Micro-grid System to Reduce Carbon Emissions while Enhancing Resilience, Maldives' Case

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Outline of the Micro Grid System in Addu Atoll

(Example of RE oriented off grid MG system)

Background

Background in Maldives

- Increasing energy demand and fuel(Diesel oil) cost
- Commitment to be carbon neutral by 2020

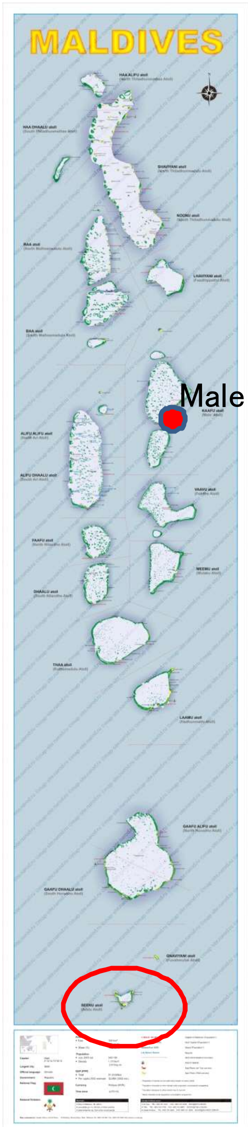
Current Step

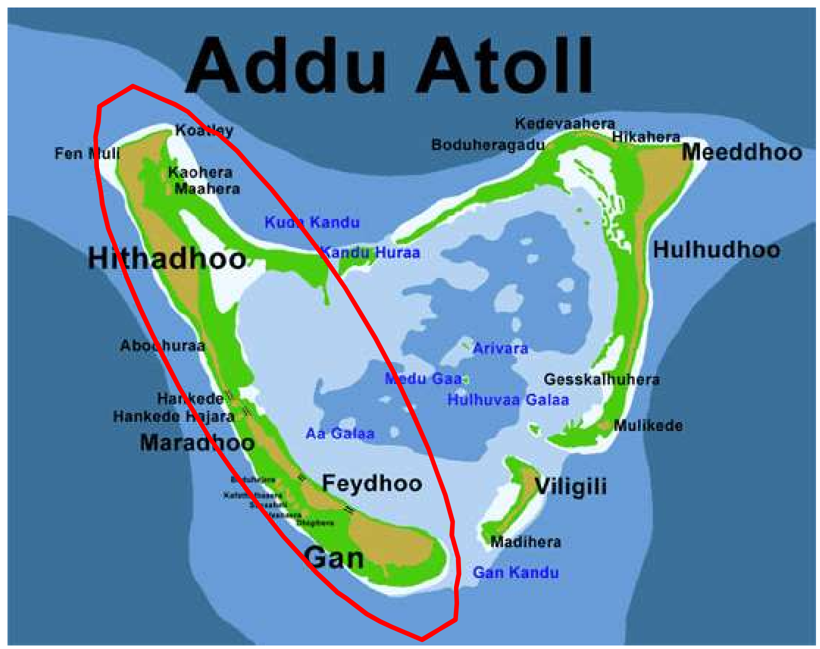
The government of Maldives is actively engaged in the introduction of renewable energy.

The Feasibility Study to develop the Smart Grid for small islands

Project Site

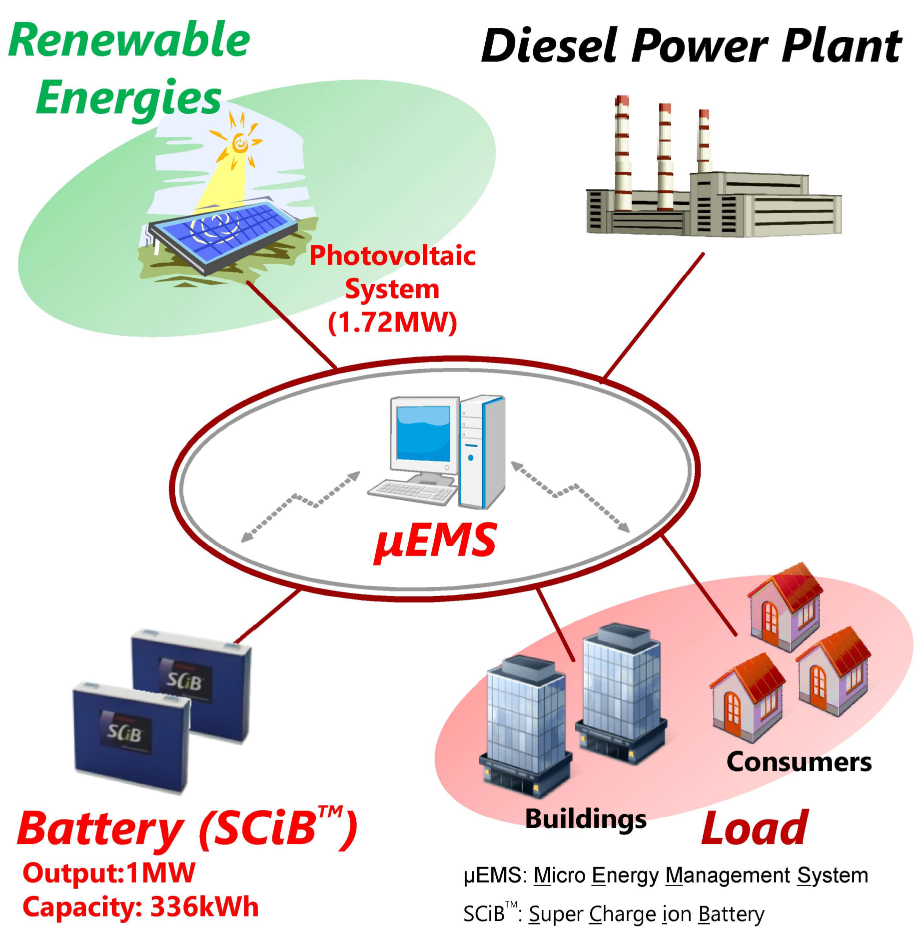
Addu Atoll in Maldives





Micro-Grid System for Addu atoll

System Configuration



Issues of REs installation

- Addu power system is isolated system.
- Feasible capacity of REs is limited due to the fluctuation in the output.
- The efficiency of Diesel Generators (DG) reduces to adjust to changing output of PV.

Benefit of this model

- The adequacy of power supply is secured by combination of μEMS, BESS and REs.
- Contribution to carbon-offset by battery's absorbing fluctuation to increase feasible capacity of REs .
- Cooperative control of DG and battery by μEMS improves the efficiency of DGs and reduces fuel cost.

