

Transition to new fuels

Optimized power generation solutions
for the transition in the Caribbean

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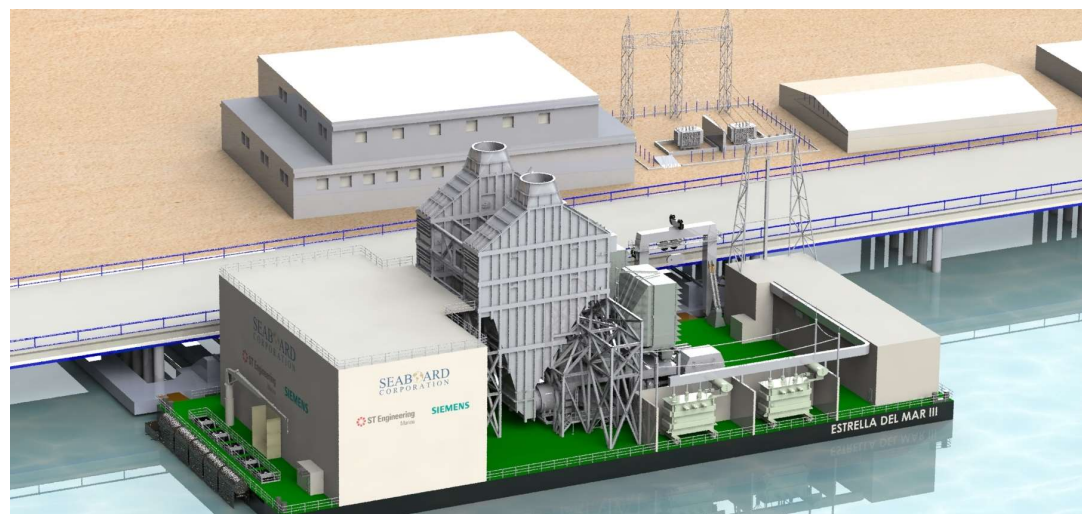


Estrella del Mar III, Dominican Republic

- ✓ Hybrid power plant solution with integrated battery energy storage
- ✓ Fuel efficient and environmentally friendly hybrid power generation without land consumption
- ✓ Replaces existing RICE barge
- ✓ Scheduled to start operation in Santo Domingo in spring 2021

