Oorja Protonics, Inc.

Direct Methanol Fuel Cells

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Oorja Highlights

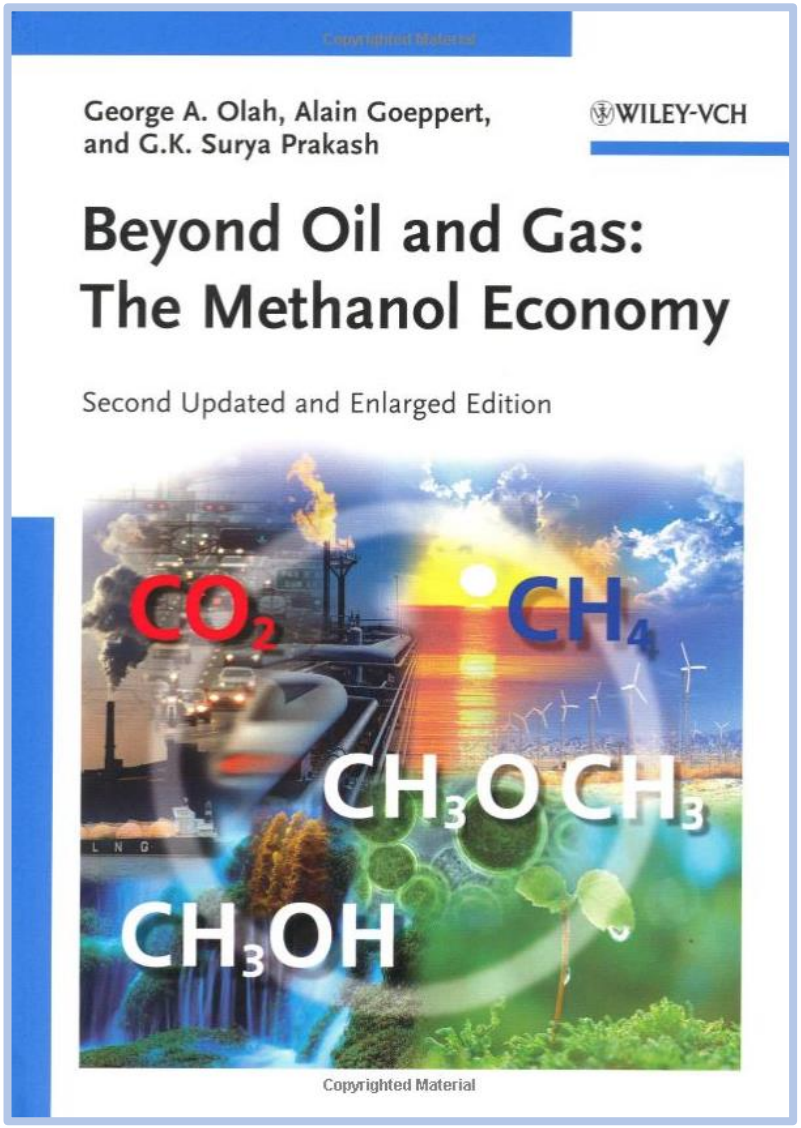
Oorja is the first and only company manufacturing large, scalable Direct Methanol Fuel Cells (DMFCs) with reliable fifth-generation products:

- Oorja has eight years of experience developing high-performance DMFC stacks and fuel cell solutions.
- Methanol has many advantages over hydrogen in terms of safety, cost, storage weight, ease of availability, and transportation.

Oorja is selling to several multi-billion dollar markets with strong customer demand:

- **Wireless telecom**: Providing clean and quiet back-up power for cellular base stations.
- **Materials handling**: Extending the battery range for forklifts and aviation scissor lifts.
- **Back-up Power:** Security, surveillance and military.
- **Oil and Gas:** Pipeline instrumentation and operations.
- **Future markets:** Consumer and residential, emergency power (lights, buildings, shelters), micro grids, and distributed energy generation.

