CCREEE
CARIBBEAN CENTRE FOR RENEWABLE ENERGY & ENERGY EFFICIENCY
AN INSTITUTION OF CARICOM

Utility-Scale Solar PV Micro-Economics

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IRRP
INTEGRATED RESOURCE AND RESILIENCE PLANS

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Investment Decision

Fixed Costs ($/MW):

- Equipment.
- Land.
- Financing.
- Project management.
- Grid connection.
- Power plant construction.

Variable Costs ($/MWh):

- Fuel.
- Operation and maintenance.
- Cost of labour.
- Emission charges (if applicable).

Investment Decision

- Considerations for replacement or addition of new generation:
  - **Average variable generation cost** for **utility-scale grid-connected variable generation** sources (solar PV, wind) (CARICOM –US$ 0.07 – 0.13/kWh).
  - **Average variable generation cost + distribution losses** for **distributed generation technologies** (CARICOM –US$ 0.07 – 0.18/kWh).

Source: IDB Sustainable Energy Paths for the Caribbean 2020

Comparable Generation Costs for Generation Technologies.

Generation Technology	Average LCOE (US$/kWh)
Dispatchable utility - scale	
Conventional combustion turbine (natural gas)	0.10
Combined cycle gas turbine	0.15
Geothermal	0.12
Biomass	0.17
Energy from municipal solid waste	0.23
Battery storage plus vRE	0.21
Utility - scale variable renewable generation	
Solar PV	0.11
Wind	0.11
Distributed generation	
Residential solar PV	0.25

Source: IDB, Sustainable Energy Paths for the Caribbean (2020)

Relative Costs for Renewable Energy Technologies (Assumptions for LCOE Calculations)

		Intermittent Renewable Sources			Dispatchable Renewable Sources		
Assumption	**Units**	**Solar PV Utility**	**Wind Onshore**	**Hydro (run-of-river)**	**Biomass**	**Energy from-MSW**	**Geo-thermal**
Capacity Type		Variable	Variable	Variable	Dispatch-able	Dispatch-able	Dispatch-able
Capacity	MW	10	10	25	15	15	10
Unit capital cost	US$M/ MW	2.40	1.42	4.32	3.68	5.33	12.90
Lifetime	Years	20	20	25	25	25	30
Capacity Factor	%	23%	30%	50%	84%	85%	85%
Fixed O&M	US$/ kW-yr	45.0	33.30	42.5	142.28	457.16	41.22
Variable O&M	US$/ MWh	0	7.505	0	8.05	11.71	21
Unit cost of the resource	US$/ MMbtu	0	0	0	3.91	-2.41	0
Heat rate	Btu/kWh	N/A	N/A	N/A	15,857	15,819	N/A

Source: Sustainable Energy Paths for the Caribbean (IDB 2020)

Additional cost:

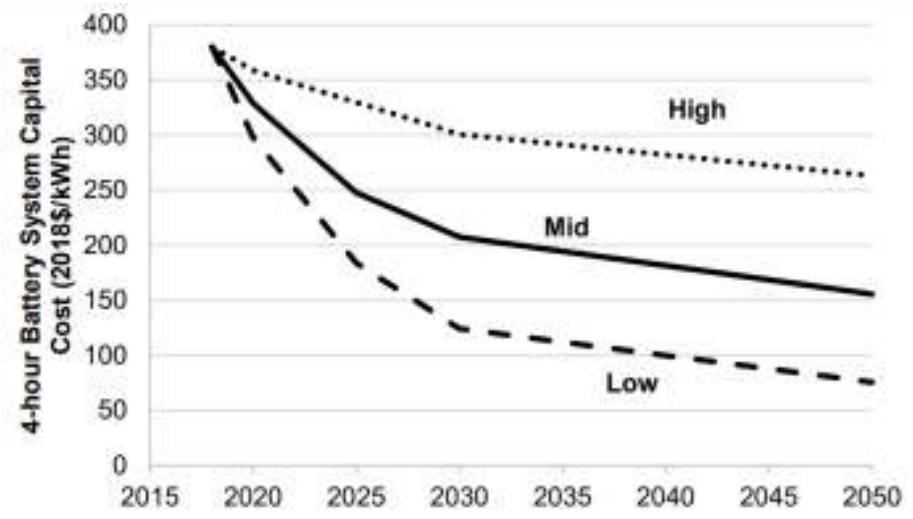
- *Sub-stations.*
- *Road Infrastructure.*
- *Land lease.*
- *Administrative & Legal Costs for License and PPA.*

Storage Costs

- Battery storage costs have declined rapidly over the past several years with volumes and technological advancements, especially for utility-scale lithium-ion battery systems.

- A 4-hr lithium-ion system in 2018 was around US$380-620/kWh however this has declined and is projected to decline further as the NREL chart shows (NREL, June 2019).

- Storage has now become an attractive component of utility scale renewable energy generation, reducing intermittency and grid instability.



Battery cost projections for 4-hour lithium ion systems.
These values represent overnight capital costs for the complete battery system.