Combination of μEMS and Battery system realize both the installation of large-scale renewable energy, high-efficiency operation of existing diesel generators and reliable system.

Outline of Micro-grid Addu atoll

- **Peak demand of Addu system: 4.5 MW (2013 at FS)**
- **PV installation: 1.6MW**
- **BESS: 360kWh for a largest 1MW solar at Convention center**

Resilience of Micro-grid system

- **Addu system is secured a power supply adequacy by μEMS+BESS and PV installation.**
- **This type of Micro-grid system is able to supply from REs in case of a problem on DGs, when a self-excitation inverter type PCS is adopted in BESS.**

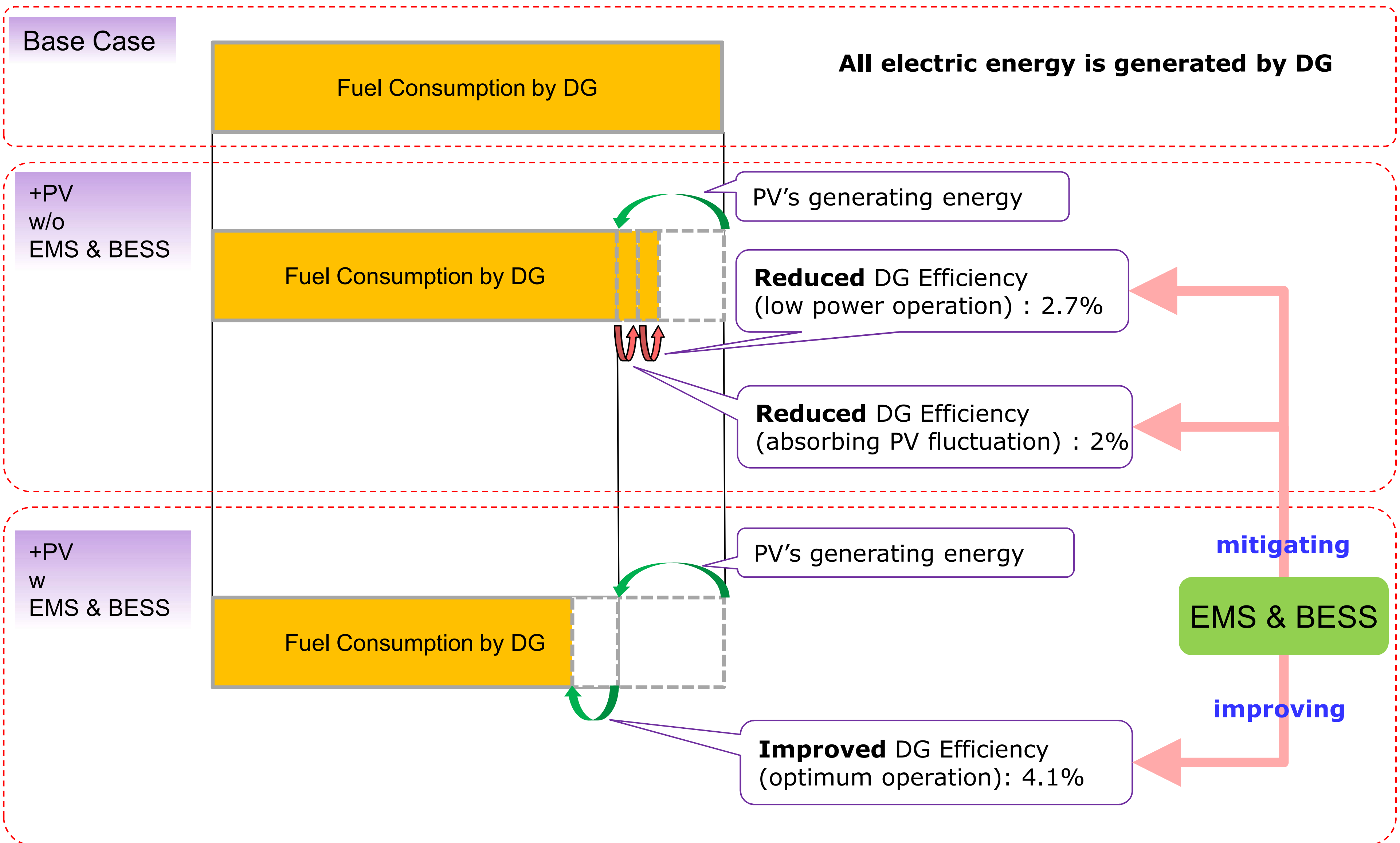
Potential site of PV

Potential Installation Area of PV systems（~1.7MWp, 6 areas)

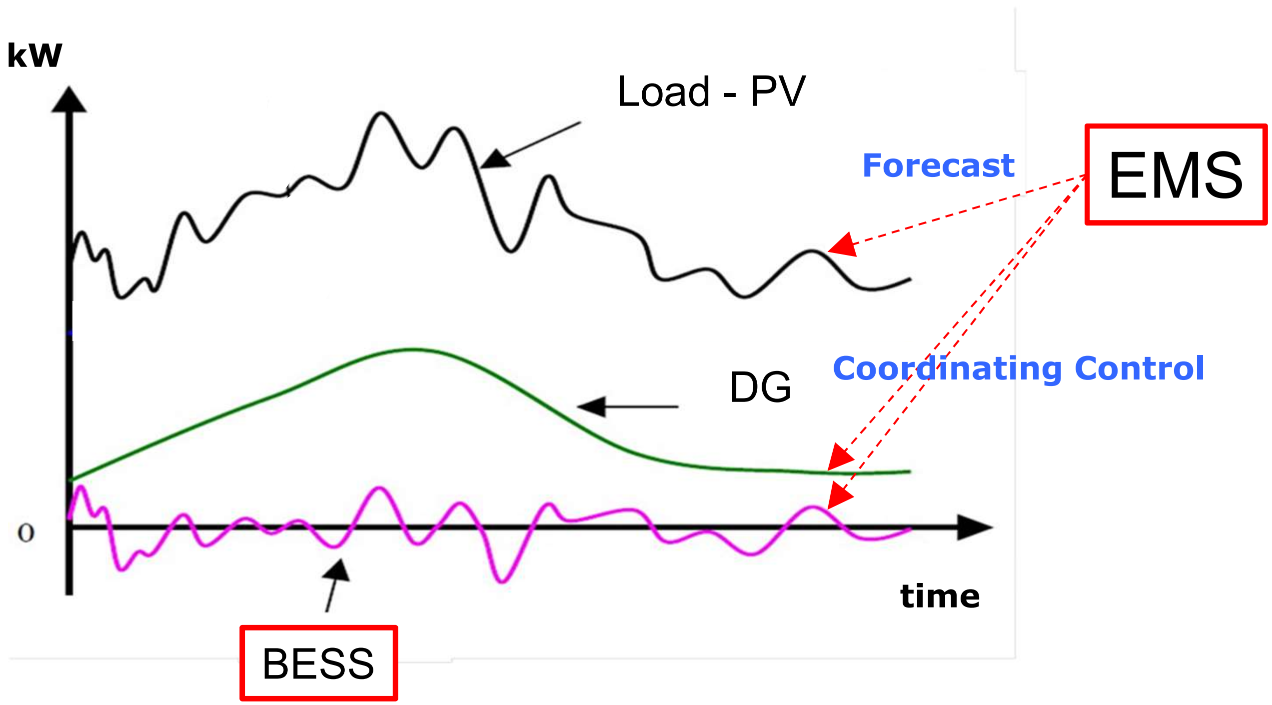
Island	No.	Site	Capacity [kWp]	Remarks	Photes
Hithadhoo Island	1	Convention Centre	1,000	No necessary of renovation of roof	
	2	Regional Port	250	Angle of Inclination=8°	
	3	S.T.O Storage Yard	250	Angle of Inclination =5°	
	4	Sharafudheen School	100	Necessary of renovation of roof	
	5	Addu Council	20		
Gan Island	6	Gan Airport Terminal	100		

