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Powering 2020

The role of diesel, gas and hybrids in Australia's energy mix over the next decade

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AN ENERGY POWER SYSTEMS AUSTRALIA WHITE PAPER

> "Weather forecasts are now the most important input into forecasting of demand and supply of generation for the NEM. As well as the impact of the increase in renewable resources, extreme temperatures and events including bushfires, lightning, storms, and high winds can reduce the output of all types of generation, impact transfer capacity of transmission lines, and result in loss of supply. Drought is also a factor in the output of hydro generation, which uses water as fuel, and thermal generation, which uses water in cooling."[6]
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> AUSTRALIAN ENERGY MARKET OPERATOR, SUMMER 2019-20 READINESS PLAN - DECEMBER 2019

Powering the next decade of energy generation in Australia

The National Electricity Market (NEM) broke through the 50 per cent benchmark for renewable energy in one trading period on Wednesday 6 November 2019. For the very first time, the combined output of rooftop solar, large-scale wind, and large-scale solar reached 50.2 per cent of the almost 25 GW being produced on the main grid for Queensland, NSW, Victoria, Tasmania and South Australia.[1] Yet, the average quarterly investment in new clean energy generation fell 60 per cent in 2019, from more than 1,600 MW of generation capacity to about 500 MW.[2]

Australia has long used a diverse range of its energy resource base for electricity supply

The majority of our energy has traditionally been powered by coal and gas. So, as we embark on a new decade, what does the power generation sector look like for Australia?

Around three-quarters of Australia's coal-fired power stations are operating beyond their original design life. Some have had extensive refits with gas – already integral to Australia's energy mix – primed as a short-term substitute for coal due to lower emissions and its ability to be more responsive to grid pressures.[3] There has been an increasing reliance on renewable energy resources including wind, solar, geothermal, ocean, hydro and bio-energy, along with the emergence of battery and storage technologies, and hydrogen power. All renewable power generation requires a back-up generator on-site, and Cat® gas or diesel generators provide reliable and durable energy solutions.

In the coming decade, Australia will need to reconsider its energy supply mix

This is just as we are being warned of big climate-based challenges that are happening right now. Beyond 2020, the Australian Energy Market Operator (AEMO) forecasts "only slight improvements in reliability for peak summer periods until new transmission and dispatchable supply and demand resources become available"[4]. While, In Western Australia, rooftop solar is now the state's single largest generator – yet, fluctuations in supply caused by the weather mean low-power days are an issue as the "the only way to manage the solar was to scale back or switch off the coal- and gas-fired power stations that were supposed to be the bedrock of the electricity system" according to AEMO chief executive Audrey Zibelman[5].

EPSA provides Cat® products for all power generation requirements across all industries

From off-the-shelf low-cost engines and generators to full turnkey solutions including project management and commissioning, EPSA is the exclusive supplier of Cat® engines, generators and power solutions in Australia, Papua New Guinea and the Solomon Islands. EPSA is also the exclusive provider of the Cat® Hybrid Energy Solutions (Solar PV and Energy Storage), which can be integrated into traditional power generation solutions. EPSA also provides short or long-term Cat® rental solutions for power generation, temperature control and compressed air equipment.

While we can't change Mother Nature's plans nor fast-track much-needed changes to Australia's ageing energy infrastructure, as we enter a new decade at EPSA, we are future-focussed and can look at measures to prevent blackouts and keep businesses operational. We're ready and equipped to support businesses – large and small – in order to prepare for any scenario with reliable standby generators that keep the power on.

