



Waste-to-Energy Potentials in Grenada

Summary of Scoping Study

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Overview

- Waste to Energy (WtE)
- Energy Sector in Grenada
- Solid Waste Management in Grenada
- Wastewater Management in Grenada
- WtE Technologies for Grenada
 - Incineration
 - Anaerobic Digestion (Biogas Generation)
 - Biodiesel
- Scenarios for anaerobic digestion of solid and liquid wastes
- Summary and Conclusion

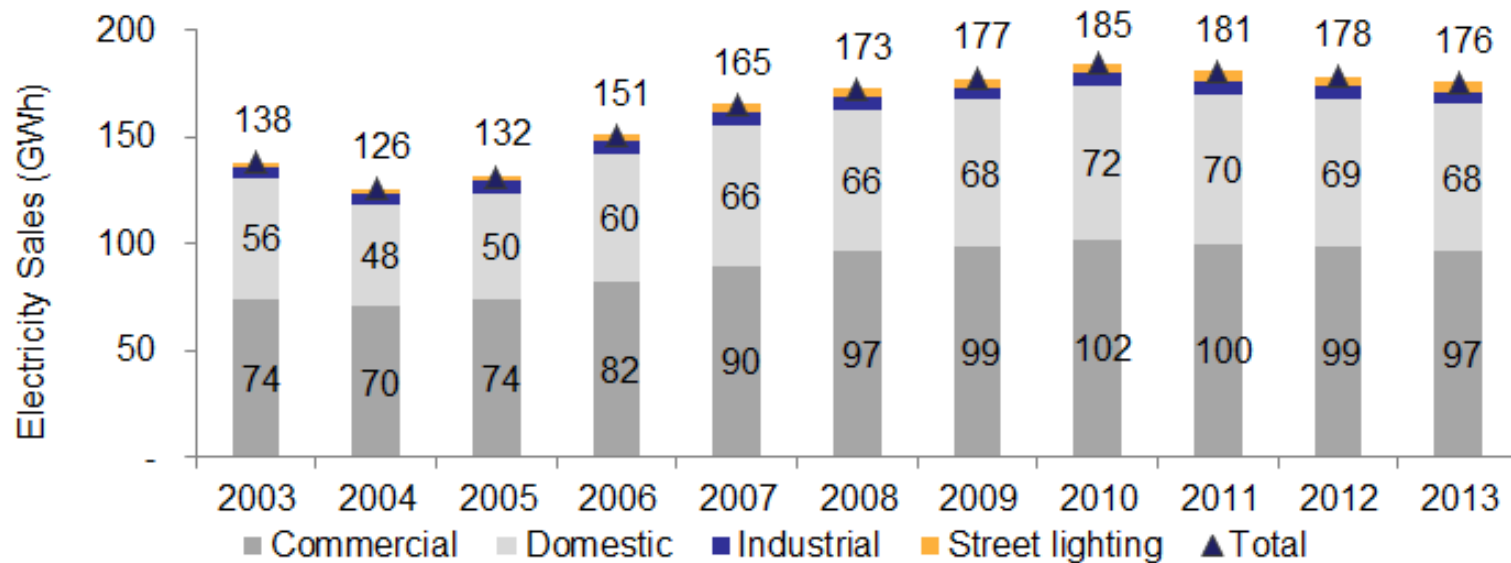


Energy Sector

- Grenada has one of the highest electricity prices in the Caribbean and worldwide: 1.08 XCD/kWh
- Main supply provided by **diesel generators** (175 GWh in 2013)
- Renewable Energy (RE) has high potential
- Long-term electricity monopoly hinders the promotion of RE
- Liquefied Gas is important domestic and commercial energy source
 - 4500 tons have been imported in 2010
- In 2014 average price for LPG is USD 16,67 (45 XCD) for a 20 pound cylinder and USD 82 (220 XCD) for a 100 pound cylinder.



