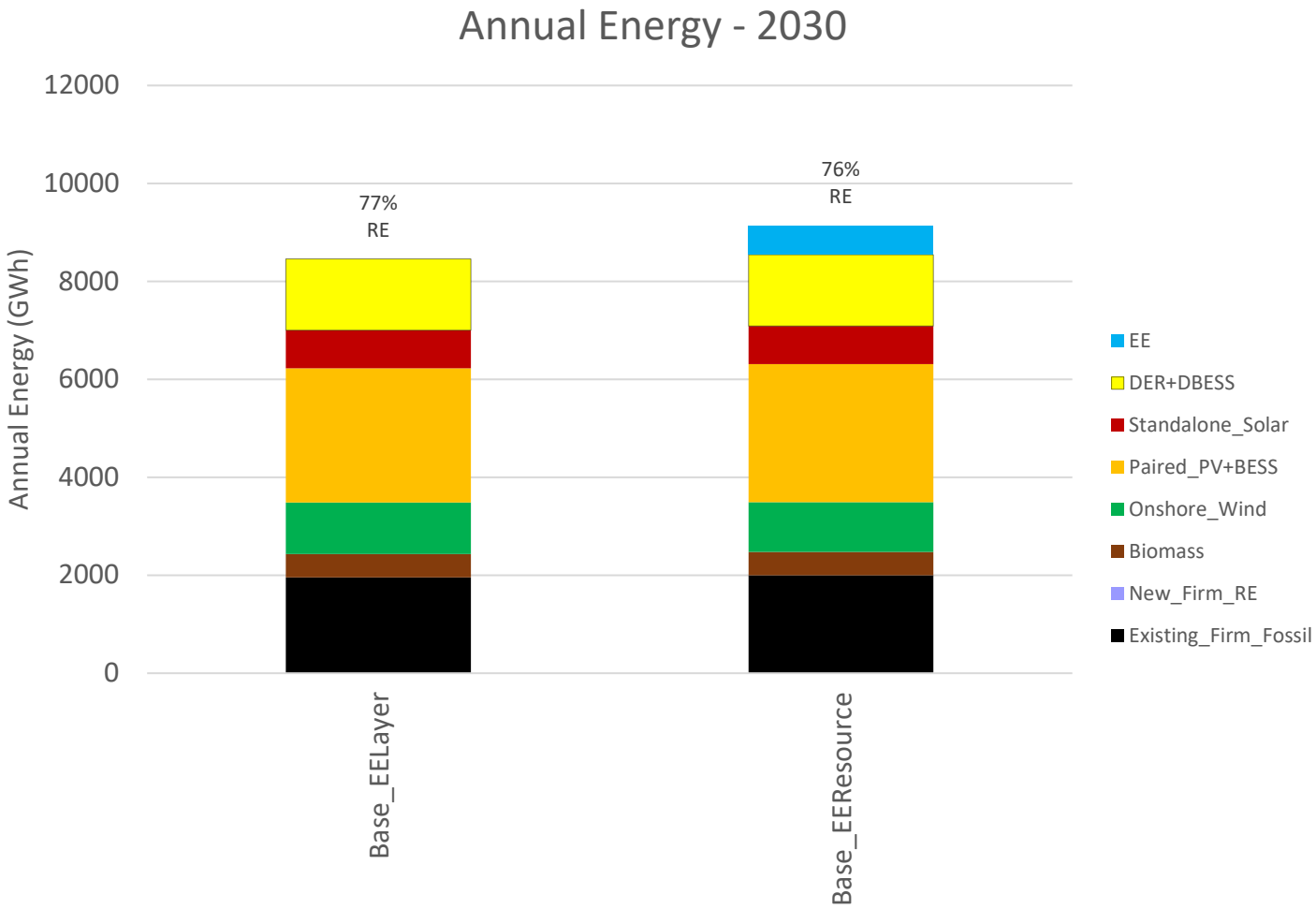
Moloka'i – EE Shape Comparison – 2030



- Selected energy efficiency was more than assumed in the base forecast

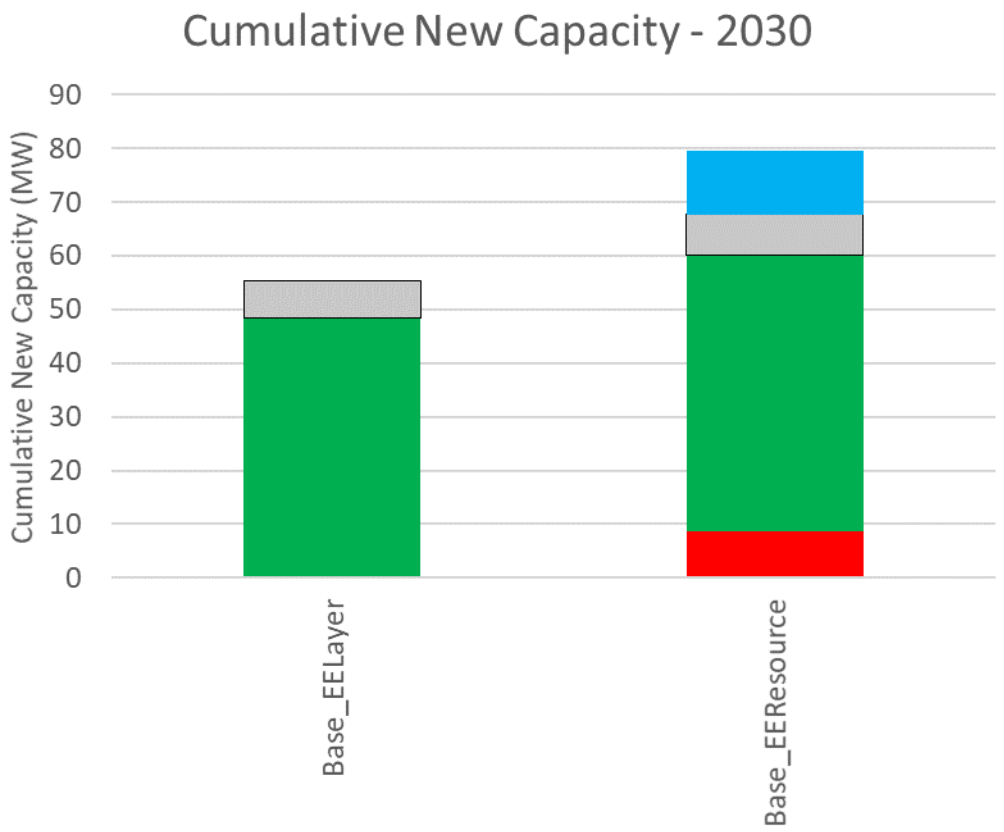
O'ahu – EE Supply Curves – 2030

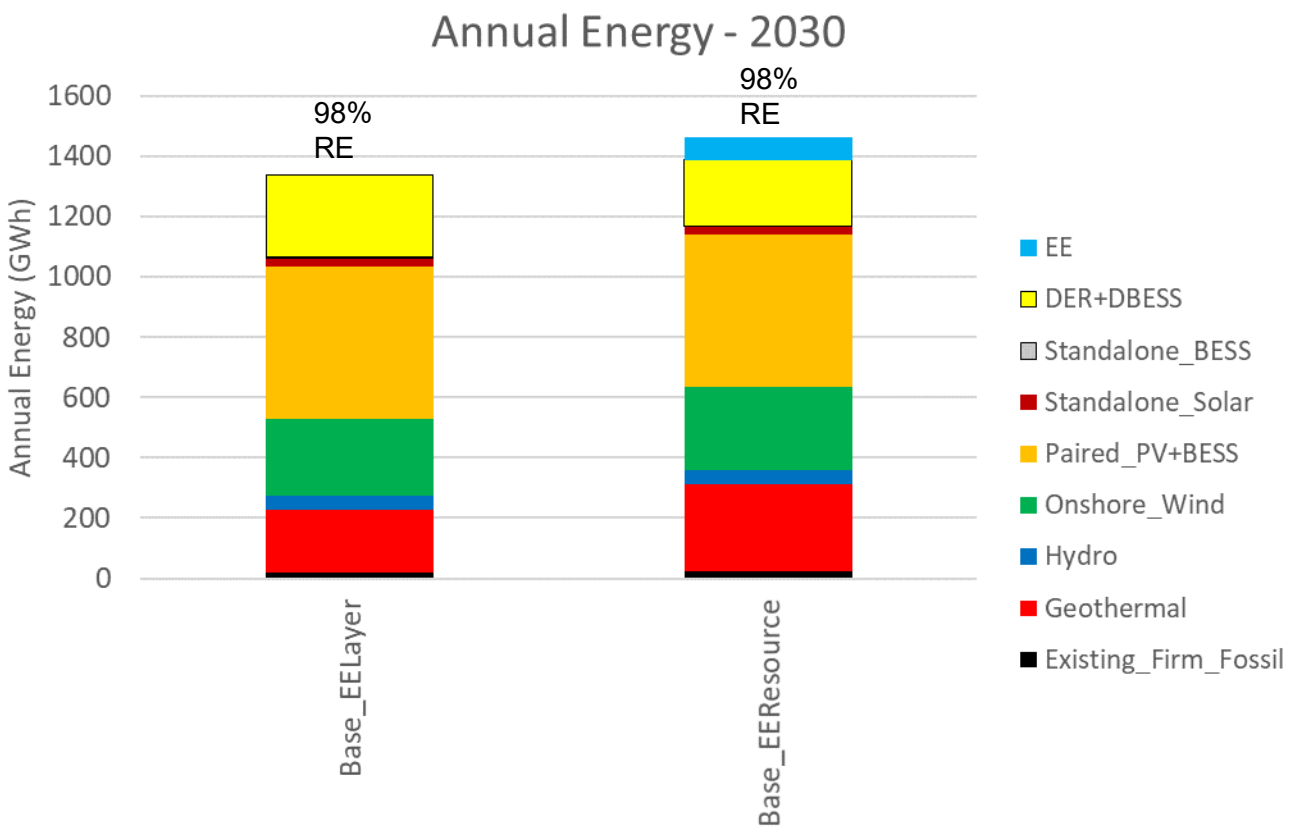




- On O‘ahu, additional paired PV was selected when EE supply curves were available.

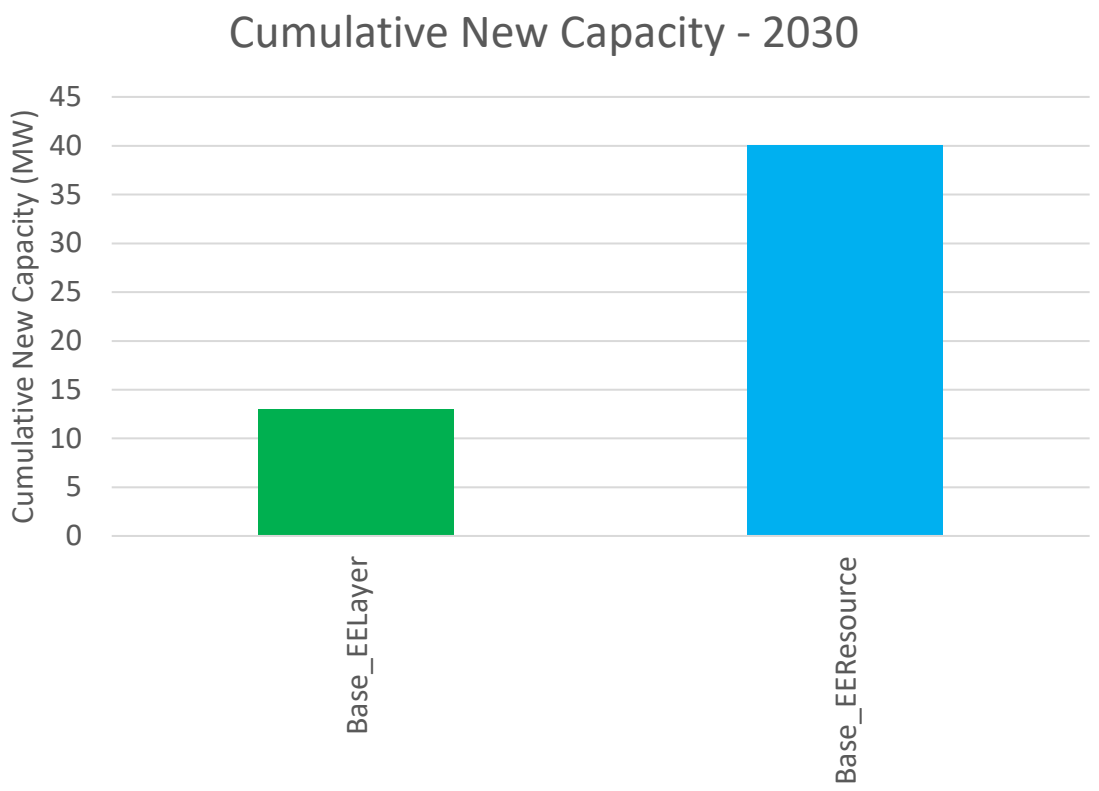
Hawai'i – EE Supply Curves – 2030

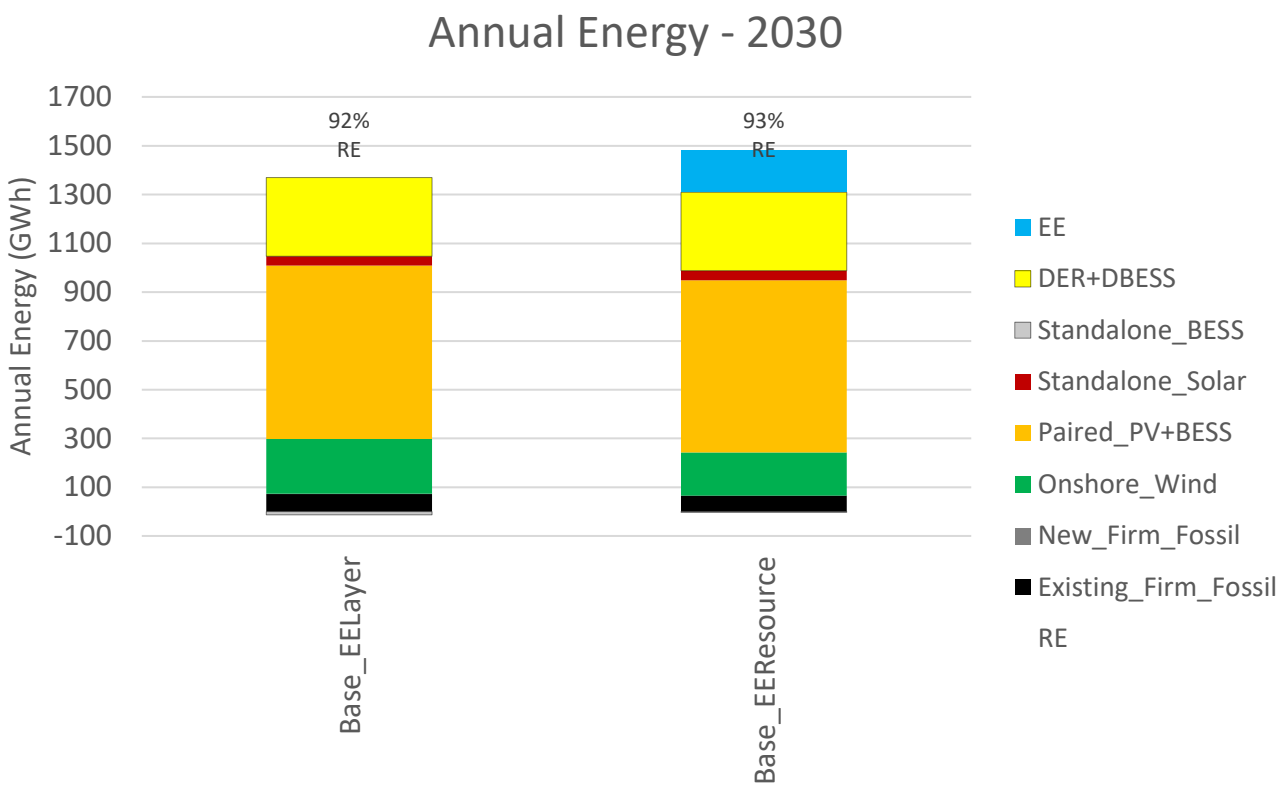




- On Hawai'i Island, additional wind and geothermal were selected when EE supply curves were available.

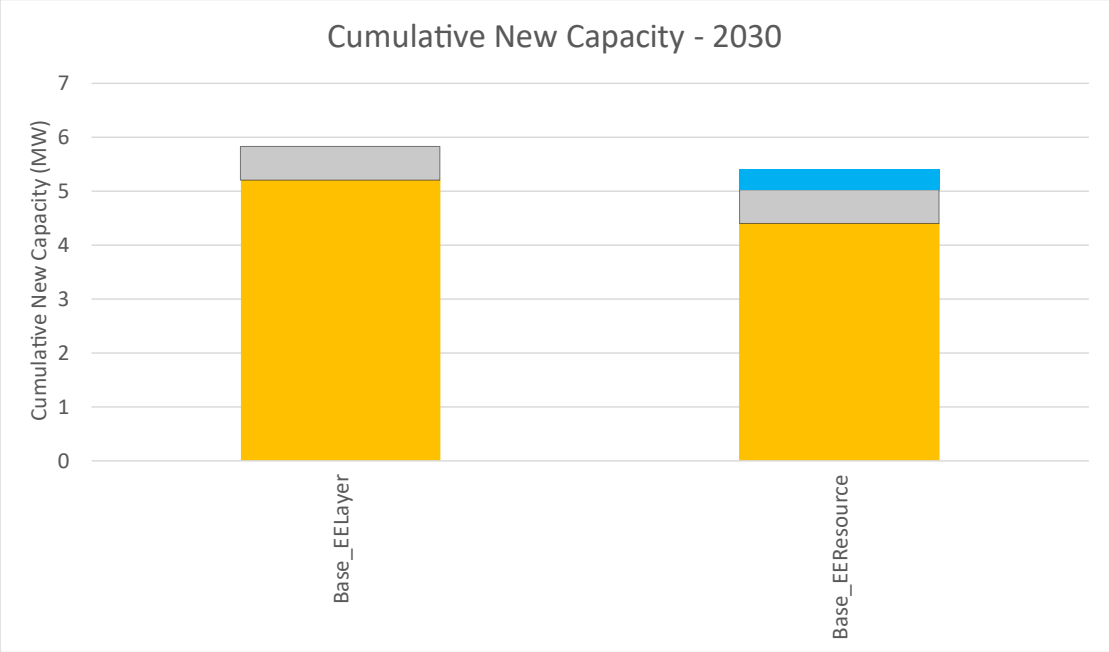
Maui – EE Supply Curves – 2030

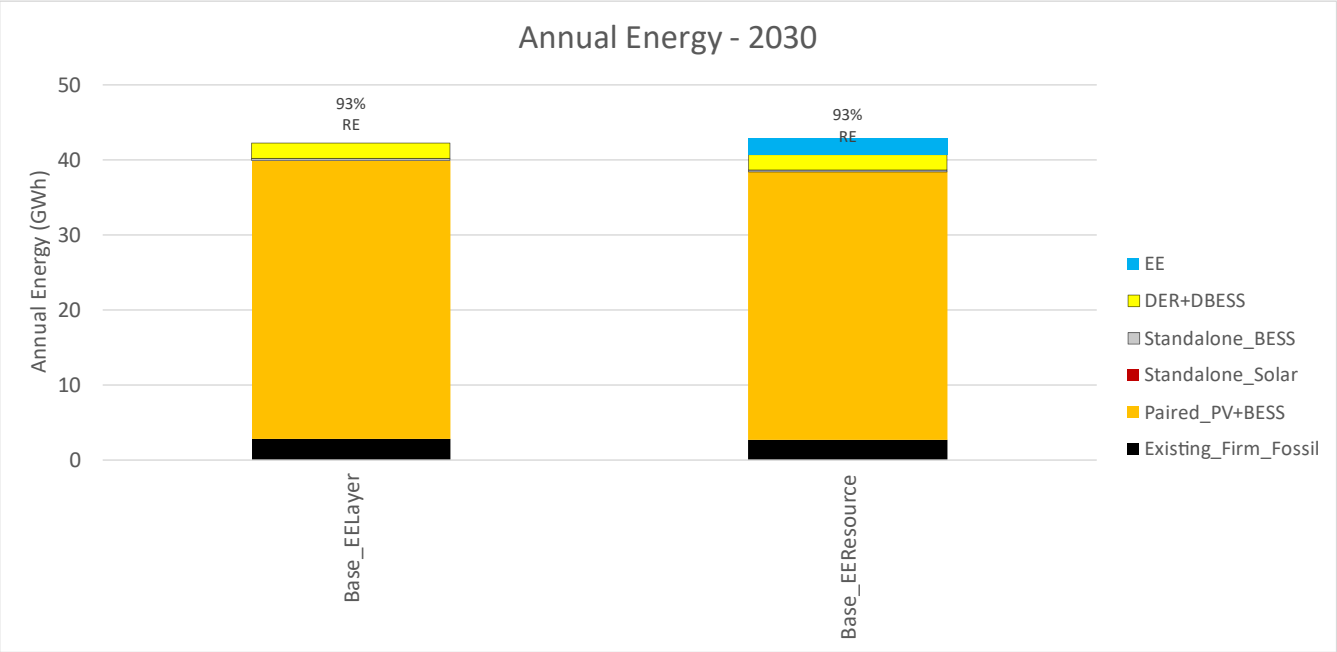




- On Maui, less onshore wind was selected when EE supply curves were available.