Noel Rosario

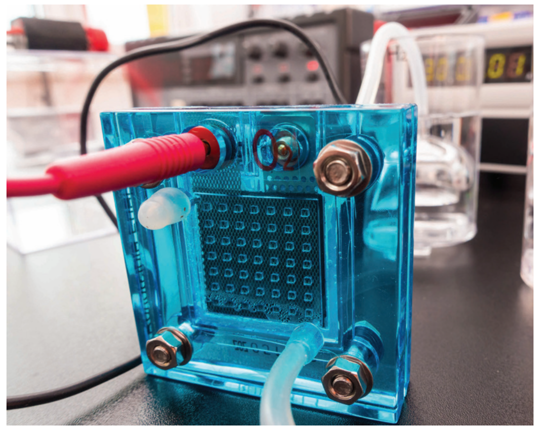
Segment Manager, Inventor Product, EPID and EPIG, Energy Power Systems Australia

1. G Parkinson, Australia's main grid reaches 50 per cent renewables for first time, Renew Economy, 6 November 2019, accessed 29 November 2019 https://reneweconomy.com.au/australias-main-grid-reaches-50-per-cent-renewables-for-first-time-17935/ 2. K Murphy, A Morton, Consumers will pay the price for short-term thinking on electricity, energy suppliers warn, The Guardian, 21 November 2029, accessed 29 November 2019, https://www.theguardian.com/australia-news/2019/nov/21/energy-ministers-warned-not-to-overreact-on-electricity-reliability-rules 3. M Stewart, The Future of Australian Electricity Generation, Institution of Engineers Australia, 2017, accessed 29 November 2019, https://www.engineersaustralia.org.au/sites/default/files/resources/Public%20Affairs/The%20Future%20of%20Australian%20Electricity.pdf 4. Australian Energy Market Operator, 2019 Electricity Statement of Opportunities, accessed 1 2 December 2019, https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/NEM_ESOO/2019/2019-Electricity-Statement-of-Opportunities.pdf 5. D Mercer, The rise of solar power is jeopardising the WA energy grid, and it's a lesson for all of Australia, ABC News, 1 December 2019, accessed 2 December 2019 6. Australian Energy Market Operator, Summer 2019-20 Readiness Plan - December 2019, accessed 6 December 2019, https://www.aemo.com.au/-/media/Files/Electricity/NEM/System-Operations/Summer-2019-20-Readiness-Plan.pdf

Power Spotlight

Diesel and Gas

- Despite advances in battery storage technology and a push towards a carbon neutral environment, diesel power generation is still the preferred form of emergency standby power.
- The market is actually growing due to the phenomenal rate at which hyperscale data centres are expanding and increasing their mission-critical power demands.
- Diesel prime power is still a viable solution for remote power where grid power or gas pipelines are scarce. Efficiencies on site can be increased by coupling with a battery for energy storage solutions.
- As long as coal mines will be operating, there will be a case to collect coal mine methane and burn for mine consumption and/or grid power.
- Natural gas is still the preferred fuel for remote power stations, due to Australia's extensive gas pipeline network and the price of gas in comparison to diesel. Efficacy can be increased by introducing hybrid energy systems.



Hydrogen fuel cell

Renewables, Landfill Gas and Hydrogen

- Unprecedented investment in large wind and solar power projects has put Australia on track to meet the Federal Government's 2020 large-scale renewable energy target.
- Australia's renewable energy rate is growing ten times faster than the world average per capita.
- Increased deployment of rooftop solar PV helps reduce system demand during most summer heatwave peaks (providing there is no cloud cover) but shifts the maximum peak event to later in the day as the sunlight lessens.
- South Australia has the highest penetration of intermittent renewable generation in the world. Over 45 per cent of the state's generation comes from wind energy.
- Landfill gas is a very cost-effective and reliable renewable base-load power source. Landfill gas-to-energy projects are fast gaining momentum by using generators to turn waste into economically viable electricity.
- Colourless and odourless, hydrogen is the most common chemical element in the universe. It is not freely available as a gas but bound into many common substances including water and fossil fuels and requires various technologies plus an energy source to power it all.
- Hydrogen can be turned into electricity or methane and through pipelines as a gas or on ships as a liquid. It can also be generated by renewable energy.
- Global demand for hydrogen exported from Australia is predicted to be over three million tonnes each year by 2040[9]

