Rolls-Royce Solutions America Inc.
39525 MacKenzie Dr.
Novi, MI 48377
T +1 248 560 8000

Company Name: Rolls-Royce Solutions America Inc. July 13th, 2022
Address: 39525 MacKenzie Dr, Novi, MI 48377 USA
Company Contact & Information:

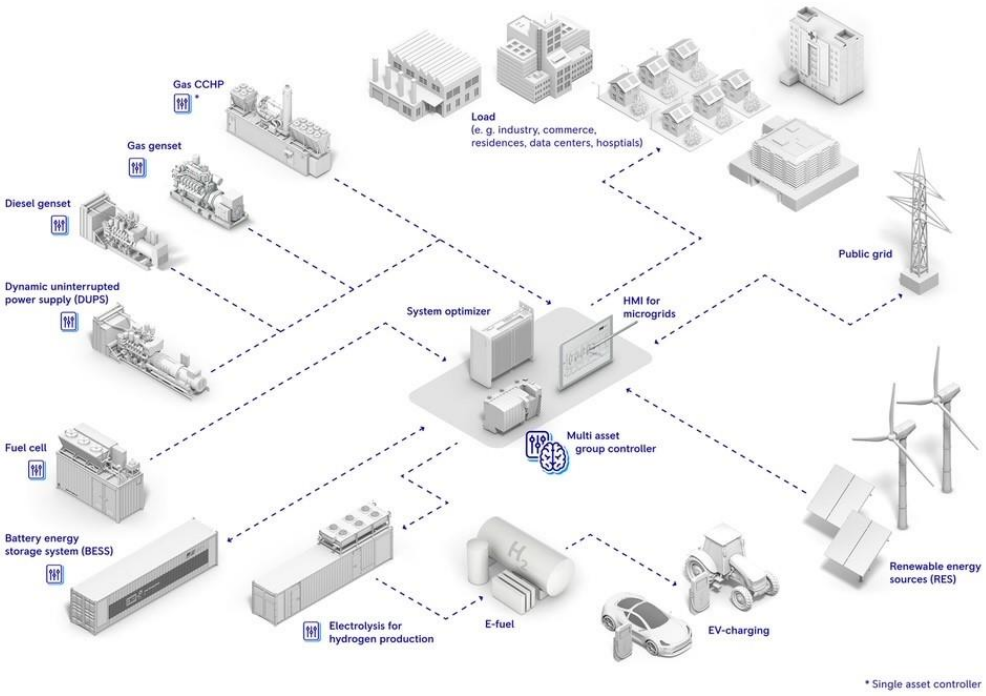
- Alexander Darovskikh, *Sr. Sales Manager - Microgrids North America*
  - +1 (786) 423-0670 / alexander.darovskikh@ps.rolls-royce.com

Summary of Services: (See attached: *"Rolls-Royce Company Overview"*)

- Energy Generation & Storage Equipment:
  - Battery Energy Storage Systems
  - Diesel Rotary Uninterruptible Power Supply (DRUPS)
  - Continuous Gas Gensets
  - Standby Diesel
  - H2 Electrolyzers & Fuel Cells
  - Microgrid Controllers
- Services
  - Microgrid Modelling
  - Equipment/Solution Provider, Installation, Commissioning & Training
  - Monitoring, Maintenance & Repair
- Relevant Experiences: (See attached files - listed below)
  - *"Case Study - Rolls-Royce Microgrid - Daly River Microgrid Australia"*
  - *"Case Study - Rolls-Royce Microgrid - Electriz Pork Processing Mexico"*
  - *"Rolls-Royce Microgrid References"*

What role(s) from Section 3 would the respondent fulfill?

- Please provide a brief description of relevant experience for each role. (See attached files - listed below)
  - *"Rolls-Royce Company Overview"*
  - *"Rolls-Royce Solutions Guide"*
  - *"Whitepaper - Rolls-Royce Microgrid Design"*
  - *"Rolls-Royce Microgrid Controls"*
- Please provide any edits to the role's definition or responsibilities.
  - N/A
- Optional - Within this section, consider providing a hypothetical organizational chart, a Responsible, Accountable, Consulted, and Informed (RACI) matrix, or other visual to help define roles and relationships. (See graphic below)
  - ***Role:*** "Design and Construction Team (Engineering, Procurement, Construction) of Distribution Infrastructure, Distributed Generation, and/or Microgrids."
  - Rolls Royce would specifically size and provide turn-key microgrid equipment. If EPC work outside of our scope is required, Rolls-Royce would work with pre-qualified EPC partners.



mtu Microgrid – Products, Solutions & Partner Support

Are there other roles not identified in Section 3 that the County should be aware of?

- Rolls-Royce can potentially provide energy as a service. Although in the early stages of development, an owner/operator and off-taker relationship can occur for the right project. Needs further discussion.

What duties would these new roles perform?

- Providing energy for a cost. Management and maintenance of the microgrid would be done by Rolls-Royce whereas the customer would received reliable and inexpensive energy.

What else should the County know about each newly defined role?

- What challenges or barriers could you see for your role(s) as envisioned by the County and what might be ways for the County to address those challenges?
    - Energy storage and Microgrids are simple concepts; nevertheless, they become complex when sizing the right assets and solution. A challenge we see is the oversimplification of this process. Therefore, we recommend a thorough analysis of the application, available resources and loads before assigning costs to the overall project. Our objective is to provide the best blend based on historic, current and future energy consumption. To achieve this, transparency is best via a thorough analysis.
- What's the typical timeline/cycle for the respondents proposed role(s)? (e.g. it takes X year(s) to find customers for a microgrid and build it)
    - The timeline/cycle between initial inquiry to implementation depends on the customer's needs. Realistically, a technical evaluation can take anywhere from 1 to 3 months depending on the complexity of the system, available data and alignment between teams. Once the microgrid architecture and assets are established, equipment lead times make take an additional 40 to 52 weeks. Controls and programming are done in parallel then tested again onsite during the

commissioning process. This can take as little as two weeks or more depending on the number of installations.

- Would the respondent meet with the County and / or its representatives to present ideas and to answer follow up questions?
    - Yes, our team can certainly meet with the country.

Optional / Encouraged Information:

- Published case studies:
    - Granjas Carrol / Electriz case study & video presentation link)
        - ***Granjas Caroll - Reliable off-grid power supply (en/es) - YouTube***
        - *"Case Study - Rolls-Royce Microgrid - Electriz Pork Processing Mexico"*
    - *"Case Study - Rolls-Royce Microgrid - Daly River Microgrid Australia"*
    - ***Media Center (mtu-solutions.com)***
- Press releases:
    - ***Press releases | Rolls-Royce - Rolls-Royce makes Duisburg container terminal climate-neutral with mtu hydrogen technology***
    - ***Media Center (mtu-solutions.com)***
- Technical / Marketing Material:
    - *"Technical Description - Rolls-Royce Grid EnergyPack Battery Energy Storage Solution"*
    - *"Rolls-Royce Energypack Brochure"*
    - *"Rolls-Royce Hydrogen Ecosystem"*
    - *"Rolls-Royce Microgrid Controls"*
    - *"Rolls-Royce Microgrid Overview"*
    - *"Whitepaper - Rolls-Royce Microgrid Design"*
- Detailed company profile information:
    - *"Rolls-Royce Company Overview"*
    - *"Rolls-Royce Solutions Guide"*
- Questions that the County should consider in the development of potential RFQs / RFPs
    - How many types of generation / storage assets does the respondent have in their Microgrid product portfolio?
    - What experience does the respondent have with integrating distributed energy resources (ex: gas, diesel and renewables)
    - BESS capacity expectations (BOL / EOL)?
    - Can an analysis be provided up front at no cost?
    - What kind of support & service is available for each sub-system? Network

Appendix Questions:

1. **Vision:**

- What is your vision as to how the County Utility could fit into the emerging energy ecosystem?
    - We see this as an outstanding opportunity for the Cuyahoga Country to optimize energy usage, align localized generation and secure grid independence.
- How might the County Utility improve services compared to traditional systems?
    A microgrid complete with energy storage will find the perfect balance between local renewable resources, more robust dispatchable assets (diesel & gas) while interfacing with loads. This will reduce utility and fuel costs while driving efficiency and independence.
- How would you propose building a system in a manner that constrains costs based upon available loads, yet is flexible enough to adapt to new end users who are attracted to the system?

- Yes, this is possible through augmentation of the energy storage system and other generation. When our team models your grid, multiple scenarios will be tested, and growth contingencies will be considered. After an analysis, a best-case scenario will be selected for immediate implementation. In addition, a roadmap can be presented to meet future needs.

- How might your approach be different for new developments, such as industrial or commercial parks, versus existing customers? Would you envision merging district energy or transportation or hydrogen into the development?
  - The merging of district energy, transportation (especially EV's) and hydrogen is possible. Like our previous answer, the process of modelling will consider growth and new energy needs. Granularity (load sizes an da list of vetted assumptions) will dictate the appropriate assets/sizing.
- How might you go about marketing your vision to end users?
  - Completed projects are followed up with case studies, press releases and video productions. For pre-sales, our process follows configured product presentations and detailed modeling overviews. TBD – What does the country needs to incentivize local organizations to participate?

2. Business Economic Models:

- How do you envision revenue flowing through the various entities?
  - TBD – N/A
- The County envisions a scenario where the developer/concessionaire is compensated through a pass-through model from power purchase agreements with individual customer/off-takers. Do you see any problems with this model or have suggestions on possible alternative compensation models?
  - N/A
- What process would you take with the County to design customer billing (i.e., tariffs) in a fair and transparent way?
  - N/A
- What types of tariffs are needed to support the County initiative?
  - N/A
- Would you be willing to provide the capital for the scope/role the County envisions?
  - Rolls-Royce cannot provide capital for projects. Power or Energy as a service may be considered but requires further discussions.
- How would you ensure prices for specific projects (e.g. new distribution line or a microgrid) are competitive?
  - TBD

3. Organization Models:

- Would you be willing to contract directly with the County to be responsible for the full scope of this initiative?
  - Rolls-Royce would prefer to have an EPC act as a prime contractor.
- What are the tradeoffs for one firm serving all roles versus separate firms serving separate roles?
  - Integration is typically the advantage of having one firm. However, Rolls-Royce will already be integrating the assets whereas the EPC will handle local codes and other specifics particular to the territory they represent.

- How would you structure the relationship between yourself, the County, and other entities (if applicable)?
  - TBD

- What level of responsibility, if any, would you be willing to have for microgrid project identification and development, customer identification and selection, customer contract negotiations, etc.?
    - If introductions to local participants can be made, then our team can qualify the likelihood for each opportunity and solution.
- What level of pre-design and other information or assurances would you need to respond to an RFP/Q and engage in negotiations with the County?
    - TBD
- What level of commitment would you need to have from potential County utility customers to respond to an RFP/Q and engage in negotiations with the County?
    - TBD – High peak tariffs, poor power quality, space for renewable generations etc.

4. Concession Agreement & Other Contracts:

- What contracts will need to be in place and between what entities? (Attached)
    - "Rolls-Royce General Terms and Conditions of Sale V-601"
- What critical terms and conditions need to be addressed? Attached)
    - "Rolls-Royce General Terms and Conditions of Sale V-601"
- What term lengths would respondent be comfortable with for a distributed energy or microgrid PPA?
    - With the right contingencies, maintenance and planning, Rolls-Royce is comfortable assessing any term lengths for a distributed energy or microgrid PPA. Our goal is to match the right solution and contract terms for our customers.
- What additional information would you need to sign a contract with the County for a scope of work?
    - We would require a detailed analysis before any contracts can be executed. Load profile data and modeling are essential.

5. Initiative Timelines:

- What is a typical turn-around time for you to sign a contract for your role(s)?
    - Assuming we have enough material for an analysis, we require between 2 to 8 weeks (based on the complexity of the system) to provide a quote. PPA / PEaaS is not defined at this time.
- What is a typical development time for a microgrid, from customer recruitment through operation? What are the major milestones? Development times.
    - TBD – unique to each customer.
- What impact on this initiative do you foresee, if any, from the current supply chain disruptions?
    - We foresee supply chain disruptions (COVID / Ukraine) to remedy themselves within the year.

6. Technology:

- What technologies should the County consider to address power issues for commercial and industrial customers? (Power quality issues vs. short power outages vs. long power outages).
    - Batteries, UPS, and backup diesel are ideal for outages. UPS systems can handle short interruptions while kickstarting diesel systems for longer backup. Batteries can also be sized for backup loads but this not usually their primary application.
- Can you provide high-level cost estimates for distribution infrastructure, distributed generation, and/or microgrid technologies across different sizes? (e.g. 14.4 kV feeder, 1 MW/1 MWh battery, 5 MW solar PV)
    - Yes, energy storage pricing can be provided but more information will be needed. Beginning of Life, End of Life (BOL / EOL) capacity, application, available space, etc. We request that time is set aside for a separate discussion.

- Are there ranges of economic feasibility that the County should be aware of when considering on-site generation, storage, etc. For example, do projects only over X MW prove to be economically feasible in your experience?
    - Feasibility will depend on the value assigned to each objective. Tangible value is demonstrated through cost reduction such as peak shaving whereas the role of renewable integration and image are intangible value. In this regard, both smaller and large-scale solutions are possible depending on what you are trying to measure.
- How should cybersecurity of the utility, individual microgrids, customers, or other pertinent entities be ensured?
    - Our solutions will integrate into the preferred cybersecurity platform. Industry experts who specialize in cybersecurity must be consulted for this role.
- What is your approach to managing: capacity and transmission peak load contributions? Energy market arbitrage? Frequency regulation?
    - Our solutions can handle all three applications and more. Usually, a hierarchy of importance is assigned to manage each benefit. Depending on the conditions, the battery (or other solutions within the microgrid) will engage to produce the desired outcome.

7. Diversity, Equity, and Inclusion:

- How will you ensure Diverse, Equitable and Inclusive (DEI) partnership(s) throughout this Initiative?
    - TBD – Depends on RFP initiatives.

8. Other:

- What potential risks, setbacks, or hurdles do you see for this Initiative?
    - To be determined after meeting with County.
- Please provide any other information that you feel would be pertinent to the County at this stage of the process. (Complete attachment list)
    - *"Case Study - Rolls-Royce Microgrid - Daly River Microgrid Australia"*
    - *"Case Study - Rolls-Royce Microgrid - Electriz Pork Processing Mexico"*
    - *"Rolls-Royce Company Overview"*
    - *"Rolls-Royce Energypack Brochure"*
    - *"Rolls-Royce General Terms and Conditions of Sale V-601"*
    - *"Rolls-Royce Hydrogen Ecosystem"*
    - *"Rolls-Royce Microgrid Controls"*
    - *"Rolls-Royce Microgrid Overview"*
    - *"Rolls-Royce Microgrid References"*
    - *"Rolls-Royce Solutions Guide"*
    - *"Technical Description - Rolls-Royce Grid EnergyPack Battery Energy Storage Solution"*
    - *"Whitepaper - Rolls-Royce Microgrid Design"*

Contact Information

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Dear Cuyahoga Country Leadership & Administrative Team,

Thanks for developing this RFI and your interest in microgrid solutions. The Rolls-Royce team is very excited to support this initiative and collaborate with your stakeholders. Please review our responses and please let us know if you have any questions.

Sincerely, Alexander Darovskikh

Alexander Darovskikh

Hybrid Solutions

SUSTAINABLE HYBRID SYSTEM ENSURES COST-EFFECTIVE SUPPLY IN AUSTRALIA'S NORTHERN TERRITORY

Many aboriginal communities in the Northern Territory of Australia power their homes by electricity generated from diesel power plants. With the aim of reducing the dependence on diesel fuel and acquire the advantages of using renewable energy, Power and Water Corporation started a project located in small community of Daly River. The project expanded the power plant by implementing solar modules and a battery storage unit from the Rolls-Royce solution brand, *mtu* (former Qinous). The hybrid system project achieved a reliable 24/7 energy operation and currently reduces fuel consumption by 50 percent.

A Rolls-Royce solution

Who Power and Water Corporation
What Hybrid power supply system consisting of diesel gensets, solar cells and battery storage system
(Previous model of todays *mtu* EnergyPack QL)
Where Daly River (also known as Nauiyu), Australia

With a population of around 250,000, the Northern Territory in Australia is sparsely populated. The majority of the population lives in the small towns of Darwin, Palmerston and Alice Springs. About 20 percent of the population live in small and remote communities. The energy supply of these places is mainly generated by diesel generators. The utilization of renewable energy at the Northern Territory is below the national average.

This project was jointly funded by the Australian Government via ARENA and the Nothern Territory Government, both parties aim to reduce diesel consumption and promote the usage of renewable energy. Daly River, with its 500 inhabitants, was the first community that implemented a battery storage to their energy system. Additionally, Titjikala, a small town in Central Australia, has also been selected as the next location for a hybrid project where Daly River's acquired knowledge is essential for the new success.

"With an average of 12 hours of sunshine a day, Daly River has the best conditions to use solar energy and reduce fuel consumption. In addition, the location is easy to reach all year round due to road accessibility - an important decision-making factor for technical service access even during rainy season," explains former Power and Water project manager Dow Airen. The government-owned corporation is responsible for the transmission and distribution of electricity, and also handles water supply and sanitation in the Northern Territory.

The hybrid system ensures reliable and sustainable power supply

Daly River is about 220 kilometers south of the coastal city of Darwin. The favorable weather conditions and dazzling views to the river make the village a popular destination for anglers and weekend tourists. Freshwater and saltwater crocodiles live in the picturesque tidal river. During April and May, sport fishermen come to fish Barramundi, predatory fish from the giant bass family.

Model project for Power and Water
To reduce dependence on diesel fuel and promote the use of renewable energy, Power and Water Corporation launched a model project in the small community of Daly River. It expanded the existing diesel power plant to include solar modules and a battery storage unit from Rolls-Royce's *mtu*.

Place of residence and weekend destination
The 500 inhabitant town of Daly River, located about 220 kilometers south of Darwin on the river of the same name, is a popular destination for anglers and weekend tourists.

With a decentralized hybrid power supply system, the small community has been characterized by another special feature since 2015. “The system combines regenerative and fossil energy sources and stores the electricity in a battery storage as needed. This mix ensures the power supply for the community and the surrounding settlements - reliable, efficient and sustainable,” explains Dow Airen.

Before the program commenced, the original power plant consisted of three powerful diesel generators for regular and backup operation depending on the load profile. Power and Water integrated into the existing power plant a photovoltaic system with a megawatt output and an *mtu* battery storage unit with an output of 800 kW and a capacity of 1.9 MWh.

“This mix ensures a reliable, efficient and sustainable power supply for the community and surrounding settlements.”

Dow Airen
Former Project Manager from Power and Water

Battery Storage: Previous model of todays *mtu* EnergyPack QL compensates for varying energy requirements

“The battery storage system serves as an important buffer if the energy generated does not match the actual load profile of the municipality. It stores the excess energy from the photovoltaic system at peak times and thus ensures the optimal usability of the solar energy produced,” explains Steffen Heinrich from Rolls-Royce Solutions Berlin (formerly Qinous).

The battery storage system was prefabricated and delivered to Daly River in a factory tested condition. It could be put into operation quickly and smoothly. It is ideally suited for the extreme weather conditions in the dry and rainy seasons in Daly River. The closed housing protects all components from temperature changes, dust, moisture and insects.

“The battery storage system stores the excess energy from the photovoltaic system at peak times and thus ensures the optimal usability of the solar energy produced.”

Steffen Heinrich
Rolls-Royce Solutions Berlin (formerly Qinous)

The inverter concept prevents constant air exchange with the surroundings. The water-cooled inverter with a nominal output of 1.5 MVA is thermally designed for continuous charging or discharging operation of 800 kW. At ambient temperatures below 45 °C, an output of up to 1 MW is possible. The combination of higher kilowatt and kilowatt hour expandability is expected to ensure that the reliable battery storage device will last at least 10 years.

The battery storage design has additional space that can be used in the Daly River project if required. “There are currently 12 racks, i.e. battery racks, in use. The number can be expanded to 14, which enables an additional capacity of 17 percent. This option and the additional land available for the expansion of the photovoltaic system make it possible to expand the hybrid system with increasing energy requirements over the life of the battery storage system”, says Steffen Heinrich from Rolls-Royce Solutions Berlin.

Battery storage
The battery storage was prefabricated, factory tested and shipped to Daly River. The closed housing protects all components against temperature changes, dust, humidity and insects. A constant air exchange with the environment is prevented by the inverter concept.

Possible extension
The battery storage design provides additional space in the battery room for further project extensions i.e. For the Daly River project, 12 battery racks, are in use. The number can be expanded to 14, providing an additional 17 percent capacity.

Less fuel consumption, more solar energy

With the expansion of the existing plant to a hybrid power supply system, Power and Water was able to achieve its project goals. “The share of renewable energy sources used in Daly River has been more than the designed target of 50 percent since the transition to regular operation. The diesel generators are completely switched off on average for 10 hours a day,” summarizes Dow Airen from Power and Water. Fuel consumption was reduced by 50 percent. This makes the community significantly less dependent on diesel fuel, which is subject to volatile prices and unpredictable supply chains.

Follow-up project in Titjikala in the Northern Territory

When Power and Water embarked on a second diesel/battery project, Rolls-Royce were the successful tenderer for the energy solution component of the project through an open tender process. The power plant of Titjikala consists of three diesel generators, one photovoltaic plant (400kW) and additionally implemented a battery storage (970 kW). The goal is to reduce fuel consumption by 66 percent after the plant is completed in December 2020. Similar to the Daly River project, the battery stores excess solar energy and enables the diesel engines to be switched off during the day. When the battery storage is discharged at night, the diesel engines start up again. The transitions between on and off states occur seamlessly without interrupting the power supply.

“The share of renewable energy used in Daly River is 50 percent since their transition to battery storage. The diesel generators are completely shut down for an average of 10 hours per day”

Dow Airen
Manager Energy Strategy from Power and Water

Pictures: Power and Water, Rolls-Royce, http://dalylanguages.org/index.php

Rolls-Royce provides world-class power solutions and complete lifecycle support under our product and solution brand *mtu*. Through digitalization and electrification, we strive to develop drive and power generation solutions that are even cleaner and smarter and thus provide answers to the challenges posed by the rapidly growing societal demands for energy and mobility. We deliver and service comprehensive, powerful and reliable systems, based on both gas and diesel engines, as well as electrified hybrid systems. These clean and technologically advanced solutions serve our customers in the marine and infrastructure sectors worldwide.

News Release

February 26, 2019

Rolls-Royce supports pork processing facility with power plant in island mode

- *MTU Onsite Energy delivers gas and diesel gensets for power plant that provides electricity to Mexican hog industry*
- *Microgrid solution which operates in full island mode due to missing grid availability*
- *Gensets are capable of handling the pork processing facility's altitude of 8,000 feet above sea level*

Mankato, MINNESOTA – Rolls-Royce continues its expansion into the Latin America market through the supply of MTU Onsite Energy generator sets for the power plant of a new pork processing facility in Mexico. It is operated by one of the country's largest and most technically advanced producers. The power plant is supported by four MTU Onsite Energy Series 4000 gas generators and one MTU Onsite Energy diesel generator under one overall control system, making this the first microgrid solution of its kind in the Americas for MTU. The site is not connected to the grid; therefore, the power solution is completely independent.

Local distributed energy systems expert, Electriz, S.A. de C.V., was awarded the business, leading engineering, procurement and construction for the project, as well as operation and ongoing maintenance of the power plant. Electriz's ability to customize and deliver highly-efficient systems was a success factor to win the project.

Alfredo Carrasco, Latin American senior sales manager of gas power systems at MTU Onsite Energy, said: "As the customer has to rely 100 percent on his own grid, the challenge was to deliver a complete solution which ensures grid stability on a high level. Therefore, the reliability and

efficiency of the MTU Onsite Energy systems were major factors in the decision of the customer. The ability of the team to meet the customer's stringent requirements of gas, diesel and an integrated control system from a single supplier also contributed to us being awarded this project."

The four gas units are the highly-rated 20-cylinder Series 4000 natural gas systems delivering all together 7.7 MW electrical power, capable of handling the pork processing facility's altitude of 8,000 feet above sea level with the lowest derating, ensuring maximum power availability at the site. In a second phase, it is planned to use the heat out of the exhaust gas, the oil cooler and the mixture cooler to produce steam and hot water which can be used in the production processes.
A single 16-cylinder Series 4000 diesel generator system with an electrical output of 2 MW is tasked with absorbing greater load blocks than the natural gas units, offering long-term stability to the power plant. The diesel unit will run continuously with loads as low as 10 percent to minimize fuel consumption, allowing the natural gas units to produce more energy. MTU Onsite Energy's MCS master control panel integrates plant control and remote operation, and all systems run in isolation from the power grid, providing reliable, stable and efficient electrical power to the entire facility.

The pork processing facility, located in Veracruz, Mexico, features a power plant that will operate using three different fuel sources, including biogas from livestock waste in a later stage. With the help of the flexible MTU Onsite Energy systems, the plant will have the ability to double its power capacity in the future. The customer already owns and operates a combined heat and power (CHP) plant at a nearby facility using a medium-speed Bergen gas generator unit from Rolls-Royce.

The systems are expected to begin full operation this month.

About Rolls-Royce Holdings, plc.

1. Rolls-Royce pioneers cutting-edge technologies that deliver the cleanest, safest and most competitive solutions to our planet's vital power needs.

2. Rolls-Royce Power Systems is headquartered in Friedrichshafen in southern Germany and employs around 10,000 people. The product portfolio includes MTU-brand high-speed engines and propulsion systems for ships, power generation, heavy land, rail and defence vehicles and for the oil and gas industry. Under the MTU Onsite Energy brand, the company markets diesel gensets for emergency, base load and peak load applications as well as cogeneration plants using gas engines for the combined generation of heat and power. Bergen medium-speed engines power ships and power generation applications.

3. Rolls-Royce has customers in more than 150 countries, comprising more than 400 airlines and leasing customers, 160 armed forces, 4,000 marine customers including 70 navies, and more than 5,000 power and nuclear customers.

4. Annual underlying revenue was $21.2 billion in 2017, around half of which came from the provision of aftermarket services. The firm and announced order book stood at $110.7 billion at the end of December 2017.

5. In 2017, Rolls-Royce invested $2.0 billion on research and development. We also support a global network of 31 University Technology Centers, which position Rolls-Royce engineers at the forefront of scientific research.

6. Rolls-Royce employs almost 55,000 people in 50 countries. Approximately 19,400 of these are engineers. The Group has a strong commitment to apprentice and graduate recruitment and to further developing employee skills. In 2017 we recruited 313 graduates and 339 apprentices through our worldwide training programmes.

For further information, please contact:

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Rolls-Royce Power Systems

A World of Solutions

A Rolls-Royce solution

The Rolls-Royce vision

Rolls-Royce pioneers cutting-edge technologies that deliver the cleanest, safest and most competitive solutions to fulfil our planet's vital power needs.

A Rolls-Royce solution

Rolls-Royce group

A world-class technology company, built on three strong and complimentary business units.

Power Systems being the groups 2nd largest business and frontrunner in electrification.

