15 JANUARY 2026

CAN EITHER OF THESE TWO REPLACE DIESEL POWERED GENERATORS?

SOFC & MICRO-GASTURBINE VS DIESEL GENSET

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INSIGHTS

This report takes a deep dive at comparing characteristics of power generation systems based on **solid oxide fuel cell technology,** and **micro-gas turbines** with conventional diesel based gensets for the backup power market. The ultimate goal, in the long-term, is to replace diesel based generators (for backup power production) with a new system that is more efficient, cleaner, and is able to perform as good or even better than the diesel genset.

Backup power production refers to the kicking in of the system for power production when there is a power cut or black out. The backup power system must do so immediately, predictably, and repeatedly. The key benchmark parameters and aspects for backup power generation that are **non-negotiable** are mentioned in Table 1.

Besides the non-negotiable characteristics, there are also some benchmarks related to operational flexibility, maintenance, cost, and regulatory aspects which needs to be met by backup power generation systems. They are mentioned in Table 2.

The implicit benchmark is the **diesel genset + battery UPS** (Uninterrupted Power Supply). This system combination is widely deployed (worldwide) and delivers the following:

- Instant response - System kicks in immediately
- Long duration - Is available as long as one wants subject to fuel run out
- Extreme robustness - Very robust to environmental and operating conditions
- Known failure modes - Allows predictable maintenance

Availability & Reliability	
Availability	≧99.9%
Start success rate	≧99.5%
Failure mode	Predictable, detectable
Mean time to repair (MTTR)	< 4 to 8 hours
Start and response time	
Cold start to full load	< 10 seconds
Black-start capable	Yes
Load acceptance	100% step load (or ≧70% instant)
Grid-forming ability	Native
Standby behaviour	
Standby duration	Weeks to months
Parasitic power	Near zero
Degradation during idle	Minimal
Restart after long idle	Guaranteed
Fuel logistics & autonomy	
On-site fuel	Yes
Fuel energy density	High
Refueling complexity	Low
Fuel shelf life	≧1 year
Cold climate operability	Yes
Environmental robustness	
Ambient temperature	-20 to +45 °C
Dust/humidity	High tolerance
Flood/vibration	Tolerant
EMI/grid noise	Immune

Table 1: Non-negotiable benchmark characteristics

Load behaviour	
Minimum stable load	0 to 10%
Load following	Instant
Cycling tolerance	Unlimited
Partial load penalty	Acceptable
Duty cycle extremes	
Option 1	Duty cycle extremes
Option 2	200+ hours/year
Option 3	Sudden multi-day operation
Maintenance philosophy	
Routine maintenance	Simple
Skill requirement	Technician-level
Spares availability	Local
Service intervals	Predictable
Total cost expectations	
CAPEX	Low to moderate
OPEX	Low when idle
Cost of failure	Zero tolerance
Replacement timeline	Decades
Regulatory & integration benchmarks	
Codes & standards	Mature
Certification	Straightforward
Grid compliance	Proven
Permitting	Fast

Table 2: Other necessary benchmark characteristics

The report analyses the three technologies under several categories and based on this analysis, the following two key questions are posed and subsequently addressed.

1. **Can either of these two technologies replace diesel based gensets on field and create a market to disrupt the incumbent?**

2. **If diesel is phased out as a fuel, what alternatives do we have for backup power generation?**

Answers to the above two questions will provide critical insights into developing future systems for backup power generation.

Boundary conditions:

- All comparisons are on a system level.

- Latest trends and technological advances for each of the technology is taken into consideration.

1. BASIC OPERATING PRINCIPLE

Feature	SOFC	Micro-gas turbine	Diesel Genset
Primary process	Electrochemical conversion chemical energy in fuel to electrical energy	Thermodynamic Brayton cycle	Internal combustion engine driving an alternator
Energy conversion type	Direct electrochemical, Chemical -> Electrical, no moving parts	Chemical -> Mechanical -> Electrical via rotating turbine	Chemical -> Mechanical -> Electrical
Operating temperature	700 to 1000 ^{o}C	600 to 950 ^{o}C	500 to 800 ^{o}C

Table 3: Operating principle comparison - SOFC, Micro-gas turbine & Diesel genset

The key difference among the three technologies is in the conversion of energy from one form to another. SOFC technology coverts chemical energy of fuel directly to electrical energy (via electrochemical conversion), and has no moving parts (in the stack) whereas micro-gas turbines and diesel gensets have moving parts and chemical energy is first converted to mechanical and then to electrical energy. The temperature of operation for all three technologies is more or less in the same range. The temperature in the case of micro-gas turbine and diesel genset refers to the combustion temperature whereas in the case of SOFC, it refers to the operating temperature at which electrochemical reactions are facilitated.

