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Paving the way for renewable electricity in Barbados

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Structure of the Presentation

- The task
- Stable Pricing for RE
- Supply modes for RE
- Market structure and liberalisation
- Pricing RE and stakeholder objectives
- Choice of pricing mechanism
- Suggestion of a tailor made FIT system for Barbados
    - Design elements of the new FIT system
    - Assumptions
    - Suggested first price points
- Possible target scenarios for steering the FIT system
- Discussion

The Task

- Develop a sustainable market structure for electricity from renewable sources for Barbados

- Concerns:

  - Pricing of renewable electricity

  - Supply modes for renewable electricity

  - Electricity market structure

  - Appropriate model for electricity market liberalisation

Pricing of Renewable Energy

- Develop a pricing mechanism for renewable energy technologies
- The mechanism needs to establish a stable price regime for a competitive supply of affordable electricity
- Needs to be part of a sustainable market structure for electricity
- Recommend first price points
- Develop mechanisms for price adjustments for current technologies

Pricing of Renewable Energy

- Needs to discuss RE support mechanisms like:
  - Net metering
  - Net billing
  - Renewable energy rider (RER)
  - Feed-in tariff (FIT)
  - Auctioning
  - Renewable portfolio standards (RPS)
- Needs to analyse the cost situation of RE to derive first price points

Supply Modes for Renewable Electricity

- Develop a sustainable supply mode for electricity from renewable sources for Barbados
- Give recommendations for policies to establish an equitable, safe and affordable supply of renewable electricity
- Possible supply modes discussed:
  - guaranteed priority market access
  - buy-all/sell-all
  - net metering or net billing
  - wheeling of renewable electricity
  - banking of renewable electricity
  - renewable electricity certificates
  - combinations of some modes and mechanisms

Market Structure and Possible Liberalisation

- Does the present market structure need to be liberalised to support the increasing number of (RE) electricity suppliers?
- How does the suggested support mechanism for renewable electricity connect to the overall market structure?
- What is the stage of liberalisation reached?
- Is a further liberalisation possible?
- Is a further liberalisation needed?
- Give policy recommendations for a sustained liberalised electricity market

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The Results on Market Liberalisation

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- The degree of market liberalisation is already high in Barbados
- Seven out of nine steps have already been achieved
- Only legal vertical unbundling of BL&P into *'BL&P Generation' and* 'BL&P *Grid and System Operation*' can be recommended

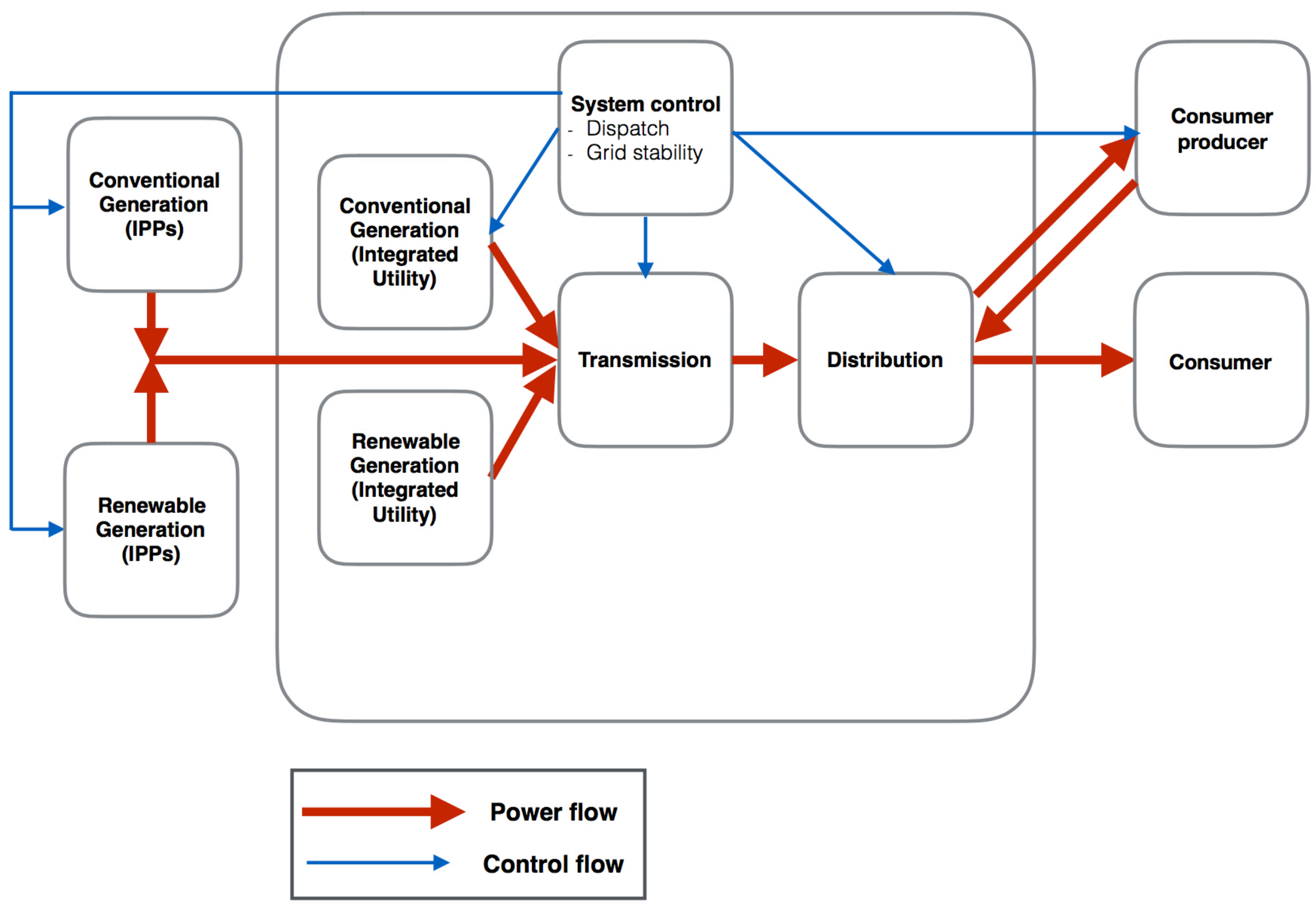
	State of liberalisation	Short characterisation	Status in Barbados
1	Corporatisation	Transformation of the utility into a separate legal entity	Achieved
2	Commercialisation	Cost recovering prices etc.	Achieved
3	Passage of requisite legislation	Provides legal framework for restructuring and private ownership	Achieved
4	Establishment of independent regulator	Aims to introduce transparency, efficiency and fairness in the management of the sector	Achieved
5	Independent power producers (IPPs)	Introduce new private investment in generation with long-term power purchase agreements (PPAs)	Legally achieved
6	Restructuring	Involves horizontal and/or vertical unbundling of the incumbent (state-owned) utility as preparation for privatisation	Not achieved
7	Divesture of generation assets	Divests state ownership of generation assets to the private sector	Achieved
8	Divesture of distribution assets	Divests state ownership of distribution assets to the private sector	Achieved
9	Competition	Introduces wholesale and retail markets for electricity	Not achieved

Source: GSEC Ltd. 2017, p. 140

Barbados' Present Legal Market Structure

- Barbados has all legal provisions for independent power producers of conventional and renewable electricity

Present theoretical structure of Barbados power supply system (own graphical representation)

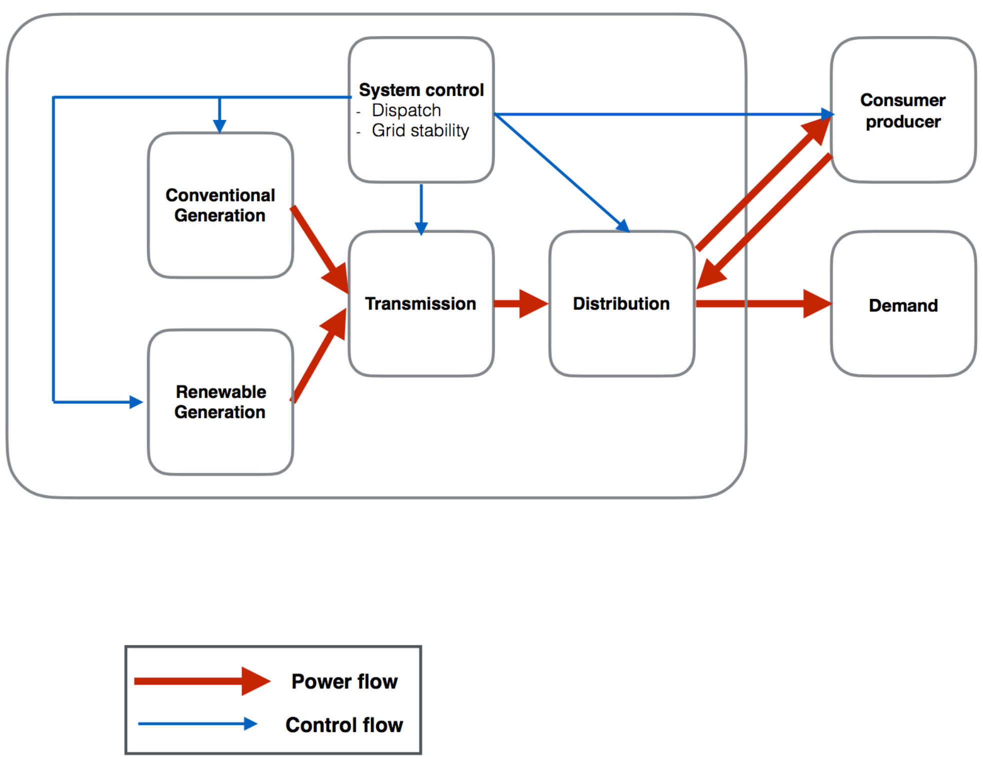


Source: GSEC Ltd. 2017, p. 140

Barbados' Present Factual Market Structure

- In fact there are no IPPs in conventional or renewable electricity production in Barbados
- Conventional power production is not economically attractive for IPPs in Barbados due to small market size and high efficiency of existing equipment
- Renewable energy IPPs are confronted with an asymmetric bargaining situation and unclear licensing procedures

Present factual structure of Barbados power supply system (own graphical representation)



Source: GSEC Ltd. 2017, p. 140

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No Market for Conventional Generation IPPs

