Economic Analysis and Policy Proposals for Island Microgrid in China

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Outline

Part I Background

Part II Characteristics of Island Microgrid

- Technical Characteristics
- Sizing Considerations

Part III Case Study: Dawanshan Island

- Overview & System Structure
- Control Strategies & Microgrid Design
- Economic Evaluation & Policy Proposals

Part IV Policy Proposals for Development of Island Microgrid in China

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Background

Status & Importance to develop island microgrid

- More than 7000 islands (> 500 m^2)
- 450 islands with residents, 80,000 km^2
- Most powered by diesels in limited hours

Island Microgrid can:

- Make use of renewable energy on islands such as wind, solar and sea energy
- Economical & Environmental friendly
- Improve power reliability for residents
- A new energy-utilization model

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Technical Characteristics

① Operation Mode

Islanded Mode:

- Independent of the bulk power grid
- Standalone mode
- Supplied by local power sources

② Energy Source

The renewable:

- Solar Energy
- Wind Energy
- Sea/Tidal Energy
- Biomass Energy
- … …   … …

③ Power Cost

Much Higher:

- Higher than urban micro-grid
- Expensive transportation
- Expensive install cost
- Expensive construction cost

Sizing Considerations

Wind Turbines

- Abundant wind energy on islands but not in accordance with load demand
- Consider the system cost and excess wind energy
- Use pitch control (variable-pitch blades)

Photovoltaic Arrays

- Abundant solar energy on islands and often in accordance with load demand
- Installed capacity depends on the spe-cific conditions
- Install PV as much as possible due to its simple control

Sizing Considerations

Energy Storage System

- Act as main power source when diesel generator is off, providing power regulation and voltage/frequency control
- Support power fluctuation independently
- Depends on control strategies

Diesel Generators

- Act as back-up power supply
- Large capacity leads to low efficiency
- Depends on load demand
- Consider using several small diesel generators instead of a large one

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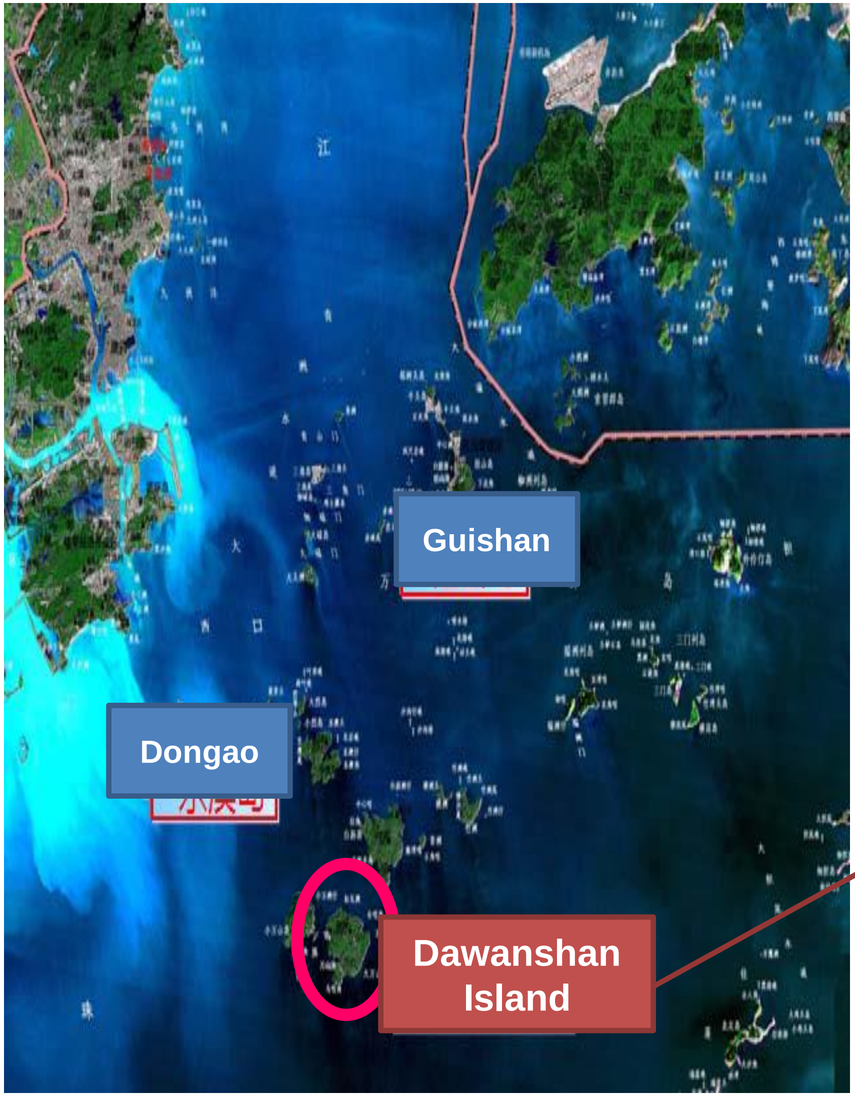
Overview