Since energy is converted in two steps in an SOFC stack as compared to three steps in a micro-gas turbine and diesel genset, the amount of energy conversion losses are reduced. Table 3 summarises the information for the basic operating principle on all three technologies.

So, looking solely at this table, all three technologies are more or less on a level playing field, with SOFC technology having the upper hand due to energy conversion in lesser number of steps.

2. EFFICIENCY AND PERFORMANCE

Parameter	SOFC system	Micro-gas turbine	Diesel Genset
Electrical efficiency (stand-alone)	45-60%	25-35%	30-40%
CHP (Combined Heat & Power) efficiency	75-85%	70-80%	60-70%
Part-load efficiency	High (less sensitive to load changes)	Poor (Drops significantly at part load)	Poor (Drops significantly at part load)
Start-up time	Long (hours)	Short (minutes)	Very short (seconds to minutes)
Typical power range	1 kW to 2 MW	30 kW to 500 kW	1 kW to 10 MW

Table 4: Performance characteristics - SOFC, Micro-gas turbine & Diesel genset [1 - 5]

Table 4 summarises the efficiency and performance characteristics for all three technologies. In terms of CHP efficiency, where both residual heat and electrical power from the system are put to use, there is not much difference between the three technologies. However, the electrical efficiency of SOFC technology is significantly higher than the other two and this gives SOFC technology an edge. This is because chemical energy is directly converted to electrical energy, a two step process, as compared to a three step process in the other two.

Depending on the temperature and mass flow rate of the exhaust from the power generation system, one can decide the application potential of this residual heat in a downstream process that might warrant it.

Technology	Export heat temperature	Quality
SOFC System	150-250 °C	Medium
Micro-gas turbine system	250-350 °C	Medium to High
Diesel genset	350-450 °C (exhaust gas) 70-95 °C (Jacket cooling water)	High (when considering exhaust gas) Low (when considering jacket cooling water)

Table 5: Exportable heat from all three systems [5-7]

Table 5 provides information on the exhaust temperature or the export heat temperature[1] that is available at the tail pipe from all three systems (with different technologies).

When one considers the whole system and the potential to use the heat coming out of it, we see that the temperature range at which heat comes out of an SOFC system is not that high. This is contrary to the belief that SOFC systems generate high quality heat[2] which can readily be used for downstream processes. The reason why the exhaust temperature from the SOFC system is not that high is because **most of the heat generated within the stack is used internally within the SOFC system**. Diesel gensets and micro-gas turbines have much higher exhaust gas temperatures which in turn mean the quality of heat coming out is quite high. When one talks about **utilising residual heat from a system what truly counts is the amount of heat** (temperature and mass flow) that comes from the exhaust as this alone can be tapped into for use in any downstream process.

The part-load efficiency of a micro-gas turbine and diesel genset is quite poor when compared with an SOFC system. This gives SOFC technology an edge where the electrical efficiency still remains above 40% at part-load [8].

One key feature that is required from a power generation system used for backup power production is that they must start instantaneously, ideally within seconds, and this feature is readily provided by diesel gensets. Not having this feature can prevent a technology from entering the market. This is because no customer or application will be willing to wait for more than a few minutes for the backup power system to kick into operation. So far, **an SOFC system (on its own) doesn't have the technical capability to start within seconds or a few minutes** and this is a huge disadvantage for SOFC technology in this particular market segment.

Note: *Here, the CHP efficiency does not account for heat quality. Exergy provides a quantitative measure of heat quality (from a stream) which can be used to determine the amount of useful work which can be accomplished. A separate analysis is required to analyse the Exergy potential of the exhaust stream from systems of all three technologies and this is not in the scope of this report.*

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[1] The numbers provided are an average value. Exact numbers warrant calculations

[2] The exhaust temperature at the tailpipe of an SOFC system is high only when heat is not used internally within the system or there is an external reformer or burner which supplies heat to the system.