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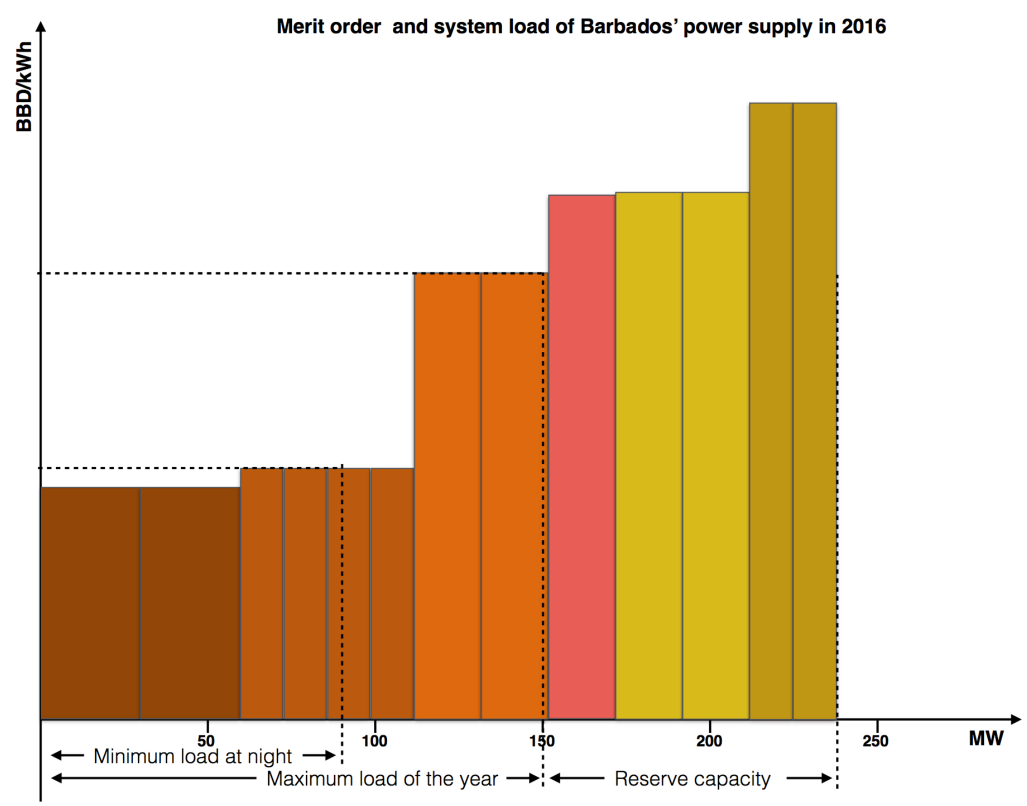
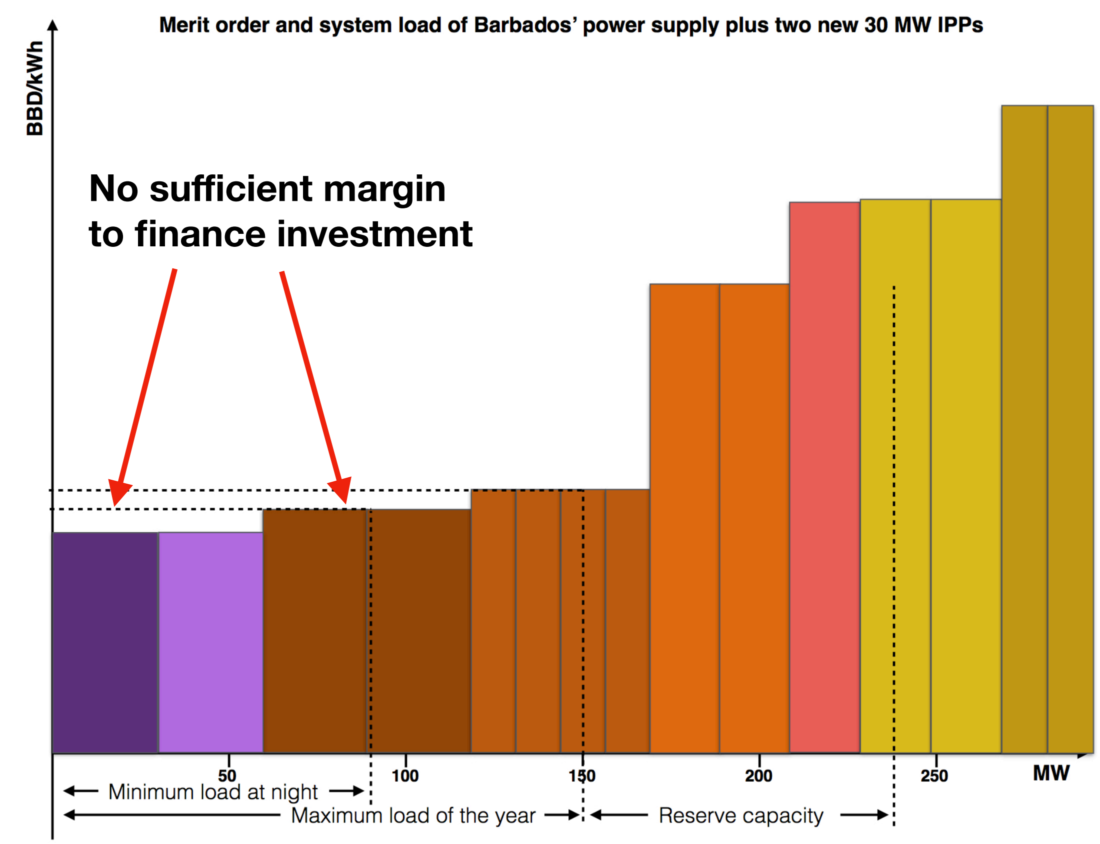
Conventional power production is not economically attractive for IPPs in Barbados due to small market size and high efficiency of existing equipment

Merit order and system load of Barbados' power supply in 2016 (based on heat rates of generators, used fuels and international fuel prices in April 2017)



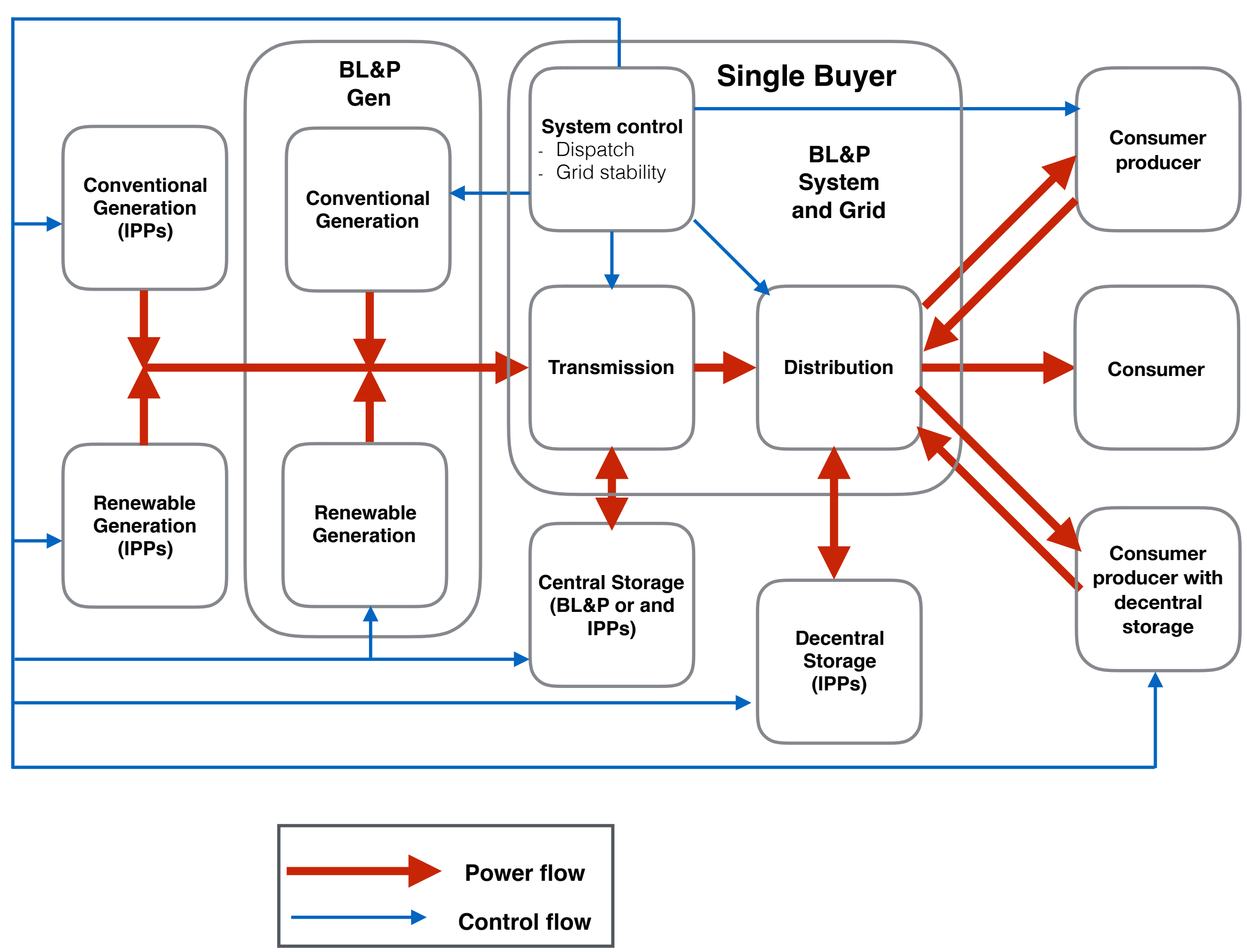
Barbados' merit order with two additional IPP generators of 30 MW each



Source: GSEC Ltd. 2017, p. 140

Vertical Legal Unbundling Could Work

- A legal vertical unbundling of BL&P is suggested for the future into:
  - *BL&P Generation* and
  - *BL&P Grid and System Operation* (acting as single buyer)



Source: GSEC Ltd. 2017, p. 229

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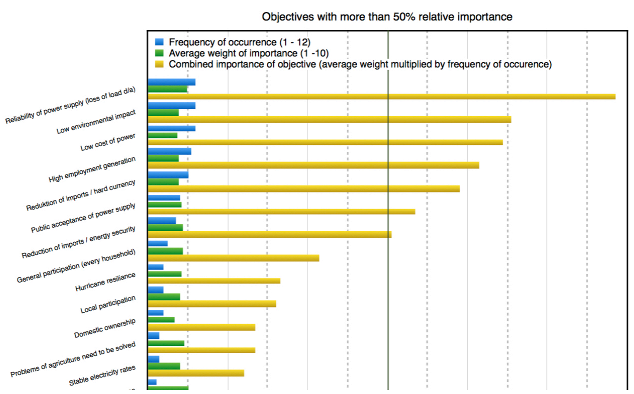
The Results on RE Policy: Objectives

First stakeholders were interviewed on their views on the most important objectives for Barbados' energy policy



	Objectives	Frequency at which the objective was mentioned	Average weight attached to objective	Relative importance of objective (Frequency x average weight)
1	**Reliability of power supply (loss of load d/a)**	12	9.8	117.0
2	**Low environmental impact**	12	7.6	91.0
3	**Low cost of power**	12	7.4	89.0
4	**High employment generation**	11	7.5	83.0
5	**Reduktion of imports / hard currency**	10	7.8	78.0
6	**Public acceptance of power supply**	8	8.4	67.0
7	**Reduction of imports / energy security**	7	8.7	61.0
8	**General participation (every household)**	5	8.6	43.0
9	**Hurricane resiliance**	4	8.3	33.0
10	**Local participation**	4	8.0	32.0
11	**Domestic ownership**	4	6.8	27.0
12	**Problems of agriculture need to be solved**	3	9.0	27.0
13	**Stable electricity rates**	3	8.0	24.0