Energy Demand in Grenada

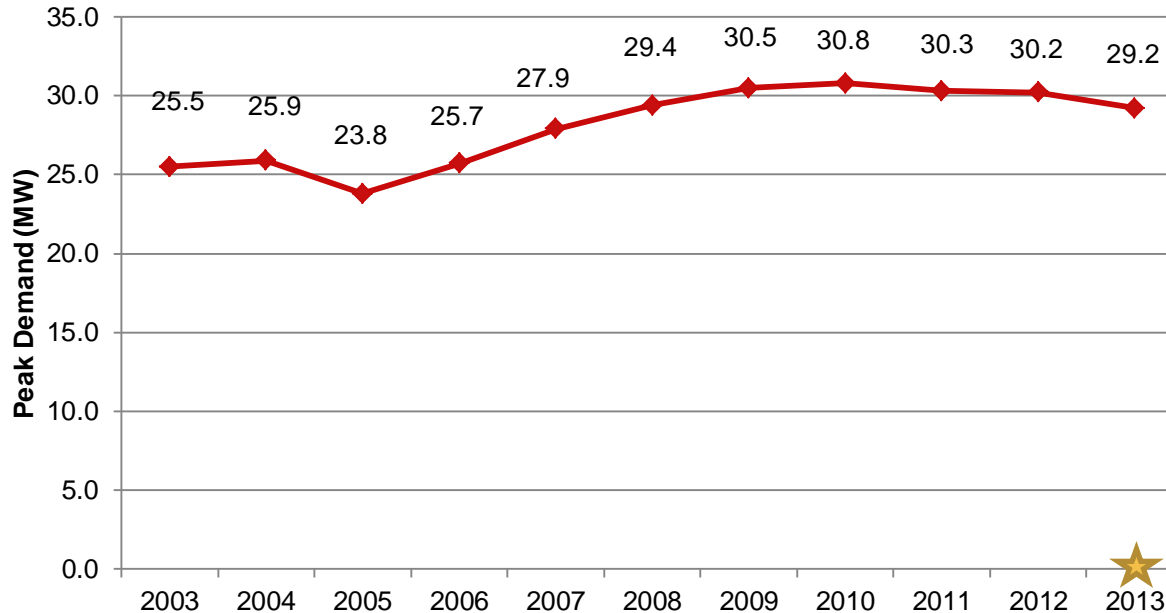


Grenlec Annual Report , 2013



Peak demand and installed capacity in Grenada

Installed capacity: **52 MW**



Solar 0.3 MW

Grenlec Annual Report , 2013



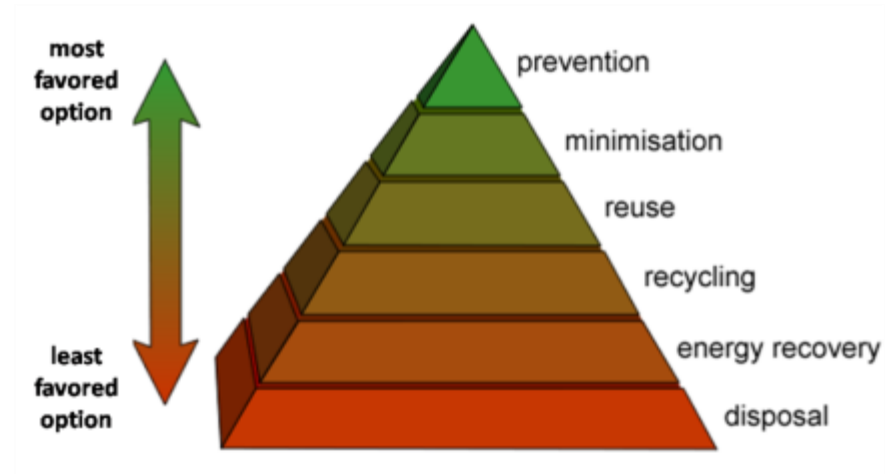
Renewable Energy - Potential

- Wind – First plant is planned for Carriacou
- Solar water heating – mainly in hotels and some domestic houses – much higher potential
- Photovoltaic – contribute only 0.3 MW to Grenadas capacity. Much higher potential, but undermined by current energy sector structure
- Geothermal – long-term planning, studies underway
- Biomass – information available for solid waste and wastewater. Green waste and Wood has not been assessed in detail.
- Energy plants are hardly present – new EU project for energy plants in the Caribbean in planning.