DMFC: Key Enabler of the Methanol Economy



Methanol (CH_3OH) can be made from:

- **Coal***
- Methane in natural gas
- Agricultural waste
- Animal waste-- Smithfield Farms hog waste
- Construction waste--lumber, plywood
- Forestry and forestry products waste
- Municipal solid waste
- Waste CO_2 and atmospheric CO_2

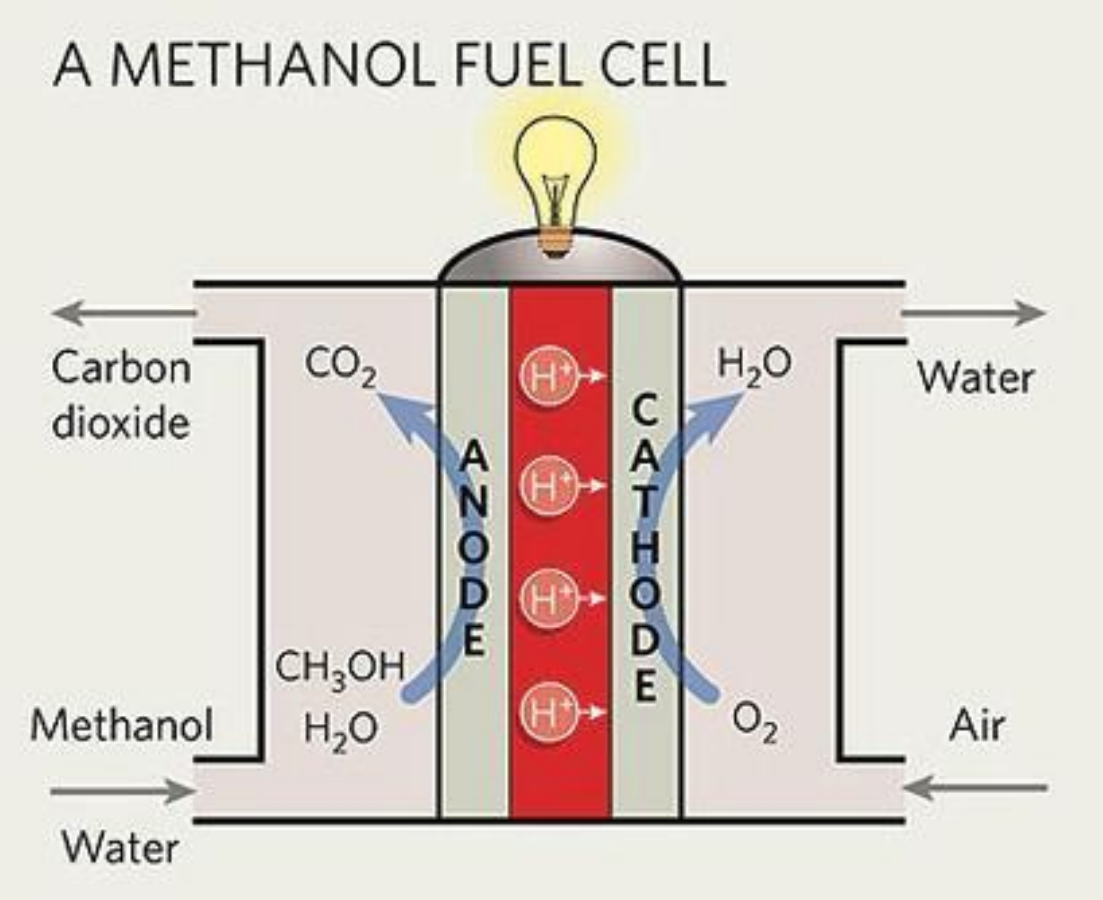
Methanol is available globally and is used for cooking, heating, lighting, and transportation.

Oorja delivers clean, methanol-based electrical power.

*** Steam-reformed coal is sometimes used as a feedstock for methanol production, particularly in China (Source: Wikipedia)**

How Does a Methanol Fuel Cell Work?

- Converts chemical energy stored in methanol into electricity.
- Produces usable water and heat as byproducts.



Key benefits:

- Lower greenhouse gas emissions than fossil-fuel-based electricity production
- No SO_x, NO_x, or particulate emissions
- Operable 24/7
- Multiple applications as battery range extender

Products Overview

- **Model-T**
  - 1.1 kW Net Power
  - Applications: Telecom and Back-up applications
  - Scalable Fuel Tank, Modular Design, all in one solution

- **Model-3**
  - 1.1 kW Net Power
  - Applications: MHE, Mobile back-up
  - Integrated fuel tank 12 liters, standalone

- **Model-D (Releasing Q1: 2017)**
  - 500 Watts Net
  - Applications: Portable Power, mobile standalone
  - Built in Inverter and battery

Product Market Road Map: 2015–2019

	Q4 2015	Q1 2016	Q4 2016	Q4 2017	Q3 2018	Q3 2019
Model Release	**3**	**T-1**	**D**	**T-3**	**S**	**M**
Net power	1.1 kW	1.1 kW	500 Watts	5 kW	100-300 Watts	> 10 kW
Target market	Class III forklift and pallet loader	Telecom tower base station micro-cells	Portable Auxiliary Power Unit Security Surveillance	Telecom	Consumer Military	Distributed grid power Emergency power

