2019 Gas-Electric Partnership Offgrid Power Review

GENTHERM
GLOBAL POWER TECHNOLOGIES

Contents

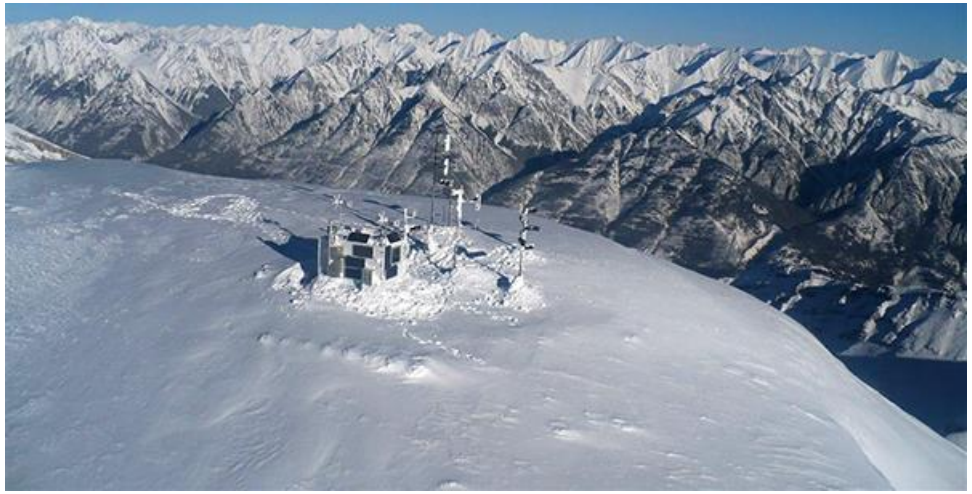
Offgrid Power for Critical Applications

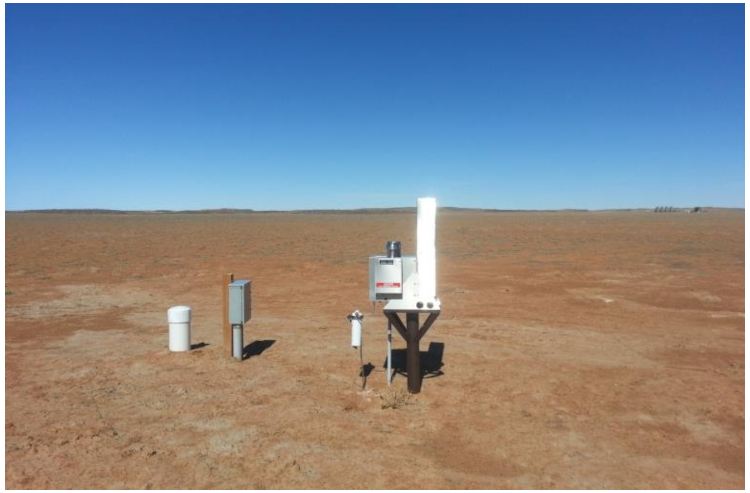
- Remote and unmanned locations, which are difficult and costly to access, are a prime candidate for utilizing automation to safely monitor and control processes.

Reliable onsite power generation
is a critical component of these systems

TEG Model 5220
South Texas, USA

From the field





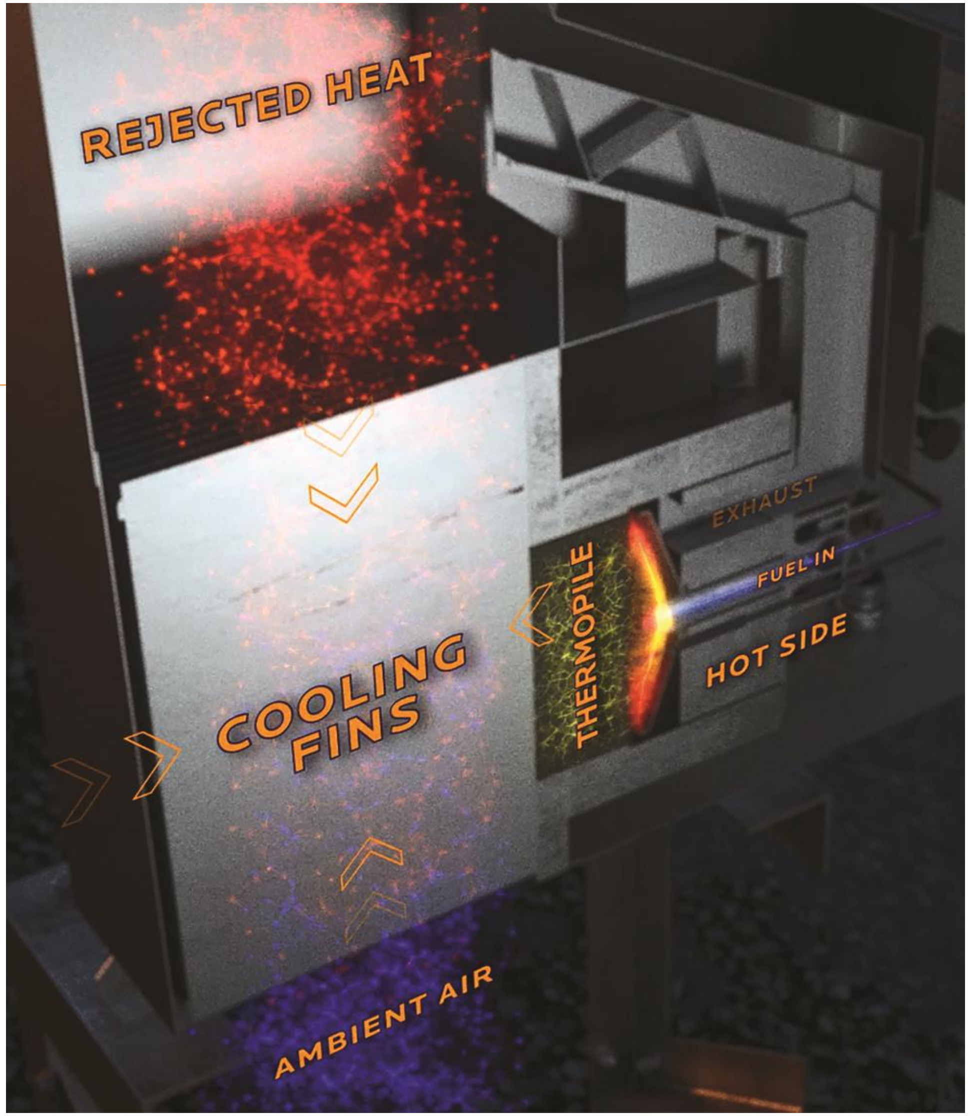
Common Design Oversights

- Misunderstanding the load profile
- Treating off-grid sites like grid power sites
- Overlooking operating expenses
- Selecting an unreliable power source for critical loads
- Choosing the wrong backup battery bank
- Regulatory requirements