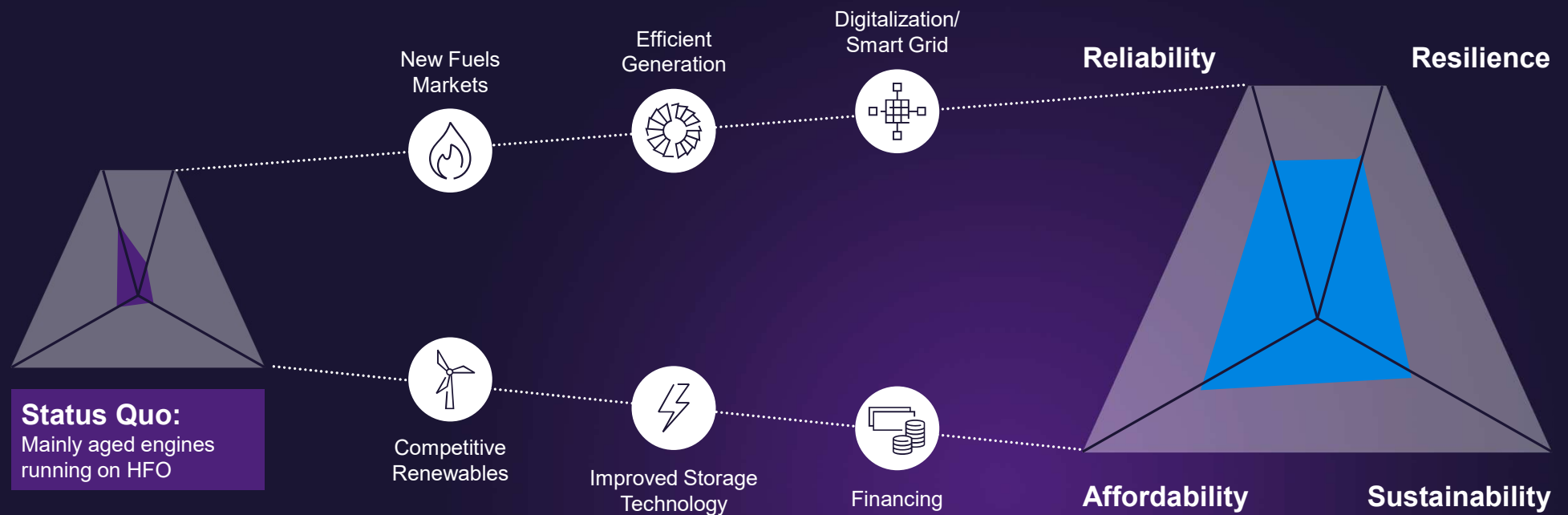
Scope

- 145 MW from two SGT-800 gas turbines generation without land consumption
- 5 MW/10 MWh Battery Energy Storage System



Siemens and the marine arm of ST Engineering Marine in Singapore have jointly received an order for a SCC-800 2x1C SeaFloat barge-mounted power plant from Seaboard Corporation subsidiary Transcontinental Capital Corporation (Bermuda) Ltd., an Independent Power Producer (IPP) with operation in Dominican Republic.

New fuels and generation technology will help to overcome challenges in Caribbean power generation



Best technology fit depends on Project size and specific needs

Best technology fit for power generation solutions in the Caribbean (multiple unit configurations)

Power range



Reciprocating Internal Combustion Engines (RICE)

- Acceptable efficiencies for small sizes
- For cogeneration high temperature applications gas turbines fit best for all sizes



Project Specific

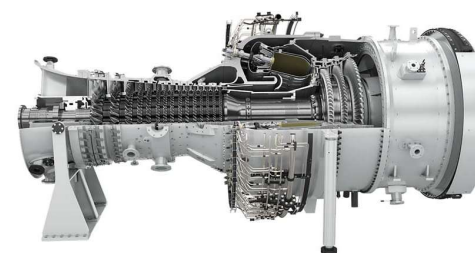
Best fit depends on specific project requirements, e.g.,

- Fuel costs & type
- Efficiency
- Flexibility
- Availability
- Reliability
- Stability
- Operating regime
- Site conditions
- Noise
- Emissions



Combined Cycle Gas Turbine (CCGT)

- Highest efficiencies and low maintenance effort lead to lowest cost of electricity



Sweet spot

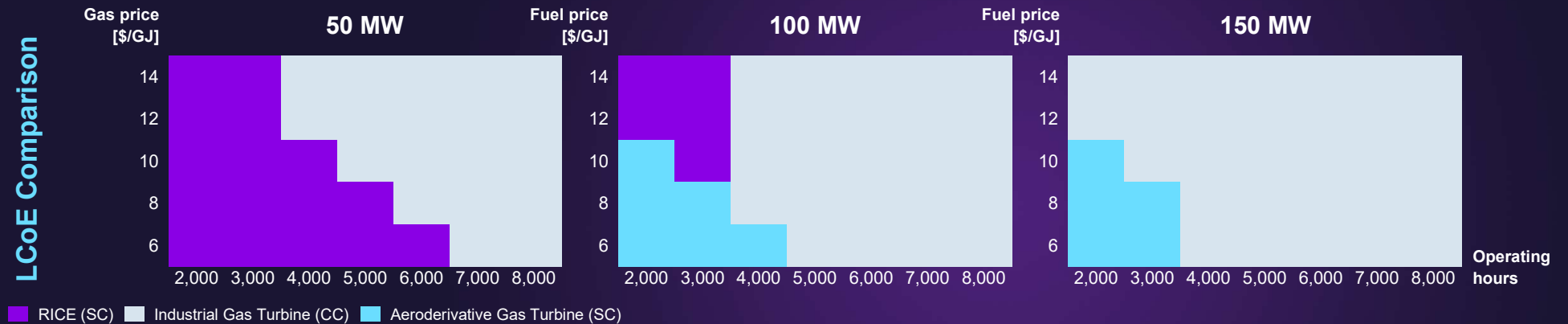


Fuel price, plant size and operating regime are most important factors for comparison of life cycle cost

