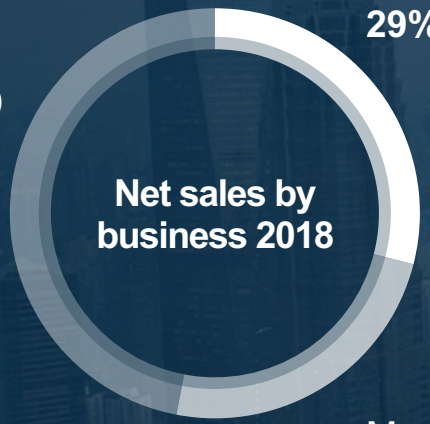
LPG FOR POWER GENERATION

Congreso Internacional del GLP, Bogota 20-21.08.2019

Wärtsilä Energy Solutions / Mr. Gonzalo Granda

WÄRTSILÄ

Solutions for **POWER GENERATION & MARINE**



19,000 professionals in more than **80** countries

- Established **1834**
- **Headquarters in Finland**
- Order intake **EUR 6,307 million**
- Net sales **EUR 5,174 million**

Do things better than anyone else in our industry

Capture opportunities and make things happen

Foster openness respect and trust to create excitement

Installed power generation capacity:
70 GW in 177 countries around the world of which 7 GW in Latin America North & Caribbean

Comparison figures for 2017 have been restated due to the internal reorganisation of service activities and the adoption of IFRS 15.

Why LPG to Power?

- Lower emissions
- Savings in fuel costs
- LPG security of supply, supply chain and storage
- Flexibility in thermal generation for integration of renewable generation.

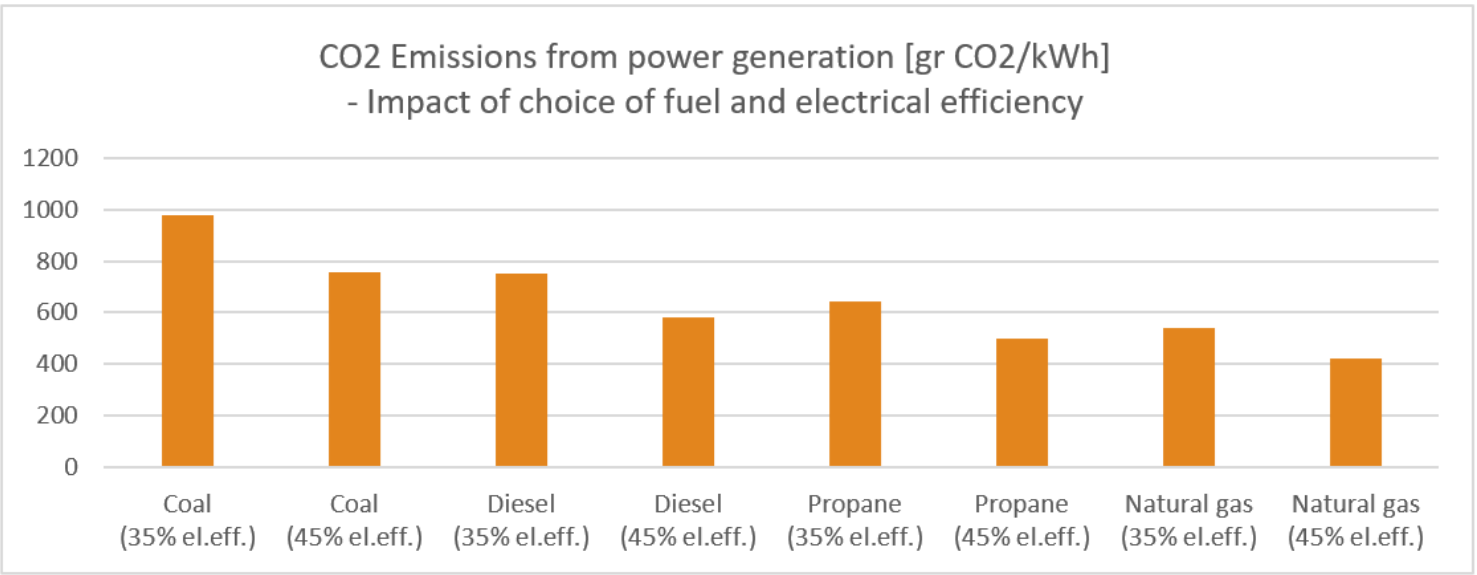
CO2 Emissions Coefficients by Fuel (extract from EIA table)

Carbon Dioxide (CO2) Factors:	Kilograms CO2 Per Million Btu
Coal (All types)	95,35
Residual Heating Fuel (Businesses only)	78,79
(Distillate)	73,16
Butane	64,95
Propane	63,07
Natural Gas	53,07

Source: U.S. Energy Information Administration estimates.

Note: To convert to carbon equivalents multiply by 12/44.

Coefficients may vary slightly with estimation method and across time.