Source: GSEC Ltd. 2017, p.245

The Match of Pricing Policies and Objectives

Possible market structures/support mechanisms have been discussed in view of the most important objectives

Priority objectives	Relative importance of objective (Score, max. 120)	Support mechanisms						
		Barbados today			Options for the future			
		RER	FTC fixed tariffs	Single PPAs	Net metering	FIT	RPS	Auctioning
Applicable to Barbados								
Administrative effort necessary								
Reliability of power supply (loss of load d/a)	117.0							
Low environmental impact	91.0							
Low cost of power	89.0							
High employment generation	83.0							
Reduktion of imports / hard currency	78.0							
Public acceptance of power supply	67.0							
Reduction of imports / energy security	61.0							
General participation (every household)	43.0							
Hurricane resiliance	33.0							
Local participation	32.0							
Domestic ownership	27.0							
Problems of agriculture need to be solved	27.0							

- Market to small for RPS and unstable prices
- Auctioning needs international investors
- Original RER is too expensive and has unstable prices
- Fixed RER too expensive
- Single PPAs don't function with monopoly
- Net metering too expensive
- Feed-in Tariffs fit the country best

Source: GSEC Ltd. 2017, p.165

The Results on RE Pricing

- The total market size of Barbados' electricity market limits the choices substantially
    - Renewable portfolio standards and renewable energy certificates can not be introduced due to market size
    - Auctioning would require substantial international participation in the bidding process and would risk low benefits for Barbados' economy
- Unlimited net metering would risk a non equitable distribution of electricity system costs at the expense of the poorest ratepayers
- Non dynamic mechanisms don't capture cost reduction potential of renewable energy sources (fixed RER rates)
- Non cost based mechanisms risk highly unstable prices for renewable energy sources and electricity costs to consumers (old RER or unlimited net metering)
- The most appropriate market structure/support mechanism for Barbados is a differentiated dynamic Feed-in tariff (FIT) system

FIT Structure and Price Points Were Developed

- Detailed recommendations for the structure of the FIT system have been developed

- Based on an assessment of national and international cost data first price points/tariffs for the FIT system have been suggested for:

  - Solar PV
  - Onshore wind energy
  - Bagasse combustion
  - King-Grass gasification
  - Biogas from manure and agricultural residues
  - Waste to energy

Design of Suggested FIT System (1)

- Based on generation costs
- Differentiated by:
  - technology
  - fuel type
  - resource quality
  - location
- Dynamic tariff degression
- Indexed tariff degression
- Responsive tariff degression
- Inflation adjustment
- Front-end loading
- Residual load responsive
- Bonus for community ownership
- Ownership by impact
- Long term guaranteed tariff
- Payment in BBD
- Limited net metering

	Design options	Possible choices	Choice for Barbados
		FIT Payment choices	
1	Prices setting based on	- Cost of generation - Value of generation / avoided cost - Fixed price incentive - Auction based price discovery	Cost of generation
2	Payment differentiation by	Technology	Yes (wind, biomass, waste to energy, storage)
3		Fuel type (biomass)	Yes (biomass: bagasse, syngas from gasification)
4		Project size	Yes (PV, biomass)
5		Resource quality	Yes (wind, PV)
6		Location (roof top, facade, ground mounted)	Yes (PV: roof top or ground mounted)
7	Ancillary design elements	Pre-established tariff degression	Yes (wind, PV, biomass)
8		Indexed tariff degression (international cost development)	Yes (PV, wind, storage)
9		Responsive tariff degression	Yes (PV, wind, biomass, storage)
10		Inflation adjustment (O&M and fuel costs)	Yes (O&M for wind, PV, storage and waste to energy; fuel costs for biomass)
11		Front-end loading	Yes (PV, wind, biomass, storage)
12		Time of delivery (dispatchable production)	Yes, eventually (for biomass and waste to energy)
13	Further differentiation (bonus)	Bonus for community ownership	Yes (wind, PV)
14		Ownership by impact (proximity to wind turbines)	Yes (wind energy, up to 10% of investment cost)
15	Payment duration	Short, medium and long term	Long term (20 years plus x)
16	Payment currency	BBD / USD	BBD
17	Net metering	Yes / No. Capacity limits are possible. Limitation to certain customer groups is possible.	Yes (PV with a capacity limit of 1 kWp and and a limit to 25% of all households (lowest income quarter)

Source: GSEC Ltd. 2017, p.173

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Design of Suggested FIT System (2)

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- All technologies, sizes, owners and locations eligible
- Priority access of RE to grid within technical limits
- Grid operator purchases all
- Automatic tariff adjustments
- FIT policy review every four years
- Caps per grid section due to technical limits
- Plans and timelines for removing technical limits published with caps
- Priority dispatch of RE within technical limits
- Super shallow interconnection cost allocation

Design options		Possible choices	Choice for Barbados
		Implementation options	
18	Eligibility	All technologies, possible operators, sizes and locations can be eligible or eligibility can be restricted.	All RE technologies, all owners, all sizes, all locations (based on location specific caps)
19	Purchase obligation / Interconnection guarantee	Yes/No	Yes, within the technical limits BL&P has to buy
20	Purchasing entity	Utility company, grid operator, government	Grid operator (BL&P)
21	FIT policy adjustment	Yes / No. Adjustment of FIT payment levels or of FIT program	Adjustment of payment levels (every two or three years) in addition to automatic degression After five years a revision of the overall policy should be considered in the light of the lessons learned (without endangering investor trust in the policy).
22	Caps	Capacity cap, project size cap, cap to program cost	Technical caps for every grid section. Grid operator has to remove technical limits as planned and agreed with the Energy Division. In the planning of the transition pathway the cost to the ratepayer should be analyzed in advance in order to limit rate increases above the average rate development under conventional electricity production.
23	Interconnection priority for RE	Yes / No	Yes (within the limits set by the caps, otherwise queuing until technical limit has been removed)
24	Dispatch priority for RE	Yes / No	Yes, to the extent possible
25	Obligation for production forecast	Yes / No (for larger installations)	No, much cheaper to do for entire system
26	Transmission and interconnection cost allocation	- Super shallow (no connection cost) - Shallow (connection cost to the nearest transmission point) - Deep (All cost for grid connection including transmission and substation upgrades) - Mixed (connection cost plus some share of transmission and substation upgrade)	Super shallow for systems up to 100kW. (No connection cost paid by RE operator.) and shallow for system larger than 100kW. (Connection cost to the nearest transmission point paid by RE operator.)

Source: GSEC Ltd. 2017, p.181

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Design of Suggested FIT System (3)

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- Transparency as key to success
- All information on the internet, updated daily:
    - connected capacities
    - RE power production
    - planned RE capacities by target years
    - available RE connection capacities per grid area
    - caps and actual queues plans on increasing connection capacities
    - timelines for relevant technical improvements
    - all relevant information on FIT calculations
- Agriculture friendly FIT
    - FIT for bagasse
    - FIT for King Grass gasification
    - FIT for biogas from manure and residues

Design options		Possible choices	Choice for Barbados
		Implementation options	
28	Inter-utility cost sharing	Yes / No (In the case of more than one utility cost increases are shared between them)	Does not apply to Barbados
29	Transparency	Different levels of transparency in FIT calculations, cap setting, actual installed capacities, capacities in application.	All relevant information on FIT calculations, cap setting, actual installed capacities, actual RE output, capacities in application procedures, planned grid upgrades, available capacities under local caps and other relevant information needs to be made available on a daily basis on the internet accessible for every potential investor
30	Agriculture friendly	Yes / No (FIT tariff setting takes into account the special challenges for the agricultural sector and incorporates such considerations into the making of the FIT structure and rates)	Yes. Special FITs are payed for biomass to contribute to the solution of the agricultural challenges faced by Barbados

Source: GSEC Ltd. 2017, p.190

Design of Suggested FIT System (4)

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- Guaranteed duration 20 years
- Front loaded for 10 years (loan pay-back time)
- Automatic digression (2.4%/a for PV)
- Capacity corridor (needs to be agreed for each RE technology)
- Increase of FIT by each 10% underachievement of target corridor (to be discussed)
- Decrease of FIT by each 10% overachievement of target corridor (to be discussed)

Technology	Size range in kW	Initial FIT rates Phase I	Initial FIT rates Phase II	Guarantee period	Annual reduction	Capacity target corridor	Increase by under-achievement	Decrease by over-achievement
		Duration in years for reference site	Duration in years for reference site	in years	in %	in MW/a	in % per 10%	in % per 10%
PV roof	1-10	10	10	20	2.4 %	5 - 10	1 %	1 %
	10-100	10	10	20	2.4 %		1 %	1 %
	100-1,000	10	10	20	2.4 %		1 %	1 %
	> 1,000	10	10	20	2.4 %		1 %	1 %
PV ground mounted		10	10	20	2.4 %	5 - 10	1 %	1 %
Wind	Investor owned	10	10	20	0 %	0 - 20	?	?
	Community owned	10	10	20	0 %		?	?
Biogas from manure	0-75	20	0	20	0 %	?	?	?
	75-150	20	0	20	0 %	?	?	?
	150-500	20	0	20	0 %	?	?	?
	500-5,000	20	0	20	0 %	?	?	?
	> 5000	20	0	20	0 %	?	?	?
Biomass gasification		10	10	20	0 %	?	?	?
Solid biomass combustion		10	10	20	0 %	none	none	none
Solid waste combustion		10	10	20	0 %	?	?	?

Source: GSEC Ltd. 2017, p.187

General Assumptions for FIT System

- Share of debt financing: 60% / 70% / **80%**
- Interest on debt: 4% / **5%** / 6%
- Return on equity before tax: 6% / **8%** / 10%
- Income tax rate applied: 25%
- Return on equity after tax: 4.5% / 6% / 8%
- Total guarantee period: 20 years
- Duration of first high FIT: 10 years

Parameter	Unit	Assumed value	Reason for the assumed value
Duration of loan	years	10	Low risk loans are available for at least 10 years duration in Barbados
Share of loan financing	%	60 / 70 / **80**	Highest possible share of low interest loan allows lowest financing costs
Interest rate on loan	%/a	4 / **5** / 6	Low risk loans have been seen in this range in Barbados for RE investments
Lenders fee	%	3	Taken from international literature (NREL). Needs Barbados specific adjustment.
Rate of return on equity (before income tax)	%/a	6 / **8** / 10	Seems to be a reasonable to high range for low risk investments in Barbados
Income tax rate	%	25	General income tax rate for Barbados
Rate of return on equity after tax	%/a	4.5 / **6** / 7.5	Is derived from rate before income tax minus 25% income tax
Total duration of guaranteed FIT payment	years	20	Based on most successful international FIT practices (e.g. Germany).
Duration of first payment period for reference plant (front loaded FITs)	years	10	Based on available loan duration for project financing.