LCoE

- Levelized Cost of Electricity (LCoE) is most important economic indicator to evaluate power generation projects
- Most important factors are operating conditions, CAPEX, fuel price, efficiency, evaluation time and financing conditions
- The higher the fuel price and the more the power plant is dispatched, the more will efficiency be the dominating factor in the comparison of different configurations

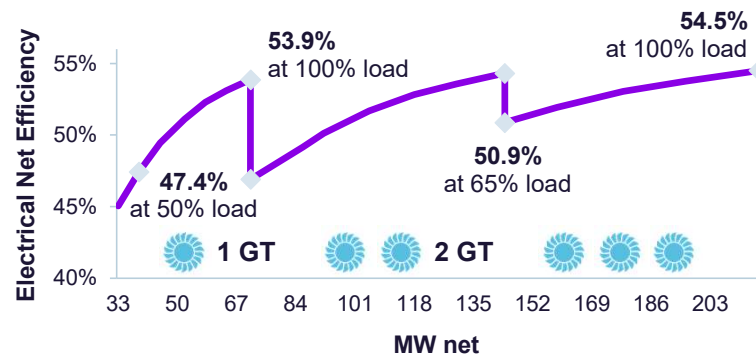
Model	Siemens Configuration Tool: CAPEX/OPEX comparison of wide range of turbines and engines
Assumptions	<ul style="list-style-type: none"> • 20 years lifetime, WACC 12%, 30% equity • Only multiple unit configurations considered • All reasonable configurations (#units, SC, CC) considered
Sources	GTW handbook, Thermoflow, Diesel and Gas Turbine, OEM publications, Siemens data and competitive intelligence



High operational flexibility over a broad range while maintaining high efficiency is key for the region

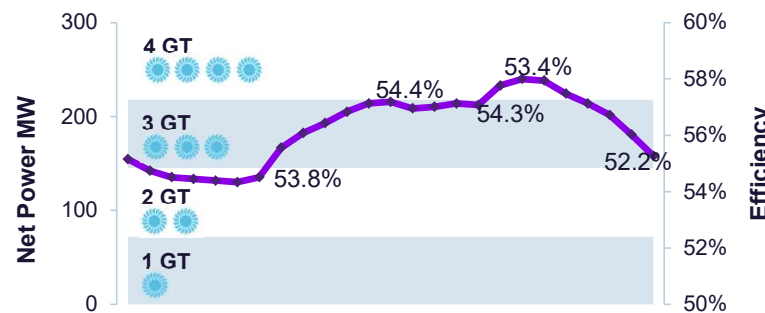
Efficiency

- High exhaust temperatures lead to superior efficiency of combined cycle gas turbine solution
- Multiple unit concepts guarantee high efficiency over broad power range



Flexibility

- Renewables will play an increasing role in the region, while fossil power will remain backbone to ensure reliable power generation
- Instead of traditional base load plants, fossil power plants will need to provide high operational flexibility and high efficiency over broad power range



- Efficiency is most important lever in any life cycle cost assessment for power projects in the Caribbean, leading to lower electricity prices
- Difference in fuel costs on a typical 200 MW plant ~16 mio USD/year