9. Australian Renewable Energy Agency, Hydrogen, accessed 17 December 2019, https://arena.gov.au/renewable-energy/hydrogen

Global Energy Predictions - McKinsey & Co[7]

- Global primary energy demand will plateau after 2035 despite strong population expansion and economic growth.
- Electricity consumption will double until 2050 driven by increased demand in buildings and a shift toward electricity as an energy source in road transport, while renewables are projected to make up over 50% of power generation by 2035.
- Gas will continue to grow its share of global energy demand—the only fossil fuel to do so—and then plateau after 2035.
- Oil demand growth will slow with a projected peak in the early 2030s.
- Carbon emissions are projected to decline due to decreasing coal-fired power.
- By 2030, new-build renewables will outcompete existing fossil fuel generation on energy cost in most countries—one of the key tipping points in the energy transition.
- Hydrogen could play a vital role in the renewable-energy system and in future mobility. It is a versatile energy carrier and can be produced with a low carbon footprint[9].

"While the increased reliance on air conditioning has caused a rise in peak demand over the past couple of decades, in recent years this has been somewhat tempered by the greater role household solar and batteries are playing and a reduction in demand from large industrial facilities, some of which have closed."

6. M Stocks, A Blakers, K Baldwin, Australia is the runaway global leader in building new renewable energy, The Conversation, 25 September 2019, accessed 2 December 2019, http://theconversation.com/australia-is-the-runaway-global-leader-in-building-new-renewable-energy-123694 7. McKinsey & Co, Global Energy Perspective 2019: Reference Case, Energy Insights by Mkinsey, January 2019, accessed 1 December 2019, https://www.mckinsey.com/~/media/McKinsey/Industries/Oil%20and%20Gas/Our%20Insights/Global%20Energy%20Perspective%202019/McKinsey-Energy-Insights-Global-Energy-Perspective-2019_Reference-Case-Summary.ashx 8. Australian Energy Networks, FACTSHEET: Heatwaves and Electricity Supply January 2019, accessed 6 December 2019, https://www.energynetworks.com.au/resources/fact-sheets/heatwaves-and-energy-supply-explained/ 9. McKinsey & Co, Hydrogen: The next wave for electric vehicles?, accessed 17 December 2019, https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/hydrogen-the-next-wave-for-electric-vehicles

Understanding electrical power

The reciprocating engine is the main part of a generator set. The purpose of an engine is essentially to convert chemical energy stored in fuels into thermal and eventually mechanical energy as shaft work. Engines can be divided into two categories based on their fuel and thermal cycle;

- compression ignition engines (diesel engines)
- spark-ignition engines (gas engines).

Each cycle is based on four strokes: intake stroke, compression stroke, power stroke and exhaust stroke.

The difference between the two is in how the air-fuel mixture is ignited

- **diesel engines –** at the end of the compression stroke, the temperature of the compressed air in the cylinders forces the atomised diesel to be injected into the cylinders just before the piston reaches the top dead centre (TDC), to ignite.
- **spark-ignition engines –** because a spark plug is required to initiate the combustion process just before the piston reaches the TDC, the air-fuel mixture is compressed to lower pressures compared to diesel engines and the temperature reached is below the ignition point of the fuel.

The mechanical and electric characteristics of both types of gensets are very similar

Both engines require the following mechanical auxiliary systems to run:

- fuel system
- air intake system
- exhaust system
- cooling system
- lube oil system
- starting system.

From the electrical side, they use same kinds of generators, switchgear and controls.

Diesel engines

- Diesel engines operate at higher pressure with a compression ratio that is generally between 16:1 and 18:1.
- Diesel is the most commonly used fuel for generator sets as it is widely available and largely presents a greater efficiency compared to spark-ignition engines.
- At ambient temperatures, diesel does not form flammable vapours as its flash point is above 60° Celsius and is therefore safer to use in areas classified as hazardous, whereas gas engines require special precautions.