Curtailment of Fuel Consumption

Curtailment of Fuel Consumption (w/o or w EMS & BESS)

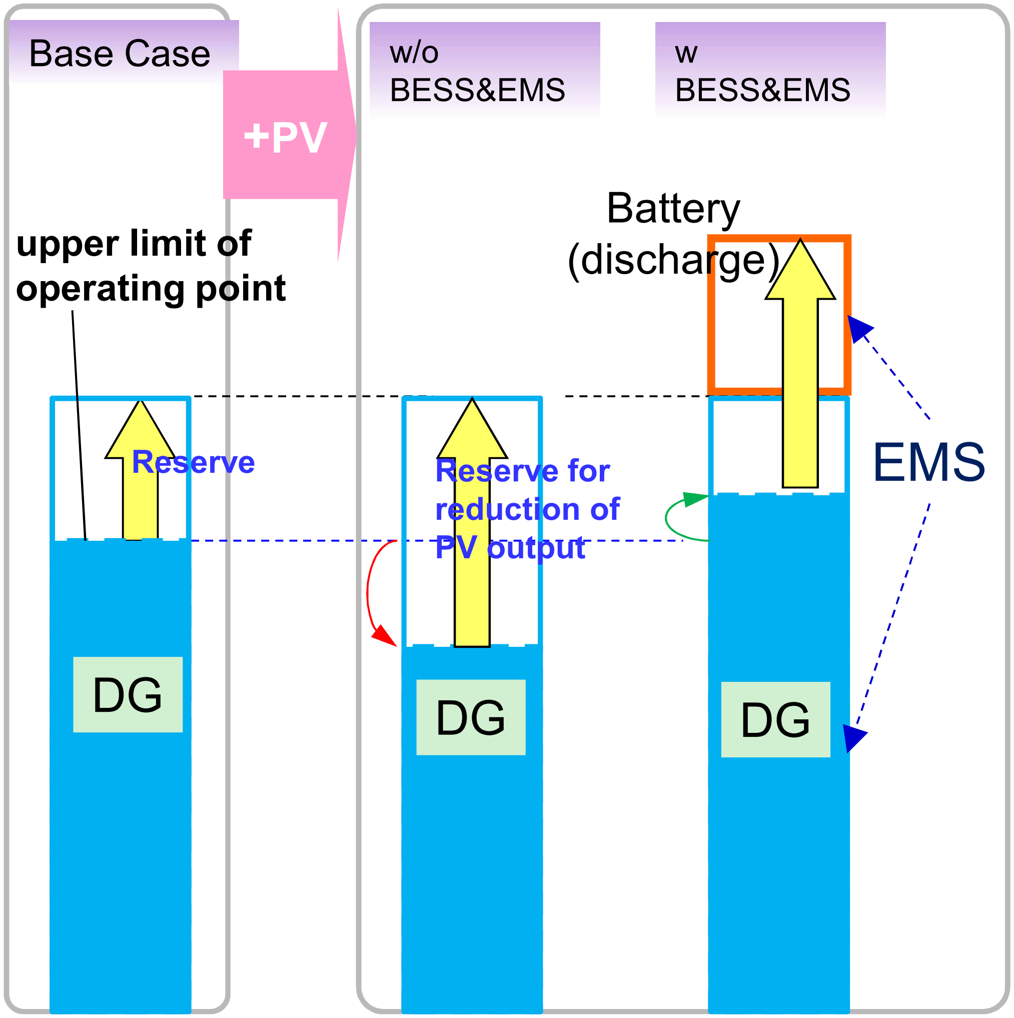


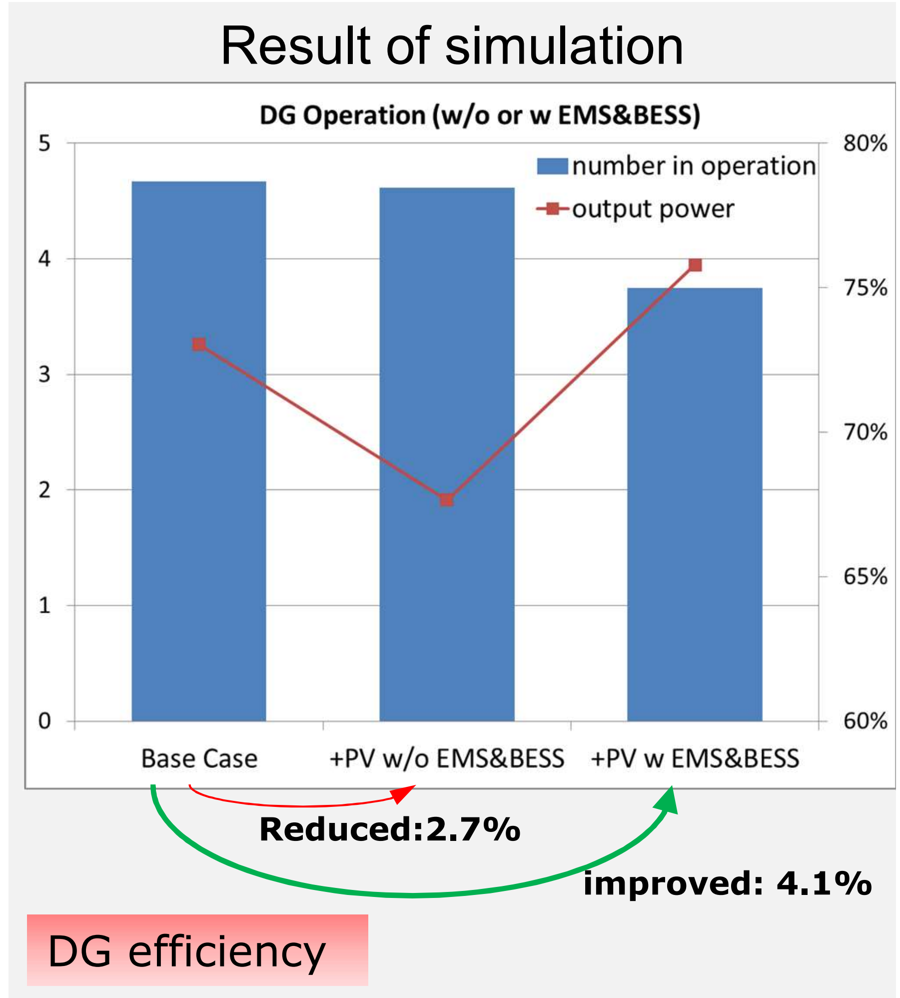
Absorbing Fluctuation by EMS & BESS



- Mitigation of reduction in DG efficiency
- Mitigation of mechanical stress on DG
- Mitigation of system frequency fluctuation

Operation point of DGs

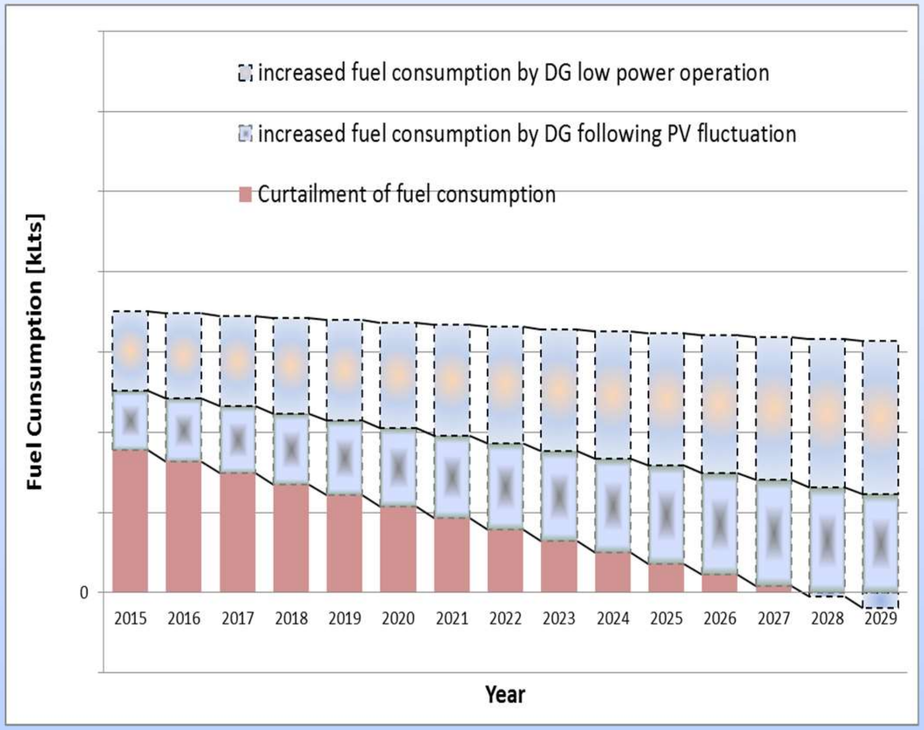