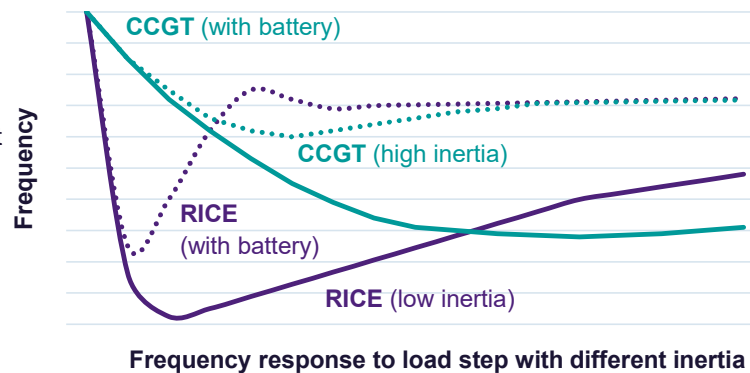
High operational flexibility increasingly important in region to follow load and complement intermittent renewable generation



Grid Stability support and fleet reliability critical for safe network

Stability

- Any disturbance of power balance (e.g., load step or change of renewable generation) need to be instantaneously dampened of network. Grid with small inertia is sensitive can easily trip out
- Small grid sizes and growing share of intermittent of renewables make frequency stability a major and increasing concern for many islands
- Rotating masses of combined cycle gas turbine plants provide significantly higher inertia to system compared to reciprocating engine or renewable generators



Reliability

- Reliability of power generation is of upmost concern, especially essential for small networks
- Gas turbines with significant higher unit reliability
- Lower unit reliability together with more units in a power plant results in a much higher chance to lose a unit of a plant



- CCGT with “in-built fly-wheel” act as stability anchor to the system, especially with increasing share of renewables
- Less additional investment in stability measures for grid



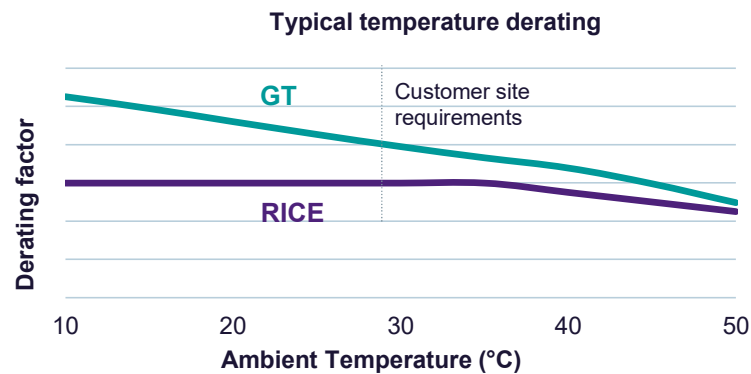
N+2 requirements to RICE plants due to lower unit reliability and availability are not applicable for gas turbine plants



Temperature derating creates upside in business case. Low frequency noise could create problems

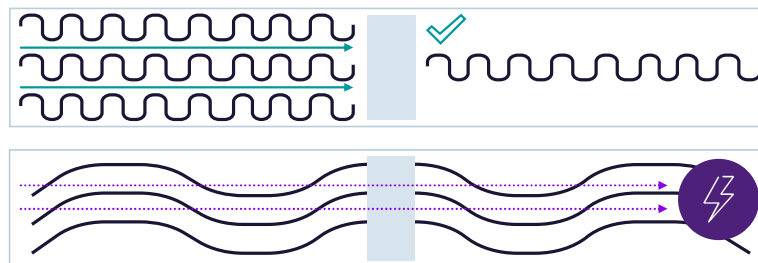
Temperature

- Gas turbines in Caribbean often with derating compared to ISO power and efficiencies
- Quotations and examples (including this presentation) however always already corrected for site conditions (most of the times 25° or 30° C)
- Lower temperature (during night or in general in winter) with significant upside in power output and efficiency compared to guarantees values



Noise

- Noise, especially lower frequencies, needs to be considered in populated areas but could also cause health issues for plant personal
- Gas Turbines with high frequency (e.g., 4,400 Hz, near field <85dB), noise enclosure is effectively working
- RICE with low frequencies (e.g., 90 – 120Hz, near field >113 db). Noise enclosure is ineffective