A Rolls-Royce solution

Civil Aerospace

35
types of commercial aircraft powered by us

13,000
engines in service around the world

26,100
total employees

8,107m
underlying revenue

Defence

150
customers in over 100 countries

16,000
engines in service around the world

9,900
total employees

3,250m
underlying revenue

Power Systems

>40,000
customers in 13 different industries

20,000
reciprocating engines sold per year

10,400
total employees

3,545m
underlying revenue

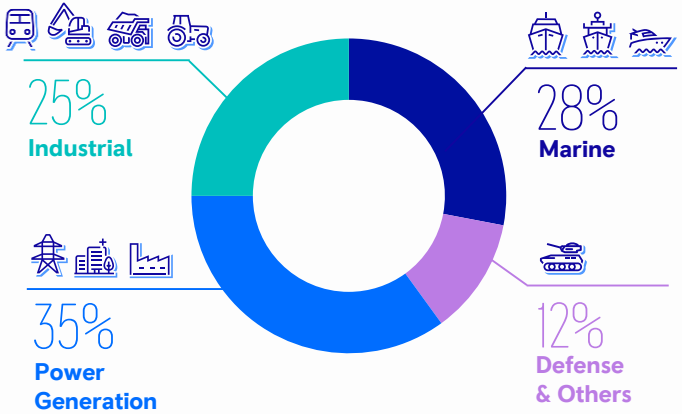
Power Systems at a glance

Revenue 2019

£3,545m

Employees

10,400



A Rolls-Royce solution

Rolls-Royce with its strong solution brand: MTU

We at Rolls-Royce provide world-class power solutions and complete life-cycle support under our product and solution brand MTU.

mtu A Rolls-Royce solution

We strive to develop climate-neutral drive and power generation solutions by utilizing the potential of digitalization and electrification.

We deliver and service comprehensive, powerful and reliable systems, based on both gas and diesel engines, as well as electrified hybrid systems.

These clean and technologically advanced solutions serve our customers in the marine and infrastructure sectors worldwide.

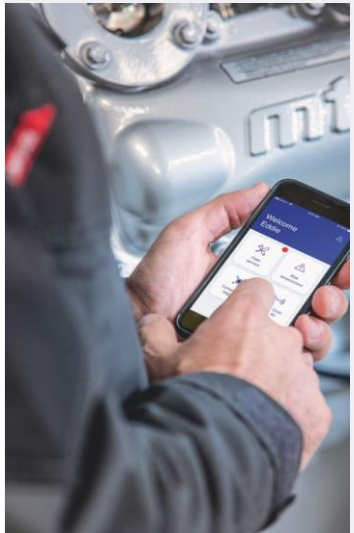
Our mission

We anticipate the vital power needs of Marine and Infrastructure customers globally by creating interconnected solutions admired for their lifecycle performance, energy optionality and responsiveness.





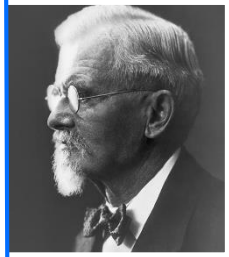







A Rolls-Royce solution

Building on a successful 110-year history



1909

Wilhelm & Karl Maybach found "Luftfahrzeug-Motorenbau" GmbH

1969

The company changes its name to "Motoren- und Turbinen Union" (MTU)

2006

MTU becomes part of Tognum AG and is publicly traded at FWB1 for 2 years

2011

Rolls-Royce & Daimler jointly acquire Tognum which is renamed to Rolls-Royce Power Systems

2019

Power Systems starts rebranding; MTU brand as "a Rolls-Royce solution"

110-years of positive earnings and cash flow

1910

Maybach AZ engine is used for the first time in Zeppelin LZ6

1996

The Series 4000 line is introduced – the first engine with common-rail direct fuel injection

2011

Power Systems enters the continuous gas market under its MTU Onsite Energy brand

2014

Rolls-Royce buys shares of Daimler and takes full ownership of Rolls-Royce Power Systems

2020

Power Systems acquires KINOLT

A Rolls-Royce solution

Global market trends: Catalyst for change

Triggering demand for new solutions

A Rolls-Royce solution

Decarbonization

Decentralization

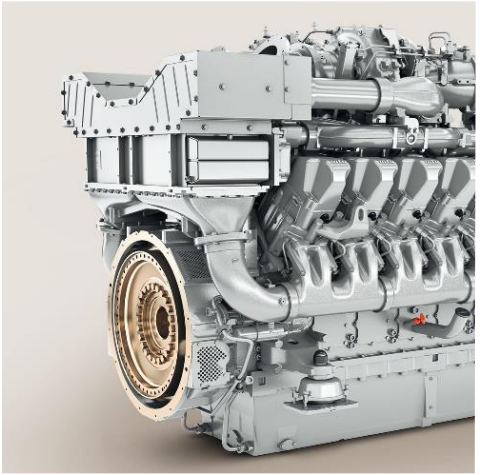
Electrification

Digitalization

Power Systems strategy PS2030

Our transformation from a traditional engine manufacturer to an integrated & sustainable solution provider

1 Reshape Core



Strengthen our traditional system & engine portfolio

2 Become a Solution Provider

Expand existing portfolio with new components, digital products and services

3 Lifecycle Services

Transform our business model to leverage entire product lifecycle

A Rolls-Royce solution

Global presence

Represented in over **175** Countries

More than **420** Distributor and service partners

More than **1,200** Locations worldwide

- HQ / Hubs
- Factories
- Joint Ventures
- Customer Care Center
- Subsidiaries

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A comprehensive product and solution portfolio

Original Equipment

- Diesel engines
- Power modules diesel & gas
- Gas engines
- Open power units diesel & gas
- PowerPacks
- Emission reduction technologies
- Gensets
- Energy storage

Systems

- Automation systems
- Microgrids
- Diesel systems
- Gas systems
- Drive systems
- Propulsion systems
- Rail hybrid
- Marine hybrid

Lifecycle Solutions

- Connectivity
- ValueCare agreements
- Advanced trouble shooting
- Predictive maintenance
- Fleet management
- Digital solutions
- Operations analytics
- Reman

Business areas of Power Systems

Marine & Defense

Solutions for

- Commercial marine
- Yacht
- Naval & authorities
- Land defense

Power Generation

Solutions for

- Continuous power
- Prime power
- Grid and stability power
- Standby and mission critical power

Industrial

Solutions for

- Rail
- Oil & gas
- Mining
- Construction & industrial
- Agriculture

Service solutions

Digital solutions for smart maintenance and asset management, 24/7 service and technical support, dedicated training and documentation

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Marine & Defense

MTU PRODUCTS AND SOLUTIONS

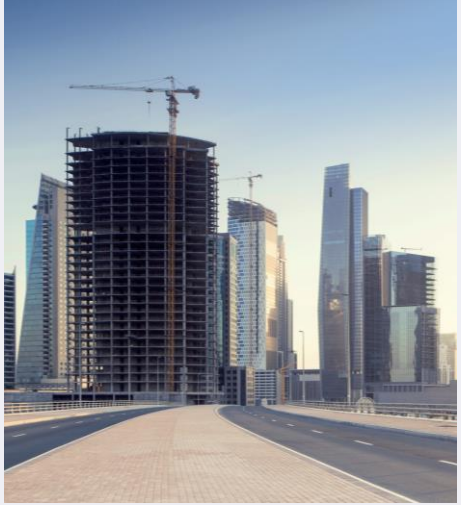
- Diesel Systems
- Gas Systems
- Battery Systems
- Marine Gensets
- Combined/ Hybrid Systems
- Integrated Propulsion Systems
- Auxiliary & Noise reduction solutions
- Emission reduction solutions
- Control, Automation & Integrated Bridge

SERVICE SOLUTIONS

- ValueCare Agreements
- Upgrades & Modernizations & Retrofit
- Repower & Overhaul Capabilities
- Project Development/ Engineering
- Integrated Logistic Support (ILS)
- Equipment Health Management System

A Rolls-Royce solution

Power Generation



MTU PRODUCTS AND SOLUTIONS

- GenDrive Engines
- Diesel & Gas Gensets
- Control / Automation
- Dynamic UPS
- Battery Systems
- Microgrid & Hybrid Solutions

SERVICE SOLUTIONS

- ValueCare Agreements
- Upgrades & Modernizations
- Repower & Overhaul Capabilities
- Project Development/ Engineering

PARTNER / INTEGRATION

- Financing Support
- Grid Interface & Trading
- Wind Power
- Photovoltaic
- Balance of Plant

mtu A Rolls-Royce solution

Industrial: Rail

MTU PRODUCTS AND SOLUTIONS

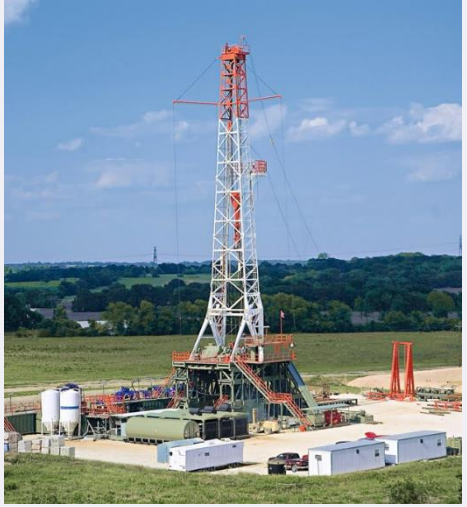
- Diesel Systems
- PowerGen Systems
- Combined/ Hybrid Systems
- Propulsion Systems
- Noise reduction solutions
- Emission reduction solutions
- Control / Automation

SERVICE SOLUTIONS

- ValueCare Agreements
- Upgrades & Modernizations
- Repower & Overhaul Capabilities
- Project Development/ Engineering

A Rolls-Royce solution

Industrial: Oil & Gas



MTU PRODUCTS AND SOLUTIONS

- Diesel Systems
- PowerGen Systems
- Combined/ Hybrid Systems
- Noise reduction solutions
- Emission reduction solutions
- Control / Automation

SERVICE SOLUTIONS

- ValueCare Agreements
- Upgrades & Modernizations
- Repower & Overhaul Capabilities
- Project Development/ Engineering

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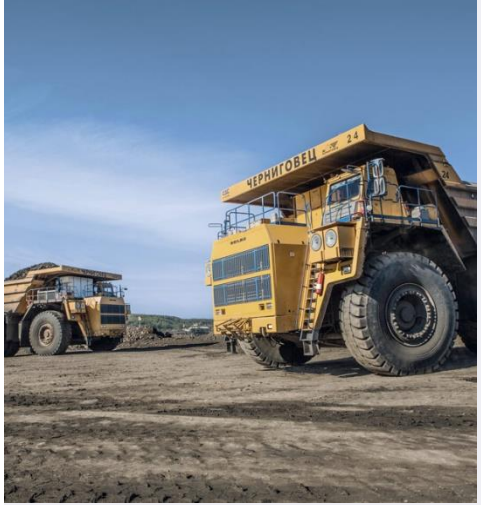
Industrial: Mining



MTU PRODUCTS AND SOLUTIONS

- Diesel Systems
- PowerGen Systems
- Combined/ Hybrid Systems
- Drive Systems
- Emission reduction solutions
- Control / Automation

SERVICE SOLUTIONS

- ValueCare Agreements
- Repower & Overhaul Capabilities
- Project Development/ Engineering

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Industrial: Agriculture and C&I

MTU PRODUCTS AND SOLUTIONS

- Diesel Systems
- PowerGen Systems
- Emission reduction solutions

SERVICE SOLUTIONS

- ValueCare Agreements
- Repower & Overhaul Capabilities

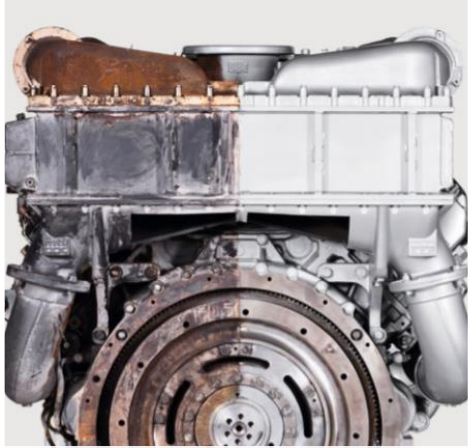
A Rolls-Royce solution

Lifecycle solutions

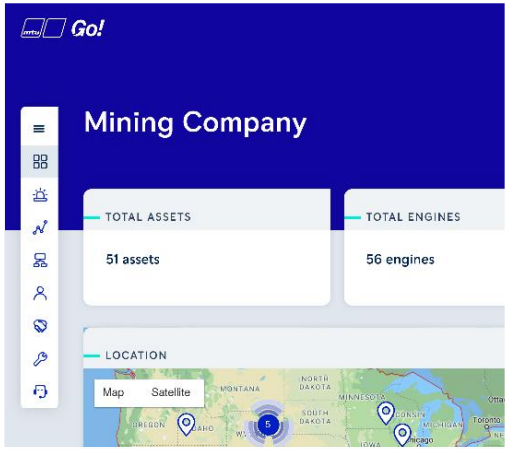
Our engines and systems are built to deliver robust, reliable performance. But our commitment to your success doesn't end there.

For maximum uptime, longer life, and optimized costs, rely on MTU ValueCare – the only service portfolio designed specifically with your equipment in mind.

Upgrades and **Modernization**



Factory Reman and **Overhaul**



Digital Products

Customer Care Center

A Rolls-Royce solution

Ensuring protection with **Extended Coverage**

Genuine Parts and **Consumables**

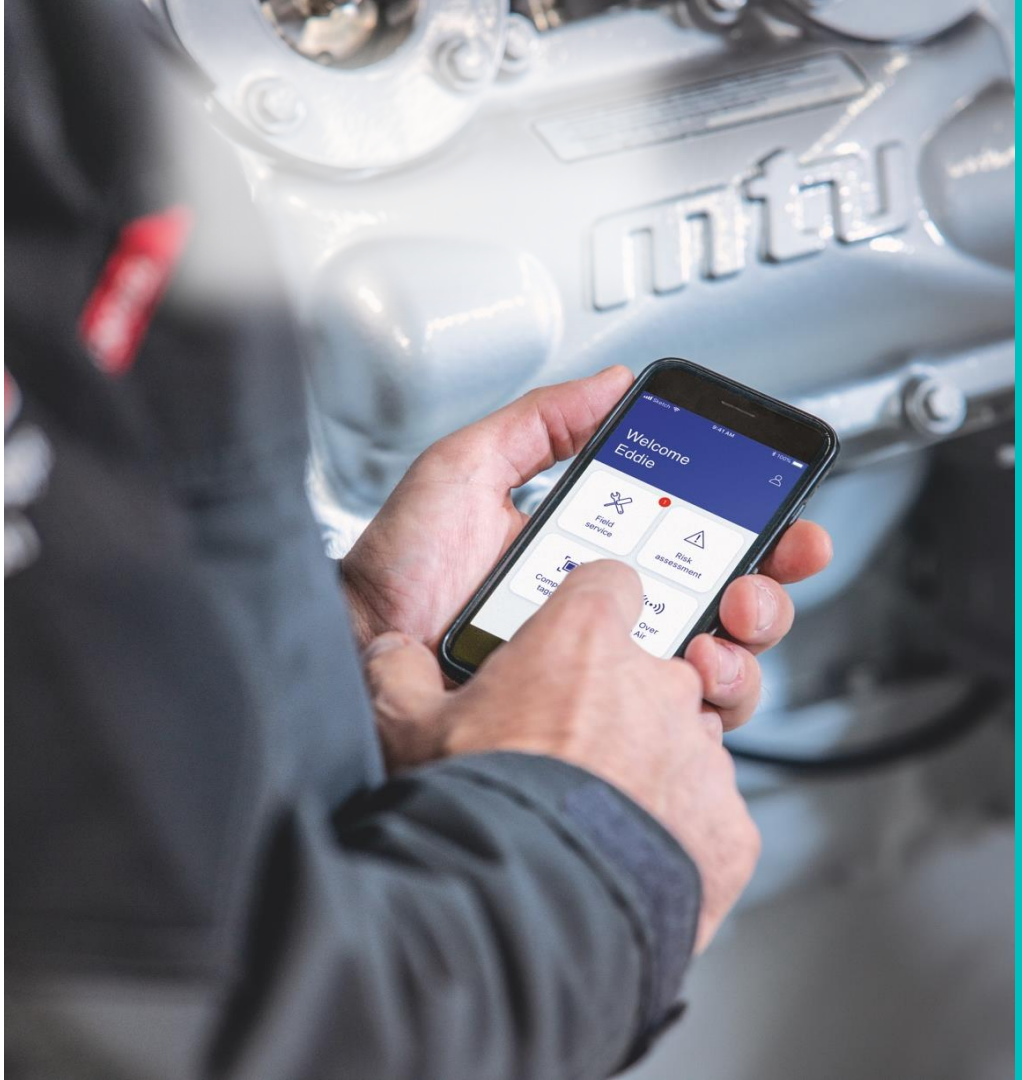
Trainings - empower your operators

Maximize uptime with **Preventive Maintenance**

Peace of mind with **Value Care Agreements**

Support you can trust

Focus on your business.
Leave the rest to us.



Increased operational uptime

Optimized maintenance planning

Predictable equipment-related costs

Guaranteed parts availability and service quality

MTU-certified technicians

24/7 support through Customer Care Center

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Pioneering the power that matters

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THANK YOU

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BACKUP

The Power Systems leadership team

Board of Management

Louise Öfverström
CFO

Andreas Schell
CEO

Dr. Otto Preiss
COO

Executive Leadership Team

Dr. Petar Pelemis
Strategy & Product Mgmt.

Matthias Vogel
Sales, Service & Network

Alexandra Kuebler
Human Resources

Dr. Martin Teigeler
Research & Development

Eugenia Valente
Network, Distribution & Bergen Engines

Beate Reimann
Finance & Controlling

Erik Manning
Operations & Purchasing

Tobias Ostermaier
President PS Greater China

Dr. Thomas Karst
Legal, Compliance & Export Control

Norbert Veser
Safety & Quality Management

Jürgen Winterholler
Digital & IT

A Rolls-Royce solution

We have a whole set of more than 70 new icons

The icons are based on the Rolls-Royce icon guideline. The Icons are scalable in size without quality losses. In general Icons should be used in the exact size seen on the right.

A Rolls-Royce solution

We have a whole set of more than 70 new icons

The icons are based on the Rolls-Royce icon guideline. The Icons are scalable in size without quality losses. In general icons should be used in the exact size seen on the right.

… and much more.

Existing icons can be found on the Rolls-Royce brand portal https://rollsroyce.sharepoint.com/sites/engineroom/en-gb/brand/Pages/default.aspx

A Rolls-Royce solution

Power Generation

MTU ENERGYPACK: THE SCALABLE ALL-IN-ONE SOLUTION

A Rolls-Royce solution

Multiple applications

OPTIMIZER, ENABLER, INTEGRATOR. STORAGE CREATES OPPORTUNITIES.

Energy storage creates multiple opportunities for more efficient power production, better grid management, and increased stability and availability. Our scalable, all-in-one EnergyPack is a perfect fit for the changing energy environment, enabling existing power systems to adapt to current trends, and creating a host of possibilities when combined with renewable energy sources – aimed at creating sustainable energy systems that are in tune with the times and ready for the future.

Grid & utility service providers

The MTU EnergyPack can take care of frequency regulation, manage grid congestion and allow the avoidance of significant investment in grid infrastructure, for example to enable a scale-up of electric vehicle charging. It will also make solar and wind power more reliable and dispatchable, while enabling gas or diesel power plants to operate more efficiently when combined with the MTU EnergyPack.

Commercial

Facilities with onsite generation such as solar arrays or combined heat and power (CHP) plants can increase their self-consumption by adding an MTU EnergyPack and take advantage of time-of-day electricity tariffs by shifting their demand. If needed, backup power capability can also be provided.

Industry

Remote industrial operations currently running on diesel power with no grid connections can reduce their fuel consumption and meet legal or company environmental standards more easily by integrating renewable sources with an MTU EnergyPack. When connected to the public grid, the MTU EnergyPack helps reduce demand charges and increase self-consumption of existing onsite generation to mitigate rising energy costs.

Community

The MTU EnergyPack increases the self-sufficiency of urban areas with local power generation, and provides reliable backup power in the event of grid failure. In areas unconnected to the public grid, adding an MTU EnergyPack to a local microgrid ensures high quality power supplies and allows the integration of renewable energies to reduce carbon footprint and save fuel.

Public sector

Where a grid connection is not reliable, the MTU EnergyPack increases security and quality of supply for public facilities. Stability of existing power plants can be improved by spinning reserve from the MTU EnergyPack, and solar arrays can be built in to reduce fuel consumption. If grid-connected, self-consumption of solar power can be increased to lower the amount of power drawn from the grid.

Multiple benefits

STORAGE SOLUTIONS FOR MICROGRIDS & ENERGY SYSTEMS

The EnergyPack is a key component for improving the reliability and profitability of microgrids and energy systems. It stores electricity from any distributed power source – such as gensets, wind turbines or solar panels – and delivers it when needed.

Grid stabilization
The MTU EnergyPack is able to provide grid support services and can form an autonomous grid, enabling customers to operate independently during grid outages.

Highest power density
Thanks to the extremely compact battery system designs and the small footprint of the housings, the MTU EnergyPack is the ideal solution for projects with logistical restrictions and limited space.

Digitally connected
The MTU EnergyPack is equipped with a data logger providing access to our digital solutions, including remote monitoring, fast and reliable service support and – coming soon – further features such as predictive failure prevention and operational optimization.

Scalable in size
Storage capacity and type of battery rating can easily be adapted, whatever your individual power and capacity requirements.

Ultra-fast response
By bringing power on-stream immediately, the MTU EnergyPack provides essential fast response capability for power quality, black starts, frequency response, and backup applications.

Seamless integration with existing power plants
The system can be built into existing conventional and renewable power plants, making it easy to optimize operation and preparing them for the future.

Multilevel safety features
A multilevel safety concept monitors and ensures safe operation of batteries, inverters, and heating, ventilation and air conditioning (HVAC) systems. The outstanding fire and explosion protection system detects smoke and explosive gases. The safety design also includes a specially designed aeration mode and an optional built-in Novec® fire extinguishing system as well as optional pipework connections for flooding with water in case of fire.

Black start capability
The battery energy storage system (BESS) can be used as a black start unit due to its grid capability. The BESS can perform black starts without auxiliary voltage, and can form an autonomous grid.

Factory tested plug-and-play design
The MTU EnergyPack comes factory-tested onsite. The highly mobile, fully integrated plug-and-play design ensures fast, easy installation, reducing setup time and costs. Power is available more quickly, and at lower cost.

Flexible use
The MTU EnergyPack can accept customer setpoints or be upgraded with the MTU microgrid controller to support various applications: storage of wind and solar power in microgrids, shaving peak loads to reduce demand charges, support for electric vehicle charging, flexibilization of generation assets, frequency and voltage regulation services, and much more.

Versatile technology

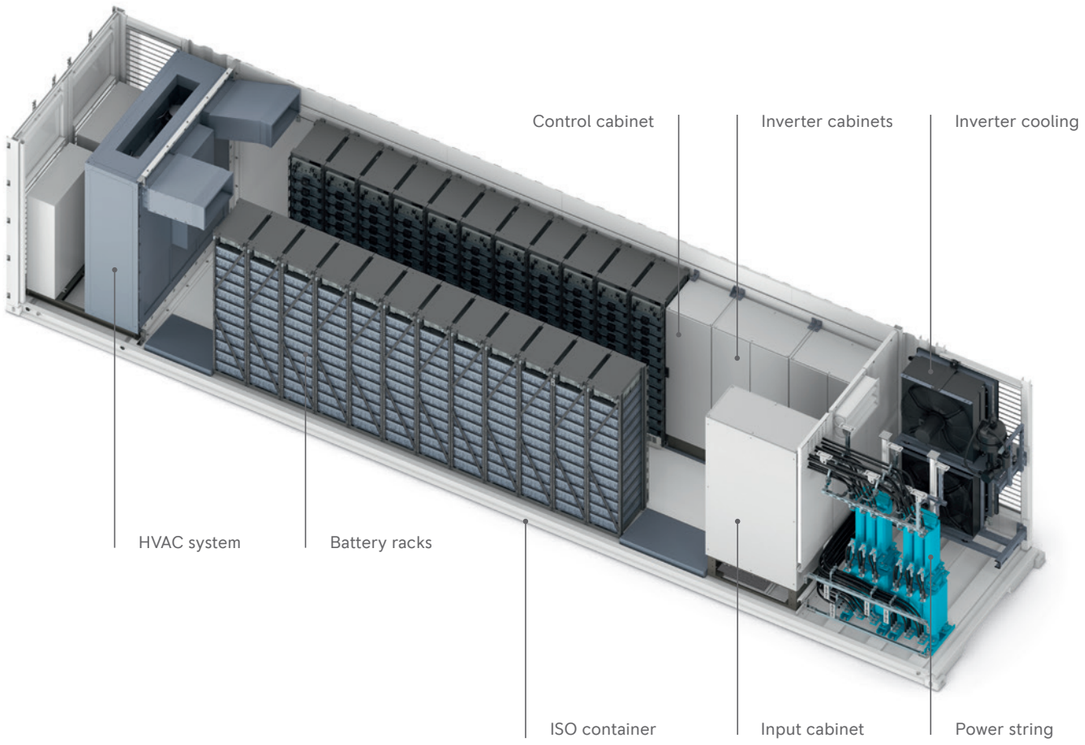
COMPACT, FLEXIBLE, AUTONOMOUS. INSTANT POWER WHEREVER YOU NEED IT

Housing
The MTU EnergyPack is available in different sizes and different housings. The enclosed QS system and the containerized QM and QL systems are as tough as they come and have been custom-designed for harsh environments and challenging logistics, offering superb protection from dust, insects, humidity and heat – both inside and out. The interiors of the containerized housings are divided into sections – some with outside air contact and some without – to keep the sensitive electrics and batteries protected from any pollution.

Batteries and battery management system
The MTU EnergyPack integrates 0.5C/1C/2C rated high-quality cells from leading manufacturers. The battery system consists of vertical racks, scalable in number to meet the required energy capacities.

Each rack contains several battery modules and one battery management system (BMS) to monitor and control the battery modules. The BMS units connect the racks to a DC power switch, allowing each rack to be disconnected from the inverter as required. All rack BMS are connected to the MTU EnergyPack's control cabinet via a master BMS.

Inverter
The inverter operates bidirectionally, converting AC from the grid into DC for charging the batteries, and vice versa. It supports both grid-supporting and grid-forming modes.



Transformer
The transformer is the interface to the upstream power grid. Its task is to transform the voltage to the level required by the inverter or grid. Dependent on the MTU EnergyPack configuration, the transformer is either installed inside or delivered as separate equipment for outdoor installation.