Note: Output power suppression system for 1MW PV site is necessary to reduce the reserve for increase of PV output.

Curtailment of Fuel Consumption

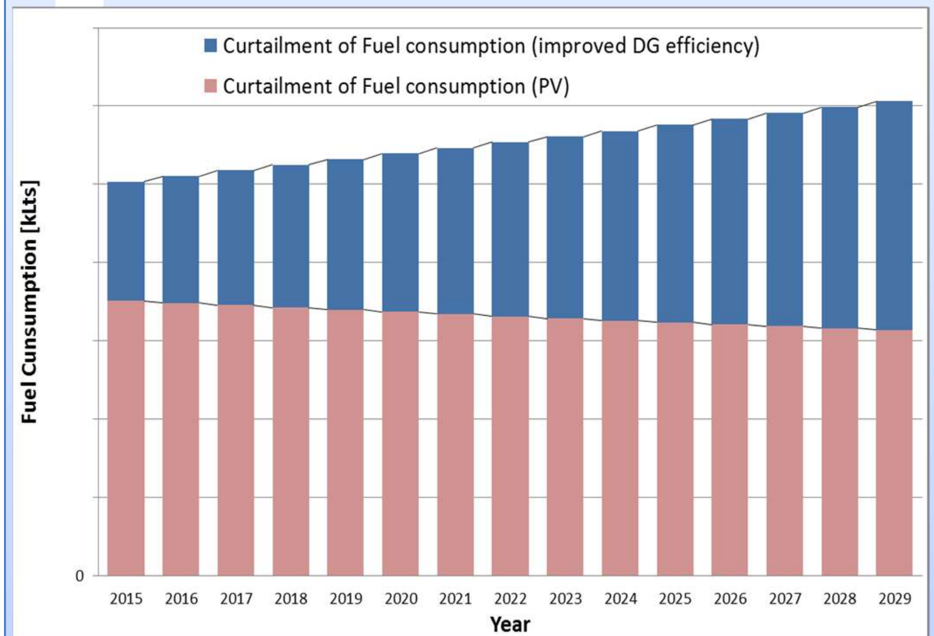
+PV without EMS & BESS



- Half of the PV's effect is canceled out due to the reduction of DG efficiency in the 1st year.
- PV's contribution will be lower due to aging.
- Fuel wastage caused by DG efficiency reduction will increase according to the Demand growth.