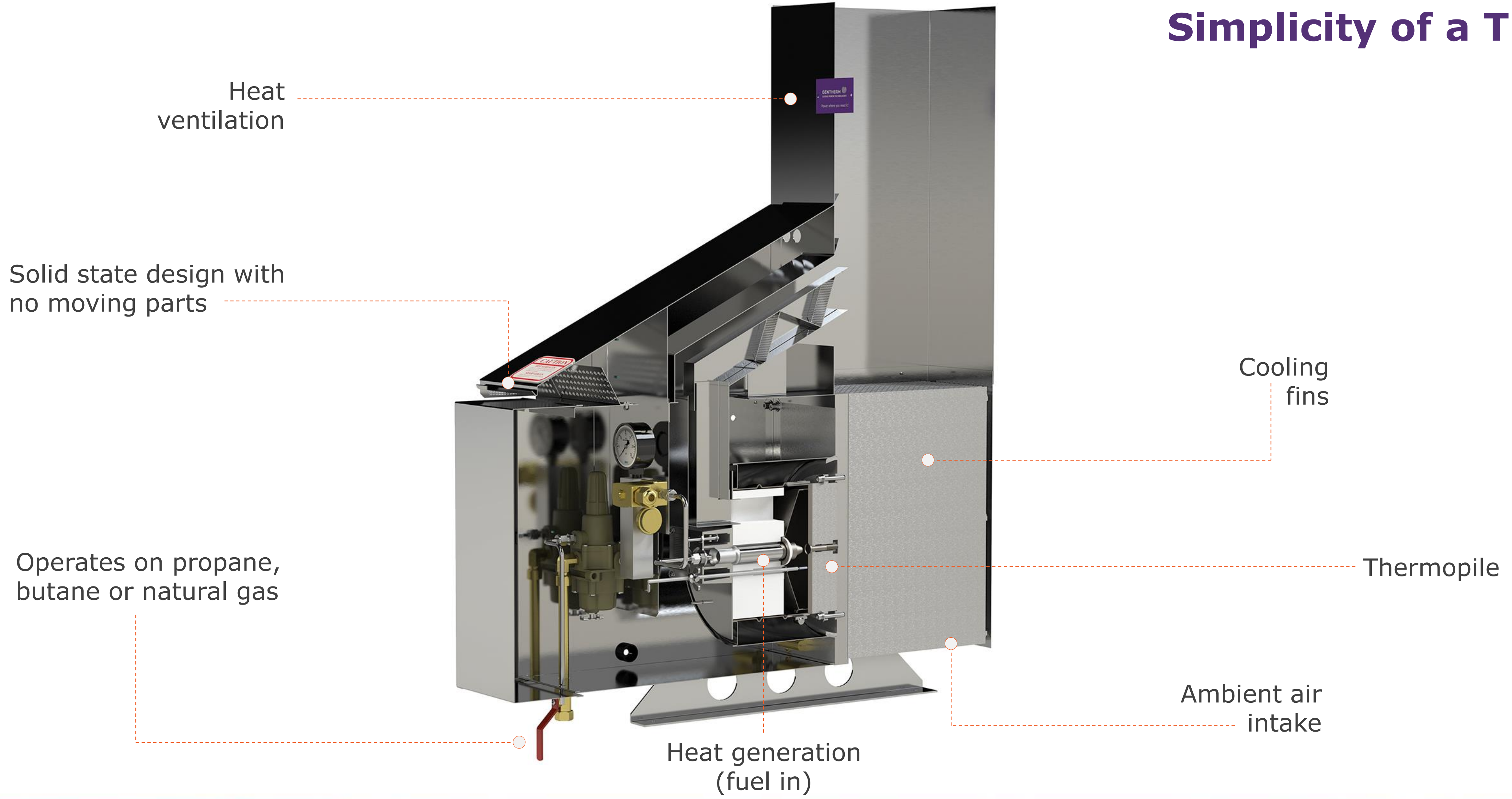
Thermoelectric generators (TEGs)

Thermoelectric generators convert heat directly into electricity.

- Natural gas or propane fuel generates heat
- Converts heat into DC electricity (Seebeck effect)
- Solid state design (no moving parts)
- 20-year design life
- Optional battery bank
- Up to 5 kW power systems (multiple TEG system)



Simplicity of a TEG



Solar/PhotoVoltaic Power (PV)

Solar panels provide DC-charging for batteries

- Solar panel collects solar energy to top off battery charge each sunny day
- Solar controller throttles solar charging and protect batteries against overcharging
- Solid state design (no moving parts)
- 20-year design life
- Size and cost increases significantly as power demand increases above 50W
- Operational costs and battery replacement issues

TEG hybrid systems

Complete system available or choose only the components you need and **retrofit** your existing system.

Hybrid power systems combine the advantages of both thermoelectric and photovoltaic (PV) technologies. By combining these systems, a small environmental footprint is achieved along with reduced fuel consumption, resulting in reliable, continuous power production. Battery bank size is also reduced and battery life extended due to a reduction in deep-cycling requirements. Particularly attractive for crude pipeline applications, when propane tank for TEG power is required.

Choose Only the Components You Need	or	Complete System

TEG

Stand

Charge Control Unit (CCU)

PV

Battery Bank

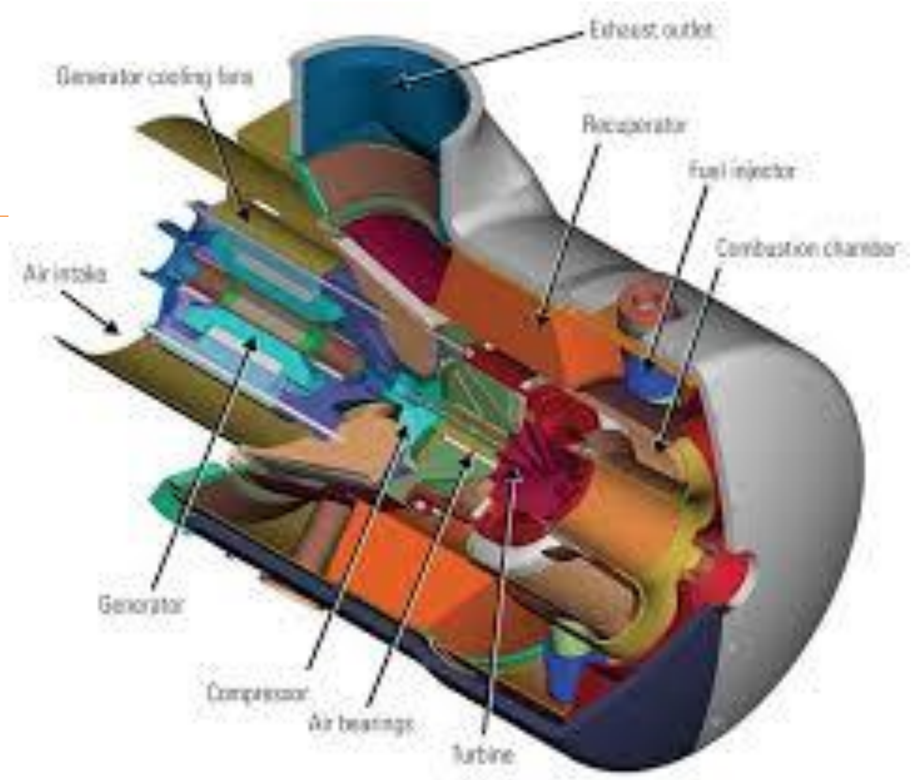
Diesel or Gas Generators (GENSETS)