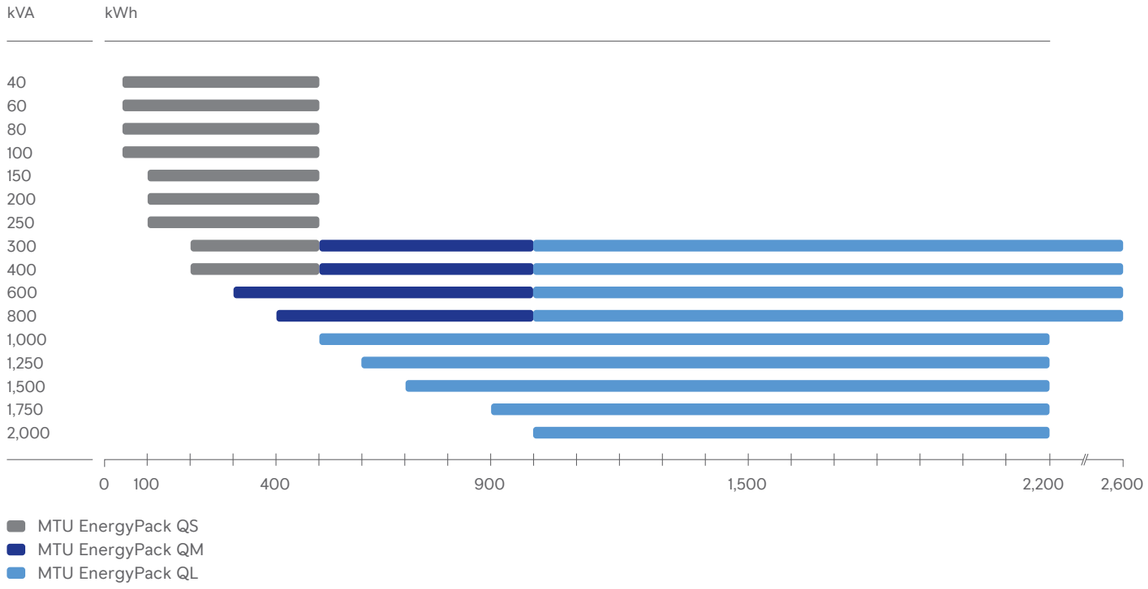
HVAC system
The HVAC equipment is located inside the housing and feeds temperature and humidity-controlled air to the cleanroom, protecting the sensitive electrical equipment and batteries from contact with ambient exterior conditions. The HVAC system regulates temperature and humidity to required levels to ensure the BESS equipment works to optimum effect.

Control system
A top-level battery energy storage controller (BESC), specially designed for this application, controls all aspects of the BESS, e.g. the inverter, batteries, HVAC system, and lighting. The BESC is located inside the control cabinet, a separate compartment within the container. A built-in touchscreen and simple remote access via Modbus-IP enable full control over the MTU EnergyPack.

Safety features
The MTU EnergyPack features a comprehensive safety concept comprising a multilevel safety architecture, fire & gas detection, fire extinguishing options, etc.

THE FULL POWER RANGE

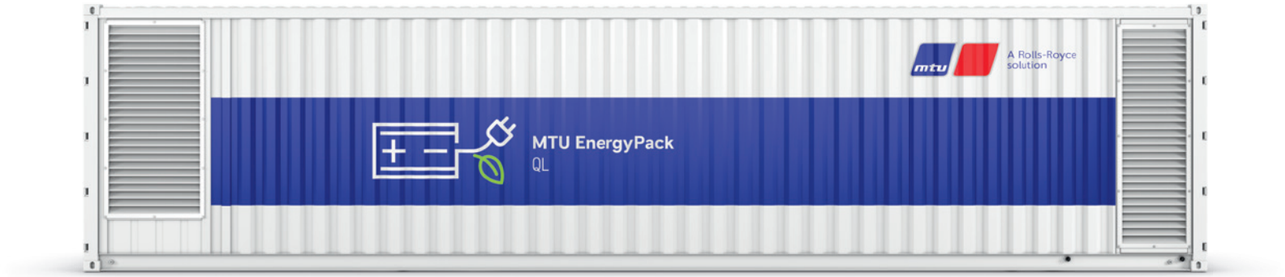
The EnergyPack portfolio covers a broad power and capacity range, enabling us to offer exactly the right size of battery storage solution for your energy requirements. The EnergyPack comes in three versions: QS, QM and QL.



EnergyPack QL

LARGE AND POWERFUL

The EnergyPack QL is designed for customer applications with power and capacity requirements up to 2,000 kVA and 2,600 kWh. It is suitable for integrating solar assets and wind parks, and for providing frequency regulation and other ancillary services in the utilities sector.

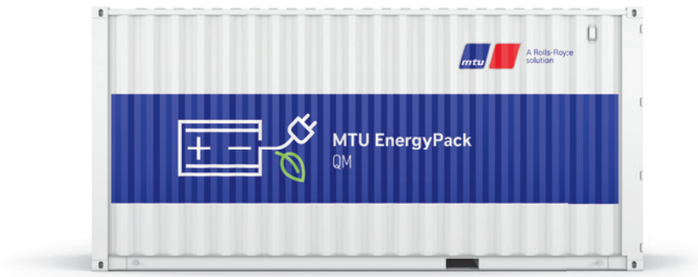


Key technical data MTU EnergyPack QL		
Cell chemistry		NCM
Nominal capacity	kWh	up to 2,600
Nominal apparent power	kVA	up to 2,000
Maximum apparent power (1 min)	%	up to 150%
Transformer		optional
Nominal voltage	V	515 V (400 V with internal transformer)
Enclosure		40ft ISO HC container
Black start capability		yes

EnergyPack QM

MEDIUM AND VERSATILE

The EnergyPack QM is designed for customer applications with power and capacity requirements of up to 800 kVA and 1,000 kWh. It is suitable for off-grid solutions, for reducing fuel dependence in remote communities, or for reducing demand charges in the industrial sector.



Key technical data MTU EnergyPack QM		
Cell chemistry		NCM
Nominal capacity	kWh	up to 1,000
Nominal apparent power	kVA	up to 800
Maximum apparent power (1 min)	%	up to 150%
Transformer		optional
Nominal voltage	V	515 V (400 V with internal transformer)
Enclosure		20ft ISO HC container
Black start capability		yes

EnergyPack QS

SMALL AND STURDY

The EnergyPack QS is designed for customer applications with power and capacity requirements of up to 400 kVA and 550 kWh. It is suitable for off-grid solutions, for reducing fuel dependence in small remote communities, and for enabling self-consumption of solar power in the commercial and public sectors.

Key technical data MTU EnergyPack QS		
Cell chemistry		NCM
Nominal capacity	kWh	up to 550
Nominal apparent power	kVA	up to 400
Maximum apparent power (1 min)	%	up to 150%
Transformer		internal
Nominal voltage	V	400 V
Enclosure		compact housing
Black start capability		yes

Service Solutions

ENSURING LONG, RELIABLE SERVICE LIVES

EnergyPacks are built to deliver the highest performance with low life-cycle costs. Our maintenance services keep them performing that way with a full portfolio of service solutions.

Remote operation control and diagnostics, digital connectivity solutions and optimised maintenance keep the life-cycle costs of the MTU EnergyPack to a minimum. With high availability of spare parts, we ensure your systems stay up and running, wherever in the world they happen to be, and operators can have the benefit of peace-of-mind provided by performance guarantee agreements that can be tailored to fit your specific requirements.

Reporting & optimization
add transparency to system performance and allow constant improvement of system parameters based on operational experience

Preventive & corrective maintenance
performed by trained technicians to ensure a high quality of work

Active monitoring
by trained personnel to identify failures in time and initiate required actions to reduce down-time

Remote diagnostics
by experts to identify root causes of malfunctions (3rd level support) and perform low-level configuration changes and bug-fixes

Repair guidance
for local personnel from experts via phone, video conference or e-mail/mail to minimize down-time and costs

ValueCare Agreements
make it easy to optimize lifecycle costs, maximize uptime and devote more time and resources to your core business, with tailored solutions to move your business forward

Extended warranty cover
for MTU products, protecting against unexpected costs with a scope tailored to customer needs

Local support. Worldwide. 24/7
We ensure you get tailored support from our global network of over 1,200 service centers – anytime, anywhere. Whether it's connecting you with a local service partner or assigning an urgent problem to a dedicated team of our experts, we're ready to assist – wherever you are, whatever you need.

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Subject to change. | 16120788 | Edition 01/20 | ESM 2020-05 | Printed in Germany on chlorine-free bleached paper.

Rolls-Royce Group
www.mtu-solutions.com/powergen

ROLLS-ROYCE SOLUTIONS AMERICA INC.

General Terms and Conditions of Sale

1. GENERAL

1.1. These General Terms and Conditions of Sale ("Conditions of Sale") shall apply to all contracts for goods ("Goods") and/or services ("Contract") entered into by the Rolls-Royce Solutions America Inc. ("RRSA") and buyer ("Customer"). These Conditions of Sale also apply to other ancillary services (e.g. assembly or installation and commissioning) supplied by RRSA pursuant to any such Contract. Such ancillary and primary services are collectively referred to as "Services."

1.2. Each party represents and warrants to the other that it has the power to enter into, perform, and deliver, and has taken all necessary action to authorize its entry into these Conditions of Sale and any Contract hereunder.

2. FORMATION OF CONTRACT

2.1. Quotes by RRSA are non-binding and subject to change. RRSA retains all rights, title, and interest in any intellectual property rights to quotes, samples, cost estimates, drawings, technical information, and other documents. Customer will not disclose such documentation to any third parties without the prior written consent of RRSA.

2.2. Any purchase orders and related documents for the purchase of Goods and Services ("Orders") from Customer will only be effective on the date accepted in writing by RRSA. The Order will include the technical and commercial terms found in RRSA's quotation, including these Conditions of Sale. Verbal agreements are not valid unless confirmed in writing.

2.3. These Conditions of Sale apply exclusively to each Contract. The parties have agreed, and it is their intent that these Conditions of Sale will exclusively control the relationship of the parties with respect to each Contract for Goods and/or Services as further set forth in clause 20.8(a). Acceptance by RRSA of an Order, or Customer's acceptance of RRSA's quotation, is expressly limited to and conditioned upon Customer's acceptance of these Conditions of Sale, payment for, or acceptance of any performance by RRSA constituting Customer's acceptance. These Conditions of Sale may not be changed or superseded by any different or additional terms and conditions proposed by Customer to which terms RRSA hereby objects. No variation, amendment, or addition to these Conditions of Sale or any Contract will be effective unless it is in writing and signed by the parties.

3. CONDITION/QUALITY OF THE GOODS AND SERVICES

3.1. The Goods and Services will conform to specifications agreed to in writing by the parties. Where the Customer requires compliance with different technical regulations and standards, this must be agreed in a signed writing by RRSA beforehand, and resulting adjustments to affected provisions, including price, schedule, and guarantees mutually agreed in writing prior to implementation of the change. Where the Customer requires the provision by RRSA of specific local approvals or licenses, such as for the import or operation of the Goods supplied, such additional services must also be agreed to in writing by RRSA.

3.2. Unless otherwise agreed to in a writing signed by RRSA, any information about the Goods and Services, including but not limited to technical data, operating costs, consumption figures, power outputs, weights, dimensions, and service lives are only approximate and estimated figures. Power outputs, speeds, consumption figures, etc. are deemed to be proven by the bench-test results from RRSA's facility. To that extent, ISO 3046 or SAE J1995 (in the case of the S60) shall apply. Where the Goods are gas-operated, the test run is completed using natural gas.

3.3. Information about the Goods or Services (e.g. printed in brochures, catalogs, product information sheets, electronic media, or on labels) is based on RRSA's general knowledge and experience, and merely constitutes a guide or indication; it is non-binding and subject to change in the absence of a written agreement to the contrary. Neither the product information nor expressly agreed features/intended uses release the Customer from its responsibility for testing the product's fitness for the Customer's intended purpose.

3.4. RRSA reserves the right to alter the design, shape, and materials of the Goods, provided the Goods are not fundamentally changed and are reasonable, or to comply with changes to standards, regulations, or law. RRSA reserves the right to vary physical dimensions and chemical values to the extent customary in the industry or technically unavoidable, including variations in color, formula, processes, and the use of raw materials and order quantities, provided this is not unreasonable for the Customer.

4. PRICES AND TAXES

4.1. Prices are stated without discount or other reductions and exclusive of value added tax ("VAT"), use tax, goods or services tax, sales or turnover tax, or any other tax of a similar nature at the relevant statutory rate where applicable. If any such tax is or becomes chargeable, the Customer will pay to RRSA (in addition to and at the same time as paying that amount) an amount equal to the amount of that tax. Charges imposed by public authorities (taxes, fees, customs duties) incurred as a result of shipping the Goods internationally, as well as packing, loading, transportation, installation, insurance, or any other costs (e.g. for consular certificates, export, transit, import, and other permits or certificates of origin) are payable by the Customer.

4.2. RRSA is entitled to appropriate additional payment (even in cases where a fixed price is agreed upon) in those cases where: (a) the Customer requests changes in technical specifications or timeframes for delivery/performance after the Contract has been formed and/or (b) new technical specifications, regulations and/or standards must be complied with, which had not been applicable at the time the Contract had originally been entered into. In the event of changes in the price of materials, labor costs, freight charges, or other cost factors, RRSA reserves the right to adjust prices accordingly, provided there is a period of at least four months between the date the Contract is concluded and the delivery date, and a fixed price has not been agreed upon. The same applies to continuing obligations.

4.3. The Customer will make all payments without any deduction in accordance with clause 5, unless applicable law requires a tax deduction to be made. If a tax deduction is required by applicable law to be made by the Customer, the Customer will: (a) increase the amount of the payment to an amount which (after making the tax deduction) leaves an amount paid free and clear of tax equal to the payment which would have been due if no tax deduction had been required; (b) make the minimum tax deduction allowed by law, and will make any payment required in connection with it within the time allowed; and (c) deliver to RRSA an official receipt or other evidence satisfactory to RRSA (acting reasonably) that the tax deduction has been made or, as applicable, any appropriate payment has been paid to the relevant taxing authority.

4.4. RRSA will, in consultation with and at the request and expense of the Customer, take all reasonable steps to mitigate any circumstances which arise and that result or would result in any payment by the Customer to RRSA relating to a tax deduction or under any indemnity given by the Customer in respect of tax under these Conditions of Sale. This does not in any way limit the Customer's obligations under these Conditions of Sale or any Contract.

4.5. The Customer will indemnify RRSA against any loss or liability that RRSA may suffer or incur (directly or indirectly) for or on account of tax, and which arises as a result of or is attributable to a payment received or receivable from the Customer under a Contract. This does not apply to any tax assessed on RRSA under the laws of its jurisdiction of incorporation if that tax is imposed on or calculated by reference to its net income, profits, or gains.

5. PAYMENT TERMS

5.1. Unless agreed in a writing signed by RRSA, payment shall be remitted to RRSA's account in full within fourteen (14) days of invoicing as follows: one third (1/3) on Order acceptance in accordance with clause 2.3, one third (1/3) after half of the delivery period has elapsed, and one third (1/3) on notification that the individual Goods are ready for shipment.

5.2. Bank charges and letter of credit are payable by the Customer. Payment instructions, checks, and bills of exchange are only accepted by special arrangement and only for the purposes of settlement. No interest is paid on advance payments on account.

5.3. If at any time during manufacture or prior to shipment, RRSA determines that the financial condition of the Customer is such that RRSA does not reasonably feel secure in the continued manufacture or the shipment of the Goods on the credit terms previously agreed upon, then RRSA may require full or partial payment before completing manufacture or in advance of shipment of the Goods.

5.4. In the event of a late payment by the Customer, RRSA may, without prejudice to any other statutory or contractual rights such as provided for in clause 6.8 and 8.4, claim interest at a rate of 10% or 8 percentage points above the base interest rate set by U.S. Prime Rate. If RRSA has reasonable grounds for insecurity with Customer's performance obligations, then RRSA may refuse to supply the Goods or Services (including under other contracts) until the Customer has fully met its obligations or provided adequate assurances.

5.5. The Customer may only set off its claims against claims of RRSA or exercise a right to reduce or withhold payment only if the Customer's counterclaim is undisputed and agreed to in writing by RRSA or been declared final and binding by a court of law.

5.6. RRSA is entitled to set off its claims against the Customer's claims from Rolls-Royce Power Systems AG or any of its affiliates or any Rolls-Royce Group companies ("Affiliates"). The same applies to setting off these companies' claims from the Customer against the Customer's claims from RRSA. Offsetting may also be utilized by RRSA in the event of bankruptcy, insolvency, liquidation, or an arrangement with creditors on the part of the Customer, provided it is allowable under the bankruptcy or insolvency administration law applicable to the Customer.

6. RETENTION OF TITLE

6.1. All Goods shall remain the property of RRSA until Customer fulfills all commitments and obligations arising from the Contract, including these Conditions of Sale.

6.2. Any processing or modification of the Goods by the Customer shall be performed on behalf of RRSA. If the Goods are combined or comingled with other goods not belonging to RRSA, RRSA shall acquire co-ownership of the resulting products in proportion to the value of the goods.

6.3. To secure payment of the purchase price and of all monies which may be due hereunder, and to secure performance of all of Customer's additional obligations hereunder, Customer hereby grants to RRSA a purchase money security interest in all Goods sold to Customer by RRSA, and agrees to immediately execute such other Security Agreements and Financing Statements as RRSA may reasonably request. Customer hereby appoints RRSA as Customer's attorney-in-fact to execute on behalf of Customer any necessary Security Agreements and Financing Statements as necessary to carry out the terms of the parties' agreement.

6.4. RRSA agrees to allow the Customer to resell the Goods as part of its normal course of business subject to the right of revocation and the provisions of clause 6.9. The Customer may not pledge or assign the Goods as security. The Customer hereby assigns to RRSA the amounts Customer is owed from selling the Goods to its customer, regardless of whether they have been further processed, to the value of the purchase price claimed (including VAT). Until and unless revoked, the Customer is entitled and obliged to collect the receivables assigned to RRSA. RRSA is entitled to revoke the authorization to collect granted in this clause if the Customer falls into arrears with its payments, suspends its payments, files for bankruptcy, liquidates, or seeks an arrangement with creditors, or institutes similar proceedings. After revocation of the authorization to collect, RRSA shall be entitled to collect the receivables. The Customer will comply with RRSA request for details of the assigned receivables and by whom they are owed, supply all information necessary for collection, provide the associated documentation, and notify the third parties of the assignment.

6.5. At the request of the Customer, RRSA shall release the security to which it is entitled under clause 6.3 and 6.7 upon full and complete payment of the Goods.

6.6. Prior to the transfer of title, the Customer is required to store and handle the Goods in a safe and secure manner for RRSA. The Customer will maintain the Goods according to specification, provide corrosion-proofing, service, or repair work that may become necessary. Except in cases of emergencies, Goods will be repaired at RRSA's facilities or RRSA's authorized service outlet.

6.7. Until the full and complete payment of the Goods, the Customer must on request insure the Goods to the value of the existing remaining debt against all risks, with RRSA named as an additional insured and beneficiary of the insurance proceeds.

6.8. The Customer must inform RRSA without delay in the event of seizure of property or other impairment of RRSA's interest.

6.9. Should the Customer fall into arrears with its payments or fail to meet its insurance obligations or the obligations arising from the Goods, including the assignment of receivables, then the entire remaining debt shall become immediately due even where the Contract has a later due date. The Customer's right to resell the Goods under clause 6.3 shall become void and revoked. The same applies where bankruptcy, administration or comparable proceedings are voluntarily and involuntarily petitioned against the Customer, or RRSA receives an insurer's notification as provided for in the insurance certificate as a result of the behavior of the Customer. If the entire remaining debt is not immediately paid, the Customer's rights of use with respect to the Goods shall become void. RRSA is then entitled to repossess the Goods from the Customer's premises. Where the Goods are co-owned by third parties, such repossession is taken on behalf of the co-Customers at the same time. All costs arising from taking possession shall be chargeable to the Customer. If the Goods have been used, RRSA is entitled to claim as a minimum for depreciation an amount of 25% for the first six (6) months of use and of 7.5% for each succeeding six (6) months of use without having to provide evidence of damage. The Customer may provide evidence to RRSA that no damage or depreciation has occurred or is substantially less. RRSA is entitled to demonstrate that greater depreciation has occurred as a result of use and claim the greater depreciation.

7. SUPPLY OF GOODS/SERVICES

7.1. Unless otherwise agreed in a writing signed by RRSA, Goods shall be delivered as follows: (a) for any sales within the continental United States, all deliveries of products shall be free on board, RRSA's designated facility or (b) for any sales outside the continental United States, all deliveries shall be FCA (Incoterms 2010) RRSA's designated facility. Partial deliveries, partial services, and consignments are permissible. Dates/deadlines shall be extended/postponed accordingly if and to the extent that the documents required for processing orders on time are not received by RRSA in due time, contractual obligations (e.g. payments on account, provision of letters of credit, etc.) are not met, contract-related work on the part of RRSA suffers from interruptions or delays caused by the Customer, or delays occur due to other events over which RRSA has no control (e.g. strikes, lockouts, business disruptions, delays by subcontractors, events of force majeure, or action by government authorities) regardless of whether they occur at RRSA, the Customer, and/or at a third party. RRSA shall notify the Customer of the occurrence of events. Those events shall not be the responsibility of RRSA even if they occur during an instance of default. If the delivery of Goods and/or Services is delayed by such events by more than six (6) months, both parties shall be entitled to rescind the Contract and RRSA shall be relieved of any liability owed to the Customer thereunder.

7.2. If a delivery period has been agreed (and barring any written agreement of the parties to the contrary), that delivery period shall commence as soon as the Order has been accepted and the Customer has complied with the payment terms in clause 5.1. An agreed delivery period shall be deemed complied with if a ready-for-shipment notice has been sent to the Customer before that period expires.

7.3. RRSA's compliance with the contractually agreed delivery period shall be contingent on the Customer's performance of all contractual and non-contractual obligations owed to RRSA. A delivery period may be reasonably extended by RRSA in those cases where: (a) RRSA does not receive the information it requires to perform the Contract in due time and/or in full, and/or the Customer subsequently changes that information; or (b) the Customer or a third party is behind schedule with the work to be performed by it, or the Customer is in arrears in the performance of its obligations; or (c) where Customer fails to provide any necessary approvals, access to facilities, or fails to provide reasonable cooperation; or (d) obstacles arise, which RRSA is unable to avoid despite having exercised due care and made reasonable efforts, regardless of whether those obstacles are encountered at RRSA, the Customer, or a third party (including, in particular, the events outside RRSA's sphere of control set out in clause 7.1); or (e) any other circumstances arise for which RRSA is not responsible.

7.4. If a delivery period has been agreed and the Customer can show that the delivery of Goods and/or Services is more than six (6) weeks overdue, that RRSA is solely responsible for such late delivery, and that such late delivery is not due to causes beyond RRSA's control as enumerated in clause 7.1, the Customer shall be entitled to, after affording RRSA a reasonable cure period of no less than thirty (30) days, a late delivery charge in the amount of 0.05% of the purchase price for the delayed component per calendar week, up to a maximum of 2.5% of the purchase price for such delayed component. The aforementioned late delivery charge shall be Customer's sole and exclusive remedy in the event of a late delivery by RRSA. RRSA and Customer agree that actual costs suffered by Customer as a result of a late delivery may be difficult to ascertain, uncertain in nature, and incapable of exact determination in each instance, and that the late delivery charge is a good faith estimate of the costs suffered by Customer, and not a penalty resulting from the late delivery.

7.5. RRSA reserves the right to supply the Customer with different goods of a similar type or design within the bounds of what is reasonable if the type or design ordered is no longer in production as of the planned delivery date. RRSA is under no obligation to deliver the Goods originally ordered or to pay indirect, incidental, consequential or compensatory damages for non-performance.

7.6. Should shipment of the Goods be delayed for reasons for which RRSA is not responsible, the Customer shall reimburse the costs incurred for storage as of the second month of the delay. If the Goods are stored at RRSA, the reimbursement shall be 0.5% of the value of that part of the entire Goods to be supplied that is delayed, per month.

7.7. The Customer's claims arising out of and/or in connection with delays in the performance of the contract are solely and exclusively governed by the provisions of this clause 7. The Customer agrees that any other or further claims of the Customer are hereby expressly waived.

8. TRANSFER OF RISK, ACCEPTANCE, CUSTOMER'S DEFAULT

8.1. The risk of loss of the Goods shall pass to the Customer (a) on delivery in accordance with clause 7.1 (even if partial deliveries are made, the Goods or any part thereof are placed on consignment, or RRSA is providing ancillary Services), or (b) on the acceptance date in accordance with clause 8.2, as applicable. From this point on, the Goods shall be stored and insured for the account and at the risk of the Customer.

8.2. Where RRSA is responsible for the completion of Services other than ancillary Services, an acceptance inspection is to be carried out by the Customer without delay by the appointed acceptance date, or upon notification by RRSA that the Goods are ready for acceptance. The Customer may not refuse acceptance of the Goods if the concerns are insignificant. Acceptance by the Customer shall be deemed to have taken place if the Customer does not inspect the Goods within a certain appropriate period specified by RRSA even though the Customer is obliged to do so. In addition to clause 8.1, risks of loss shall pass to the Customer on acceptance or at such time as acceptance by the Customer becomes overdue. The Customer shall bear the risk of war, civil war, acts of terrorism, and damage caused by nuclear radiation as of delivery.

8.3. The Goods shall be subjected to standard testing by RRSA in accordance with clause 3.2 as demonstrated by the bench-test results from RRSA's facility. The Customer may arrange to have specific trials in addition to the above tests carried out by RRSA at extra charge. Should the Customer or its agent wish to be present at the tests or any additional trials to be conducted, this must be agreed in writing at least four

(4) weeks before the expected delivery date. If the Customer does not attend the tests conducted by RRSA or any additional trials agreed, it may not require them to be repeated. To the extent the Goods are inspected for warranted qualities during the acceptance inspection, proof of warranted qualities shall also be affected in the context of the acceptance inspection.

8.4. Without prejudice to RRSA's other rights or remedies, if the Customer falls into arrears with agreed payments, is late providing the agreed security or taking receipt of or accepting the Goods, or issuing the dispatch requirements after notification that they are ready for collection or where applicable for acceptance, RRSA shall be entitled to withdraw from the Contract and demand reimbursement of the actual losses accrued. If RRSA does not exercise that right, then RRSA may dispose of the Goods as it chooses and supply equivalent Goods within an acceptable period according to the terms of the Contract instead.

9. SHIPPING

9.1. Where shipping has been agreed in a writing signed by RRSA to be RRSA's responsibility, RRSA may at its sole discretion use the most economical mode of transportation.

9.2. The Customer shall bear the risk of accidental damage or loss from loading at RRSA's location. If the Goods are ready for shipping and should shipping be delayed for reasons not caused by RRSA, (a) the risk of loss shall pass to the Customer upon receipt of the notification that the Goods are ready for shipment, and (b) payment shall be due on the date RRSA is prepared to make the shipment. The same applies to partial deliveries. Goods that are stored by RRSA longer than ninety (90) days from date of shipment are subject to special preservation requirements. Contact RRSA's Factory Service Center for instructions.

9.3. For Orders placed with RRSA, Customer will have forty-eight (48) hours to arrange shipment of the Goods after RRSA provides notice the Goods are ready for shipment. If shipping arrangements for the Goods are not made within the 48-hour period, at the Customer's cost, RRSA will cause McDonough Truck Lines to pick up the equipment and store it at McDonough Truck Lines' facility. Unless otherwise agreed in advance and in writing, RRSA will invoice the Customer for the Goods in accordance with clause 9.2, and normal payment terms will apply. McDonough Truck Lines will invoice the Customer for handling and freight to their warehouse, as well as for any storage charges. Customer will be responsible for invoice payment of any handling, freight, or storage charges related to the Goods to McDonough Truck Lines before Goods will ship from their warehouse. Please contact your factory representative for the current storage rates. Arrangements to ship the Goods from the McDonough Truck Lines' facility will be the responsibility of the Customer. To arrange payment for any freight, handling and storage charges, and shipping, please contact McDonough Truck Lines at +1 800-642-1374.