Dawanshan Island

- Located to the southeast of Guangdong, China.
- The area of the island is 8.1 km^2, and the population is 300.
- Main industries: fishing and tourism
- Relied on diesel generation with high cost and low reliability

Resources & Demand

Load Demand

- Mainly at: Wanshan, southwest and northwest of the island
- Load changes with tourism:

  High-season: May – Oct;

  Low-season: Jan-April, Nov-Dem
- Peak load: 810kW; 59% of load is 200kW-400kW

Wind Resource	**Abundant**	Average wind speed: **6.89 m/s ~ 7.58 m/s** at the height 10m ~ 70m
		Average wind power density: **426.1 W/m^2 ~ 444.3 W/m^2**
		Average wind speed: **Winter > Summer**
Solar Resource	**Medium**	Average annual solar radiation: **4996.25 MJ/m^2**
		Typical year solar radiation: **4975 MJ/m^2**
		Solar radiation is **high from May to October**

System Design

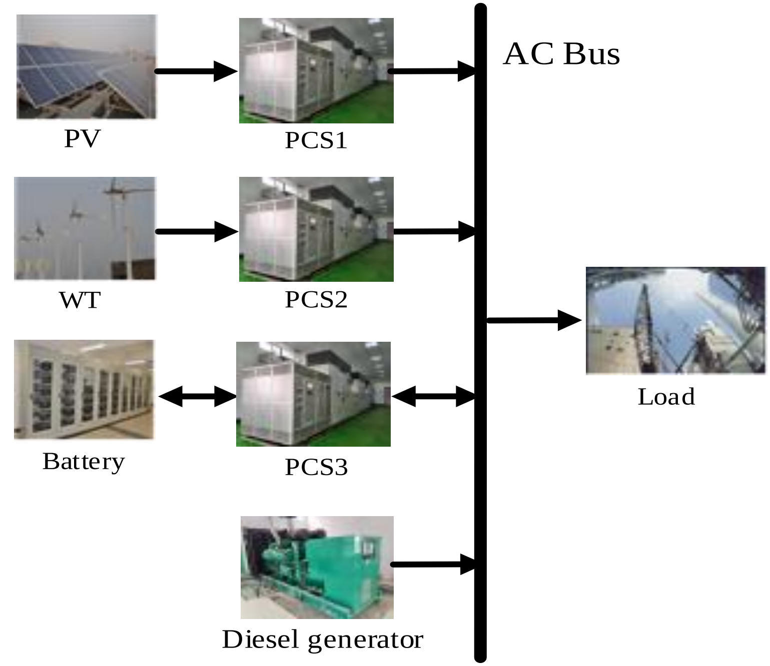
Objective Function:

Net Income = Total Income − Cost

$$\max \quad f = B_{net}^{pre} - C_{\mathrm{TEI}}^{pre}$$

$$B_{net}^{pre} = \sum_{l=1}^{T} (B_{ele,l} - C_{fuel,l}) / (1+r)^{l}$$

$$C_{\mathrm{TEI}}^{pre} = C_{\mathrm{I}} + \sum_{l=1}^{T} (C_{D,l} / (1+r)^{l})$$