Waste to Energy

- WtE is considered Renewable Energy
- Energy Recovery from Waste
- **Incineration**: Controlled Burning of Waste
- **Anaerobic Digestion**: treatment of the organic fraction of solid and liquid wastes
- **Secondary Fuels**: Conditioned recycled waste or recycling residues (e.g. After sorting or anaerobic digestion)



- **Reuse/Recycling has priority**



Waste Management and Climate Change

- Organic waste in landfills emits Methane over decades
- Landfill gas can be recovered/ flared from **engineered** landfills
- Anaerobic digestion of organic waste as means of methane reduction
- Organic waste management for animal fodder – greenhouse gas reduction
- Recycling can generate new raw material (e.g. PET, Aluminum) or secondary fuels – reduction of fossil fuels
- Management of wood waste as fuel/ secondary fuel
- Recycling prolongs the life span of existing landfills – improved management
- Incineration – waste as renewable energy source



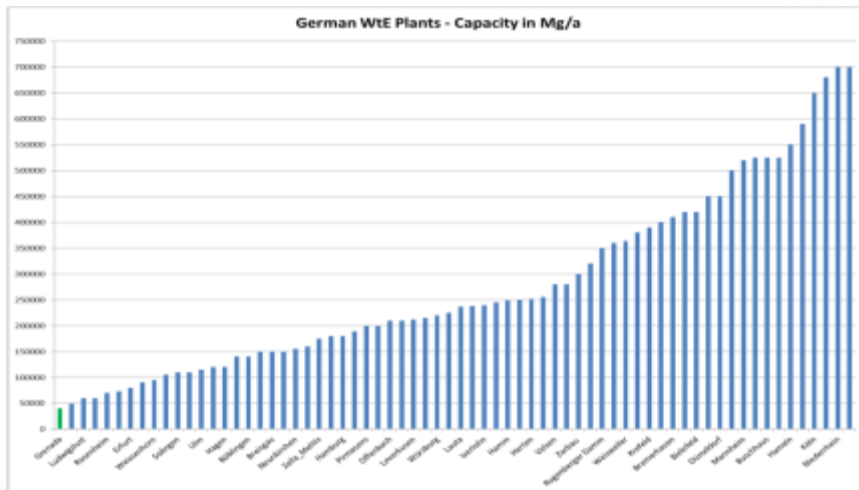
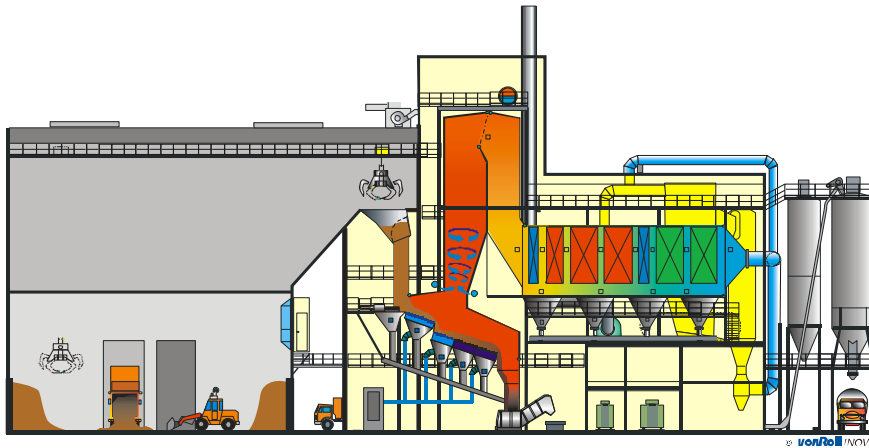
Solid Waste Management (GSWMA)

Waste Categories	%
Organic Waste	27.1
Site cleaning waste	21.30
Plastics	16.4
Paper Cardboard	13.6
C&D	11.6
Glass	3.1
Metal	2.4
Textiles	2.3
Tyres	0.90
Household Bulky Waste	0.70
Street sweeping waste	0.60

- 40 000 ton of domestic and commercial waste / year
- Domestic waste has about 45 % organic fraction (27 % based on total waste)
- Landfill space is VERY limited, new developed cells will last only 7 years without recycling concept
- Incineration would prolong landfill use to 25 years, but is not economic viable.



