PPA

A PACIFIC POWER ASSOCIATION PUBLICATION

VOLUME 30 ISSUE 1 - MARCH 2022

IMPROVE RELIABILITY.

PREVENT TEMPORARY FAULTS FROM BECOMING SUSTAINED OUTAGES.

ENHANCE YOUR SPUR/LATERAL PROTECTION STRATEGY WITH S&C'S TRIPSAVER® II CUTOUT-MOUNTED RECLOSER

When temporary faults occur, customers may experience a sustained interruption caused by conventional equipment—resulting in an unnecessary truck roll and prolonged time without power.

Prevent temporary faults from becoming sustained outages and reduce your O&M costs with an advanced spur/lateral protection strategy using S&C's TripSaver II Cutout-Mounted Recloser. Restore power automatically with technology you—and your customers—can rely on.

Learn more at sandc.com/tripsaver2022

CONTENTS



PPA

March 2022, Volume 30 Issue 1

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Pacific Power Association, Suva, Fiji Islands. The PPA is an inter-governmental agency and member of the Council of Regional Organisations in the Pacific (CROP) established to promote the direct cooperation of the Pacific Island Power Utilities in technical training, exchange of information, sharing of senior managment and engineering expertise and other activities of benefit to the members.

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The articles published in this magazine do not necessarily represent the policies of the Board of Pacific Power Association.

Cover Page Photograph: Palau Public Utilities Corporation's new Chief Executive Office, Mr Frank Kyota.

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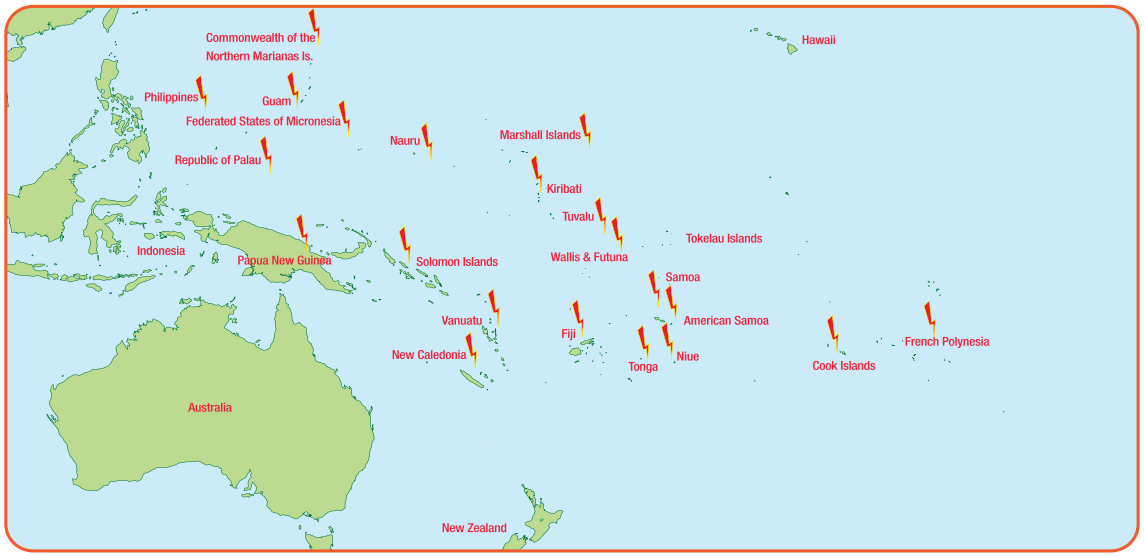

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Editor's Note

Gordon Chang
Acting Executive Director

Bula vinaka and welcome to you all.

For the PPA and its membership, a new year presents new challenges but also ongoing ones, especially on the COVID-19 as it will still be around for many more months to come. The continuing oil price volatility, the need to explore renewable energy resources and the reforms that need to take place are the challenges that we are faced with.

We remember our brothers and sisters in Tonga in the aftermath of the Hunga Tonga-Hunga Ha'apai volcanic eruptions and the Tsunami, especially the 80% of the nation's people who were affected. We applaud the friends of Tonga, the Tonga diaspora and the donor countries who have shown resilience and resistance with their gifts to help the folks badly affected.

This edition of the PPA Magazine profiles Mr. Frank Kyota, the new Chief Executive Officer of Palau Public Utilities Corporation (PPUC). Mr. Kyota replaces Gregorio Decherong. Mr. Kyoto brings to the Corporation over 25 years of private sector experience, and also served a four-year term as a congressman and as a Senator in the 9th and 10th OEK (Palau National Congress), respectively, from 2013 to 2020. Frank holds a BS degree in Criminal Justice from the University of Guam, School of Business and Public Administration. He was instrumental in the success of Belau Petroleum Products, Inc. (BPPI) a forerunner of Shell Co. (Pacific Islands) Ltd. until its transition to IP&E Palau Inc., logging a total of 29 years in the petroleum industry in various management capacities and leadership roles.

The implementation of the World Bank financed Sustainable Energy Industry Development Project (SEIDP) is continuing with the World Bank granting an additional one-year extension of the project to February 2023. Should all the PICTs borders reopening this year, the remaining activities of training workshops, Benchmark training and the wind measuring activity should be completed before February 2023. The PPA has also received interest from ADB to work with the Secretariat to implement projects with our member utilities. The PPA secretariat is in the process to submit the proposal in March 2022.

I would also like to welcome Komaihaltec Inc. who has rejoined our Allied Membership after a period of absence.

HEAT TO POWER – TOMORROW'S TECHNOLOGY TODAY - ELECTRATHERM PACIFIC FOCUS

David Knight
Business Development Analyst, ElectraTherm Inc

ElectraTherm, as a dedicated renewable energy company, is singularly focussed on providing practical solutions, to achieve energy efficiency and carbon emissions reduction through heat to power generation.

ElectraTherm has been part of the Pacific Power Association family since 2016 and is dedicated in our support for the Pacific Power Authorities to provide the latest technology solutions for emission-free power generation.

In association with B:Power, ElectraTherm is providing a heat recovery project for the Pohnpei Utilities Corporation incorporating the ElectraTherm Power+Generator 6500B+ Organic Rankine Cycle (ORC) System.

This system recovers waste heat from both the engine exhaust and jacket water cooling systems to generate additional renewable energy providing operating savings to the PUC. Whilst all the equipment has been delivered, unfortunately due to CORVID- 19 travel restrictions the installation of the equipment has been delayed.

Pacific Future Energy Mix

The future energy mix for the Pacific Island nations will be a mix of different renewable energy technologies supported by engine-based power generation.

Engine-based power generation will remain an important part of the energy mix, to provide base load power and grid stabilisation. With the introduction of new fuels such as hydrogen, ammonia and plant based liquid fuels, engine-based power generation will be part of the solutions to achieve committed climate action.

Further emission reductions will also be achieved by improvements in generating efficiency through the use of ORC technology converting waste heat to electrical power. This will become even more important to offset the increased cost of the next generation fuels.

With regards to renewables many Pacific nations have already installed renewable energy systems incorporating solar photovoltaics (PV), Wind and battery storage and these technologies will continued to be developed, but the fact remains that these technologies will still need to be coupled with other forms of power generation to ensure reliable power generation 24/7.