Costs Utility Scale Solar PV

Cost Components	% of Installed Costs
Modules	46%
Structures	27%
Inverters	8%
Power System Controls	6%
Balance of Plant	7%
EPC:	2%
Owners Cost:	5%
Total	100%

Cost of Resilience

- United States National Oceanic and Atmospheric Administration (NOAA) predicts:
  - Rising sea levels, which cause larger storm surges.
  - More rainfall during hurricanes, increasing an average of 10–15%
  - More frequent category 4 and category 5 hurricanes (NOAA 2020).

Cost for Resilience

- Resilient solar PV and wind projects would increasing CAPEX by 20 % compared to a standard project (IDB, 2020).

- 28 MW **Content Solar (Jamaica)** was built with additional resilience to withstand category 4 hurricanes.
  - *Flood and wind surveys done for climate risks.*
  - *Racking was designed with screw piles to withstand severe weather conditions (WRB Enterprises 2018)*

- For the grid, burying distribution lines increases resilience by protecting the infrastructure from damage and reduces duration of power outages.
  - Undergrounding lines costs US$650,000 - US$2 million/km (depending on the terrain, vegetation, and existing structures)
  - Standard overhead lines cost about US$90,000/km. (Pacific Gas and Electric Company 2017, Kury 2017).

Cost for Resilience

Estimated Costs and Benefits of Energy Resilience (2020–2040) for CARICOM COUNTRIES

Costs and benefits	Non-resilient scenario (US$ millon)	Resilient scenario (US$ millon)	Difference (US$ millon)
CAPEX to underground distribution lines	0	2,491	(2,491)
Estimated damage to distribution lines	1,087	917	170
Net costs of undergrounding			**(2,321)**
CAPEX to strengthen solar PV and wind assets	0	46	(46)
Total estimated damage to solar PV and wind generation	139	82	57
Net cost for hurricane -resistant RE			**11**
Economic loss caused by power outage	11,394	4,769	6,625
Avoided cost of economic loss due to power outages			**6,625**
Total net benefits			**4,315**

(All values are calculated in present value terms, assuming a social discount rate of 10%)

Source: Sustainable Energy Paths for the Caribbean. (IDB 2020)

Project Financing

- Project financing for the Region can be difficult due to smaller project scales, however there are opportunities from different sources for private sector and public sector financiers:

- Current emphasis on climate change mitigation and the significant solar resources in the region has attracted financing support from established development partners such as **UNDP and UNEP** which provide grant funding through the Global Environment Facility (GEF) for multiple grid-interactive small distributed generation systems in the range of 50 – 200 kW. Beneficiaries include Jamaica and St Kitts and Nevis.

- Other development agencies such as **USAID** has funding for its Public Private Sector alliance programme in Jamaica, to the sum of US$4 M to overcome barriers to renewable energy projects and co-finance the buildout of solar energy systems with battery storage, with private sector parties firms. An estimated US$50 M will be invested for this initiative.

Project Financing

- Other sources of funding from Europe, UK and Asia such as:
  - Department for International Development (DFID) (UK).
  - Department of Energy and Climate Change (DECC) (UK).
  - European Development Fund (EDF).
  - Spanish Agency for Development Cooperation (AECID).
  - China Development Bank (ChDB).
- Such projects support the commercial interests of private sector nationals with collateral benefits for the Region.

Project Financing

- Technical support for project development continue to come from established partners from foreign governmental agencies with result in financing energy projects, usually on a State to State basis such as:
    - Canadian International Development Agency (CIDA).
    - Deutsche Gesellschaftfür Internationale Zusammenarbeit (GIZ).
    - National Research Energy Laboratory (NREL) (USA).
    - Abu Dhabi Fund for Development (ADFD).

Financing supports important technical assessment, feasibility studies and other consultancies but may not finance grid-integrated utility scale renewable energy infrastructure.

Project Financing

- Direct international private sector financiers are also investing in the Region using Special Purpose Vehicle (SPV) economic instruments along with national partners to fund renewable installations.
- Swiss battery maker Leclanché has a SPV with St Kitts & Nevis for a 35.7 MW solar PV farm with 45.7 MWh battery energy storage system (BESS), which would allow integration with the grid.

- Various development and commercial banks provide commercial debt financing for renewables with grid parity being achieved, global clean energy commitments, rise in national renewable energy ambitions and retirement of fossil fuel gensets including:
  - Eastern Caribbean Central Bank (ECCB).
  - Caribbean Development Bank (CDB).
  - International Finance Corporation (IFC).
  - Caribbean Basin Sustainable Energy Fund (CABEF).

Project Financing

- Development banks and commercial banks (cont.):
  - Overseas Private Investment Corporation (OPIC) (U.S. International Development Finance Corporation).
  - InterAmerican Development Bank (IDB) and its Inter-American Investment Corporation
  - Caribbean Renewable Energy Technical Assistance Facility (CRETAF).
  - Caribbean Renewable Environmental Fund (CREF) (CARICOM).
  - Agence Française de Développement (AFD) through strategic alliances, partnering with multilateral and bilateral agencies in the region (e.g. such as IDB, ECLAC, World Bank, AECID of Spain, among others).

Summary

- Utility scale solar PV is a mature and applicable technology for generation replacement or addition, achieving national environmental, financial and sustainability goals.

- The opportunity to add commercial battery storage, and remain commercially competitive, overcomes barriers of intermittency.

- Commercial and "green" debt financing is available for infrastructure projects and grant financing for removing technological, capacity and policy barriers.

Thank you for your attention.

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