3. FUEL FLEXIBILITY AND EMISSIONS

Parameter	**SOFC**	**Micro-gas turbine**	**Diesel Genset**
Fuel types	Natural gas, Biogas, Syngas, and Hydrogen	Natural gas, Biogas, Landfill/Sewage gas, Syngas, Hydrogen, Diesel (Liquid fuels)	Diesel
Internal reforming	Possible with natural gas	Requires external combustion	Requires external combustion
NOx & CO emissions	Extremely low	Low - lean premixed combustion	High
CO_2 emissions	Lower per kWh	Higher per kWh	High (carbon intensive fuel)
SOx & Particulate matter (PM)	SOx negligible PM -None	Depends on type of fuel used, PM - extremely low	Moderate to high (depends on sulphur in diesel) PM - Significant (soot, ultra fine PM)
Noise	Very quiet	Quiet	Loud (engine + exhaust)

Table 6: Fuel flexibility and emissions from all three technologies

In terms of fuel flexibility, an SOFC system and a micro-gas turbine system can operate on a range of different fuels whereas diesel gensets need just diesel (liquid hydrocarbon). This gives the SOFC and micro-gas turbine technology an edge in terms of employing green or renewable fuels (diesel is heavily polluting). From a fuel flexibility perspective, systems based on SOFC and micro-gas turbine technologies are able to provide opportunities for products that can be catered to different markets. For e.g. if biogas is readily available in a certain region, systems running on biogas will make the most sense as compared to systems running on hydrogen. Diesel on the other hand is widely available as a fuel and is accessible to all markets currently. This both a boon and a bane, boon because here the product (diesel genset) in all the markets is more or less the same and bane because diesel is fossil based and not environment friendly.

The energy density of different fuels needed for the three technologies to operate is summarised in Table 7.

Fuel	Gravimetric energy density (MJ/kg)	Volumetric energy density (MJ/m^3)	Volumetric energy density (kWh/m^3)
Diesel	42-43	~ 36000	~ 10000
Hydrogen (gas)	120	~ 10.8	~ 3
Natural gas	50-55	~ 35-39	~ 9.7-10.8
Biogas	~ 20-23	~ 21-23	~ 5.8-6.4
Syngas	~ 10-15	~ 4-6	~ 1.1-1.7

Table 7: Energy density of different fuels [9-13]

The only two fuels that can be directly fed into an SOFC stack are hydrogen and natural gas, the rest all require some type of external reformer prior to feeding the fuel to the stack inlet, thereby increasing system complexity.

Biogas, hydrogen (green hydrogen) and Syngas (made from green hydrogen and captured CO_2) are considered to be green gases. Hence, using these fuels in power generation systems will automatically lead to reduced emissions.

When speaking of emissions, the following pollutants need to be considered from the system exhaust - **NO_x, CO, CO_2, SO_x** and **PM**.

NO_x emissions occur when nitrogen and oxygen in the air react at high temperatures. This is present in diesel gensets because the fundamental process is fuel combustion. In micro-gas turbines the amount of NO_x is low because they employ lean premixed combustion which prevents the flame from getting hot enough or dense enough to generate NO_x and in SOFCs the fundamental process is electrochemical combustion and hence the chances of NO_x formation are extremely low.

The amount of CO from an SOFC system is quite low or almost negligible because most of the CO is converted to CO_2 and H_2 via the water gas shift reaction (when using natural gas or biogas or syngas). The amount of CO from a micro-gas turbine is also quite low because of the presence of lean conditions along with hot residence times. whereas it is significantly high from a diesel genset.

CO_2 emissions are quite high from diesel gensets and micro-gas turbines. This is because a heavy hydrocarbon fuel is employed and is combusted. The fundamental process of combustion generates CO_2. On the other hand CO_2 emissions from SOFC systems are low because the fuel (biogas, natural gas or syngas) is electrochemically combusted[3].

The amount of sulphur present in the fuel will determine the SO_x emissions at the system outlet and this has nothing to do with the three technologies per se. The degree of sulphur removal from the raw fuel and its subsequent processing will be the determining factor for the SO_x emissions. A high sulphur content in the fuel will immediately degrade the SOFC stacks and thereby warranting a stack replacement. PM or particulate matter is significant when using diesel gensets, and extremely low when using micro-gas turbines and not present at all when using SOFC systems.