Gas engines

- Spark-ignition engines are designed typically with a compression ratio in the range 10:1 and 12:1.
- Although the combustion process in gas engines is at a lower pressure, they are required to withstand higher combustion temperatures.
- The engine block and most of the main components in Cat® gas engines (i.e. crankshaft, rods, bearings and pistons) are designed to withstand the same operating pressures and stress of diesel engines. This results in the production of more robust components and a greater improvement in reliability of spark-ignition engines.

When choosing between engines, consider that the initial cost for a gas engine is higher than a diesel engine, but the operating costs are lower and will result in a greater return in investment and a lower total cost of ownership and operation.

Gas gensets boast very low emissions and can utilise unconventional fuels

Landfill gas, biogas produced by anaerobic digestion of organic waste products, and coal-bed methane are all valuable resources that can contribute to the reduction of carbon emissions. The low cost of alternative fuels is an enticing advantage; however, they may present lower heat values and contain contaminants that need to be removed such as moisture, carbon dioxide, hydrogen sulfide, ammonia, siloxanes and halides that can produce acids, which may corrode engine components.

Gas impurities also effect the methane number – a critical parameter for engine performance

Low values of the methane number indicate a low resistance to detonation – an uncontrolled form of combustion that can seriously damage cylinder components and cause engine failure. The methane number is evaluated on a scale that is based on the combustion of pure hydrogen and pure methane. A value of 0 is representative of an explosive combustion that occurs when burning hydrogen, while methane with a value of 100 burns more smoothly with a high resistance to uncontrolled combustion. Appropriate design considerations, such as reducing the compression ratio or delaying ignition timing can avoid detonation and guarantee optimised performance and engine life. A fuel treatment system may be needed to purify the gas before it enters the engine and increase the initial plant costs and maintenance.

Operational differences between diesel and gas

Down and dirty with diesel

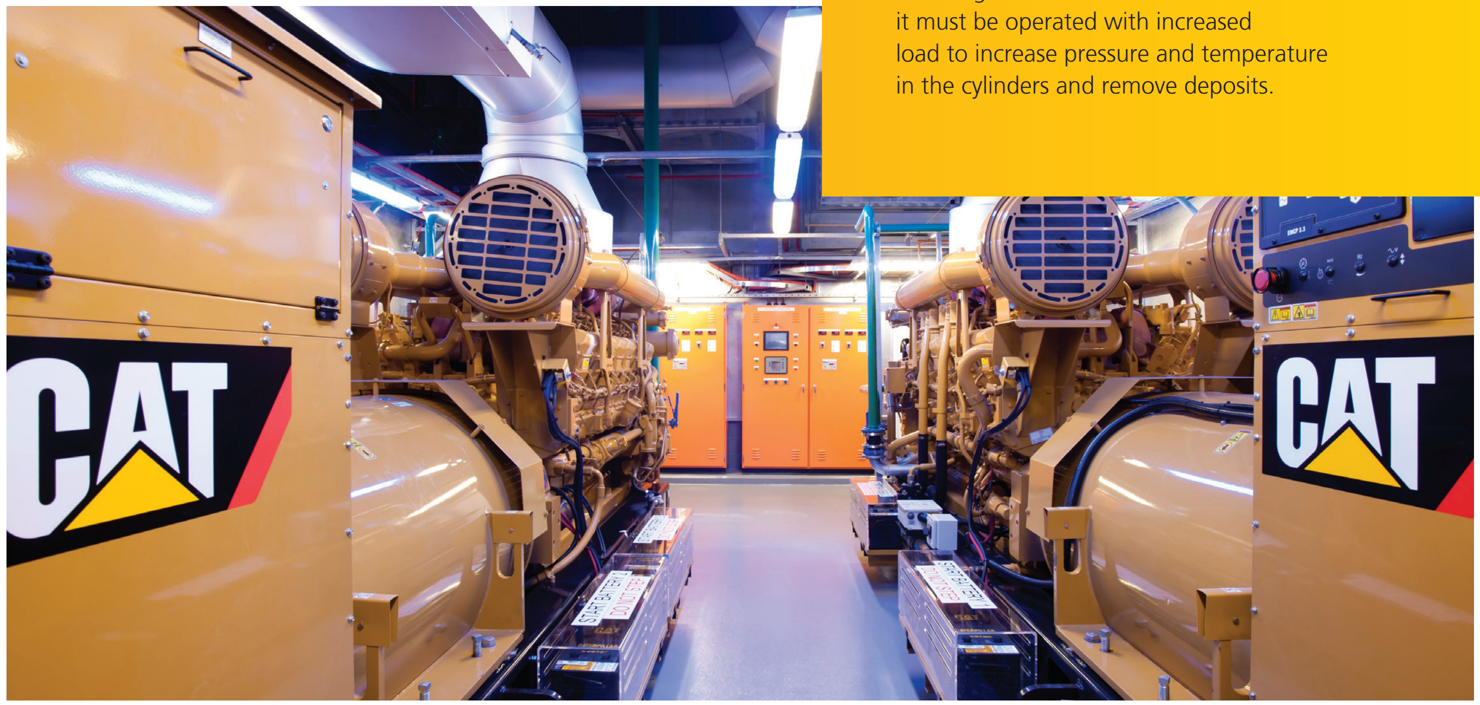
To maintain optimal performance and reliability, it is important to run standby diesel engines between 50-85 per cent of their nameplate rating and continuous gensets between 70-100 per cent. Occasional low load levels of operation can be maintained by diesel gensets if appropriate measures are taken to avoid build-up of deposits in the combustion chamber and if improved maintenance plans are adopted.