- Gas turbines have capability for more power generation at even higher efficiency at lower ambient conditions



- RICE's low frequencies with potential health effects in populated areas or to plant personal

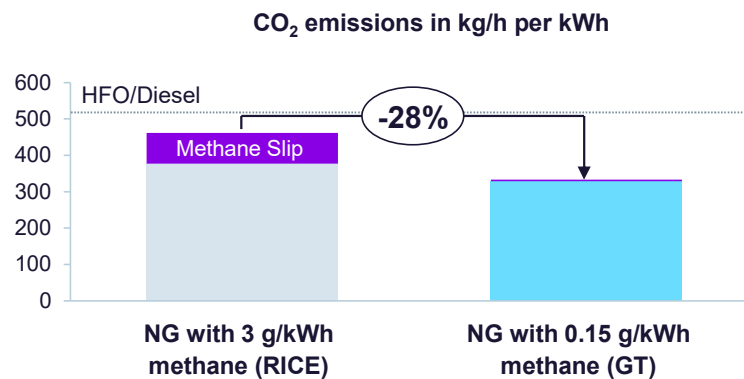


Significant reduction in global and local emissions

Switching to gas and combined cycle gas turbine tech.

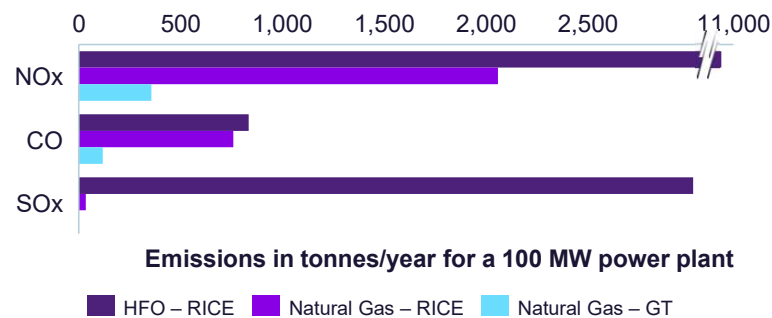
Global emissions

- CO₂ emissions from power generation dependent on efficiency and fuel type
- Natural Gas has the lowest CO₂ emissions (propane is close behind)
- Methane slip (unburned fuel getting to atmosphere) is significant problem of RICE. Methane is a 30x more potent green house gas than CO₂



Local emissions

- Switching from HFO/diesel to natural gas or LPG brings huge reduction in unhealthy and potentially toxic local emissions. Still significant differences between GT and RICE
- Unabated RICE often non-compliant with local or e.g., world bank guidelines: Additional CAPEX/ OPEX needed for scrubber/catalyst
- Operational complexity increases with scrubber/catalyst: Impact on reliability, safety, start-up time, suitability for cycling



- High levels of methane slip in RICE offset green house gas savings when switching from burning diesel/HFO to natural gas



- Need for scrubber/catalyst adds CAPEX/OPEX and operational complexity. Potentially completely changes project evaluation