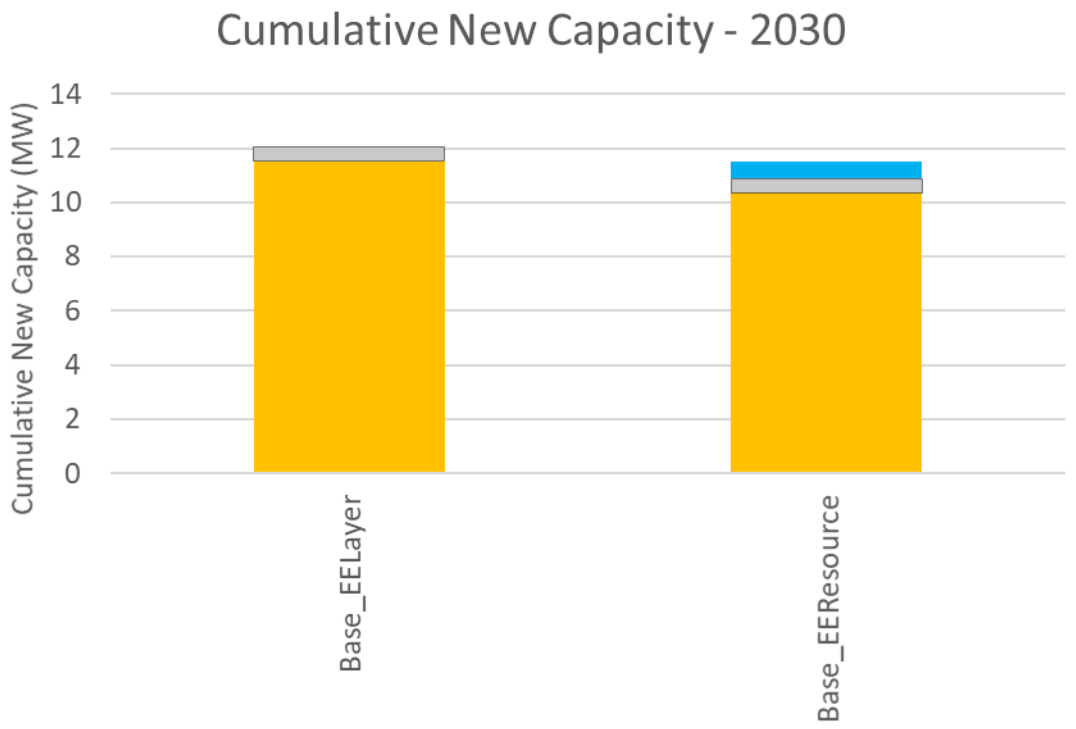
Lana'i – EE Supply Curves – 2030

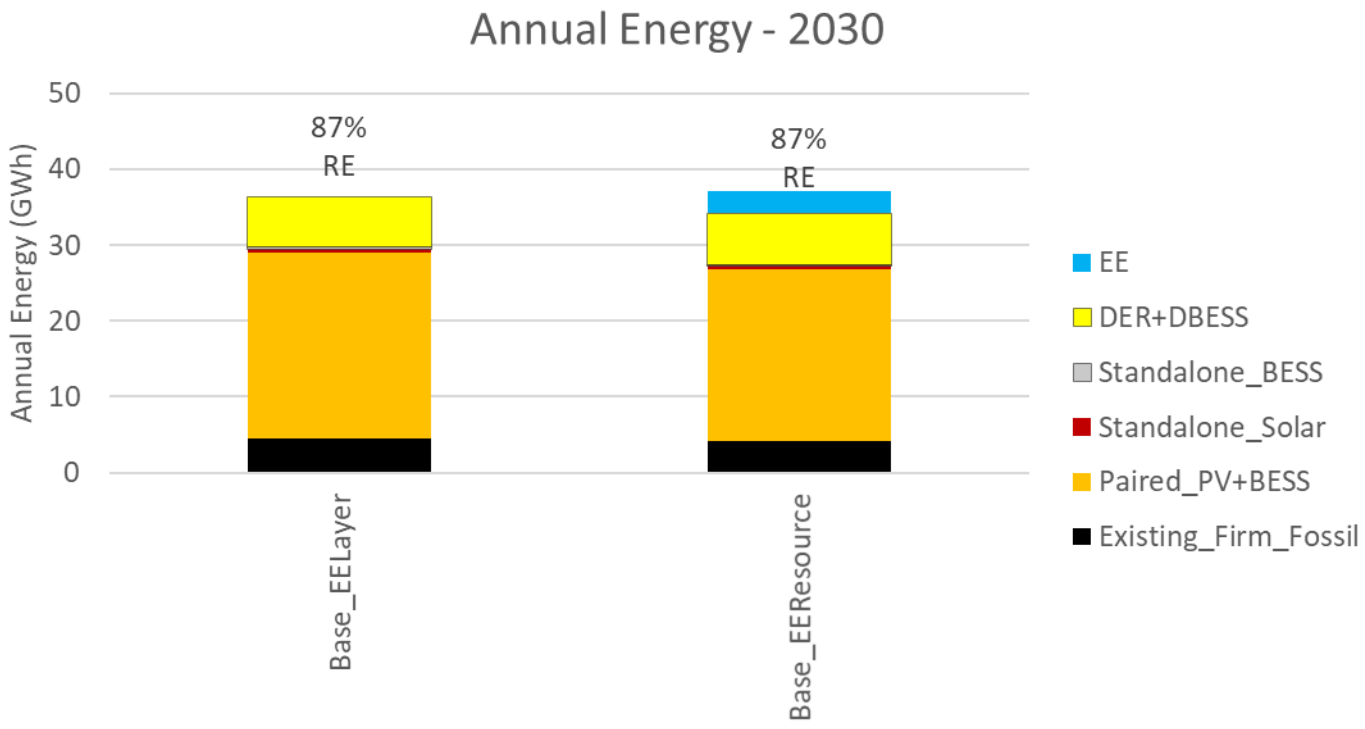




- On Lānaʻi, less paired PV was selected when EE supply curves were available.

Moloka'i – EE Supply Curves – 2030





- On Moloka‘i, less paired PV was selected when EE supply curves were available.

Next Steps

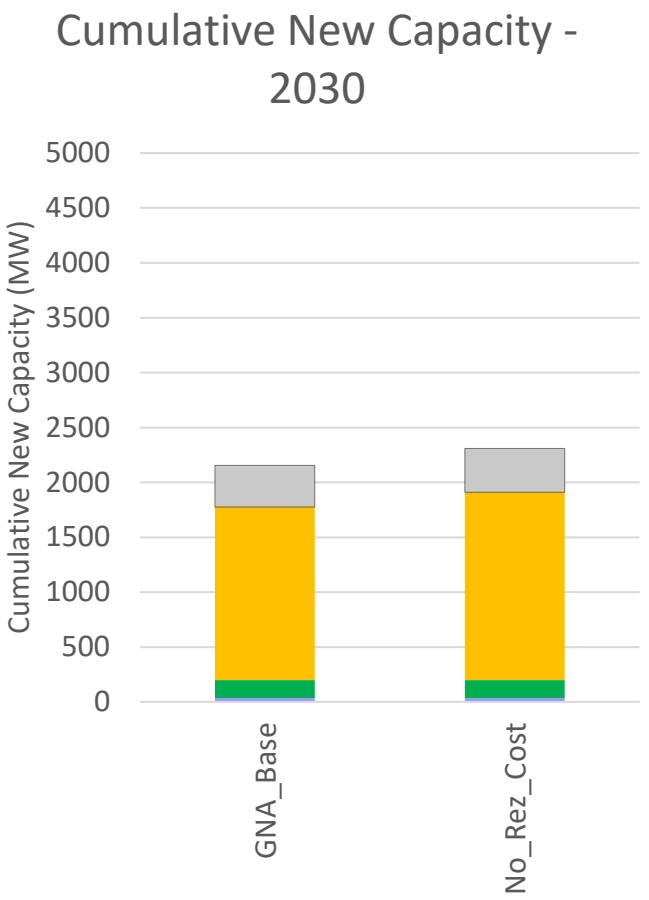
Since the Companies are continuing with T&D Needs and Resource Adequacy analysis, the Companies request any feedback or comments on the Capacity Expansion (RESOLVE) analysis presented in this deck by December 14, 2022. At the December 15, 2022 STWG meeting, the Companies will share any feedback and any adjustments that may be needed.

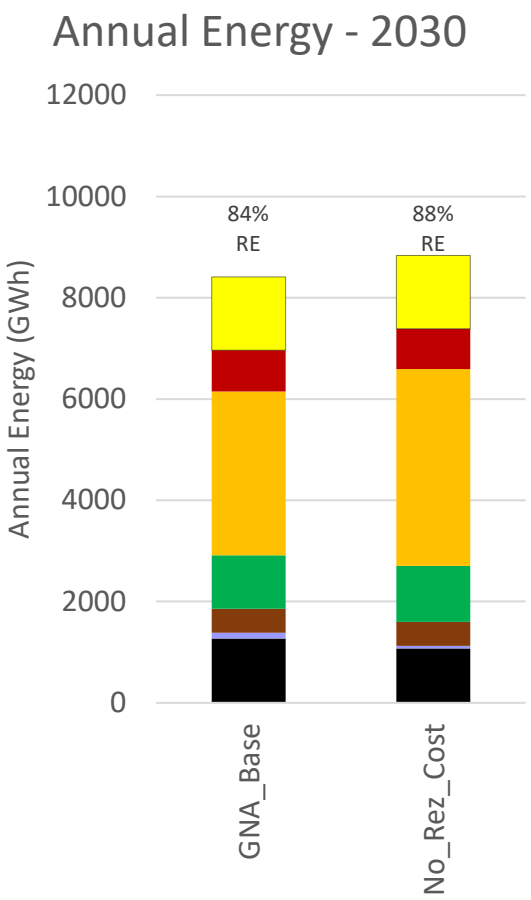
Comments on the Base case should be prioritized since the Resource Adequacy analysis will be based upon the Base resource plan.

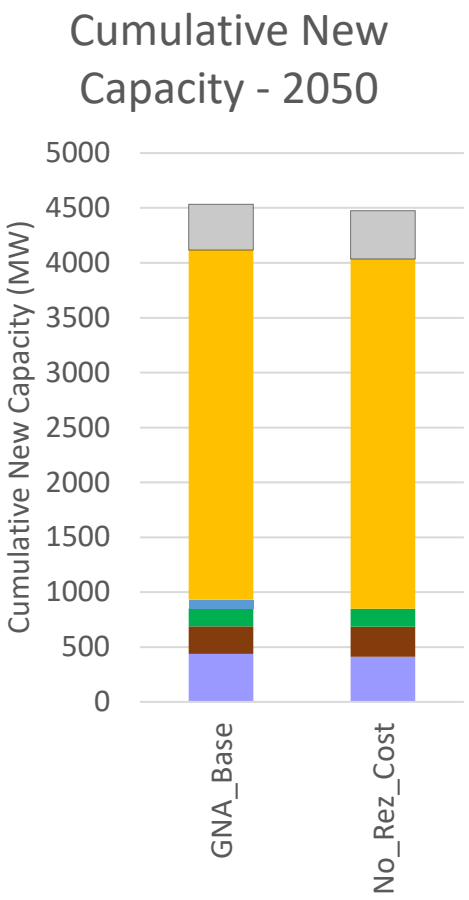
The next step in the IGP process is to conduct Resource Adequacy on the Base Case for each island system and continue with the Transmission Needs analysis.

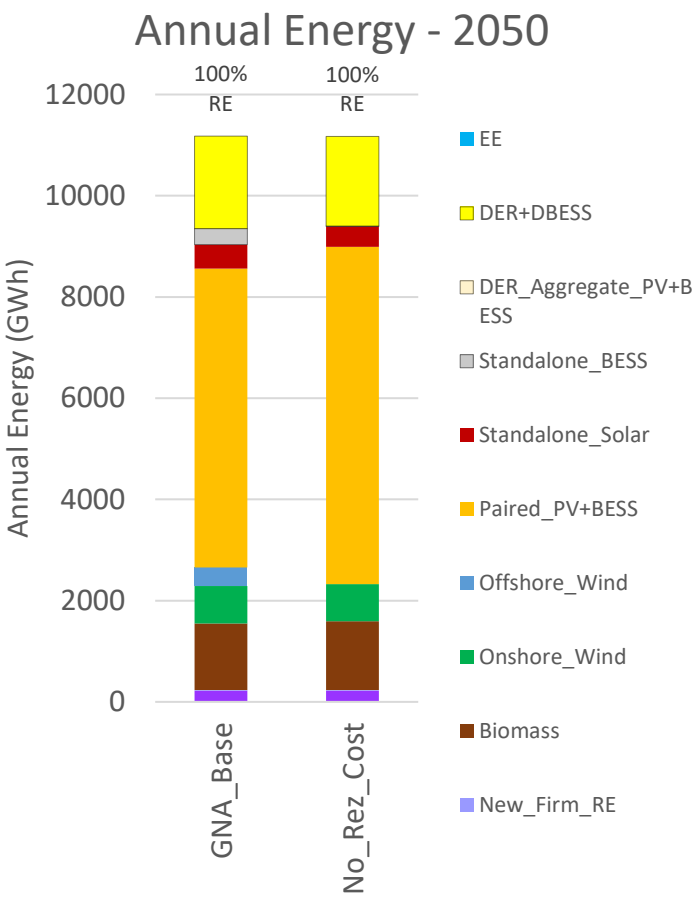
Appendix

O‘ahu No REZ Cost



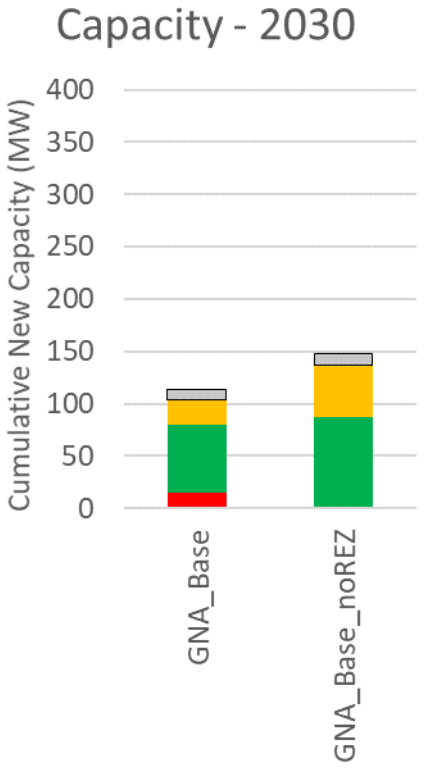


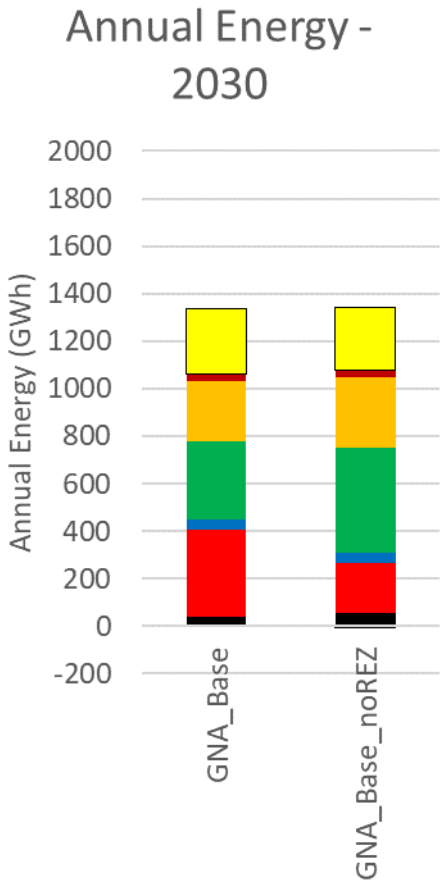


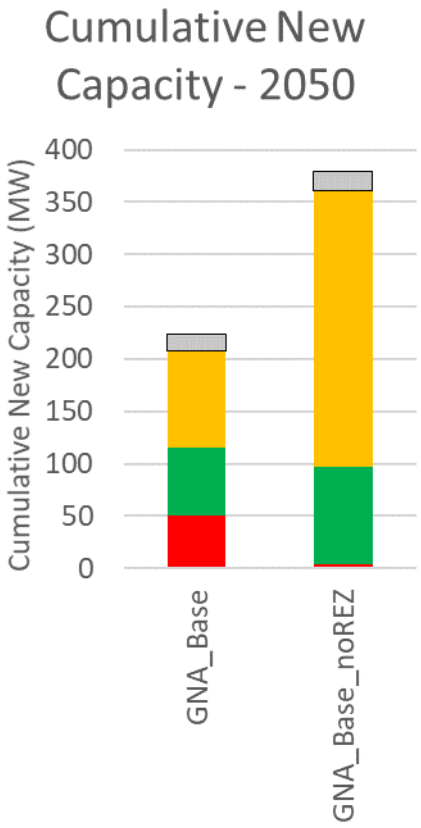


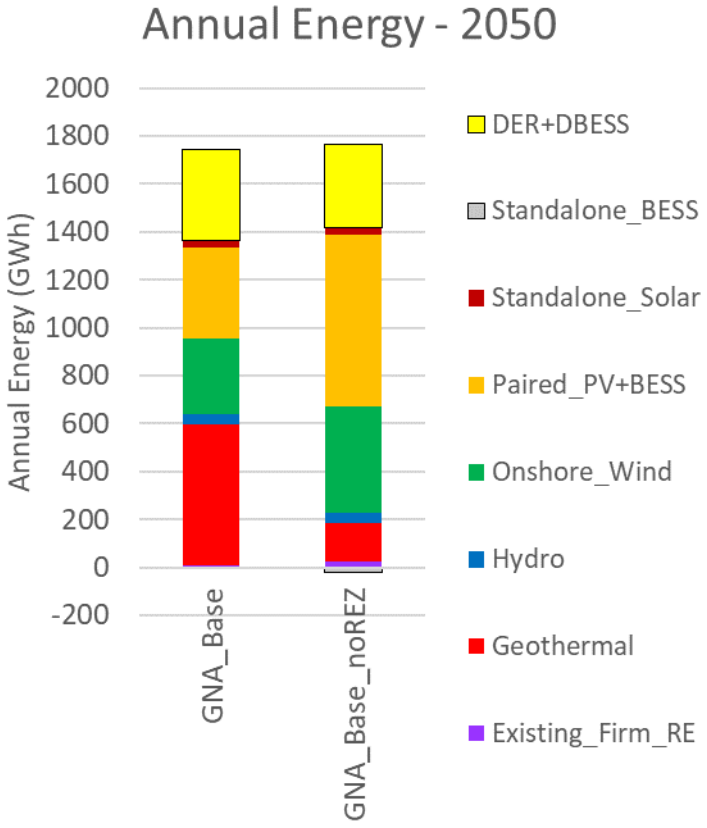
- With no REZ costs, more paired PV is built sooner. In later years, a small amount of firm RE switches to biomass and offshore wind is not built.