As power demand continues to grow there will be a requirement to diversify power generation through other renewable sources such as micro hydro, biomass and biogas systems, waste to energy and micro geothermal. Different forms of energy storage including heat batteries, pumped hydro, green hydrogen and plant-based liquid fuels will also be an important component.

ElectraTherm's Contribution

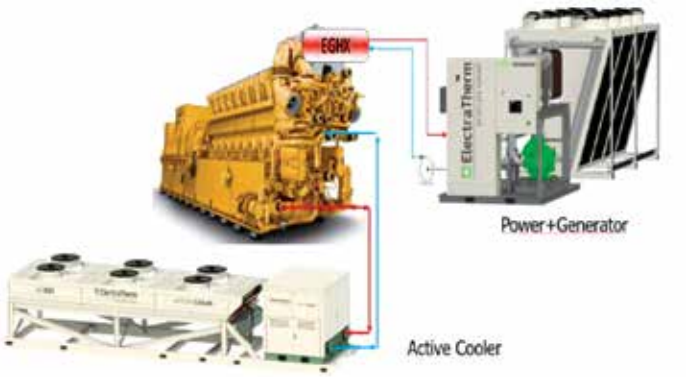
ElectraTherm's contribution to the future's energy needs will be based on technology solutions for power generation, energy efficiency and innovation.

ElectraTherm undertake a comprehensive R& D program to continue the development of the Power+Generator and Active Cooler. These developments include improved efficiencies, increased output, "islanding" capability and the next generation of ultra-low GWP working fluids.

With regards to power generation and energy efficiency this is provided through the use of the Power+Generator and Active Cooler utilising waste heat to generate additional electricity from the same fuel input. The Power+Generator is also suitable as the primary generation unit for small to medium sized alternative heat to power generation systems.

Examples of energy efficiency include the use of waste heat from engine power generation with the Power+Generator utilising the high temperature waste

heat from the engine exhaust and the next generation Active Cooler system using waste heat from the jacket water to provide electrical power for the operation of the engine cooling system.



Alternative power generation sources include both primary and waste heat from small to medium sized biomass, biogas, waste to energy and geothermal resources.

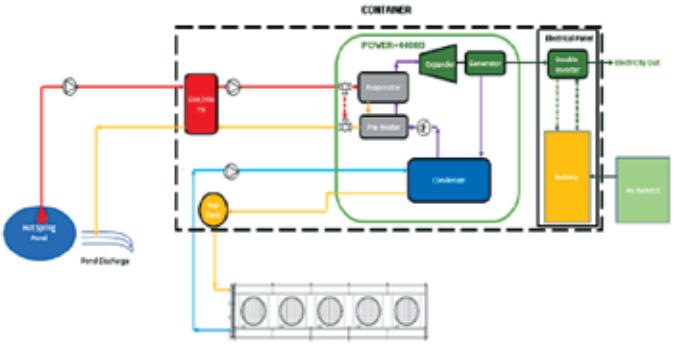
Innovative solutions include incorporating the Power+Generator with a heat storage to provide power demand load shifting and localised power generation systems using available heat sources such as micro geothermal and hybrid systems.

Hybrid power generation systems combine the Power+Generator with other systems such as micro grids, battery storage, wind, solar PV and solar thermal.

Pagan Island Innovative Power Concept

As an example of the innovative approach to power generation, ElectraTherm was approached to develop a small generation system based on a remote geothermal resource on Pagan Island located in the Northern Marianas. The Tano Group required a 35kW power generation system to provide power to meet a localised power demand.

The innovative solution proposed by ElectraTherm and our partners was based on the Power+Generator 4400B ORC installed in a 20' shipping container complete with all necessary balance of plant.



The electrical system included a twin inverter system to provide a stable micro grid for "islanding" operation, battery storage for black start capability and power demand management and a solar PV array.

ElectraTherm Pacific Commitment

ElectraTherm's commitment to the Pacific not only includes the supply of the latest ORC based power generation technology in the form of the Power+Generator and Active Cooler but also includes;

- Working with the power authorities in the development of innovative heat to power generation projects and the preparation of documentation to access project finance
- Providing training of local staff in the operation and maintenance of ORC technology,
- Providing continuing support through online assistance and technology upgrades, and
- A commitment to stay and support all PPA members in the long term.

The future for power generation in the Pacific will change with development of new technologies and ElectraTherm will continue to be part of that future though the provision of advanced technology based solutions for power generation and energy efficiency.

ORC COOLING TO POWER

BENEFIT FROM NET ZERO COOLING, WHILE GENERATING CLEAN POWER.

ElectraTherm
BY BITZER GROUP

SUPPORTING THE PACIFIC POWER AUTHORITIES

Radiator alternative that pays for itself through ORC power generation.

A modular, scalable, and robust design fits the specific needs of any project.

During peak cooling demand, the ORC is bypassed and the system prioritizes cooling. Fulfilling cooling requirements regardless of power generation.

Offset the previous cooling system's power demand while generating up to 75 kWe (gross) - with no additional fuel consumption or emissions.

Any heat source that requires cooling is a potential fit for the ElectraTherm Active Cooler. In the market for a new radiator? Consider upgrading to a cooling solution that offers a positive return on investment.

PROFITABLE
RELIABLE
FLEXIBLE
SUSTAINABLE
REDUCE EMISSIONS
INCREASE EFFICIENCY

COMPANY OVERVIEW

100+ *UNITS SOLD GLOBALLY*

2,000,000+ *OPERATING HOURS*

40,000+ *TONS OF CARBON SAVED*

ElectraTherm is a global leader in Organic Rankine Cycle waste heat recovery. Backed by BITZER, the world's largest independent manufacturer of refrigeration compressors, the ElectraTherm team continues to develop industry-leading energy efficiency solutions that are good for business and the planet.

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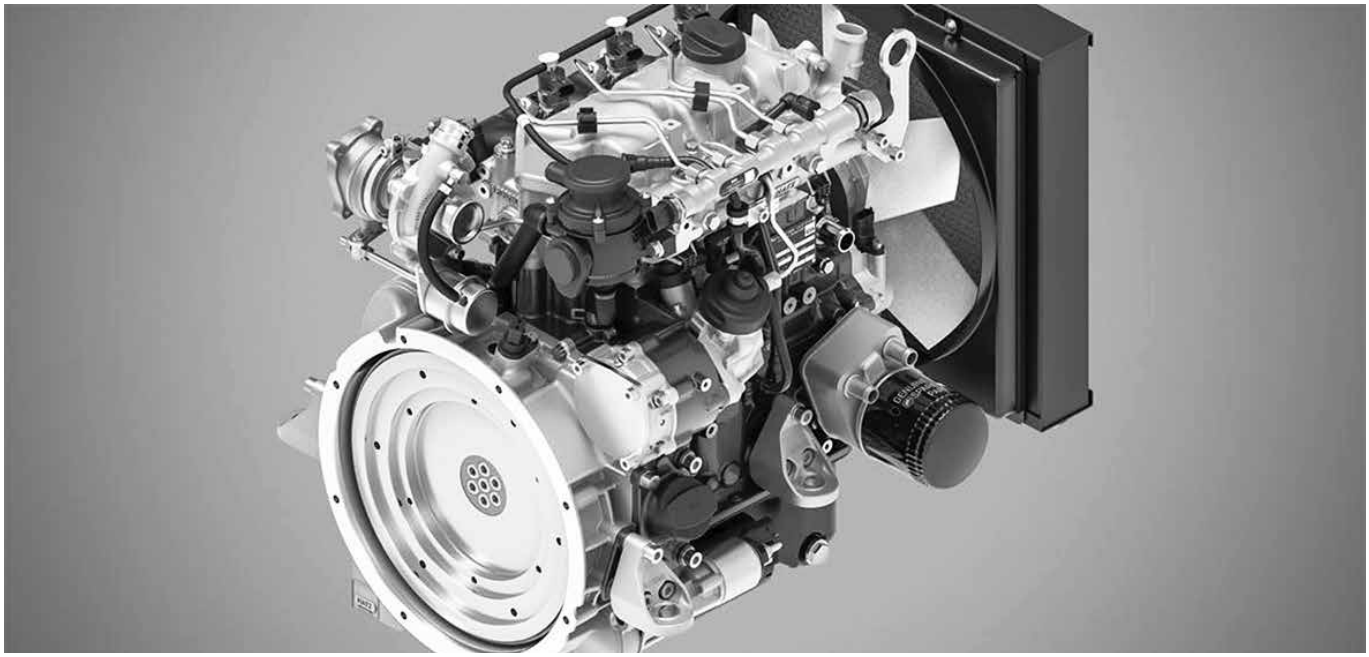
PRODUCTION LAUNCH OF A NEW POWER PACK: THE HATZ 3H50T