Curtailment of fuel consumption: **2,368** [kℓ/15years]
CO2 reduction: **6,305** [t-CO2/15years]

+PV with EMS & BESS



- EMS & BESS improves DG efficiency and reduces fuel consumption. This effect will increase according to the Demand growth.
- PV's contribution will decrease due to aging.

Curtailment of fuel consumption: **16,624** [kℓ/15years]
CO2 reduction: **44.259** [t-CO2/15years]

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Project Details

Toshiba Energy Systems & Solutions Corporation

Issue of the Project

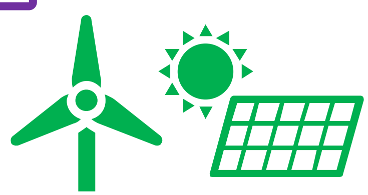
Does renewables adress the issue of demand increase?

The answer is sometimes NO. Because..

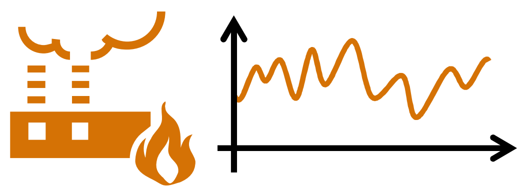
Renewables save “kW” but require “⊿kW”

As a result, fuel cost and $CO2$ emission will be unexpectedly increased.

Demand Increase



Renewables Integration



System instability
Fuel cost increase

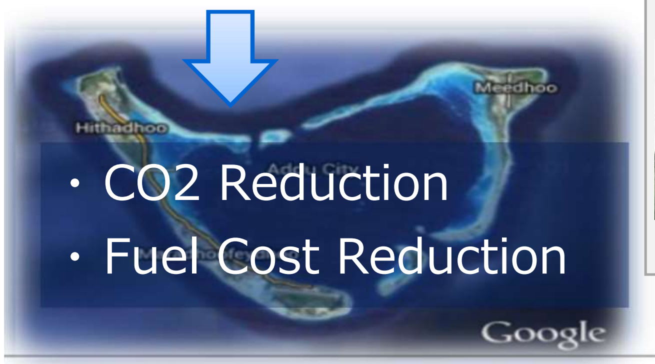
System Outline

EMS controls diesel generators and battery system to stabilize the system and to reduce the fuel cost

EMS (New)

Energy Management System for Micro-grid

- Fluctuation reduction of PV
- Economic operation of DGs



- CO_2 Reduction
- Fuel Cost Reduction

Battery System (New)

1MW-336kWh Capacity

Li-ion Battery SCiB™

Diesel Generators (DGs)

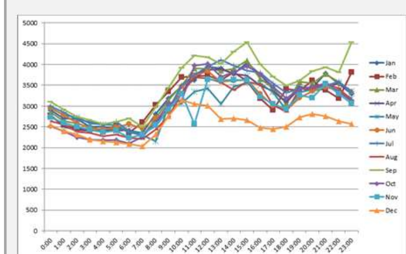
Total: 18MW Rated (17 DGs)

PV System

Total: 1.6MW

Load

Peak Demand: 6-7MW

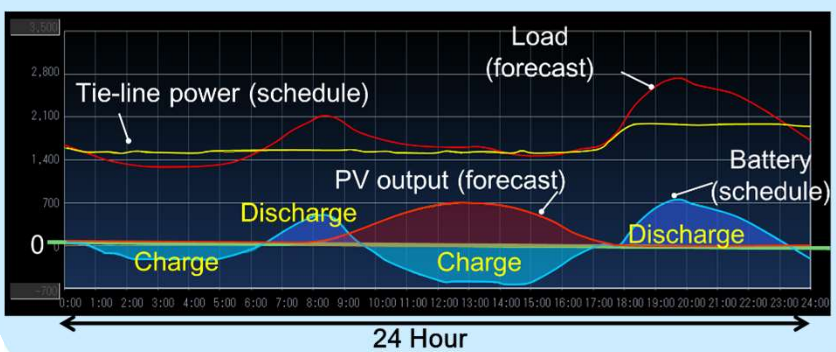


https://www.toshiba-energy.com/info/info2019_0122.htm

Key Technologies of the Project

EMS (Energy Management System)

- Highly reliable technology based on domestic central dispatching system
- Supporting hydrogen control

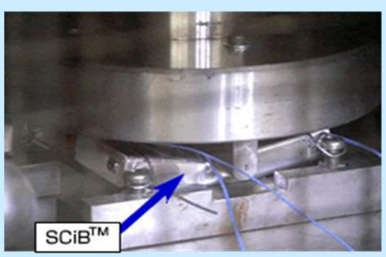


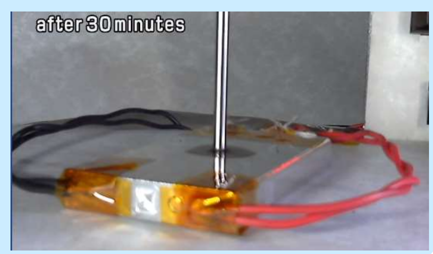
BESS (Battery Energy Storage System)