Wireless Telecom Problems

- Wireless carriers need a solution to keep their cell sites operating in the event of an extended power outage.
- Relying on battery banks only is not practical (need too many of them to cover long outages, takes space, requires more maintenance, etc.).
- Current solutions include diesel gen sets, which come with many shortcomings:
  - Fuel and generators get stolen.
  - Generators require lots of maintenance, otherwise they do not start when needed. They tend to break down.
  - Noise and pollution are increasingly viewed as unacceptable, especially in urban environments.
  - Regional laws restricting use of Diesel Gensets

Advantages of Methanol Fuel Cells for the Telecom Market

Footprint:

- The space required for the same run time is considerably less for fuel cells than for battery banks. Methanol fuel cells do not require cooling like batteries, eliminating the need for spacious cooling systems.
- Methanol fuel cell systems are available as either standalone units similar in size to a small refrigerator (for applications like base stations), as units inserted into 19" racks, or in outdoor enclosures.

Operations:

- Methanol fuel cells have few moving parts, reducing the need for regular maintenance.
- Unlike generators, methanol fuel cells do not use combustion; therefore, there are no NO_x, SO_x, or particulate emissions.
- Methanol fuel cells operate as long as fuel is available, so an 8-hour, 1-day, or 3-day extended runtime can be enabled by storing the appropriate amount of fuel on site.

Fuel (Methanol):

- Operating Oorja fuel cells requires industrial-grade methanol, which is readily available and fairly cheap; easy to store; and with much lower infrastructure costs than hydrogen.
- Methanol is far less explosive/flammable than hydrogen or gasoline.

T-1 Systems – Modular Units

Installations China Telecom

Installations Africa (Vodacom/MTN)

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Installations Philippines (Globe/SMART)

Installations Scissors Lift

Installations Material Handling

Remote Power Units (Ensol Systems)

Materials-Handling Problems

- Forklifts slow down noticeably after 4 to 5 hours, causing a loss in productivity, often during rush time, when orders need to be shipped promptly.
- Forklifts can barely do one shift on one battery, but sometimes two or three shifts are needed.
- Changing batteries takes time (10 minutes) and requires additional and expensive batteries and charging stations (which also take warehouse space away from the storage of goods).
- The life of the batteries is shortened when they are deeply discharged.
- Operations come to a stop during extended power outages.
- Electricity costs are often determined based on peak power consumption, and forklifts are usually the main users of power in a warehouse.
- Sometimes there is no more space available to add additional forklifts as needed, affecting the ability to ship more; therefore any increased in productivity with the fuel cells will translate into the ability of taking more orders.

DMFCs Reduce High CapEx and OpEx Costs for Powering Materials-Handling Forklifts, Pallet Loaders, etc.

Battery Swapping Station

Rapid Charging Station

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Advantages of Methanol Fuel Cells for Materials-Handling Class III Equipment

Performance

- Increased productivity.
- No degradation of power over time. Without Oorja fuel cells, forklifts slow down noticeably after ~4 hours.
- Constant efficiency even at partial loads.
- Reduced downtime.

Operation

- One person can be trained in a matter of hours to refuel the forklift, reducing the need for an additional operator.
- The required infrastructure requires significantly less footprint.
- Refueling is considerably quicker than the battery charging process.
- Eliminates the need for having extra batteries and chargers.
- Additional refueling points can be installed to reduce the distance travelled to refuel and the associated downtime.