Hatz Diesel Australia



Convincing power and internal values in the smallest of space. Technical refinement, the most compact dimensions and the best fuel efficiency in its class are key to the development of the H series by Hatz. The Lower Bavarian company is now upping the ante with its modern series and is offering the 3H50T model with immediate effect.

The compact 24.6 horsepower (18.4 kilowatt) pack rounds off the lower end of the H Series range of engines. With almost (130 Newton metres), the 3H50T engine has the highest torque in its class on the market and achieves EPA tier 4 final standards in the USA and EU Stage V without any exhaust emission after-treatment. When it comes to its torque, the 3H50T is quite capable of replacing an engine from a higher power class without any problems. In the class up to 25.5 horsepower (19 kilowatts), it therefore serves the range of engines that normally covers a magnitude of up to almost 50 horsepower (37 kilowatts). In addition, it impresses largely due to its dynamism, easy maintenance and quiet running. The basic design of the Hatz 3H50T is ready for installation and use and can be universally employed in stationary and mobile machines as well as in working machines.

The Hatz 3H50T is also available as an open power unit (OPU). The cooler is mounted free of vibration and can be delivered as a complete system ex works. Customers have the advantage of being able to install the engine directly into the application as well as adding mounting parts for each of the application areas themselves. This supports in particular small and medium-sized companies, as it does away with the effort of, for example, correctly adding coolers or air filters.

Overall, the H series engines convince with their long-life construction based on a conservatively innovative approach. They are equipped with two valves per cylinder, which achieves a high level of efficiency, mechanical robustness and functional simplicity. The basic downsizing approach of the development creates a reduction in size and the lowest power/weight ratio in its class in conjunction with high power and good exhaust gas values as well as low fuel consumption values.

Mainly responsible for this is the iHACS Technology (intelligent Hatz advances combustion strategy) with its combustion chamber geometry, Bosch injection

technology, lowest possible friction and a maximum boost pressure of 24.6 PSI (1.7 bar).

ABOUT MOTORENFABRIK HATZ GMBH & CO. KG

At Hatz, we create benefit-driven solutions worldwide. As a strong partner, we enable machine manufacturers and operators to master their core tasks more easily and efficiently. Hatz is a renowned manufacturer of industrial engines and power units. We also offer innovative digital products and services. Our excellent solutions constitute the centerpiece of a wide variety of equipment and machines.

MH072153+3H50T prototype med

MH154420+3H50T prototype med

YOUR TRUSTED ASSET REPAIR SPECIALISTS

EMACS's highly experienced service and repair technicians are committed to meeting the demands of your power generation network. Our customized solutions, efficiency and reputation for excellence ensures your key assets remain reliable.

ELECTRICAL

- Generators and alternators
- AC & DC motors
- HV & LV electrical testing and rewinding
- 2.1MW load testing capabilities
- Overhaul, repair & replacement
- Capabilities from 1kW to 50MW
- White metal bearing service

MECHANICAL

- Pumps (centrifugal, vacuum, slurry, submersible, positive displacement)
- Fans and blowers (single and two-stage centrifugal)
- Gearboxes (in-line, multi-stage, parallel offset, planetary)
- Turbines & compressors
- Overhaul, repair & replacement

ONSITE

- HV & LV electrical testing
- Critical asset audits and inspections
- Onsite overhaul & rewinding up to 50MW
- Thermography, laser alignments, dynamic balancing
- Vibration analysis and ultrasonic
- Installation, supervision and commissioning

Electrical & Mechanical Repairs
Contact us to discuss our full range of services
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EMACS

New Modern Solution for Grid-Edge Outages

S&C Electric Company

S&C Electric Company, a leading grid innovator improving reliability and delivery worldwide, announced its newest innovation, the VacuFuse® II Self-Resetting Interrupter, the latest spur solution for grid-edge protection. The VacuFuse II interrupter brings fault-testing to the edge of the grid and mitigates nuisance outages, ensuring greater reliability for customers and fewer call outs for utilities.

As severe storms become more frequent and as more people work from home, outages at the edge of the grid are having a greater impact than ever before. These areas are typically protected by overhead distribution transformer fuses, which operate whether a fault is temporary or permanent. When up to 70 percent of these faults are caused by nuisance issues, such as wildlife or foliage, overhead distribution transformer fuses are causing lengthy power outages that can be avoided.

S&C's new VacuFuse II interrupter tests whether faults are temporary and automatically restores power when they are. Because issues at the edge of the grid tend to cluster into pockets, this advanced protection device can target troublesome spots on the grid. Not only can utilities lower their maintenance costs with this new solution, but they also can keep customer satisfaction high and meet their expectation of a modern, reliable grid.

"Throughout our 110-year history, innovation has been the foundation of S&C Electric Company," said Anders Sjoelin, president and CEO of S&C Electric Company. "We work closely with our customers to understand their challenges and develop solutions for real-world applications. As utilities are facing a major energy transformation, they are looking for ways to modernise and improve reliability and resiliency in every part of the grid. The VacuFuse® II Self-Resetting Interrupter is the latest example of how we've collaborated with customers to solve industry challenges and created an innovative, easy-to-use solution that tackles outages at the grid edge."

The VacuFuse II Self-Resetting Interrupter brings a variety of benefits to utility customers:

- Improves Customer Satisfaction: Targets outage-prone areas on the grid and helps address Customers Experiencing Multiple Interruptions (CEMI)
- Lowers O&M Costs: Saves O&M costs by mitigating the 70 percent of outages caused by nuisance fuse operations above overhead distribution transformers
- Drives Reliability and Resiliency: Provides advanced protection to meet rising customer expectations and enables faster systemwide restoration during severe weather

The VacuFuse II Self-Resetting Interrupter works with overhead distribution transformers from 7.2 kV through 12.5 kV and is available in sizes compatible with 15-kV and 25-kV cutouts to accommodate most lateral systems. At only 5.4kg, the VacuFuse II interrupter is easy to install and is factory-configured prior to shipping with standard curves (i.e., K, KS, T), customisable curves, or S&C's new transformer-specific curves.