Incineration

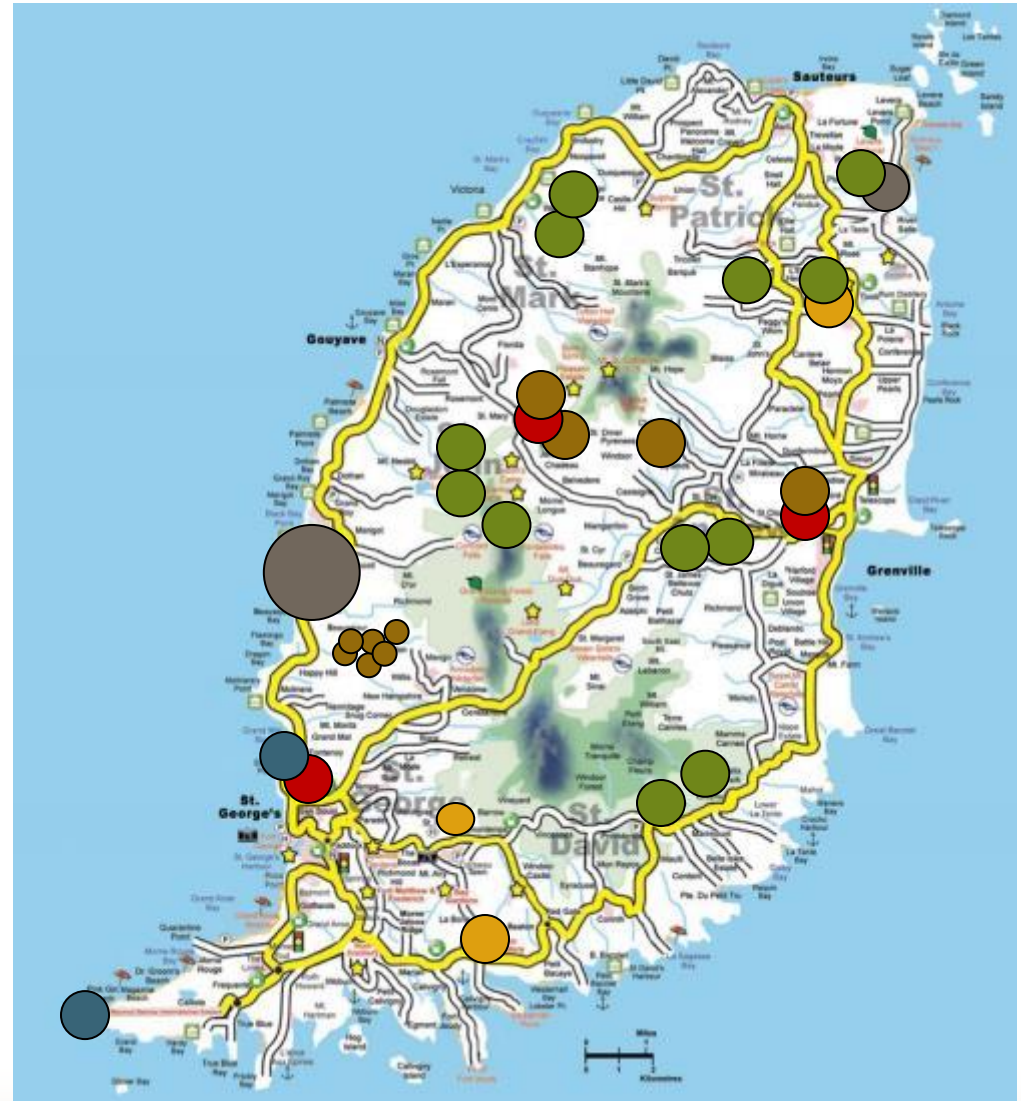


- Advantage with regard to volume reduction of waste and energy output 18 GWh/year
- High Investment Costs: 138 Mio. XCD
- High O&M Costs
- 40 000 t/year is half of the viability limit for such systems.
- Increase of tipping fee, commercial fees or high subsidy via energy sector required



Location of Waste

- **Municipal Solid Waste**
- **High-calorific effluents**
- **Sewered Wastewater**
- **Agricultural / Animal Waste**
- **Plant Residues**
- **Slaughterhouse Waste**





Origin of Organic Waste

- Hotels & Restaurants (partly already reused)
- Markets
- Agro-Industries
- Breweries and Distilleries
- Animal farms (chicken, pig, etc.)
- Slaughterhouses
- Vegetable and Fruit Farms
- Wastewater Treatment