Gassing up

Gas engines should ideally operate above 70 per cent of their rating both in standby and continuous applications. Gas generator sets have more stringent requirements and time limits that must be followed:

- 30-minute operation between 0-30 per cent load factor
- 2-hour operation between 30-50 per cent load factor
- Continuous operation between 51-100 per cent load factor if the manifold air pressure is greater than the atmospheric pressure.

After a generator set has run underload it must be operated with increased load to increase pressure and temperature in the cylinders and remove deposits.



Sunshine and Waste

Organic waste food as fuel beyond the body

Blended biofuel powering flights of the future

Tyre waste driving another future energy source

"**Food waste should have a high value. We're treating it as a resource, and we're making marketable products out of it… Food waste is still carbon – a lot of carbon.**"

Roy Posmanik, Postdoctoral Researcher – Cornell University[1]

In 2014-15, about 542 kilograms per capita of non-hazardous organic wastes were generated – just over half were recovered mostly through garden composting but some energy recovery was predominantly from organics sent to landfills with gas collection systems linked to the electricity grid.[2]

But researchers at Cornell University in the US have discovered a way to capture nearly all of the energy in a food waste product, leaving little behind for landfill using a process called hydrothermal liquefaction.[3] The waste is 'pressure cooked' to produce a crude bio-oil that can be refined into biofuel, while the remaining food waste is anaerobically digested by microbes and converted into methane.[4] Currently, with the exception of agricultural and forestry biomass, extensive energy generation from solid organic wastes is not well-developed outside landfill but is promising.[5]

"**Sustainable aviation biofuel will decrease carbon emissions and support the continued growth of aviation.**"

Sustainable Aviation Fuel Users Group[6]

In January 2018, Qantas operated a dedicated biofuel flight between the United States and Australia: QF96 from Los Angeles to Melbourne was a trans-Pacific 15-hour flight using approximately 24,000 kilograms of blended biofuel, saving 18,000 kilograms in carbon emissions.

The biofuel processed from brassica carinata, a non-food, industrial type of mustard seed.

The flight was part of the partnership announced in 2017, which will also see the company work with Australian farmers to grow the country's first commercial aviation biofuel seed crop by 2020.