GENSETs convert tanked fuel into electricity.

- Natural gas, propane or Diesel tanked fuel
- Excellent size-to-power
- Excellent for high power demands
- Good acquisition costs
- Expensive operation costs
- Battery or direct power

A small turbine powers a compressor, recuperator and generator through fuel combustion

- Uses a variety of fuels
- Co-generation increases efficiencies, but generally fair-to-poor fuel efficiency
- Expensive to acquire and maintain
- Excellent size-to-power makes it good for offshore oil platforms



Rankine Cycle Generator

Solar panels provide DC-charging for batteries

- Working fluid is pumped to a boiler where it is evaporated, passed through an expansion device (turbine or other expander), and then through a condenser heat exchanger where it is finally re-condensed.
- Working fluid often in 2-phase condition, which can damage turbine.
- Efficiency and longevity improvement with super-heating steam
- Expensive acquisition cost

Fuel Cell Generator

Solid Oxide or Hydrogen fuel cell cracks fuel molecule through fuel combustion to create electricity

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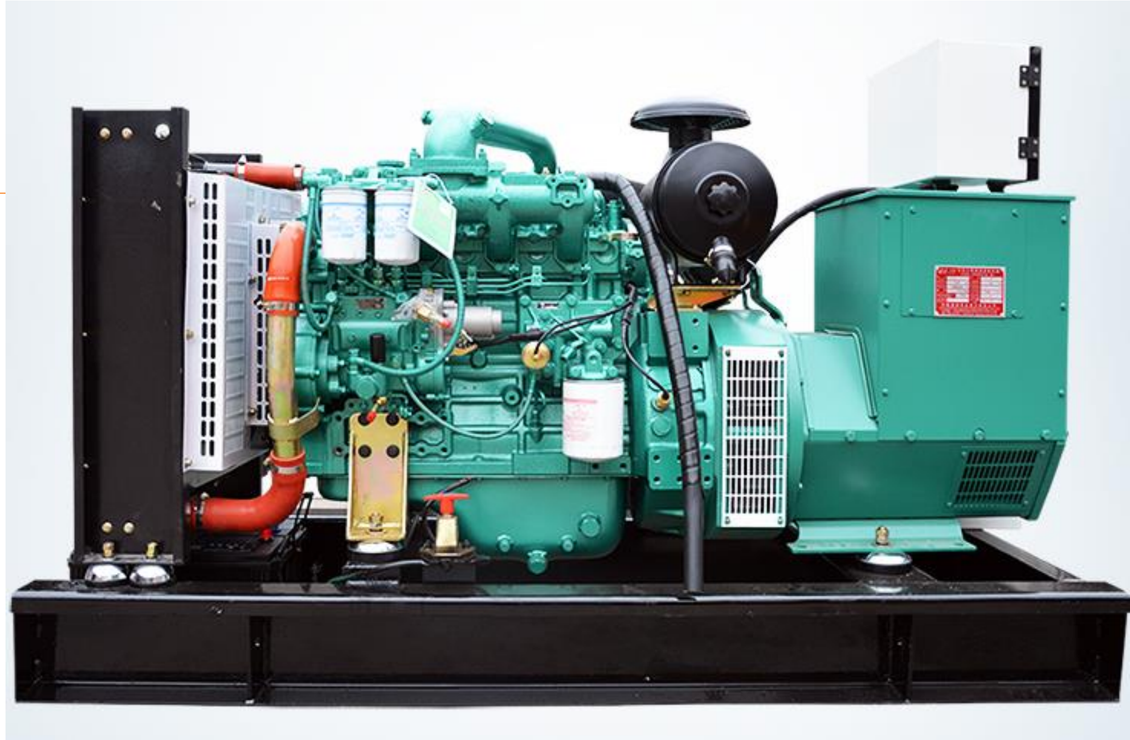
- Solid state design with excellent fuel efficiency
- Needs pristine NG or propane
- 250W-2kW power
- Expensive acquisition and core replacement costs
- Fair-Poor reliability due to H2S sensitivity

Stirling Engine

Works by alternately heating and cooling a gas by an external heat source, extracting energy from the gas' expansion and contraction.

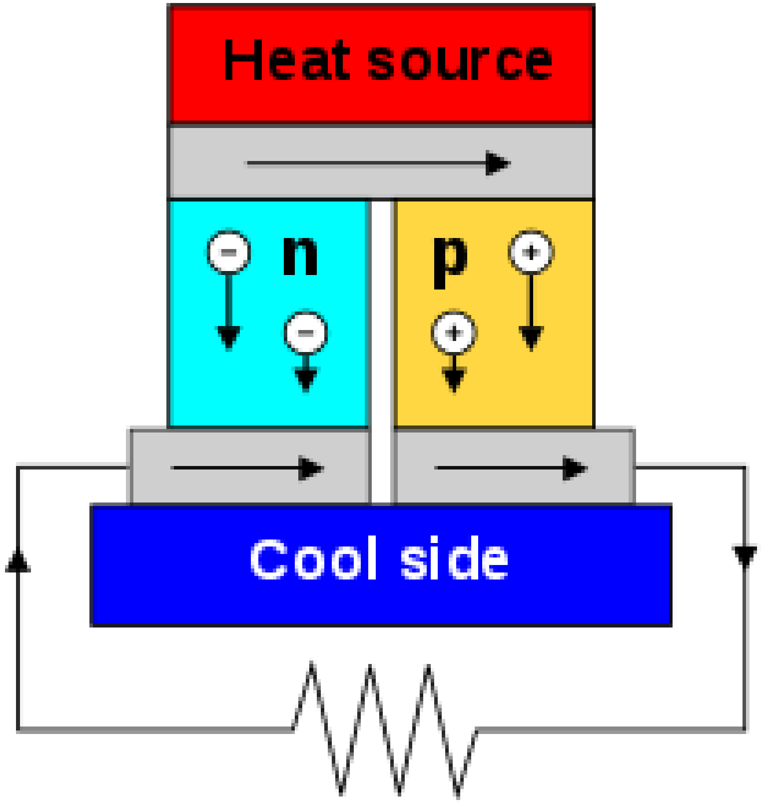
- Excellent fuel efficiency
- Can use various fuel sources
- Quitest reciprocating engine available
- Good reliability
- Expensive to acquire and repair
- Very few manufacturers, limited parts chain



TAC Thermoelectric Generator

Thermoelectric generators convert heat directly into electricity.