Hawai‘i Island No REZ Cost



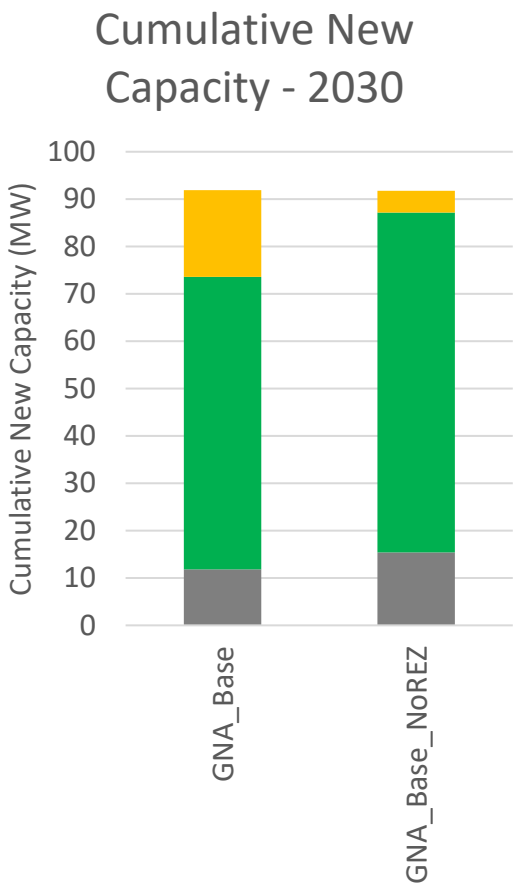


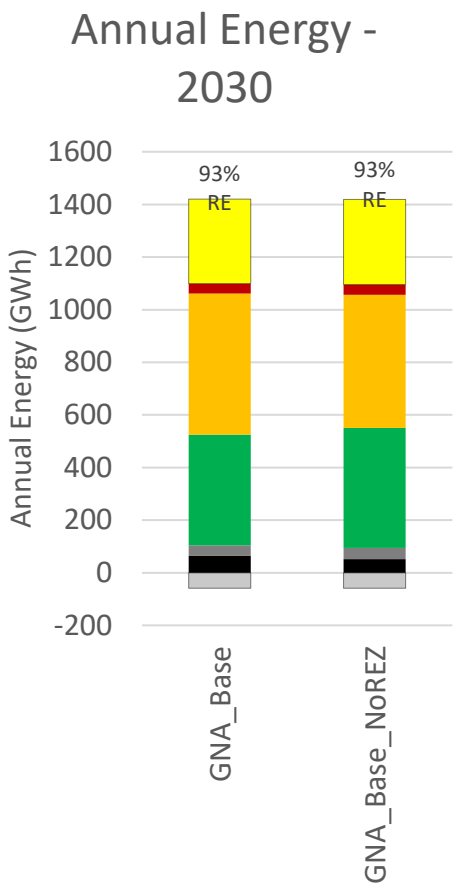


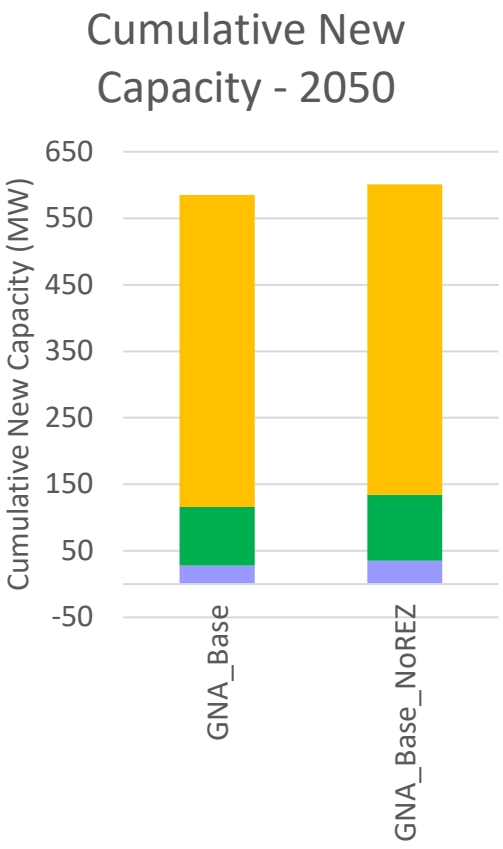


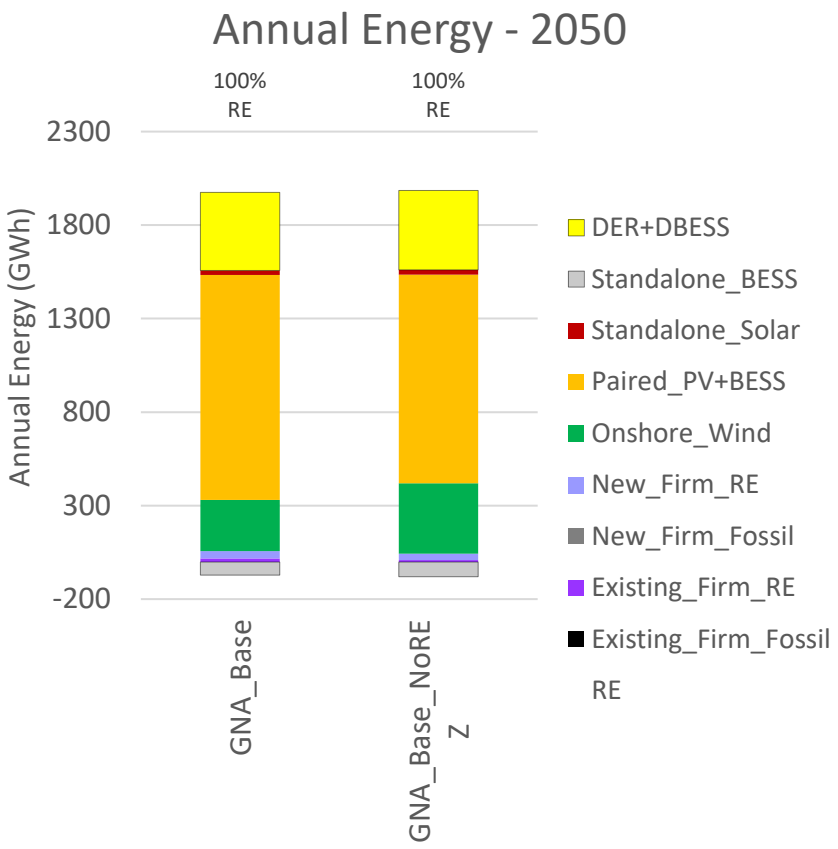
- With no REZ costs, more onshore wind and less geothermal is built.

Maui No REZ Cost



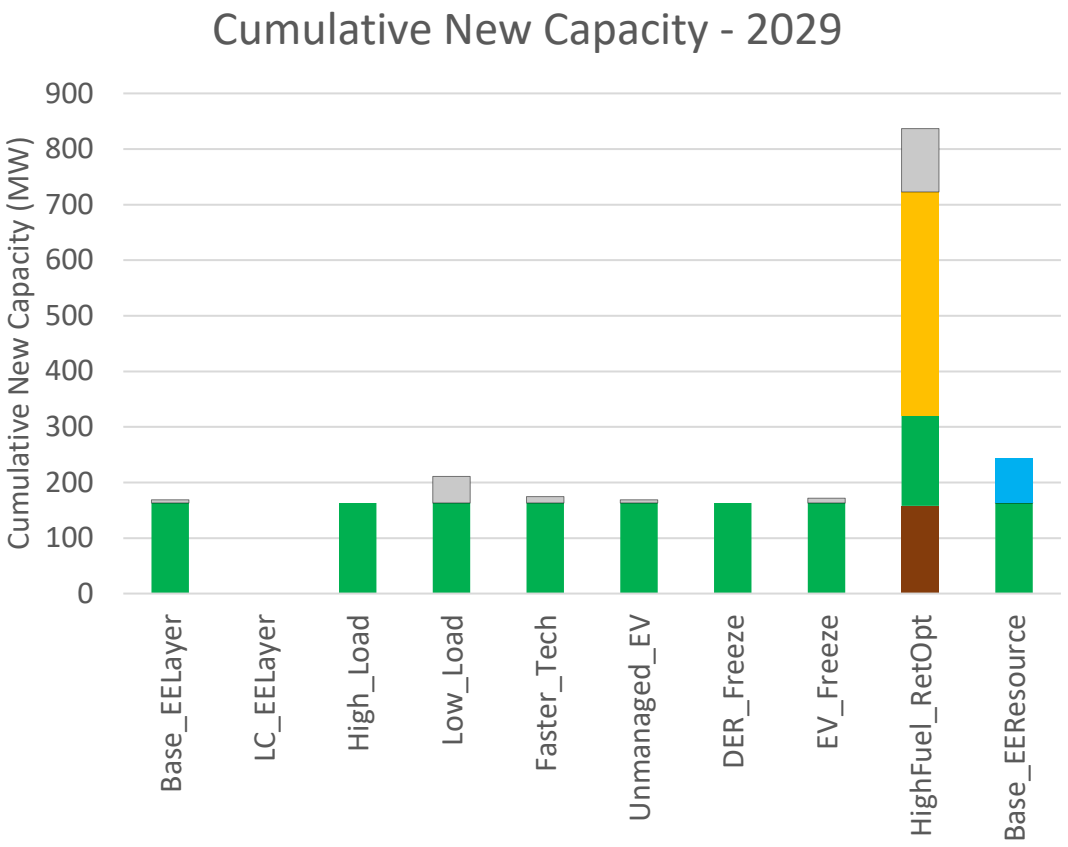


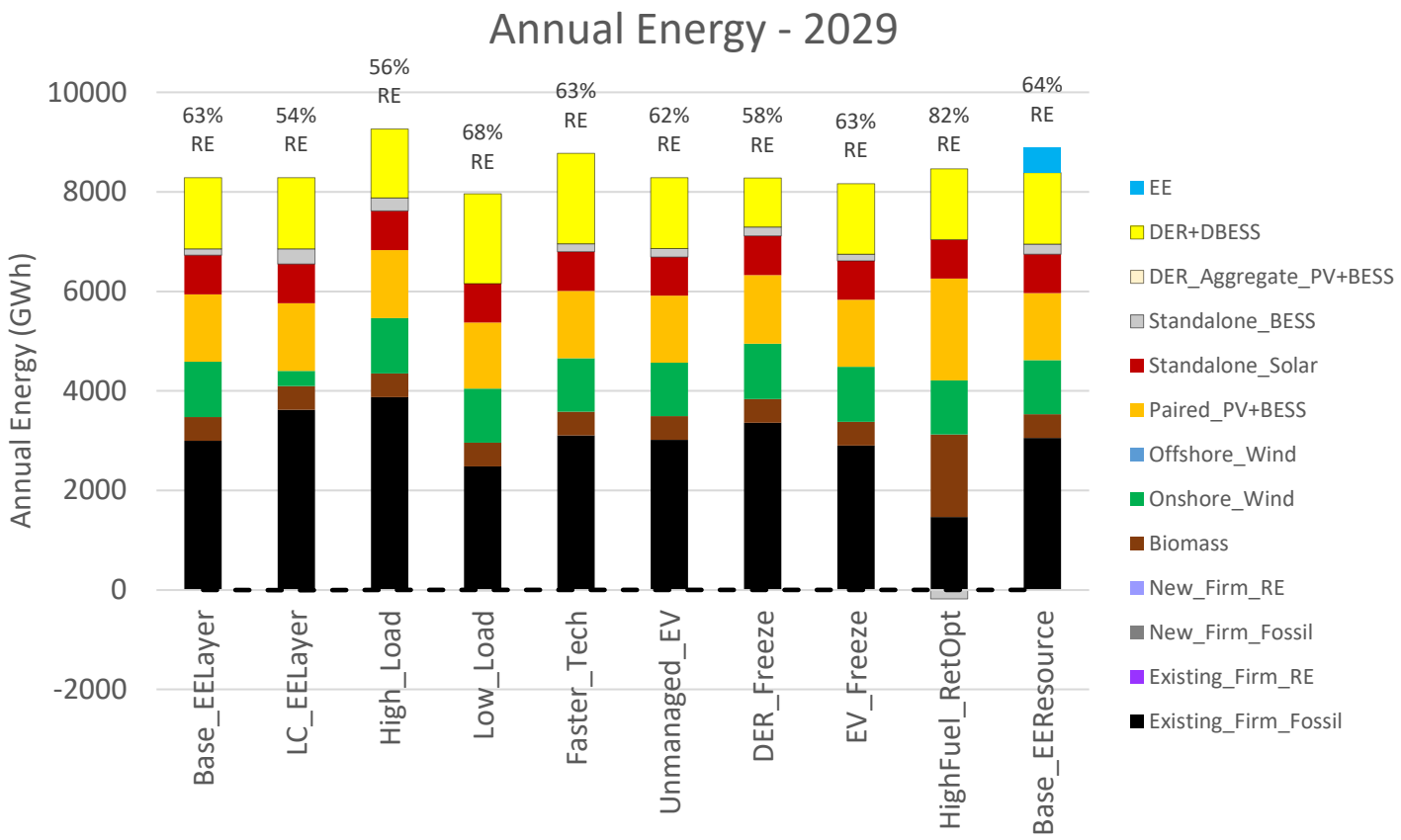




- With no REZ costs, more onshore wind and less paired PV is built.

O'ahu– 2029

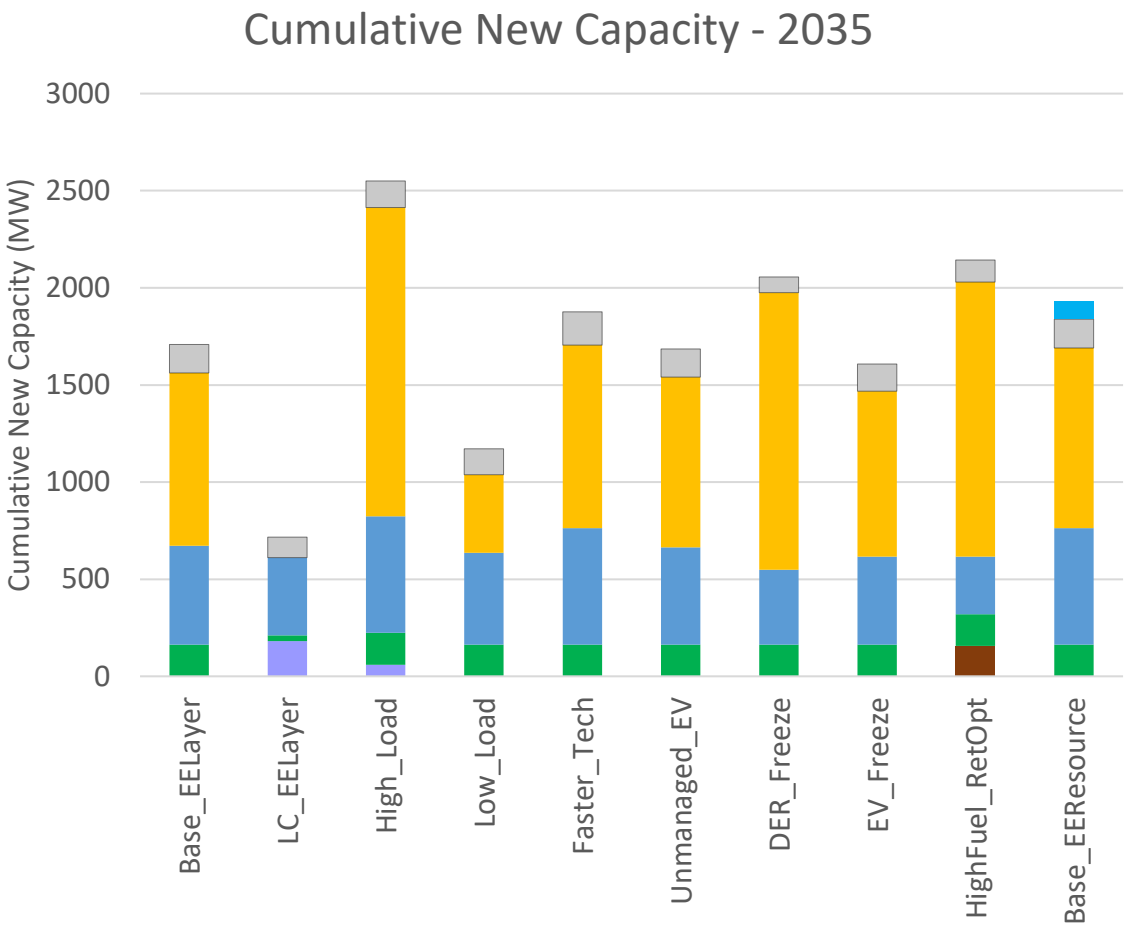


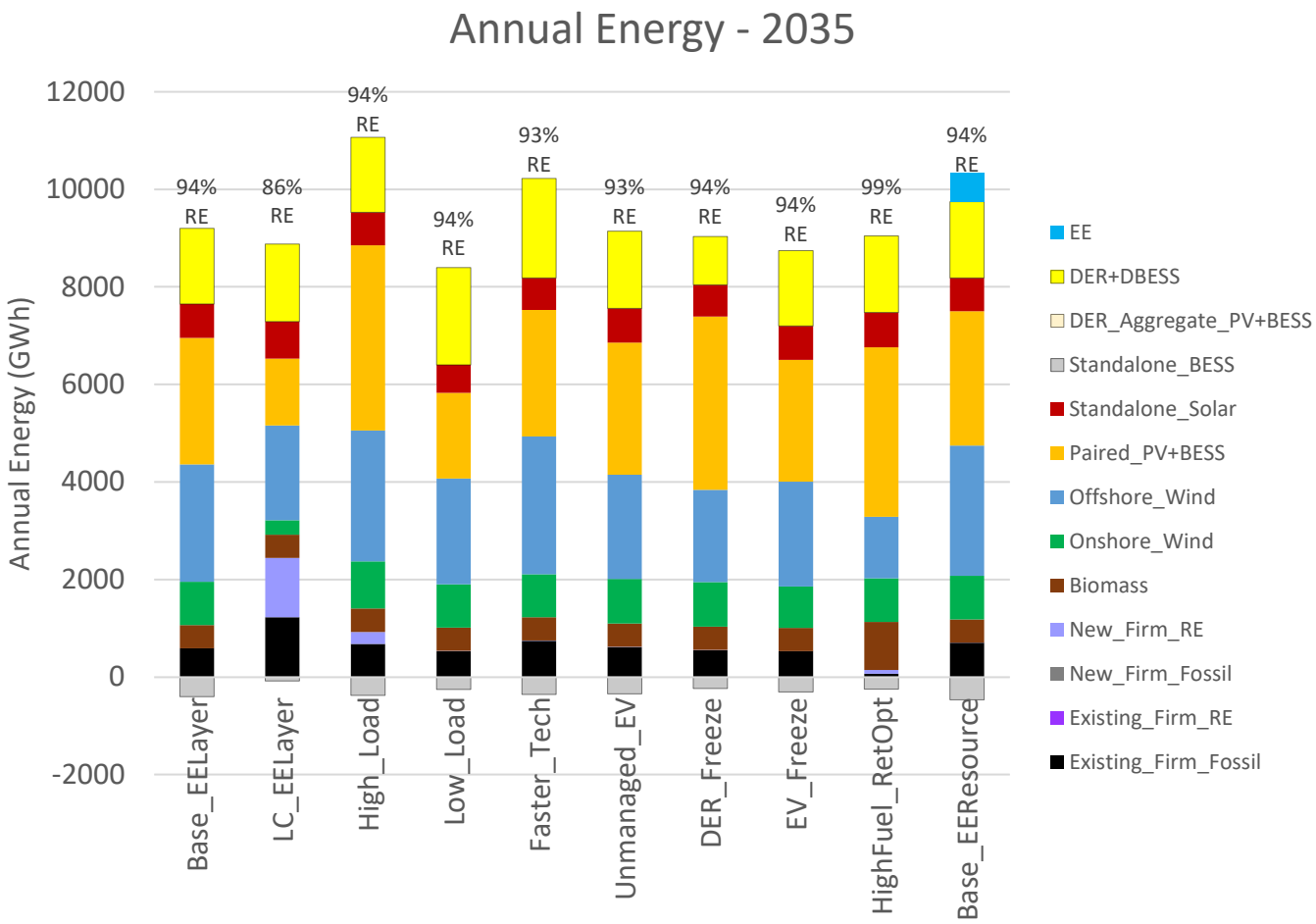


In the HighFuel_RetOpt case, RESOLVE Retires 694 MW of firm capacity and builds 837 MW of new Firm and Variable RE causing the RE to be higher than the other cases in the same year.

In the Land Constrained (LC_EELayer) case, it is assumed that the Stage 3 resources use all available potential and is unable to build any utility scale PV and onshore wind.