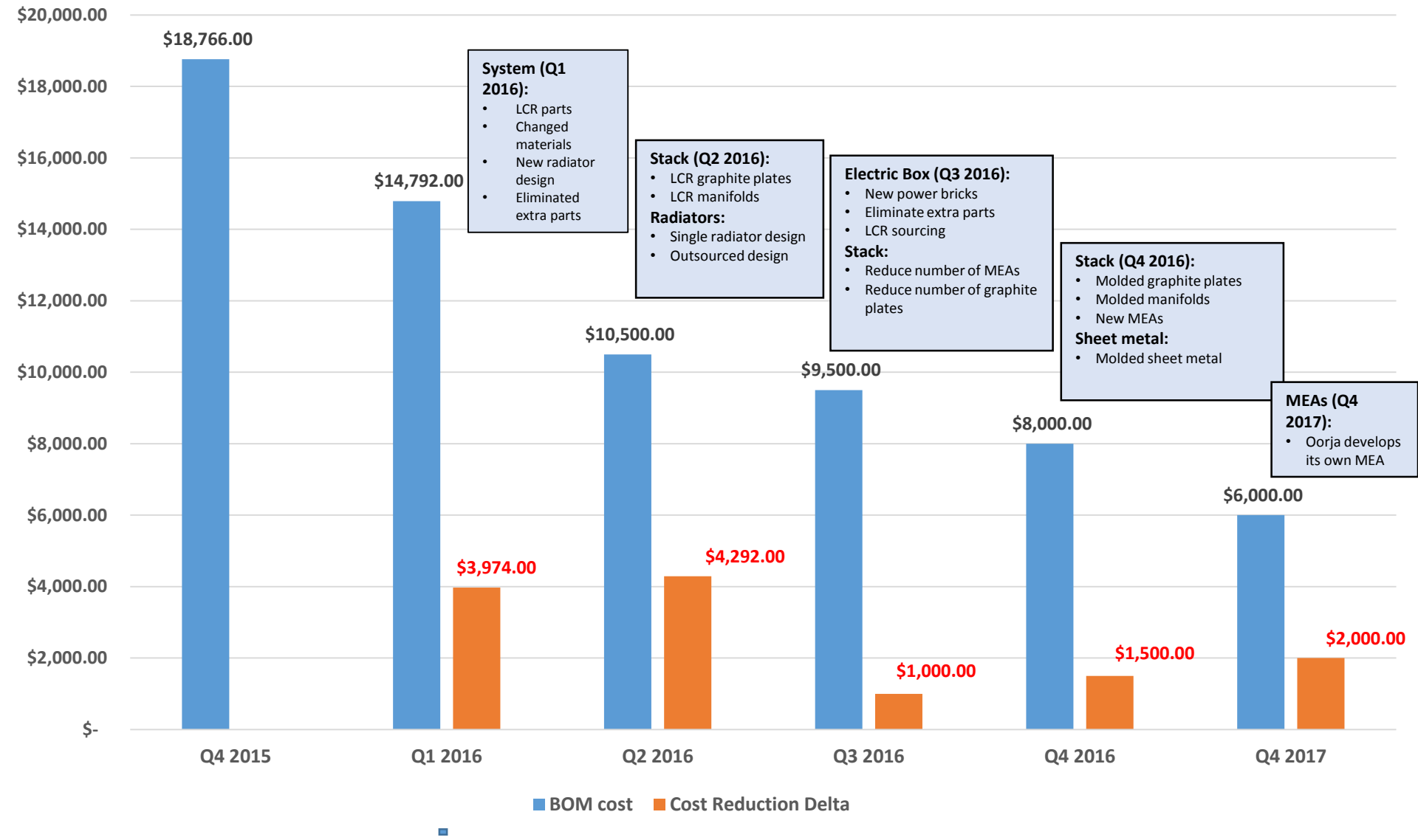
Environmental

- Using methanol there are no direct harmful emissions — no NO_x, SO_x, or particulates.
- Emits only water vapor and very small amounts of CO_2 and methanol.

Field Deployment Status

Country	Customer	Market Segment	Status
Philippines	SMART	Telecom	Trial Completed, negotiating purchase order
	GLOBE	Telecom	Trial Completed, negotiating purchase order
	Phillipines Navy	Back-up Power	Units Shipped, Trial to start in mid May
Mexico	Telcel	Telecom	Trial to start late May
China	China Telecom	Telecom	Trial in progress
	China Mobile	Telecom	Trial to begin in May
	China Tower	Telecom	Trial to begin in May
Japan	Toyota Tsusho	Back-up Power/MHE	Under evaluation
Africa	Vodacom	Telecom	Trial in progress
	MTN	Telecom	Trial in progress
USA	Accumentrics	Back-up Power	Signed agreement
	Baldor Foods	MHE	Follow on order completed
	Berry Engineering	MHE	Installation completed and received follow on order
	Siruis Integrator	Security and Surveillance	Under negotiation
	Apsara Networks	High speed trading	Under negotiation
	Airworks	Cellular on Wheels	Under negotiation
India	Tata Power SED	Military	Under evaluation
	Indus Tower	Telecom	Had initial meeting
	Aseem Oorja	Military	Putting together proposal for end customer
Canada	Ensol Systems	Security and Surveillance	Certification and packaging process started
	Total North	Security and Surveillance	Certification and packaging process started

Cost Reduction Roadmap



Thank You

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Back-up Slides

How We Work with Our Customers - Field Test Plan Example

1. **Select Trial Cell Sites:** Conduct site technical assessment and selects trial site(s).