- Natural gas or propane fuel generates heat
- Converts heat into DC electricity (Seebeck effect)
- Solid state design (no moving parts)
- Classified area-ready
- Requires l battery bank
- Low power (50W max)
- Poor longevity (~2 year replacement)



Wind Turbine Generator

Uses wind and a turbine to convert kinetic energy to electricity

- Unlimited, free power
- Fair reliability in W-Texas
- Power ranges from 1W to 3MW
- Inconsistent, unreliable power in many regions
- Susceptible to damage
- Safety and wildlife concerns
- Significant industry failure rate

Charge controller

Technology Review

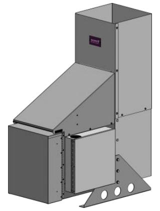
PRODUCT	TEG	Genset	PV	MicroTurbine	Rankine Cycle	Fuel Cell	Stirling Engine	TAC
Power range	30W – 4kW	6kW+	1W+	15kW+	400W – 3kW	50W+	1kW - 7kW	1kW – 7kW
Maturity	Excellent	Excellent	Excellent	Good	Excellent	Fair	Poor	Poor
Reliability	Excellent	Fair	Fair	Fair	Good	Fair	Fair	Fair
Life	Excellent	Poor	Excellent	Fair	Fair	Poor	Fair	Fair
Efficiency	Poor	Good	Fair	Fair	Fair	Fair	Fair	Good
Fuel Tolerance	Good	Fair	N/A	Fair	Fair	Fair	Good	Good
Weather Tolerance	Excellent	Fair	Poor	Fair	Fair	Fair	Excellent	Excellent
Maintenance	Excellent	Poor	Fair	Poor	Poor	Fair	Fair	Fair
Footprint	Excellent	Excellent	Poor	Fair	Excellent	Excellent	Excellent	Excellent
Acquisition Cost	Fair	Excellent	Excellent	Good	Good	Poor	Fair	Good
Operational Cost	Excellent	Fair	Fair	Poor	Poor	Fair	Fair	Fair

Total Cost of Ownership

Natural Gas Wellhead

90w TEG vs. PV **over 10-year life cycle**

$100,000+



TEG w/battery

Float Charge

TEGs provide lower capital cost and operating expenses

One year warranty **Once per year minimal maintenance**

Methanol Fuel Cell Hybrid (PV/Solar)

Fuel Cartridge and Battery Cycling

Photovoltaic (PV/Solar)

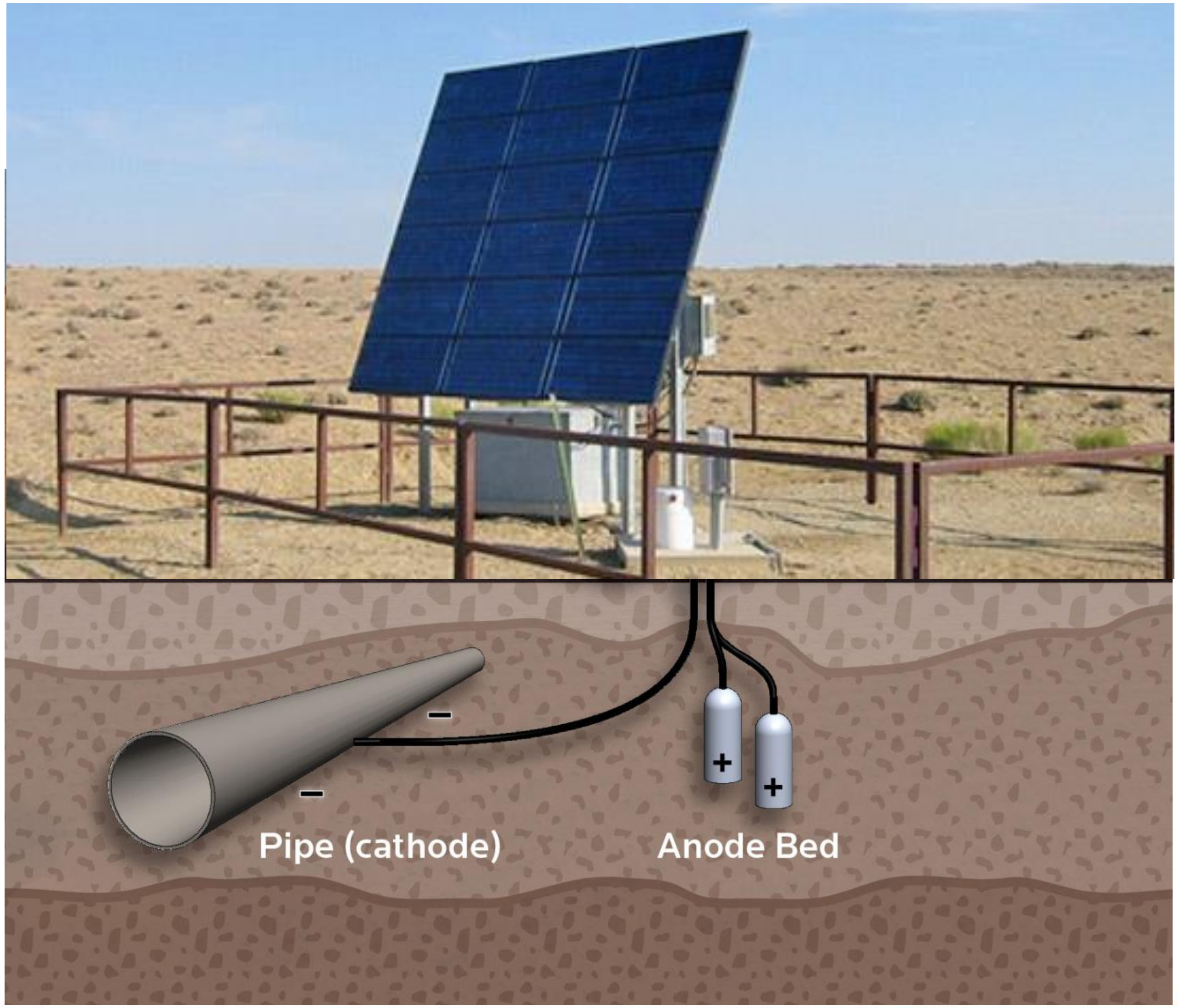
Deep Cycle

*Costs based on location-based solar data and site-specific application (USD)