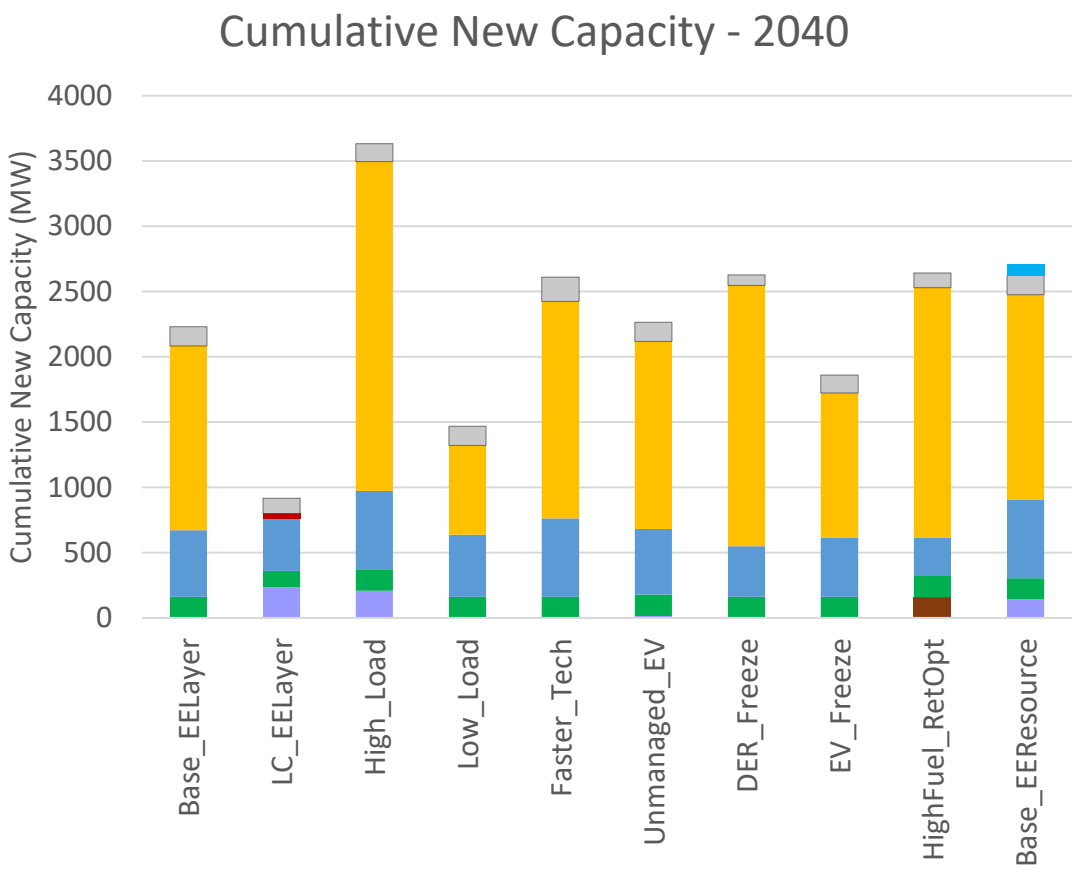
O'ahu– 2035

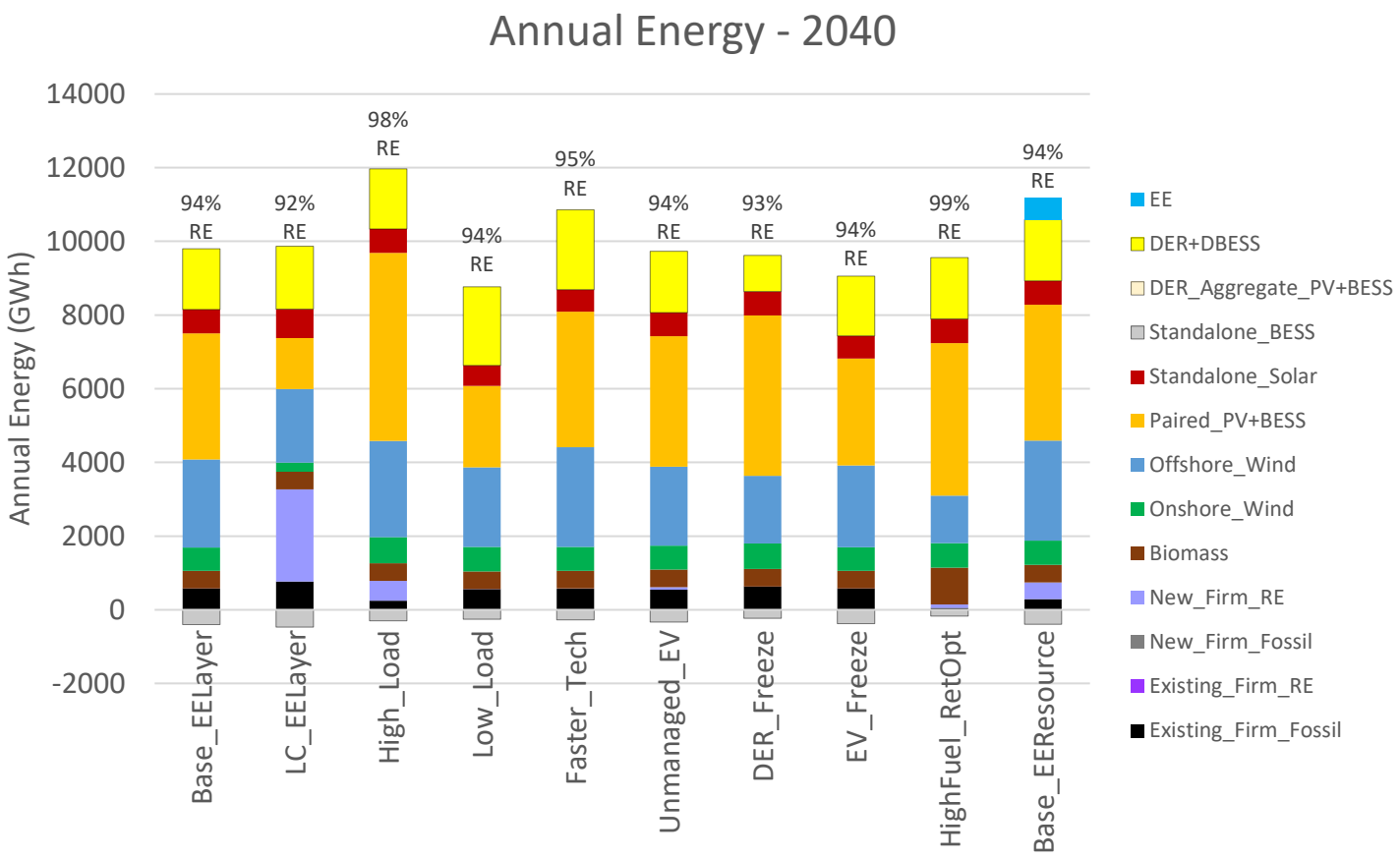




In the Land Constrained (LC_EELayer) case, the onshore wind that is being built is from expired PPAs where their potential is made available to RESOLVE to build replacement resources of the same type.

O'ahu– 2040

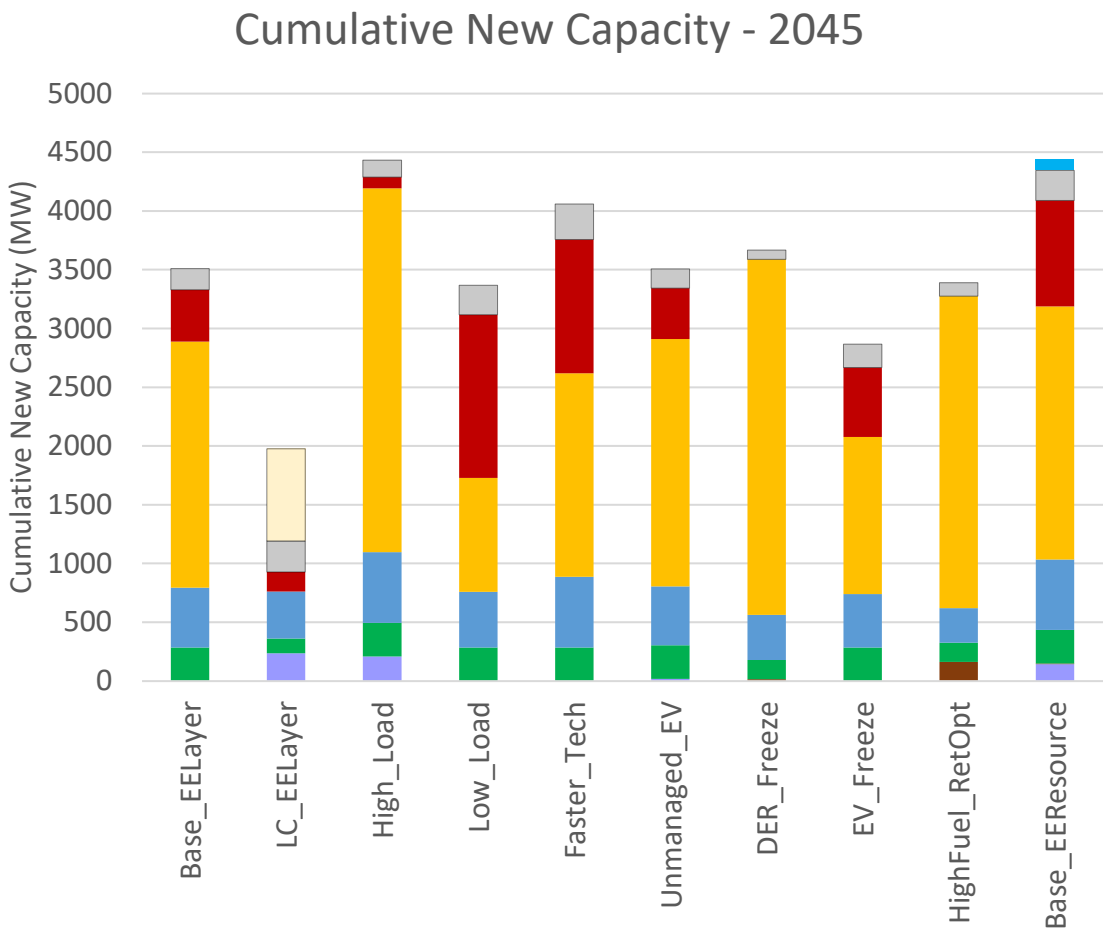


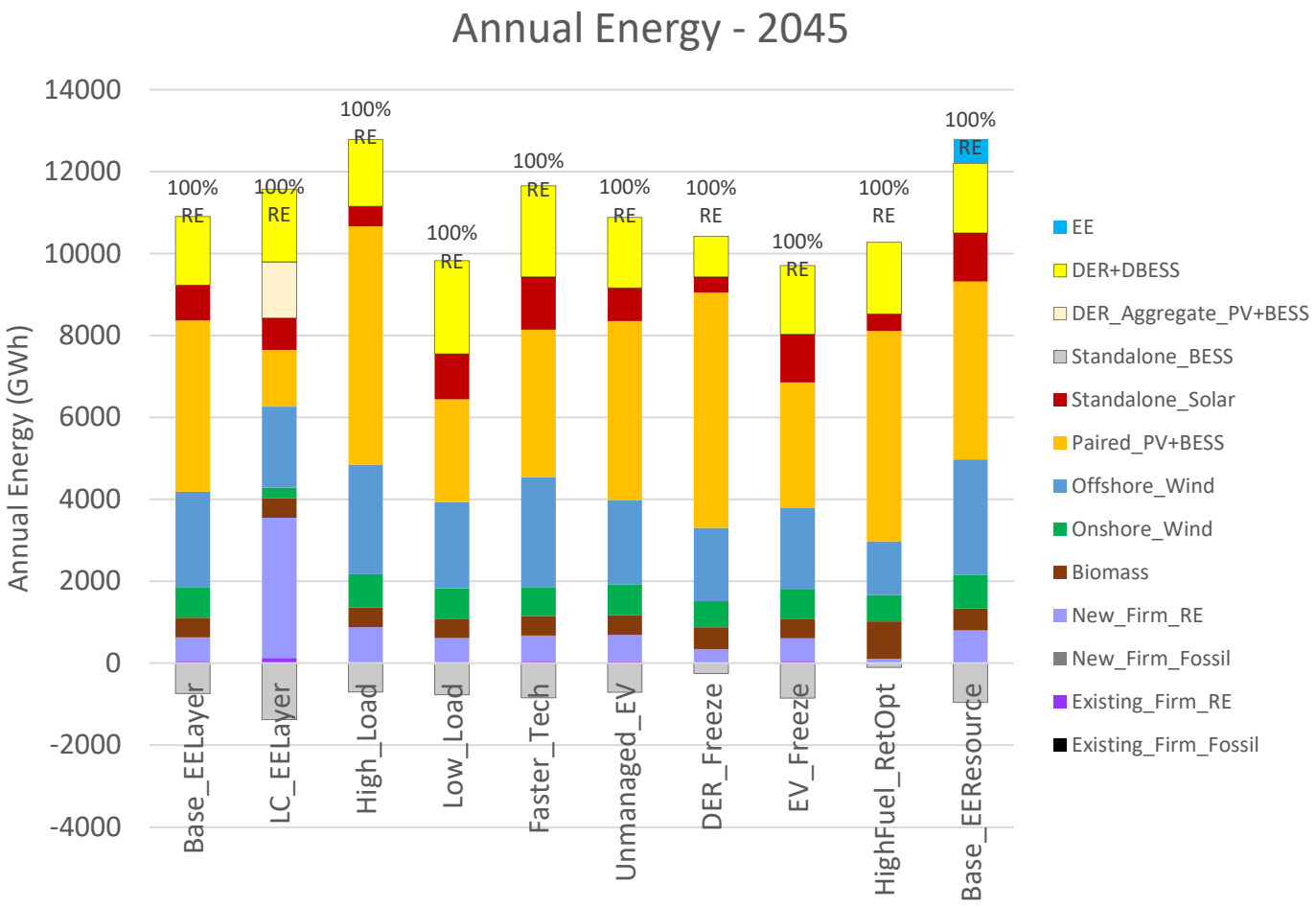


In the Land Constrained (LC_EELayer) case, the standalone PV that is being built is from expired PPAs where their potential is made available to RESOLVE to build replacement resources of the same type.

The HighFuel_RetOpt case consumes the least amount of fossil fuel where Biomass and New Firm RE served a portion of the energy needs.

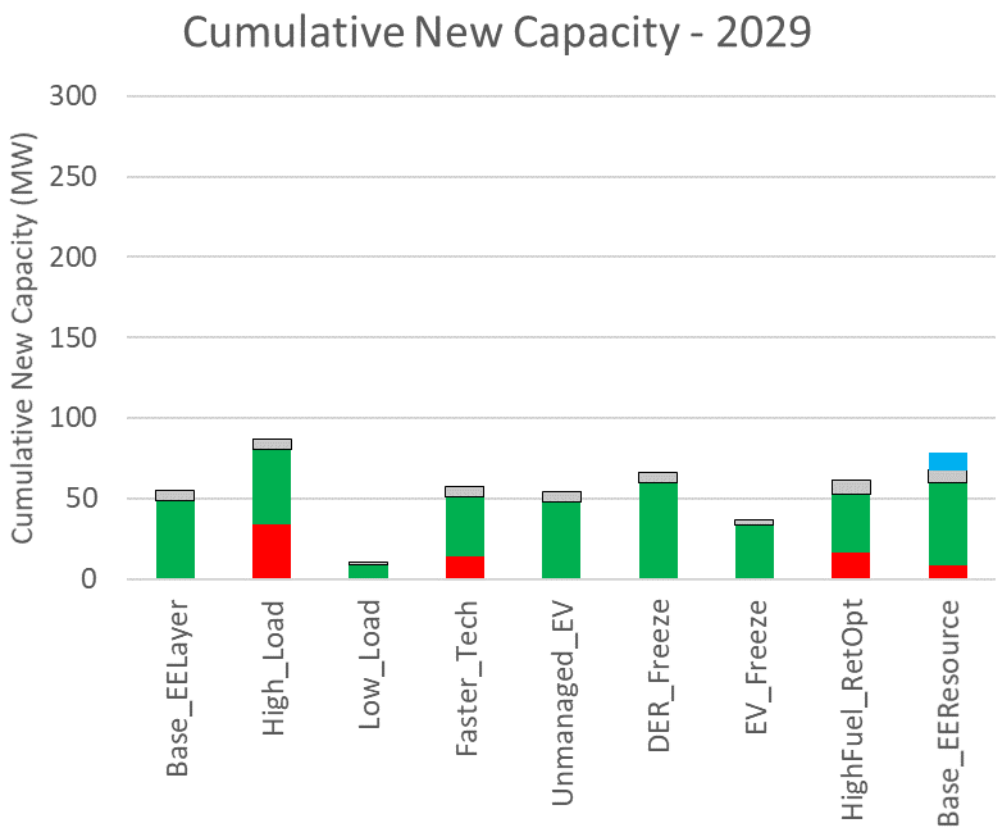
O'ahu– 2045

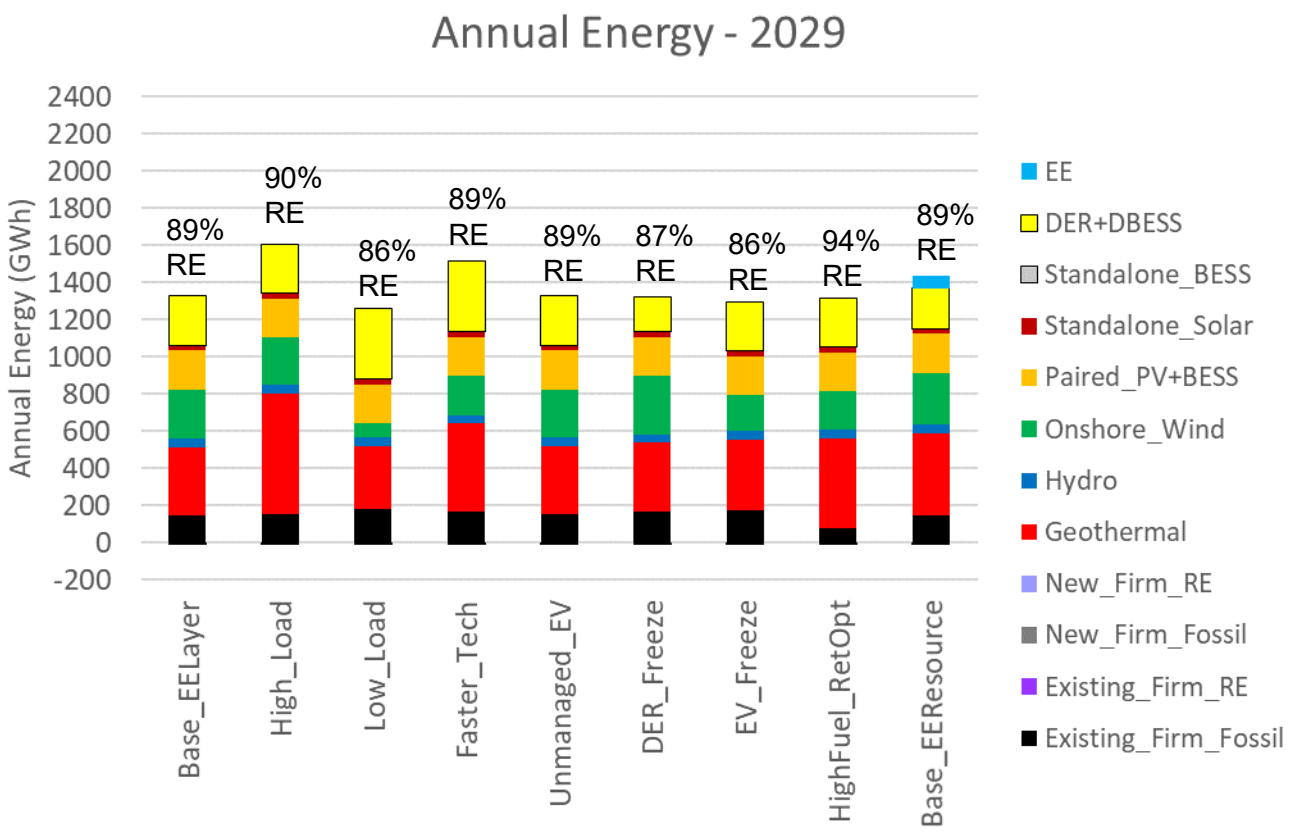




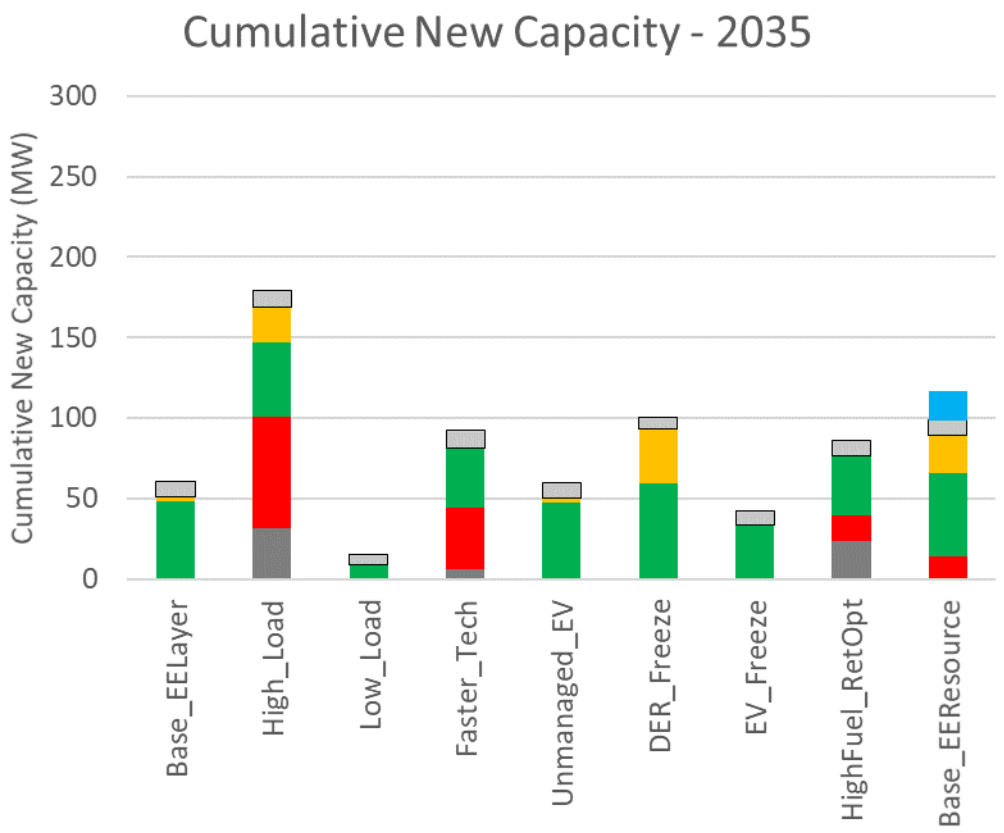
In the Land Constrained (LC_EELayer) case, Aggregated DER is built to reach 100% RE and New Firm RE serves a larger portion of the load than in other cases.