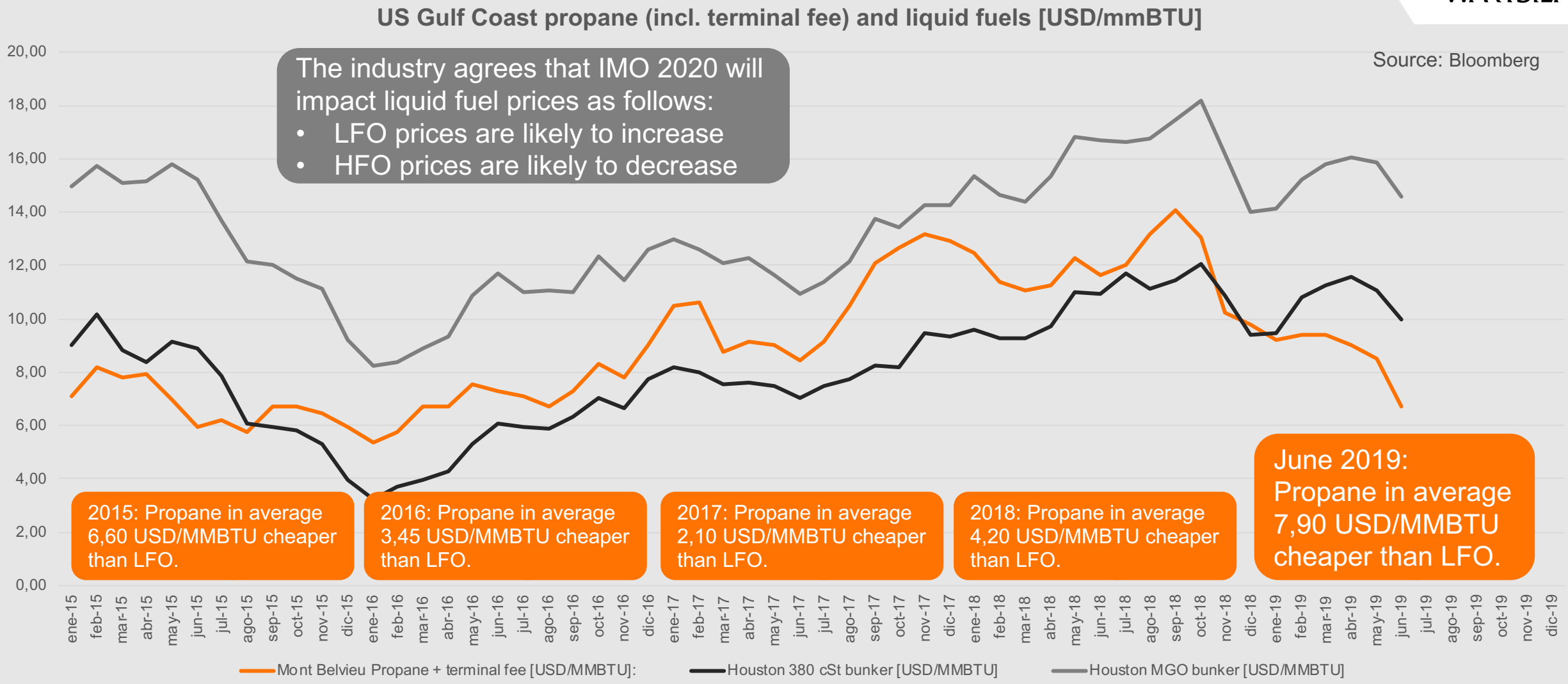


Impact of choice of fuel and electrical efficiency on CO2 emissions

Fuel	CO2 factor [kg CO2/MMBTU]	Electrical efficiency [%]	CO2 Emissions [gr CO2/kWh]
Coal	95,35	35%	976
Coal	95,35	45%	759
Diesel	73,16	35%	749
Diesel	73,16	45%	582
Propane	63,07	35%	646
Propane	63,07	45%	502
Natural gas	53,07	35%	543
Natural gas	53,07	45%	422

Source: https://www.eia.gov/environment/emissions/co2_vol_mass.php

US GULF COAST - REFERENCE LPG AND LIQUID FUEL PRICE DEVELOPMENT 2015-2019



PROPANE IS CHEAPER THAN DIESEL ***and it is a relevant power plant fuel for the region today and in the foreseeable future. Refer to LPG traders for project-specific landed prices.***

MAJOR EXPORTERS, FLOATING STORAGES AND PRESSURIZED SMALL TANKER FLEET GUARANTEE LPG AVAILABILITY

3 major LPG exporting countries, floating VLGC storages and a large fleet of small and medium-sized pressurized tankers guarantee competitive LPG pricing and security of supply in the region.