When one is looking at emissions, SOFC is a clear winner, diesel gensets are heavy polluting and micro-gas turbines sit between SOFC and diesel gensets. When looking at fuel flexibility, both SOFCs and micro-gas turbines score an edge over diesel gensets.

SOFC technology and micro-gas turbines also score high in terms on noise dB level. Nobody prefers a noisy system which is harsh on the ears and health.

[3] The reader is asked to refer other detailed texts or articles for electrochemical fuel combustion of different fuels or fuel oxidation studies at the fuel electrode of an SOFC for calculating the exact amount of CO_2 generated.

4. SYSTEM INTEGRATION AND MAINTENANCE

The complexity of a system and its subsequent maintenance plays a crucial role in determining if the product is successful in the market and some of the characteristics of all three technologies is summarised in Table 8.

Parameter	SOFC system	Micro-gas turbine	Diesel Genset
Moving parts	None in the core stack but present in the system	High speed turbine (up to 100000 rpm)	Many moving parts
Maintenance frequency	Low, but sensitive to contaminants (sulphur, siloxanes)	Moderate, regular bearing and filter maintenance	High (oil changes, fuel filter, overhaul cycles)
Durability	3-5 years stack life (under steady state conditions)	20000 to 40000 hours overhaul intervals	10000 to 20000 hours before overhaul
Heat recovery	Possible (low to moderate grade)	Possible (moderate grade)	Possible (low to high grade heat)

Table 8: System maintenance aspects for all three technologies

Although the SOFC stack itself has no moving parts, the SOFC system as a whole is constructed of a lot of moving parts and this does not give an SOFC system an advantage over the other two technologies. However, there are no high speed moving components in the SOFC system unlike the other two. The SOFC stack has shown durability for 3 to 5 years but that is under controlled conditions [14] and not under dynamic operation. Hence, one must treat this number with caution.

Additional system integration information on electrical, thermal, maintenance skill & infrastructure, and operational level is given in Tables 9 to 12 respectively.

Electrical integration:

Aspect	SOFC system	Micro-gas turbine	Diesel Genset
Power output	DC (AC only with built-in inverter)	High-frequency AC	50/60 Hz AC
Inverter required	Yes	Yes	No
Grid-forming	Possible (advanced)	Possible	Excellent
Black start	Limited	With battery	Native

Table 9: Electrical integration aspects for all three technologies

'Native' (in Table 1 & 9) refers to the intrinsic capabilities of the technology and not dependent on digital control loops.

Thermal integration:

Aspect	SOFC system	Micro-gas turbine	Diesel Genset
Heat control	Complex	Moderate	Simple
Heat quality matching	Critical	Flexible	Limited
CHP design effort	High	Medium	Low

Table 10: Thermal integration aspects for all three technologies

Maintenance skill & infrastructure:

Aspect	SOFC system	Micro-gas turbine	Diesel Genset
Skill level	High (specialist)	Medium	Low-medium
Field serviceability	Limited	Good	Excellent
Local technician availability	Rare	Moderate	Widespread
Spare parts	Custom	OEM-specific	Commodity

Table 11: Maintenance skill & infrastructure aspects for all three technologies

Operational resilience:

Stress factor	SOFC system	Micro-gas turbine	Diesel Genset
Fuel quality variation	Poor tolerance	Good	Excellent
Grid disturbances	Sensitive	Moderate	Robust
Ambient temperature	Moderate sensitivity	Low	Low
Dust/contamination	Sensitive	Moderate	Robust

Table 12: Operational resilience aspects for all three technologies

When one considers the information from Tables 8 to 12, one can see that from a system integration and maintenance perspective, an SOFC system is complex and cumbersome and does not fit the backup power generation system market. A micro-gas turbine system comes close to challenging the incumbent diesel genset but still falls short in some aspects.

5. OPERATIONAL CHARACTERISTICS

A backup power generation system must be operational when needed and must spring to life immediately when called upon. Some of the operational characteristics required of backup power systems and comparison of parameters across the three technologies is described in Table 13. One can also refer back to Tables 1 and 2 respectively, at the very beginning of the report and draw out suitable conclusions and comparisons.