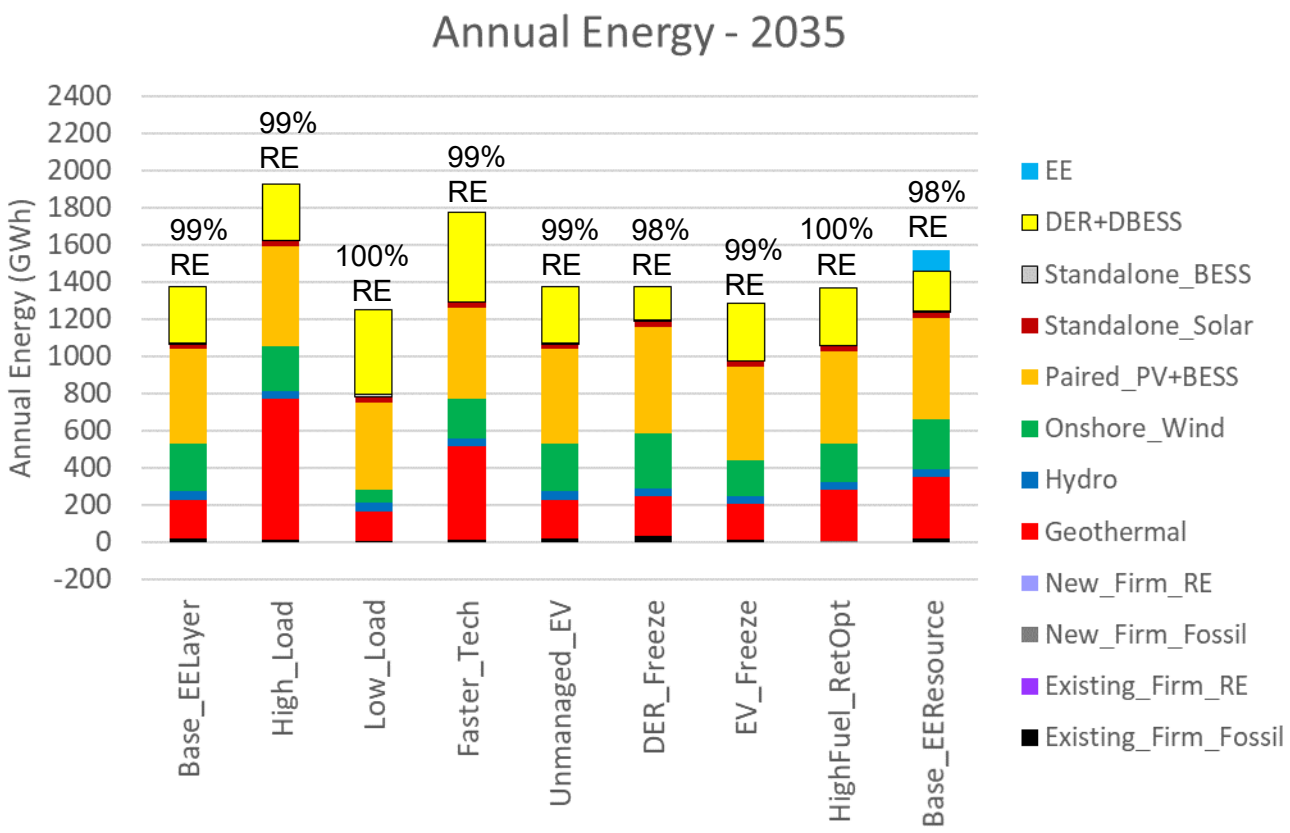
Hawai'i Island – 2029



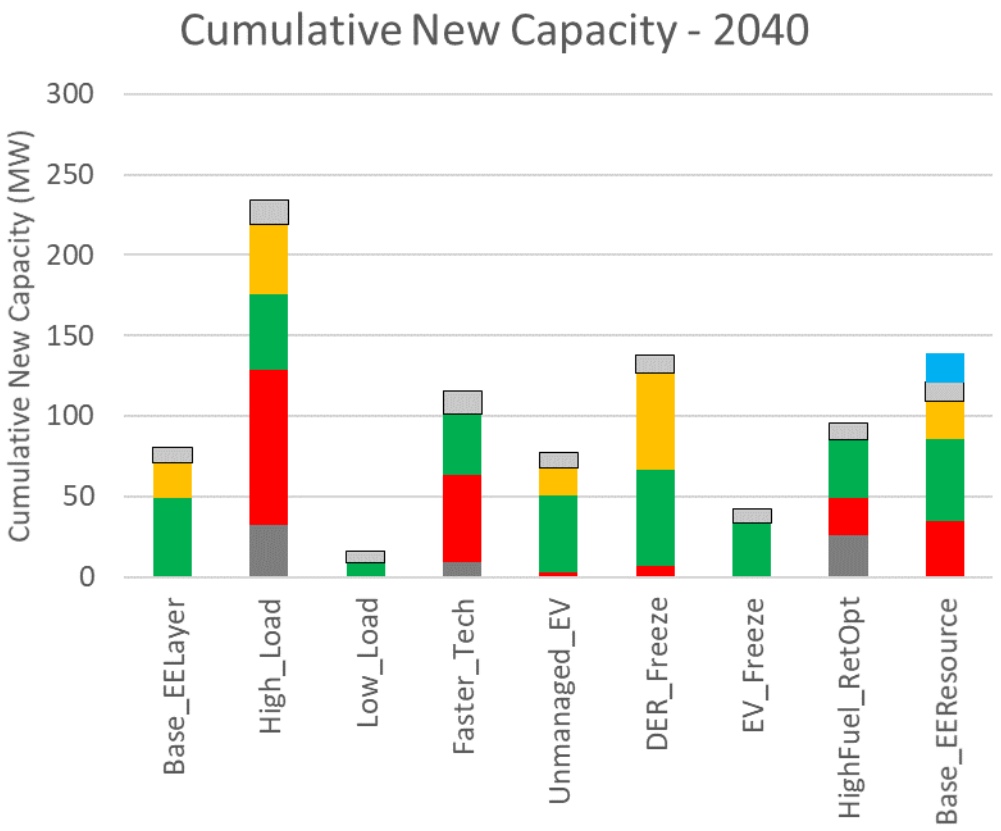


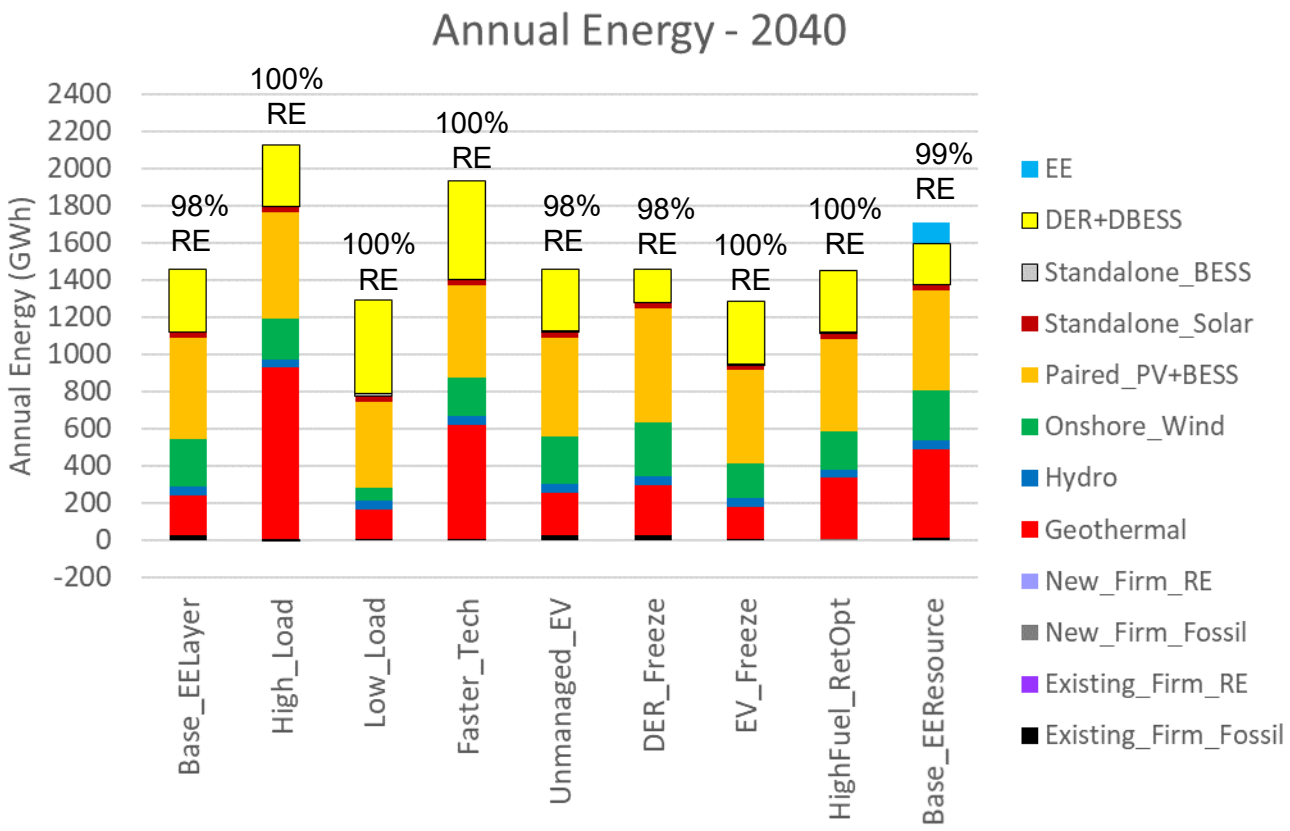
Hawai'i Island – 2035



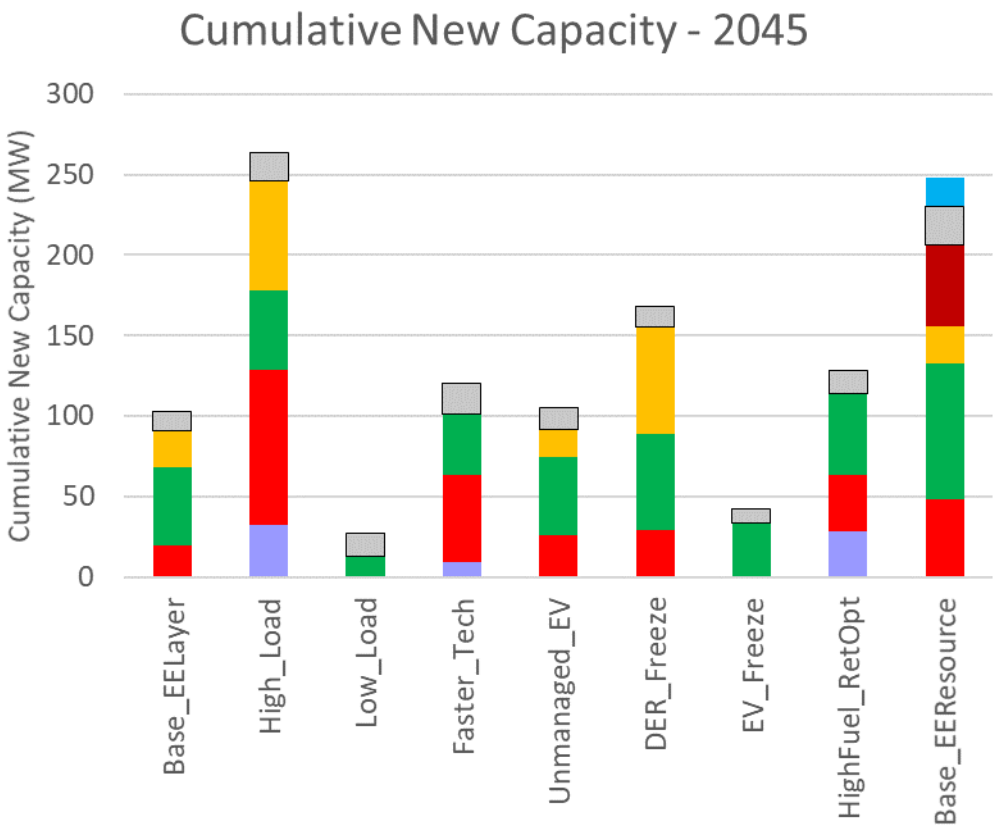


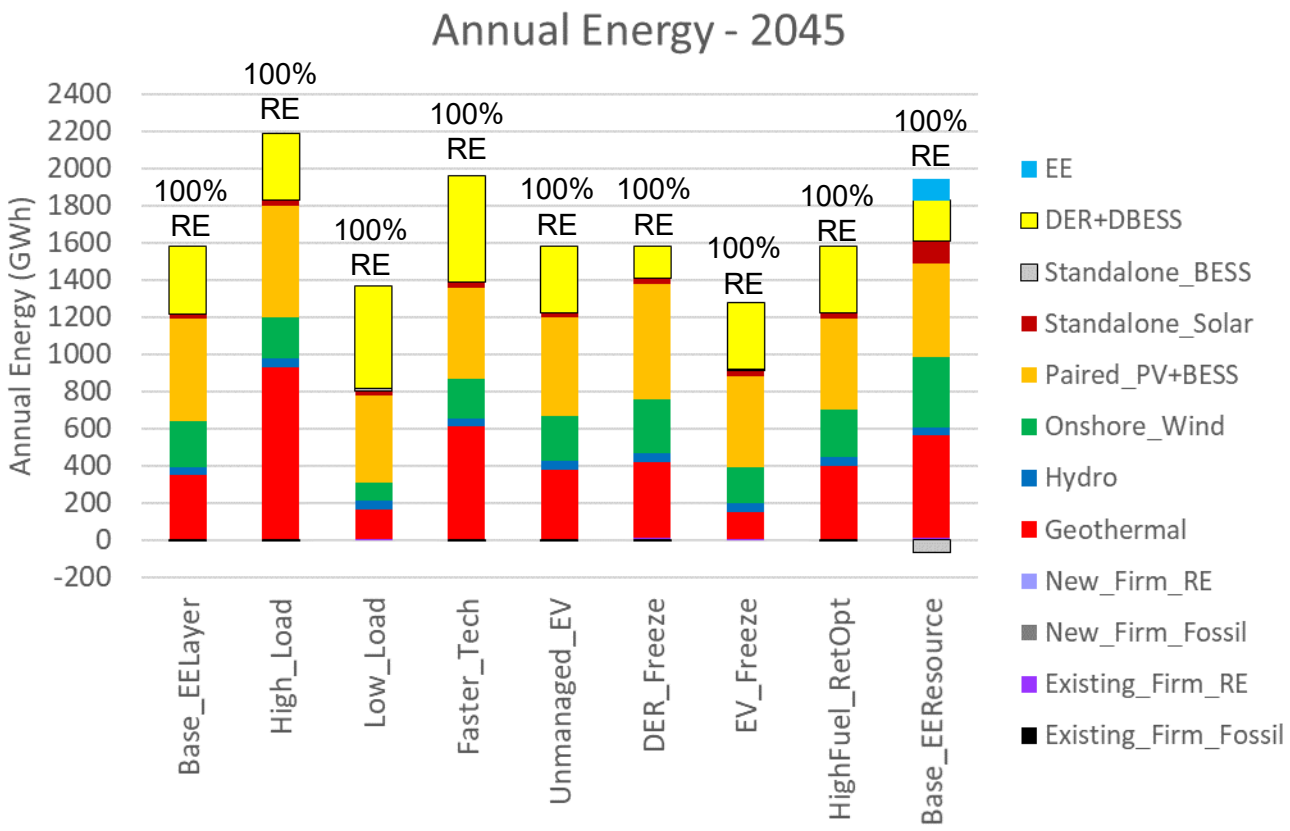
Hawai'i Island – 2040



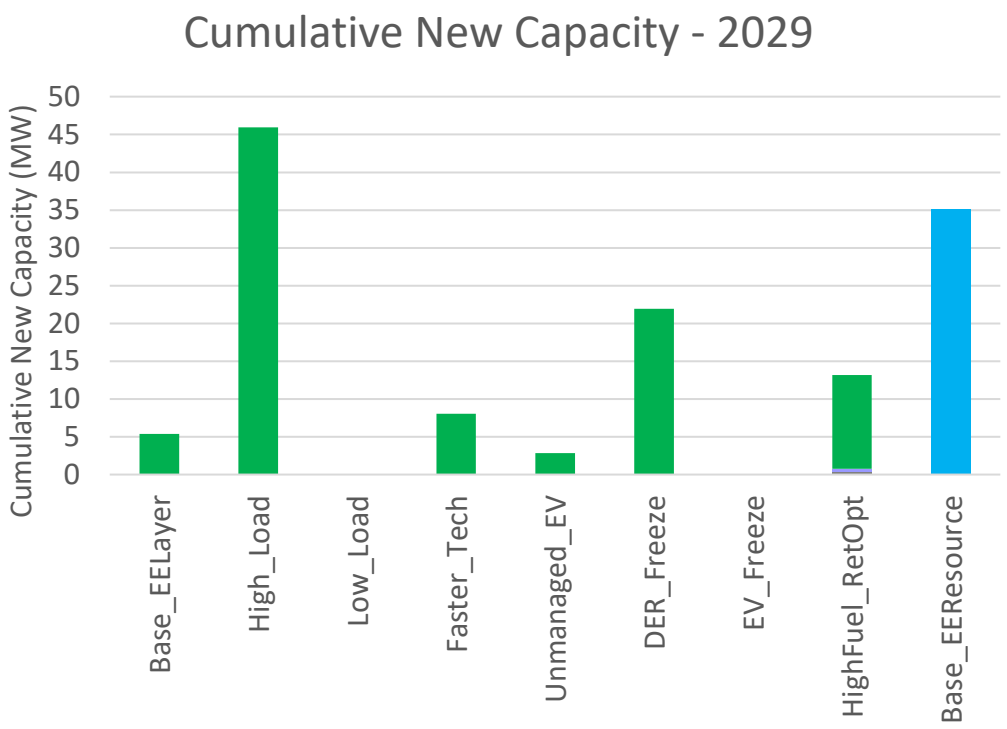


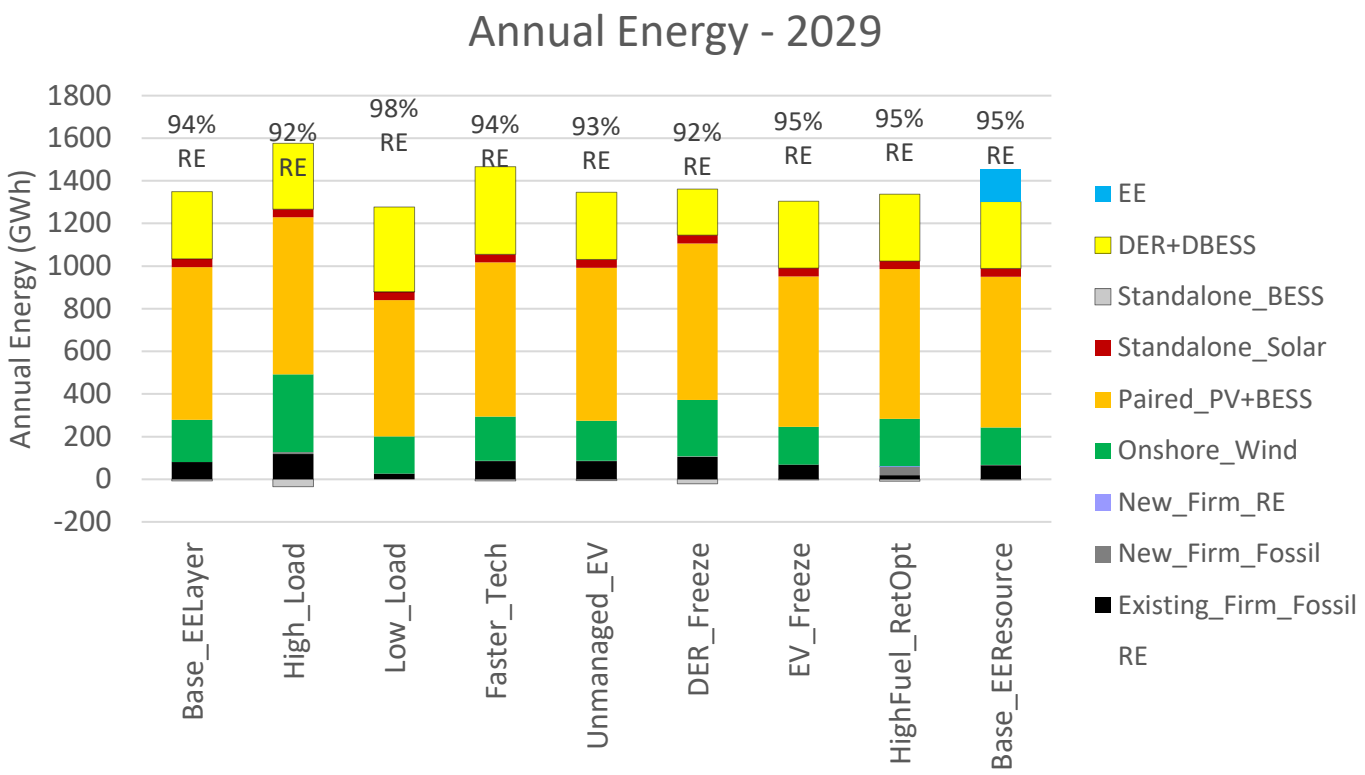
Hawai'i Island – 2045



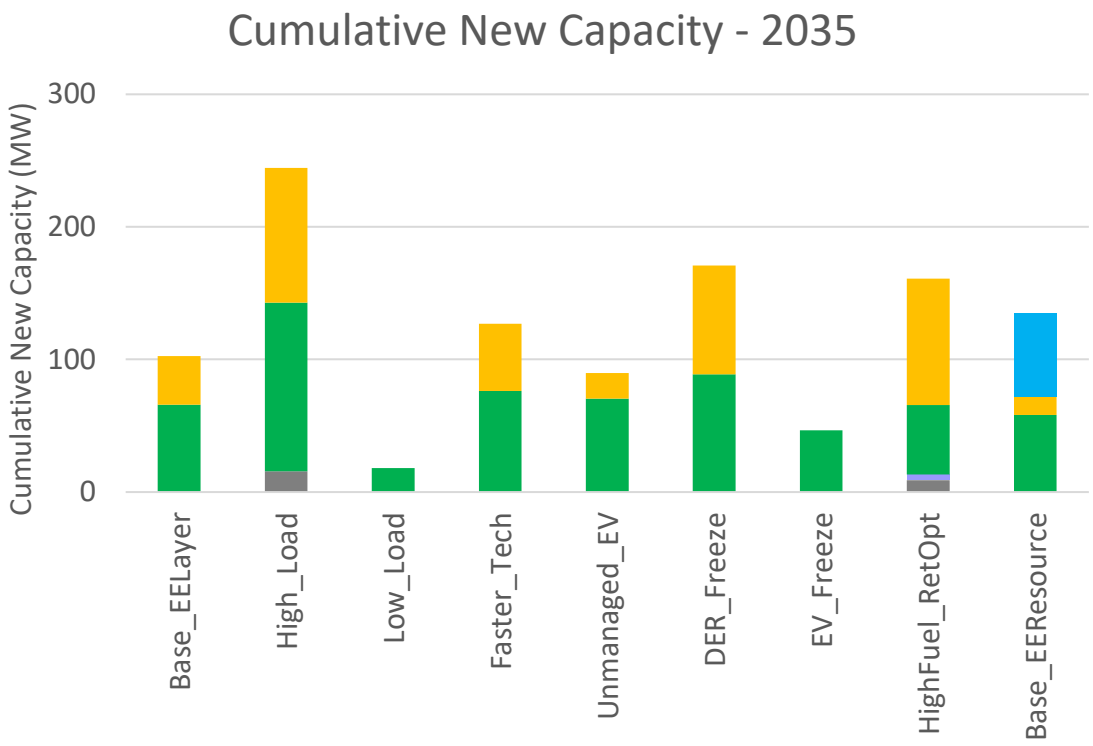


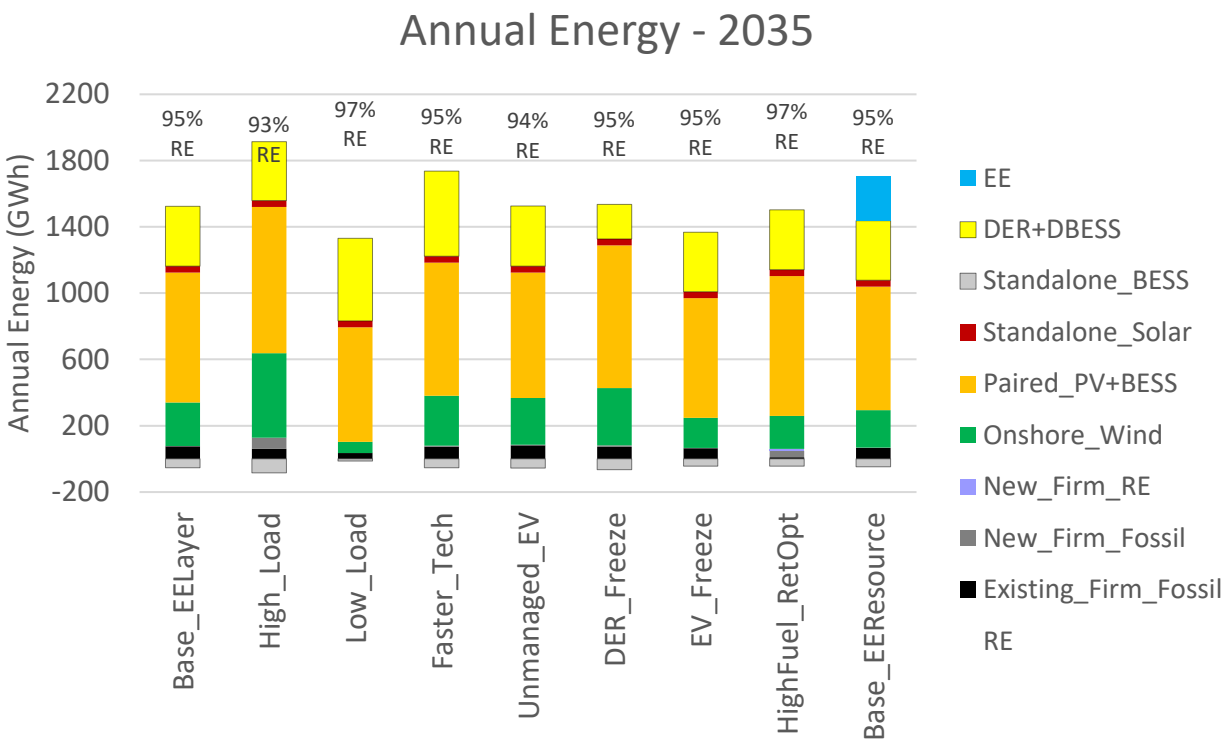
Maui – 2029


Cumulative New Capacity - 2029
Cumulative New Capacity (MW)
50
45
40
35
30
25
20
15
10
5
0
Base_EELayer
High_Load
Low_Load
Faster_Tech
Unmanaged_EV
DER_Freeze
EV_Freeze
HighFuel_RetOpt
Base_EEResource

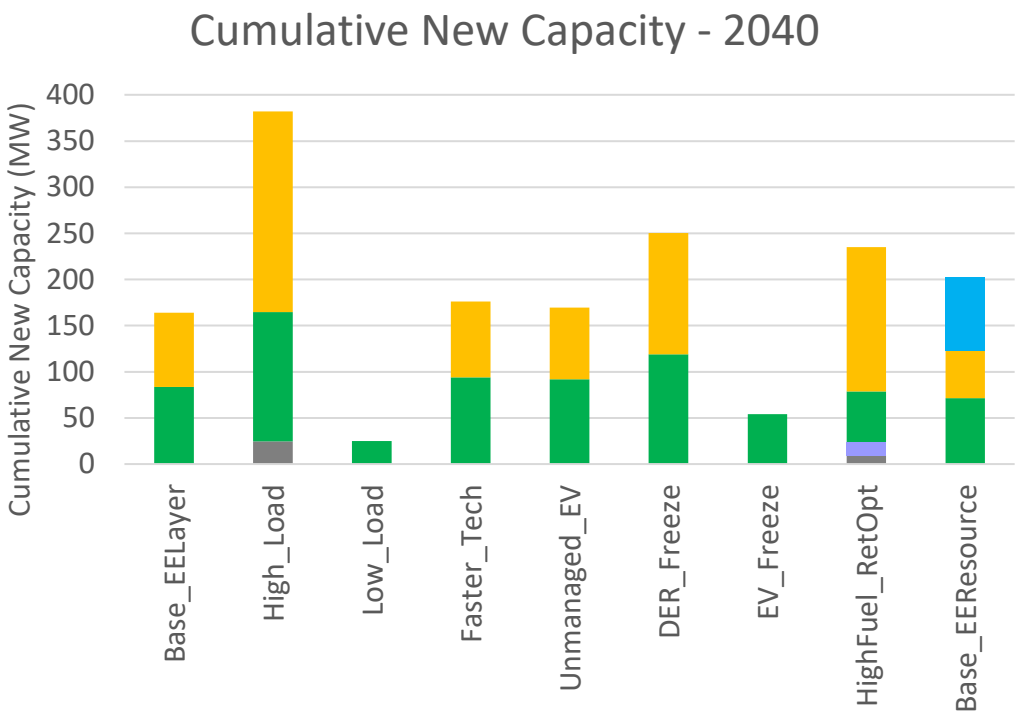

Annual Energy - 2029
Annual Energy (GWh)
1800
1600
1400
1200
1000
800
600
400
200
0
-200
94% RE
92% RE
98% RE
94% RE
93% RE
92% RE
95% RE
95% RE
95% RE
Base_EELayer
High_Load
Low_Load
Faster_Tech
Unmanaged_EV
DER_Freeze
EV_Freeze
HighFuel_RetOpt
Base_EEResource
EE
DER+DBESS
Standalone_BESS
Standalone_Solar
Paired_PV+BESS
Onshore_Wind
New_Firm_RE
New_Firm_Fossil
Existing_Firm_Fossil
RE

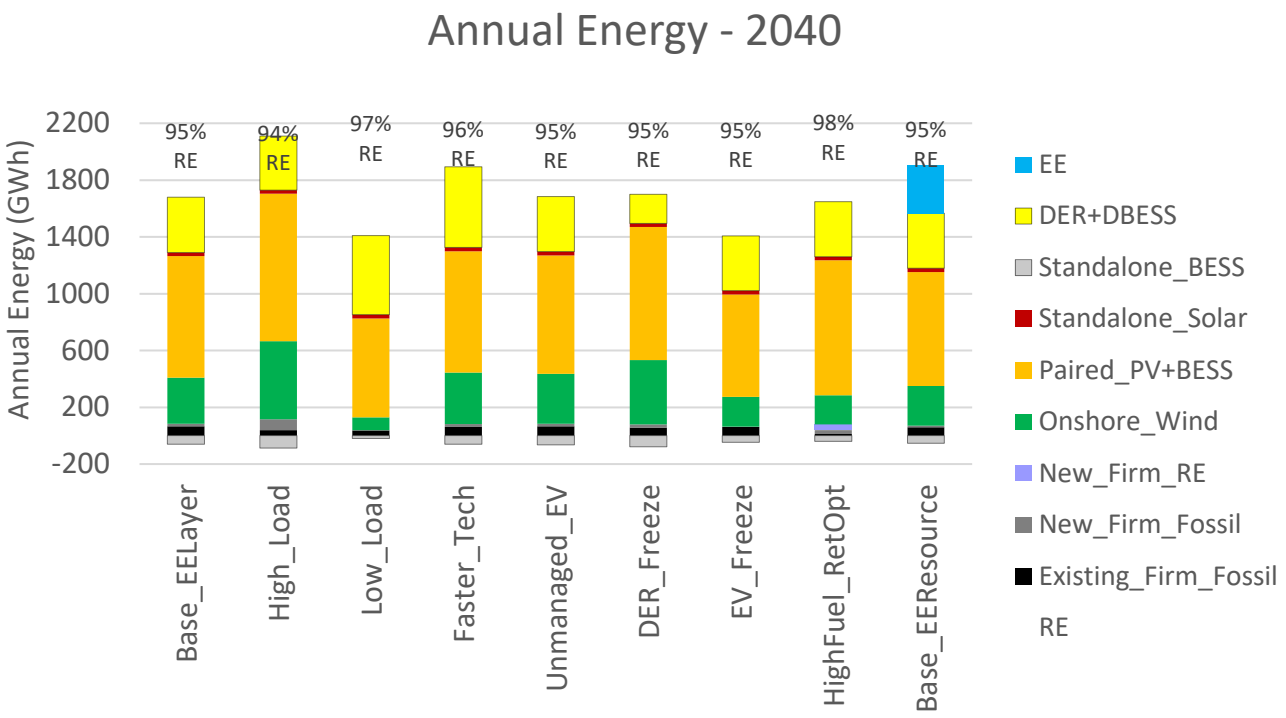
Maui – 2035


Cumulative New Capacity - 2035
Cumulative New Capacity (MW)
300
200
100
0
Base_EELayer
High_Load
Low_Load
Faster_Tech
Unmanaged_EV
DER_Freeze
EV_Freeze
HighFuel_RetOpt