US annual LPG export 2017: 69.000.000 m3

Competitive VLGC shipment from Mont Belvieu to floating storages and other large offtakers in region, max 4-5 days voyage

Dominican Rep. long term floating VLGC storage (78.900 m³)

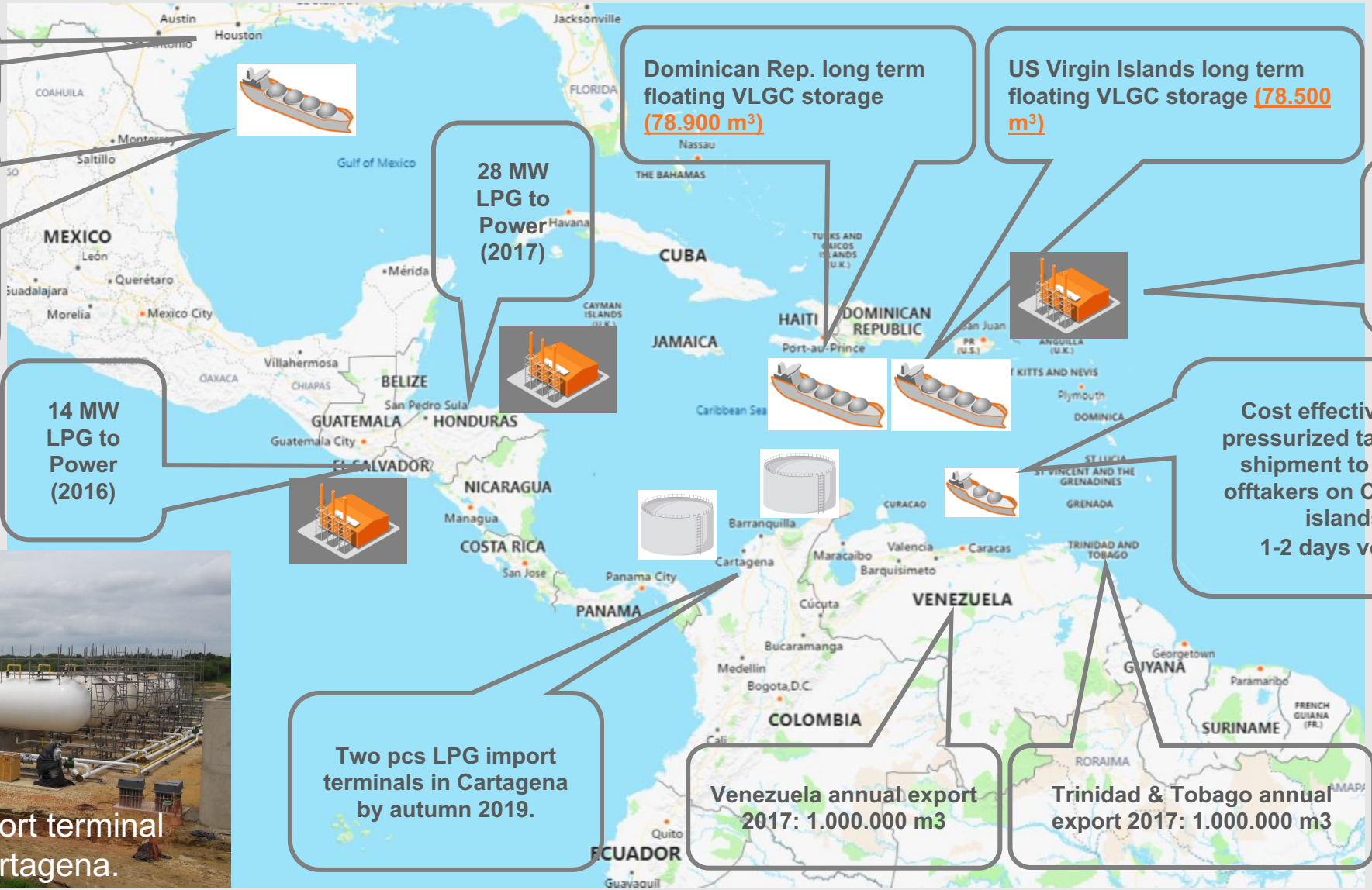
US Virgin Islands long term floating VLGC storage (78.500 m³)

28 MW LPG to Power (2017)

21 MW LPG to Power (2019)

14 MW LPG to Power (2016)

Cost effective small pressurized tankers for shipment to smaller offtakers on Caribbean islands, 1-2 days voyage



Two pcs LPG import terminals in Cartagena by autumn 2019.

Venezuela annual export 2017: 1.000.000 m3

Trinidad & Tobago annual export 2017: 1.000.000 m3

Plexa 4100 m3 LPG import terminal under construction in Cartagena.

BERGE SUMMIT 78.900 m3 VLGC floating storage and EPIC CURACAO 3.500 m3 fully pressurized LPG tanker doing ship-to-ship operation 10 nautical miles off the US Virgin islands.

Photo credit: BW LPG

Roatan Electric Co 4100 m3 LPG bullet tankyard

Tank configuration 12 x 340 m3 (12 x 90000 USG) bullet tanks. Bullet tanks allow for fast track construction. Photo Credit: Transtech Energy

EPIC BALTA, 6.300 m3 fully pressurized LPG tanker discharging at Roatan

Photo credit: EPIC GAS

Multi-fuel technologies for LPG power plants

OPEX, CAPEX, preferred fuel flexibility and the composition of the LPG all influence the choice of engine technology.