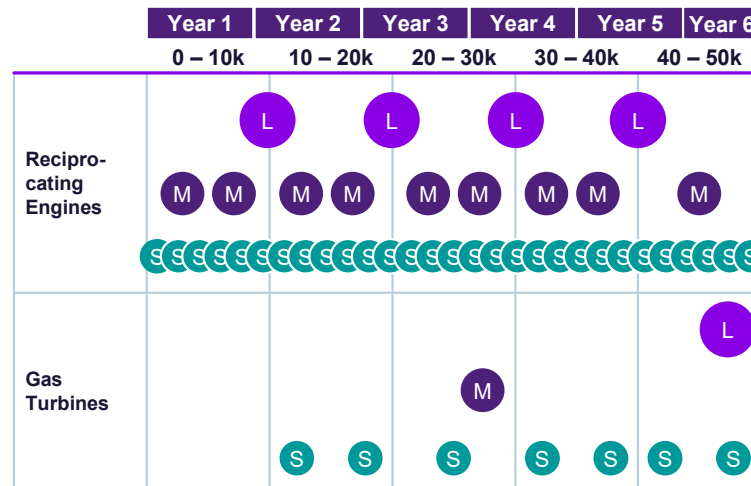
Gas Turbines

Maximum availability with minimum maintenance

Availability and Maintenance

- RICE require constant monitoring and numerous regular short time interval jobs, e.g., lubrication oil replacements, valve or filter change
- GT is simple, single rotating piece. Easy to operate, non-invasive day-to-day maintenance. Could even run remotely controlled for periods without local supervision
- Also, OEM service effort is significantly different: Gas Turbines maintenance could be as low as 40 days in 20 years with spare core

Typical maintenances schedules



● Small service¹ ● Medium service² ● Larger service³
 1 Xxx | 2 Xxx | 3 Xxx

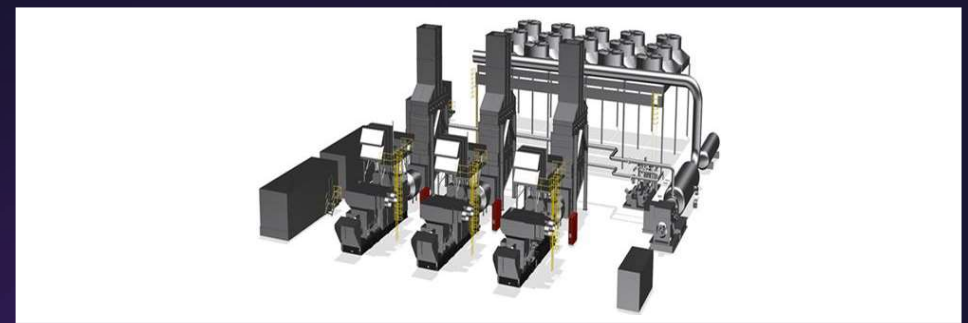
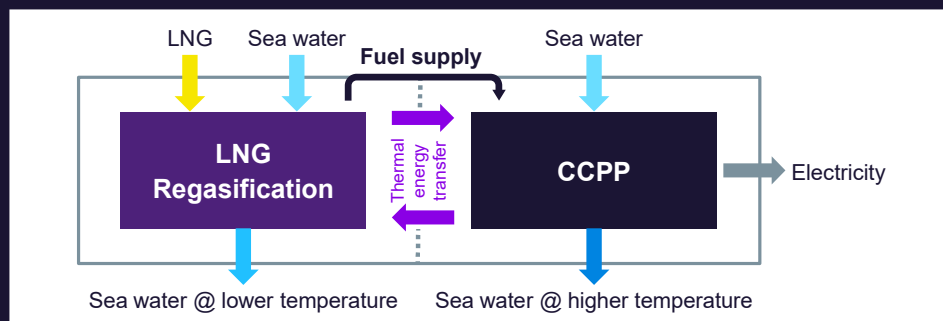
April 2020

- Significant savings and availability from gas turbines through less maintenance effort
- Difference in O&M costs on a typical 200 MW plant >10 m \$/year



Tailored Solutions for the Caribbean

Regas integration and Organic Rankine Cycle



CCPP – Regas Integration

Use residual chilling energy to reduce GT inlet air temperature

Benefits

- More power output due to GT air intake cooling
- Less costs/kW due to higher installed capacity
- Additional power output increases with higher ambient temperature – countering the temperature derating

Organic Rankine Cycle (ORC)