Base_EEResource

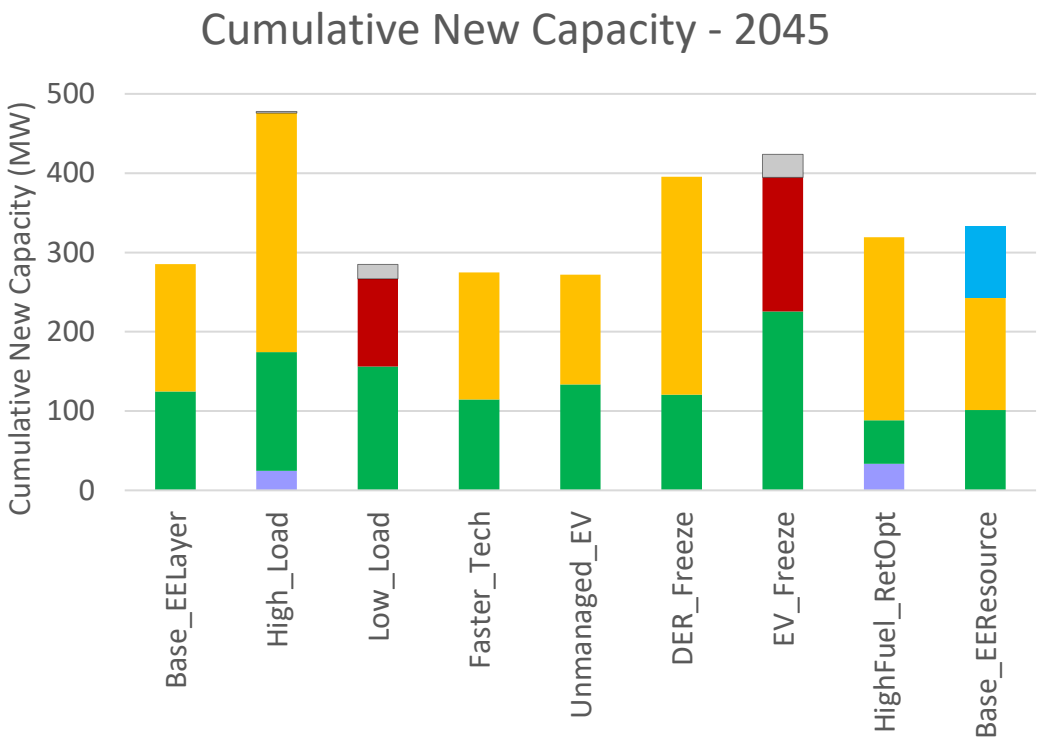

Annual Energy - 2035
Annual Energy (GWh)
2200
1800
1400
1000
600
200
-200
95% RE
93% RE
97% RE
95% RE
94% RE
95% RE
95% RE
97% RE
95% RE
Base_EELayer
High_Load
Low_Load
Faster_Tech
Unmanaged_EV
DER_Freeze
EV_Freeze
HighFuel_RetOpt
Base_EEResource
EE
DER+DBESS
Standalone_BESS
Standalone_Solar
Paired_PV+BESS
Onshore_Wind
New_Firm_RE
New_Firm_Fossil
Existing_Firm_Fossil
RE

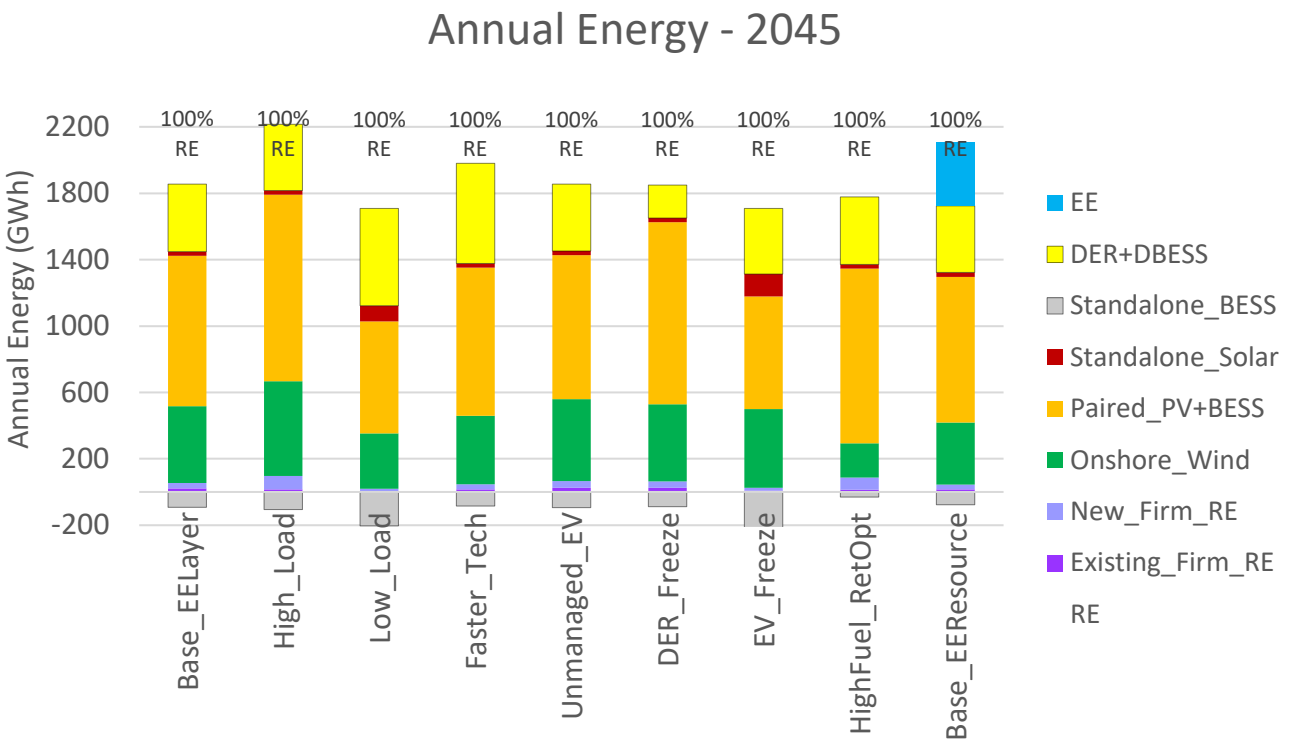
Maui – 2040


Cumulative New Capacity - 2040
Cumulative New Capacity (MW)
400
350
300
250
200
150
100
50
0
Base_EELayer
High_Load
Low_Load
Faster_Tech
Unmanaged_EV
DER_Freeze
EV_Freeze
HighFuel_RetOpt
Base_EEResource

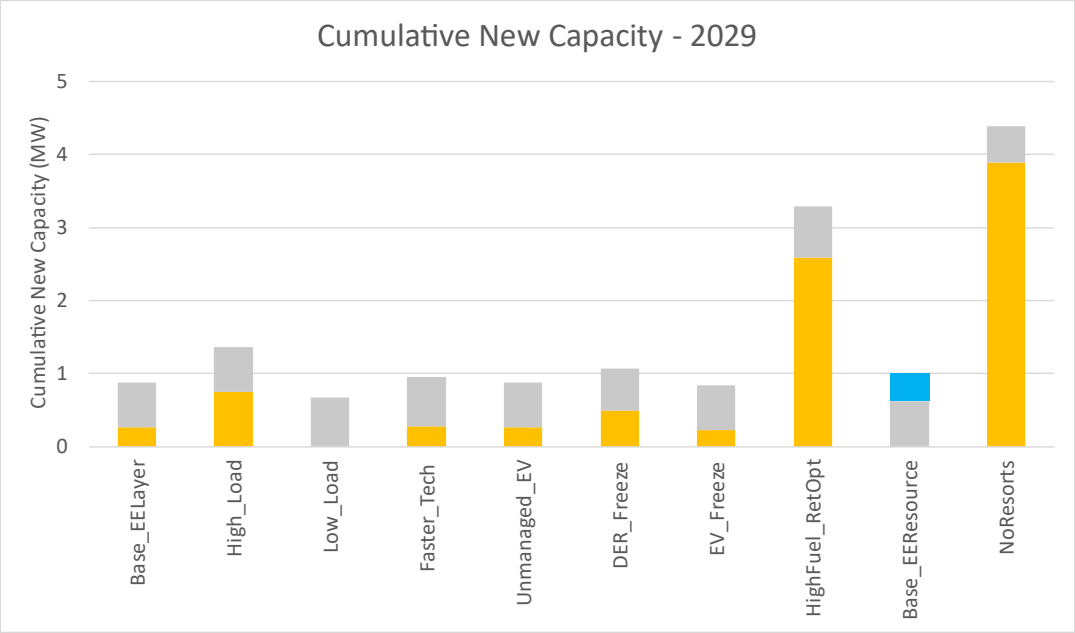

Annual Energy - 2040
Annual Energy (GWh)
2200
1800
1400
1000
600
200
-200
95% RE
94% RE
97% RE
96% RE
95% RE
95% RE
95% RE
98% RE
95% RE
Base_EELayer
High_Load
Low_Load
Faster_Tech
Unmanaged_EV
DER_Freeze
EV_Freeze
HighFuel_RetOpt
Base_EEResource
EE
DER+DBESS
Standalone_BESS
Standalone_Solar
Paired_PV+BESS
Onshore_Wind
New_Firm_RE
New_Firm_Fossil
Existing_Firm_Fossil
RE

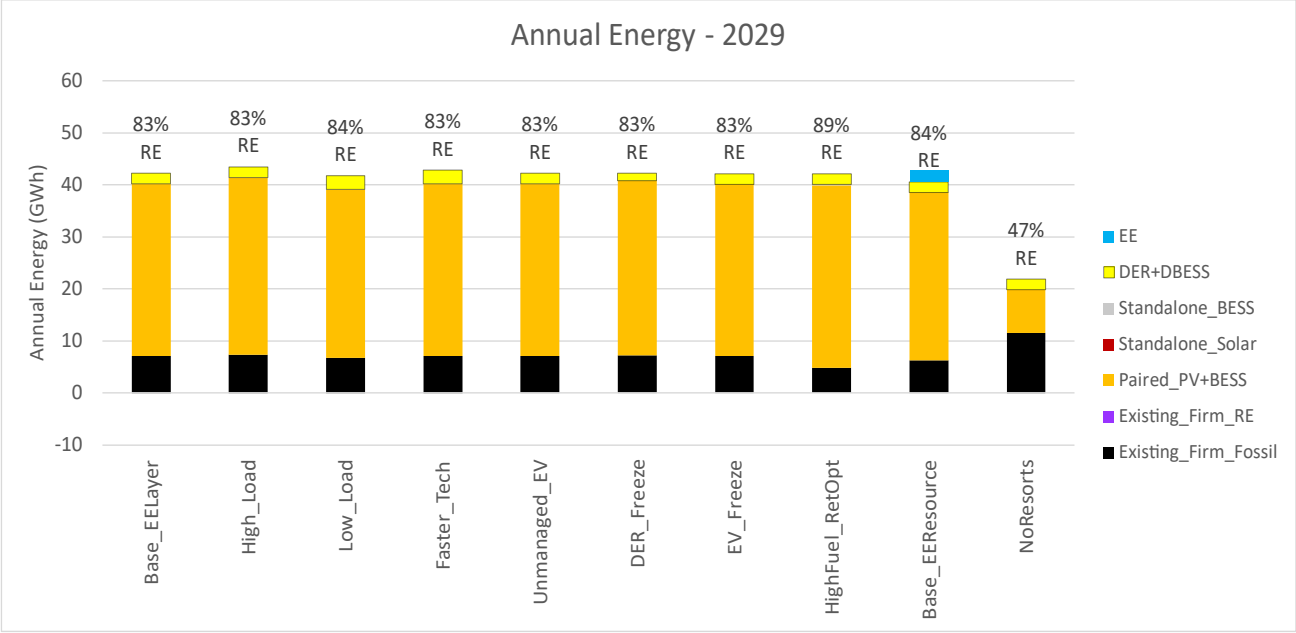
Maui – 2045


Cumulative New Capacity - 2045
Cumulative New Capacity (MW)
500
400
300
200
100
0
Base_EELayer
High_Load
Low_Load
Faster_Tech
Unmanaged_EV
DER_Freeze
EV_Freeze
HighFuel_RetOpt
Base_EEResource