System Structure of Dawanshan Microgrid

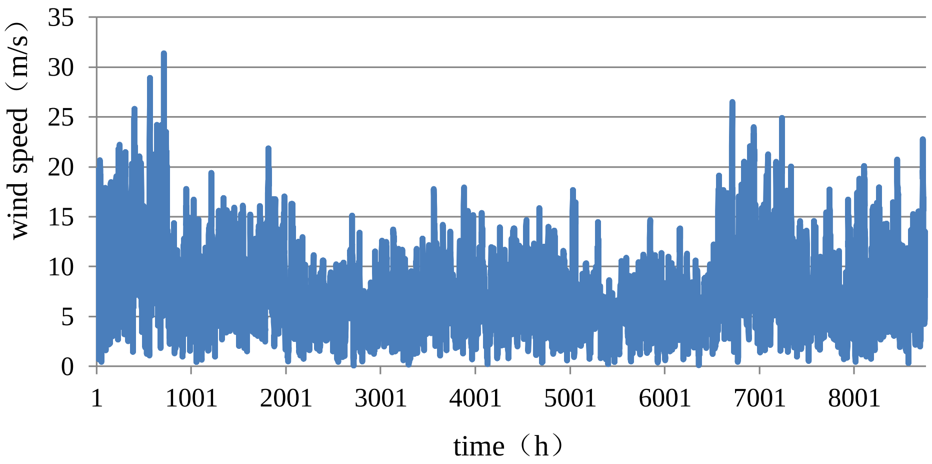
Constraints:

Device	Range/Alternatives	Considerations
DE	1000kW, 500kW	Load Level
WT	500kW, 850kW	Cost & Tech Readiness Level; Peak Load 810kW
PV	≤ 200kWp	Local Environment; Roof Space
ESS	2000kWh ~ 5000kWh	Consider the Worst Situation

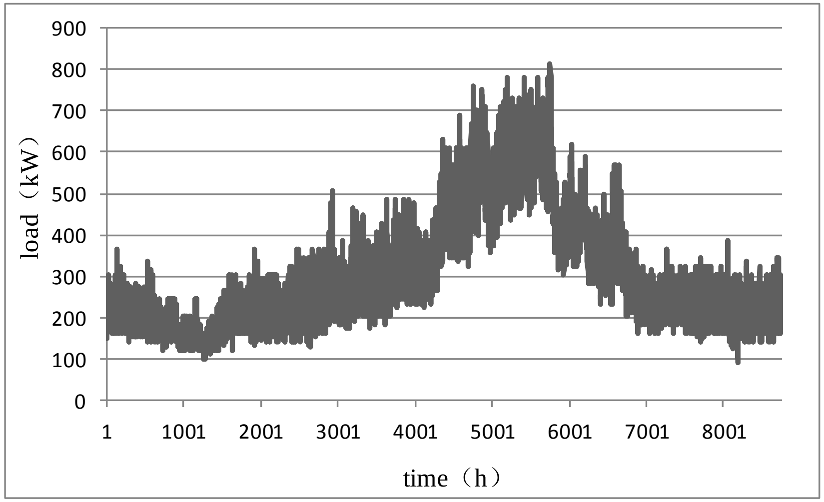
Resource/Load Data

Solar/Wind/Load Data:

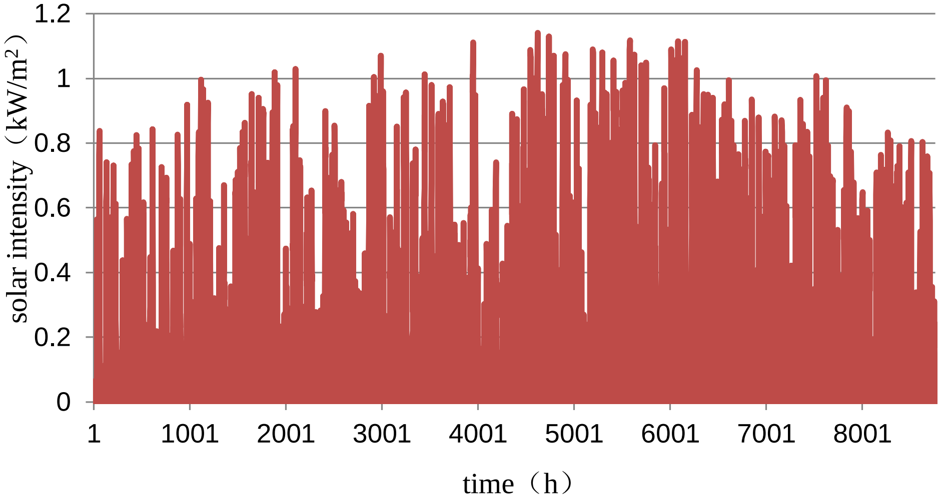
According to the solar and wind resources of Dawanshan Island, data needed in the optimization model was generated by HOMER.