Water is an increasingly scarce commodity

Principle

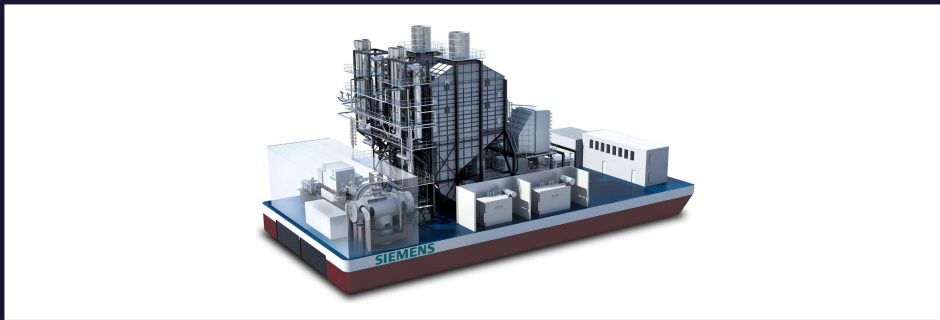
Instead of water-steam, the ORC system vaporizes an organic, high molecular mass fluid in the bottoming cycle

Benefits

- ORC offers a water-free combined cycle solution at comparable “steam” combined cycle efficiency
- CAPEX and OPEX advantages

Tailored Solutions for the Caribbean

Off-Shore power plants and hybrid solutions

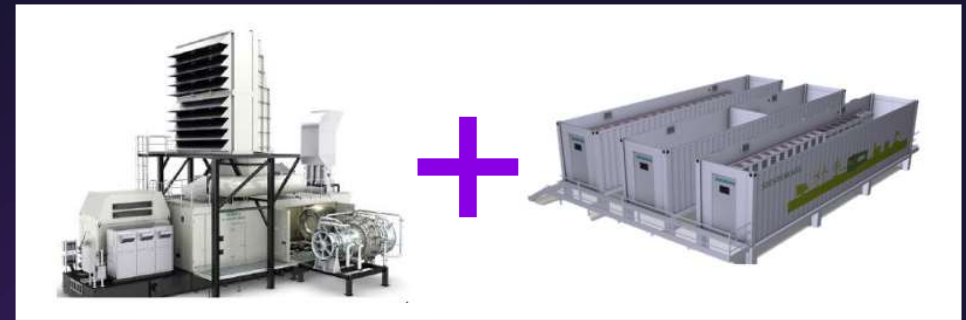


Off-Shore Power Plants – SeaFloat

Power generation installation off-shore, for on-shore power supply

Benefits

- Short project duration and less project risk
- Highest quality with low CAPEX
- Smallest footprint of a world class combined cycle power plant
- Easy installations and maintenance due to pre-designed solutions with plug & play concept



Enabling Renewables growth – Hybrid Solutions

Combination of gas turbines with battery storage is the ideal complement for renewables

Benefits

- High inertia of combined cycle supports already high share of renewables in network
- Combination with battery (initially or at later stage) provides additional synthetic inertia and ensures readiness for future
- Additional benefits for network like frequency control, immediate start-up, grid restoration

Recent regional successes with Siemens gas turbine and engine technology



Martano Panama

Highly efficient and flexible LNG to power combined cycle solution

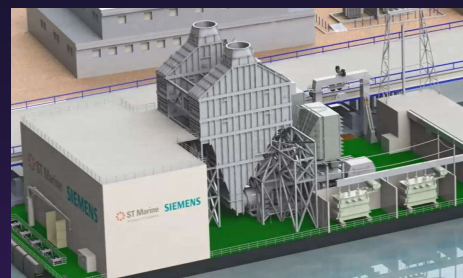
- 420 MW from six SGT-800 gas turbines and one steam turbine
- LNG import terminal with 170,000 m³ FSU and on-shore regas
- Supports stability for existing renewables and further growth
- Developer: Martano Inc.