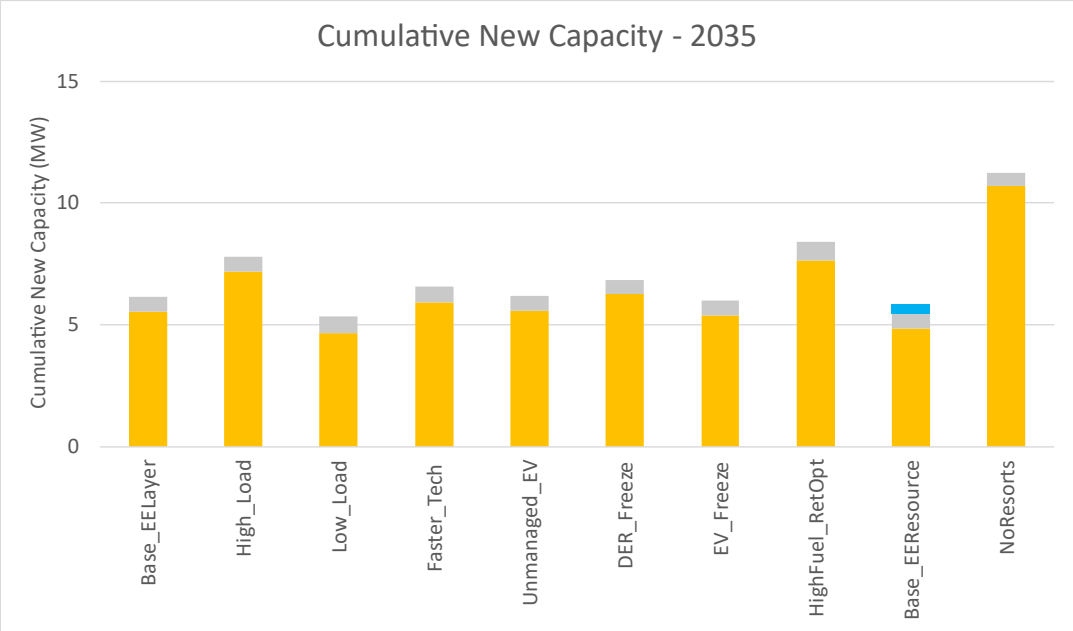

Annual Energy - 2045
Annual Energy (GWh)
2200
1800
1400
1000
600
200
-200
100% RE
Base_EELayer
High_Load
Low_Load
Faster_Tech
Unmanaged_EV
DER_Freeze
EV_Freeze
HighFuel_RetOpt
Base_EEResource
EE
DER+DBESS
Standalone_BESS
Standalone_Solar
Paired_PV+BESS
Onshore_Wind
New_Firm_RE
Existing_Firm_RE
RE

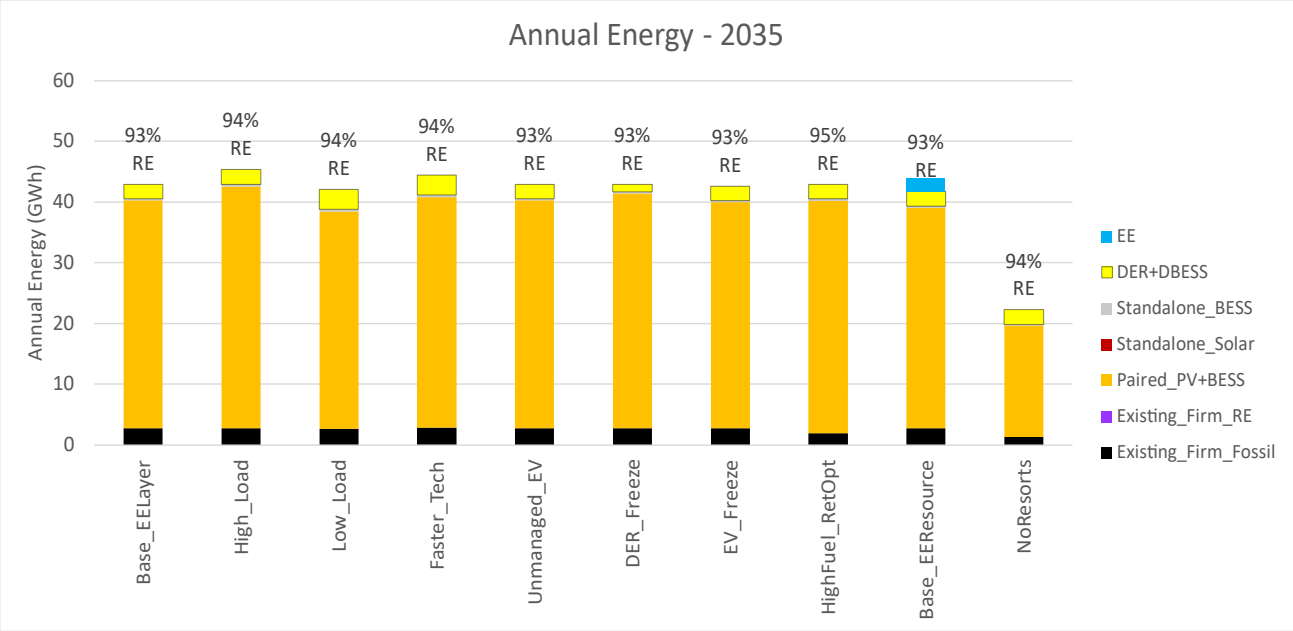
Lānaʻi – 2029


Cumulative New Capacity - 2029
Cumulative New Capacity (MW)
5
4
3
2
1
0
Base_EELayer
High_Load
Low_Load
Faster_Tech
Unmanaged_EV
DER_Freeze
EV_Freeze
HighFuel_RetOpt
Base_EEResource
NoResorts

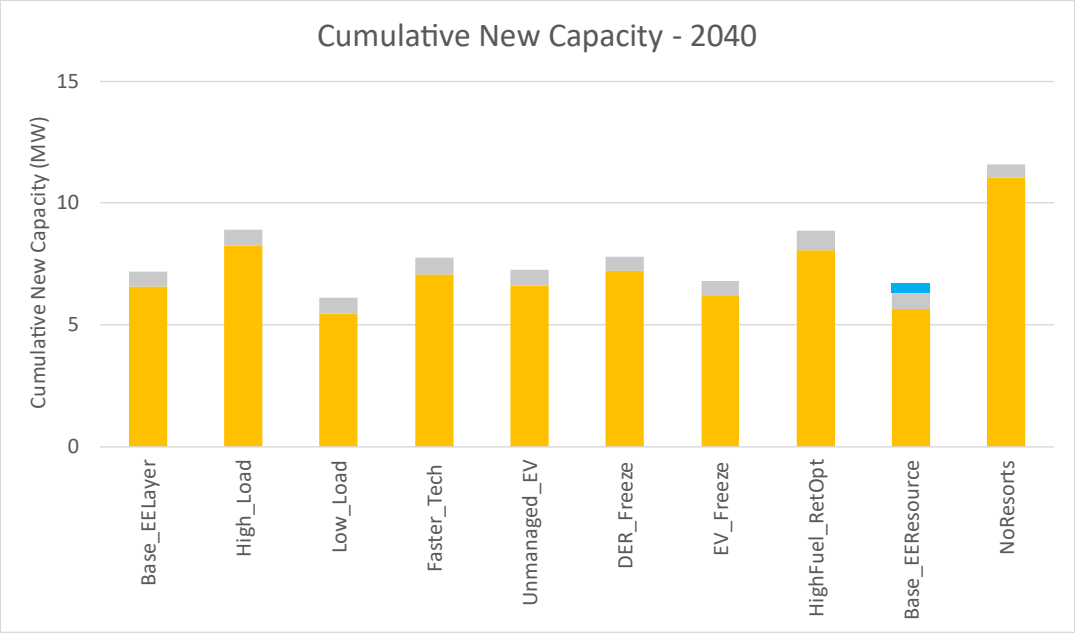

Annual Energy - 2029
Annual Energy (GWh)
60
50
40
30
20
10
0
-10
83% RE
83% RE
84% RE
83% RE
83% RE
83% RE
83% RE
89% RE
84% RE
47% RE
Base_EELayer
High_Load
Low_Load
Faster_Tech
Unmanaged_EV
DER_Freeze
EV_Freeze
HighFuel_RetOpt
Base_EEResource
NoResorts
EE
DER+DBESS
Standalone_BESS
Standalone_Solar
Paired_PV+BESS
Existing_Firm_RE
Existing_Firm_Fossil

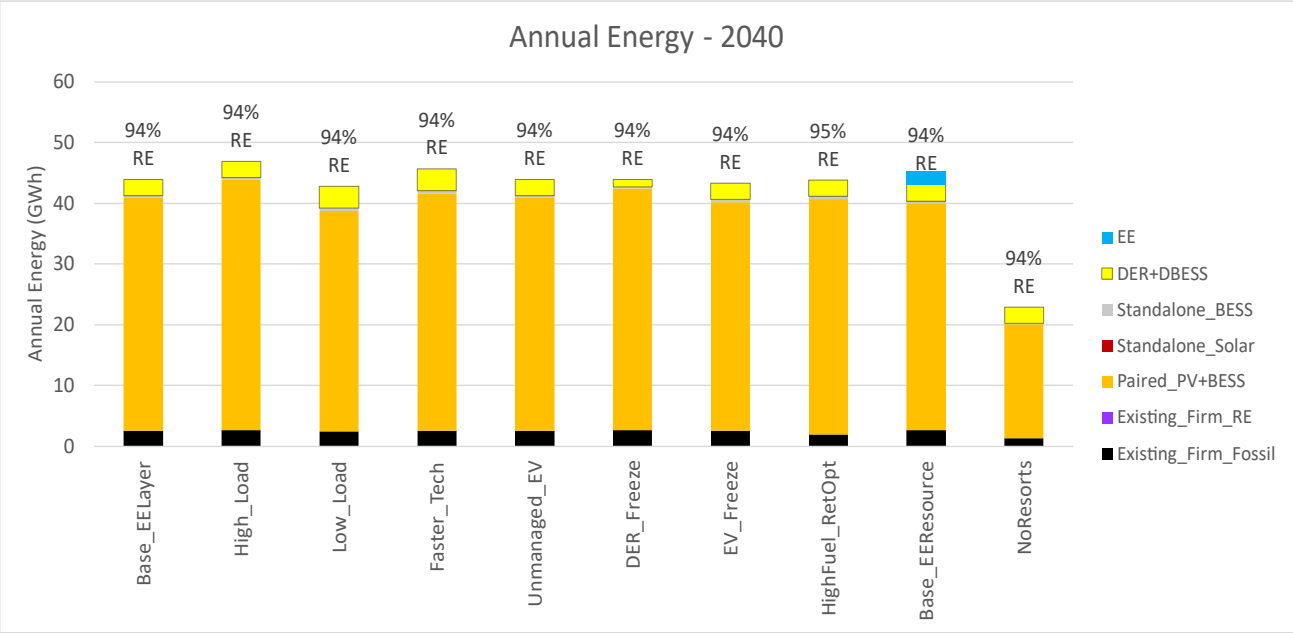
Lānaʻi – 2035


Cumulative New Capacity - 2035
Cumulative New Capacity (MW)
15
10
5
0
Base_EELayer
High_Load
Low_Load
Faster_Tech
Unmanaged_EV
DER_Freeze
EV_Freeze
HighFuel_RetOpt
Base_EEResource
NoResorts

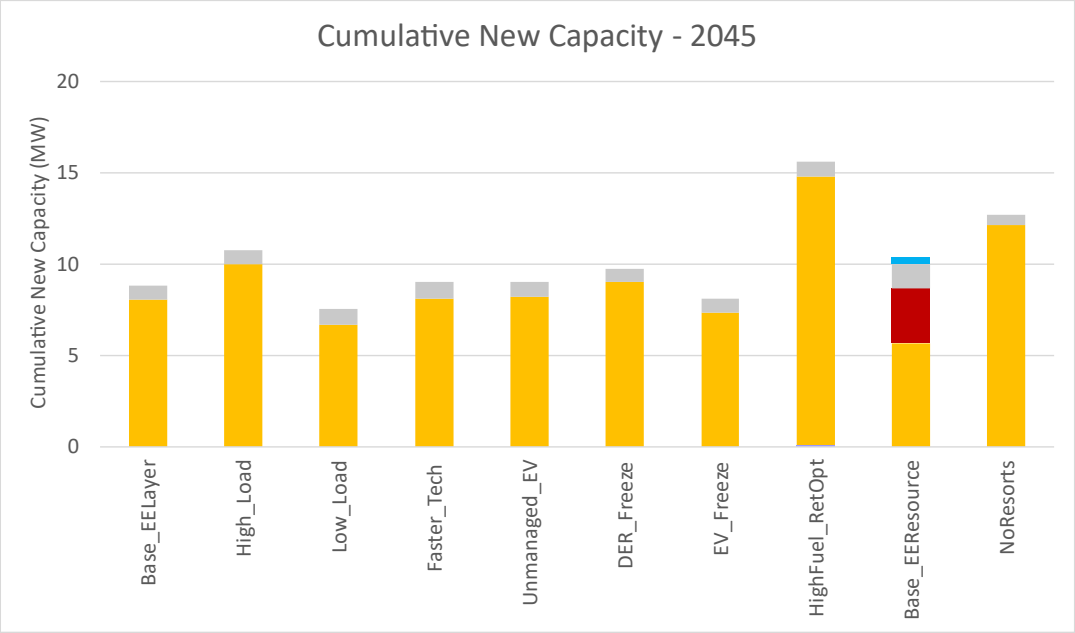

Annual Energy - 2035
Annual Energy (GWh)
60
50
40
30
20
10
0
93% RE
94% RE
94% RE
94% RE
93% RE
93% RE
93% RE
95% RE
93% RE
94% RE
Base_EELayer
High_Load
Low_Load
Faster_Tech
Unmanaged_EV
DER_Freeze
EV_Freeze
HighFuel_RetOpt
Base_EEResource
NoResorts
EE
DER+DBESS
Standalone_BESS
Standalone_Solar
Paired_PV+BESS
Existing_Firm_RE
Existing_Firm_Fossil

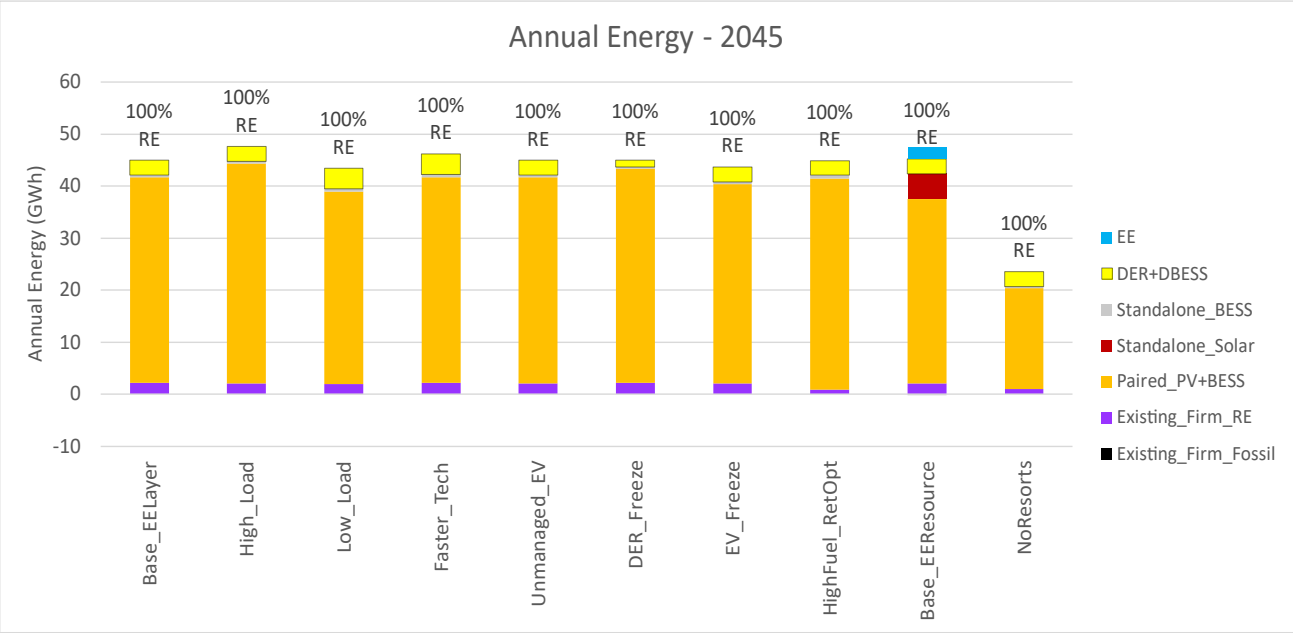
Lānaʻi – 2040


Cumulative New Capacity - 2040
Cumulative New Capacity (MW)
15
10
5
0
Base_EELayer
High_Load
Low_Load
Faster_Tech
Unmanaged_EV
DER_Freeze
EV_Freeze
HighFuel_RetOpt
Base_EEResource
NoResorts

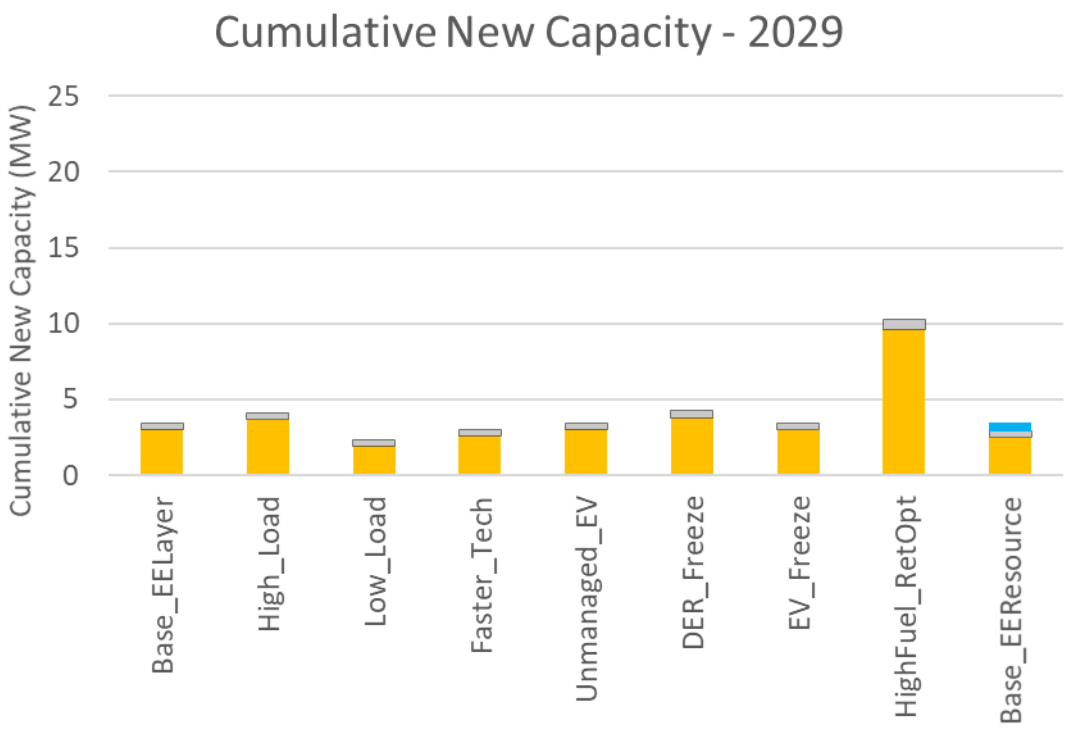

Annual Energy - 2040
Annual Energy (GWh)
60
50
40
30
20
10
0
94% RE
94% RE
94% RE
94% RE
94% RE
94% RE
94% RE
95% RE
94% RE
94% RE
Base_EELayer
High_Load
Low_Load
Faster_Tech
Unmanaged_EV
DER_Freeze
EV_Freeze
HighFuel_RetOpt
Base_EEResource
NoResorts
EE
DER+DBESS
Standalone_BESS
Standalone_Solar
Paired_PV+BESS
Existing_Firm_RE
Existing_Firm_Fossil