- Extreme long life rather than the other kind of Li-on batteries

  More than 75% remaining capacity after 20,000 cycles

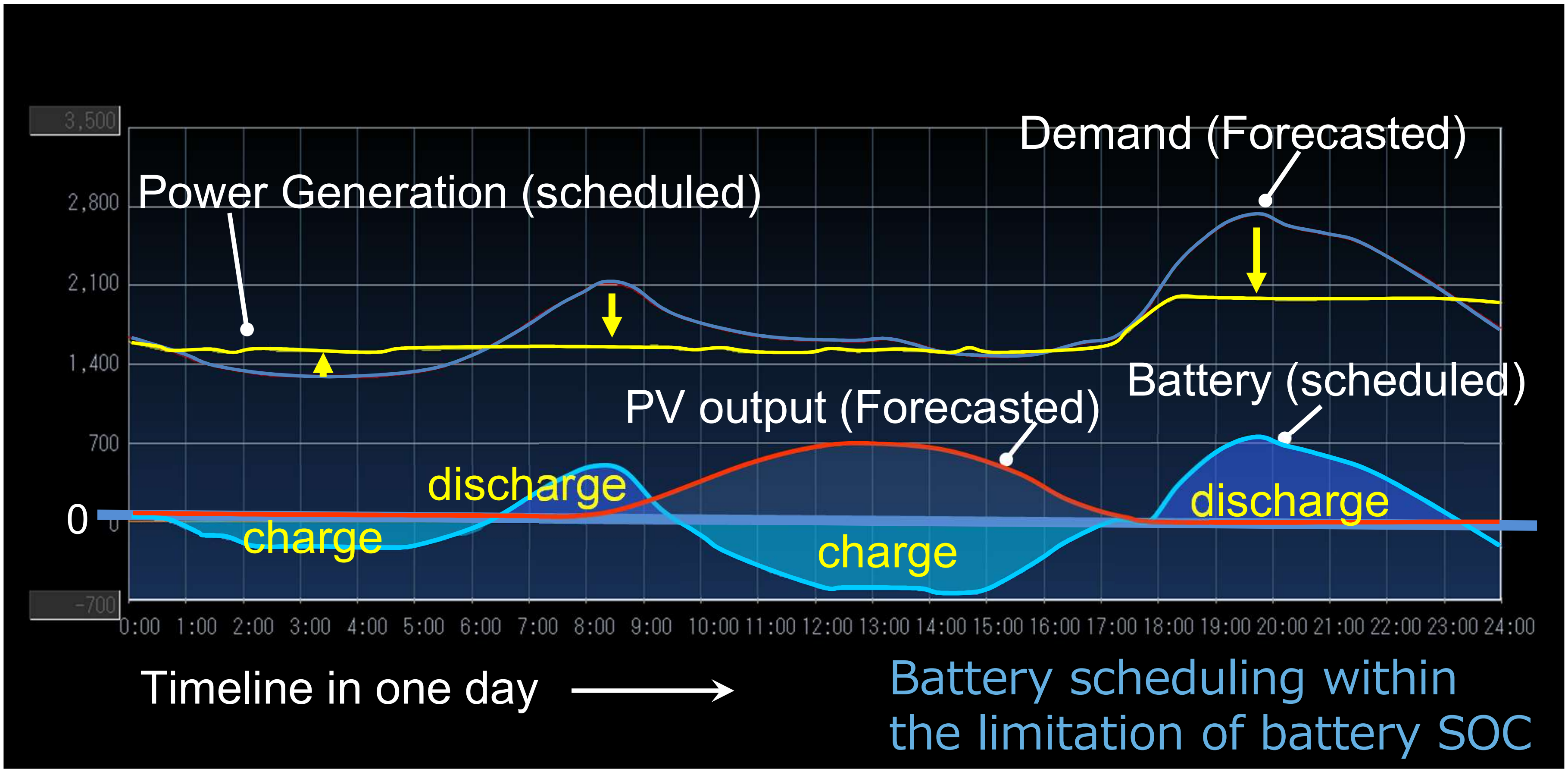
- Proven safety by crash and nail penetration test





No fire!