	WÄRTSILÄ SG-LPG TECHNOLOGY	WÄRTSILÄ LG TECHNOLOGY
Engine frame	Same proven engine frame as used in Wärtsilä's diesel, gas and dual-fuel engines.	
Engine fuel supply system	Same as used for Wärtsilä SG gas engines. LPG is gasified in external system by heating.	Common rail principle similar to Wärtsilä common rail diesel engines. LPG is pumped as a liquid and atomized in the injection valve.
LPG fuel	Minimum 90% propane.	Propane and butane in any relation.
Fuel flexibility	Methane (natural gas) and ethane.	Light fuel oil, kerosene, naphtha, condensates and other hydrocarbons in the range C_3 to C_{20} in any relation.

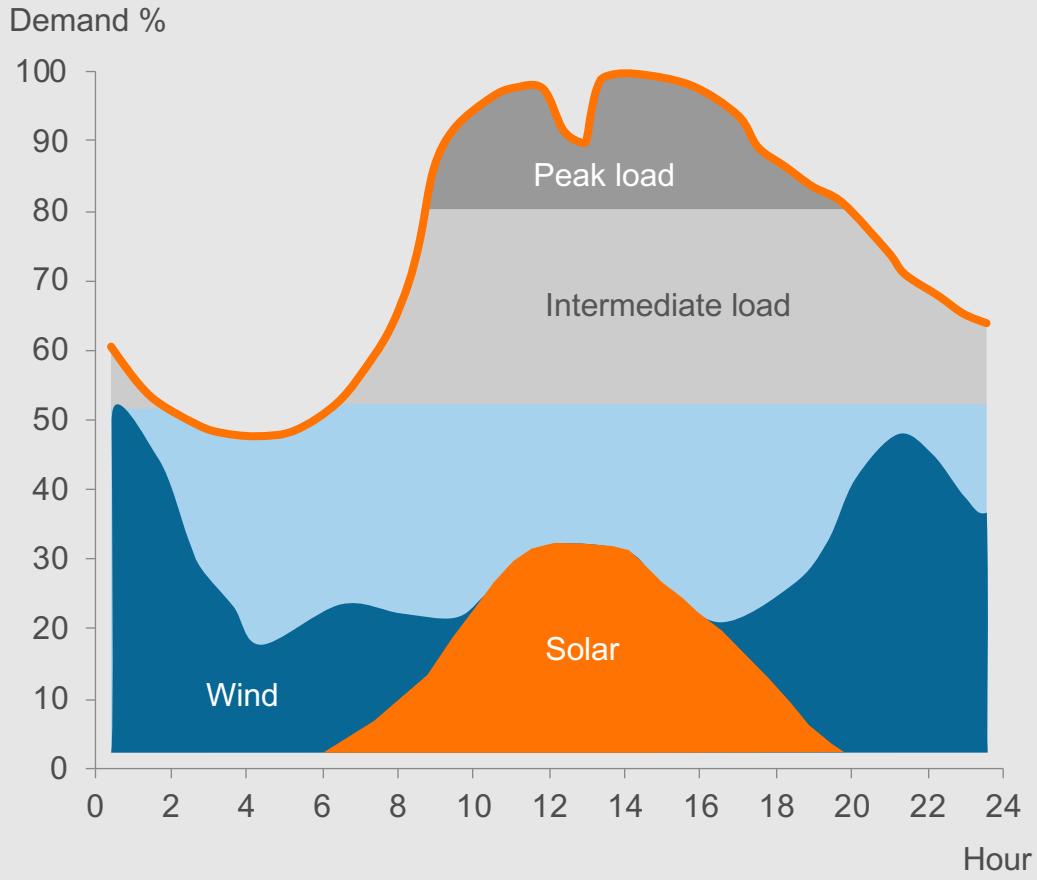
INDUSTRIAL SELF-GENERATION - EL SALVADOR 14 MW LPG POWER PLANT

Industrial cogeneration	
Location	Central America
Operating mode	Baseload with steam cogeneration
Total output	14 MW
Fuel	LPG
Scope	Engineered equipment delivery
Delivery	In service early 2016

The first Wärtsilä LPG power plant was delivered in 2016 in El Salvador. The cogeneration plant generates baseload power and steam for local industry.