This new innovation was unveiled during a virtual launch on January 24, 2022. To watch the event on-demand, please visit *https://youtu.be/bkwB8ft2fi8*.

S&C's VacuFuse® II Self-Resetting Interrupter.

ComAp
The heart of smart control

Control Systems for across the Pacific and beyond

A hybrid energy management system from ComAp ensures that power is delivered to your customers safely, efficiently and reliably.

Our solutions for integrating solar, wind, and energy storage into a diesel power generation system allow you to control your costs, update your systems to the latest technology, monitor your power station online, reduce emissions and more.

ComAp's products and solutions are in use across the Pacific providing reliable, sustainable power to many different communities.

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comap-control.com

Tesla Batteries Grid Connected with NOJA Power GMK

NOJA Power Switchgear Pty Ltd

Electrical engineering firm NOJA Power today celebrate the completed construction of the Black River Battery Energy Storage System (BESS), designed by Australian engineering consultants Yurika.

The Battery Energy Storage equipment, 5 MW of Tesla batteries were connected to the medium voltage distribution grid through a NOJA Power GMK Ground Mount Kiosk Circuit Breaker.

The Black River BESS system is among the first distribution grid scale battery storage systems. This system improves the networks' ability to integrate more renewable energy by improving system strength for "asynchronous generation" such as solar power.

"As the world targets net carbon zero by 2050, a large amount of storage will be required at all levels of the grid," says NOJA Power Group Managing Director Neil O'Sullivan.

"This BESS system where our GMK product provides the direct connection to the medium voltage grid is a great example of the type of systems that will ultimately be rolled out globally."

This BESS installation is first in a large program of works throughout the Australian state of Queensland, where it is expected future significant rollout of BESS Systems connecting the distribution network will be occurring over the coming years. This increase in storage capacity supports grid stability under high renewable penetration, where engineers report Queensland rooftop solar already exceeds base load coal generation in the middle of the day.

For more information, visit *https://www.nojapower.com.au/product/gmk*

A NOJA Power GMK connecting the Tesla Battery System to the Medium Voltage Distribution Grid, courtesy of Yurika

About NOJA Power

Founded in 2002 in Brisbane Australia, NOJA Power is a switchgear engineering company that has grown to serve over 104 countries from their Brisbane manufacturing headquarters.

The company develops safe, environmentally friendly medium voltage equipment, such as the OSM Recloser, GMK Ground Mount Kiosk Circuit breaker and NOJA Power VISI-SWITCH® Load Break Switch.

These products are used to protect and control the distribution grid, serving in applications such as overhead lines protection, renewable and distributed energy integration and medium voltage private infrastructure protection.

Naumade Cleaning Solutions Cost Effective, Safe cleaning of Energised Power Lines & Other Electrical Equipment

Transnet NZ Limited

Problem

Typical pollution and contamination on distribution and transmission networks:

- Dust deposits which become conductive in high humidity and reduce the insulation properties of insulators and other electrical equipment
- Biological pollution e.g. algae, fungi, and lichens that can degrade the surface of insulators and/or create a conductive layer
- Industrial pollution e.g. cement dust, residues from fertilizers, or other aggressive chemicals
- Salty deposits from sea spray
- Salty deposits on ground-based equipment and in substations after a tsunami
- Volcanic ash deposits on OH equipment
- A mix of volcanic ash and saline water on ground-based equipment

Effects of Pollution on Distribution & Transmission Networks

- Reduced creepage distance on insulators and other equipment resulting in flashovers
- Reduced insulation coordination and BIL
- Corrosion and galvanic processes on metallic components and contacts resulting in increased contact resistance and overheating
- Intermittent and permanent faults
- Secondary faults caused by unnecessary stress on already weakened upstream joints and connections
- Increased SAIDI and SAIFI
- Decreased network reliability
- Customer dissatisfaction
- Increased OPEX

Traditional Solutions Have Many Disadvantages

- Natural washing e.g. waiting for rain; after a prolonged dry season there are a lot of flashovers under light rains
- Washing with pressure washers (water blasters) with water or cleaning agents e.g. requires planned shutdowns, outages affect customers and SAIDI, very costly, environmental impact
- Replacement with new equipment e.g. usually premature replacements of otherwise healthy equipment before the end of its useful service life
- Spraying with silicone to prevent or minimize future contamination on insulators e.g. unpractical and costly, with limited success

In most cases, the above solutions just temporarily prevent surface leakages, PD, dry-bands, etc., and associated overheating, deterioration, and failure of equipment

- Furthermore, many contaminant particles and residues can't be washed with water e.g. will not dissolve in water
- In addition, using water or cleaning agents can create more corrosive conditions.

Naumade Safety Cleaning Solutions

Easy and Safe cleaning of electrical equipment while it is still in service (energized):

- Efficiently removes dirt, contamination, and dust from internal parts of switchboards and panels, insulators, busbars etc.
- Efficiently removes dirt, contamination, and dust from OH insulators and other equipment
- Non-conductive cleaning agent and aerosol (Dielectric breakdown voltage 97.6 kV)
- Applicable from electronic circuits & low voltage to 220kV

Benefits:

- Prevents surface leakages, PD, dry-bands, etc., and associated overheating, deterioration, and failure of equipment
- Safe to use and apply, non-corrosive, high ignition point (230 C)
- No residues left
- Certified eco-friendly (International Green Certification)
- Prevents fires due to overheating and flashovers

Naumade Applications and Examples

''A Picture is Worth a Thousand Words''

China 110kV and 66kV Applications

300kVA Transformer Panel

YK Steel in Korea

Current Users of Naumade Cleaning Technology

Major users in Korea:

- KEPCO (Korea Electric Power Corporation - the #1 power company in the world)
- YK Steel Corporation (Korean steel plant)
- Hyundai
- Korean Rail
- K Water (Korean water utility)
- Kumho Tyre, etc.

International users:

- China
- Kuwait
- Saudi Arabia
- Morocco
- Equador, etc.

Other Major Clients

Nauru 6MW Solar Development Project

Carmine Piantedosi
Chief Executive Officer - Nauru Utilities Corporation

The Nauru Utilities Corporation (NUC) is responsible for energy generation and distribution, including water supply in Nauru.

Nauru predominantly sources its energy through diesel power generators to supply energy to its customers as well as reverse osmosis water production facilities.

About 9% of NUC's current energy demand is sourced from renewable energy, of which all is from solar power (PV) installations. There is currently a 500-kW and 1.1-MW ground-mounted solar installations and a number of residential, commercial and government customers that have rooftop solar PV installations throughout Nauru.

The Asian Development Bank (ADB) provided Government of Nauru (GoN) a transactional technical assistance to prepare a Nauru power expansion plan. The plan identified that a solar PV array and battery energy storage system (BESS) was to be constructed. ADB also provided GoN support to prepare a Feasibility Study for the recommended Nauru Solar Power Development Project.

The project includes the construction of a 6 MW grid-connected solar power plant and a 2.5MWh, 5MW battery energy storage system to supply continuous power when solar energy is interrupted by cloud cover and to maintain network stability.