2. **Oorja Recommended Solution:** Based on Oorja's Battery Range Extension Model, Oorja recommends a system design solution for the customer's problem. Oorja and the customer then agree on a trial plan.

3. **In House Testing:** Oorja validates the recommended design by conducting extensive in-house testing simulating the customer's trial site conditions; Oorja shares the resulting data with the customer.

4. **Field Trial:** Oorja's design solution is then implemented at the selected sites; the customer and Oorja jointly conduct the trial over a 1- to 2-month (typical) period. During the trial, Oorja collects performance data.

5. **Business Case Analysis:** Based on customer-supplied and field-trial data, Oorja calculates TCO (Total Cost of Operation) and ROI (Return on Investment) vs. alternative solutions.

Advantages of Methanol vs. Hydrogen

vs.

$120 and 170 kg
Direct Methanol Fuel Cells

1 Drum of Methanol (200 liters) enables 250 hours of backup time at 1.1 kW

Compared to compressed Hydrogen, Methanol is very cheap, and it efficiently stores energy in a compact format.

Methanol, CH_3OH, is a user-friendly, easily-available, easily-transportable, non-explosive, low-cost liquid that is safe for stationary or mobile storage.

$4,300 and 2,900 kg
Hydrogen Fuel Cells

43 cylinders (49 liters, 200 bars, 66 kg, $100) = 2,107 liters of Hydrogen enable 250 hours of backup time at 1.7 kW

H_2 is highly volatile and explosive. It requires high pressure or cryogenic storage in expensive and heavy-to-transport containers. **The cost of a hydrogen infrastructure is extremely high.**

Competitive Analysis (< 100 kW)

Type of Fuel Cells	Vendors	Operating Temp	Power Range	Advantages	Disadvantages	Target Markets
Hydrogen PEM Fuel Cells	• Altergy • Ballard • Intelligent Energy • Nuvera • Plug Power	~70˚C	1kw–20 kW	• Doesn't require additional batteries • Environment safe • High efficiency • No noise	• High fuel cost • Hard to store hydrogen • Limited availability • High infrastructure cost • Requires additional safety certifications • Highly flammable • Sensitive to temperature and contamination. • High manufacturing cost	Forklifts Back-up power
Direct Methanol Fuel Cells	• Oorja • SFC (EFOY)	~60–70˚C	0.1kw–1.5 kW (now) > 1.5kw–100kw (future)	• Liquid base easy to store • Low fuel infrastructure cost • High availability of fuel • Low fuel cost • Multi market opportunity • Easy fuel transportation • Environment safe • Operates @ < 2 psi • Low maintenance cost	• Requires battery bridge during start ups. • Sensitive to contamination.	Multiple
Solid Oxide Fuel Cells	• Acumentrics • Bloom Energy	~600–800˚C	1kw–>100 kW	• Power scalability • No need for metal catalyst due to high operating temps	• Material/durability issues • Long start-up times • Market limitation • High operating temps • Requires heat isolation • Sensitive to temperature and contamination	Large buildings
Reformer-Based Fuel Cells	• Acumentrics • Nuvera • Plug Power	200–300˚C	1kw–20 kW	• Doesn't require additional batteries • High efficiency • Environment safe	• Durability issues • Long start-up times • High infrastructure cost • Additional maintenance cost for reformers • Operates at high temperatures. • Highly flammable • Sensitive to temperature and contamination.	Back-up power

Ballard ElectraGen-ME with Reformer vs. Oorja Model T-1

- **Safety**
  - If a pipe containing hydrogen bursts, this could have catastrophic consequences
  - Operates at higher pressure and temperature
- **Outdoors Only**
- **Space**: takes a lot of space: 2.7 m^3. 4.5 X Oorja. More difficult to install
- **Weight**: 256/295 kg vs. 68 kg for Oorja
- **Tight Fuel Specs**: little variability in required fuel mix (62 % methanol, 38% water) otherwise efficiency drops substantially
- **Fuel Efficiency**: substantial drop in fuel efficiency of the 5 kW units below a 3.0 kW load, and of the 2.5 kW unit below a 1.5 kW load
- **Power level Tied to Peak Load** vs. average load for Oorja
- **Higher Fuel Consumption** vs. when only one or two Oorja fuel cell are needed
- **Limited Modularity**: 2.5 kW and 5kW vs. 1.1 kW for Oorja
- **Risk of Hard Failure**: No redundancy, no battery
- **Shorter Stack Warranty**: 1,500 hours vs. 3,500 for Oorja