Parameter	**SOFC system**	**Micro-gas turbine**	**Diesel Genset**
Load following	Slow (minutes to hours)	Fast (seconds)	Fast (seconds)
Start/stop cycles	Limited (degrades stack)	Frequent cycling possible	Frequent cycling possible
Fuel logistics	Needs pipline gas or clean biogas	Needs pipeline gas (when using gaseous fuel)	Diesel storage & transport required
Operation mode	Continuous baseload ideal	Continuous, standby or variable load	Standy or variable load suitable

Table 13: Operational characteristics - SOFC system, Micro-gas turbine & Diesel genset

An SOFC system fails in the very first parameter - *load following*. It is simply not able to respond to changes in load in a matter of seconds or a few minutes (less than 5 minutes ideally). This is due to the fact that SOFC systems operate at high temperatures and when there is a load change, temperatures get affected (an inherent phenomena based on physics) and due to thermal inertia, the system takes time to get back into steady state. Also, if an SOFC system is called for operation from a cold start, it will take hours to kick-in. This feature is a no go for backup power systems.

Micro-gas turbines and diesel gensets have excellent operational characteristics and the only drawback of the micro-gas turbine is the necessity of a pipeline gas supply which may not be available at all places and in all markets. Refer to Table 7 on energy density of different fuels in order to make a calculation for fuel storage and tank size[4]. **Volumetric energy density dominates backup power system design** and this is the reason why diesel as a fuel dominates backup power and why gaseous fuels struggle with autonomy.

[4] The reader is advised to make this calculation on their own.

6. ECONOMIC FACTORS

Finally, as with any product, the economic factors must be feasible and favourable for a new technology to enter a market and displace the incumbent. A few of the important economic parameters for all three technologies is summarised in Table 14.

Parameter	SOFC system	Micro-gas turbine	Diesel Genset
Capital cost	$ 4000 - 10000 /kW	$ 1000 - 2000 /kW	$ 500 - 1500 /kW
Operating cost	Low but periodic stack replacement	Moderate	Moderate to high
Fuel cost per kWh	Lower for natural gas	Lower for natural gas	Higher for diesel
Payback time	5-10 years	3-6 years	2-4 years

Table 14: Economic factors - SOFC system, Micro-gas turbine & Diesel genset

Diesel gensets and a system based on micro-gas turbine score high on all economic parameters except for operating cost and here SOFC technology has an edge. But, the SOFC stacks need periodic replacement and if the stack price is high ($/kW) then this advantage is lost. The payback time is crucial for any customer and in most situations the customer prefers a product with the highest performance and the least payback time and currently diesel gensets satisfy both these criteria.

DISCUSSION & OUTLOOK

Taking into account the information from all the six categories presented before, a holistic discussion and future outlook can be presented on what it takes to replace the incumbent diesel genset for the backup power market.

Backup power systems are to be defined not by efficiency or emissions, but by their ability to deliver *immediate*, *reliable power* under worst-case conditions after long idle periods. Let us define a term Backup Readiness Index (BRI for short) which quantifies how well a power system fulfils the true mission of backup power which is defined above.

The BRI is categorised into the following categories:

Category	Weight	Measurable parameters
Start & response capability	25%	Speed, black start, and load acceptance
Standby survivability	20%	Degradation during idle, restart certainty
Reliability & availability	20%	Failure rates, MTTR, predictability
Load and operational flexibility	15%	Step loads, cycling, part-load
Fuel autonomy and logistics	10%	On-site fuel, shelf life
Robustness and simplicity	10%	Environmental tolerance, operability

Table 15: Backup Readiness Index categories

A scoring scale is created to in order to meet the above categories.

5 - Fully meets or exceeds the current benchmark

4 - Meets the benchmark with minor limitations

3 - Partially meets, needs system-level support

2 - Major limitations

1 - Fundamentally unsuitable

0 - Cannot fulfil backup role

Diesel gensets (with battery UPS) have a a BRI score of 4.5 out of 5 and this is the current benchmark to beat for any new system entering the market. Evaluation of the SOFC system and micro-gas turbine system for the BRI score is given in Table 16.

Category	**SOFC System**	**Micro-gas turbine**
Start & response capability	1	3
Standby survivability	2	4
Reliability & availability	3	4
Load and operational flexibility	2	3
Fuel autonomy and logistics	3	3
Robustness and simplicity	2	4
BRI score	2.05	3.55

Table 16: BRI scores for an SOFC system and a micro-gas turbine system

The answers to the two questions posed at the beginning of this report are:

1. Can either of these two technologies replace diesel based gensets on field and create a market based on new technologies?