Wastewater Management (NAWASA)

- Sewered system in St. Georges: fall out pipe at the stadium bridge with an average flow of 130.000 gal/ day (28,6 m³/ day or 10.451 m³/year)
- Sewered system along Grand Anse: fall out pipe at Point Salines with an average flow of 660.000 gal/ day (145 m³/day or 53.062 m³/year)
- Coarse grid as mechanical treatment/ pump protection
- No large-scale treatment planned by NAWASA
- Non-sewered households have septic tanks
- Accumulated septage can be estimated at about 34.700 m³/year



Mechanical Filter System for Wastewater

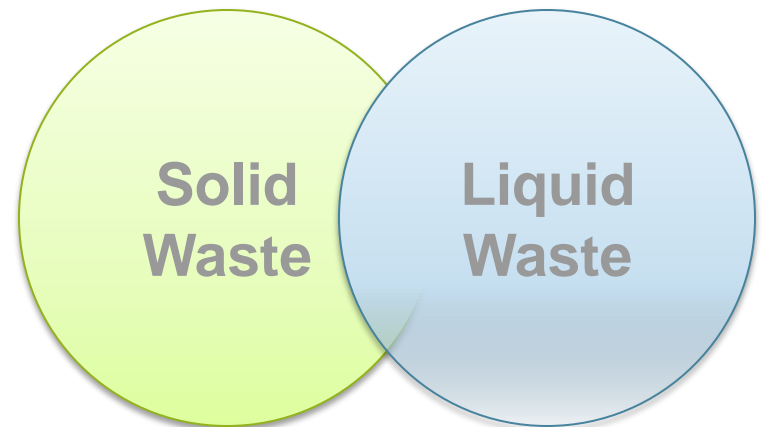


- HUBER Two-stage micro filtration technology (6 - 0,1 mm)
- TSS reduction of 30-60 % and a COD reduction of 10-30 % with minimal land requirements and reasonable costs
- Solid residues have high energy content with regard to biogas production
- Improves water quality
- Provides input for biogas
- Fertilizer?



Typical Input Material for Anaerobic Digestion

- Animal manure
- Energy plants such as corn, sugar beet, grass
- Organic solid waste like food residues, grass, domestic waste
- Vegetable oils and wastewater from agro-industries (e.g. distilleries, breweries, dairy side products)
- Slaughterhouse waste
- Sewerage sludge and blackwater from toilets and septic tanks





Biogas Generation

- Anaerobic digestion is the microbiological breakdown of organic materials in the absence of oxygen
- Anaerobic digestion works under mesophilic (35-42 °C) as well as under thermophilic (50-60°C) conditions
- Biogas contains between 50 and 70 % methane, depending on the input material.
- Biogas can be directly used as fuel or further upgraded to bio-methane with a higher calorific value.
- Rule of thumb: energy content of 1 m³ biogas (60 % methane) equals about 6 kWh or 0,6 liter domestic fuel oil
- **Broad range of technologies available!**



Small-Scale Digesters (Ökobit, Germany)



- High-tech material for low-tech applications
- Applicable for small animal farms and agro-industries
- Modular from 3 m³-100 m³ volume
- Direct use of gas for cooking and hot-water generation
- Except of the membrane tank, all materials locally available



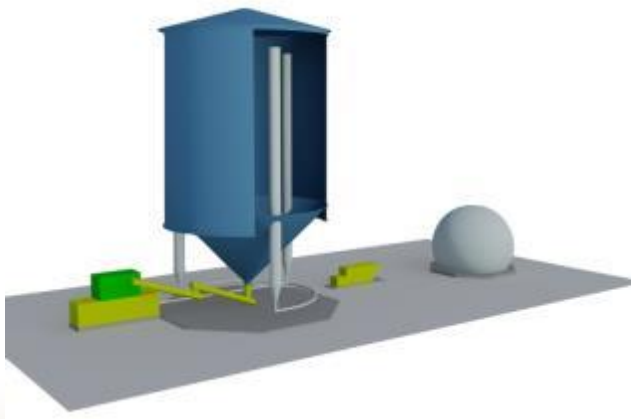
Large-scale Wet-Anaerobic Digestion



- Animal and liquid wastes
- TS content 3 -15 % TS
- Pond Systems (various providers)
 - widely spread in South Amerika
 - No mixing required
- Basin Systems (various providers)
 - typical for Europe
 - Often equiped with agitators or pumps for mixing
- Retention time: 20-60 days