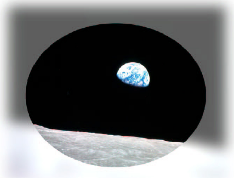
Source: GSEC Ltd. 2017, p.193

Assumptions for PV FIT

- Solar radiation: 2,196kWh/m^2
- DC to AC efficiency: 80%
- AC output per year: 1,757 kWh/kW_p
- Investment per kWp (roof):
  - 1 to 10 kW_p 6,000 BBD/kW_p
  - 10 to 100 kW_p 5,332 BBD/kW_p
  - 100 to 1,000 kW_p 3,838 BBD/kW_p
  - larger 1,000 kW_p 3,118 BBD/kW_p
  - ground mounted 3,118 BBD/kW_p
  - O & M cost 34 BBD/kW_p*a
  - Inverter replacement: 10 years
  - Inverter cost: 470 BBD/kW_p
  - Useful project life: 25-40 years

Parameter	Unit	Assumed value	Reason for the assumed value
Solar radiation per year	kWh/m^2*a	2,196	Average radiation on a horizontal surface in Barbados
PV DC to AC system efficiency	%	80 %	Average operating temperature assumed at 62.5°C with output reduction of 0.4%/1°C temperature increase over 25°C design temperature. 98% inverter efficiency assumed
Output (AC to grid) per year	kWh/kW_p	1,757	Resulting from solar radiation and AC system efficiency
Capacity factor (AC)	%	20.1 %	Resulting from AC output
Investment cost per kW_p			
- roof up to 10 kW_p	BBD/kWp	7,300	Based on Barbados cost figures for 2015 and 2016
- roof 10.1 to 100 kW_p	BBD/kWp	6,497	Based on Barbados cost figures for small systems times NREL (2016a) ratio for larger size (89%)
- roof 100.1 to 1,000 kW_p	BBD/kWp	4,672	Based on Barbados cost figures for small systems times NREL (2016a) ratio for larger size (64%)
- roof larger 1,000 kW_p	BBD/kWp	3,796	Based on Barbados cost figures for small systems times NREL (2016a) ratio for larger size (52%)
- ground mounted PV	BBD/kWp	3,796	Based on Barbados cost figures for small systems times NREL (2016a) ratio for larger size (52%)
Operation and maintenance cost	BBD/kW_p*a	34	Based on NREL 2013 (17 USD/kW_p*a)
Duration till first partial equipment replacement	years	10	Assumed replacement of inverter after 10 years
Cost of first partial equipment replacement	BBD/kW_p	470 BBD	Assumed cost for inverter replacement based on NREL 2016a (235 USD/kW_p)
Duration till second partial equipment replacement	years	20	Assumed second inverter replacement after 20 years
Cost of second partial equipment replacement	BBD/kW_p	470 BBD	Assumed cost for inverter replacement based on NREL 2013 (235 USD/kW_p)
Useful life of project	years	25 - 40	International experience with lifetime of PV plants operating (NREL 2017)

Source: GSEC Ltd. 2017, p.197



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First Price Points for PV FIT

System	Average FIT rate over the entire period	FIT rate period 1 (year 1-10) in BBD/ kWh	FIT rate period 2 (63% of period 1 for year 11-20)	Assumed investment cost in BBD/kW$_p$	Share of equity assumed	Assumed interest on debt financing	Interest earned on equity in %
PV rooftop							
1-10 kW$_p$	**0.4014**	**0.4925**	**0.3103**	6.000 BBD	20 %	5.0 %	8.0 %
10.1-100 kW$_p$	**0.3615**	**0.4435**	**0.2794**	5.340 BBD	20 %	5.0 %	8.0 %
100.1-1,000 kW$_p$	**0.2722**	**0.3340**	**0.2104**	3.840 BBD	20 %	5.0 %	8.0 %
over 1,000 kW$_p$	**0.2813**	**0.3630**	**0.1997**	3.120 BBD	20 %	5.0 %	8.0 %
PV ground mounted	**0.2298**	**0.2820**	**0.1777**	3.120 BBD	20 %	5.0 %	8.0 %
Impact of varied assumptions	Rooftop PV system 10.1 - 100 kWp						
4% interest rate on debt financing	**0.3615**	**0.4435**	**0.2794**	5.340 BBD	20 %	4 %	8.31 %
6% interest rate on debt financing	**0.3615**	**0.4435**	**0.2794**	5.340 BBD	20 %	6 %	7.77 %
70% share of debt financing	**0.3615**	**0.4435**	**0.2794**	5.340 BBD	30 %	5 %	6.00 %
60% share of debt financing	**0.3615**	**0.4435**	**0.2794**	5.340 BBD	40 %	5 %	4.60 %

Source: GSEC Ltd. 2017, p.198 (modified figures)

Sensitivity of First Price Points for PV FIT

System	Average FIT rate over the entire period	FIT rate period 1 (year 1-10) in BBD/ kWh	FIT rate period 2 (63% of period 1 for year 11-20)	Assumed investment cost in BBD/kW_p	Share of equity assumed	Assumed interest on debt financing	Interest earned on equity in %
Impact of varied assumptions							
Basic wind turbine	**0.1860**	**0.2400**	**0.1320**	4372	20 %	5 %	8.00 %
4% interest rate on debt financing	**0.1860**	**0.2400**	**0.1320**	4372	20 %	4 %	8.26 %
6% interest rate on debt financing	**0.1860**	**0.2400**	**0.1320**	4372	20 %	6 %	7.71 %
70% share of debt financing	**0.1860**	**0.2400**	**0.1320**	4372	30 %	5 %	5.95 %
60% share of debt financing	**0.1860**	**0.2400**	**0.1320**	4372	40 %	5 %	4.56 %

Source: GSEC Ltd. 2017, p.198 (modified figures)

Assumptions for Wind FIT

- Capacity factor of reference site: 39.9%
- Output AC to the grid in kWh/kW: 3,496
- Investment cost per kW: 4,732 BBD
- O&M costs per year: 129 BBD/a
- Duration of construction: 6 months
- Interest during construction: 5%/a
- Replacement of rotor module after: 10 years
- Replacement cost of rotor module: 826BBD/kW
- Replacement of drive train after: 15 years
- Replacement cost of drive train: 608 BBD/kW
- Useful project life: 20 years +

Parameter	Unit	Assumed value	Reason for the assumed value
Capacity factor of reference site	%	39.9	Average capacity factor for Barbados seven wind zones according to Rogers 2015
Output (AC to grid) per year	kWh/kW$_p$	3,496	Output of reference plant with average capacity factor (see above)
Investment cost per kW$_p$	BBD/kW	4732	Cost according to NREL 2014 and 2016a plus 25% adder for higher cost in Barbados
- Rotor module	BBD/kW	825	Cost according to NREL 2014 and 2016a plus 25% adder for higher cost in Barbados
- Nacelle module	BBD/kW	1942	Cost according to NREL 2014 and 2016a plus 25% adder for higher cost in Barbados
- Tower module	BBD/kW	591	Cost according to NREL 2014 and 2016a plus 25% adder for higher cost in Barbados
- Balance of system	BBD/kW	949	Cost according to NREL 2014 and 2016a plus 25% adder for higher cost in Barbados
- Financial cost	BBD/kW	424	Cost according to NREL 2014 and 2016a plus 25% adder for higher cost in Barbados
Operation and maintenance cost	BBD/ kW*a	129	Cost according to NREL 2014 and 2016a plus 25% adder for higher cost in Barbados
Duration of construction period	Months	6	First guess for duration of construction period in Barbados.
Interest rate during construction period	%/a	5	Based on the interest rate assumed for the debt financing of the overall investment.
Duration till first partial equipment replacement	years	10	Based on international experiences
Cost of first partial equipment replacement	BBD/kW$_p$	826 BBD	New rotor module after 10 years
Duration till second partial equipment replacement	years	15	Based on international experiences
Cost of second partial equipment replacement	BBD/kWp	608 BBD	New drivetrain after 15 years
Useful life of project	years	20	International experience with lifetime of wind turbine operation (NREL 2017)

Source: GSEC Ltd. 2017, p.197

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First Price Points for Wind FIT

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Barbados

System	Average FIT rate over the entire period	FIT rate period 1 (year 1-10) in BBD/kWh	FIT rate period 2 (55% of period 1 for year 11-20)	Assumed investment cost in BBD/kW_p	Share of equity assumed	Assumed interest on debt financing	Interest earned on equity before taxes in %/a
Basic wind turbine (investor owned)	**0.1975**	**0.2549**	**0.1402**	4732	20 %	5 %	8.00 %
Basic turbine (community owned)	**0.2118**	**0.2733**	**0.1503**	5205	20 %	5 %	8.00 %
Basic wind turbine investor owned plus 10% ownership for proximity	**0.2075**	**0.2678**	**0.1473**	4732	20 %	5 %	8.80 %
4% interest rate on debt financing	**0.1975**	**0.2549**	**0.1402**	4372	20 %	4 %	8.26 %
6% interest rate on debt financing	**0.1975**	**0.2549**	**0.1402**	4372	20 %	6 %	7.71 %
70% share of debt financing	**0.1975**	**0.2549**	**0.1402**	4372	30 %	5 %	5.95 %
60% share of debt financing	**0.1975**	**0.2549**	**0.1402**	4372	40 %	5 %	4.56 %

Source: GSEC Ltd. 2017, p.198

Moving towards a sustainable world

Impact of Reference Yield on Wind FIT Payments in Different Wind Regions

GSEC Ltd. Barbados

Area	Installed capacity at 3 MW	Fraction of total potential	Capacity factor	Output in kWh/a per kW installed	Weighted capacity factor	Duration of high FIT rate in months	Average FIT rate in BBD/kWh	Total FIT payments over 20 years in BBD/kW
1	57	0.125	45.3 %	3,968	5.66 %	105.7	0.1918	15,226
2	72	0.158	42.9 %	3,758	6.77 %	111.6	0.1939	14,575
3	72	0.158	41.6 %	3,644	6.57 %	115.1	0.1953	14,237
4	48	0.105	46.7 %	4,091	4.92 %	102.5	0.1909	15,623
5	48	0.105	40.5 %	3,548	4.26 %	118.2	0.1967	13,959
6	120	0.263	34.3 %	3,005	9.03 %	139.6	0.2085	12,531
7	39	0.086	31.5 %	2,759	2.69 %	152.0	0.2168	11,964
Total	456	1.000		3,496	39.90 %	120	0.1975	13,808

Source: GSEC Ltd. 2017, p.202

Moving towards a sustainable world

Assumptions and Price Point for Bagasse FIT

- Installed capacity: 25 MW
- Capacity during cane season: 18.6 MW
- Capacity out of cane season: 22.4 MW
- Capacity factor cane season: 69.7%
- Capacity factor out of cane season: 90.4%
- Total investment cost (all invest.): 460 mill.BBD
- Investment power generation: 175 mill.BBD
- Output per year: 169 GWh/a
- Fuel cost bagasse: 5.77 BBD/GJ
- Fuel cost river tamarind: 5.49 BBD/GJ
- Share of electricity from bagasse: 24.5%
- Share of electricity from river tamarind: 75.5%
- Acreage for river tamarind: 29 km^2
- Estimated LCOE: 0.315BBD/kWh
- Useful project life: 25 years

