Advantages and Disadvantages

	Advantages	Disadvantages
Reciprocating Engines	High power efficiency, achievable over a wide load range; Relatively low investment cost per kWe electrical output Wide range of unit sizes from 3 kWe (there are 2,000 3kWe installations in Germany) upward Part-load operation flexibility from 30% to 100% with high efficiency Can be used in island mode (all ships do this) good load following capability Fast start-up time of 15 seconds to full load (gas turbine needs 0.5 to 2 hours) Real multi-fuel capability, can also use HFO as fuel Can be overhauled on site with normal operation Low investment cost in small sizes Can operate with low pressure gas (down to 1 bar)	Must be cooled, even if the heat recovered is not reusable Lower power : weight ratio and out-of-balance Forces requiring substantial foundations High levels of low frequency noise High maintenance costs

Advantages and Disadvantages

	Advantages	Disadvantages
Micro-turbine	High reliability due to small number of moving parts Simplified installation Low maintenance requirement Compact size Lightweight Acceptable noise levels Fuelled by domestic natural gas resource with expanded fuel flexibility Competitive costs when built in quantity Low emissions High temperature exhaust for heat recovery Acceptable power quality	Costs

Advantages and Disadvantages

	Advantages	Disadvantages
Gas Turbine	High reliability which permits long-term unattended operation High grade heat available Constant high speed enabling—close frequency Control of electrical output High power:weight ratio No cooling water required Relatively low investment cost per kWe electrical output Wide fuel range capability (diesel, LPG, naphtha, associated gas, landfill sewage) Multi fuel capability Low emissions	Limited number of unit sizes within the Output range Lower mechanical efficiency than Reciprocating engines If gas fired, requires high-pressure supply or in-house boosters High noise levels (of high frequency can be easily alternated) Poor efficiency at low loading (but they can operate continuously at low loads) Can operate on premium fuels but need to be clean of dry Output falls as ambient temperature rises due to thermal constraints within the turbine May need long overhaul periods

Advantages and Disadvantages

	Advantages	Disadvantages
Steam Turbine	High overall efficiency Any type of fuel may be used Heat-to-power ratios can be varied through flexible operation Ability to meet more than one site heat grade requirement Wide range of sizes available Long working life	High heat power ratios High cost Slow start-up

Advantages and Disadvantages

	Advantages	Disadvantages
Wind Turbine	Newer technologies are making the extraction of wind energy much more efficient Wind is a free source of energy Small space requirement—windmills only have to occupy a few square meters for the base; this allows the land around the turbine to be used for many purposes—for example—agriculture	Reliability of wind Wind turbines generally produce a lot less electricity than the average fossil fuelled power station, requiring multiple wind turbines to be built in order to make an impact Construction can be very expensive Noise pollution—the noise pollution from commercial wind turbines are sometimes similar to a small jet engine; protests and or petitions usually confront an proposed wind farm development People feel the countryside should be left intact for everyone to enjoy its beauty

Advantages and Disadvantages

	Advantages	Disadvantages
Photovoltaics	PV systems require no fuel supply Completely silent Require little maintenance Long shelf life Solar panels are excellent for load balancing—because maximum electricity usage and peak solar generation both occur on hot sunny days	Expensive—very high initial cost System components are expensive to replace High Tech-Requires a skilled labor force to create—although operation and maintenance of PV cells themselves is relatively easy May require the use of toxic materials such as the Cadmium in Cadmium Telluride solar cells Many have argued that in the panel itself the Cd is secure from the environment—but then it demands careful end of life treatment Intermittent—solar cells only produce electricity when the sun is shining—at night or in bad weather, you need either storage batteries or a secondary power source

Advantages and Disadvantages

	Advantages	Disadvantages
Fuel Cells	Low emissions and low noise High efficiency over load range Modular design, sitting flexibility, short construction time Automated operation, quick load changes, low maintenance Many fuels, but require processing unless pure hydrogen Flexible heat to power ratio; Low or high-grde heat—depending on design and fuel cell type	Costs Durability Power density Start-up time Degradation Corrosion for liquid electrolytes Sulphur

Advantages and Disadvantages

	Advantages	Disadvantages
Stirling Engines	Technical advantages: much experience in high power range Less moving parts with low friction No internal burner chamber High theoretical efficiency Suitable for mass production Advantages for micro-cogeneration: no extra thermal-boiler necessary Electrical production independent from heat production Very low emissions Easy to control Can be built as an interchangeable unit	Little experience in low power range Poor shaft efficiency by the existing machine (350-800 Watt shaft power) Better efficiency at 3,000 Watt shaft power First machines have been very expensive

Comparison of Various Power Generation Options

Description	Units	Combined GT & ST	Conventional Steam Plant	Diesel Engine Power Plants
Thermal Efficiency	%	40-46	33-36	43-45
Initial Investment of Installed Capacity	Rs/kW	8,500-10,000	15,000-18,000	7,500-9,000
Cooling water requirement with once through cooling	(Lt/kWh)	-	-	-
Space requirement	-	125% (Approximately)	250% (Approximately)	100% (Approximately)
Construction time	Months	24-30	42-48	12-15
Project period	Months	30-36	52-60	13-12
Auxiliary Power Consumption	%	2-4	8-10	13-21
Plant Load Factor	K Wh/kW	6000-7000	5000-6000	7200-7500
Range of Control of Electrical output on Heavy oil	%	0-100	42-100	25-100
Start-up time from cold	Minutes	About 10	120-180	15-20

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Technology Comparison

Technology	Reciprocating Engine: Diesel	Reciprocating Engine: NG	Microturbine	Combustion Gas Turbine	Fuel Cell	Stirling Engine	Photovoltaics
Size	30kW - 6+MW	30kW - 6+MW	30-400kW	0.5 - 30+MW	100-3000kW	1 - 75 kW	
Installed Cost [1] ($/kW)	600-1,000	700-1,200	1,200-1,700	400-900	4,000-5,000	2,000 - 36,000	7,500-9,500
Electrical Efficiency (LHV)	30-43%	30-42%	14-30%	21-40%	36-50%	7-38%	12-24%
Overall Efficiency [2]	~80-85%	~80-85%	~80-85%	~80-90%	~80-85%	~50%	~30%
Total Maintenance Costs [3] ($/kWh)	0.005 - 0.015	0.007-0.020	0.008-0.015	0.004-0.010	0.0019-0.0153	0.05-0.01	0.002-0.01
Footprint (ft^2/kW) (m^2/kW)	0.22-0.31 0.020-0.029	0.28-0.37 0.026-0.034	0.15-0.35 0.014-0.032	0.02-0.61 0.002-0.057	0.9 0.084	2-10 0.186-0.929	140-350 13 - 32
Emissions (gm / bhp-hr unless otherwise noted)	NO_x: 7-9 CO: 0.3-0.7	NO_x: 0.7-13 CO: 1-2	NO_x: 9-50ppm CO: 9-50ppm	NO_x: <9-50ppm CO:<15-50ppm	NO_x: <0.02 CO: <0.01	Energy Source Dependent	Cd: 0.3-0.9 microgram/ kWh over whole life - cycle

1 Cost varies significantly based on siting and interconnection requirements, as well as unit size and configuration.

2 Assuming CHP.

3 Fuel costs vary significantly by region, and the numbers in this row assume minimum fuel cost. For a specific application, contact manufacturers of specific equipment to get an idea of fuel consumption. Contact local gas, diesel or other fuel supplier (or see Department of Energy databases) to get an estimate of what fuel will cost.

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