9.4. RRSA will charge for the costs of shipping and packaging. RRSA-owned packing apparatus such as containers and pallets shall remain the property of RRSA. The Customer shall handle such items with care and return them at its own expense.

9.5. On request, RRSA shall provide the Customer with an advance shipment notice (ASN) where required for freight insurance purposes. Where the Customer issues such an instruction, RRSA will take out insurance for land, sea, and air freight at the Customer's expense. Goods damaged in transit or delivery must be notified to the carrier or freight forwarder within three (3) business days.

9.6. RRSA charges for disposable packaging and will generally not require that the Customer return it. However, if returnable packaging is designated as property of RRSA, the Customer must return it to the point of origin at its expense.

10. WARRANTY

10.1. RRSA warrants to the Customer that at the time risk of loss passes to the Customer in accordance with clause 8, the Goods will be free of defects in material and workmanship in accordance with the specifications, as set forth in the Limited Warranty parchment applicable to the Goods purchased under the Contract, which are available by accessing RRSA's Business Portal at http://partner.mtu-online.com or as may be set forth and provided for in an RRSA quotation. Any such Limited Warranty is incorporated herein by reference in its entirety to the extent and with the same force as if fully set forth herein ("Limited Warranty").

10.2. In the event a Limited Warranty is not provided by RRSA, RRSA warrants to the Customer that at the time risk of loss passes to the Customer in accordance with clause 8, the Goods supplied will be free of defects in material and workmanship in accordance with the specification for a period of twelve (12) months from commissioning, but in any case no longer than eighteen (18) months after the Goods have shipped from RRSA's manufacturing facility ("Limited Warranty Period"). Any nonconformity to the foregoing is defined herein as a Warrantable Defect.

10.2.1. *RRSA Responsibilities*. If a Warrantable Defect is found during the Limited Warranty Period, and provided the Customer has complied with its obligations under clause 10.2.2, RRSA will, during normal working hours, through RRSA's authorized distributor, dealer, or service outlet, perform some or all of the following: (a) Repair or replace, at RRSA's sole election, the defective part with a new or remanufactured replacement part; (b) Replace lubricating oil, filters, anti-freeze, and other consumable service items rendered unusable by a Warrantable Defect; (c) Provide reasonable or customary labor needed to correct a Warrantable Defect; (d) Provide reasonable technician travel time to and from the closest RRSA authorized distributor, dealer, or service outlet to the Goods location; or (e) Part removal and re-installation, if necessary and as solely determined by RRSA. If RRSA repairs or replaces a part or the Goods under this clause 10.2, the repaired or replaced part or Goods assumes the unexpired portion of the warranty period remaining from the original part or Goods. Repair or replacement of a part or Goods will not extend the term of the original Limited Warranty Period. Parts or Goods replaced shall become the property of RRSA.

10.2.2. *Customer Responsibilities.* During the Limited Warranty Period, the Customer is responsible for, and RRSA will not reimburse for the following: (a) Premium or overtime labor costs; (b) Labor and material costs for Goods removal and reinstallation; (c) Transportation costs or travel expenses related to delivery of the Goods to the designated distributor, dealer, or service outlet; (d) Incidental and consequential costs, damages or administrative expenses of whatever nature; (e) Non-Goods repairs, vehicle damage, "downtime" expenses, cargo damage, fines, lost income, any business costs of any kind, Customer's travel expenses, and other losses resulting from a Warrantable Defect; (f) Shipping charges for replacement parts/Goods in excess of those which are usual and customary; or (g) Local taxes, if applicable. In addition, Customer must: (a) Operate, use, and maintain the Goods in accordance with the applicable Customer's manual and/or any other manuals specified by RRSA, including without limitation handling, inspection, servicing, or operating instructions; (b) promptly notify RRSA or its authorized representative of a Warrantable Defect and make the Goods available for repair; (c) Comply with RRSA's or RRSA's authorized representative's reasonable directions regarding the timing, sequence, and location of warranty repairs, and make the Goods available for inspection; (d) Perform all required maintenance, and maintain and provide proof that all required maintenance has been performed; (e) Use RRSA-specified consumables such as fuel, oil, and coolant; (f) Allow RRSA access to all electronic data stored in the Goods Electronic Control Module, as applicable; (g) Promptly return to RRSA all parts replaced under this clause 10.2; (h) Comply with

RRSA's long term storage guidelines, if applicable, and maintain and provide proof of compliance; and (i) Reimburse RRSA for all costs incurred in providing warranty service where, following examination, the request or claim for warranty coverage proves to be unfounded or excluded, as well as all incidental costs including those incurred investigating the claim.

10.2.3. *Limitations.* RRSA is not responsible, and this clause 10.2 is not available under any circumstances, for any of the following: (a) Failure of Customer to fulfill its obligations under clause 10.2.2; (b) Defects which were obvious or capable of being identified by reasonable inspection and not reported to RRSA within three (3) days of receipt of the Goods; (c) Defects caused or potentially caused by service work performed by non-RRSA authorized service providers and/or the use of non-genuine RRSA parts; (d) Defects resulting from natural wear and tear or external action, negligence, natural disasters, accidents, incorrect use, improper handling or storage or inadequate corrosion-proofing, incorrect assembly or installation or modification of the Goods, or chemical, electrical, or other harmful effects; (e) Defects resulting from abuse or neglect, including unauthorized modifications to the Goods; (f) Repair or any use or installation which RRSA determines, in its sole discretion, to be improper; (g) Defects caused by use of incorrect oil or fuel or by water, dirt, or other contaminants in the fuel or oil; (h) Defects resulting from Customer's delay in making the Goods available after being notified of a potential problem or failure to take immediate measures to avoid or mitigate damage; (i) Damage to parts, fixtures, housings, attachments, and accessory items, which are not part of the Goods, or transmission (if supplied by RRSA), including any other manufacturer's products packaged and sold by RRSA; (j) Repair of parts sold by RRSA that are warranted directly to the Customer by the respective part's manufacturer; (k) Goods operating for duty periods outside of the definition of their application group; (l) Any failure, other than those resulting from a defect in material or factory workmanship of the Goods; (m) Use of the Goods for purposes other than those for which it was intended, including without limitation use of the Goods under extraordinary operating conditions not made known to RRSA in writing at the time of the order; or (n) Material provided by or a design specified by the Customer.

10.2.4. *Software Warranty.* Where software is included in the Goods, RRSA warrants to the Customer that (a) the software will be substantially free from material program errors and material defects in material and workmanship, and that (b) it shall function substantially in accordance with RRSA's specification at the time of dispatch from the RRSA manufacturing facility. RRSA does not warrant that the software is error-free or free from "bugs" as commonly categorized by the computer industry. RRSA shall, during the Limited Warranty Period, endeavor to remedy at its cost, in its sole discretion, by repair or replacement of any material program errors or material defects of which Customer has promptly notified RRSA. RRSA, at its option, may elect to provide the most current software at no cost, and in such case RRSA will not cover the cost to install the applicable updated software. RRSA shall have no obligation with respect to any nonconformities resulting from unauthorized modifications to the software or any Customer interfacing.

10.2.5. *Emissions Warranty.* The Goods may be covered under an emissions warranty specified by the U.S. Environmental Protection Agency and/or the California Air Resources Board. The terms of the warranty, if applicable, may be accessed at the following link: https://www.mtu-solutions.com/eu/en/technical-information/emissions-warranty.html. The Goods, if certified, may only be certified to comply with the required country or region-specific emission regulations. Where applicable, the Goods is only certified to those specific emission regulations/standards which are clearly stated in the respective RRPS/RRSA-defined technical specifications. IT IS THE CUSTOMER'S SOLE RESPONSIBILITY TO ENSURE THAT THE EXPORT/IMPORT, INSTALLATION AND USE OF THE GOODS(S) COMPLIES WITH THE APPLICABLE EMISSION REGULATIONS IN THE COUNTRY OR REGION WHERE THE GOODS(S) WILL BE USED.

10.2.6. **LIMITATION OF WARRANTIES: THIS WARRANTY IS GIVEN EXPRESSLY AND IN PLACE OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR PARTICULAR PURPOSE, FREEDOM FROM INFRINGEMENT OR THIRD PARTY INTELLECTUAL PROPERTY RIGHTS, OR ARISING FROM COURSE OF DEALING, COURSE OF PERFORMANCE OR USAGE OF TRADE. THERE ARE NO UNDERSTANDINGS, AGREEMENTS, REPRESENTATIONS, OR WARRANTIES NOT SPECIFIED HEREIN. THIS CLAUSE 10.2, THE OBLIGATIONS OF RRSA AND THE RIGHTS AND REMEDIES OF THE CUSTOMER SET FORTH IN THIS CLAUSE 10.2 ARE EXCLUSIVE AND ARE EXPRESSLY IN LIEU OF, AND THE CUSTOMER HEREBY WAIVES AND RELEASES, ALL OTHER OBLIGATIONS, WARRANTIES (INCLUDING WARRANTY AGAINST REDHIBITORY DEFECTS), REPRESENTATIONS OR LIABILITIES, EXPRESS OR IMPLIED, ARISING BY LAW IN CONTRACT, TORT (INCLUDING NEGLIGENCE OR STRICT LIABILITY) OR OTHERWISE, INCLUDING BUT NOT LIMITED TO ANY CLAIMS ARISING OUT OF, CONNECTED WITH OR RESULTING FROM THE PERFORMANCE OF THIS CLAUSE 10.2 OR FROM THE DESIGN, MANUFACTURE, SALE, REPAIR, LEASE OR USE OF THE GOODS, ANY COMPONENT THEREOF AND SERVICES DELIVERED OR RENDERED HEREUNDER OR OTHERWISE. IN NO EVENT, WHETHER AS A RESULT OF BREACH OF CONTRACT OR WARRANTY, ALLEGED NEGLIGENCE, OR OTHERWISE, SHALL RRSA BE SUBJECT TO LIABILITY FOR INCIDENTAL, CONSEQUENTIAL, INDIRECT, SPECIAL OR PUNITIVE DAMAGES OF ANY KIND, INCLUDING WITHOUT LIMITATION TO DAMAGE TO THE GOODS, OR OTHER PROPERTY, COMMERCIAL LOSSES, LOST PROFITS, LOSS OF USE, INCONVENIENCE, LOSS OF TIME, COST OF CAPITAL, COST OF SUBSTITUTE EQUIPMENT, DOWNTIME, OR CLAIMS OF CUSTOMERS. RRSA AMERICA INC. SHALL NOT BE LIABLE FOR ANY CLAIM GREATER IN AMOUNT THAN THE PURCHASE PRICE OF THE PRODUCT.**

10.2.7. The Customer is entitled to rectify the defect or to have it rectified by third parties only in urgent cases where operational safety is at risk or in order to prevent disproportionately extensive damage; provided that Customer has informed RRSA and obtained RRSA's prior written consent. In such cases, RRSA shall, in its sole discretion, reimburse the costs incurred by the Customer up to an amount equivalent to the costs RRSA would have incurred had it remedied the defect itself.

10.2.8. This clause 10.2 gives the Customer specific legal rights, and the Customer may also have other rights, which vary from state to state. Some states do not allow warranty duration limitations and/or certain exclusions or limitation of incidental or consequential damages. Therefore, the previously expressed exclusion(s) may not apply to Customer. If any one or more of the provisions contained in this clause 10.2 shall be invalid, illegal, or unenforceable in any respect, the validity, legality, or enforceability of the remaining provisions contained therein shall not in any way be affected or impaired thereby.

10.2.9. In order to obtain performance of an RRSA warranty obligation, the Customer should contact the nearest RRSA authorized distributor, dealer, or service outlet for instructions. To find the location of the nearest RRSA authorized distributor, dealer, or service outlet call +1 248-560-8000 or use the Sales and Service Locator which is located on the RRSA website at www.mtu-solutions.com.

11. LIABILITY

11.1. The Customer accepts that the various limitations or exclusions relating to the performance or non-performance of the obligations of RRSA as set out in these Conditions of Sale will limit or exclude the liability of RRSA to the extent and in relation to the matters specified; and that, subject to such limitations and exclusions, the liability of RRSA (if any) to the Customer in respect of all other matters arising from or in connection with these Conditions of Sale or any Contract, including the design, manufacture, sale, delivery, resale, repair, replacement, installation, technical direction of installation, inspection, operation, or use of any Goods covered by or furnished under these Conditions of Sale or any Contract, or from any services rendered in connection therewith, will be limited to the lower of either (a) 15% of the total amount received by RRSA under all Contracts from Customer in the calendar year in which the cause of action arose, or (b) $500,000.

11.2. **THE CUSTOMER'S ENTITLEMENT TO THE WARRANTIES AND ALL OTHER RIGHTS AND PRIVILEGES GRANTED BY THESE CONDITIONS OF SALE OR ANY CONTRACT ARE IN LIEU OF AND TO THE EXCLUSION OF ANY OTHER RIGHTS OR REMEDIES OF THE CUSTOMER WHETHER ARISING UNDER ANY CONDITION OR WARRANTY OF MERCHANTABILITY OR FITNESS OR QUALITY, INTELLECTUAL PROPERTY INFRINGEMENT, OR ANY OTHER CONTRACTUAL CONDITION OR WARRANTY EXPRESSED OR IMPLIED BY STATUTE OR OTHERWISE; AND ANY OTHER CAUSE OF ACTION IN CONTRACT (INCLUDING NEGLIGENT BREACH OF CONTRACT), TORT (INCLUDING NEGLIGENCE AND PRODUCT LIABILITY WHETHER STRICT OR OTHERWISE) OR UNDER STATUTE OR ANY OTHER LEGALLY RECOGNIZED CAUSE OF ACTION OR LIABILITY.**

11.3. The parties agree RRSA will have no liability to the Customer arising from or in connection with any loss or damage suffered by its customers.

11.4. The protection afforded by this clause 11 extends to, and for the benefit of, any employees, servants, agents, and suppliers of RRSA.

11.5. Nothing in these Conditions of Sale or any Contract will exclude or limit any liability on the part of RRSA other than to the extent permissible by applicable law. To the extent that any part of these Conditions of Sale or Contract has such effect, the parties agree to replace such part of these Conditions of Sale or Contract with provisions modified to the extent necessary to ensure such exclusion or limitation is permissible by law, but no further.

11.6. Subject to clause 11.5 and except where expressly specified in these Conditions of Sale, RRSA will not be liable to the Customer for any of the following losses or damages: (a) a loss of profit, interest, goodwill, business opportunity, business, revenue, anticipated savings, loss of use of the Goods, downtime costs, cost of capital, or costs of substitute equipment, facilities, and services; (b) those related to damage to reputation; and (c) indirect, incidental, special, punitive, or consequential losses, even if they were foreseeable and despite RRSA being advised of the possibility that they were in the contemplation of the Customer.

11.7. The Customer and RRSA agree that these Conditions of Sale have been the subject of negotiation at arms' length between sophisticated parties, is fully understood by each, and that any purchase price and the other agreements of the parties set out in these Conditions of Sale and any Contract have been arrived at having regard to: (a) the terms of these Conditions of Sale and any Contract; (b) the express warranties given by RRSA and the Customer's rights under these Conditions of Sale; and (c) the exclusions, waivers, and limitations of liability set out in these Conditions of Sale.

11.8. The Customer will indemnify RRSA against all losses incurred by RRSA in connection with any third-party claims that arise out of or in connection with, the performance (or non-performance) by RRSA of its obligations under these Conditions of Sale or any Contract.

11.9. Any claims to compensation, price reduction, cancellation of a Contract, or withdrawal from a Contract not expressly stated in these Conditions of Sale shall be excluded. That applies in particular to claims for compensation for damage not occurring on the Goods themselves, including but not limited to loss of production, loss of use, loss of orders, loss of profit, or other direct and/or indirect loss or damage.

12. INTELLECTUAL PROPERTY RIGHTS

12.1. The Customer's rights of use of the Goods and the accompanying documentation are limited to the operation, maintenance, and repair of the Goods. All intellectual property rights ("IPR") remain with RRSA. Where software is included in the Goods, the Customer is granted a non-exclusive right to use the software supplied, including its documentation, exclusively with the Goods. Any other use, including use of the software on more than one system, is prohibited. The Customer undertakes not to remove producer's details or copyright marks, or to alter them without the prior written consent of RRSA. All other rights to the software and the documentation (including copies) remain with RRSA. Sublicenses are only permissible with written permission by RRSA.

12.2. In the event that the Goods are resold, the Customer must contractually impose the restrictions in this clause 12 onto its customer.

12.3. Except for the limited rights granted in clause 12.1, the Customer will not acquire any title, right, or interest in or to any IPR belonging to or licensed to RRSA or developed by RRSA, including any IPR relating to: (a) any new parts or any processes, procedures, or documentation used by RRSA in the performance of any work under these Conditions of Sale; (b) any Goods provided under these Conditions of Sale; (c) any information provided under these Conditions of Sale; (d) any Services or any processes, procedures, or documentation used by RRSA in the performance of any Services under these Conditions of Sale or any Contract.

12.4. Subject to clauses 12.5 and 12.6, the sole liability of RRSA in respect of any claims for infringement of a third party's IPR, will be to indemnify the Customer against any loss resulting from a third party claim that the use by the Customer of any Goods or Services infringes any IPR owned by such third party, provided that RRSA will not be liable to the Customer for any loss of profit, contracts, revenue, or goodwill, indirect losses, or any loss of use of such Goods or Services, arising as a result directly or indirectly of any such claim.

12.5. The Customer will, as soon as is practicable, give notice in writing to RRSA of any such claim providing full details, following which RRSA may at its own expense and at its sole discretion: (a) assume the defense, disposal, or settlement of such claim, and the Customer will give RRSA all reasonable assistance and will not by any act or omission do anything which may directly or indirectly prejudice the position of RRSA in respect of such claim; and/or (b) modify either (i) the allegedly infringing component or (ii) the Goods and/or Services to eliminate any claim which may result from its use hereunder; and/or (c) replace either (i) the allegedly infringing component or (ii) the Goods and/or Services with functionally equivalent non-infringing component or Goods; and/or (d) remove any allegedly infringing component or Services and refund the portion of the price allocable to the infringing Goods; and/or (e) procure Customer the right to continue to use the Goods and/or Services as contemplated hereunder.

12.6. The indemnity contained in clause 12.4 will not apply to claims for infringement in respect of: (a) any product or component not of RRSA design, but in the event of any claim for infringement, RRSA will pass on to the Customer, insofar as it has the right to do so, the benefits of any indemnity given to RRSA by the designer, manufacturer, or supplier of such product or component; or (b) any use of the Goods in a manner not permitted by the specifications or requirements of such Goods; or (c) any modification to the Goods which is carried out by or on behalf of the Customer, if such modification is not authorized by RRSA in writing; or (d) any Goods manufactured to the design of the Customer; (e) any patent or other intellectual property right issued after the date hereof; (f) any action settled or otherwise terminated without the prior written consent of RRSA; or (g) Losses resulting from the Customer failing to observe its obligations under these Conditions of Sale and/or to the extent that such losses could be, but have not been, mitigated by the Customer.

12.7. To the extent that said Goods or any part thereof is modified by Customer, or combined by Customer with goods or processes not furnished hereunder, or used by Customer in a manner not permitted by the specifications or requirements of such Goods and by reason of said modification or combination or use, an action is brought against RRSA, Customer shall defend and indemnify RRSA in the same manner and to the same extent that RRSA would be obligated to indemnify Customer under this clause 12.

13. CONFIDENTIAL INFORMATION

13.1. Subject to clause 13.2, each party agrees to hold in confidence any information, which it acquires directly or indirectly from the other party and agrees: (a) to protect the information with a reasonable degree of care and at least the same degree of care used to protect its own information; (b) not to use the information other than for the purposes of these Conditions of Sale or a Contract it was provided under or for; (c) not to disclose the information at any time or to any third party without the written approval of the other party; (d) not to copy or reduce the information to writing or store, whether in a machine readable form or otherwise, except as may be reasonably required for the purposes of these Conditions of Sale or a Contract; and (e) not to remove, alter, or deface any proprietary, confidentiality, or security designations denoted on the information.

13.2. The provisions of clause 13.1 do not apply to information which is: (a) in the public domain through no fault of the Receiving Party (as defined below); (b) received from a third party who is without an obligation of non-disclosure; or (c) subject to compliance with clause 13.4 below, required to be produced by a legitimate legal authority; and will not prevent either party from disclosing these Conditions of Sale or a Contract and financial information concerning the business between the parties to affiliates, subcontractors and appointed auditors, legal advisers, insurers, and accountants.

13.3. Each party will be responsible for the observance of the provisions of this clause 13 by its employees or any other third parties to whom information is disclosed in accordance with this clause 13.

13.4. If the party receiving information (the “Receiving Party”) believes it is required by law, or is otherwise obliged, to disclose any information to any third party for any reason, then such party will provide the party disclosing the Information (the “Disclosing Party”) with immediate written notice of such requirement or obligation (together with a copy of any relevant access request, court order, or other evidence giving rise to such belief or obligation) to enable the Disclosing Party to seek appropriate protective relief and/or to take steps to resist or narrow the scope of any required disclosure. The Receiving Party must cooperate with the Disclosing Party with respect to such matters and will, in any event, disclose only such information as it has ascertained, after taking legal advice, it is legally compelled to disclose, and will use all reasonable endeavors to ensure that all information so disclosed is accorded confidential treatment in the terms of these Conditions of Sale. The Receiving Party will always notify the Disclosing Party in writing of the means, content, and timing of such disclosure prior to such disclosure being made.

13.5. Customer agrees not to: (a) act in breach of any duty of confidentiality owed to any third party in the course of performing its obligations under these Conditions of Sale or a Contract; and (b) offer or provide any Prohibited Information, whether specifically related to the subject matter of these Conditions of Sale or a Contract, or otherwise. Prohibited Information means any information whether offered in written, verbal, or other form that Customer is not authorized to have and use in connection these Conditions of Sale or a Contract, including, but not limited to, any information from a competitor’s confidential proposals, bid terms, or contract and pricing terms.

14. TERMINATION BY RRSA

14.1. RRSA may terminate these Conditions of Sale or a Contract in whole or in part immediately on written notice to the Customer if: (a) the Customer is in material breach or persistent breach of these Conditions of Sale, any Contract, or any other agreement with RRSA or its Affiliates, and (in the case of a breach that is remediable) does not remedy such breach within ten (10) days of receiving from RRSA written notice of the breach and a request to remedy the breach; (b) the Customer is in breach of any obligation to make any payment under these Conditions of Sale or any Contract or any other agreement with RRSA or its Affiliates and such breach continues for a period of ten (10) days from the due date; (c) if it becomes unlawful in any applicable jurisdiction for RRSA to perform any of its obligations under these Conditions of Sale; (d) any representation or warranty made by the Customer was incorrect when made; or (e) Customer (i) becomes insolvent, (ii) has a receiver, administrator, custodian, or trustee appointed over Customer or its assets, (iii) is unable to pay debts as they mature, (iv) makes an assignment for the benefit of creditors, or (v) institutes any proceeding or a proceeding is instituted against Customer under any bankruptcy, insolvency, or similar laws.

14.2. Without prejudice to its other rights or remedies, if RRSA is entitled to terminate, but elects not to terminate these Conditions of Sale or a Contract in whole or in part, then RRSA may do one or more of the following: (a) stop performing its obligations under these Conditions of Sale or a Contract; (b) treat all invoiced amounts as immediately due and payable; (c) exercise a lien upon any Goods in the possession of RRSA to secure any monies due to RRSA under these Conditions of Sale or a Contract; and (d) retake possession of any items or Goods either owned by RRSA or in which RRSA retains an interest and held by the Customer.

15. TERMINATION BY CUSTOMER.

15.1. The Customer may terminate these Conditions of Sale or a Contract in whole or in part immediately on written notice to RRSA if: (a) a force majeure event: (i) continues for a period of more than twelve (12) months; (ii) has not been caused in whole or in part by the Customer’s default; and (iii) affects a material and substantial element of a Contract, then the Customer may, on thirty (30) days written notice to RRSA, terminate such Contract; or (b) RRSA breaches a material and substantial element of these Conditions of Sale or a Contract then the Customer may, (in the case of a breach that is remediable) does not remedy such breach within ninety (90) days of receiving from the Customer written notice of the breach and a request to remedy the breach, terminate such Contract.

16. CONSEQUENCES OF TERMINATION

16.1. Where RRSA terminates these Conditions of Sale or a Contract pursuant to clause 14 then, without prejudice to the rights and remedies of RRSA under law, the Customer will indemnify RRSA against any losses which RRSA may sustain or incur as a result of such termination within thirty (30) days of RRSA providing the Customer with a written claim by RRSA, confirming that such losses were reasonably and properly incurred.

16.2. Where the Customer terminates a Contract pursuant to clause 15.1(a), then, without prejudice to the rights and remedies of RRSA under general law, RRSA will be entitled to retain all amounts previously paid by the Customer to RRSA under such Contract (including any deposits).

16.3. Where the Customer terminates a Contract pursuant to clause 15.1(b), then the Customer will pay to RRSA any costs RRSA has incurred in performing such terminated Contract up to the date of termination as notified by RRSA to the Customer.

17. ORDER MODIFICATION & CONFIGURATION CHANGES

17.1. The Customer may not modify the Goods or cancel the Contract if it is (a) within the quoted standard lead time and (b) less than 180 days before the delivery date.

17.2. The Customer may modify the Goods and cancel the Contract if it is (a) not within the quoted standard lead time and (b) greater than 180 days before delivery date, if all of the following conditions are met to the satisfaction of RRSA: (i) Customer sends a written cancellation request to its assigned RRSA sales representative and RRSA has accepted the cancellation in writing; and (ii) Customer reimburses RRSA for the following cancellation charges: (1) actual cost incurred by RRSA as a result of the cancelled Contract, including costs associated with acquisition of materials, (2) cancellation fee equal to 10% of the purchase price of the cancelled Contract, and (3) any additional reasonable costs incurred by RRSA resulting from the cancellation. Customer understands, acknowledges, and agrees to reimburse RRSA for the cancellation charges noted above and expressly authorizes RRSA to recover those charges.

17.3. The Customer may request the delivery date to be moved out by four (4) weeks or more from the original delivery date. If an Order is within the standard lead time, RRSA has the right to invoice the customer for the Contract on the previously agreed ship date and move the Goods into storage. Title to the Goods, and risk of loss, will pass to the Customer on the invoice date. The Customer will also be responsible for all storage charges incurred and transportation cost to the storage location.

17.4. If an Order is placed with a delivery time that is shorter than the standard lead time and accepted by RRSA in writing, RRSA has the right to charge the Customer a premium to cover the cost of expediting delivery of the Goods.

18. EXPORT CONTROL

18.1. The supply of Goods and Services by RRSA is subject to its permissibility under national and international export control provisions and the procurement of any export license that may be required. To that extent the Customer undertakes to provide all necessary information and documentation, any final destination declaration that may be required is due at least six (6) months before delivery. Delayed cooperation on the part of the Customer or delays in the approval procedure shall entitle RRSA to postpone the delivery dates accordingly. Should an export license not be granted, RRSA shall be entitled to terminate the Contract. RRSA shall not be liable to Customer for compensation or damages as a result of a delay or termination under this clause.

18.2. In the event that the Goods are resold by the Customer, the Customer shall be responsible for compliance with the requirements of the applicable United States and/or local foreign trade regulations.