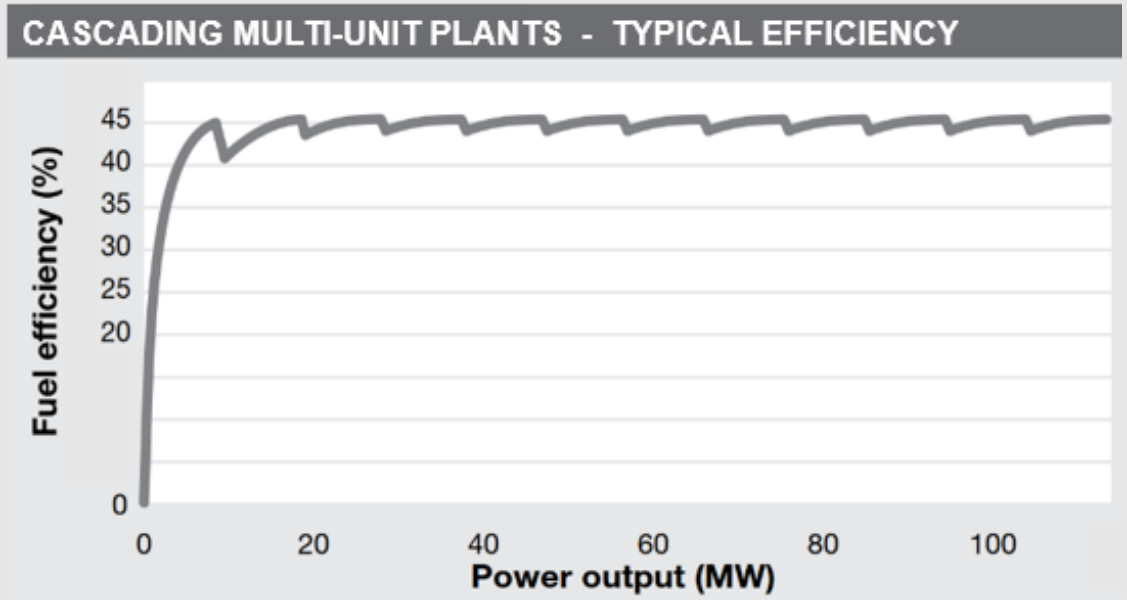
Major changes in power systems

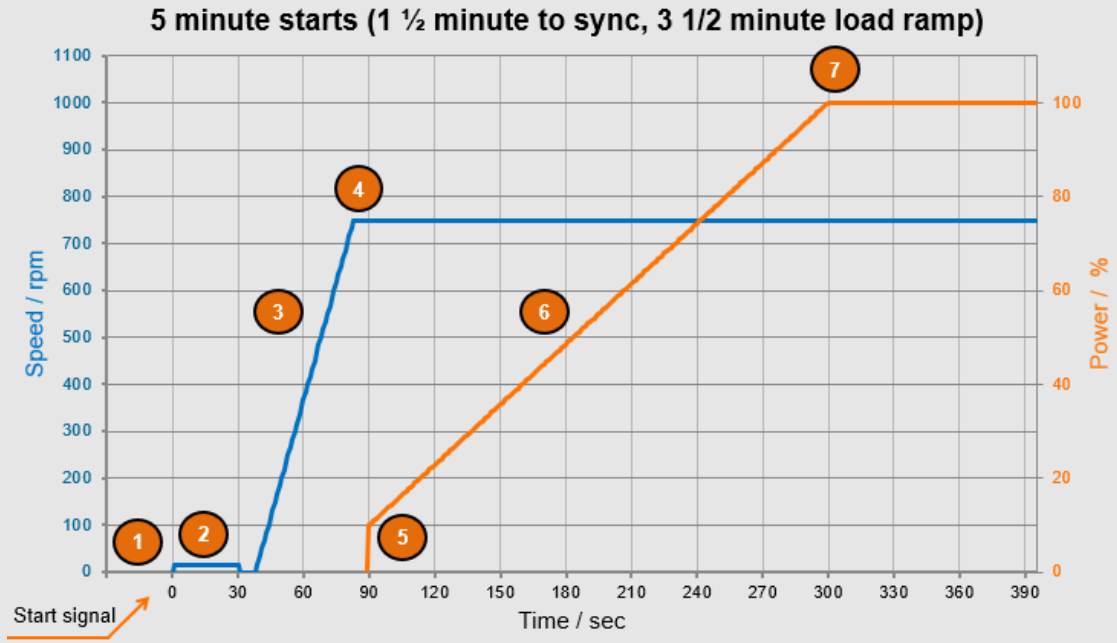
- **Power systems** are the largest man-made dynamic systems – inherently complex systems for any optimization.
- Intermittency of wind and solar power represent the biggest challenge and **change** to the power system operation since the dawn of power generation.
- Where did the thermal baseload go?
- New investment is needed for the power system, but what and how?
- Flexibility in thermal generation is required.



Benefits of multi-unit, fast-starting plants

- Cascading plants offer truly flexible load following
- Operate units at the maximum efficiency by starting or stopping units as per demand
- High plant level efficiency over a wide load range thanks to multiple units
- Unmatched plant level availability due to maintenance of one unit at the time.
- Load following with fast starts and ramping support intermittent renewable generation





FLEXIBLE BASELOAD - RECO ROATAN 28 MW LPG POWER PLANT

Roatan Electric Company	
Location	Roatan Island, Honduras
Operating mode	Flexible baseload
Total output	28 MW
Fuel	Propane
Scope	EPC
Delivery	In service early 2017

Besides saving fuel costs and reducing emissions due to the switch from diesel to LPG, the flexible Wärtsilä LPG power plant facilitates an increased integration of renewable energy generation in the Roatan power system. Wärtsilä built the power plant under an EPC contract.