Parameter	Unit	Assumed value	Reason for the assumed value
Expected operational life	Years	25	Personal communication Mr. Charles Simpson Barbados Cane Industry Association
Installed capacity	MW	22.3	Personal communication Mr. Charles Simpson Barbados Cane Industry Association
Capacity available during cane season	MW	18.5	Personal communication Mr. Charles Simpson
Capacity factor during cane season	%	83 %	Personal communication Mr. Charles Simpson
Capacity factor during rest of season	%	90 %	Barbados Draft NAMA Strategy 2013
Total investment cost	Million BBD	460	Personal communication Mr. Charles Simpson
Output per year	GWh/a	169	Personal communication Mr. Charles Simpson
Fuel costs bagasse	BBD/GJ	5.0-5.6	Personal communication Mr. Charles Simpson
Fuel costs for river tamarind	BBD/GJ	7.49	Personal communication Mr. Charles Simpson
Share of energy from bagasse	%	29 %	Personal communication Mr. Charles Simpson
Share of energy from river tamarind	%	71 %	Personal communication Mr. Charles Simpson
Estimated cost per kWh	BBD/kWh	0.28	Personal communication Mr. Charles Simpson
Acreage required for river tamarind production	km^2	29	Barbados Draft NAMA Strategy 2013

Source: GSEC Ltd. 2017, p.203

Moving towards a sustainable world

Assumptions and Price Point for Bagasse FIT

Parameter	Unit	Assumed value	Reason for the assumed value
Expected operational life	Years	25	Personal communication Mr. Charles Simpson Barbados Cane Industry Association
Installed capacity	MW	22.3	Personal communication Mr. Charles Simpson Barbados Cane Industry Association
Capacity available during cane season	MW	18.5	Personal communication Mr. Charles Simpson
Capacity factor during cane season	%	83 %	Personal communication Mr. Charles Simpson
Capacity factor during rest of season	%	90 %	Barbados Draft NAMA Strategy 2013
Total investment cost	Million BBD	460	Personal communication Mr. Charles Simpson
Output per year	GWh/a	169	Personal communication Mr. Charles Simpson
Fuel costs bagasse	BBD/GJ	5.0-5.6	Personal communication Mr. Charles Simpson
Fuel costs for river tamarind	BBD/GJ	7.49	Personal communication Mr. Charles Simpson
Share of energy from bagasse	%	29 %	Personal communication Mr. Charles Simpson
Share of energy from river tamarind	%	71 %	Personal communication Mr. Charles Simpson
Estimated cost per kWh	BBD/kWh	0.28	Personal communication Mr. Charles Simpson
Acreage required for river tamarind production	km^2	29	Barbados Draft NAMA Strategy 2013

Source: GSEC Ltd. 2017, p.203

Assumptions for King-Grass FIT

- Investment costs per plant: 7.4-24 mill.BBD
- Capacity per pl 500, 600 and 1,000 kW
- Investment cost per kW: 11,000 - 40,000 BBD
- Power production per kW: 7000 kWh/a
- Debt pay-back time: 10 years
- Interest on debt: 5%/a
- Share of debt financing: 80%
- Interest on equity before taxes: 8%
- Capital cost: 1,466-5,330 BBD/kW
- Fuel cost King Grass: 6.67-8.12 BBD/GJ
- Total biomass required kW and year: 123.1GJ/a
- Cost of biomass per kW*a: 820-1,000BBD/kW*a
- Useful project life: 20 years

Parameter	Unit	New data ARMAG Farms		Assumed values		
		500 kW_{el}	1 MW_{el}	Low	Medium	High
Expected operational life	Years	20	20	20	20	20
Investment cost	Million BBD	7.4	11	10	17	24
Capacity	kW_{el}	500	1,000	600	600	600
Investment cost	BBD/kW	14,800.0	11,000.0	16,666.7	28,333.3	40,000.0
Total el production	kWh/a	3,503,333	7,006,667	4,204,000	4,204,000	4,204,000
Power production per kW	kWh/kW*a	7,007	7,006.7	7,006.7	7,006.7	7,006.7
Debt pay-back period	Years	10	10	10	10	10
Interest on Debt in %	%	5.0 %	5.0 %	5.0 %	5.0 %	5.0 %
Share of debt financing	Fraction of 1	0.8	0.8	0.8	0.8	0.8
Interest on equity	%	8.0 %	8.0 %	8.0 %	8.0 %	8.0 %
Compound interest in %	%	5.6 %	5.6 %	5.6 %	5.6 %	5.6 %
Annuity per kW	BBD/kW	1,770.08	1,315.60	1,993.33	3,388.67	4,784.00
Capital cost per kWh	BBD/kWh	0.2526	0.1878	0.2845	0.4836	0.6828
Fuel cost per t dry biomass	BBD/t	146 BBD	146 BBD	120.00	120.00	120.00
Fuel cost per GJ	BBD/GJ	8,12 BBD	8,12 BBD	6,67 BBD	6,67 BBD	6,67 BBD
Total biomass required per year	Dry t/a	4,104	4,104	4,104	4,104	4,104
GJ/t dry biomass	GJ/t dry biomass	18	18	18	18	18
Total biomass required per year in GJ	GJ	61,560	123,120	73,872	73,872	73,872
Total cost of biomass per a	BBD/a	500,000	1,000,000	492,480	492,480	492,480
Cost of biomass per kW and year	BBD/kW*a	1,000.0	1,000.0	820.8	820.8	820.8
Operation and maintenance cost per kW and year	BBD/kW*a	1000	700	1,666.7	2,833.3	4,000.0

Source: GSEC Ltd. 2017, p.204 plus new figures

Moving towards a sustainable world

Assumptions for King-Grass FIT

GSEC Ltd.
Barbados

Parameter	Unit	New data ARMAG Farms		Assumed values		
		500 kW_{el}	1 MW_{el}	Low	Medium	High
Expected operational life	Years	20	20	20	20	20
Investment cost	Million BBD	7.4	11	10	17	24
Capacity	kW_{el}	500	1,000	600	600	600
Investment cost	BBD/kW	14,800.0	11,000.0	16,666.7	28,333.3	40,000.0
Total el production	kWh/a	3,503,333	7,006,667	4,204,000	4,204,000	4,204,000
Power production per kW	kWh/kW*a	7,007	7,006.7	7,006.7	7,006.7	7,006.7
Debt pay-back period	Years	10	10	10	10	10
Interest on Debt in %	%	5.0 %	5.0 %	5.0 %	5.0 %	5.0 %
Share of debt financing	Fraction of 1	0.8	0.8	0.8	0.8	0.8
Interest on equity	%	8.0 %	8.0 %	8.0 %	8.0 %	8.0 %
Compound interest in %	%	5.6 %	5.6 %	5.6 %	5.6 %	5.6 %
Annuity per kW	BBD/kW	1,770.08	1,315.60	1,993.33	3,388.67	4,784.00
Capital cost per kWh	BBD/kWh	0.2526	0.1878	0.2845	0.4836	0.6828
Fuel cost per t dry biomass	BBD/t	146 BBD	146 BBD	120.00	120.00	120.00
Fuel cost per GJ	BBD/GJ	8,12 BBD	8,12 BBD	6,67 BBD	6,67 BBD	6,67 BBD
Total biomass required per year	Dry t/a	4,104	4,104	4,104	4,104	4,104
GJ/t dry biomass	GJ/t dry biomass	18	18	18	18	18
Total biomass required per year in GJ	GJ	61,560	123,120	73,872	73,872	73,872
Total cost of biomass per a	BBD/a	500,000	1,000,000	492,480	492,480	492,480
Cost of biomass per kW and year	BBD/kW*a	1,000.0	1,000.0	820.8	820.8	820.8
Operation and maintenance cost per kW and year	BBD/kW*a	1000	700	1,666.7	2,833.3	4,000.0

Source: GSEC Ltd. 2017, p.204
plus new figures

Moving towards a sustainable world

Possible Costs of King-Grass for FIT

GSEC Ltd. Barbados

Parameter	Unit	New data ARMAG Farms		Assumed values		
		500 kW_{el}	1 MW_{el}	Low	Medium	High
Capital cost per kWh	BBD/kWh	0.2526	0.1878	0.2845	0.4836	0.6828
Cost of biomass per kWh	BBD/kWh	0.1427	0.1427	0.1171	0.1171	0.1171
O&M costs per kWh	BBD/kWh	0.1427	0.09990	0.23787	0.40438	0.57088
	Possible resulting FIT rates of first rough calculations					
FIT rate year 1 to 10	BBD/kWh	0.5381	0.4304	0.6395	1.0052	1.3708
FIT rate year 11 to 20 (25% investment cost after 10 years for replacements)	BBD/kWh	0.3486	0.2896	0.3550	0.5215	0.6880
Average FIT rate	BBD/kWh	0.4433	0.3600	0.4973	0.7633	1.0294

Source: GSEC Ltd. 2017, p.205 plus new numbers ARMAG Farms

Moving towards a sustainable world

Assumptions and Price Points for Biogas FIT (International Price Points)

GSEC Ltd. Barbados

Size of installation	FIT in BBD/kWh	Source
	Early FIT rates for Biomass in the UK (2011-2012)	
0-250 kW	0.513	Ofgem 2017
250-500 kW	0.474	Ofgem 2017
500-5,000 kW	0.346	Ofgem 2017
	Early FIT rates for Biomass in Germany (2004-2009)	
0-150 kW	0.542	EEG 2004
150-500 kW	0.498	EEG 2004
500-5,000 kW	0.415	EEG 2004
Larger than 5,000 kW	0.298	EEG 2004
	Special tariff for anaerobic digestion of manure in Germany 2012-2014	
0-75 kW	0.661	EEG 2012
	First suggested FIT rates for Barbados	
0-75 kW	0.826	German FIT rates times 1.25
75-150 kW	0.678	German FIT rates times 1.25
150-500 kW	0.623	German FIT rates times 1.25
500-5,000 kW	0.519	German FIT rates times 1.25
Larger than 5,000 kW	0.373	German FIT rates times 1.25

Source: GSEC Ltd. 2017, p.203

Assumptions for Biogas FIT (Biogen Inc. BB)

Parameter	Unit	New data Biogen BB			Source of assumed value
		100 kW_{el}	250 kW_{el}	1 MW_{el}	
Expected operational life	Years	20	20	20	Own assumption
Investment cost	Million BBD	0.56	1.25	3	Biogen Barbados
Capacity	kW_{el}	100	250	1,000	Biogen Barbados
Investment cost	BBD/kW	5,600.0	5,000.0	3,000.0	Biogen Barbados
Total el production	kWh/a	780,000	1,950,000	7,800,000	Biogen Barbados
Power production per kW	kWh/kW*a	7,800	7,800.0	7,800.0	Biogen Barbados
Debt pay-back period	Years	10	10	10	Biogen Barbados
Interest on Debt in %	%	5.0 %	5.0 %	5.0 %	Biogen Barbados
Share of debt financing	Fraction of 1	0.8	0.8	0.8	Biogen Barbados
Interest on equity	%	8.0 %	8.0 %	8.0 %	Biogen Barbados
Compound interest in %	%	5.6 %	5.6 %	5.6 %	Biogen Barbados
Annuity per kW	BBD/kW	669.76	598.00	358.80	Resulting calculations
Capital cost per kWh	BBD/kWh	0.0859	0.0767	0.0460	Resulting calculations
Fuel cost per t dry biomass	BBD/t	146 BBD	146 BBD	146 BBD	ARMAG Farms
Fuel cost per GJ	BBD/GJ	8,11 BBD	8,11 BBD	8,11 BBD	Resulting calculations
Gas (CH4)/t biomass)	m3/t dry matter	301	301	301	Biogen Barbados
Gas in GJ/t dry biomass	GJ/t dry biomass	9.7524	9.7524	9.7524	Resulting calculations
Total biomass required per year	Dry t/a	599.9	1,499.6	5,998.5	Resulting calculations
GJ/t dry biomass	GJ/t dry biomass	18	18	18	Fichtner 2016 /ARMAG Farms
Total biomass required per year in GJ	GJ	10,797	26,993	107,973	Resulting calculations
Total cost of biomass per a	BBD/a	87,578	218,946	875,784	Resulting calculations
Cost of biomass per kW and year	BBD/kW*a	875.8	875.8	875.8	Resulting calculations
Operation and maintenance cost per kW and year	BBD/kW*a	468	468	468	Resulting calculations