18.3. The Customer acknowledges that any information, Goods, parts, or materials provided to or received by it in relation to these Conditions of Sale or a Contract may be subject to export control laws and regulations, including the United States Department of State International Traffic in Arms Regulations (ITAR) and the United States Department of Commerce Export Administration Regulations (EAR). The Customer will comply with all applicable requirements under such laws and regulations. The Customer warrants and undertakes it will not use or permit the use of, export, or transfer (by any means, electronic means or otherwise), any information or goods which are subject to export control laws and regulations without fully complying with the same, including all codes of conduct, relevant export license(s), guidelines, notices and instructions, and all requests and requirements of RRSA.

19. ANTI-BRIBERY AND CORRUPTION

19.1. Customer represents, warrants and undertakes to RRSA that neither it nor its Affiliates, directors, employees, representatives, nor any other person acting on its or their behalf: (a) have engaged, or will engage, in any conduct which was or would be an offense under any ABC Laws (whether or not Customer is subject to that ABC Law), (b) have done, or will do anything, that may put RRSA or any of its Affiliates in breach of any of the ABC Laws, (c) have authorized, offered, promised, paid or otherwise given, or will authorize, offer, promise, pay or otherwise give, any Inappropriate Inducement; and (d) have undertaken or will undertake any action or activity intended directly or indirectly to facilitate any offence of tax evasion with respect of this Agreement.

19.2. Notwithstanding any other provision of these Conditions of Sale, RRSA may, without prejudice to any of its rights under law, contract, or equity, terminate these Conditions of Sale or a Contract immediately by written notice if Customer is in breach of this clause 19, or if, at any time, the representations, warranties, and undertakings given by Customer in this clause 19 would not be true and accurate in all respects.

19.3. For purposes of this clause: (a) “ABC Laws” means the United Kingdom Bribery Act 2010, the United States Foreign Corrupt Practices Act 1977 (15 U.S.C. Section 78dd-1, et. seq.), as amended, and any other laws relating to anti-bribery and corruption matters applicable to the subject matter of these Conditions of Sale or a Contract, (b) “Affiliates” means, as to any person, any other person that is in Control of, is Controlled by, or is under common Control with, such person, (c) “Control” means the power, directly or indirectly, either to: (i) vote 50% or more of the securities having ordinary voting power for the election of directors (or persons performing similar functions) of such person; or (ii) direct or cause the direction of the management and policies of such person, whether by contract or otherwise in relation to these Conditions of Sale or a Contract and “Controls” and “Controlled” will be construed accordingly, (d) “Government Official” means any person who would constitute either: (i) a "foreign public official" as defined in the UK Bribery Act 2010; or (ii) a "foreign official" as defined in the United States Foreign Corrupt Practices Act (15 U.S.C. Section 78dd-1, et. seq.), as amended, (e) “Inappropriate Inducement” means any payment or thing of value or any financial or other advantage to or for the use or benefit of: (i) any Government Official; or (ii) any director, officer, employee, agent, or representative of any commercial organization or private individual; or (iii) any other person, entity, or third party intermediary while knowing or having reason to know that all or any portion of such payment, thing of value, or advantage would be offered, promised, paid, or given to

any of the persons described in this definition, for the purpose of influencing any act or decision of any such person, including a decision to do or omit to do any act in violation of the duty of such person in order to obtain or retain business, secure any improper advantage, or obtain any license, permit, approval, certificate, or clearance.

20. MISCELLANEOUS

20.1. *Further Assurance.* Each party agrees from time to time to promptly do and perform such other and further acts, and execute and deliver any and all such other instruments as may be required by law to carry out and effect the intent and purpose of these Conditions of Sale or any Contract.

20.2. *Costs and expenses.* Each party will pay its own charges, costs, and expenses it incurred in the negotiation, preparation, and execution of these Conditions of Sale or any Contract.

20.3. *Waiver.* The rights of each party under these Conditions of Sale or Contract may be exercised as often as needed, are cumulative, and apply in addition to its rights under law, except where expressly stated otherwise, and may be waived only in writing and specifically. Not exercising or delaying exercise of any right is not a waiver of that right.

20.4. *Severability.* If any term of these Conditions of Sale or any Contract is or becomes illegal, invalid, or unenforceable in any jurisdiction in relation to any party, that will not invalidate the remaining provisions of these Conditions of Sale or any Contract, or affect the legality, validity, or enforceability of that or any other provision in any other jurisdiction.

20.5. *Variation.* The provisions of these Conditions of Sale or any Contract may not be varied, other than by written agreement between the parties.

20.6. *Survival.* Clauses 3, 10-13, 16, and 18-21 of these Conditions of Sale will survive the expiration or termination of a Contract, and such provisions will remain in full force and effect.

20.7. *Assignment.* (a) The Customer will not assign or transfer (whether voluntarily or involuntarily, by the operation of law or otherwise), declare a trust in respect of, or create or permit to exist any security interest over, any of its rights or obligations under these Conditions of Sale or any Contract and (b) RRSA may, after having given prior written notice to the Customer, assign, transfer, or subcontract any or all of its rights and obligations under these Conditions of Sale or any Contract to any of its Affiliates.

20.8. *Entire agreement.* (a) These Conditions of Sale govern each Contract, and together with RRSA's quotation, if any submitted to Customer, including technical specifications and other documents referenced therein, any RRSA Limited Warranty and Customer's Order, excluding any of Customer's standard or pre-printed terms and conditions contained therein to which RRSA hereby objects, constitute the entire agreement between the parties with respect to their subject matter. The Contract is intended to be read as a whole, however, if there is a conflict of terms in the Contract, the documents constituting the Contract will be given precedence in accordance with the following order: (i) RRSA's quotation, if any; (ii) the Limited Warranty, if any; (iii) these Conditions of Sale; and (iv) Customer's Order. For the avoidance of doubt, any subsequent amendment to any one of the above-listed documents will be deemed as incorporated within such document, overriding any previous provisions therein as appropriate. (b) RRSA assumes no contractual obligation with respect to the supply of Goods or Services other than as expressly set out in each Contract, whether arising under any condition or warranty of merchantability, fitness or quality, or any other contractual condition or warranty, express or implied, by statute or otherwise. (c) RRSA assumes no collateral duty in tort or negligence to the Customer with respect to the supply of Goods or Services. (d) The terms of these Conditions of Sale apply to the exclusion of the terms of any other document which may be issued by either party relating to the supply of Goods or Service. (e) Neither party has placed any reliance on any representations, agreements, statements, or understandings made prior to the signature of these Conditions of Sale; or any Contract, whether orally or in writing, relating to the supply of Goods or Services other than those expressly incorporated in these Conditions of Sale; and the parties agree and acknowledge that these Conditions of Sale represent their entire agreement relating to the Goods or Services and supersede all such prior representations, agreements, statements, and understandings. (f) The only remedies available for breach of any representation or statement which was made prior to entry into these Conditions of Sale or any Contract, and which is expressly set out in these Conditions of Sale or any Contract shall be for breach of contract. (g) Neither party may place any reliance on any and all future representations whatsoever in respect of the performance of these Conditions of Sale or any Contract, unless expressly agreed by the parties in writing to form a part of these Conditions of Sale or any Contract. This clause 20.8 does not apply to any statement, representation, or warranty made fraudulently, or to any provision of these Conditions of Sale, or any Contract induced by fraud, for which the remedies available are those available under the applicable law as set forth in clause 21.

20.9. *No partnership or agency.* (a) Nothing in these Conditions of Sale or any Contract will: (i) constitute a partnership or joint venture between the parties; (ii) constitute any party as the agent of any other party; or (iii) create any fiduciary obligations between the parties. (b) Neither party will: (i) represent itself as the agent or partner of the other party; or (ii) do anything (or omit to do anything) which might result in any person believing that such party has the authority to contract or enter into commitments on behalf of, or in the name of, the other party.

20.10. *Waiver of Immunity.* (a) The Customer irrevocably and generally consents to the issue of any process or the giving of any relief in connection with any claim brought against it, including the making, enforcement, or execution of any order or judgment against any of its property or assets (regardless of their use or intended use). (b) If the Customer or any of its property or assets is or are entitled in any jurisdiction to any immunity from service of process or of other documents relating to any proceedings or to immunity from jurisdiction, suit, judgment, execution, attachment (whether before judgment, in aid of enforcement, or otherwise), or other legal process, the Customer irrevocably waives such immunity to the fullest extent permissible under the law of that jurisdiction. The Customer also irrevocably agrees not to claim any such immunity for itself or its property or assets.

20.11. *Publicity.* Subject to clause 13, neither party will disclose nor publicize the existence of these Conditions of Sale or any Contract to any third party without the prior written consent of the other party.

20.12. *Notices and Communications.* (a) Except where these Conditions of Sale provide otherwise, any notice or communication in connection hereunder or any Contract must be in writing and, unless otherwise stated, may be given in person, by certified post, email, or by fax. (b) Any notice given in connection with these Conditions of Sale or any Contract will only be effective: (i) if delivered in person, when delivered; (ii) if sent by certified post, five (5) days after being deposited in the post, postage prepaid, in a correctly addressed envelope; (iii) if sent by commercial courier service or recorded delivery, on the date and at the time of signature of the courier's delivery receipt or the recorded delivery receipt; (iv) if sent by fax, at the time transmitted provided the sender receives a good transmission report; or (v) if sent by email, at the time transmitted provided that the sender does not receive a notice that the transmission failed. (c) Any notice given in connection with these Conditions of Sale or any Contract will be in English. (d) Any other document provided in connection with these Conditions of Sale or

any Contract will be in English or accompanied by a certified English translation. In this case, the English translation prevails unless the document is a statutory or other official document.

21. GOVERNING LAW AND ARBITRATION

21.1. These Conditions of Sale and any Contract, and any non-contractual obligations arising out of or in relation to these Conditions of Sale and any Contract, will be governed by and construed in accordance with the laws of the principal place of business of the Rolls-Royce Power Systems Group Company identified in the quotation or invoice, without regard to its principles of conflict of laws.

21.2. All disputes, claims, questions, or disagreements arising out of or in connection with these Conditions of Sale and any Contract or its breach or validity shall be finally settled in accordance with the Commercial Arbitration Rules of the American Arbitration Association ("AAA Rules"), without recourse to courts of law, which rules are deemed to be incorporated by reference in this clause. The determination of the arbitrator shall be binding on the Parties, shall not be appealable, and judgment on the award rendered may be entered in any court having jurisdiction over the matter and the parties. The seat and place of arbitration is the principal place of business of the Rolls-Royce Power Systems Group Company identified in the quotation or invoice, the number of arbitrators is one, and the language of the arbitral proceeding is English. In the event that the parties are unable to select and agree upon a single arbitrator within twenty-one (21) days of either Party's demand to arbitrate, then each party shall select an arbitrator who may or may not be from the list of qualified arbitrators maintained by the AAA, who then shall select a neutral arbitrator from a list of Arbitrators maintained by the AAA. The arbitrator shall require exchange by the parties of documents relevant to the issues raised by any claim, defense, or counterclaim, or on which the producing party may rely in support of or in opposition to any claim, defense, or counterclaim, with due regard for eliminating undue burden and expense, and the expedited and lower cost nature of arbitration. At the request of a party, the arbitrator may, at his or her discretion, order the deposition of witnesses. Depositions shall be limited to a maximum of three depositions per party, each of a maximum of four (4) hours duration, unless the arbitrator otherwise determines.

21.3. Without prejudice to any other rights of the parties, the parties agree that any party may seek an injunction, specific performance, or other equitable relief for any actual or threatened breach of these Conditions of Sale, or any Contract in any court of competent jurisdiction. Such preservation of rights shall not be construed as a waiver or limitation of either party's consent to arbitration.

Sustainable Solutions

Rolls-Royce Power Systems

RRPS team, 2021

A Rolls-Royce solution

Rolls-Royce group

A world-class technology company, built on three strong and complimentary business units.

Power Systems is the group's 2nd largest business and frontrunner in electrification.

A Rolls-Royce solution

Civil Aerospace

35
types of commercial aircraft powered by us

13,000
engines in service around the world

19,000
total employees

5.089bn
underlying revenue

Defence

150
customers in over 100 countries

16,000
engines in service around the world

9,000
total employees

3.366bn
underlying revenue

Power Systems

>40,000
customers in 13 different industries

20,000
reciprocating engines sold per year

≈ 9,000
total employees

2.745bn
underlying revenue

The Rolls-Royce vision

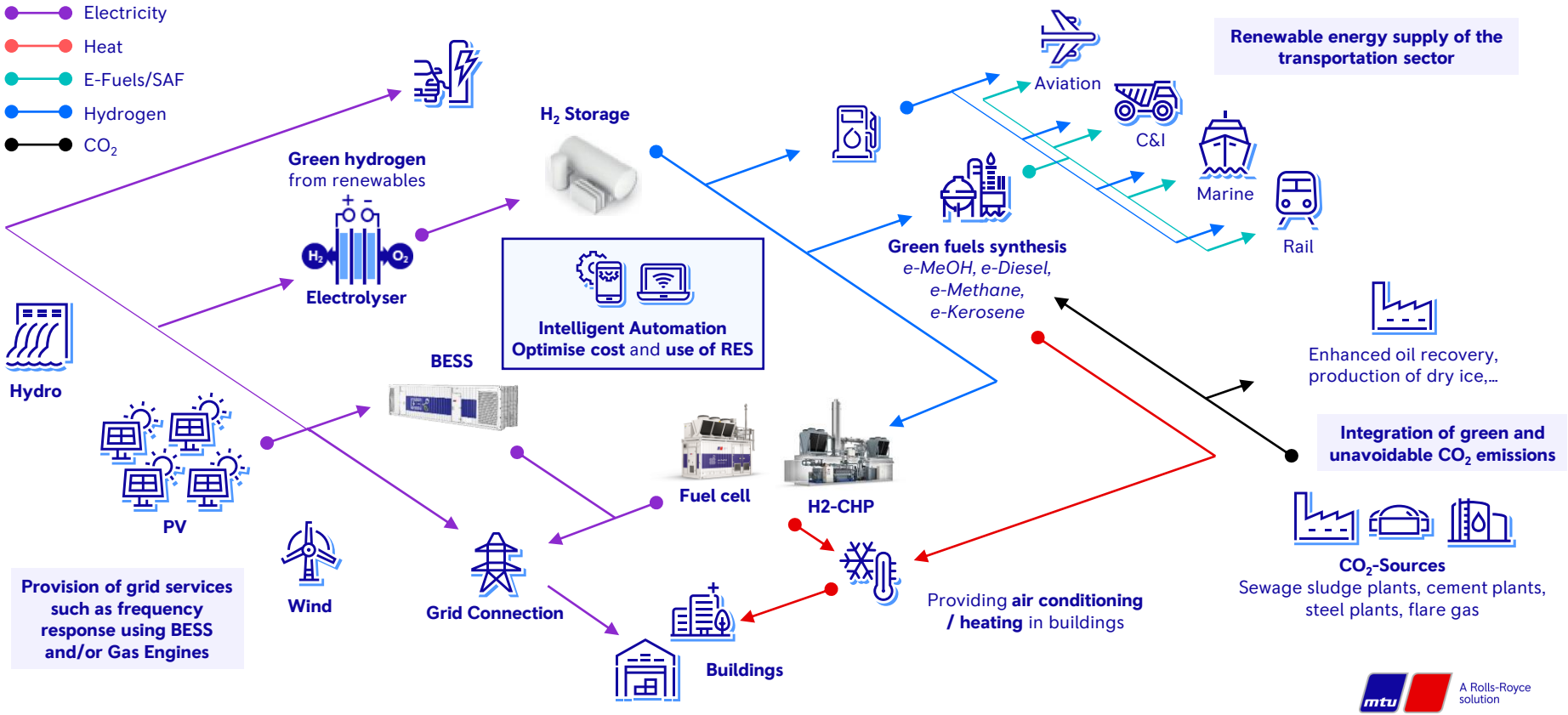
Rolls-Royce pioneers cutting-edge technologies that deliver the cleanest, safest and most competitive solutions to fulfil our planet's vital power needs.

Pioneering the power that matters

We aim to become net zero carbon in our operations by 2030 and play a leading role in enabling the sectors we're in to reach net zero carbon by 2050.

A Rolls-Royce solution

The Future of Green Transport and Energy: Renewable Cross-Sectoral Energy System

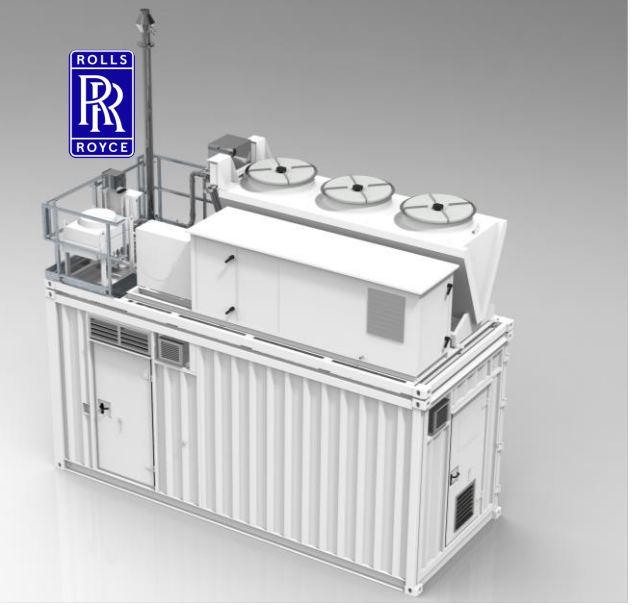


A Rolls-Royce solution

01

mtu Fuel Cells

A Rolls-Royce solution

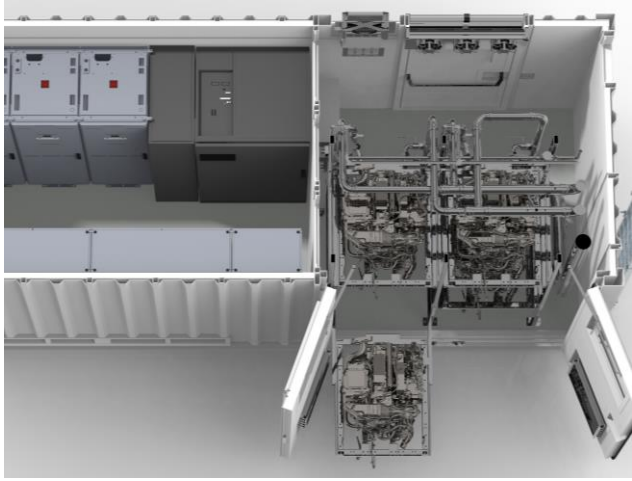


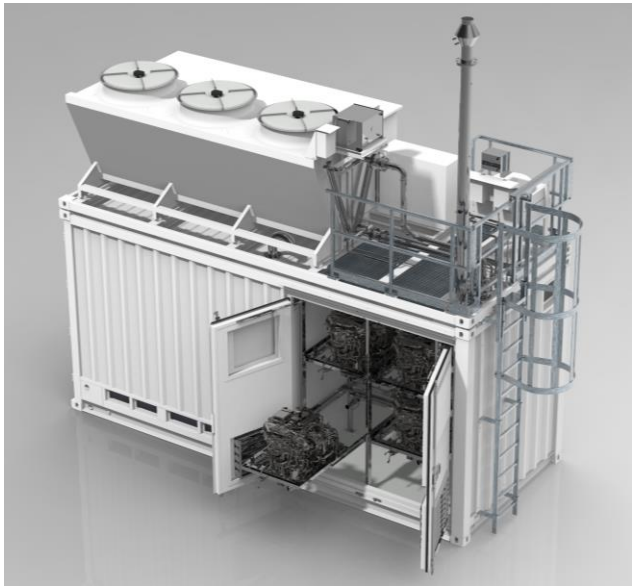
Integrated.

Operable under the open sky without any infrastructure apart from hydrogen, the standalone Fuel-Cell Demonstrator is much more than a test bench.

Versatile.

Equipped with a cutting-edge static online-UPS system and Li-Ion batteries, the demon-strator can be adapted for various different customer use-cases.





Pioneering.

Demonstration of new concepts for modular FC system integration will set the foundation for large scale power generation from PEM fuel cell technology.

A Rolls-Royce solution

Fuel Cell Solution 600 kW

mtu A Rolls-Royce solution

Performance

- 600kW electrical power
- Integrated Li-ion batteries
- Full power from fuel cell, battery or a combination of both.

Technical facts

Footprint	20 foot container (15 m²)
Weight	Container: ~ 20 tons
Electrical connection	400 V (AC), 3 phase, 50 Hz
Ambient temperature	- 15°C to 40°C
Humidity	< 23 g_{water}/kg_{air}
Waste heat	Up to 840 kW at approx. 75°C
H_2 consumption	Up to 42 kg/h at 16-20 bar
Condensate water	Up to 5 l/min

Functionality

- **Modular PEM fuel cell system** for high reliability and availability with centralized services.
- Combination of fuel cell and Lithium-ion battery with the inverter topology of a **static online UPS.**
- **Separate compartments** that provide the specific conditions required by the fuel cell and the batteries.
- Fully **autonomous**, **black-start capable system.**
- **Holistic safety concept** for electrical safety, explosion protection, fire detection and extinguishing.
- Integrated waste heat rejection from the fuel cell system and temperature conditioning of the batteries.
- Galvanic isolation (e.g. transformer) required.

02

mtu Electrolysers and Storage

A Rolls-Royce solution

Electrolyser Solution 1.4 MW

Performance

- 1.4 MW_e electrical power.
- PEM electrochemistry with flexible response time for RES combination.

Technical Facts

Nominal power	1.4 MW_e
H_2 production	630 kg/day (26.25 kg/h)
H_2 production range	0 – 100 %
Output pressure	40 Barg
Output purity	Up to 5.0
Response time	0-100 % warm standby within seconds 0-100 % cold start within minutes
Water consumption	410 l/h

Functionality

- **Fast response** times minimizing need for energy buffering.
- **Dynamic production** range between 0 and 100%.
- Fully **autonomous.**
- **Purity** suitable for **fuel cell** and **H2-ICE** applications.
- **Holistic safety concept** for electrical safety, explosion protection, fire detection and extinguishing.

Operation

- Power supply to EL can be ramped up/down between 0 and 100%, **within seconds** from standby.
- **Little to no energy** buffering costs necessary.
- Fully **autonomous.**

A Rolls-Royce solution

Fuel Cell and Storage Solution

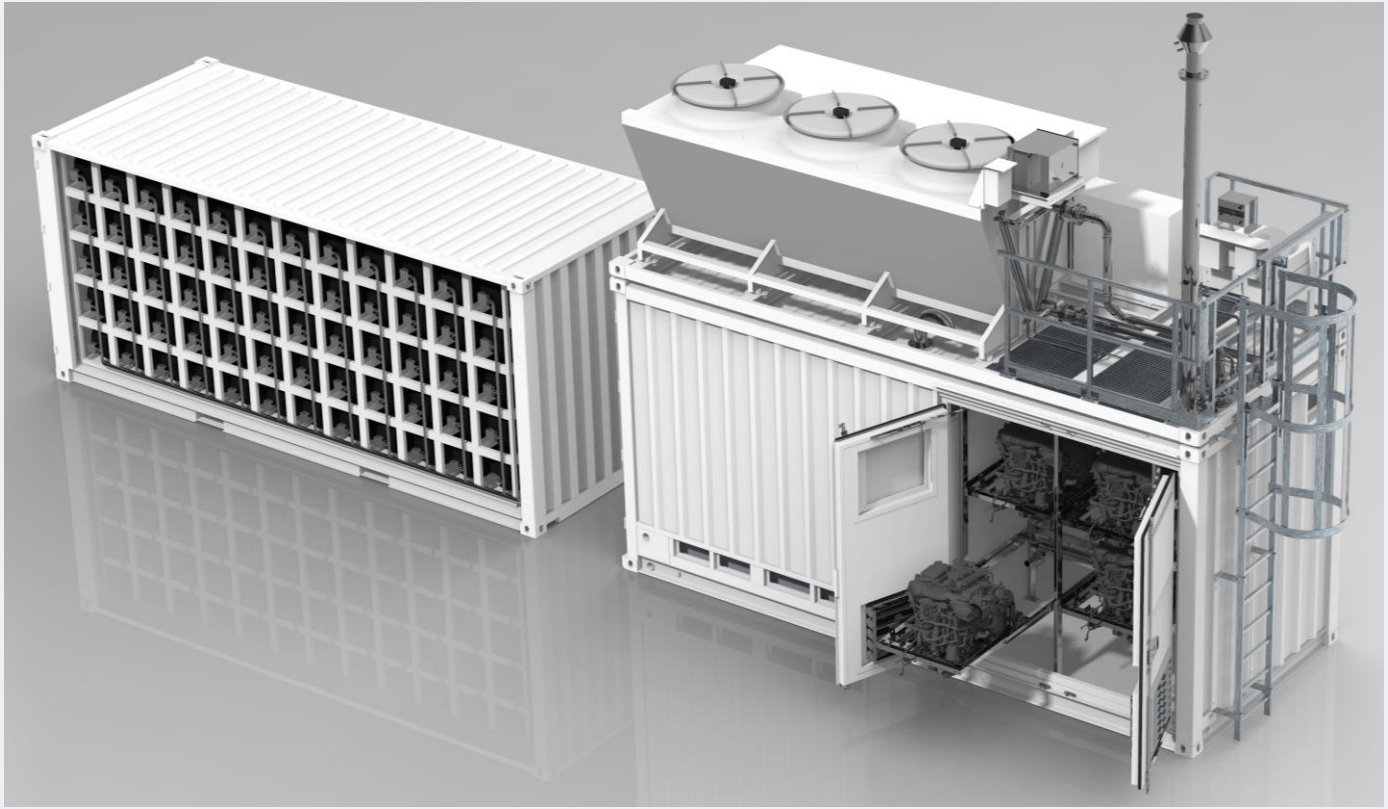
Examples of commercially available H2-Storage solutions

20ft Container

- 289 kg usable H2 at 350 bar, 6.8 h operation at 100% load
- 458 kg usable H2 at 700 bar, 10.9 h operation at 100% load

40ft Container

- 578 kg usable H2 at 350 bar, 13.7 h operation at 100% load
- 915 kg usable H2 at 700 bar, 21 h operation at 100% load



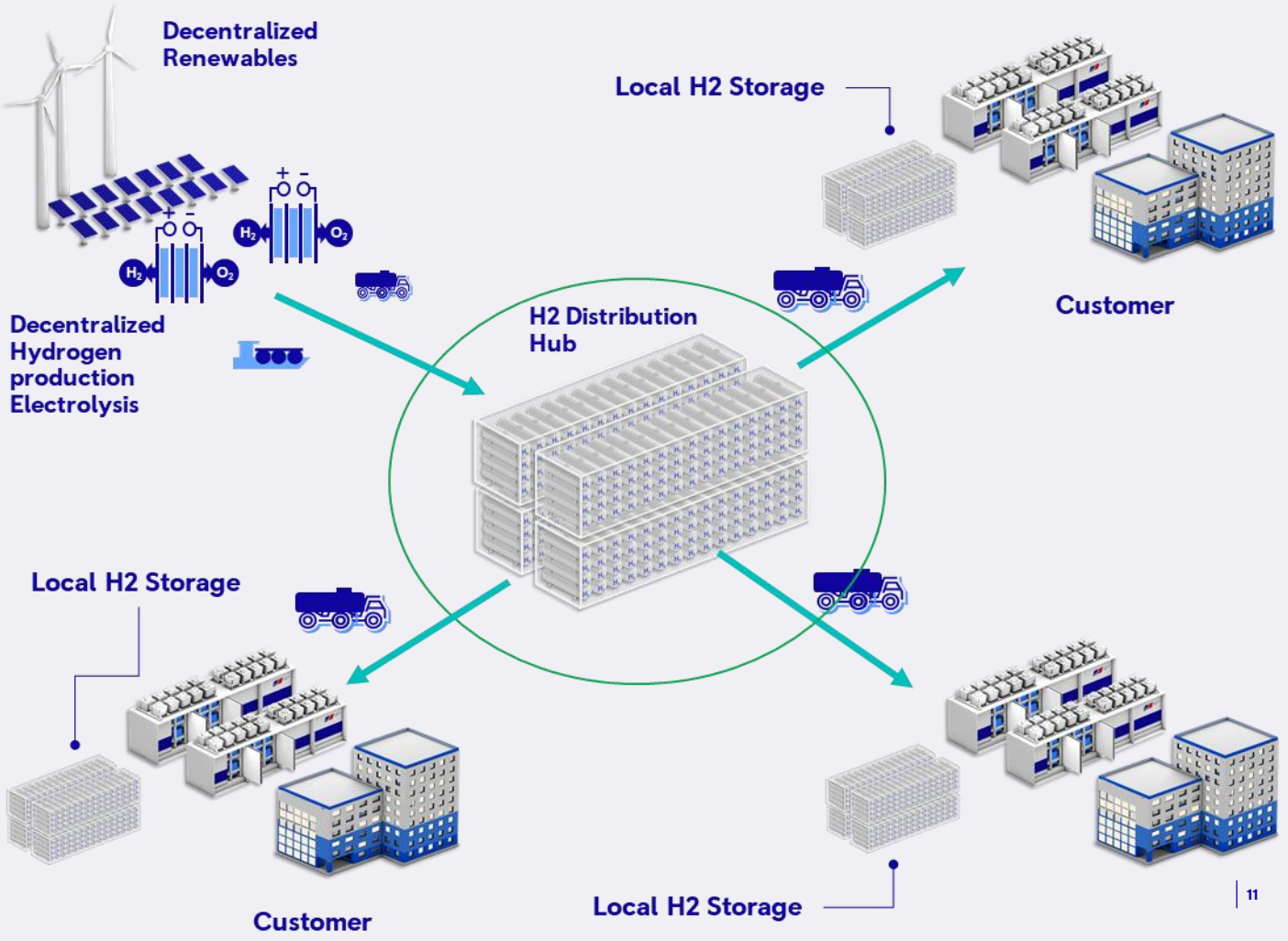
20ft Container H2-Storage

20ft Container Fuel Cell

A Rolls-Royce solution

Hydrogen Supply Concepts

- Decentralized hydrogen production @ wind/PV park
- Decentralized storage with integrated storage facility
- Applicable for vehicles fleets and/or stationary power applications.
- Direct on-site hydrogen production also possible.