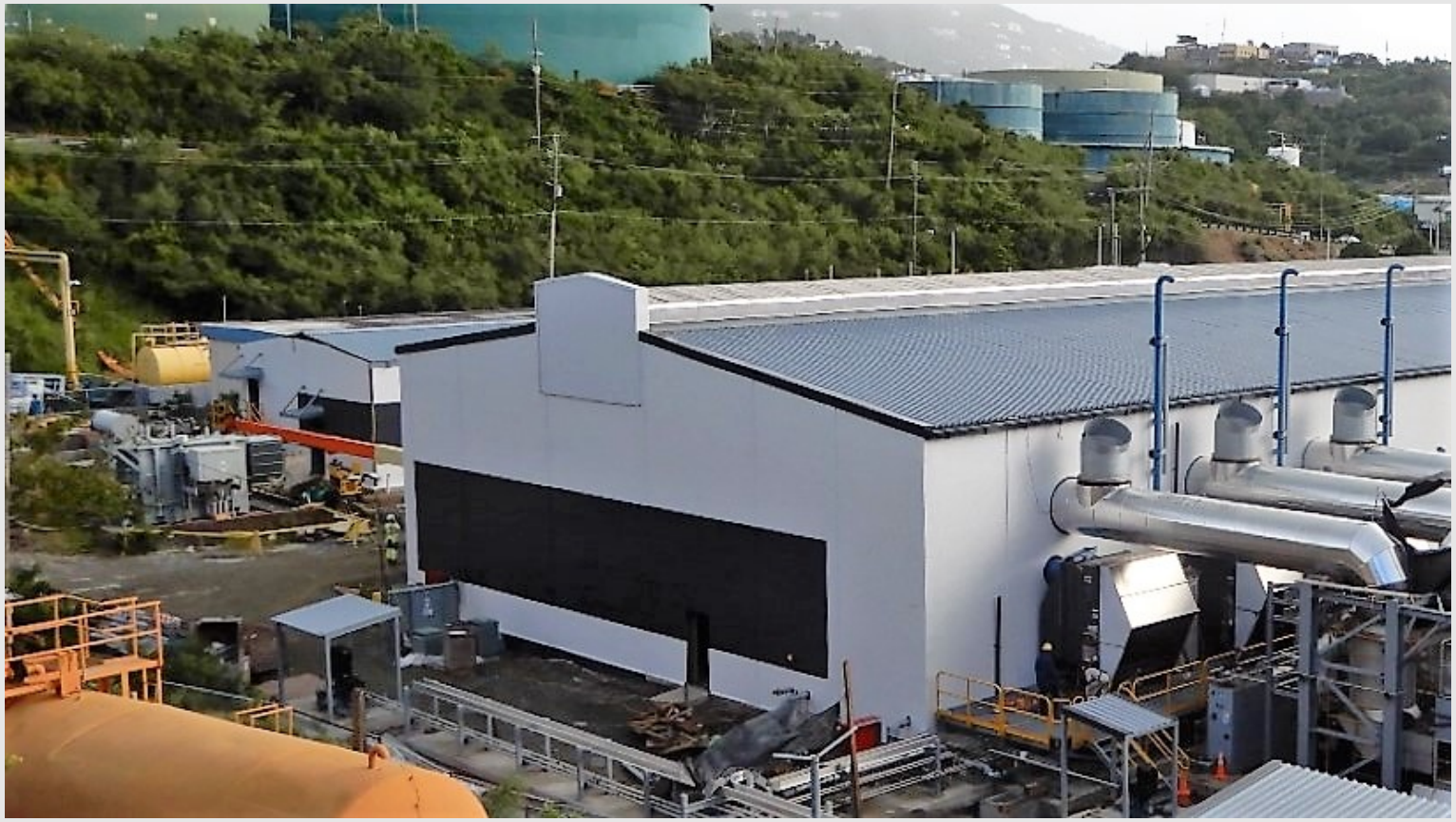
WLPGA Roatan case study.

Photo credit: Roatan Electric Company

U.S. Virgin Islands Water and Power Authority (WAPA)

Location	St. Thomas
Operating mode	Flexible baseload
Total output	21 MW
Fuel	LPG
Scope	EPC
Delivery	In service mid 2019

Wärtsilä won a public bid for the construction of a 21 MW LPG-fired power plant. The power plant is located in an existing power generation site on the island of St. Thomas. The plant construction has been completed under an EPC contract by Wärtsilä.



LPG TO POWER SUCCESS STORIES

Industrial cogeneration	
Location	Central America
Operating mode	Baseload with steam cogen.
Total output	14 MW
Fuel	LPG
Scope	Engineered equipment delivery
Status	In service early 2016

Roatan Electric Company	
Location	Roatan Island, Honduras
Operating mode	Utility, flexible baseload
Total output	28 MW
Fuel	LPG
Scope	EPC
Status	In service early 2017

US Virgin islands Water and Power Authority	
Location	US Virgin Islands, St. Thomas
Operating mode	Utility, flexible baseload
Total output	21 MW
Fuel	LPG
Scope	EPC
Status	In service mid 2019

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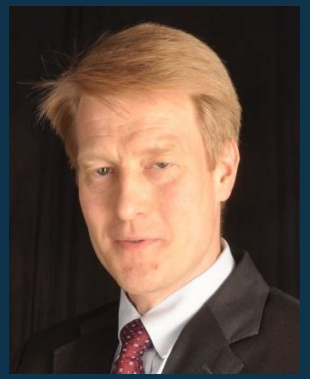

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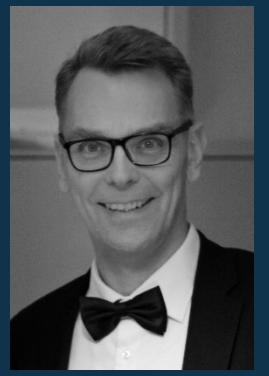