The short answer is NO. Based on the BRI scores and the discussion under several categories viz. *Basic Operating Principle, Efficiency & Performance, Fuel Flexibility & Emissions, System Integration & Maintenance, Operational Characteristics,* and *Economic Factors,* systems based on SOFC technology or micro-gas turbine **do not reach the current BRI benchmark score** and without that it is extremely difficult to enter this particular market segment. Of the different categories, System Integration & Maintenance is a very important one and Figure 1 provides an indication of what this might looks like for the three technologies.

Some of the key bullet points are as follows:

- Diesel gensets offer extreme dynamics, emergency power, and lowest CAPEX which is very hard to beat for any new technology so far.

- Diesel gensets remain the simplest to integrate and service, though they require frequent mechanical maintenance and have the highest environmental burden.

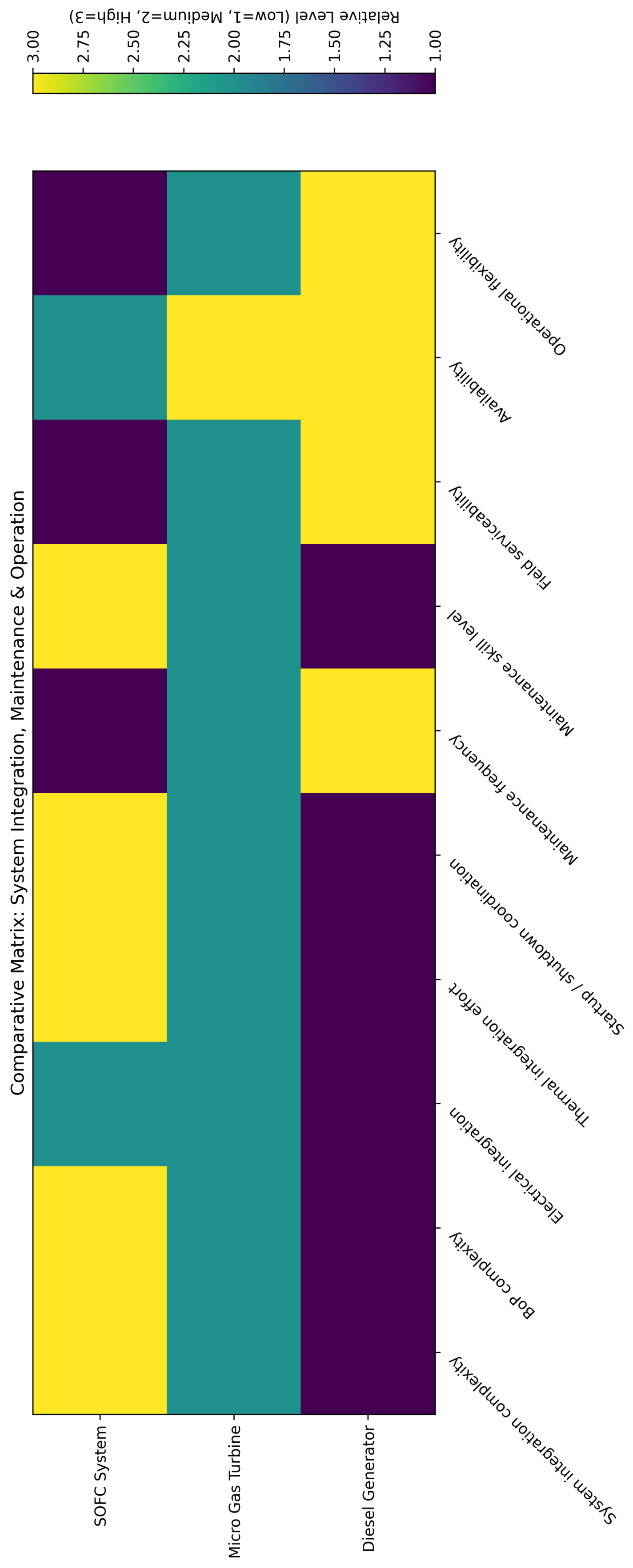

Figure 1: Qualitative matrix showing the ease of System Integration, Maintenance & Operation for all three technologies

- SOFC systems exhibit the highest integration complexity due to tight thermal coupling and fuel processing requirements, but benefit from low routine maintenance and few moving parts. Micro-gas turbine represent a middle ground, offering packaged integration, moderate maintenance needs, and good operational flexibility.