Source: Biogen Inc. Barbados 2017

Moving towards a sustainable world

Price Points for Biogas FIT (Biogen Inc. BB)

GSEC Ltd. Barbados

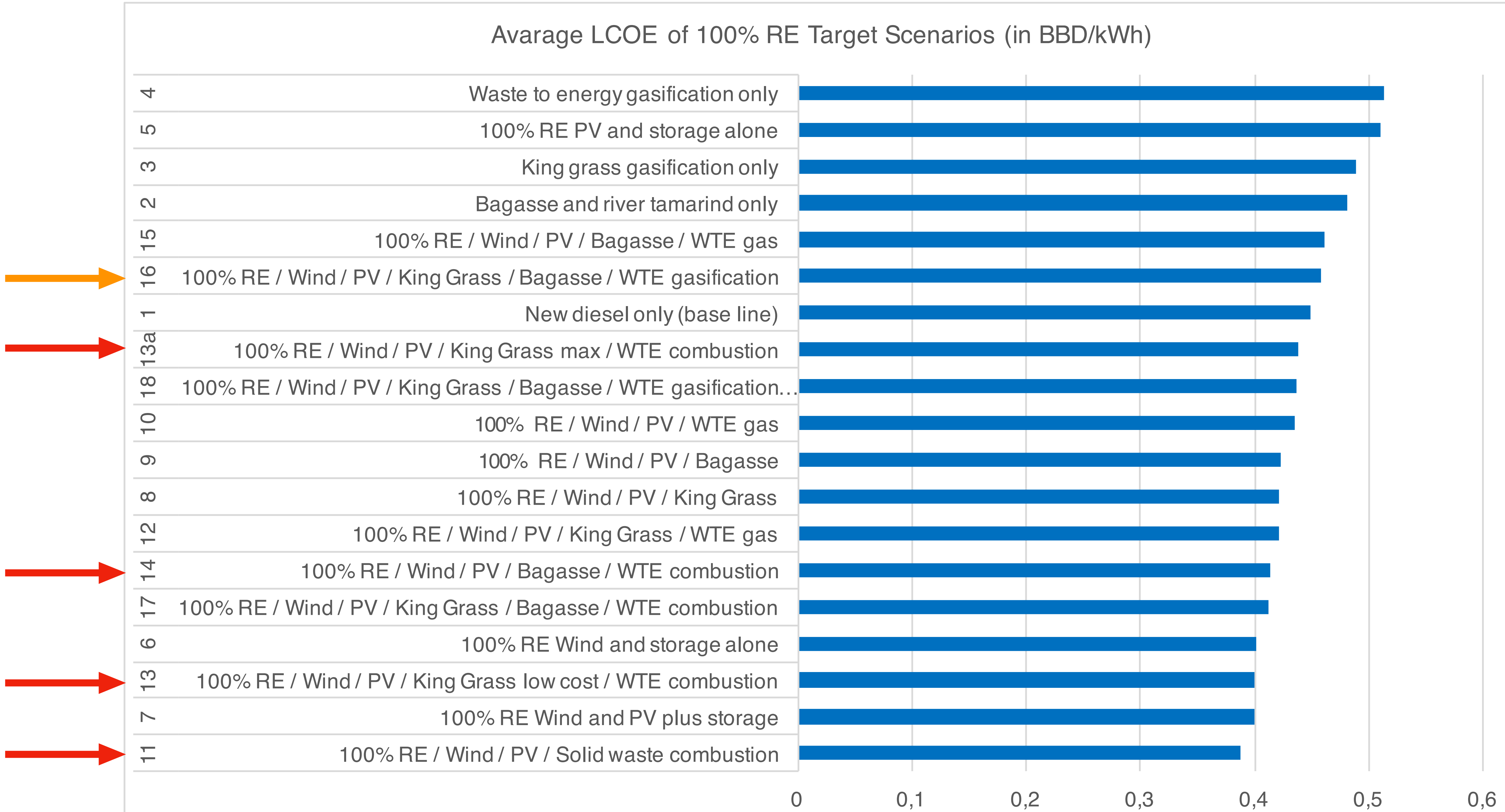
Parameter	Unit	New data Biogen BB			Source of assumed value
		100 kW_{el}	250 kW_{el}	1 MW_{el}	
Capital cost per kWh	BBD/kWh	0.0859	0.0767	0.0460	Resulting calculations
Cost of biomass per kWh	BBD/kWh	0.1123	0.1123	0.1123	Resulting calculations
O&M costs per kWh	BBD/kWh	0.0600	0.06000	0.06000	Resulting calculations
	Possible resulting FIT rates of first rough calculations				
FIT rate year 1 to 10	BBD/kWh	0.2581	0.2489	0.2183	Resulting calculations
FIT rate year 11 to 20 (25% investment cost after 10 years for replacements)	BBD/kWh	0.1937	0.1914	0.1838	Resulting calculations
Average FIT rate	BBD/kWh	0.2259	0.2202	0.2010	Resulting calculations

Source: Biogen Inc. Barbados 2017

Moving towards a sustainable world

Possible 100% RE Target Scenarios Ordered by Cost of Electricity

GSEC Ltd.
Barbados



Source: GSEC Ltd. 2017, p. 77

Moving towards a sustainable world

Possible 100% RE Target Scenarios Ordered by Cost of Electricity

GSEC Ltd. Barbados

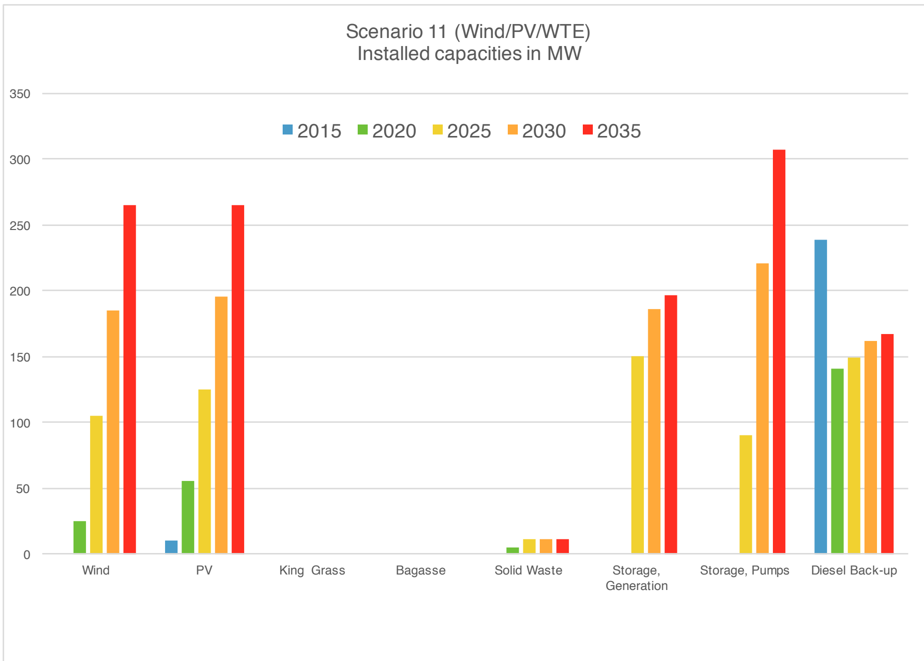
Scenario		LCOE
No.	**Name**	**BBD/ kWh**
11	100% RE / Wind / PV / Solid waste combustion	0.3883
7	100% RE Wind and PV plus storage	0.3999
13	100% RE / Wind / PV / King Grass / WTE combustion	0.4004
6	100% RE Wind and storage alone	0.4013
17	100% RE / Wind / PV / King Grass / Bagasse / WTE combustion	0.4128
14	100% RE / Wind / PV / Bagasse / WTE combustion	0.4143
12	100% RE / Wind / PV / King Grass / WTE gas	0.4209
8	100% RE / Wind / PV / King Grass	0.4212
9	100% RE / Wind / PV / Bagasse	0.4233
10	100% RE / Wind / PV / WTE gas	0.4356
18	100% RE / Wind / PV / King Grass / Bagasse / WTE gasification / WTE combustion	0.4361
13a	100% RE / Wind / PV / King Grass / WTE combustion	0.4386
1	New diesel only (base line)	0.4495
16	100% RE / Wind / PV / King Grass / Bagasse / WTE gasification	0.4584
15	100% RE / Wind / PV / Bagasse / WTE gas	0.4614
2	Bagasse and river tamarind only	0.4810
3	King grass gasification only	0.4886
5	100% RE PV and storage alone	0.5100
4	Waste to energy gasification only	0.5126