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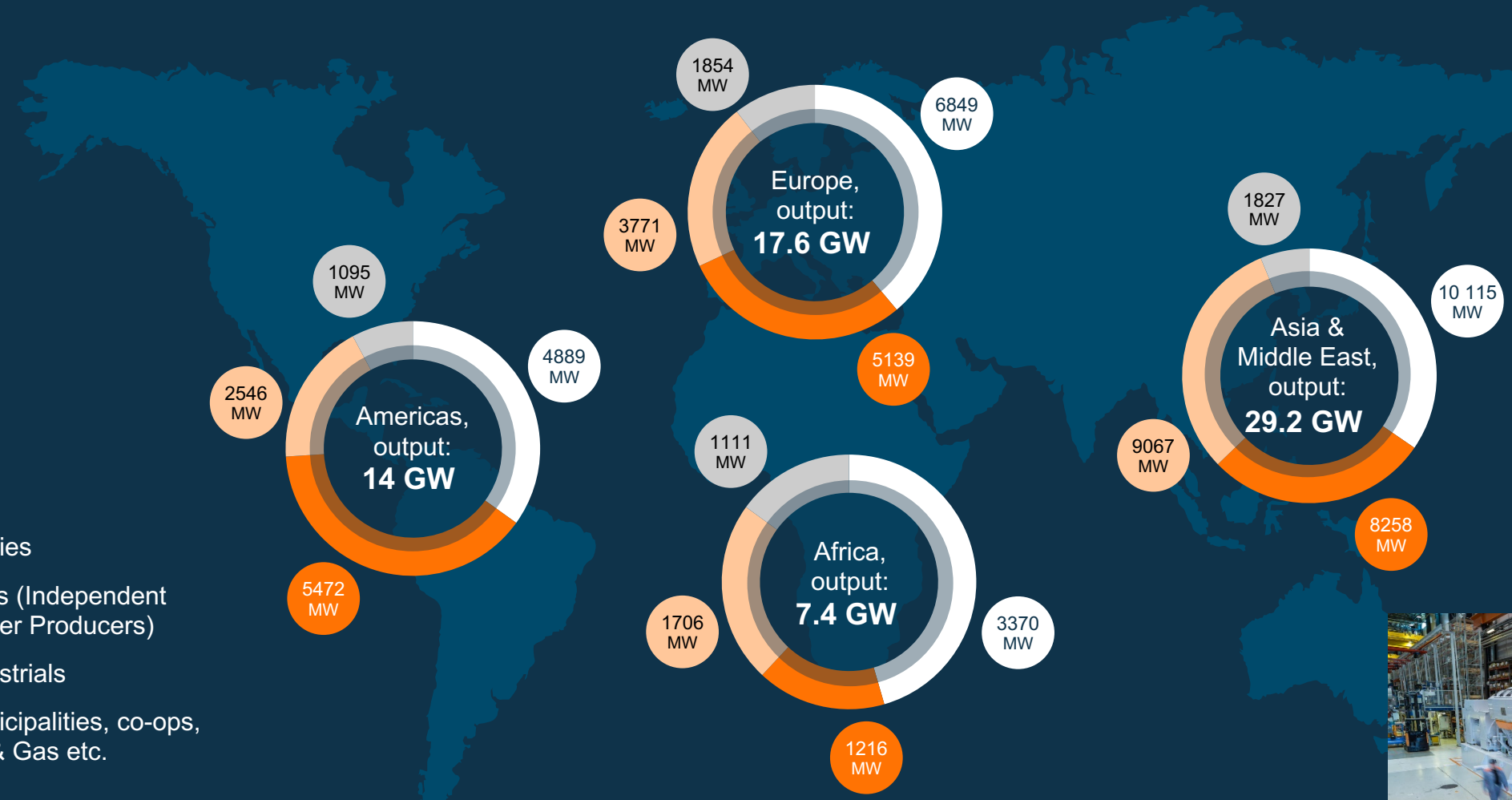
Installed power plant capacity