EMS Functions : Forecasting & Scheduling



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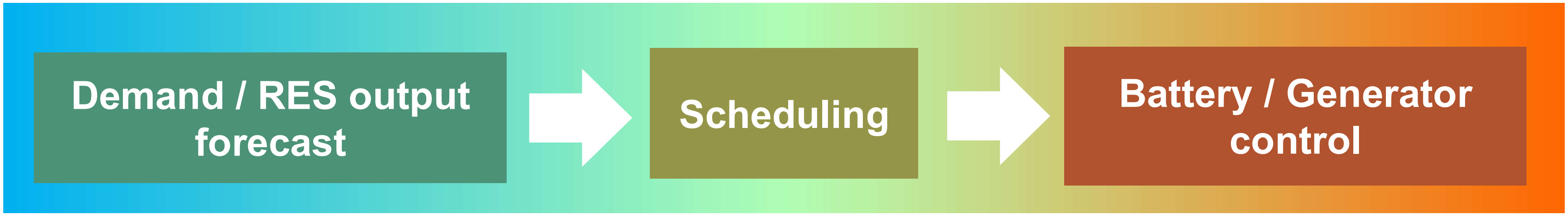
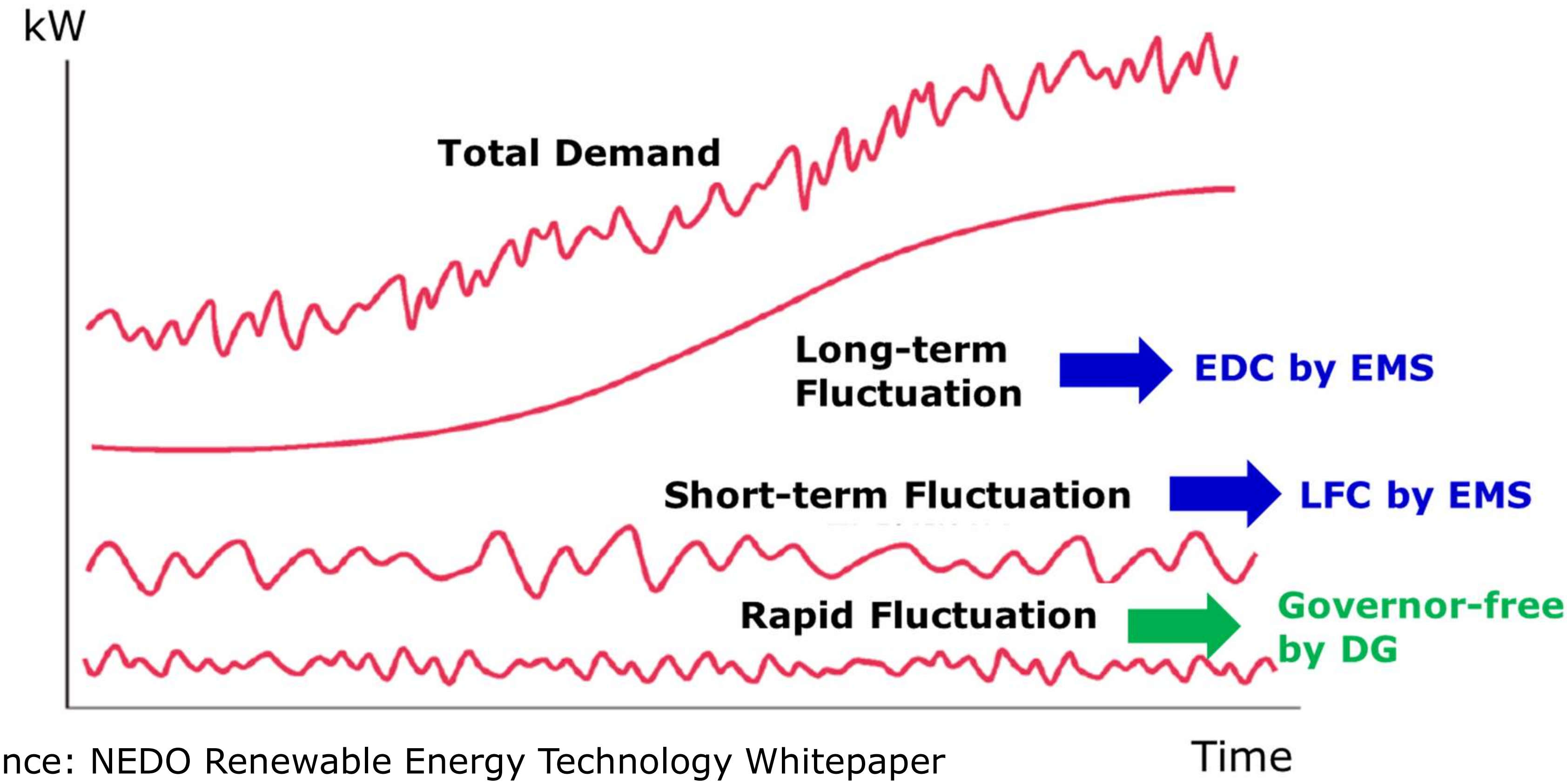
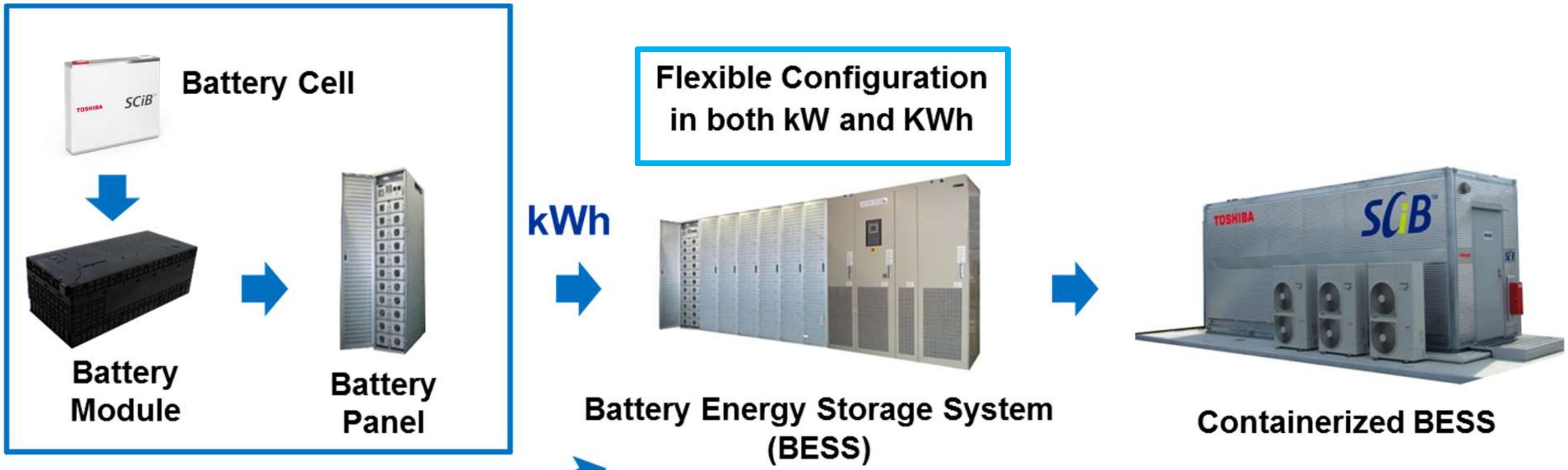
EMS Functions : Control Generators & BESS





Reference: NEDO Renewable Energy Technology Whitepaper

Battery System for Power Grid Application



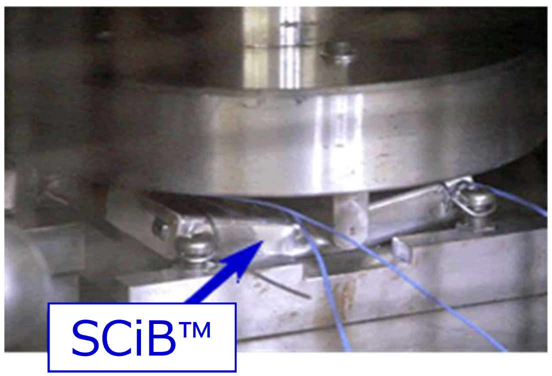
Requirements

- 15 years design life (no need to replace or add battery panels for 15 years)
- IP55 protection enclosure
- Salt weather resistance to adopt local weather at least 20 years