Forecast Results of Wind Speed



Load Forecast Results

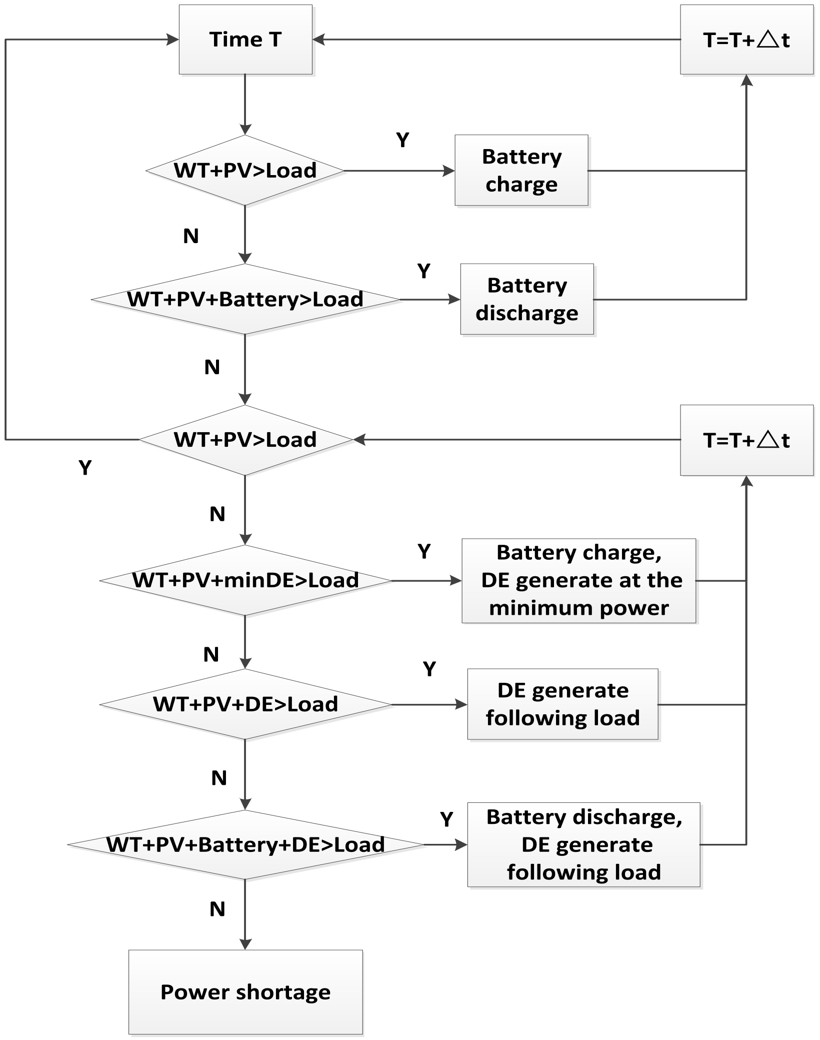


Forecast Results of Solar Radiation

Control Strategies

Load Following Strategy

- Use WT/PV/ESS first, and take ESS as main power Source;
- When WT+PV+ESS > Load, ESS would be charged by WT/PV;
- When WT+PV+ESS < Load, DE would be started to supply load along with ESS;
- When WT+PV > Load, DE would be shut down, and load would be supplied by WT/PV/ESS.