A Rolls-Royce solution

03

mtu Hydrogen Engines

A Rolls-Royce solution

Hydrogen Engine Concept

New Components:

Hydrogen Valves & Fuel System (experience from Marine Gas)

TBO of existing components:

expected to be comparable to gas Engines.

Knock Detection / Engine Controls

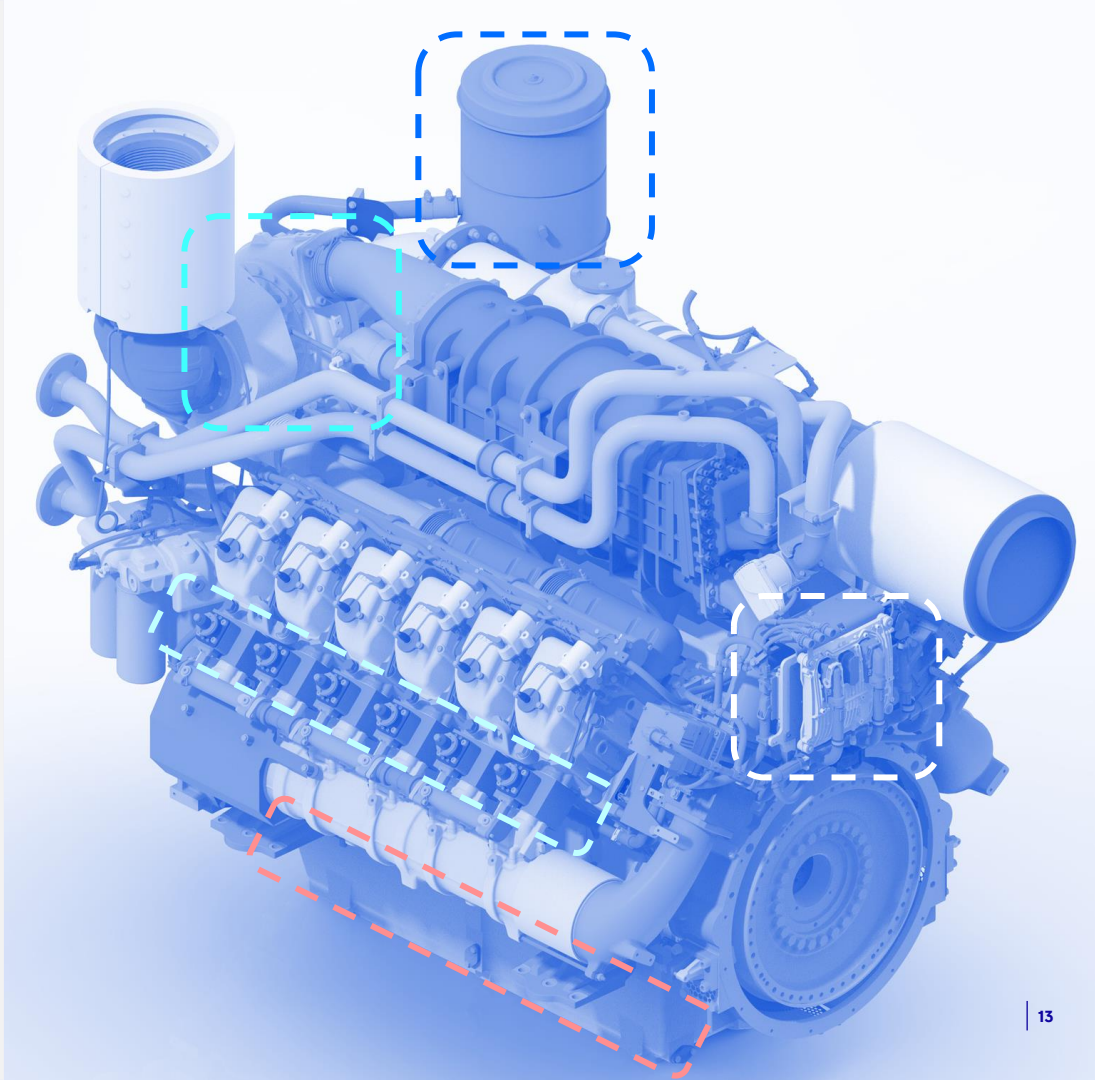
MPI Fuel System

Lubricant

Turbocharger

Piston Design

Safety features



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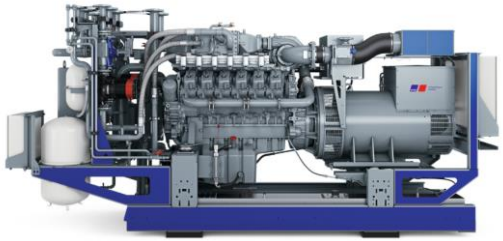
Full Hydrogen Engine Solutions

Performance

Electrical Power	360 kW
Usable heat	> 100 °C
Weight	6,150 kg
Dimensions	4,545 x 1,310 x 2,200 mm
Electrical connection	400 V (AC), 50 Hz
H2 consumption	27 kg/h

mtu Series 500



Performance

Electrical Power	960 kW
Usable heat	> 100 °C
Weight	12,000 kg
Dimensions	4,600 x 1,900 x 2,300 mm
Electrical connection	400 V (AC), 50 Hz
H2 consumption	76 kg/h

mtu Series 4000 H2 Retrofit

A Rolls-Royce solution

Vertical Integrated Hydrogen-Ready

Containerised

Demonstrator in close coordination with partner

Containerised solution as product option

Ramp-Up time

Grid-parallel operation in focus

Island mode possible

Envisaged hardware package allows fast ramp-up.

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Hydrogen Solutions Compared

Hydrogen ICE

Low/no bottleneck resources
No Lithium, precious/ rare-earth metals

Low CAPEX
Price comparable to existing engines

Exhaust heat usage
Temperature level > 100°C

Low fuel purity acceptable
< 98% Vol. hydrogen purity

Hydrogen Fuel Cells

Zero emissions
No GHG, SO_x, NO_x

Low maintenance
Fewer moving parts

Fast reaction times
Response times within seconds

High electrical efficiency
Optional use of thermal exhaust

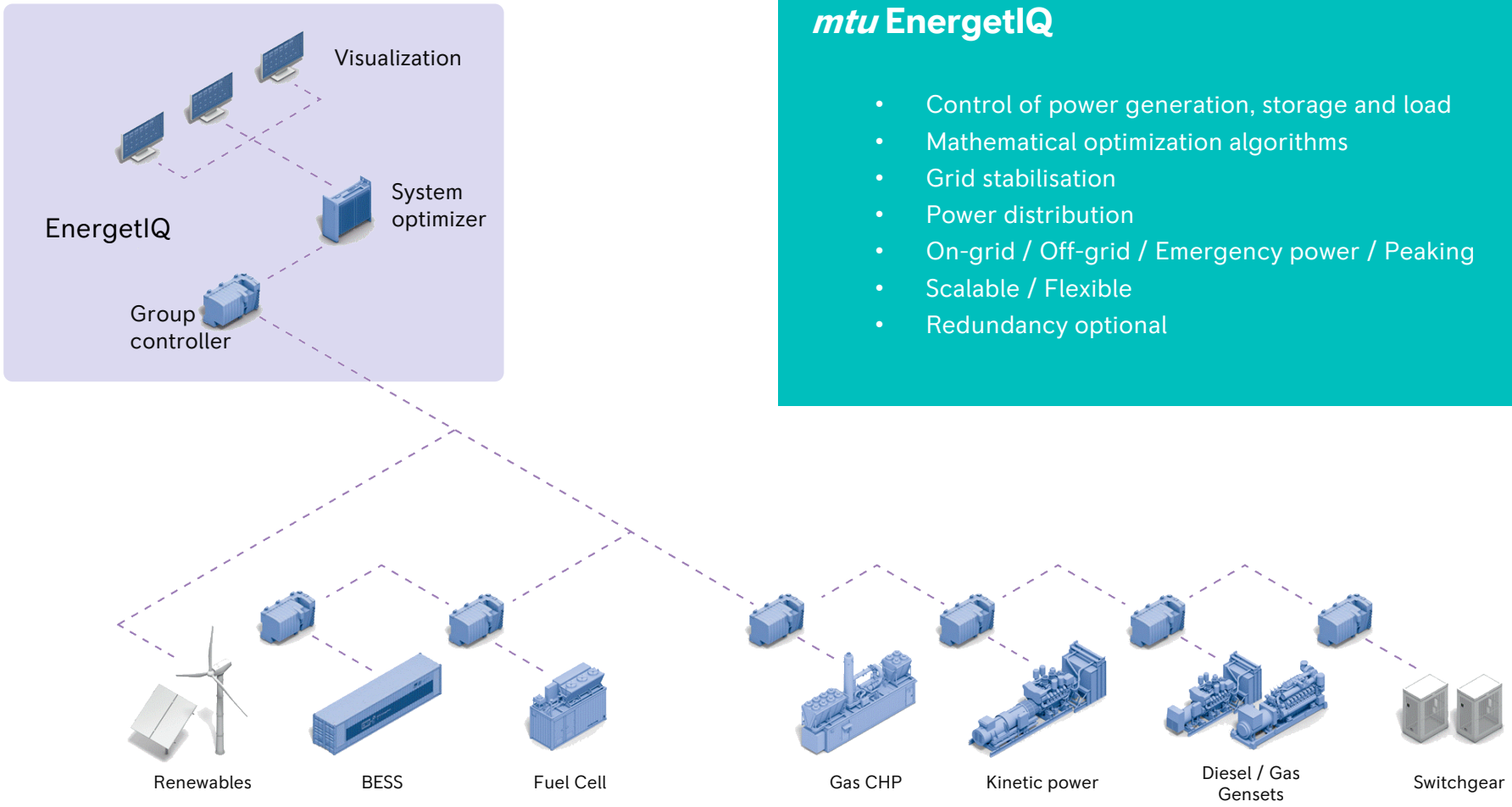
04

mtu Automation Platform

A Rolls-Royce solution

mtu EnergetIQ

- Control of power generation, storage and load
- Mathematical optimization algorithms
- Grid stabilisation
- Power distribution
- On-grid / Off-grid / Emergency power / Peaking
- Scalable / Flexible
- Redundancy optional



EnergetIQ

A Rolls-Royce solution

System Services

- **User management** with **Audit Trail** controls and records access to **EnergetIQ** and assets
- **IT Security** by hardened OS, secure boot, firewalls, LDAP, TLS encryption and trusted platform module (TPM 2.0)
- **Connectivity** to assets, switchgear, protection devices and remote systems.

Data Management

- **Data acquisition** of connected assets, switchgear and grid.
- **SQL Database** with access by web-based query technology.
- **Modular Data Analyzing** including correlation to external data.
- **Data Visualization and Reporting** with diagrams, dashboards and interactive Jasper reports.

Functionality

Control

- Frequency and voltage stabilisation
- Power management
- Switchgear control specific operation sequences

Mathematical Optimisation

- Perfect energy mix
- Group optimization
- Forecasts, predictive algorithms

Applications

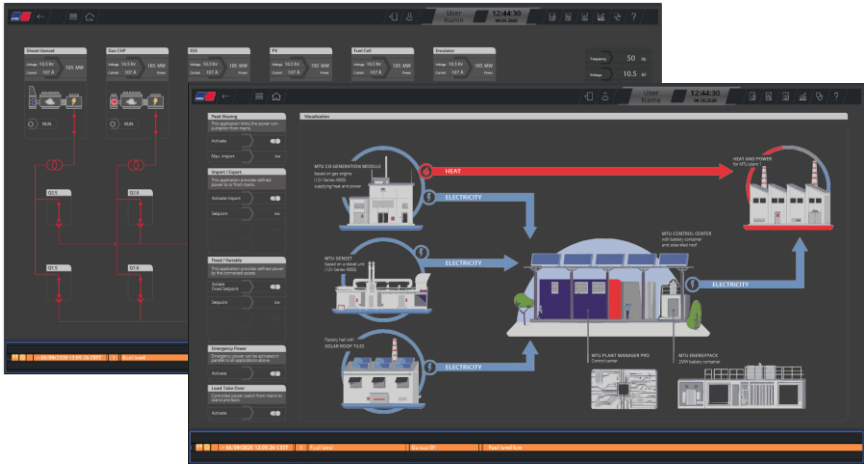
- Grid services
- Energy cost reduction
- Emergency power

Monitoring and Protection

- Continuous supervision of limits
- Redirection, limitation or interruption of power

System Overview

- Single Line
- Energy Flow
- Access to Application / Grid functions
- Warnings / Alarms
- Trending
- Reporting
- One-click access to Asset Details and Control



Asset Details and Control

- Common UI/UX throughout all different assets
- Main information like state, mode and power always present (left frame)
- Content of main frame switchable:
  - Values
  - Gauges
  - Controls
  - Trending

Friedrichshafen, Germany

Microgrid Validation Center

The Microgrid Validation Center in Friedrichshafen combines different energy generation assets with storage and load to enable validation of different stationary energy solutions.

In off grid mode, the assets and control algorithms' ability to maintain grid stability can be validated. In on grid mode, grid-forming functionality and the offering of grid services such as frequency response can be validated and further developed. The control system optimizes the energy management according to optimization goals such as cost or CO2 emissions. An integrated emulator acts as a programmable load to enable simulation of a wide variety of scenarios.

Configuration

Off grid + On grid | Solar PV | BESS | Diesel | Gas | Emulator | Fuel Cell | Electrolyser | H2 Engine

Main Benefits

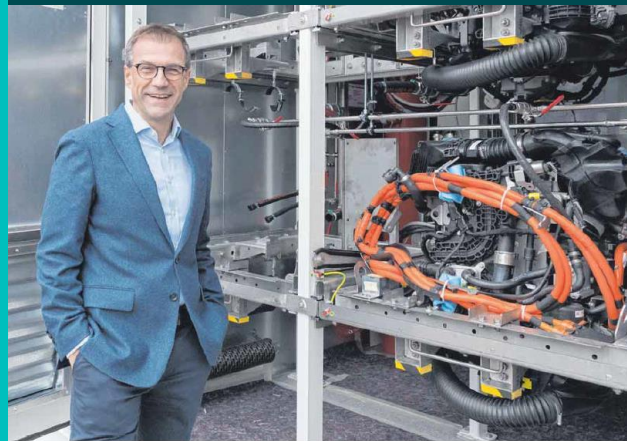
- Development and validation of new control algorithms & technologies
- Realistic show case for customers
- CO_2 and cost savings for factory

Solution

- 12V4000 Diesel 1300kW
- 12V4000L64 Gas 1300kW
- EnergyPack 2000kVA / 1000kWh
- PV 80kW
- Fuel Cell 250kW
- Emulator (SMA) 2500kW
- mtu EnergetIQ

Applications

- Integration of PV
- Regulation of Frequency and Voltage
- Load sharing
- Black start
- Island & Grid-parallel operation
- Peak Shaving / Energy Shifting
- Uninterruptible power supply (2021)



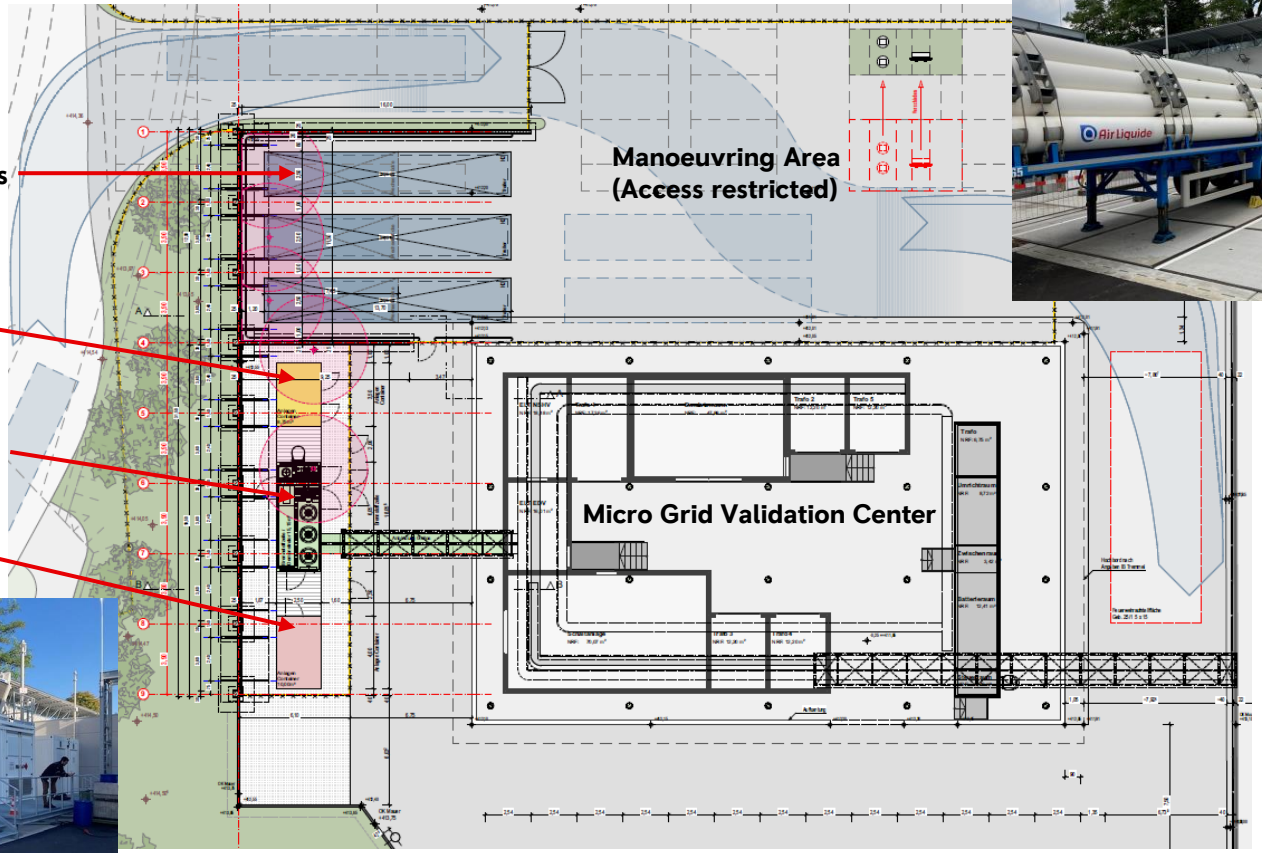
Groundplan

Hydrogen Trailers

H_2-Processing

FC-Demonstrator

Control Room



Thank You!

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Power Generation

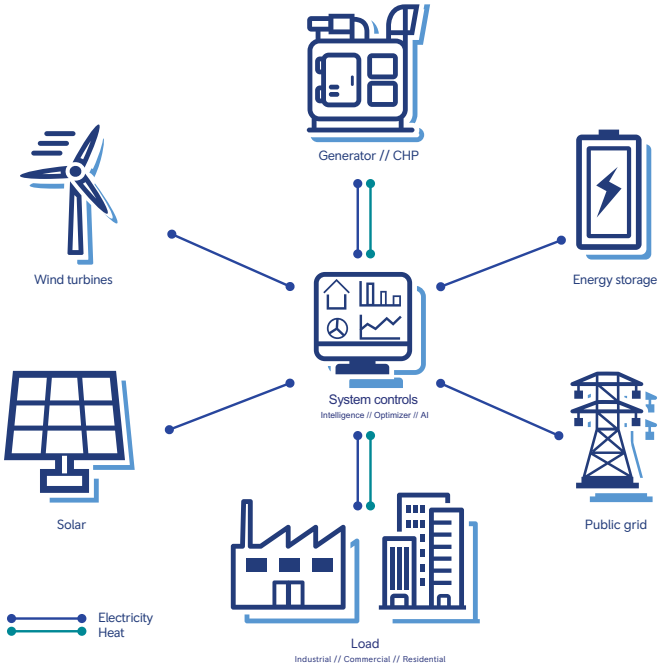
TYING MULTIPLE POWER SYSTEMS TOGETHER WITH INTELLIGENT CONTROLS

By **Tom Drake**
Senior Sales Manager – Gas Power Systems
MTU

The control system is the most essential component of a microgrid. It manages a microgrid's distributed energy assets to cost-effectively produce energy while maintaining grid stability. To deliver the right energy mix for a customer's needs, the system must be predictive, intelligent and automated. After specifying a few key parameters, a control system can calculate exactly which energy sources will be needed to ensure efficient and reliable operation of a microgrid.

The need for dispatchable generation

Whether it's powering a residential high-rise in a major city or a mining operation in a remote area, every microgrid is designed to support an electric or thermal load. A wide range of distributed energy sources can be installed to optimize load management. The options could be renewable, such as solar panels and wind turbines, or conventional, such as diesel- or natural gas-powered generator sets combined with battery energy storage systems and intelligent controls to optimize these various assets.



Components of a microgrid

Intelligent control systems can bundle a microgrid's distributed energy resources and loads together for on-grid (parallel mode) or off-grid (island mode) energy consumers. A control system works as an optimization tool to harness a microgrid's various assets. Microgrids in environments with unlimited grid access allows optimum load management (peak shaving and load shifting) and enables operators to participate in the power balancing market. For off-grid applications, the microgrid becomes the sole energy source. Intelligent controls help lower fuel consumption and maintenance requirements to reduce overall operating costs, cut exhaust and noise emissions and ensure the availability of reserve power. A well-designed microgrid system allows energy users to optimize all of these functions into one system.

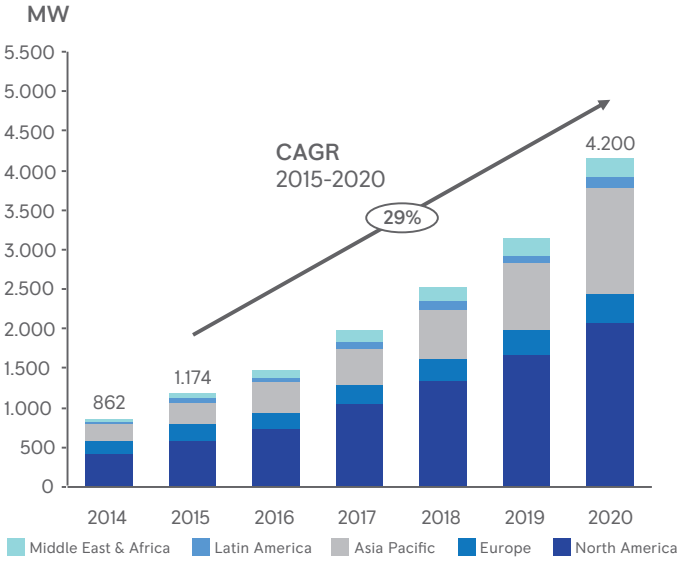
Why use a microgrid?

- Cost optimization
- Peak shaving
- Reduced environmental footprint
- Increased energy efficiency
- Increased resiliency/reliability
- Defer need for investment
- Flexible solutions
- Additional revenue streams for customer
- Grid services
- Energy arbitrage

New opportunities

As more customers realize the benefits of microgrids, the market continues to expand. Specifically, North American and Asia Pacific regions are showing the most growth potential for the future. With the growing demand for energy independence, renewable energy sources and on-site combined heat and power (CHP) systems, along with advancements in battery technology, interconnectivity and intelligent controls, the implementation of microgrids will continue to grow.

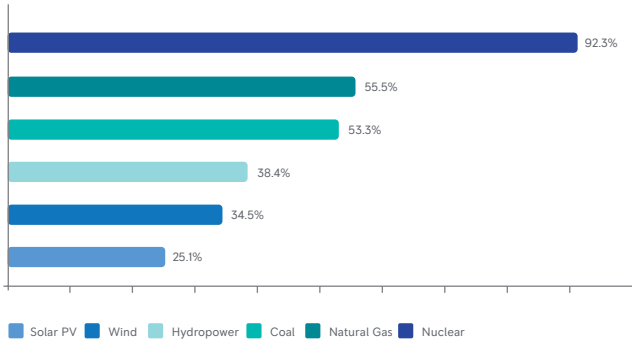
Annual total installed capacity by region, base scenario, world markets: 2014-2020



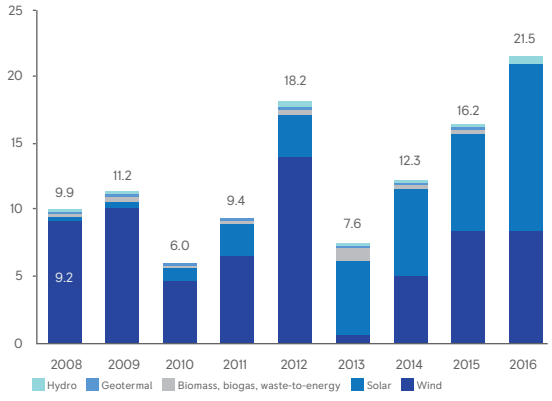
The growing need for dispatchable generation

The world continues to shift toward renewable energy sources such as solar, wind and biogas-powered components. More than 60% of new power plant installations are devoted to renewable energy. Renewable capacity has increased 70% since 2008. However, renewable energy is a variable source and not dispatchable. The maximum capacity factor (time a facility is able to produce maximum power) for wind and solar is 35%. This low capacity factor creates a risk of instability and the need for flexible generation assets, such as reciprocating engines and battery energy storage, paired with renewable sources. With a microgrid on-site, an energy user has a diverse mix of dispatchable power "behind the meter" at their command. Through flexible generation assets—whether it's engines, solar panels or battery storage—power can be instantaneously available and financially optimized at all times with intelligent controls.