- Micro-gas turbines combine high cycling tolerance and fast start up with gas based fuel logistics and flexible CHP operation, positioning them between SOFC systems and diesel generators for dynamic low emission applications. They do not require continuous operation and can be started, stopped, and load followed reliably, but they perform best in semi-continuous or planned cycling rather than instantaneous emergency standby.

- SOFC systems requires custom thermal integration, diesel genset is largely plug-and-play.

- At a system level, micro-gas turbines provide the highest exportable exhaust temperatures (250-350 °C), while SOFC systems typically export medium-temperature exhaust (150-250 °C) due to internal heat utilisation, and diesel CHP systems export mostly low-temperature exhaust after heat recovery. But keep in mind the exhaust temperature from the diesel genset is the highest (upto 450 °C). **The ability to use residual heat from a backup power system is a nice to have feature but not a necessary one**.

- SOFC systems are prime power systems that can support backup architectures only when paired with storage and kept in hot standby mode.

- Micro-gas turbines can function as backup power especially in non-instantaneous or extended backup roles, but still benefit from battery buffering.

- From an operational dynamics point of view, SOFC systems score poorly. Figure 2 shows the qualitative matrix comparing all three technologies and for the backup power market, SOFC systems just cannot keep up with the operational dynamics required of such systems.

The conclusion is diesel generators remain unmatched in simplicity and availability.