Offgrid PV Cathodic Protection

Impressed current cathodic protection

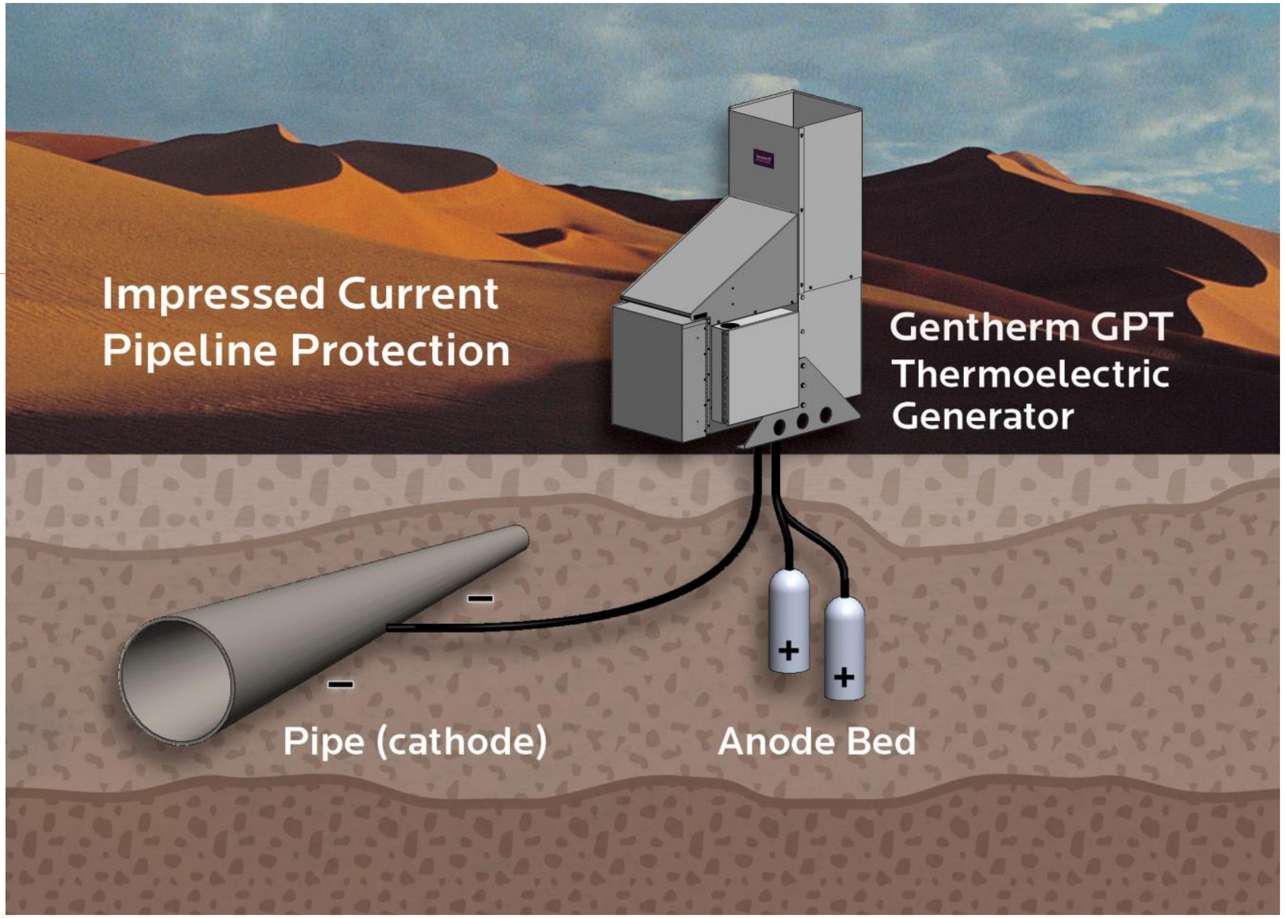
- Electrical power is generated by solar power into electricity.
- The array recharges the battery, which uses a voltage and current-selectable DC-DC controller to impress current directly into a pipeline without the need for batteries or a rectifier.
- Large array and battery bank required
- Expensive acquisition and battery replacement



Offgrid TEG Cathodic Protection

Impressed current cathodic protection

- Electrical power is generated by the direct conversion of heat from the combustion of fuel into electricity.
- The TEG impresses current directly into a pipeline without the need for batteries or a rectifier.



Thank you

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Gas Specifications Matter

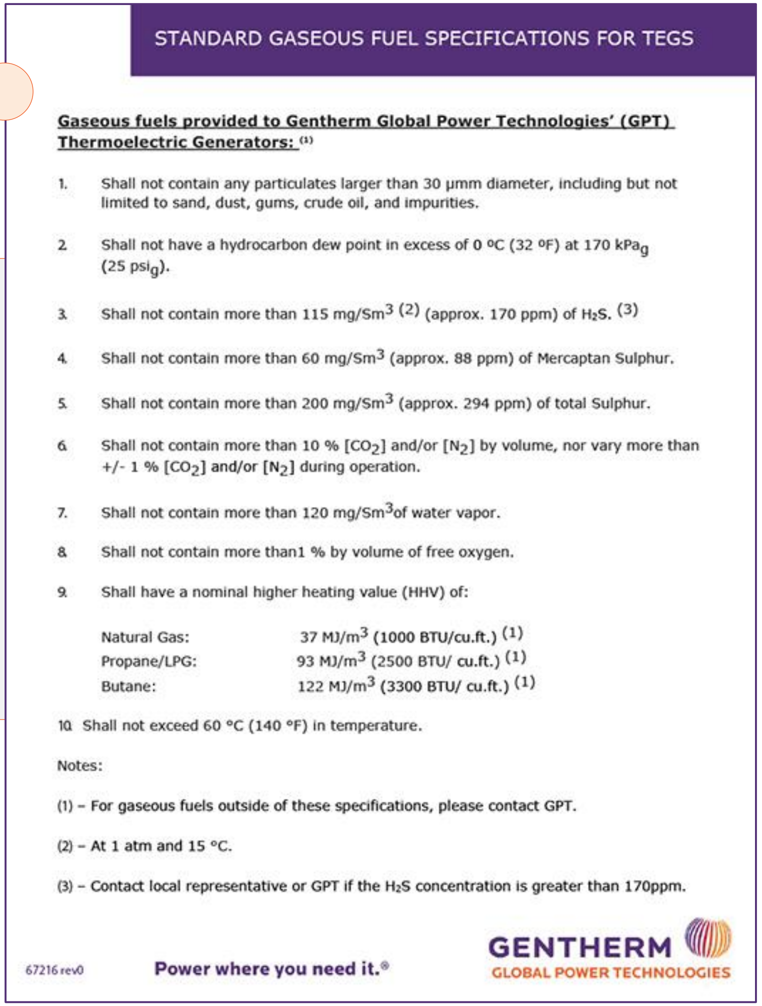
Natural Gas or Propane

Why do specifications matter?