Dry-Anaerobic Digestion (GICON or DRANCO, Germany)



- Often used for presorted organic solid waste
- TS content of 28 – 35 % -and does not require the addition of liquid
- Sizes vary, often modular systems
- GICON garage type: no mixing, low mechanisation
- DRANCO system works with pulper and pump
- Retention time: 28-30 days

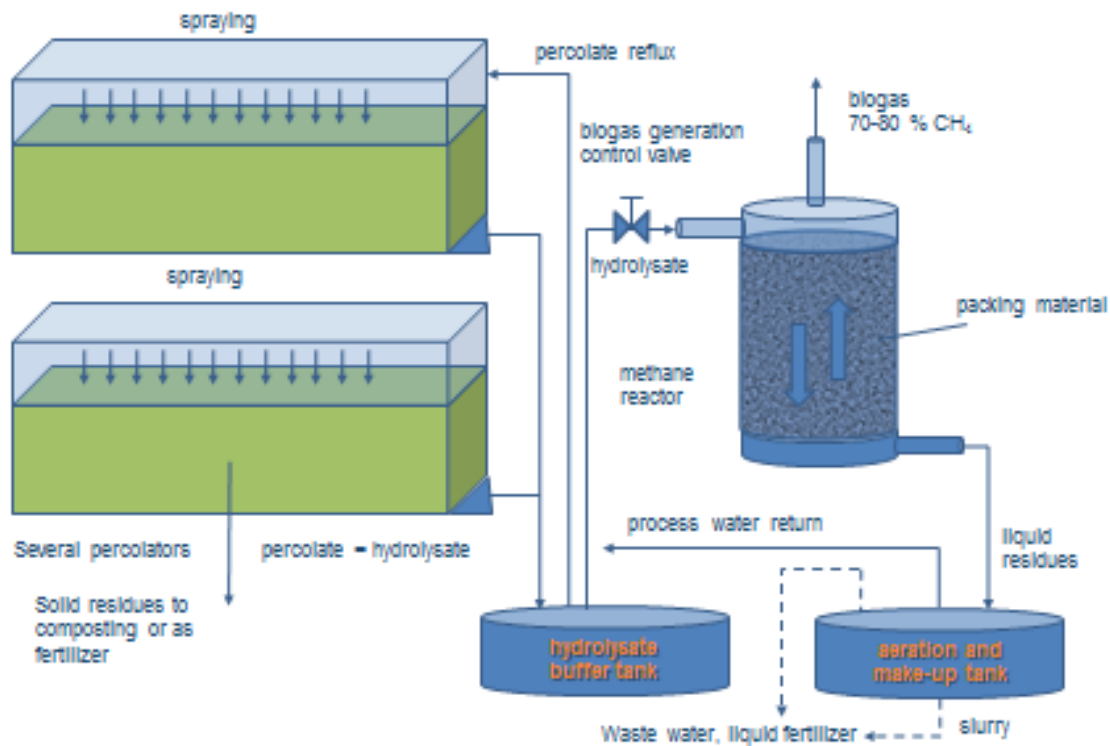


Garage-Type-Anaerobic Digestion

GICON Biogas Process: Basic Schematic

GICON®

Patent DE 10 2004 053 615.5; PCT/DE2005/001990





Management of Digestate

Digestate is the residue from anaerobic digestion

- High in nutrients: reuse as liquid fertiliser
- Dewatering/Drying: Secondary Fuel
- Aerobic Composting: Fertiliser
- Dewatering (if required): Landfill cover





Scenarios for Grenada

- Scenario 1
 - Dry Digester for organic municipal waste
- Scenario 2
 - „All-in-one“ – Organic solid waste and liquid wastes
- Scenario 3
 - Effluent Treatment at Clarke's Court Distillery
- Scenario 4
 - „Agro-Solution“ – Slaughterhouse Mirabeaux, Animal Waste
- Scenario 5
 - Decentralised small scale systems for animal farms