Flow Chart of Load Following Strategy

Design Results

Sizing Plan

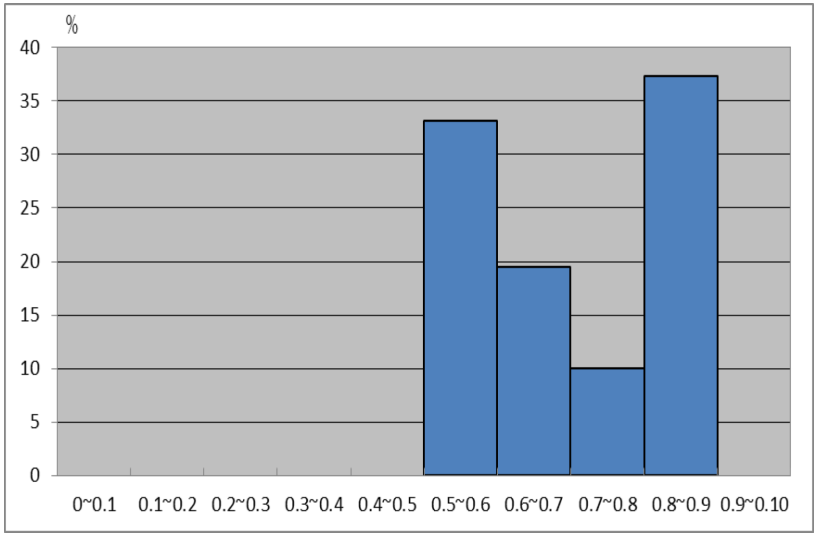
Device	Results
Wind Generators	1×850kW
PV Arrays	200kWp
Lead-Acid Battery	2000kWh
PCS	1000kW
Diesel Generators	2×500kW

Initial Investment

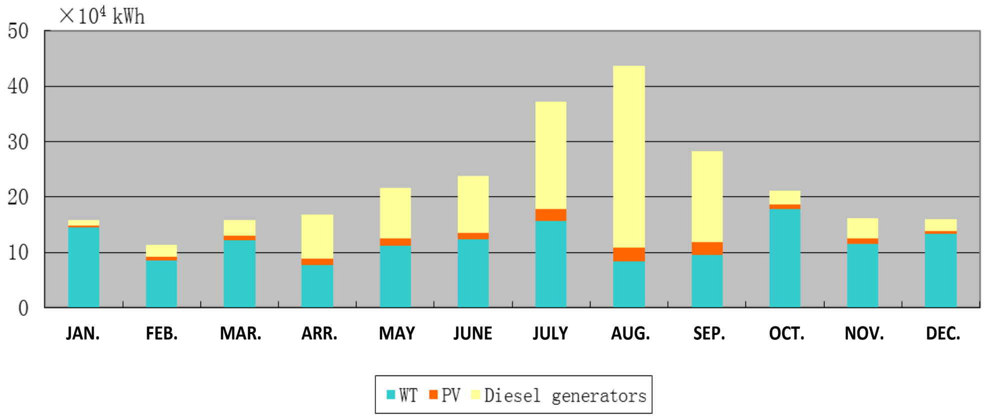
Device	Cost (USD)
Wind Generators	1,400,000
PV Arrays	325,000
Diesel Generators	130,000
Battery & BMS	600,000
PCS	325,000
Total	2,780,000

Operation Evaluation

Generation of All Power Sources			
	Generation (MWh)	Percentage (%)	Utilization Hours (hrs)
WT	1427	53.35	1680
PV	150	5.60	750
DE	1098	41.05	\