Jamalco CHP Jamaica

Cogeneration plant providing steam to Jamalco alumina refinery and electricity to national network

- Two SGT-800 gas turbines
- Increased competitiveness and reliability of refinery
- Operation planned early 2020
- Developer: New Fortress Energy



Estrella del Mar III Dominican Republic

Fuel efficient and environmentally friendly hybrid power generation without land consumption:

- 145 MW from two SGT-800 gas turbines and one steam turbine
- 5MW/10MWh Battery Energy Storage System
- Replaces existing RICE barge
- Operation planned in spring 2021
- Developer: Transcontinental Capital (Seaboard)



Olein CHP Puerto Rico

Cogeneration plant provides 100% of power and chilled water to Olein refinery

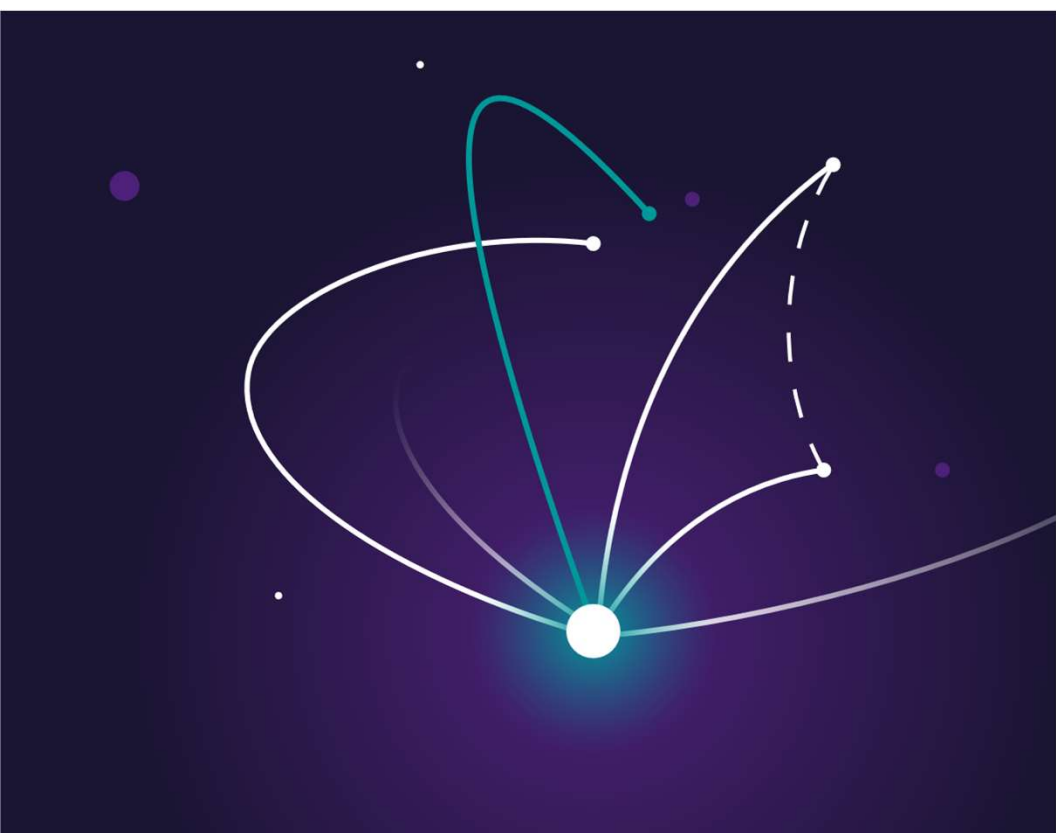
- 872kw from 2 x Siemens SGE-24SM propane-fueled generator sets
- Designed for extreme environments – overcame the Maria Hurricane
- “Plug and play” solution packaged in 40-foot container
- Turnkey contractor and Siemens integration partner: Teksol



Conclusions

- 1 Availability of new fuels, competitive renewables and new efficient generation technology radically changes the power generation sector in the Caribbean
- 2 Decision between gas turbine and RICE mainly driven by size, fuel price and operation conditions. But many other factors, like stability, emissions, noise and reliability to be considered
- 3 RICE have sweet spot <20 MW, while efficiency and low maintenance costs favor CCGT >130 MW. Between it depends on project specifics
- 4 Highly efficient, flexible combined cycle technology is ideal complement for the renewable growth while ensuring a reliable network
- 5 Recent successes of gas turbines across region show that transition in fuel also drives a new generation of technology

Thank you



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