The system will be fully automated and integrated with the existing diesel generation system to optimise solar energy use, enable optimal battery energy storage system charging and discharging, and allow optimal shut-off of the diesel engines, which will reduce Nauru's reliance on diesel for power generation and decrease production costs.

Construction activities commenced in 2020 with the preparation of the site with land surveying and leveling completed in early 2021.

The following shows the current 1.1 MW solar plant and the surrounding cleared and leveled land area to accommodate the new solar development.

Mobilization of construction personnel, materials and equipment are progressing with the initial works in the development of the solar farm also being progressed in February 2022.

The solar development project is planned for completion end of 2022 and fully operational in early 2023.

The completion of the new plant will enable Nauru in achieving its renewable energy target of 50% electricity generation from renewable sources and reduce NUC's reliance on diesel fuel for electricity production by up to 30% once the solar plant is fully operational.

Asian Development Bank - Increasing Access to Renewable Energy Project

Tuvalu Electricity Corporation

The Asian Development Bank (ADB) is contributing towards the Tuvalu Government's target of 100% renewable energy by 2025 through the grant funded IAREP (Increasing Access to Renewable Energy Project). The project has been categorised by ADB as Effective Gender Mainstreaming, so equality issues will inform planning and progress throughout. Recruitment of local staff, consultations, and preparations for construction of the project are now in early stages.

CBS Site Manager during construction of the TEC solar plant in 2015

The ADB understands some of the energy challenges faced by people in Tuvalu, and is seeking to help by improving:

- Electricity cost and pricing structure
- The availability, reliability, and quality of electricity when and where it is needed
- Social and gender considerations in electricity demand decision making
- Safeguards around managing the environmental impacts of the project construction and electricity provision
- Long-term climate resilience of electrical power systems
- Engagement with local communities around the project benefits and impacts
- Project management and development capacity through training by international experts

Community engagement will be used across the project to raise public awareness, receive feedback from communities, and report progress and results. Cross-sections of communities will be sought out so that the project is informed by males, females, youth, and people with disabilities. The project Gender Action Plan will guide community engagement. Disaggregated data will be collected at each step, anonymised, and used to inform next steps.

Having a broad range of voices (men, women, youth, urban, rural) informing decision making contributes to achieving the best results for communities. Purchasing electricity has been identified as the second highest household commodity expenditure in Tuvalu but consumption across the country is not even. Low-income households, especially in rural areas, may not be gaining a good share of the potential social, poverty, and gender benefits from subsidization of tariffs. A gender-sensitive tariff review will form part of the project, aimed at increasing affordable usage, particularly in low-income households (female headed households, peoples with disabilities, etc). Business skills training for women and men is also a feature, aimed at supporting households to increase incomes through potential opportunities from additional electricity supply. The project Gender Action Plan and the ADB's Safeguards Policy will guide project activities in these areas.

The project will help the Tuvalu government transform the Funafuti and selected outer island power systems from diesel-based power systems into modern power systems based on a high level of renewable energy. This will reduce the reliance on imported fuels for power generation, reducing the cost of generation by replacing diesel power with solar power. The project is expected to displace 6.7 million litres of diesel fuel and avoid 17,800 tonnes of carbon dioxide equivalent in greenhouse gas emissions over its lifetime.

This will be achieved by installing additional solar capacity in Funafuti, Nui, Nukufetau, and Nukulaelae and a battery energy storage system in Funafuti.

The Solar power capacity of 724 kilowatts that will be installed (500 kW in Funafuti and 224 kW in the outer Islands) will on average be able to generate enough electricity to power more than 360 homes.

The battery energy storage system, packaged in two standard 20-foot shipping containers, will support the Funafuti grid while enabling increased use of variable renewable energy.

Project Execution	Ministry of Finance
Project Implementation	TEC with oversight from Ministry of Transport, Energy and Tourism
Construction Contractor	CBS Power Solutions
Construction Supervision	Elemental Group

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Coconut oil specific consumption in power generation: a comparison to diesel.

Frederic Petit
Director of Development - UNELCO, Vanuatu

Frederic Petit has been working on the technical, financial and regulatory aspects relating to copra oil for power generation in the pacific for 15 years. He has worked in every aspect of the coconut value chain from plantation, drying, logistics, crushing to power plant transformation.

Frederic Petit has contributed to the definition of Vanuatu's 2030 target energy mix and recently been a presenter at COP24. Frederic Petit is an engineer by training and is currently the Development Director at UNELCO Engie in Vanuatu.

Executive Summary
Coconut oil has been successfully used as a substitute to diesel for the power generation in Port-Vila, Vanuatu since 2006[1] (28 GWh generated). Technical issues have been lifted and the multifaceted benefits for the utility and country of using coconut oil for power generation has been conclusively demonstrated. Coconut oil appears as Vanuatu's silver bullet to reach its 100% renewable energy by 2030[2] objective and commitment to the international community.

As other Pacific utilities and territories consider tapping into this abundant local resource to reach their own sustainability targets, this article examines and quantifies the one aspect where coconut oil cannot quite compete with diesel: its calorific value. Specifically, in our case, this article examines the energy content that coconut oil can release in a power genset. This quantification is crucial for business planning, technical dimensioning and for performance management of any coco for power strategy.

For ease of reference, this article uses a derating ratio between diesel and coconut. The derating ratio is the ratio between the energy released by a litre of coconut oil and the one released by a litre of diesel when both products are at the prevailing ambient temperature of 28°C.

This article concludes to a derating ratio of 0.956 between coconut oil and diesel for the use of a litre of each product at ambient conditions for the power generation in Port-Vila 4MW MAN 9L generator.

1. Introduction

This article presents the theoretical and empirical comparison of energy generated by combustion of coconut oil and diesel and the results of real comparison tests made in 2020.

Until recently, a derating ratio of 88.1 % had been assumed to reflect the lower energy generated by coconut oil versus diesel. That derating value stemmed from a basic ratio of the gross calorific values of coconut oil and diesel; respectively 37 MJ/kg and 42 MJ/kg. This basic ratio failed however to account for the significant density difference between the two products.

To establish a more precise empirical derating ratio, this article will examine:

- calorific value data (energy per unit of mass),
- density data stemming from international laboratory analysis (mass per unit of volume), and
- in situ consumption tests for both coconut oil and diesel.

2. Definitions

2.1. Calorific value

The calorific value of a material provides the quantity of energy released by the complete combustion under standard conditions of this substance. The calorific value is expressed in energy per mass, in our case MJ/kg (megajoules per kilogram).

[1] From July 2006 until May 2020, coconut oil has been used to generate 28.6 GWh in Port Vila, Vanuatu, during that period a total of 828.4 GWH were generated in Port Vila. While coconut oil represented only 3.5% of the total generation, it represented 17% of the annual electricity generation in 2013 and the main impediments to higher use, so far, have not been technical but rather associated to supply chain and finances.
[2] UNDP NDC's for Vanuatu https://pacificndc.org/pacific-ndcs/vanuatu-republic

Laboratory analysis results sometimes present gross calorific value (also known as higher calorific value) and/or net calorific value (also known as lower calorific value). The difference between the two accounts for the energy used to vaporize water during combustion. For this article and comparison, it is appropriate to use the gross calorific value for both coconut oil and diesel.

2.2. Density

The density (also known as specific mass) of a material is its mass per unit volume. Density will typically vary with temperature. In our case the units of density are expressed in kg/l (kilograms per litre).