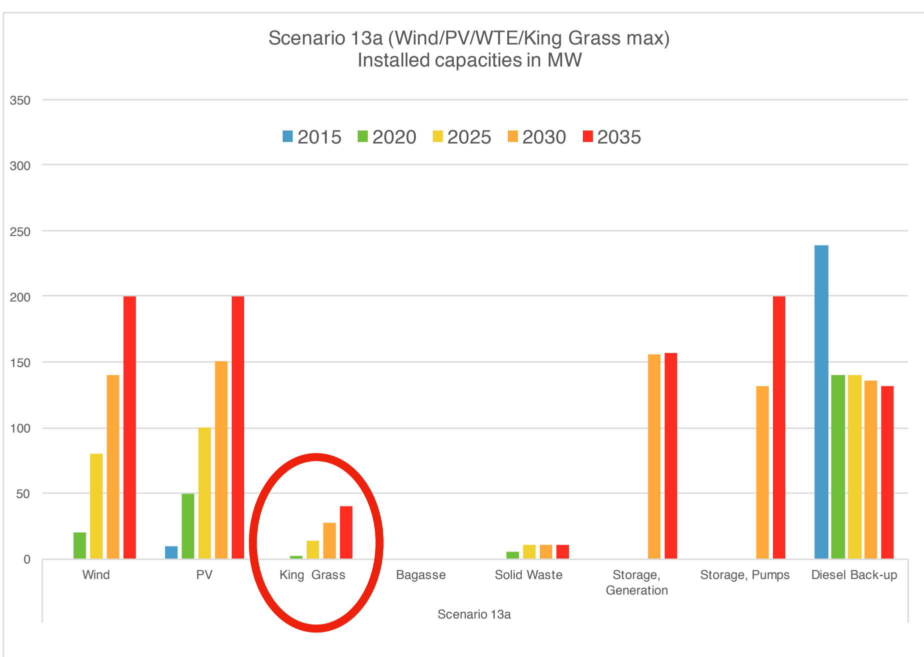
Source: GSEC Ltd. 2017, p. 77

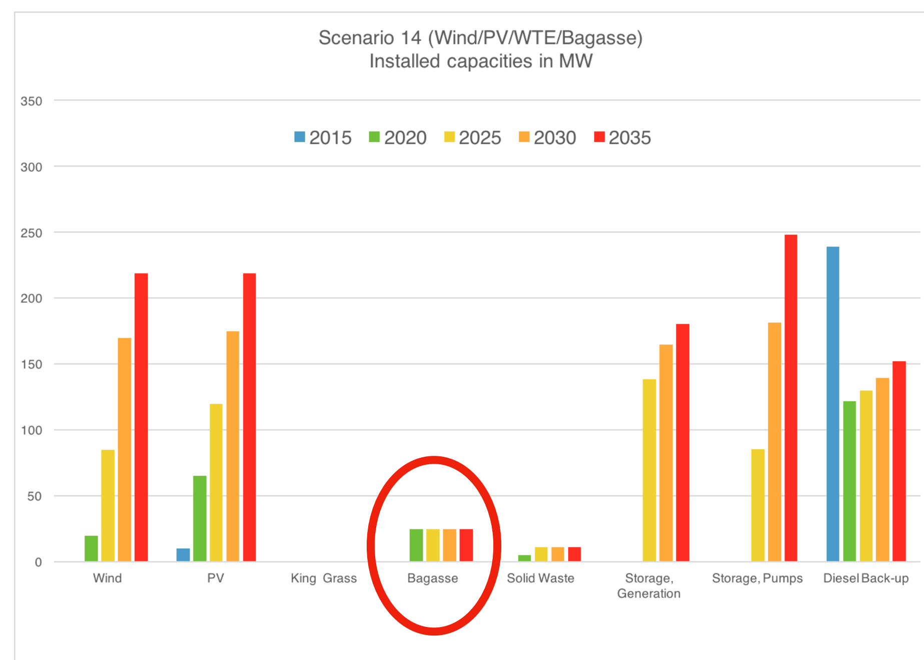
Moving towards a sustainable world

Transition Pathways to Four Favourable 100% Target Scenarios (Capacities in MW)

GSEC Ltd. Barbados





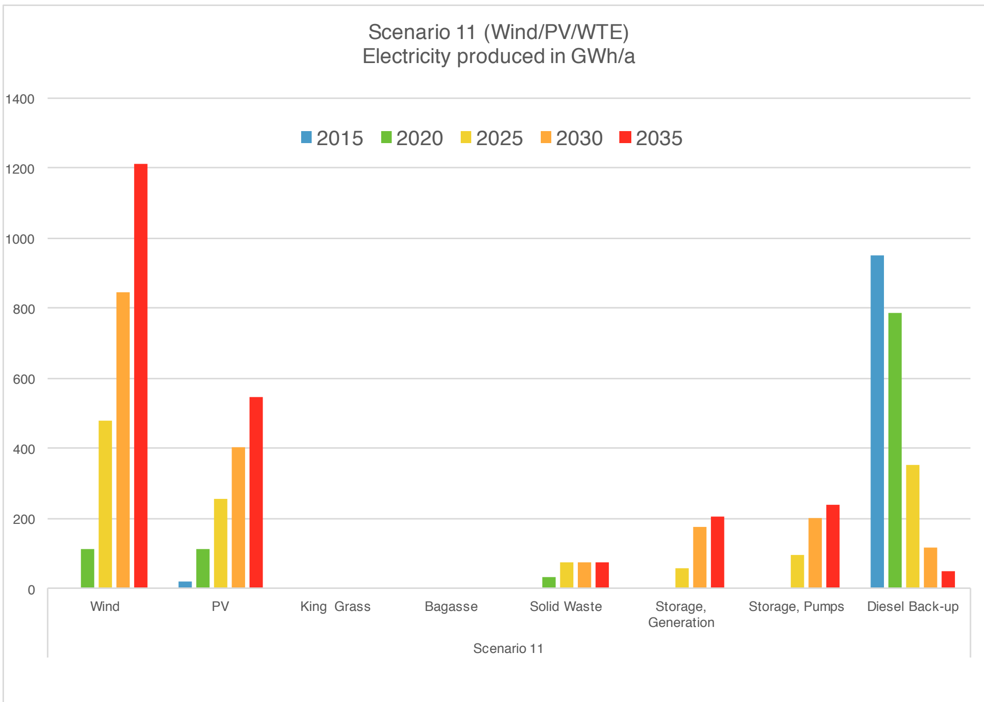


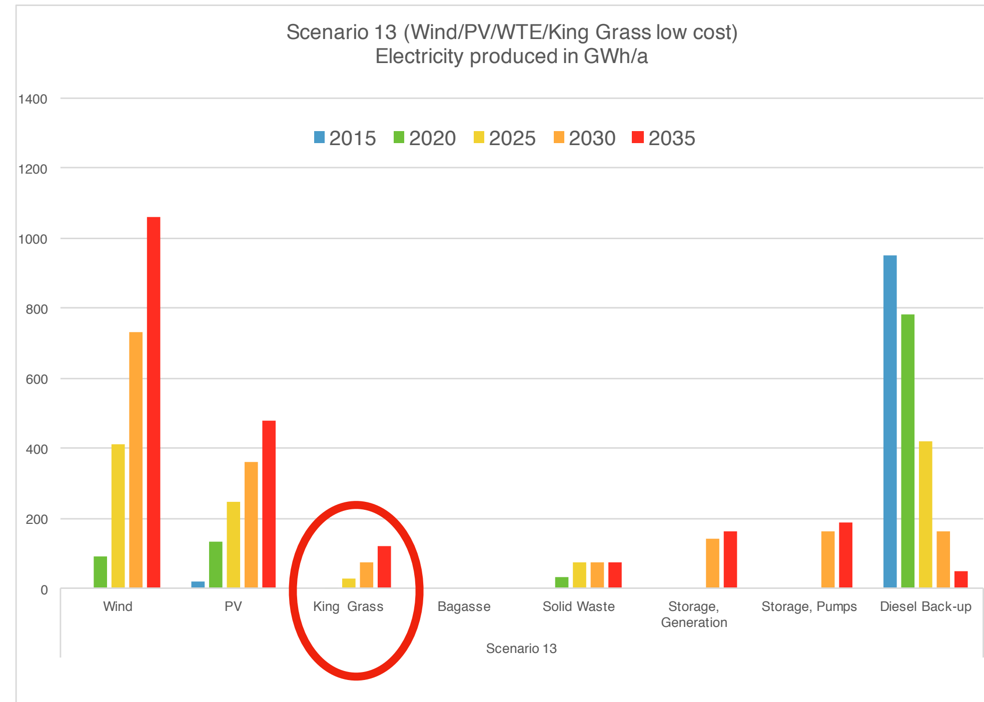
Source: GSEC Ltd. 2017, p. 89

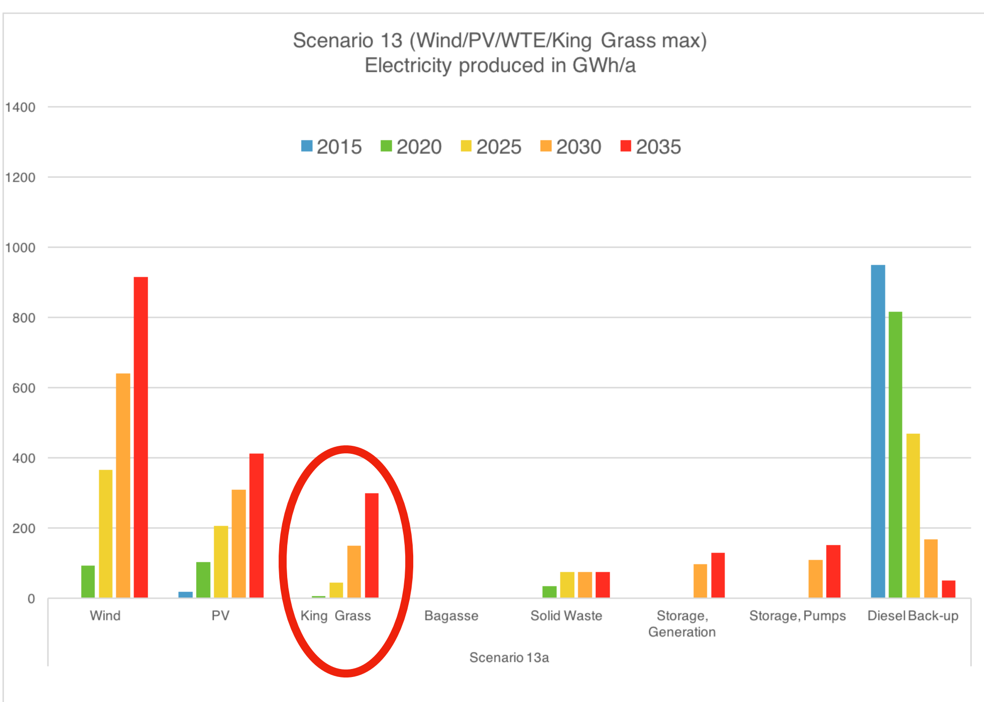
Transition Pathways to Four Favourable 100% Target Scenarios (Production in GWh/a)

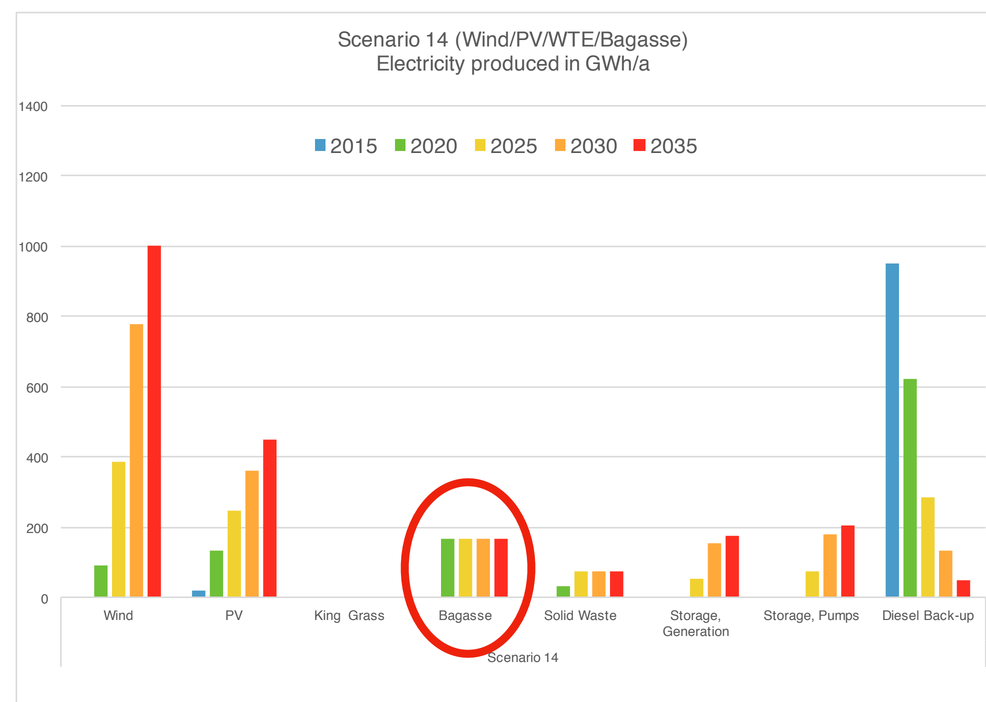
GSEC Ltd. Barbados

Moving towards a sustainable world









Source: GSEC Ltd. 2017, p. 89

Thank You for Your Attention

Time for Questions
and for
Discussion of Assumptions…

Back-up

Transition Pathways to Four Favourable 100% Target Scenarios (Target Year 2035)