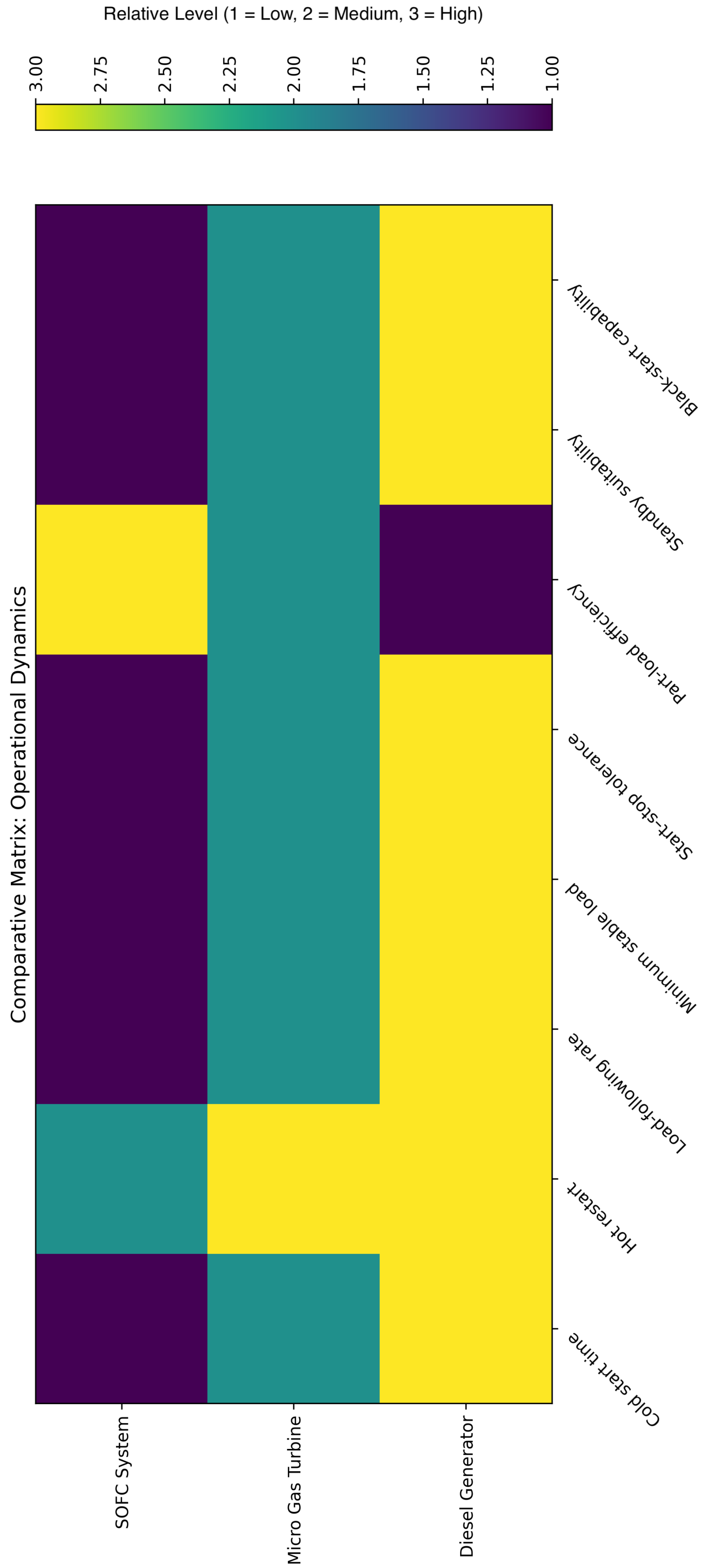

Figure 2: Qualitative matrix showing the ease of Operational Dynamics for all three technologies

2. If diesel is phased out as a fuel, what alternatives do we have for backup power generation?

If diesel is phased out as a fuel, **no single technology presently replicates the characteristics of diesel gensets**. Diesel as a fuel and the diesel genset combines, in one system the following:

- On site fuel with very high volumetric energy density
- Instant black start
- Native grid-forming
- High fault current
- Long autonomous runtime (days-weeks)
- Works at -30 to + 50 ^{o}C
- Mature service ecosystem

Near-term replacements are therefore likely to run on hybrid architectures combining batteries for fast response with gaseous or liquid fuel prime movers for energy supply. Drop-in renewable fuels and gas engines represent the least disruptive transition paths, while SOFCs remain constrained by startup and system integration challenges.

The bottom line is diesel is not being replaced because diesel gensets are bad engineering. It is being replaced because policy (coupled to climate change and environmental emissions) is changing faster than physics.

3. What is the future outlook for the backup power market?

Future systems for the backup power market will all be hybrid architectures, meaning a combination of different technologies and not one single technology. Some possibilities include:

- Battery + gas engine
- Battery + SOFC
- Battery + HVO genset

Battery forms one of the core pieces of future backup power systems. This is because it can handle the transients and black start pretty well and the technology itself is progressing at an astonishing pace. It can readily supplement the other technologies for prime power too. But batteries on their own may not be able to offer an alternative because they have a leakage rate when on idle and can be completely discharged when needed to be in operation and this risk cannot be accepted in the backup power market.

For future innovative systems to beat the BRI benchmark, they must

a. Combine fast storage (seconds) and acts as durable prime power.

b. Survive months of idle

c. Accept abuse level load dynamics &

d. Fail predictably

Note: There are parts or sections of the report which might warrant a further detailed analysis or investigation and not done in this report for brevity reasons. The reader is advised to carry their own analysis if interested or contact the author.

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This article has been written by Dr. Vikrant Venkataraman, Director & Founder of VenkaCon Consulting. The analysis and data are based on pure facts that is available on the internet and the views expressed are solely meant for providing a practical and holistic view on the whole topic which is receiving great attention.

REFERENCES

[1] A cogeneration system based on Solid Oxide and Proton Exchange membrane fuel cells with hybrid storage for off-grid applications; Volume 6 - 2018, https://doi.org/10.3389/fenrg.2018.00139

[2] https://understandingchp.com/chp-applications-guide/4-2-microturbines/

[3] https://en.wikipedia.org/wiki/Microturbine

[4] https://en.wikipedia.org/wiki/Block_heat_and_power_plant

[5] https://www.energy.gov/sites/prod/files/2013/11/f4/chp_review.pdf

[6] Theoretical and Experimental Studies of combined heat and power systems with SOFCs; *Energies* 2023, *16*(4), 1898; https://doi.org/10.3390/en16041898

[7] Micro-gas turbine role in distributed generation with renewable energy sources; *Energies* 2023, *16*(2), 704; https://doi.org/10.3390/en16020704

[8] Design and partial load exergy analysis of hybrid SOFC-GT power plant; https://doi.org/10.1016/j.jpowsour.2005.07.088

[9] Çengel, Y. A., & Boles, M. A., Thermodynamics: An Engineering Approach, McGraw-Hill

[10] https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html

[11] IEA Bioenergy task 37, Biogas Handbook

[12] O'Hayre et al., Handbook of Fuel Cells, Wiley - Syngas composition and heating values

[13] Larmine & Dicks, Fuel Cell Systems Explained

[14] https://www.bloomenergy.com/wp-content/uploads/2023-bloom-energy-sustainability-report.pdf