2.3. Specific consumption for power generation

The specific consumption for power generation expresses the quantity of energy generated (in kWh) obtained from a quantity (in g) of the fuel used in the generator. The specific consumption is therefore expressed in g/kWh.

NB: Due to density variations, it is not as accurate to express specific consumption as volume (l) per quantity of energy (kWh).

2.4. Derating ratio

Derating ratio illustrates the quantity of electrical energy that can be obtained by a litre of coconut oil compared to the one generated by a litre of diesel with both products purchased and delivered at ambient temperature at the Port Vila power plant.

It considers the variation of specific consumption and the difference of density at the delivery or storage of coconut & diesel in our case it is under ambient temperature.

3. Coconut oil and diesel physical characteristics

3.1. Coconut oil calorific value

Several analysis' of coconut oil produced in Vanuatu were conducted by independent laboratories in Australia, New Zealand and Germany. The output are summarized in the table below.

Table 1 - Gross and net calorific values of coconut oil. Italic values were computed with an average 1.062 ratio[3]

ID	Date	Laboratory	Gross calorific value (MJ/kg)	Net calorific value (MJ/kg)
1	10/03/2010	MAN (Germany)	37.037	34.840
2	15/03/2010	MAN (Germany)	36.981	34.788
3	15/03/2010	Oilcheck Pty (Australia)	37.930	35.680
4	16/06/2010	Oilcheck Pty (Australia)	37.710	35.473
5	16/06/2010	Oilcheck Pty (Australia)	36.670	34.495
6	16/06/2010	Oilcheck Pty (Australia)	38.170	35.906
7	16/06/2010	Oilcheck Pty (Australia)	38.110	35.850
8	10/08/2010	Oilcheck Pty (Australia)	35.880	33.752
9	03/05/2011	Oilcheck Pty (Australia)	38.240	35.972
10	03/05/2011	Oilcheck Pty (Australia)	39.900	37.534
11	03/05/2011	Oilcheck Pty (Australia)	38.770	36.471
12	03/05/2011	Oilcheck Pty (Australia)	39.480	37.138
13	12/02/2019	SGS (Australia)	36.110	33.968
14	24/09/2019	FlindersCook (New Zealand)	37.490	35.380
15	24/09/2019	FlindersCook (New Zealand)	37.480	35.290
16	24/09/2019	FlindersCook (New Zealand)	37.410	35.120
17	24/09/2019	FlindersCook (New Zealand)	37.360	35.070
Average			**37.690**	**35.475**

Based on these independent laboratory results, the average of 37.690 MJ/kg can be used as the gross caloric value of Vanuatu coconut oil for the subsequent analysis.

[3] Certain laboratories provide gross calorific value, some net calorific value and some both. In order to best estimate the net calorific value of all samples we can look to samples ID 14 to 17, which provide an average 1.0630 ratio between gross and net calorific values. By applying this ratio, we can therefore complete the gross and net calorific values. The numbers in italics are estimated by applying the ratio.

3.2. Coconut oil density

The analysis conducted by independent laboratories in Australia, New Zealand and Germany provide densities for coconut oil at various temperature as shown in Table 1.

Table 1 - Coconut oil densities at various temperature

ID	Date	Laboratory	Density 15°C kg/l	Density 40°C kg/l	Density 50°C kg/l
1	10/03/2010	MAN (Germany)	0.9250		
2	15/03/2010	MAN (Germany)	0.9250		
3	15/03/2010	Oilcheck Pty (Australia)	0.9258		
4	16/06/2010	Oilcheck Pty (Australia)			
5	16/06/2010	Oilcheck Pty (Australia)			
6	16/06/2010	Oilcheck Pty (Australia)			
7	16/06/2010	Oilcheck Pty (Australia)			
8	10/08/2010	Oilcheck Pty (Australia)	0.9247		
9	03/05/2011	Oilcheck Pty (Australia)	0.9270		
10	03/05/2011	Oilcheck Pty (Australia)	0.9198		
11	03/05/2011	Oilcheck Pty (Australia)	0.9269		
12	03/05/2011	Oilcheck Pty (Australia)	0.9196		
13	12/02/2019	SGS (Australia)		0.9075	
14	24/09/2019	FlindersCook (New Zealand)			0.9069
15	24/09/2019	FlindersCook (New Zealand)			0.9069
16	24/09/2019	FlindersCook (New Zealand)			0.9064
17	24/09/2019	FlindersCook (New Zealand)			0.9069

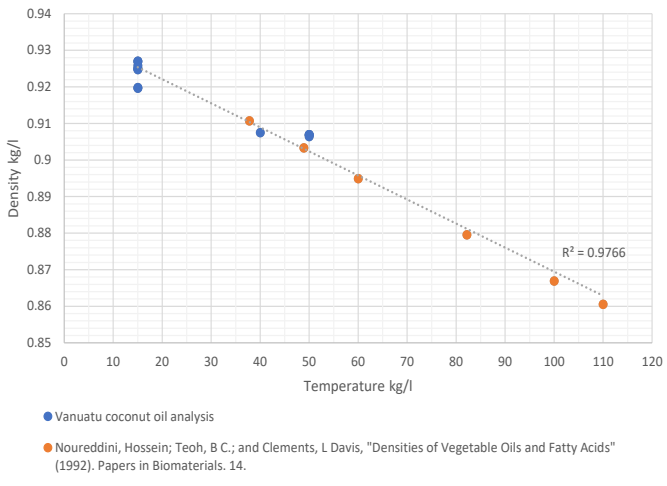
In order to normalize the data provided by laboratories at different temperatures, it is necessary to refer to a reference scientific publication[4] which provides with coconut oil densities at various temperatures.

Table 2 - Coconut oil density versus temperature, Noureddini et al [8]

Temperature °C	Coconut oil density kg/l
37.8	0.9107
48.9	0.9033
60.0	0.8949
82.2	0.8795
100.0	0.8669
110.0	0.8605

Densities at various temperature are illustrated in Figure 1 below.

Figure 1 - Coconut oil density versus temperature



[4] Noureddini, Hossein; Teoh, B C.; and Clements, L Davis, "Densities of Vegetable Oils and Fatty Acids" (1992). Papers in Biomaterials. *14. https://digitalcommons.unl.edu/chemeng_biomaterials/14*

The linear correlation provides the relation between coconut oil density in kg/l and temperature in °C with the Equation 1 below.

Equation 1 – Coconut density (kg/l) as a function of temperature (°C)

Coconut oil density = 0.935250 – 0.000658 × *Temperature*

3.3. Diesel calorific value

Gross calorific value for diesel is 45.720 MJ/kg[5].

3.4. Diesel density

Diesel density measured in Port-Vila at ambient temperature are given in Table 3 below.