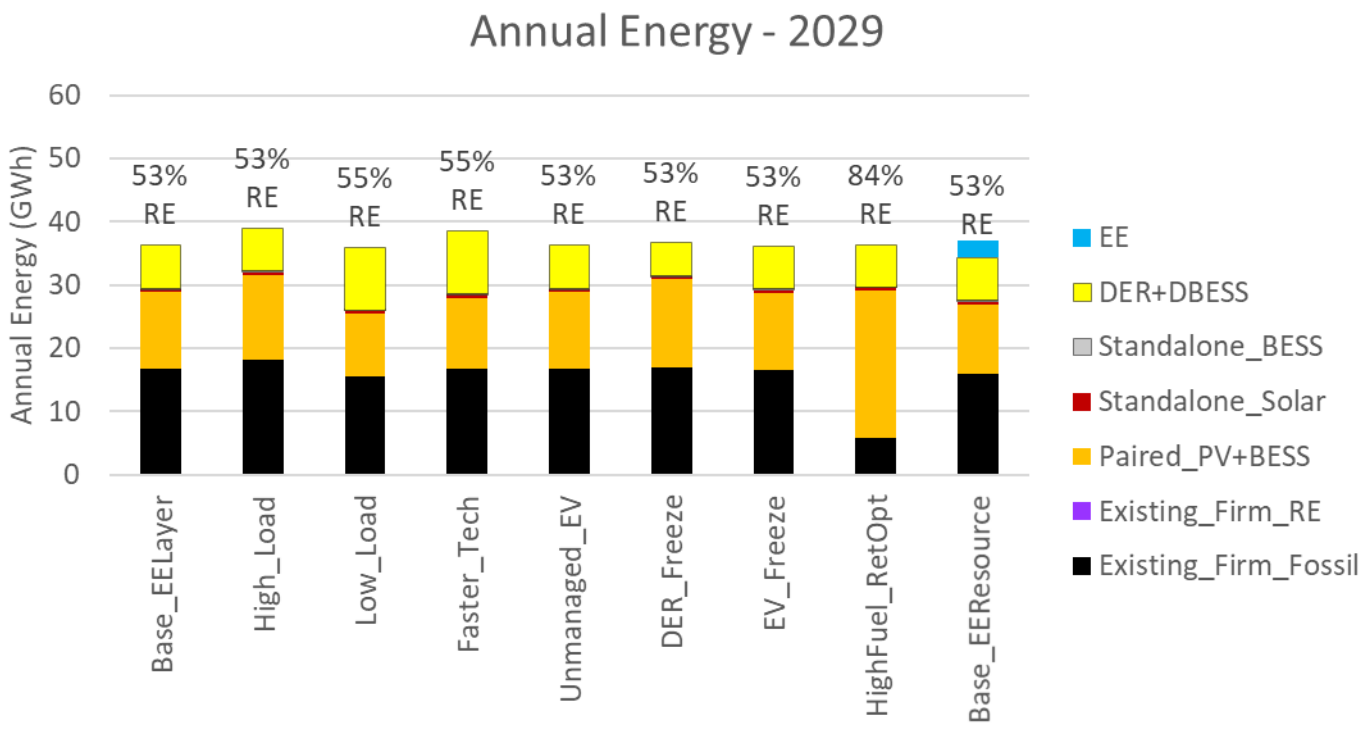
Lānaʻi – 2045


Cumulative New Capacity - 2045
Cumulative New Capacity (MW)
20
15
10
5
0
Base_EELayer
High_Load
Low_Load
Faster_Tech
Unmanaged_EV
DER_Freeze
EV_Freeze
HighFuel_RetOpt
Base_EEResource
NoResorts

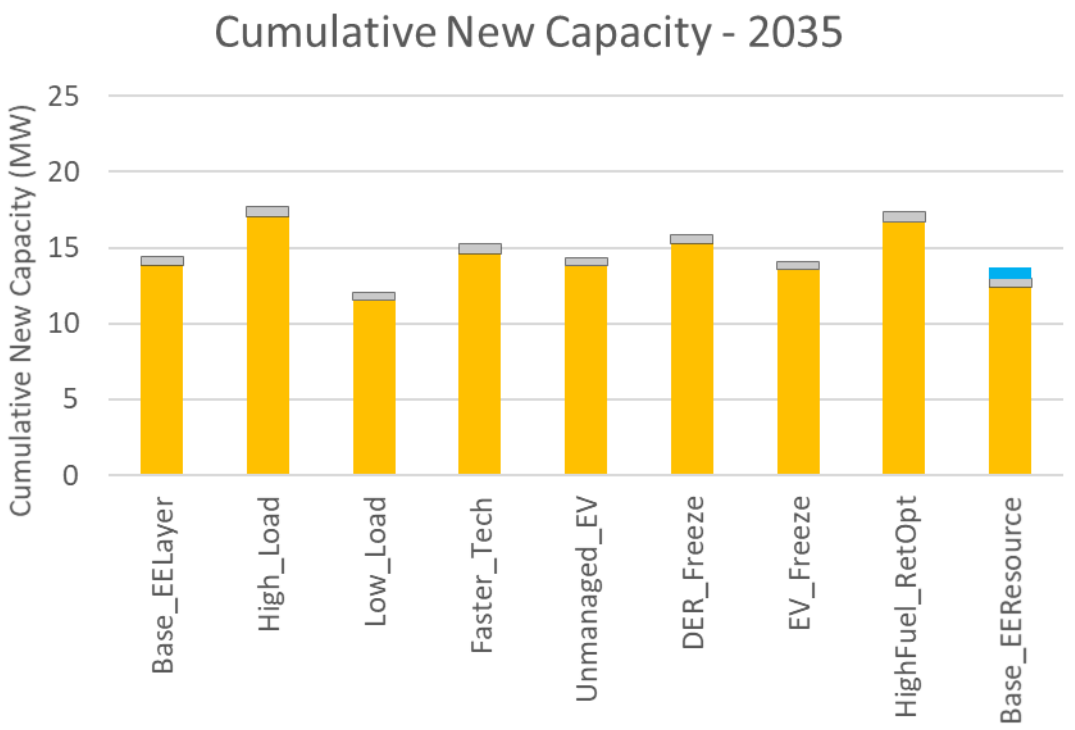

Annual Energy - 2045
Annual Energy (GWh)
60
50
40
30
20
10
0
-10
100% RE
Base_EELayer
High_Load
Low_Load
Faster_Tech
Unmanaged_EV
DER_Freeze
EV_Freeze
HighFuel_RetOpt
Base_EEResource
NoResorts
EE
DER+DBESS
Standalone_BESS
Standalone_Solar
Paired_PV+BESS
Existing_Firm_RE
Existing_Firm_Fossil

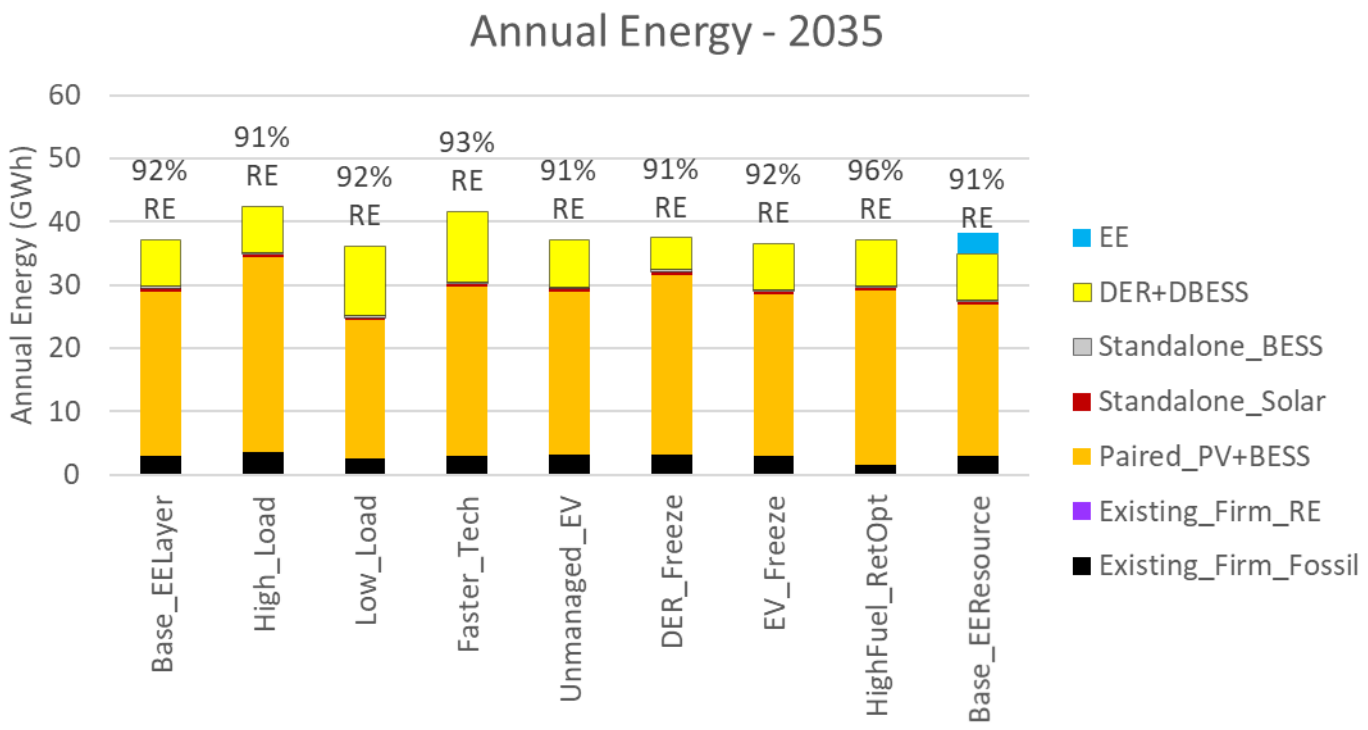
Moloka'i – 2029



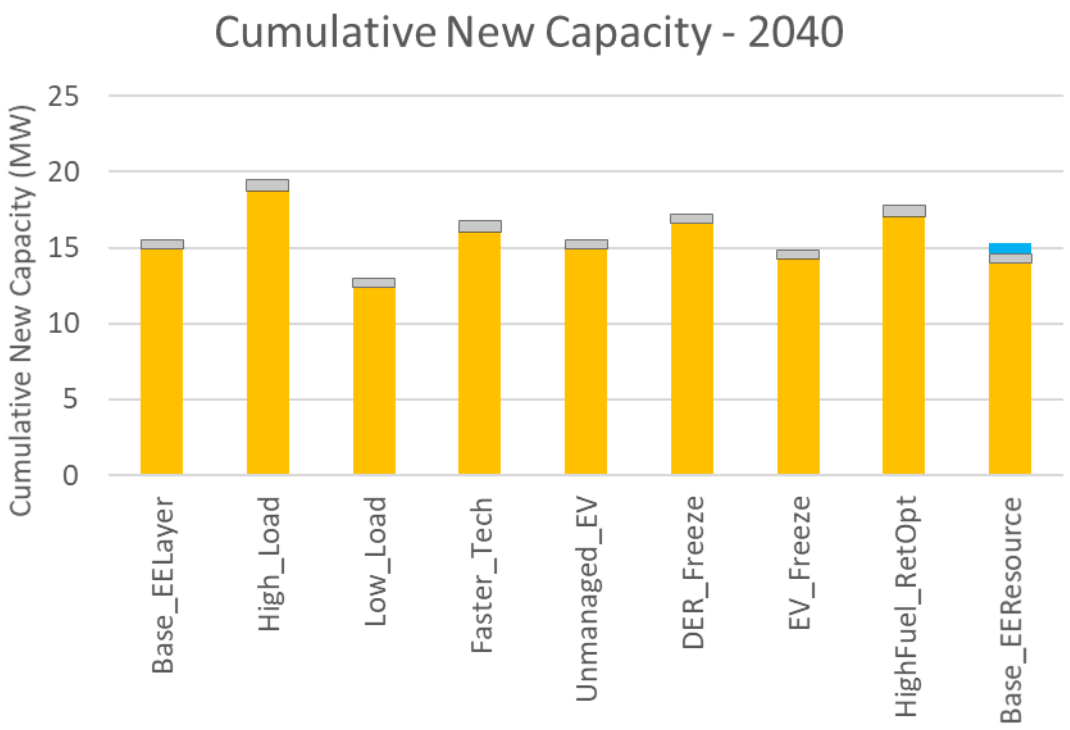


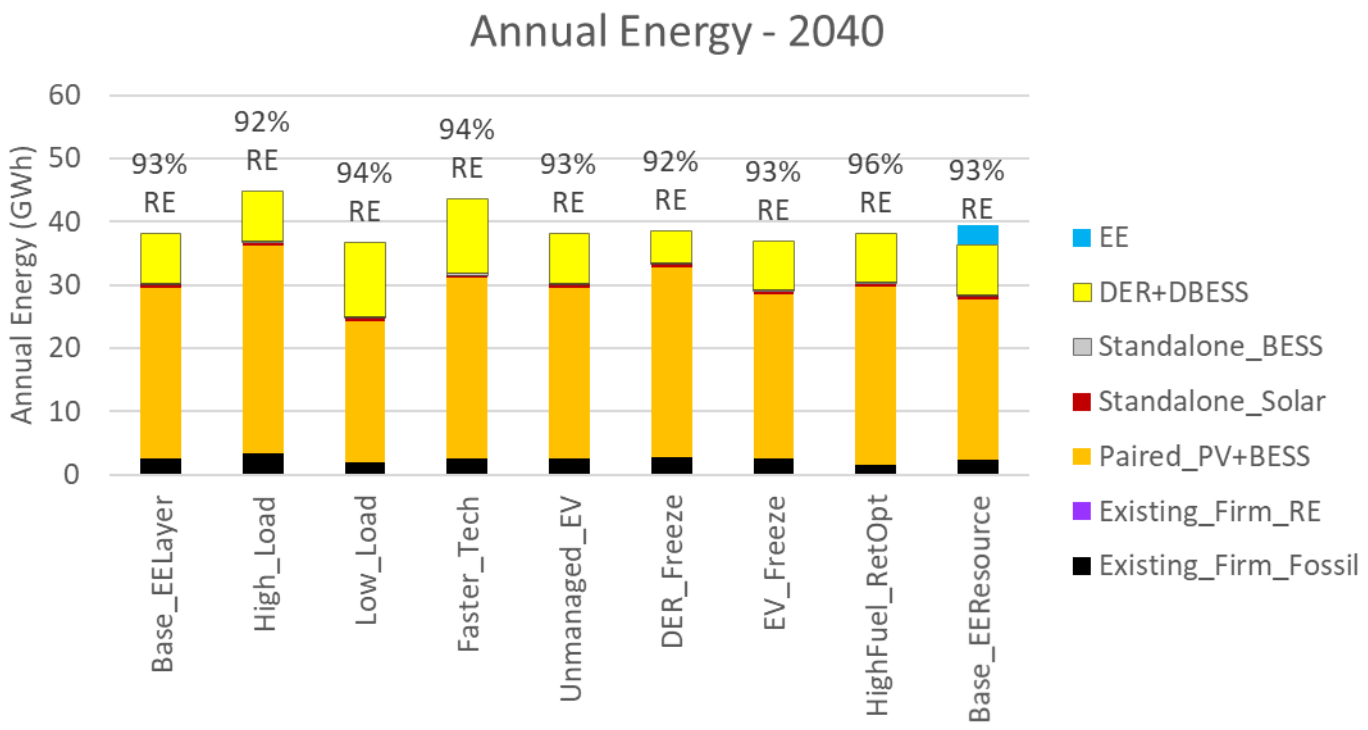
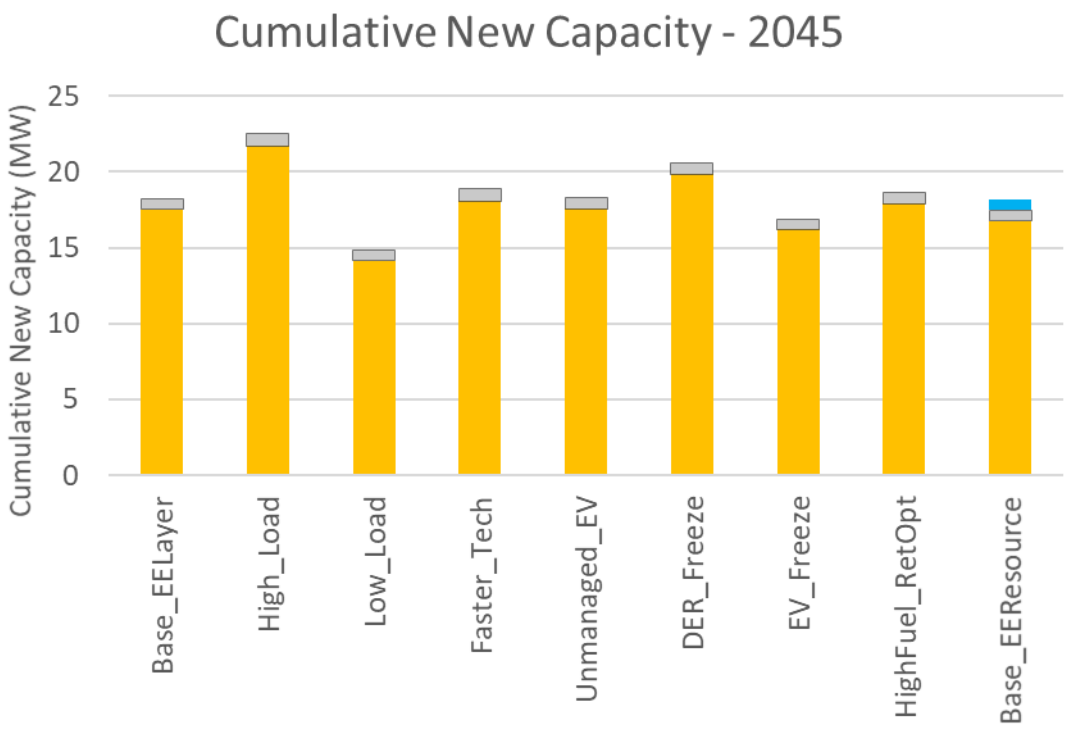
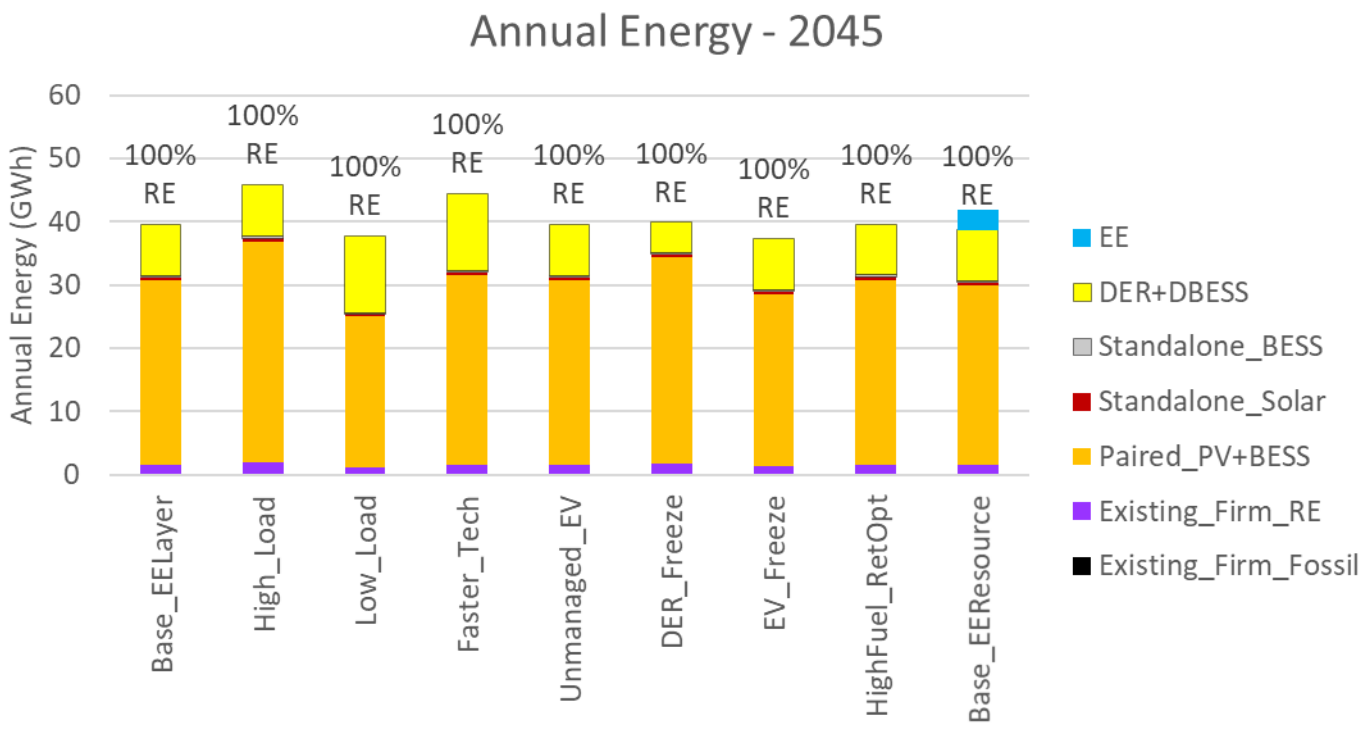
Moloka'i – 2035





Moloka'i – 2040





Moloka'i – 2045