"**Replacing one tonne of black coal with a tonne of tyre-derived fuel can save up to 1.05 tonnes of CO^2.**"

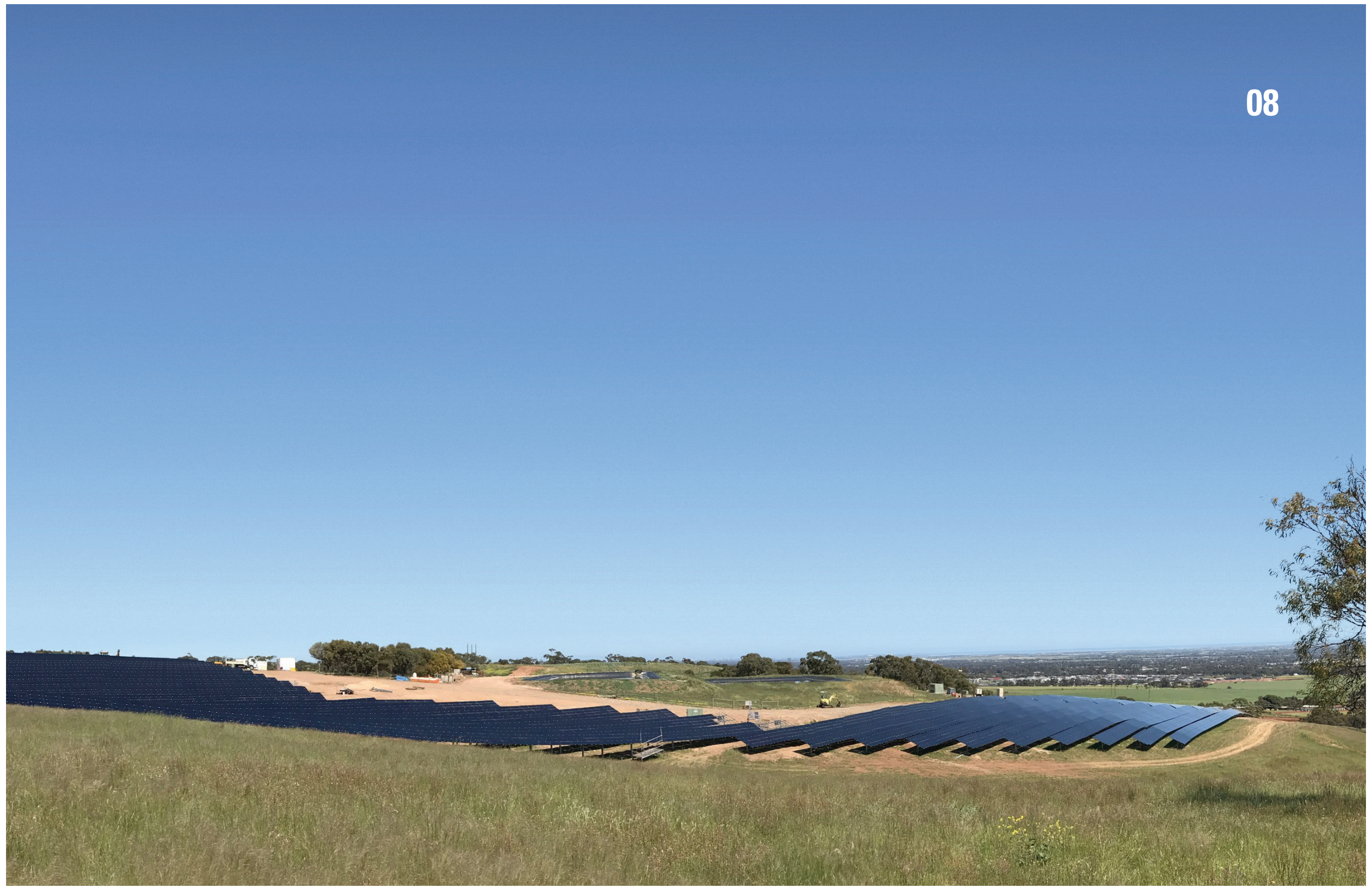
Australian Tyre Recyclers Association[7]

Around 51 million equivalent passenger units of end-of-life (EOL) tyres are generated in Australia every year[8]. Less than ten per cent are recycled; illegal dumping, burning and direct incineration presents challenges[9] – and a big opportunity.