GSEC Ltd. Barbados

Moving towards a sustainable world

Scenario / Wind year 2011		Year	Annual power demand	LCOE	Installed capacities and annual generation									
					Wind		PV		King Grass		Bagasse and river tamarind combustion		Solid wate combustion	
No.	Name			BBD/ kWh	MW	GWh/ a	MW	GWh/ a	MW	GWh/ a	MW	GWh/ a	MW	GWh/a
11	100% RE / Wind / PV / WTE combustion	2015	950		0		10	19					0	
		2020	1050	0.3664	25	114	55	113					5	34
		2025	1150	0.3002	105	481	125	258					11	74
		2030	1250	0.3123	185	847	195	403					11	74
		2035	1350	0.3883	265	1213	265	547					11	74
13	100% RE / Wind / PV / King Grass / WTE combustion	2015	950		0	0	10	19	0	0			0	0
		2020	1050	0.3696	20	92	65	134	2	5			5	34
		2025	1150	0.3253	90	412	120	248	10	30			11	74
		2030	1250	0.3161	160	733	175	361	18	75			11	74
		2035	1350	0.4004	232	1062	232	479	26	120			11	74
13 a	100% RE / Wind / PV / King Grass / WTE combustion	2015	950		0		10	19	0	0			0	
		2020	1050	0.3749	20	92	50	103	2	5			5	34
		2025	1150	0.3354	80	366	100	206	14	45			11	74
		2030	1250	0.3451	140	641	150	310	27	150			11	74
		2035	1350	0.4331	200	916	200	413	40	300			11	74
14	100% RE / Wind / PV / Bagasse / WTE combustion	2015	950		0	0	10	19			0	0	0	0
		2020	1050	0.3807	20	92	65	134			25	169	5	34
		2025	1150	0.3452	85	389	120	248			25	169	11	74
		2030	1250	0.3609	170	778	175	361			25	169	11	74
		2035	1350	0.4143	219	1003	219	452			25	169	11	74

Source: GSEC Ltd. 2017, p. 89

Transition Pathways to Four Favourable 100% Target Scenarios (Target Year 2035)

GSEC Ltd. Barbados

Moving towards a sustainable world

Scenario / Wind year 2011		Year	Annual power demand	LCOE	Installed capacities and annual generation							Total overproduction
					Diesel/ Biodiesel		Storage volume	Storage generation		Storage pumping		
No.	Name			BBD/ kWh	MW	GWh/ a	MWh	MW	GWh/ a	MW	GWh/ a	GWh/a
11	100% RE / Wind / PV / WTE combustion	2015	950		239	950						
		2020	1050	0.3664	140.9	789						0
		2025	1150	0.3002	148.8	354	3000	150.5	60	90	80	17
		2030	1250	0.3123	162.2	118	5000	186.3	176	220.7	202	192
		2035	1350	0.3883	166.7	50	5000	196.8	205	307	238	400
13	100% RE / Wind / PV / King Grass / WTE combustion	2015	950		239	950	0	0	0	0	0	0
		2020	1050	0.3696	140.2	785						0
		2025	1150	0.3253	148	422						36
		2030	1250	0.3161	155.6	164.4	5000	178	142	162.8	163	157.4
		2035	1350	0.4004	144.8	50	5000	172.9	163	253.4	190	435
13 a	100% RE / Wind / PV / King Grass / WTE combustion	2015	950		239	950						
		2020	1050	0.3749	140.2	816						0
		2025	1150	0.3354	140.5	469						10
		2030	1250	0.3451	135.3	168	5000	156	97	131.5	110	93
		2035	1350	0.4331	131.6	50	5000	156.8	129	199.8	151	403
14	100% RE / Wind / PV / Bagasse / WTE combustion	2015	950		239	950	0	0	0	0	0	0
		2020	1050	0.3807	121.7	621						0
		2025	1150	0.3452	129.9	286	5000	138.4	56	85.3	75	16
		2030	1250	0.3609	139.4	133	5000	165	157	181.4	181	265
		2035	1350	0.4143	151.9	50	5000	180.6	176	248.3	205	398

Source: GSEC Ltd. 2017, p.90

Moving towards a sustainable world

Possible 100% RE Target Scenarios
Capacities in MW and Annual Production in GWh/a

GSEC Ltd.
Barbados

Scenario		LCOE	Installed capacities and annual generation											
			Wind		PV		King Grass		Bagasse and river tamarind combustion		Wast gasification		Solid wate combustion	
No.	Name	BBD/ kWh	MW	GW h/a	MW	GW h/a	MW	GW h/a	MW	GW h/a	MW	GW h/a	MW	GW h/a
1	New diesel only (base line)	0.4495												
2	Bagasse and river tamarind only	0.4810							25	169				
3	King grass gasification only	0.4886					40	300						
4	Waste to energy gasification only	0.5126									25	200		
5	100% RE PV and storage alone	0.5100			755	1559								
6	100% RE Wind and storage alone	0.4013	505	2312										
7	100% RE Wind and PV plus storage	0.3999	286	1309	286	589								
8	100% RE / Wind / PV / King Grass	0.4212	224	1026	224	463	26	200						
9	100% RE / Wind / PV / Bagasse	0.4233	240	1099	237	485			25	169				
10	100% RE / Wind / PV / WTE gas	0.4356	265	1213	265	547					13	100		
11	100% RE / Wind / PV / Solid waste combustion	0.3883	265	1213	265	547							11	74
12	100% RE / Wind / PV / King Grass / WTE gas	0.4209	234	1071	234	483	25	110	10	67.6				
13	100% RE / Wind / PV / King Grass / WTE combustion	0.4004	232	1062	232	479	26	120					11	74
13a	100% RE / Wind / PV / King Grass / WTE combustion	0.4386	200	916	200	413	40	300					11	74
14	100% RE / Wind / PV / Bagasse / WTE combustion	0.4143	219	1002	219	425			25	169			11	74
15	100% RE / Wind / PV / Bagasse / WTE gas	0.4614	219	1002	219	425			25	169	13	100		
16	100% RE / Wind / PV / King Grass / Bagasse / WTE gasification	0.4584	212	971	212	438	25	120	10	68	13	100		
17	100% RE / Wind / PV / King Grass / Bagasse / WTE combustion	0.4128	213	975	213	440	25	120	10	68			11	74
18	100% RE / Wind / PV / King Grass / Bagasse / WTE gasification /WTE combustion	0.4361	213	975	213	440	25	120	10	68	6.5	50	5.5	37

Source: GSEC Ltd. 2017, p. 75

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Possible 100% RE Target Scenarios Storage and Back-up in MW and GWh/a

GSEC Ltd. Barbados

Scenario		Installed capacities and annual generation									
		LCOE	Diesel/Biodiesel		Storage volume	Storage generation		Storage pumping		Total overproduction	
No.	Name	BBD/ kWh	MW	GWh/a	MWh	MW	GWh/a	MW	GWh/a	GWh/a
1	New diesel only (base line)	0.4495	196.8	1350						0
2	Bagasse and river tamarind only	0.4810	177.5	1181						0
3	King grass gasification only	0.4886	156.8	1050						0
4	Waste to energy gasification only	0.5126	171.8	1154						0
5	100% RE PV and storage alone	0.5100	177.9	50	10000	196.8	661	558.8	758	259
6	100% RE Wind and storage alone	0.4013	177.3	50	10000	196.8	197	320.1	197	1012
7	100% RE Wind and PV plus storage	0.3999	175.1	50	5000	196.8	218	335.6	252	598
8	100% RE / Wind / PV / King Grass	0.4212	152.4	50	5000	182.7	184	232.7	217	389
9	100% RE / Wind / PV / Bagasse	0.4233	159.8	50	5000	190.4	188	272.2	218	453
10	100% RE / Wind / PV / WTE gas	0.4356	165.5	50	5000	196.8	193	299.7	225	560
11	100% RE / Wind / PV / Solid waste combustion	0.3883	166.7	50	5000	196.8	205	307	238	400
12	100% RE / Wind / PV / King Grass / WTE gas	0.4209	146.6	50	5000	174.9	165	256.1	192	431.6
13	100% RE / Wind / PV / King Grass / WTE combustion	0.4004	144.8	50	5000	172.9	163	253.4	190	435
13a	100% RE / Wind / PV / King Grass / WTE combustion	0.4386	131.6	50	5000	156.8	129	199.8	151	403
14	100% RE / Wind / PV / Bagasse / WTE combustion	0.4143	151.9	50	5000	180.6	176	248.3	205	370
15	100% RE / Wind / PV / Bagasse / WTE gas	0.4614	147.3	50	5000	175.4	164	241.0	191	396
16	100% RE / Wind / PV / King Grass / Bagasse / WTE gasification	0.4584	134.1	50	5000	160.0	139	219.3	162	397
17	100% RE / Wind / PV / King Grass / Bagasse / WTE combustion	0.4128	138.6	50	5000	165.2	151	228.3	176	377
18	100% RE / Wind / PV / King Grass / Bagasse / WTE gasification / WTE combustion	0.4361	136.3	50	5000	162.6	145	224.6	169	390

Source: GSEC Ltd. 2017, p. 76

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IRENA Scenario without and with Pump Storage

GSEC Ltd. Barbados

Scenario			Installed capacities and annual generation												
		LCOE	Wind		PV		Bagasse and river tamarind combustion		Diesel/ Biodiesel		Stora ge volu me	Storage generation		RE
No.	Name	BBD/ kWh	MW	GWh/ a	MW	GWh/ a	MW	GWh/ a	MW	GWh/ a	MWh	MW	GWh/ a	%
IRENA 2030	85% RE / Wind / PV / Solid biomass / 150 MWh battery storage	0.3057	155	710	155	320	18	122	123.0	156	150	126.4	51	84.4 %
IRENA 2030 mit 3 GWh PSH	95% RE / Wind / PV / Solid biomass / 3 GWh PSH	0.2884	155	710	155	320	18	122	119.7	56	3000	142	143	94.4 %

Source: GSEC Ltd. 2017, p. 78