- Damage risk
- H_2S
- BTU

Download a copy online:

http://www.genthermglobalpower.com/product/specification-summary-sheets-tegs



STANDARD GASEOUS FUEL SPECIFICATIONS FOR TEGS

Gaseous fuels provided to Gentherm Global Power Technologies' (GPT) Thermoelectric Generators: [(1)]

1. Shall not contain any particulates larger than 30 μmm diameter, including but not limited to sand, dust, gums, crude oil, and impurities.
2. Shall not have a hydrocarbon dew point in excess of 0 ºC (32 ºF) at 170 kPa_g (25 psi_g).
3. Shall not contain more than 115 mg/Sm^3 [(2)] (approx. 170 ppm) of H_2S. [(3)]
4. Shall not contain more than 60 mg/Sm^3 (approx. 88 ppm) of Mercaptan Sulphur.
5. Shall not contain more than 200 mg/Sm^3 (approx. 294 ppm) of total Sulphur.
6. Shall not contain more than 10 % [CO_2] and/or [N_2] by volume, nor vary more than +/- 1 % [CO_2] and/or [N_2] during operation.
7. Shall not contain more than 120 mg/Sm^3 of water vapor.
8. Shall not contain more than1 % by volume of free oxygen.
9. Shall have a nominal higher heating value (HHV) of:

Natural Gas:	37 MJ/m^3 (1000 BTU/cu.ft.) [(1)]
Propane/LPG:	93 MJ/m^3 (2500 BTU/ cu.ft.) [(1)]
Butane:	122 MJ/m^3 (3300 BTU/ cu.ft.) [(1)]

10. Shall not exceed 60 °C (140 °F) in temperature.

Notes:

(1) – For gaseous fuels outside of these specifications, please contact GPT.

(2) – At 1 atm and 15 °C.

(3) – Contact local representative or GPT if the H_2S concentration is greater than 170ppm.

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Back-up Slides

Case study

Eagle Ford Shale

Description	PV Solar
System and Installation cost (PV frame, skid)	$20,000
Installation labor	$3,000
Battery autonomy (days)	3
No. battery banks/batteries	8
Per unit battery cost (GEL – DEKA)	$159
Depth of Discharge (DOD)	50%
Battery lifetime (years)	2
Battery replacement labor cost	$450
PV panel life (years)	20
Number of solar PV panels	2
Maintenance frequency (yearly)	3 visits
Solar maintenance cost per visit	$150
Annual maintenance cost (3x150)	$450
Annual spare parts expense	$550
Annual cost of production loss/downtime	$5,000
Annual fuel cost NG (0.072 USD/m³)	N/A

CAPEX	$23,000
OPEX	$69,610

Total Cost of Ownership	$92,610

Description	TEG/w Battery
System and Installation cost (civil)	$16,446
Installation labor	$1,000
Battery autonomy (days)	2
No. battery banks/batteries	2
Per unit battery cost (AGM – DEKA)	$159
Depth of Discharge (DOD)	100%
Battery lifetime (years)	5
Battery replacement labor cost	$150
TEG life (years)	20
Number of TEGs	1
Maintenance frequency (yearly)	1 visit
TEG maintenance cost per visit	$150
Annual maintenance cost	$150
Annual spare parts expense	$275
Annual cost of production loss/downtime	None
Annual fuel cost NG (0.072 USD/m³)	$233

CAPEX	$25,724
OPEX	$7,236

Total Cost of Ownership	$32,960

ROI (10 years)	Payback Period
132%	4.7 Years

*ROI based upon savings utilizing a TEG system (vs. PV/solar) over 10-year period.

Black Swan energy

Case Study

Case study - Solar

Challenge

Reliable remote power was required for off-grid multi-well pad applications, in Northeastern British Columbia, Canada.

The site was equipped with photovoltaic (PV) solar panels proving difficult to maintain a continuous flow of uninterrupted power, due to location and available daily sunlight.

In addition to lack of sunlight, maintenance crews were tasked with clearing snow from PV panels on a regular basis.

Solution

With Natural Gas readily available on site, two 100w thermoelectric Generators (TEG Model 5100s) were installed at 13 sites, becoming the primary source of power for the well pad with the PV array supplying a small charge to the battery bank.

With their solid-state design the TEGs offer trouble-free, reliable and unattended operation to the site, even during extreme weather events. Power is dependably delivered as needed for Black Swan Energy site operations.

- Radio
- RTU
- Instrumentation
- Solenoids

Market
Upstream, well pad

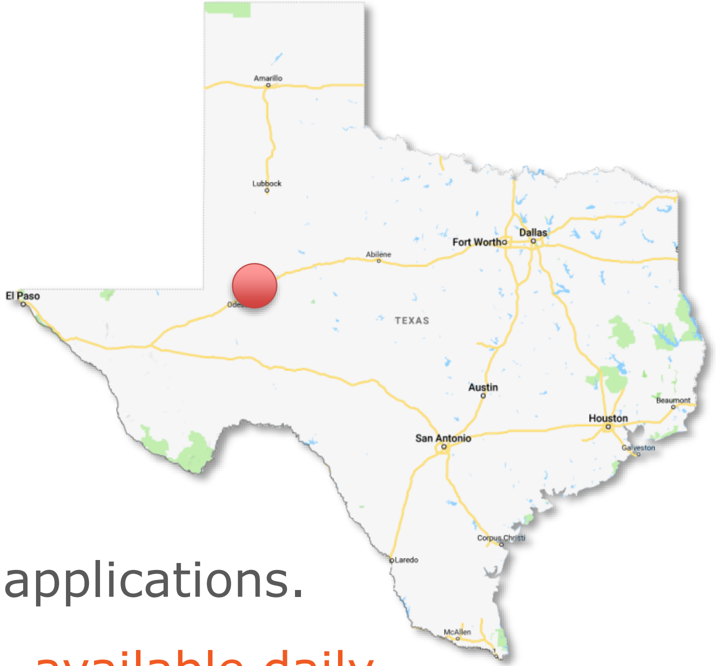
Location
Northeastern British Columbia, Canada

TEG Model 5100

Case study

Midland, Texas

+9ºF	+106ºF	Location	Sunlight



Many environments can be problematic for solar-only remote power applications.

Texas consists of several challenges including extreme temperatures, available daily sunlight and location.

When taking these factors into consideration, thermoelectric generators offer a reliable, long-term solution for remote power generation.