Tyre-derived fuel (TDF) is produced when those EOL tyres (typically cut or shredded tyres and tyre chip) are converted into a product for use as fuel feedstock.

TDF is a viable alternative for fossil fuels in power stations, smelters, cement kilns and paper mills. In Victoria alone, at least 18 per cent of total annual EOL tyres are exported as TDF – offering around $100 per tonne more revenue for a tyre collector against landfill costs.[10]

1. W Clarke, B McCabe, Capturing the true wealth of Australia's waste, The Conversation, 24 August 2017. 2. B Friedlander, Cornell engineers transform food waste into green energy, Cornell Chronicle, 13 June 2017. 3. Dr J Pickin and P Randell, Australian National Waste Report 2016, Department of the Environment and Energy and Blue Environment Pty Ltd, 20 June 2017. 4. Friedlander, ibid. 5. R Posmanika, etal, Coupling Hydrothermal Liquefaction and Anaerobic Digestion for Energy Valorization From Model Biomass Feedstocks, Bioresource Technology, June 2017. 6. https://www.qantas.com/travel/airlines/sustainable-aviation-fuel/global/en#jump5 7. B Nogrady, Transforming waste into fuel with Australian innovations, from tyres to sugar cane and agave, The Guardian, 16 December 2016. 8. Inside Waste, ATRA proves TDF an attractive alternative fuel, 10 February 2017 9. A study conducted by Arcadis (previously Hyder) in 2015 cited in Inside Waste, ibid. 10. Planet Ark, Fact sheet: tyre recycling



Caterpillar's first solar plant in action on Australian soil

11,040 Cat® PV solar modules are mounted on fixed axis steel frames that contour the challenging terrain of the Adelaide foothills.

The PV solar modules are arranged into 46 strings each feeding a dedicated 25kW (SMA) inverter – the strings are then split into three separate arrays, with AC output from each collected to supply the EPSA-supplied HV transformer kiosk. The kiosk transforms the voltage to 11,000V AC for supply to the grid via the client-operated power station.

Control of the plant is achieved using the 4G wireless network to communicate between the power station and a Cat® (SMA) Cluster Controller, which relays the information back and forth to each of the 46 inverters. The controller features a web-connected online portal to provide the client with up-to-date information on the solar plant status, including current plant output, daily yield and alarms.

A key feature of the solar plant control is the dynamic reactive power control – since this solar plant is exporting to the grid, the grid voltage is affected with higher export values. To counter the ever-growing problem of grid voltage stability, the solar plant is able to dynamically change the output power factor to import or export 100 per cent of the plant's output in reactive power in a trade-off for active power. This means that the plant can help stabilise the local grid voltage throughout the day.

The solar plant has been successfully exporting green energy into the South Australian grid since it was commissioned in late-October 2017 – Cat's® first solar plant on Australian soil.

"The NAWMA renewable energy facility will save approximately 24 million litres of water each year and prevent 63,500 tonnes of carbon (co2) from being emitted into the atmosphere when compared to a traditional coal-fired power station generating the same amount of electricity."

Cat® rated

When selecting Cat® gensets, there are five basic ratings to consider

Emergency Standby Power (ESP)

ESP gensets generally run for 50 hours annually with a maximum of 200 hours. They are not designed to run overload or constantly at rated output – the typical average variable load is 70 per cent of their rating.

Standby Power

In standby power applications, the generator sets on average run for 200 hours with a maximum of 500 hours a year. Overloading is not possible and the average variable load is 70 per cent of the nameplate rating.