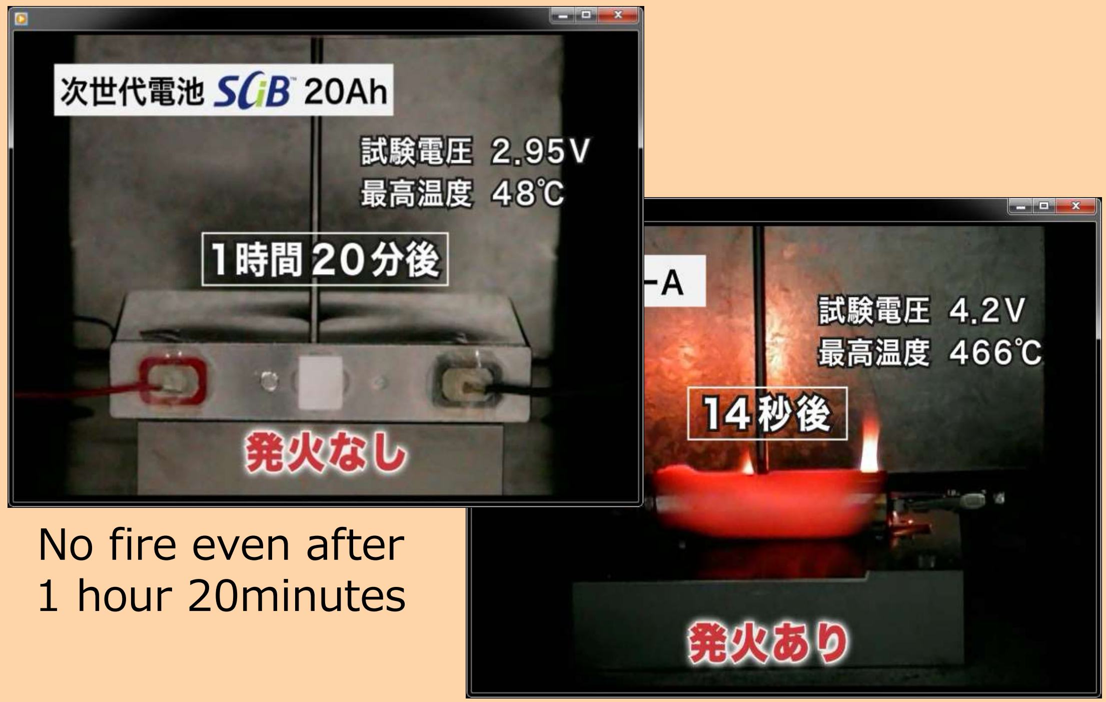
Safety of Battery Cell

No fire, No Explosion

Crash test



Bolt nail penetration test



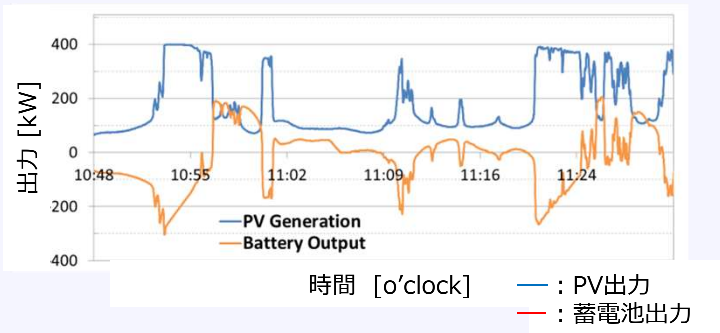
No fire even after
1 hour 20minutes

Another cell

Lifecycle Evaluation

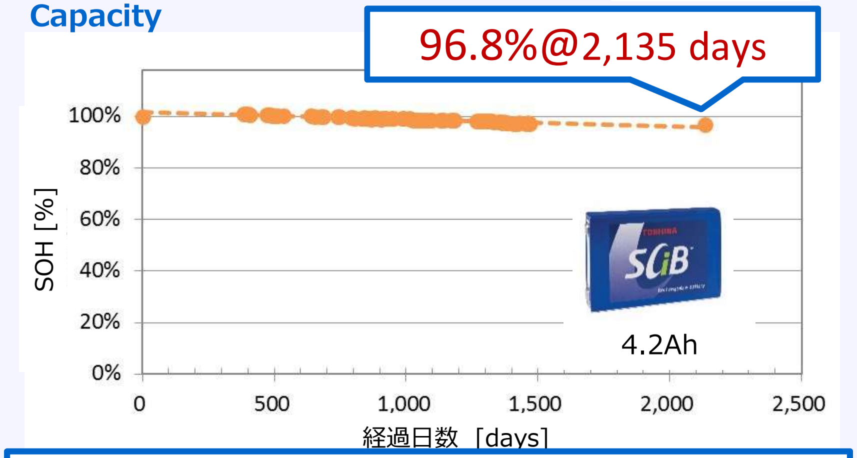
Field Data 1
Fluctuation Reduction

Charging/Discharging Pattern
(Max. 5C for PV output suppression)



Capacity

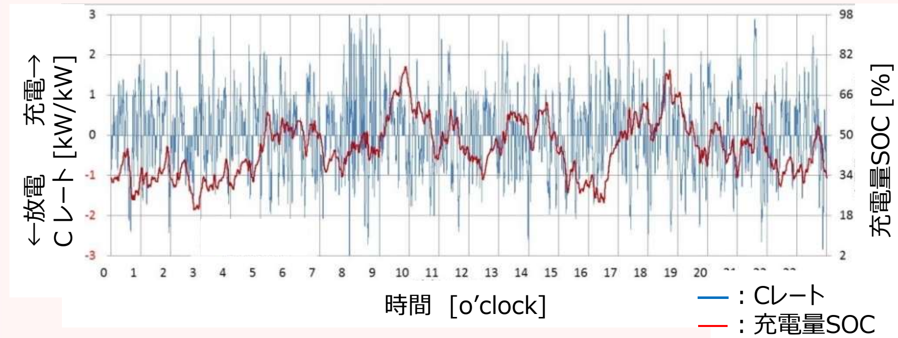
96.8%@2,135 days



Degradation is less than 1%/year
for total 6 years

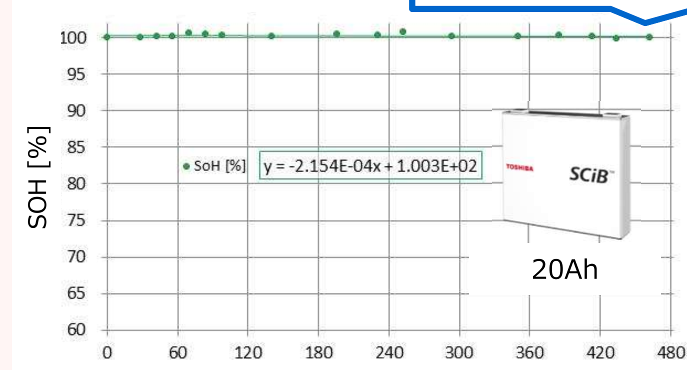
Field Data 2
Frequency Regulation

Charging/Discharging Pattern
(3C for continuous 14 months by PJM command)



Capacity

99.9%@462 days



Almost no degradation
for 14 measurement months

Resiliency of the Project

- **EMS**
  - Preventing blackout by controlling generators
  - Visualizing the system to recover from a blackout quickly
- **Battery**
  - Safe and long-life
  - Supporting degraded operation of BESS when some of battery modules are in failure
  - Redundant operation of inverters (2 circuits in 1 unit)
- **Remote Monitoring**
  - The system can be monitored remotely from the FENAKA head office in Male

Challenges for Micro-grid

- **Technical Challenges**
  - To keep the balance between supply and demand under the large amount of renewable integration
- **Operational Challenges**
  - Understanding the new technologies such as battery and EMS
  - Knowledge of dairy operation, maintenance, and trouble shooting
- **Economical Challenges**
  - Increasing durability will cause to increase cost of the system
  - How to enhance the utilization of facilities
    - Disaster comes but not often. Should we have the maximum capacity?

Thank you for your attention!