Case study

Midland, Texas

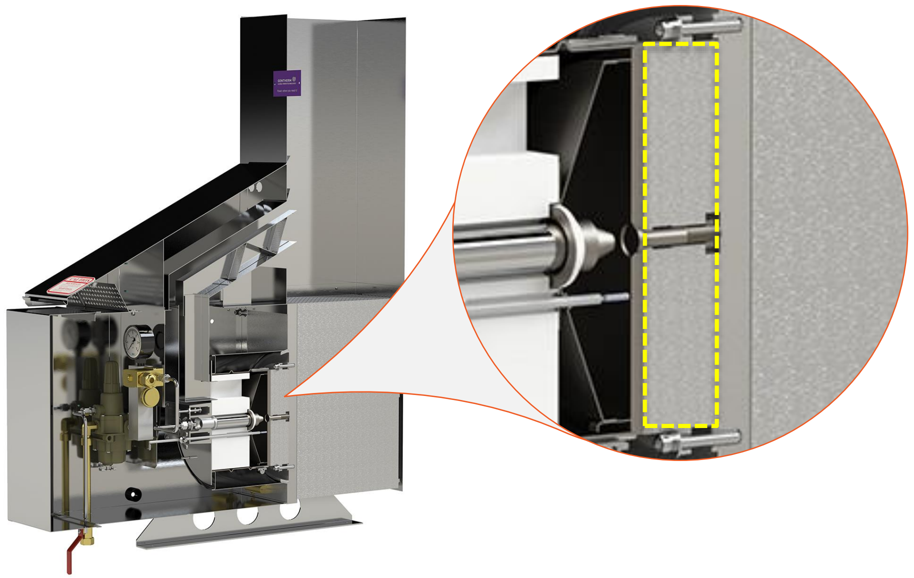
Lat/Lng: 31º 59′ 50″ N, 102º 4′ 40″ W

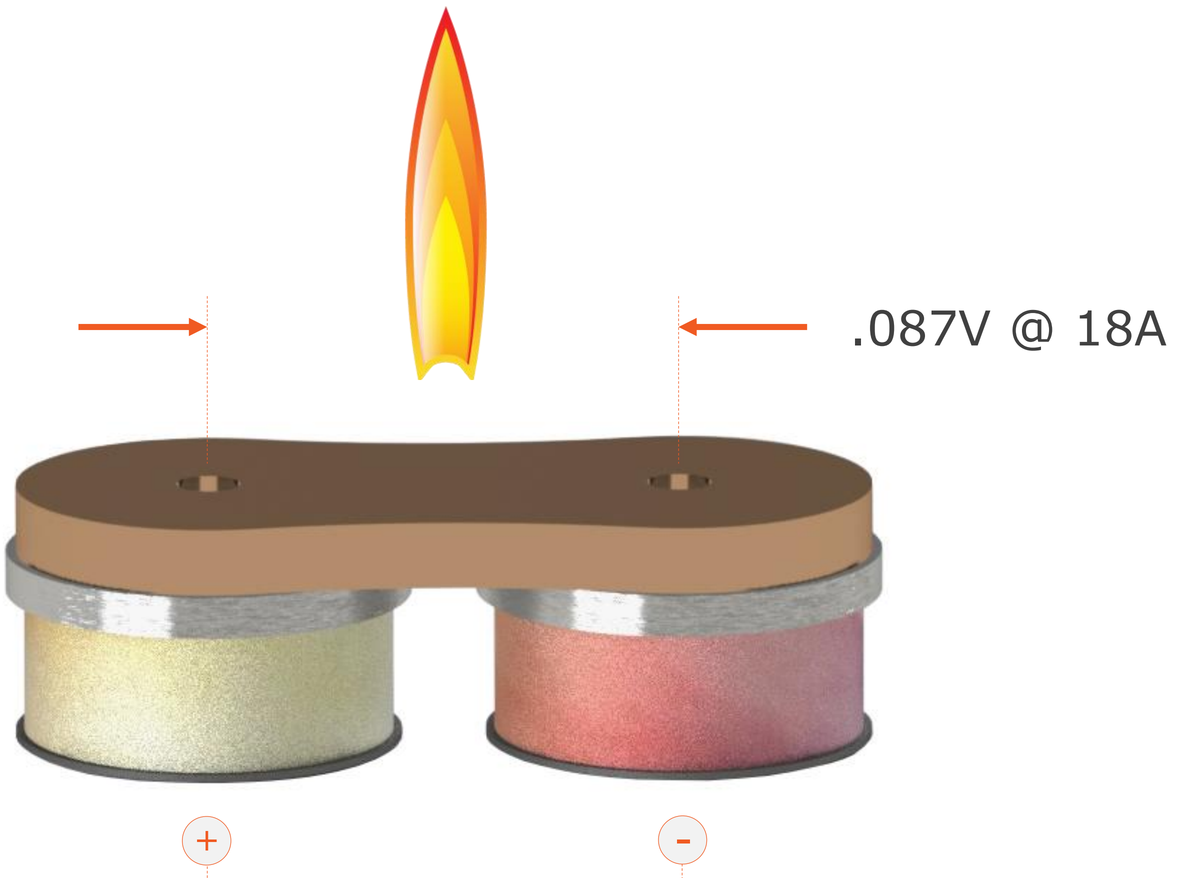
7.0	2.93	7.89	34.5°
Average peak sun hours/day in June	Average peak sun hours/day in December	Maximum No sun days	Winter Solstice Solar Altitude

The TEG advantage

FAST FACTS	TEG	Gensets	Solar Panels (Photovoltaics)	Methanol Fuel Cell (DMFC)	Solid Oxide Fuel Cell (SOFC)
Power range	30W – 4kW	6kW+	1W+	45W – 500W	250W – 1500W
Average life of unit (runtime hours)	20 Years (175,000)	1.5 Years (13,000)	20-25 years	<1 Year (4,500)	1.5 Years (13,000)
Cold start capability/ Low temp storage	Yes (-40ºC+)	No (Preheat)	Yes	No (3ºC+)	Yes (-40ºC+)
Moving parts?	No	Yes	No	Yes	Yes
Fuel availability	Natural Gas or Propane	Diesel, Natural Gas or Propane	Not Required	Ultra Pure Methanol (imported only - Germany)	Natural Gas or Propane (commercial grade only)
Solar hybrid option?	Yes	Yes	Yes	Yes – integrated Pkg required for most off-grid applications	No – can't be cycled
Reliability	High	Fair	Fair (Weather Dependent)	Fair	Fair
Maintenance	Low	High (1000H Oil change)	Fair (panel cleaning)	Low (short lifespan disposable)	Fair
Fuel considerations	Pressure Reduction	Commercial grade fuel	N/A	Liquid Handling & Leak Contaminant	Pressure Reduction & Fuel Conditioning