Prime Power

When it comes to prime power, there are no restrictions on the number of operating hours. Prime power gensets can be used in parallel with the grid and those with this configuration will be used as primary power sources generally where the national grid is not accessible. The average variable load is 70 per cent of the nominal rating. Overload is available but limited to 10 per cent of power for one in 12 hours, and below 25 hours a year.

Continuous Power

Continuous power applications are characterised by unlimited operating hours. These engines are generally used for base load and present a non-varying load factor between 70-100 per cent of their nameplate rating. Continuous gensets can be used in parallel with the grid.

Mission Critical Standby Power (MCSP)

MCSP presents an average variable load factor of 85 per cent of the nameplate rating with 100 per cent power output achievable for five per cent of the operational time. In most cases, the operational time is 200 hours for a maximum of 500 hours per year. Typical applications with MCSP include hospitals, hotels, data centres, industries and cell towers.

Standby gensets are necessary in all circumstances requiring an emergency backup power source during possible power outages. They are used where a reliable source of primary power, like the national grid, is available. Power production by the genset parallel to the grid is not permitted.

Think Cat®

The Cat® engine portfolio comprises of a broad selection of advanced engines with proven reliability and durability to suit a wide range of applications. They provide a secure and reliable supply of power to businesses, industries and communities.

Standby generators provide power to businesses during power outages; safeguarding organisations that require critical power, such as hospitals, data centres, utilities, finance institutions, telecommunications, food handling etc.

With soaring power prices and the sway towards the reduction of pollutant emissions, Cat® generator sets can play a vital role in power generation. Cat® engines can also serve in cogeneration applications, producing heat as well as power, providing high fuel conversion efficiencies, reducing energy bills and emissions.

Caterpillar® also provides Hybrid Energy Solutions (HES). EPSA delivers reliable integration of renewable energy, integrating renewable options with traditional gas and diesel power generation. EPSA is the only fully integrated service provider of Cat® Hybrid Energy Solutions, offering purpose-built products and project services.

The ratings game

From emergencies to mission critical operations, reliable and efficient power is imperative. To evaluate what is best for your situation and application, refer closely to the ratings.

Choosing the appropriate rating to fit your specific application is imperative to:

- avoid excessive fuel consumption
- lower running costs
- improve service life
- reduce engine maintenance.

For example, selecting a standby genset for a continuous application could reduce the design life of your engine and its components. And excessive wear can cause unplanned maintenance requirements. Choosing a continuous genset in a standby application could reduce engine design life, power losses and increased component wear. It can also cause deposits to develop inside the cylinders and behind the piston rings resulting in cylinder liner polishing.

The presence of exhaust manifold slobber is an immediate sign that a diesel engine has been operating for sustained periods below recommended loading.

Low pressure and temperature in the cylinders caused by underloading leads to improper sealing of the piston rings with oil entering the cylinders and poor combustion, which can produce a black oily leakage from the exhaust manifold.

Engine selection requires consideration of all detailed information relevant to installation requirements

This includes peak load, duty cycle, hours of annual operation and service requirements. Other installation environment elements affecting engine selection include ambient temperature, altitude, size and weight of the genset and emission restrictions.

Choose EPSA and the global reputation of Caterpillar® to experience a superior investment and reliable performance.

There are thousands of Cat® generators providing prime power, standby or emergency support in commercial and residential operations across Australia provided by Energy Power Systems Australia (EPSA) – the exclusive Cat® dealer in Australia.

Caterpillar® is renowned for reliability, safety and dependability with Cat® power systems boasting a proven lowest total cost of ownership and highest return on investment. EPSA has significant experience in the planning and construction of gas and diesel-powered generation sites and access to world-leading generator technology and equipment.

Let EPSA help you prepare for the energy crisis so you don't lose power and benefit from EPSA's technical knowledge and engineering expertise and over 100 Cat® Dealer Partners for service and support across Australia.

GLOBAL COVERAGE, LOCAL SUPPORT.

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