Scenario 1: Municipal Solid Waste Dry Digestion

	HYDROPLAN Assumptions (2009)	GICON Assessment (2014)
Technology applied	Wet-Thermophilic System (Uppsala)	Dry-Wet-Digester
Investment Costs	27.2 Mio XCD	27.1 Mio XCD
Electrical energy content of waste	260 kWh _{el} /t	270 kWh _{el} /t
Organic waste fraction	35 %	35 %
Total annual amount of <u>organic</u> waste to be treated	14000 t	20000 t
Annual electricity generation	3.640.000 kWh _{el}	5.400.000 kWh _{el}
Sales price for electricity to the grid	0.48 XCD/ kWh _{el}	0.52 XCD/ kWh _{el}
Revenue from Electricity to the grid	1.747.200 XCD	2.808.000 XCD

- Centralised System
- Less investment costs
- Less energy yield (5.4 GWh)
- Static system
- Production of compost or secondary fuel
- Investment costs of about 5 Mio. Euro (17.1 Mio. XCD).



Scenario 2: „All in one“ – Co-digestion of waste (wet)

Waste Type	Total annual amount (t)	TSS content (%)
Solid waste + green waste	20000	45
Animal waste (400 pigs + 2000 broilers)	1040	30
Vinasse	6930	2
Slaughterhouse	626	3
Septage (50 %)	17350	10
Sums	45.946	

- Mix of various solid and liquid wastes - Wet digestion
- Best energy yield (6.8 GWh/ year)
- Transportation is a challenge
- Investment cost of about 8-10 Mio. Euro (27-34 Mio. XCD)



Scenario 3: Clarke's Court Distillery



- High energy yield
- Direct reuse as diesel substitute (35 %)
- Partly solves marine pollution problem
- Investment: Estimate 1.7 Mio XCD



Scenario 4: Mirabeau Slaughterhouse and Agro-Waste



- Animal waste from pigs and chicken
- Slaughterhouse waste (and septage from the northern part of the island)
- Electricity yield: 665 MWh/year
- Heat and Electricity directly reused at facility
- Digestate reuse as fertiliser
- Investment: estimated 1.5 Mio.
- Existing system extendable?



Scenario 5: Decentralises Small-Scale Systems



- Small-scale farmers (e.g. 10 pigs)
- Direct use of gas as substitute for LPG in households and agro-industries
- Water-shed approach – to protect water sources
- 50 small scale farmers in Grenada, investments costs 75.000-100.000 Euro (255.000- 340.000 XCD).
- Payback 2-3 years