Generating Power – Thermopile





A pair of elements make up a thermocouple

Annual Preventative Maintenance

Regulator

- Replace fuel filter
- Drain sediment bowl

Fuel Orifice

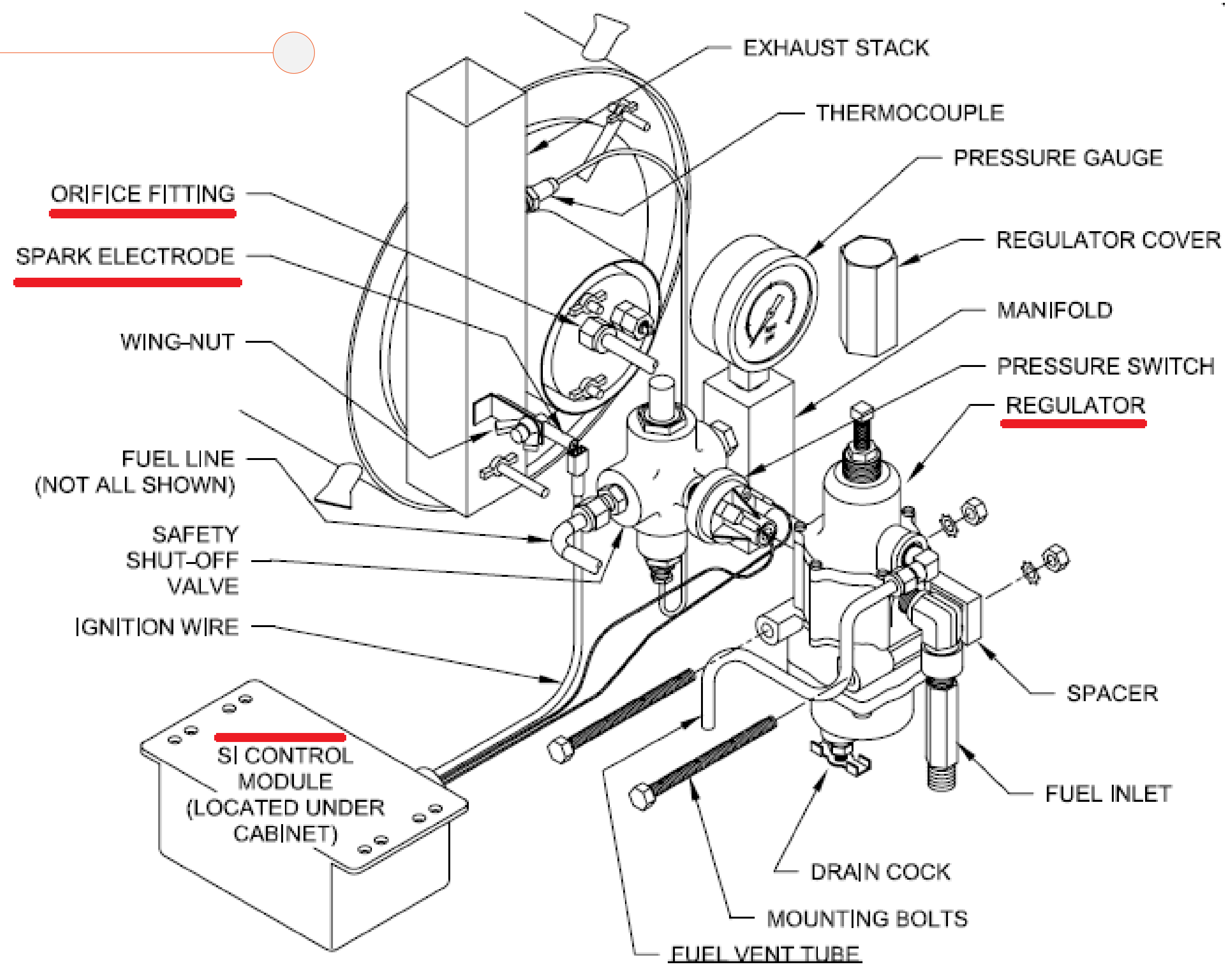
- Clean or replace

Spark Electrode

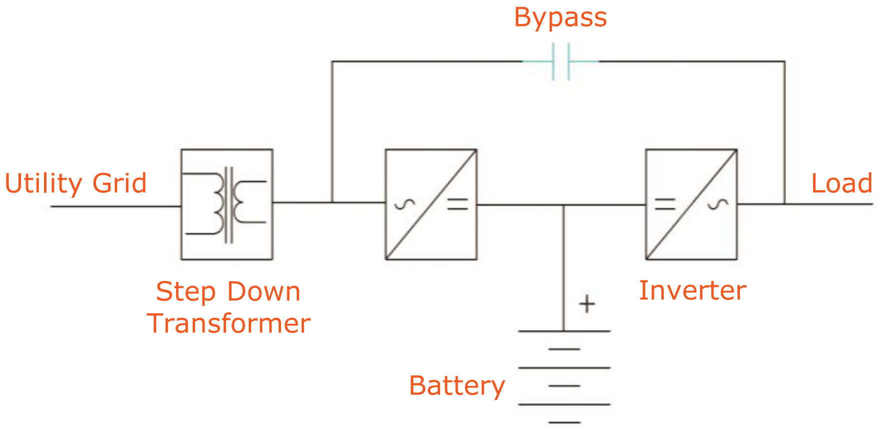
- Replace

Spark Ignition (SI)

- Replace battery every two years



Extending the grid – considerations



Grid connection costs

- Line extension
- Stepdown transformer for high voltage lines
- Meter installation
- AC rectifier for DC loads

Landowner negotiations (easement)

Utility contract

- How long will it take to bring grid to the site (cost of temporary power or delay in production)?
- Locking into long-term contracts (could extend past the life of the asset)
- Recurring power charges (peak demand charge)

UPS system cost, environmental housing & system maintenance

Grid reliability

- Backup power contingency for long-term power outage

Grid extension may not be cost-effective for low power remote sites

Cycle Charge Solutions

- Reliable power package
- Propane, diesel, natural gas
- Genset and battery solutions with solar options
- Control system to manage power with low maintenance
- Up to 25kW+
- Skid, sea-can or self-framing buildings

TEG Emissions

TEG Emissions Comparison	**Human** tCO_2 – 19.3 t/yr	**Cow** CH_4 – 100 kg/yr
50W	0.20 *3.8 t/yr*	0.03 *2.8 kg/yr*
100W	0.41 *8.0 t/yr*	0.06 *5.9 kg/yr*
200W	0.92 *17.9 t/yr*	0.27 *27.2 kg/yr*
500W	1.83 *35.3 t/yr*	1.08 *107.7 kg/yr*