Maximum Capacity Factors



Renewable Energy Usage



Soutrce: US energy overview: Renewable energy capacity build by technology (GW) [2]

Controls

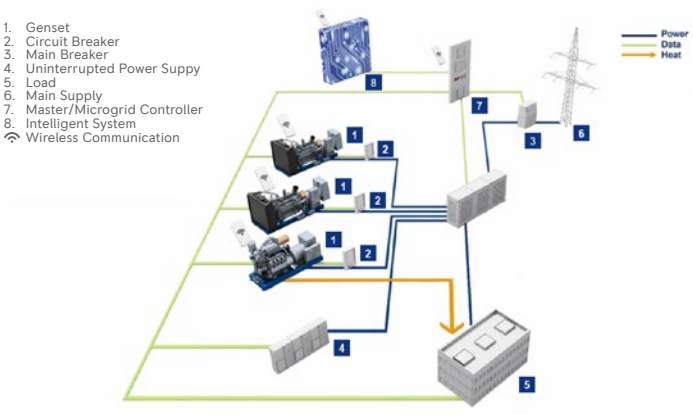
Intelligent control systems must be in place in any microgrid to balance distributed energy sources. Every piece of equipment must be integrated to safely and cost-effectively produce energy while minimizing environmental impact. At a site with multiple generator sets powering loads with electrical switchgear (shown below), a genset master controller keeps individual engines in sync with each other to seamlessly handle the load. All units work together to produce the exact power needed. A genset master controller's sole task is to monitor power generation assets.

Genset Master Controller functions

- High-level controller interfacing with individual genset controllers for multi-unit installation
- Start/stop selection and power setpoint of the gensets according to power or heat requirements
- Load sharing
- Leveling of engine run hours across units
- Synchronizing/control of main and tie breakers
- Island operation logic
- Visualization and data tracking of multiple units
- Remote access

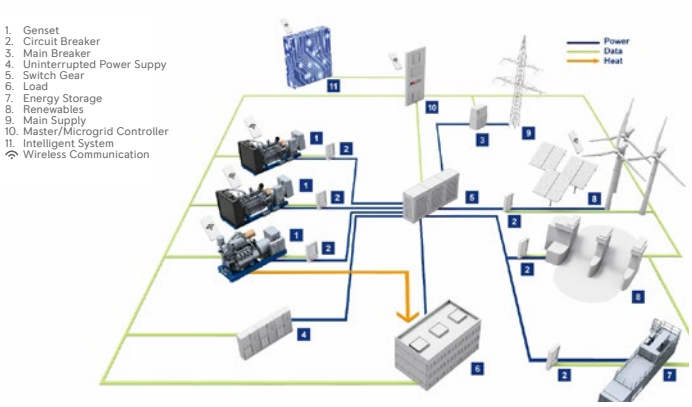
Genset master controller

As power generation systems get more complex, so do the control



systems. A microgrid controller manages many more assets than a genset master controller. In the microgrid application shown below, the control system must not only manage how diesel or gas generator sets interact with each other, but also how they integrate with renewable sources (which produce efficient yet variable power), the grid and battery energy storage systems. Adding to the complexity, on-grid or off-grid applications present different challenges. Either way, a microgrid controller must perfectly balance all assets to reduce the total cost of energy produced, optimizing the installation's financial and energy solution.

Microgrid controller



Microgrid controller functions

- Control of gas/diesel generators, solar, wind, battery storage, spinning reserves
- Grid parallel and grid forming operation in island mode
- Optimization of assets – technical and financial
- Modular platform for scalable solution
- Visualization and data tracking of multiple units
- Remote access

Grid design

The architecture of a microgrid controller is organized by function. Like a generator set controller, there are primary control functions to stabilize engine assets. Secondary controls are associated with transitioning between grid parallel mode and island mode. If there is a power outage, operation parameters must be restored between phases. Tertiary control's main objective is financial optimization—focusing on which mix of assets minimize the cost of energy.

Hierarchical control of hybrid power system

Primary Control

- Stabilize the voltage and frequency
- Offer plug-and-play capability for DERs
- Share the active and reactive power
- Mitigate circulating currents

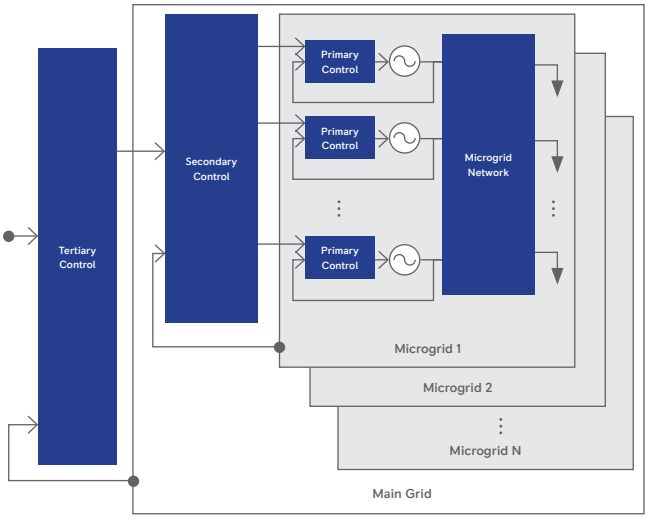
Secondary Control

- Frequency restoration
- Voltage restoration

Tertiary Control

- Optimal operation
- Power flow management

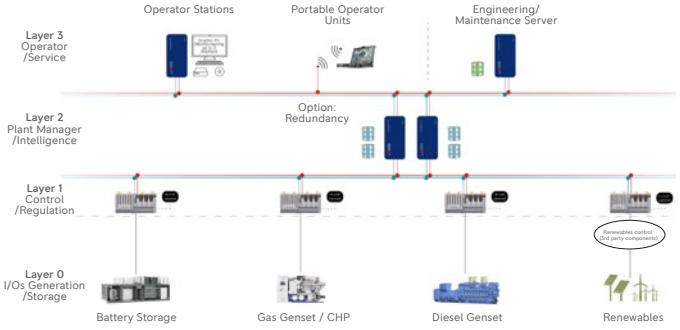
Control architecture



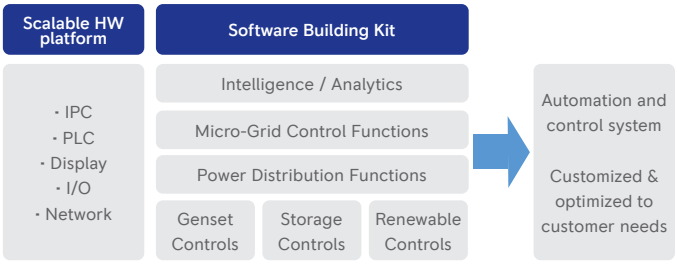
An ideal automation and control system is a fully integrated platform throughout all layers of control—from very basic functions like hardware I/O control or field device interfacing all the way to high layer SCADA functions like trending, reporting and system overview visualization.

Each layer is scalable to a customer's needs. For example, computing power can be adjusted by adding or removing industrial PCs. If you need very high availability, redundancy on all layers can be provided, from controller redundancy through network redundancy, all the way to I/O redundancy. Based on a system-wide user management, according to your role or on your individual account, you can always access all general information and control functions throughout the system, with the option of personalized profiles for access to additional functions. No matter if you are working locally at a power unit, sitting in a control room or reviewing reports at your desk, any type of interface to this automation and control system features the same user experience. This is a fully integrated, fully customizable, high performance automation and control solution with full redundancy on demand.

Layers of control



A flexible, scalable solution



Every microgrid—and customer—has different needs. A microgrid controller must provide complex functions throughout the system with user-friendly engineering tools. It functions as an automation system building kit with two parts: hardware platform and software building kit. Hardware is scalable with built-in redundancies, with functions that can be used in a wide range of Industrial PCs or controllers in a very flexible and efficient way. Hardware components provide calculation power, communication and I/O. A software building kit brings these two worlds together to intelligently dispatch multiple assets to financially optimize the system. Using analytics and artificial intelligence, hardware and software work in tandem as a powerful automation and control solution that is not limited to predefined controller devices, but is customized to a customer's exact specifications.

Operational modes

Microgrid design varies depending on whether the microgrid is connected to the main grid in grid parallel mode or isolated from the grid in island mode. In any case, a microgrid control system ensures the most reliable, economical and environmentally responsible operation possible.

Grid parallel mode

There is growing interest from on-grid energy consumers (industry, service providers and municipal services) in the development of partial or complete self-supply. The motivating factors for these customers are: independence from nationwide network providers, security of supply, cost optimization, and a "green" image.

Functions

- Active Power Control – Set active power (kW) import/export to the grid
- Reactive Power Control – Set reactive power (KVAR) import/export to the grid
- Optimize utilization of renewable generation to reduce usage of gensets/grid
- Optimize load factor/running hours of gensets
- SOC Limits – Control State of Change (SOC) boundaries of battery storage (scheduled or fixed values)

Island mode

Consumers without grid connections run self-sufficient island operations (traditionally based on conventional diesel generators). Installations include mines in remote regions, inhabited islands, and remote hotel resorts. Common goals are the development of microgrids, consisting of regenerative energy (PV, wind), battery storage, and backup generators in connection with intelligent energy management systems.

Functions

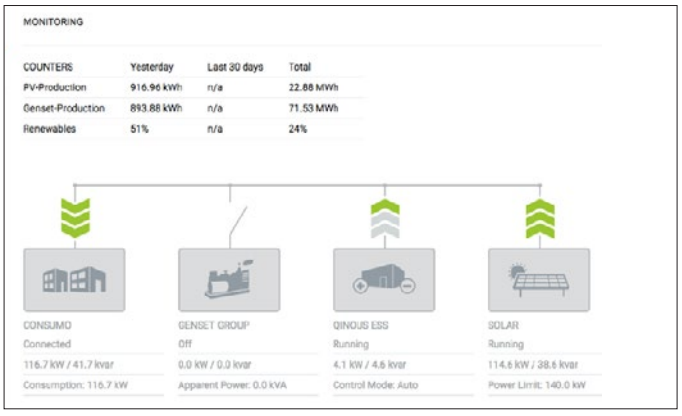
- Utilize Battery Energy Storage System (BESS) to improve power quality by supporting generators during transient load changes
- Optimize usage of renewable generation with BESS to avoid curtailment of these assets
- Renewable curtailment should power production exceed consumption

Control & monitoring functions

A microgrid controller forms an interface between a complex network of distributed energy sources, battery and load. Through user-friendly displays accessible on desktop and mobile platforms, an engineer can monitor live data and performance history while the system automatically manages the microgrid efficiently and reliably.

Example: Control System Functions

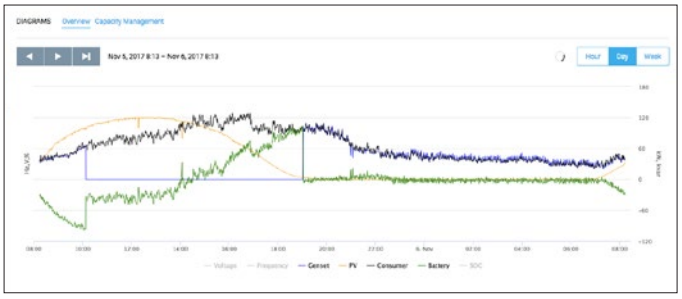
System Overview (Home screen)



Functions

- Live data overview showing flow of energy being produced, consumed and stored
- Performance history for all subcomponents
- Alarm list and history

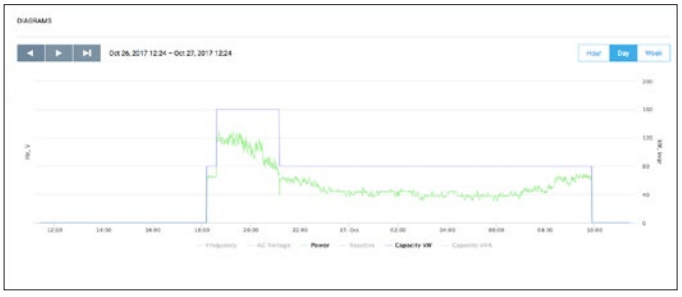
Capacity Management (System)



Functions

- Reduce utilization of generator sets
- Optimize genset starts
- SOC schedule to store energy from renewables for nighttime use
- Avoid solar curtailment
- Ensure stability of electrical system with sufficient stored energy

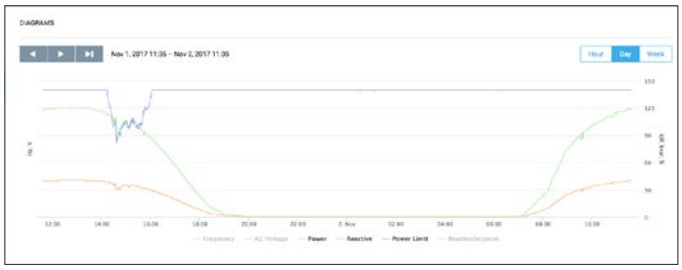
Capacity Management (Genset Group)



Functions

- Optimize genset starts
- Add/subtract genset capacity to ensure optimal load factor
- Pre-programmed generator start times/load acceptance capability to intelligently manage assets

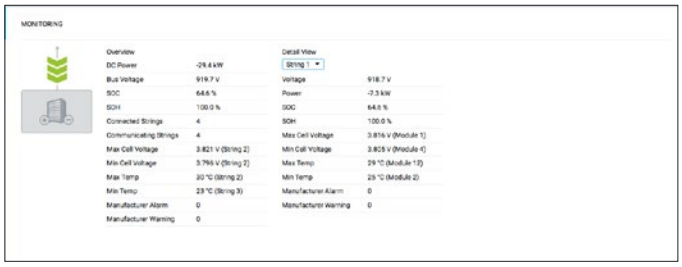
Capacity Management (Solar)



Functions

- Reliable solar curtailment, factoring in BESS SOC, BESS power limits and inverter power limits
- Avoid curtailment through analysis of solar capacity in power management

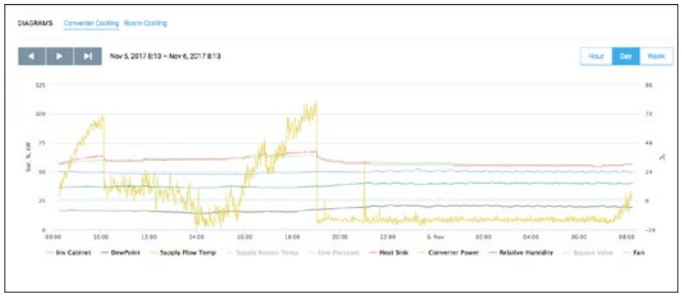
BESS Management



Functions

- Overview of battery parameters
- Monitoring to avoid undesirable SOC rest states: BESS remaining deeply discharged for prolonged time
- Full utilization of battery capacity
- Thermal monitoring

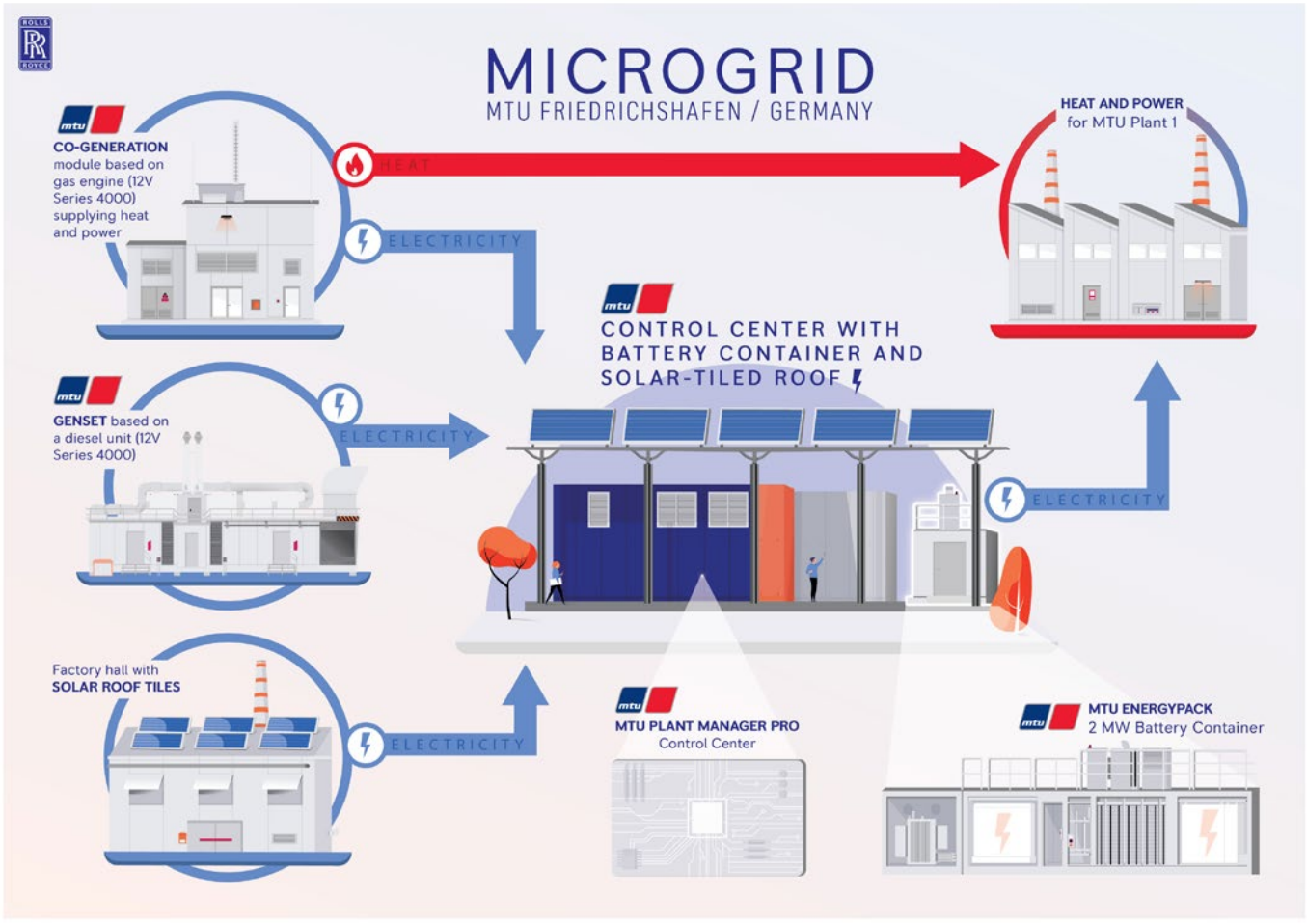
BESS Management (Thermal)



Functions

- Overview of HVAC system
- Monitor ambient and battery temperatures
- Track invertor power
- Detect overheating to prevent battery fire

Simulation tool



Every microgrid is unique. Modeling real-world applications can ensure a microgrid and its control system is designed optimally. The MTU Microgrid Validation Center in Friedrichshafen, Germany offers highly flexible simulation and testing capability. Equipped with diesel and co-generation standby generator sets, solar panels, battery storage and integrated MTU automation system, the self-sustaining center can simulate a wide range of conditions, including off-grid operation. It's an effective proving ground for customers to apply a software model to just about any real-world installation.

There are several parameters to consider when optimizing a microgrid. The facility's load profile, solar and wind conditions, fuel costs, remaining life of primary power units and the CAPEX investment on renewables, energy storage and plant power components must all be thoroughly analyzed. The process starts with a high-level analysis, to indicate whether the project should be abandoned or investigated further. These calculations simulate one year of system performance, using site-specific solar and wind energy data. The data helps predict annual generator hours of operation and fuel use. The second part of the process is financial optimization, to make sure the right equipment is selected to cost-effectively and efficiently produce power. A real-world example of this process is outlined on the next page.

Example #1:
Off-Grid Greenhouse – California

Site details
- 160,000 sq. ft. European-designed facility
- Limited three-phase power available for office area only
- Abundant natural gas available
- Cooling loads are the major challenge

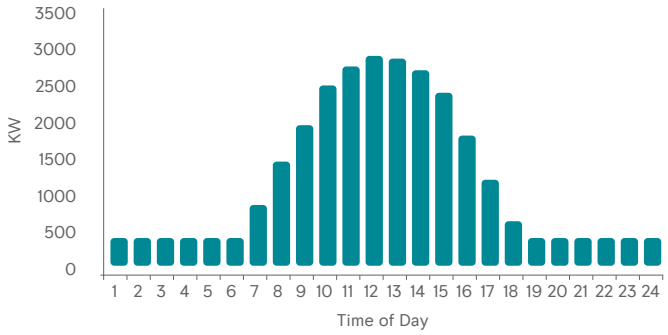
Scope of supply
- 2 x MTU 8V4000L32 natural gas generators rated at 762kW
- 2 x MTU 16V4000L32 natural gas generators rated at 1550kW
- MTU/Qinous Qlarge 700kVA/753kWh
- Site controller/Microgrid energy management system

Consumption
On a typical summer day, the facility needs a peak of over 3,000 kW. In the winter, with shorter days and less sunlight, more electricity is needed (4,000 kW). Over a 12-month period, more than 13 million kWh are required to power facility.

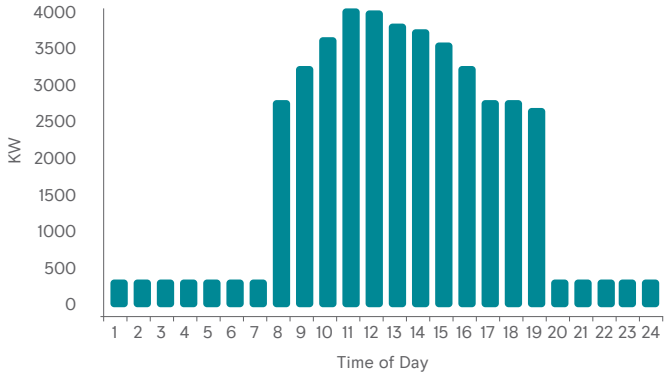
Consumption Summary

Component	Consumption (kWh/yr)	Percent
AC Primary Load	13,848,830	100
DC Primary Load	0	0
Deferrable Load	0	0
Total	13,848,830	100

Summer



Winter



Production summary

Run hours will spread across engine models leveling annual run time and extending maintenance intervals using controller.

Component	Production (kWh/yr)	Percent
Generic flat plate PV	352,777	2.54
MTU 8V4000 GS L32 60Hz	3,178,966	22.9
MTU 8V4000 GS L32 60Hz (1)	277,064	2
MTU 16V4000 GS L32 60Hz	6,059,779	43.7
MTU 16V4000 GS L32 60Hz (1)	4,012,275	28.9
Total	13,880,862	100

Engine plant statistics

Natural Gas Consumption Statistics

Quantity	Value	Units
Total fuel consumed	3,417,265	m^3
Avg fuel per day	9,362	m^3/day
Avg fuel per hour	390	m^3/hour

(1) MTU 8V4000 GS L32 60Hz Statistics

Quantity	Value	Units
Hours of Operation	6,520	hrs/yr
Number of Starts	868	starts/yr
Operational Life	9.66	yr
Capacity Factor	47.6	%

(1) MTU 16V4000 GS L32 60Hz Statistics

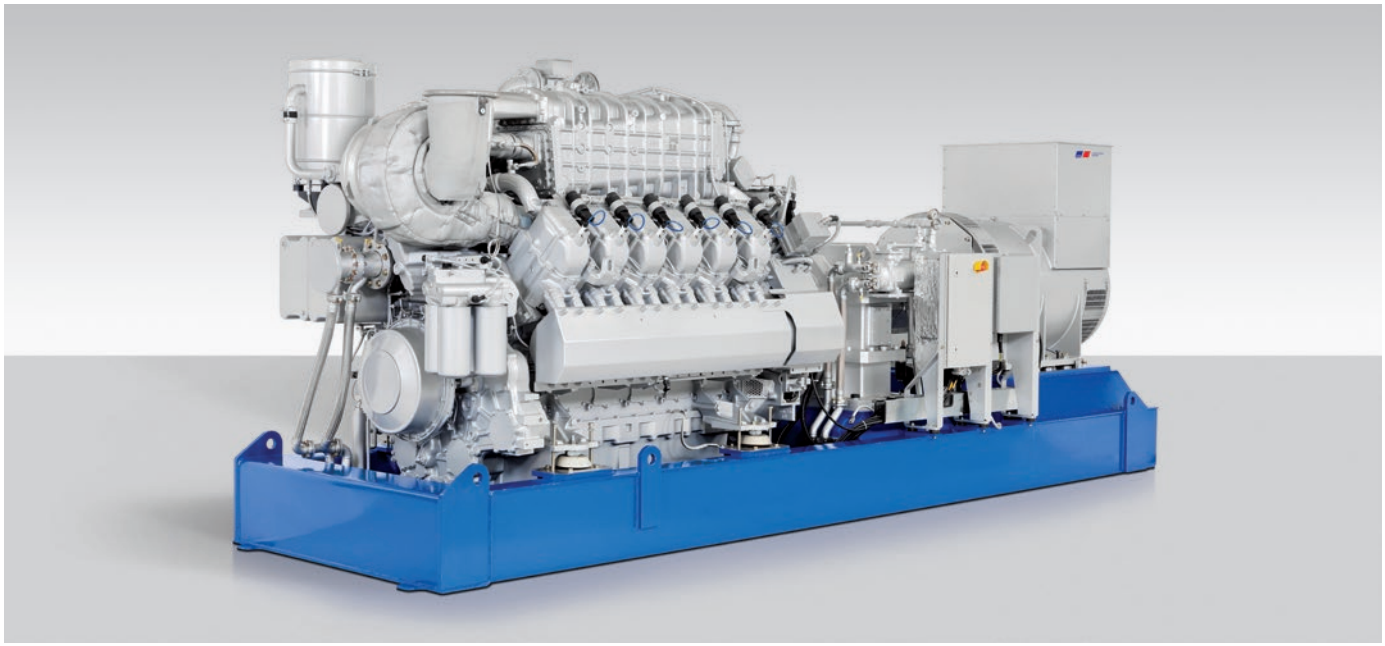
Quantity	Value	Units
Hours of Operation	3,969	hrs/yr
Number of Starts	365	starts/yr
Operational Life	15.9	yr
Capacity Factor	44.7	%

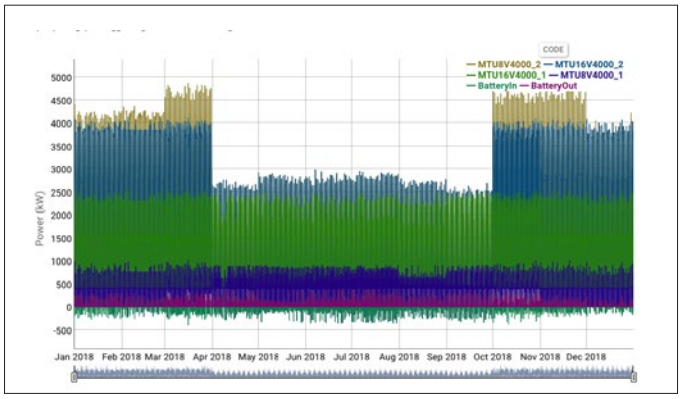
(2) MTU 8V4000 GS L32 60Hz Statistics

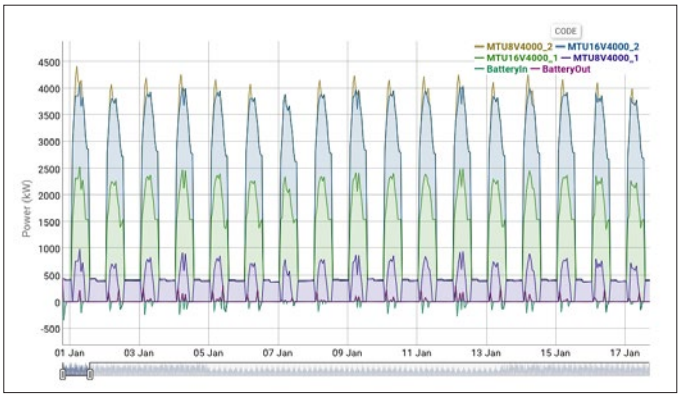
Quantity	Value	Units
Hours of Operation	597	hrs/yr
Number of Starts	194	starts/yr
Operational Life	106	yr
Capacity Factor	4.15	%

(2) MTU 16V4000 GS L32 60Hz Statistics

Quantity	Value	Units
Hours of Operation	2,854	hrs/yr
Number of Starts	396	starts/yr
Operational Life	22.1	yr
Capacity Factor	29.6	%







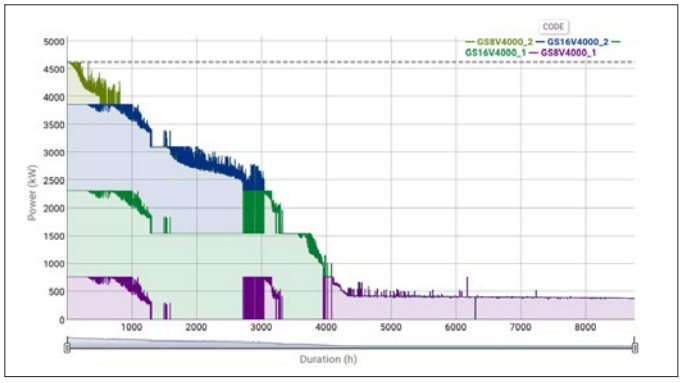
Highlights the distribution of the power demand throughout the different microgrid components. The power output or input (storage) is staged together and the covering line shows the demand timeline.