SOC Statistics of ESS of One Year



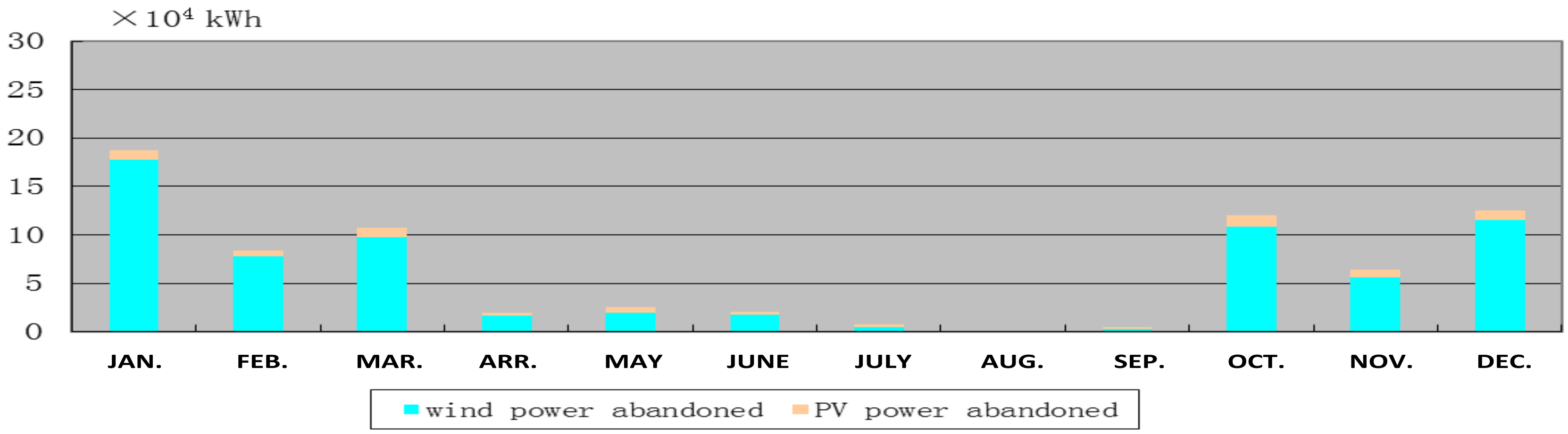
Generation of Power Sources in a Year

- SOC of batteries was set within [0.5, 0.9]. Therefore, SOC was kept above 0.8 during 37.35% time of the year to improve the power reliability especially when there is fault for diesel generators.

Operation Evaluation

Annual Renewable Energy Abandoned		
Index / Device	Energy Abandoned (MWh)	Percentage (%)
WT	694	32.72
PV	72	32.43

- In summer, load level is high but wind resource is poor. Therefore diesel generator is used a lot in summer.
- In winter, load level is low but wind resource is abundant. Therefore excess wind energy is abandoned a lot in winter.



Renewable Energy Abandoned During the Year

Economic Evaluation

Basic Information	Unit	Value
Project Cycle	year	25
Discount Rate (Interest Rate)	%	8
User Electricity Price	USD/year	0.33
Initial Investment*	USD	2,780,000

*(30% from investors, 70% loaned from banks)

Operation Results	Unit	Value
Lifetime of ESS	year	6.33
Times of ESS Replacement	time	3
Times of DE1 Replacement	time	4
Times of DE2 Replacement	time	0

Economic Indices	Unit	Value
Annual Operation Cost	USD	560,000
Annual Income Selling Elec.	USD	850,000
Annual Net Income	USD	290,000
Net Present Value of Total Income	USD	-200,000
Internal Rate of Return	%	5.925
Payback Period	year	>25

Economic Analysis

Economic Analysis:

- Only the replacement of batteries and diesel generators were considered. The replacement of wind turbines and PV arrays were not considered.
- The internal rate of return of this project is low, and the cost cannot be recovered in the project cycle. Therefore, this example cannot commercially operate without subsidies from the government.
- For islanded microgrid, central government should offer the initial investment. Subsidies can be provided through appealing electricity price for long-term operation of microgrid.

Policy Proposal

For Dawanshan Case:

- **Subsidy Principles:** With subsidies, the internal rate of return should be no less than 8%, and years of investment recovery should be around 7 to 8 years. According to this principle, subsidy regulation and level can be made.
- Subsidies can be provided in forms of initial investment or electricity price.
- Subsidy Level:

	Initial Investment	Electricity Price
Subsidy Level	70% of initial investment	0.065 USD/kWh
Years of Investment Recovery (With Subsidies)	8.15 years	8.31 years
Subsidy Period	\	10 years

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Policy Proposal

For Future Development of Island Microgrid in China:

- Provide subsidies for initial investment of island microgrid
- Provide subsidies for electricity price of areas supplied by island microgrid
- Encourage more stakeholders to participate in the construction and operation of island microgrid
- Provide integrated energy service to satisfy users' demand for electricity, heating and cooling, to improve the energy efficiency.
- Offer subsidies to device manufacturers, especially to those who produce wind turbines and batteries of medium/small capacity

Thank You

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