Table 3 - Density of diesel measured at ambient temperature by diesel fuel supplier

Date	Ambient temperature (°C)	Density (kg/l)
05/02/19	26.8	0.825
05/04/19	26.7	0.822
20/05/19	23.9	0.824
12/07/19	22.4	0.817
01/09/19	24.4	0.820
07/10/19	23.7	0.821
17/11/19	24.8	0.825
25/12/19	24.2	0.822
05/02/20	27.5	0.820
17/03/20	27.4	0.826
09/05/20	24.7	0.828
17/06/20	23.4	0.827
01/07/20	22.0	0.816
06/08/20	21.4	0.831
21/09/20	22.2	0.827
30/10/20	24.7	0.827
16/11/20	25.5	0.816
07/01/21	27.7	0.823

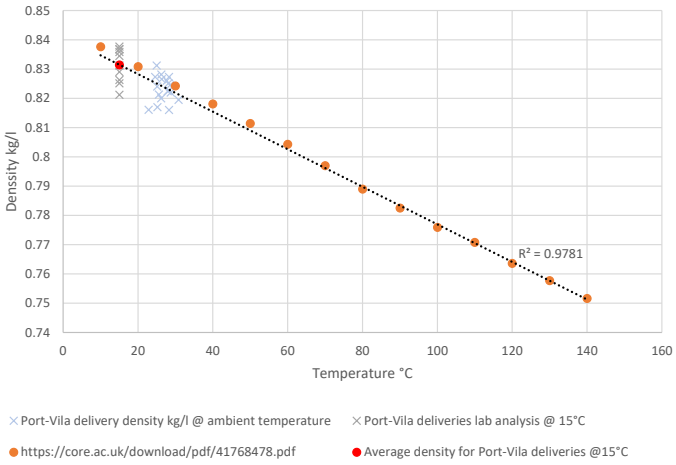
Quality certificates from international laboratories for the diesel delivered in Port-Vila are given in Table 4 below:

Table 4 - Diesel density (kg/l @ 15°C) for 2020 Port-Vila deliveries

Date	Density kg/l @ 15°C	Delivery reference
28/12/2019	0.8290	BG V49
23/02/2020	0.8368	BG V50
07/04/2020	0.8358	BG V51
21/07/2020	0.8212	BG V53
17/08/2020	0.8367	JC V92
16/06/2020	0.8312	KATRINE V60
09/03/2020	0.8377	LP V01
12/05/2020	0.8251	LP V02
06/10/2020	0.8263	LP V04
05/12/2020	0.8345	LP V05

Data available in the scientific literature[6] combine with the densities in Table 3 & Table 4 are illustrated in Figure 2 below

Figure 2 - Diesel density versus temperature



The linear correlation provides a fair relation between density and temperature with the Equation 2 below.

Equation 2 - Diesel density (kg/l) as a function of temperature (°C)

Diesel density = 0.841116–0.000642 × *Temperature*

[5] 05/12/13 Analysis report for diesel delivered to Vanuatu.

[6] Temperature dependence of density and viscosity of vegetable oils. Bernat Esteban, Jordi-Roger Riba, Grau Baquero, Antoni Rius, Rita Puig. Escola d'Enginyeria d'Igualada (EEI-Escola d'Adoberia), Universitat Polite `cnica de Catalunya, Spain. BIOMASS AND BIOENERGY 42 (2012) 164-171.

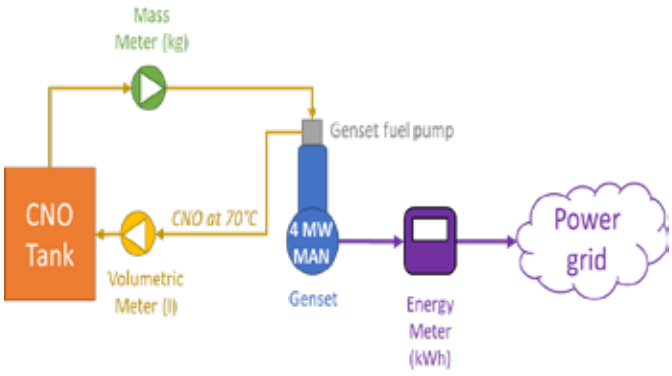
4. Power generation consumption tests

4.1. Power generation with coconut oil tests

The utility proceeded with several tests of consumption in its Port Vila (Tagabe) power station. The engine used for these tests is a 4MW MAN 9L.

The purpose of these tests was to measure the specific consumption (expressed in g/kWh) of the 4 MW MAN 9L using 100% coconut oil.

Figure 3 - General coconut oil (CNO) consumption test layout



The coconut oil (CNO) is injected in the engine at a temperature around 60-70°C. The quantity of CNO is measured in kg with a mass meter, there is no correction of density. The excess of CNO returns back to the tank, the returning quantity is measured by a volumetric meter, a correction of density with temperature is necessary. We use the Equation 1. The energy output is measured in kWh at the outlet of the genset.

The Table 5 summarizes the results of these tests. CNO specific consumption in 4MW MAN 9L genset in Port-Vila is 239.6 g/kWh.

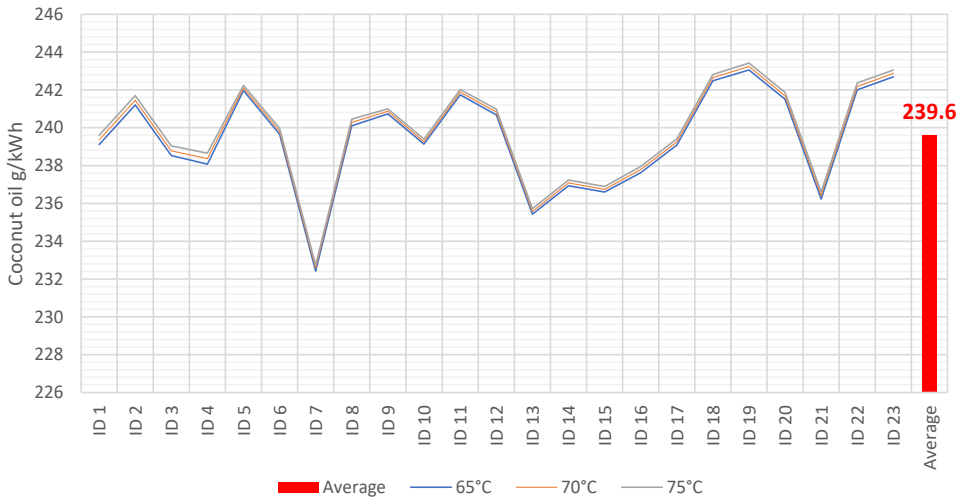
A slight variation of +/- 5°C in the injection temperature of the coconut oil does not have any impact on the specific consumption.

Considering an average specific consumption of 206.3 g/kWh for diesel, the coconut oil is then 16.1 % less efficient than diesel in the same Port-Vila power generation conditions.

Calorific values for coconut oil (37.690 MJ/kg see §3.1) and diesel (45.720 MJ/kg see §3.3) show a difference of 21.3 %.