Summary of waste types and energy yield

Waste Type	Unit	Amount	CH4 yield specific	Total CH4 yield	Total Electricity (kWh)	Total Electricity (MWh)
Solid waste+green waste	tons	25000	74	1850000		
Animal Waste						
Pigs	animal places	1500	19	28500		
Chicken	animal places	4000	164	6560		
Tot. Slaughterhouse Waste	tons	650	140	91000		
Vinasse (total)	tons	8000	11	88000		
Septage	m3	34700	4	138800		
Wastewater screenings	tons	n.n.				
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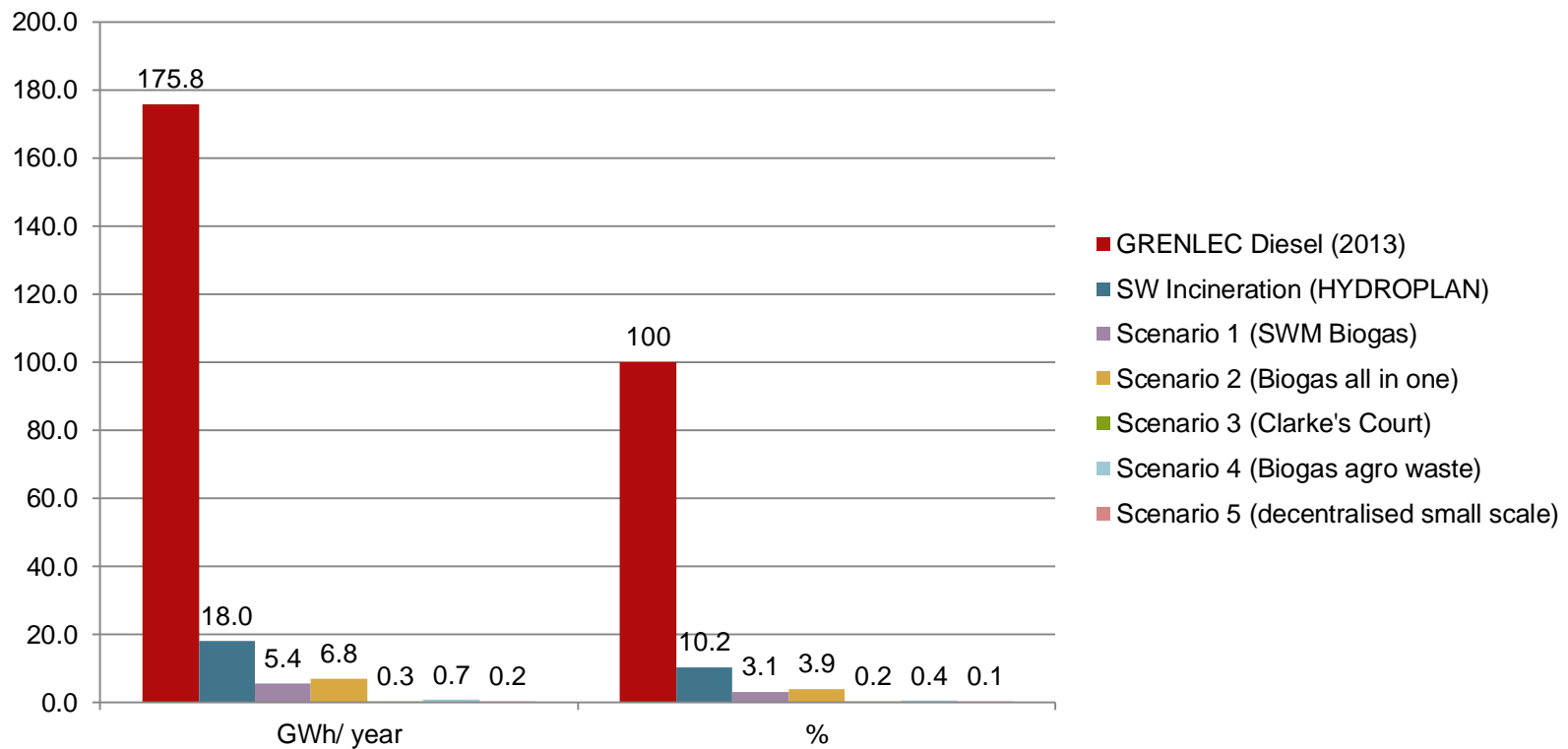


Evaluation

Scenario	Criteria				
Criteria Scores: 1: low, 5 High	Economic feasibility (investment/ operation cost, financial feasibility/ payback period)	Environmental benefits (energy yield/climate, water resources, pollution control, odor)	Technological feasibility (complexity, availability, maintenance, etc.)	Strategic attractiveness (Private Sector Involvement, Nexus)	Final Score/ Ranking
Scenario 1 a: Municipal Solid Waste dry digestion	2	3	3	2	Score: 10 Rank: 5
Scenario 1 b: Solid Waste Incineration	1	4	1	2	Score: 7 Rank: 6
Scenario 2: All-in-one Co-Digestion	3	3	3	2	Score: 11 Rank: 4
Scenario 3: Anaerobic Digestion of Distillery Effluent	4	4	4	5	Score: 17 Rank: 1
Scenario 4: Co-digestion of Slaughterhouse Waste and Animal Waste	4	4	4	3	Score: 15 Rank: 3
Scenario 5: Decentralized digestion on livestock farms	4	4	4	4	Score: 16 Rank: 2



Contribution to Energy Generation





Conclusions

- Biogas can cover a fraction of the energy demand in Grenada:
max: 6-8 % of total demand
- Anaerobic digestion is lower in investment costs and less complex with regard to O&M
- Small-scale system with a direct reuse potential of the gas are preferable (distilleries, slaughterhouses)
- Solid waste could be co-digested with other wastes in order to increase the gas potential.
- Large-scale systems are attractive even for BOT contracts, if a higher feed-in tariff for electricity can be negotiated.
- Digestate has a high reuse potential (compost or secondary fuel)
- Production of energy plants for anaerobic digestion - new market?