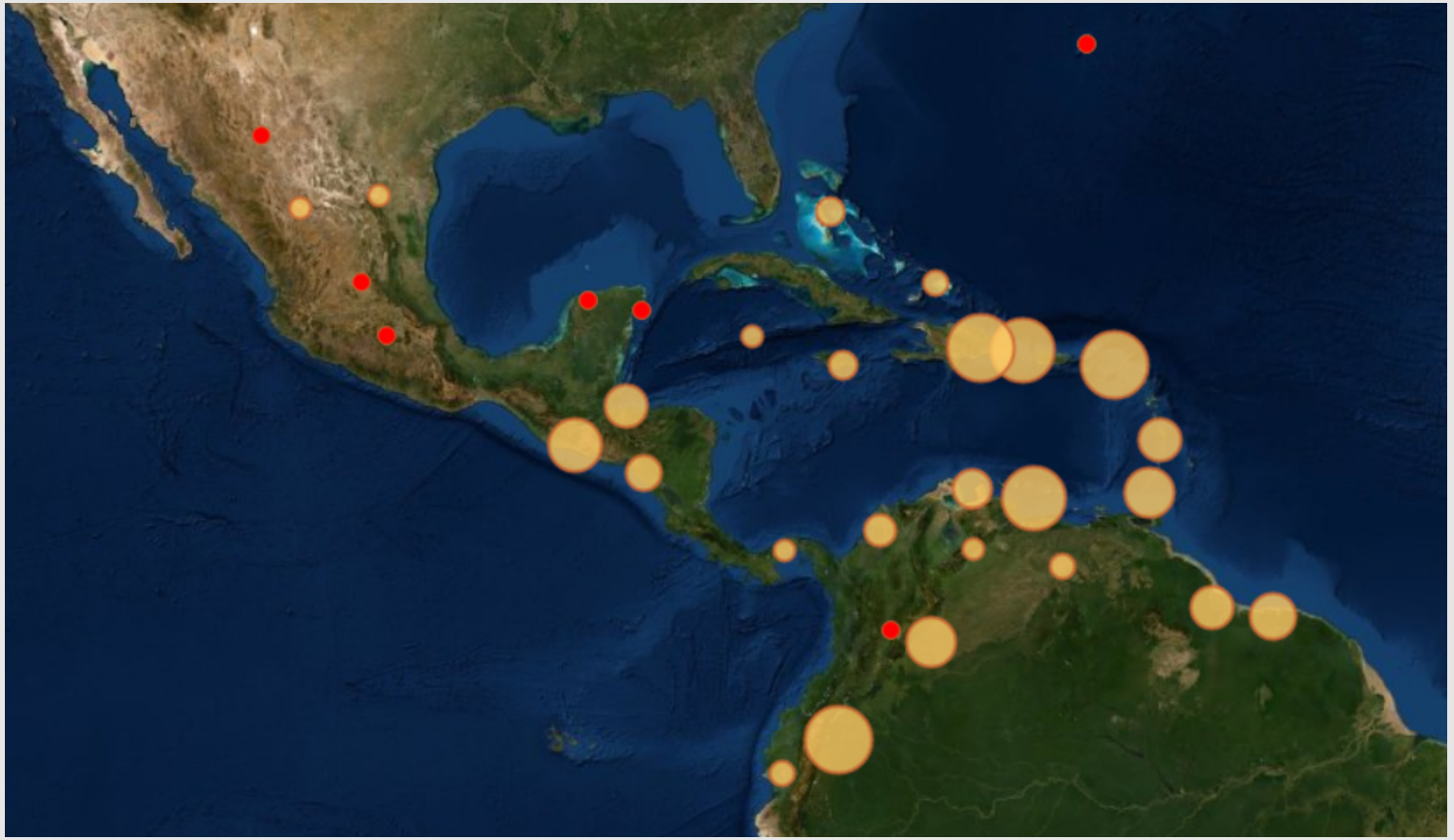
70 GW in 177 countries around the world



- Utilities
- IPP's (Independent Power Producers)
- Industrials
- Municipalities, co-ops, Oil & Gas etc.

Close to 7 GW by Wärtsilä in the region (status 2019/07)

Guatemala	373 MW
Honduras	554 MW
El Salvador	437 MW
Mexico	528 MW
Nicaragua	64 MW
Panama	146 MW
Colombia	264 MW
Ecuador	502 MW



CARIBBEAN REGION*

Anguilla	19 MW
Antigua and Barbuda	79 MW
Aruba	204 MW
Bahamas	132 MW
Belize	24 MW
Bermuda	44 MW
Bonaire	17 MW
British Virgin Islands	56 MW
Cayman Islands	21 MW
Curaçao	109 MW
Dominica	12 MW
Dominican Republic	1448 MW
Grenada	21 MW
Guadeloupe	16 MW
Guyana	145 MW
Haiti	35 MW
Jamaica	244 MW
Martinique	90 MW
Puerto Rico	24 MW
St. Kitts and Nevis	11 MW
St. Lucia	76 MW
St Maarten	157 MW
St. Vincent	15 MW
Surinam	158 MW
Trinidad and Tobago	76 MW
Turks and Caicos	35 MW
US Virgin Islands	21 MW

Wärtsilä gas, dual-fuel and diesel engines all share the same proven engine frame

Our gas and dual-fuel engine technologies are mature thanks to the extensive field experience gained from both marine and land based power plant applications.

WÄRTSILÄ GAS ENGINE TECHNOLOGIES	INTRODUCTION YEAR	REFERENCES [PCS]	REFERENCES [GW]
Gas diesel (GD)	1990	210	1.6
Spark-ignited gas (SG)	1994	2050	14.7
Dual-fuel (DF)	1997	1600	16.5

MOST POWERFUL ENGINE POWER PLANT
IPP3, Jordan, 573 MW

MOST POWERFUL ENGINE-POWERED CRUISE VESSELS
Oasis & Allure of the Seas, 98 MW

MOST POWERFUL LNG TANKERS
TeeKay Arctic LNG carriers, 67 MW

Land based power plants and marine installations, status 12/2018.


WÄRTSILÄ