Table 5 - CNO specific consumption test results

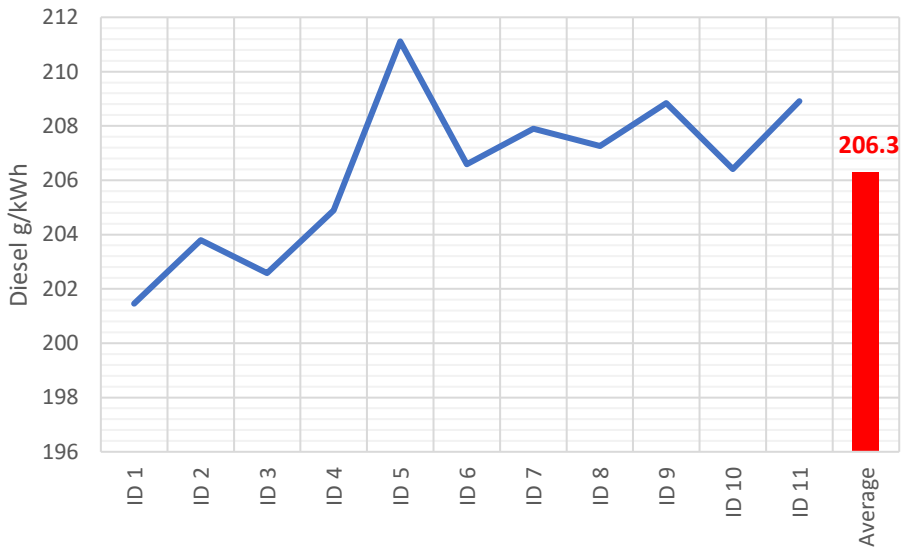
Test ID	Test duration (h)	Active energy generated (kWh)	CNO injected in the genset (kg)	CNO returning to tank (l)	Specific consumption with CNO density @65°C (g/kWh)	Specific consumption with CNO density @70°C (g/kWh)	Specific consumption with CNO density @75°C (g/kWh)
ID 1	7	22 524	6 885	1 680	239.1	239.4	239.6
ID 2	9	27 103	8 365	2 048	241.2	241.4	241.7
ID 3	7	22 677	7 003	1 786	238.5	238.8	239.0
ID 4	24	74 508	23 573	6 537	238.1	238.4	238.7
ID 5	24	79 774	22 247	3 299	242.0	242.1	242.2
ID 6	31	95 691	26 917	4 463	239.7	239.8	240.0
ID 7	22	73 470	20 246	3 552	232.4	232.6	232.7
ID 8	72	228 276	65 874	12 399	240.1	240.3	240.5
ID 9	7	23 346	6 420	896	240.7	240.9	241.0
ID 10	9	29 491	8 108	1 183	239.1	239.3	239.4
ID 11	8	25 778	7 200	1 085	241.7	241.9	242.0
ID 12	8	25 881	7 285	1 183	240.7	240.8	241.0
ID 13	8	27 736	7 623	1 225	235.4	235.6	235.7
ID 14	9	28 445	7 913	1 315	236.9	237.1	237.2
ID 15	9	27 073	7 480	1 204	236.6	236.7	236.9
ID 16	9	27 314	7 746	1 407	237.6	237.8	238.0
ID 17	16	51 577	14 630	2 576	239.1	239.2	239.4
ID 18	10	31 563	9 102	1 623	242.5	242.7	242.8
ID 19	7	23 628	6 921	1 320	243.1	243.2	243.4
ID 20	8	23 490	6 819	1 284	241.5	241.7	241.9
ID 21	7	23 038	6 599	1 296	236.2	236.4	236.6
ID 22	9	27 570	8 066	1 562	242.0	242.2	242.4
ID 23	7	22 157	6 483	1 239	242.7	242.9	243.1
Average						**239.6**	



4.2. Power generation with diesel tests

Operational statistics provide accurate evaluation of the specific consumption of the same MAN gensets using diesel fuel.

Test ID	Energy generation (kWh)	Generation duration (h)	Diesel consumption (l)	Specific consumption (g/kWh)	Average power (MW)
ID 1	1 536 015	472	375 988	201.5	3 256
ID 2	2 041 033	627	505 422	203.8	3 254
ID 3	1 609 042	531	396 053	202.6	3 029
ID 4	2 147 163	712	534 563	204.9	3 017
ID 5	2 017 034	672	517 401	211.1	3 004
ID 6	2 224 854	720	558 491	206.6	3 090
ID 7	1 978 511	621	499 801	207.9	3 184
ID 8	1 727 168	547	434 951	207.3	3 157
ID 9	865 947	308	219 743	208.8	2 811
ID 10	1 033 337	363	259 158	206.4	2 846
ID 11	1 554 971	540	394 718	208.9	2 881
Average				**206.3**	**3 065**



5. Conclusion

At ambient temperature (assumed to be 28°C):

- the densities of diesel and coconut oil are respectively 0.823 kg/l and 0.917 kg/l;
- the specific consumption for power generation for diesel and coconut oil are respectively 206.3 g/kg and 239.6 g/kWh;
- therefore 1 litre of diesel will generate 3.99 kWh and 1 litre of coconut oil will generate 3.83 kWh.
- In these conditions, **the derating ratio for coconut oil versus diesel is 0.959** (see Table 6 below).

Table 6 – Comparison of the energy generation in 4MW MAN between 1 litre of diesel and 1 litre of coconut oil

Fuel	Volume (l)	Density (kg/l)	Quantity (kg)	Specific consumption (g/kWh)	Energy (kWh)	Derating ratio
Diesel	1	0.823	0.823	206.3	3.989	1
Coconut oil	1	0.917	0.917	239.6	3.827	0.959

The calculation presented in Table 6 assumes an ambient temperature of 28 °C. A sensitivity analysis demonstrates that the derating ratio is quite stable with temperature as a 1 degree C variation only creates a 0.01% variation of the derating ratio. The derating ration can thus be considered constant within the range of normal operating temperatures.

The very tangible implication of this derating ratio is for example the calculation of the breakeven point of copra oil purchases vs. diesel oil. This signifies that, assuming other electricity generating costs being equal, if the price of a litre of copra oil at least 4.1% below the price of a litre of diesel, it is financially viable (even before taking into account the positive externalities) to use copra oil in lieu of diesel for power generation.

Palau Public Utilities Corporation's new Chief Executive Officer

Palau Public Utilities Corporation

Frank Kyota joined Team PPUC as the Chief Executive Officer of the Palau Public Utilities Corporation on September 7, 2021. He brings to the Corporation over 25 years of private sector experience, and also served four year terms as a Congressman and as a Senator in the 9th and 10th OEK (Palau National Congress), respectively, from 2013 to 2020.

Frank holds a BS degree in Criminal Justice from the University of Guam School of Business and Public Administration. He was instrumental in the success of Belau Petroleum Products, Inc. (BPPI) a forerunner of Shell Co. (Pacific Islands) Ltd. until its transition to IP&E Palau, Inc., logging a total of 29 years in the petroleum industry in various management capacities and leadership roles.

As a result of his background in both the private and public sectors, Frank brings to the Corporation a wealth of knowledge and experience in Industry Best Practice including service to its valued customers, the security of its assets, and the protection of the environment, our only Nest of Life. We are PPUC, a proud, a people-driven Corporation.

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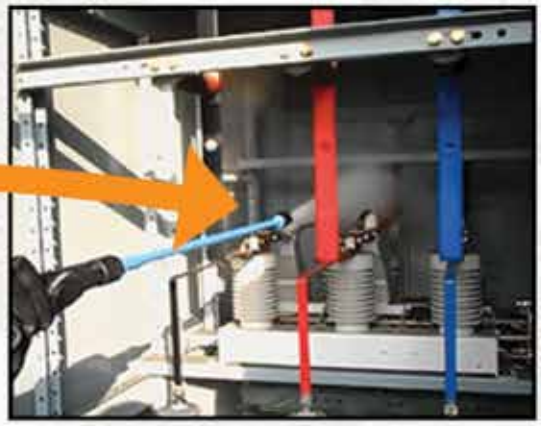

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