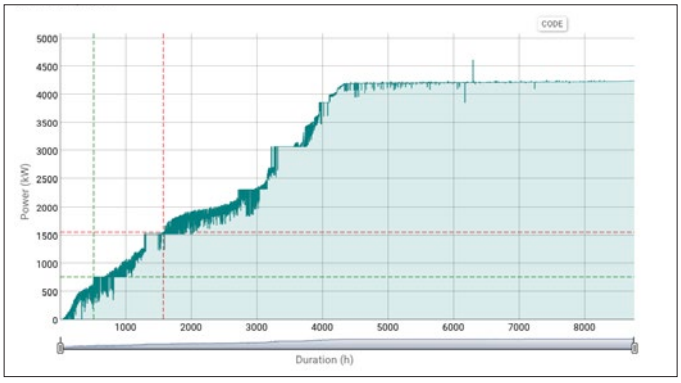
Duration curve plot

The duration curve is staged together from each genset power supply. This enables a view on how often and for how long each combination of gensets is running. The white space between the duration curve and the dashed limit line is the pure genset system reserve.

Availability calculation

An MTU generator set with service agreement has a technical availability of 96%. If the genset reserve is below the rated power of a unit, a failure will cause a blackout. The green dashed line above represents the operating hours per year the MTU 8V4000 GS must not fail, because of a lower reserve than its rated power of 762 kW. The red dashed line shows the operating hours per year that the MTU 16V4000 GS must not fail, because of a lower reserve than its rated power of 1549 kW.





Trends in intelligent controls

As we move toward a future with a growing prevalence of microgrids, energy sources will certainly diversify. Historically, throughout the world, power generation has always followed the load. Highly stable power generation facilities such as coal facilities and nuclear plants were the only source. Through these methods, the sources had to be always available since power had to be instantaneously created and consumed.

But the energy market is changing. As we look to the future, utilization of renewable sources will continue to grow. The costs are coming down and the efficiencies are going up. However, diverse assets cause a variable creation and consumption of power. To optimize wind, solar and all other assets, you'll need intelligent controls to make sure the load is always supported, whether it's connected to the grid or operating in island mode.

Conclusion

A microgrid is a technical solution that satisfies local energy demand in an economical manner, customized to a customer's specific needs and local boundary conditions. A microgrid enhanced by an active management of the loads or a flexible change of addressed value streams is called a smart grid. A hybrid system is the combination of a generator set with an energy storage system and therefore a subset out of a microgrid configuration. Energy demand includes both pure electrical and combined electrical and thermal.

Microgrids comprise distributed energy resources, energy storage systems and loads under one control system. The system can be operated two ways—interconnected to the grid or in island mode. It can take advantage of different value streams, depending on the concrete technical design and subject to applicable regulations. By integrating multiple energy assets through an intelligent control system, a microgrid can cost-effectively produce energy while maintaining grid stability.

Rolls-Royce provides world-class power solutions and complete lifecycle support under our product and solution brand MTU. Through digitalization and electrification, we strive to develop drive and power generation solutions that are even cleaner and smarter and thus provide answers to the challenges posed by the rapidly growing societal demands for energy and mobility. We deliver and service comprehensive, powerful and reliable systems, based on both gas and diesel engines, as well as electrified hybrid systems. These clean and technologically advanced solutions serve our customers in the marine and infrastructure sectors worldwide.

A Rolls-Royce solution

08 354 (72 11E)

Power Generation

MICROGRID SOLUTIONS FROM A SINGLE SOURCE

mtu

A Rolls-Royce solution

PIONEERING THE POWER THAT MATTERS

We at Rolls-Royce provide world-class power solutions and full life-cycle support under our product and solution brand MTU. By utilizing the potential of digitalization and electrification, we strive to develop climate-neutral power delivery and power generation solutions that are even cleaner and smarter, thus providing answers to the challenges posed by climate change and by society's rapidly growing demands for energy and mobility. We supply and maintain comprehensive, powerful and reliable systems based on customer needs, including energy storage systems, biogas and natural gas engines, diesel engines, and renewable energy solutions.

Market trends

TRIGGERING GLOBAL DEMAND FOR NEW SOLUTIONS

Economic growth and population growth are increasing the demand for power. Increased pressure to decarbonize, and growing demand for more flexible, sustainable, cost-effective energy solutions are guiding governments and industry away from traditional energy sources like coal and gas, and toward renewable energies such as solar and wind power.

Four megatrends are transforming the energy world:

– **Globalization** – the urbanization and industrialization of developing countries coupled with population growth – has driven major economic growth but has been accompanied by a rise in carbon emissions.

– **Decarbonization** is part of a global effort to prevent climate change by keeping temperatures from rising. Ambitious targets have been set by governments and companies around the world.

– **Electrification** is a necessary step in meeting decarbonization targets: heavy-polluting industries can be cleaned up by electrifying processes that previously ran on fossil fuel.

– **Digitalization** offers a host of new solutions and opportunities, but the resultant huge data volumes create enormous power demand.

These four factors are driving growth in energy demand, and encouraging the development of innovative, cost-effective decentralized solutions.

Microgrids

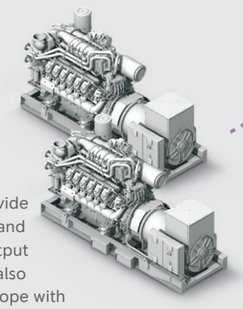
SAVING MONEY WITH RELIABLE AND SUSTAINABLE SOLUTIONS

Microgrids are decentralized energy systems consisting of a combination of renewable power generation, power storage and conventional power generation in order to meet a given demand. A microgrid may be off-grid or on-grid, and a centralized controller is in place to optimize the way the system operates.

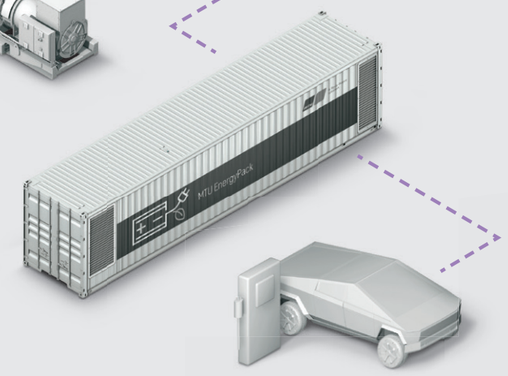
By combining different components, microgrid solutions can be tailored to every customer need. The MTU microgrid controller can be used to optimize solutions, reducing operational expenditures and securing several further important benefits.

Key benefits:
- Reliability: Independent access to power, better security of supply, higher quality of supply
- Sustainability: CO_2 avoidance and the ability to add on renewable energy sources
- Economy: Energy cost optimization and new revenue streams

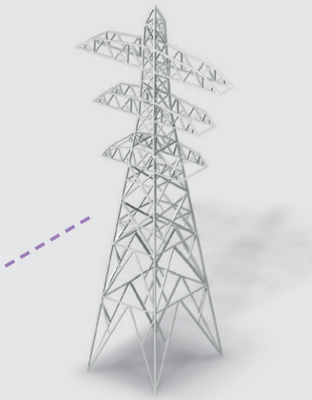
Microgrid controller
The MTU microgrid controller seamlessly integrates power generation, storage and demand. It optimizes the production and use of energy to meet a user's requirements, whether their priority is cost, carbon footprint or availability.



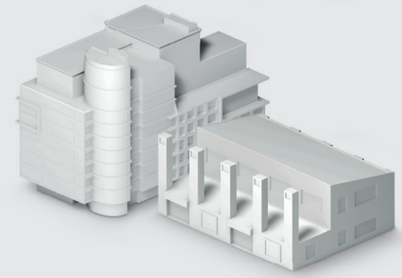
Gas and diesel generators
MTU gas and diesel generator sets provide power on demand – and do so reliably and quickly. Their load flexibility adapts output quickly to the customer's needs. They also provide emergency backup and help cope with load peaks. Our gas gensets are also suitable for combined heat and power applications (CHP).



Energy storage
MTU battery storage systems are a great complement to systems using renewable energies that cannot be ramped up and down at will. They provide grid stability, voltage and frequency control, instantaneous power, plus the ability to de-couple peaks in generation from peaks in demand. Operation and maintenance costs are low.



On-grid / off-grid
A microgrid can run while connected to a public power grid (on-grid) and can be used to safeguard stability of supply and optimize both cost and the operator's environmental footprint. Fully independent (off-grid) microgrids can be used to power remote communities and industries or to provide energy independence from the grid.



Scalable solutions
Whether on-grid or off, microgrid solutions are scalable. Use cases range from a single hotel to a remote mine, from large factories to urban utilities, and can include heating and cooling applications for industrial or residential purposes.

Renewable energy sources (RES)
Solar power, wind power and other renewables that are not always dispatchable offer key benefits – zero carbon emissions, low operating costs and low fuel expenses – but there are some drawbacks as they are dependent on weather and time-of-day, can suffer output fluctuations, and often require major capital investment. A smart microgrid uses storage and/or complementary generation technologies to optimize the use of renewables.

Microgrid applications

CUSTOMERS, CONFIGURATIONS AND BENEFITS

Grid & utility service provider

Examples: grid system operators, utilities, independent power producers

Microgrids allow the avoidance of significant investment in grid infrastructure e.g. to enable a scale-up of electric vehicle charging. Additionally, solar or wind power can be made more reliable and dispatchable, while enabling gas or diesel power plants to operate more efficiently when combined with battery storage facilities.

Typical configuration:

Community

Examples: remote communities, urban district-/town solutions

Microgrids make urban areas more self-sufficient and provide reliable backup power in the event of grid failure. In areas unconnected to the public grid, they ensure high quality power supplies and allow the integration of renewable energies to reduce carbon footprint and save fuel.

Typical configuration:

Industry

Examples: agriculture, manufacturing, mining, commodities

Remote industrial operations currently running on fossil fuels without grid connections can reduce their fuel consumption and meet legal or company environmental standards more easily. When connected to the public grid, using gas-powered CHPs and adding renewables can reduce power demand charges and so offset rising energy costs. And, being independent, any growth in electricity demand is not limited by the capacity of the public grid.

Typical configuration:

Commercial

Examples: offices, retail & warehouses, data centers, infrastructure & transport, hotels & restaurants

Facilities connected to public grids can reduce energy costs and increase self-sufficiency by diversifying their energy sources, taking advantage of time-of-day electricity tariffs and having backup power on tap whenever it's needed.

Typical configuration:

Public sector

Examples: military base, healthcare, institutional & education

Where a grid connection is not reliable, microgrid solutions increase security and quality of supply for public facilities. Stability of existing power plants can be improved by spinning reserve power (say, from batteries), and solar arrays can be built in to reduce fuel consumption. If grid-connected, own-use of solar power can be increased to lower the amount of power drawn from the grid.

Typical configuration:

Complete solutions

MICROGRID SERVICES, SYSTEM INTEGRATION AND SMART CONTROL

MTU microgrid systems offer a wide variety of solutions and service products. And each can be individually designed to serve specific needs. Special microgrid services include consulting, planning, the single-source supply of hardware and software, as well as installation and maintenance.

Simulation & sizing

We analyze the customer load profile and run techno-economic simulations of microgrid solutions. We can then offer optimized component sizing and (from 2021) grid stability analysis. We can run practical simulations for our customers in our microgrid validation center.

Integration, installation & commissioning

After developing interfaces to integrate the new components with existing assets, and after conducting the installation (optional), we commission microgrids and run on-site acceptance tests.

Engineering & manufacturing

Our solutions are customized using a portfolio of product variants and options. All in-house products are manufactured to MTU standards and undergo factory acceptance testing.

ONE-STOP-SHOP SOLUTION

Automation & smart control

The MTU microgrid controller is the brain of every microgrid. Its supports multiple applications in both on-grid and off-grid mode, and optimizes operation to save money, fuel and emissions.

Operation & maintenance

MTU services include monitoring and remote diagnostics, optimization consulting, reporting, repair guidance, and preventive and corrective maintenance. Extended warranties are also available for extra peace of mind.

Subject to change. | 1612O839 | Edition 01/20 | ESM 2020-05 | Printed in Germany on chlorine-free bleached paper.

Rolls-Royce Group
www.mtu-solutions.com/powergen

References MG Emissions

Microgrid Solutions

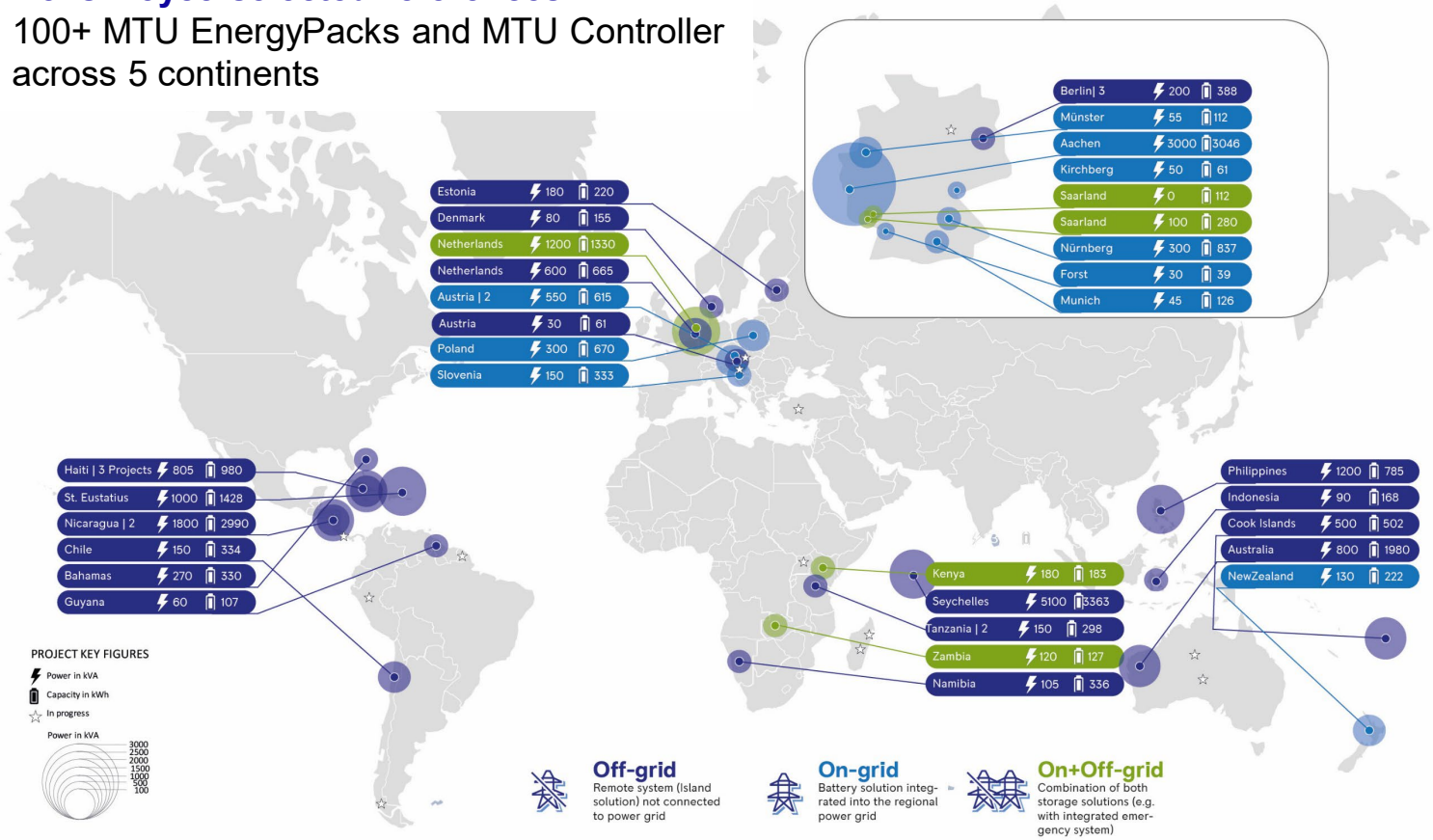
Rolls-Royce selected references

100+ MTU EnergyPacks and MTU Controller across 5 continents

5 continents

38 countries

90+ MWh installed battery capacity



Germany - 2016

Battery energy storage for EV charging integration

The Municipal Utility of Münster supllies power, gas, district heating and water to more than 10 000 households. They also operate the public transport system that is used by over 120 000 travelers a day. With the introduction of an emission free busline, fast chargers with 350 kW charging power were installed at several bus stops. At a bus stop at the end of a distribution cable, this caused voltage issues. To stabilize the voltage, an energy storage system from Rolls-Royce was added.

Configuration

On grid

Solar PV

BESS

Customer:
Municipal utility of Münster

Main benefits

- Grid stability
- Self-consumption of renewable energy
- Fast charging

Deliverables

MTU EnergyPack QS

55 kW / 112 kWh

Applications

- Solar energy integration
  - Peak shaving
  - Ramp rate control

Estimated savings | carbon emissions

200,000
kg/year

A Rolls-Royce solution

Haiti 2017 & 2019

Reliable and affordable power supply for a hospital in Haiti

The 131-bed Albert Schweitzer hospital in Deschapelles, Haiti is the only 24/7 hospital with full service in the region, and serves a population of 350 000 people. The electric power of the hospital is generated by diesel gensets, at a cost of over US$ 400.000 a year. These costs are reduced by more than 50% with the installation of rooftop solar and two Rolls-Royce energy storage systems

Configuration

Off-Grid | Solar PV | BESS | Diesel

Customer:
Albert Schweitzer Hospital

Main benefits

- Reliability of energy supply
- Energy cost optimization
- CO_2 reduction and improvement of air quality

Solution

EnergyPack M
200 kWh/227 kVA

EnergyPack S
308 kWh/105 kVA

Applications

- Integration of PV
- Regulation of frequency and voltage
- Blackstart

Estimated savings | Operating costs

$ 250.000
USD/Year

Estimated savings| Carbon emissions

700.000
kg/Year

A Rolls-Royce solution

Australia - 2018

Microgrid with solar and energy storage powering a remote aboriginal village

The Northern Territory of Australia has many indigenous communities powered solely by diesel power stations. The Nauiyu community at Daly River was the first community to benefit from a battery energy storage system to increase the Solar Energy integrated into their existing diesel power station, thereby greatly reducing the reliance on diesel fuel.

Configuration

Off grid | Solar PV | BESS | Diesel

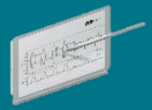
Customer: PowerWaterCorp

Main benefits

- Energy cost optimization
- CO_2 avoidance

Deliverables

EnergyPack QL
1,980 kWh / 800 kVA



MTU Microgrid Controller

Applications

- Solar energy integration
  - Peak shaving
  - Ramp rate control

Estimated savings | diesel

400,000 l/year

Renewable share | Solar Energy

51%.

A Rolls-Royce solution

Nicaragua - 2019

Renewable energy integration and grid stabilization with BESS

Due to increasing power demand on the Nicaraguan island, Big Corn Island, the existing diesel generators were no longer sufficient to meet the demands of the 8,500 inhabitants, who were suffering regular power outages. With the installation of a photovoltaic (PV) plant and a battery energy storage system (BESS), the increased load is now provided reliably, with black-outs prevented and grid stability improved.

Configuration

Off grid | Solar PV | BESS | Diesel

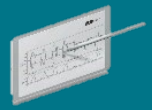
EPC: Solartia

Main benefits

- Quality & security of supply
- Energy cost optimization
- CO_2 avoidance

Deliverables

EnergyPack QL
2,220 kWh / 1,500 kVA



MTU Microgrid Controller

Applications

- Solar energy integration
- Black start capability
- Frequency & voltage control

Estimated savings | diesel

114,000 l/year

Estimated savings | Carbon emissions

320,000 kg/year

A Rolls-Royce solution

Philippines - 2019

Energy storage to integrate grid-scale solar

In order to reduce fossil fuel consumption, a large PV installation was installed on the island of Tablas. The fast fluctuations as well as the excess in energy production during the day and shortages during the night were causing stability issues in the grid, limiting the amount of renewable energy that could be used. By installing an energy storage system from Rolls-Royce, the grid can be kept stable and more solar energy can be used.

Configuration

Weak grid

Solar PV

BESS

EPC:
Suweco

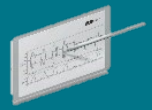
Customer:
Philippines Department of Energy

Main benefits

- Quality and reliability of energy supply
- Energy cost optimization
- CO_2-avoidance

Deliverables

EnergyPack QL
785 kWh / 1200 kVA



MTU Microgrid Controller

Applications

- Integration of PV
  - Energy shifting
  - Ramp-rate control

Estimated savings | diesel

3 Million
l/Year

Estimated savings | Carbon emissions

6.5 Million.
kg/Year

A Rolls-Royce solution

Costa Rica

Battery system for time of use optimization

The Microgrid is the largest integrated solar and energy storage system in Costa Rica. 690 photovoltaic panels with 255kWp cover the parking lots at the industrial manufacturing site. The system assist to shave the two peak periods and make better use of the produced solar energy. This makes it a model of private management that is strategically integrated into the country's carbon neutral program, as it helps prevent the release of more than 285,000 kilograms of carbon particles into the environment each year

Configuration

On grid

Solar PV

BESS

EPC

Swissol

Main benefits

- Peak shaving
- Increase renewable share

Deliverables

2x EnergyPack QL

Total 1500kVA/ 4275 kWh

Requirements

- Peak shaving / Time of use optimization

Estimated savings | 42,000 USD/month

Estimated savings | Carbon emissions 285,000 kg/Year

A Rolls-Royce solution

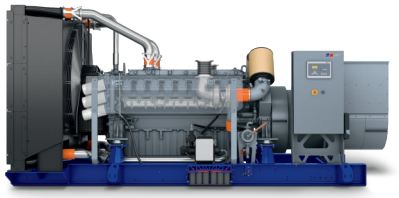
Power Generation

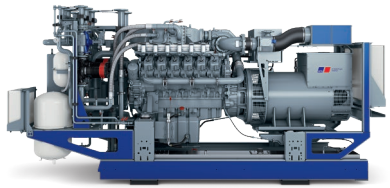
SOLUTION GUIDE

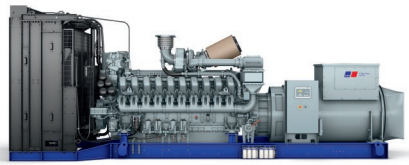
Edition 1/21, valid from 03/2021

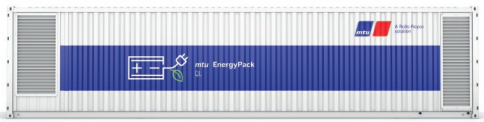
mtu A Rolls-Royce solution

CONTENTS









PIONEERING THE POWER THAT MATTERS.

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A solution provider

mtu systems power the largest yachts, the strongest tugboats and the biggest land vehicles and provide energy for the world's most important mission-critical applications. Through advanced solutions such as microgrids, we integrate renewable energies and manage the power needs of our customers.

Our customized service offerings help you maximize uptime and performance and are supported by our digital solutions, which enable remote monitoring, predictive maintenance and a range of other benefits that keep your systems running at their best.

For over 110 years, we have provided innovative power solutions for our customers – meeting even the most demanding drive requirements. Our products and services span a wide range of applications and power needs, with both standard and customized options.

An expert in technology

As part of Rolls-Royce, we have long been known for cutting-edge innovation and technological leadership in product development. That same spirit of innovation inspires our sustainability efforts. Our focus is on developing and implementing system solutions that both maximize efficiency and reduce emissions -- which in turn work to reduce our impact on the environment.

A passionate and reliable partner

We at Rolls-Royce spend every day working together with our customers, to deliver engines, systems and complete life-cycle solutions that best fit your needs. We understand that each application is different and has its own specific demands. Our engineers embrace the challenge of finding the perfect solution for your unique power requirements. Every step of the way – from project planning, through design, delivery and commissioning; to the lifetime care of your equipment – we are dedicated to helping you get the most from your ***mtu*** investment.

Rating definitions

FOR POWER SOLUTIONS.

Standby power

Standby power (3D)

Standby power applies to installations served by a reliable utility source. The standby ratings are applicable to varying loads for the duration of a power outage.

Prime power for stationary emergency (3E)

Prime power for stationary emergency provides classical standby power comparable to the application group standby power (3D). The difference is that this application group offers a 10% overload capability to cover for e.g. voltage variations or peak loads.

Data center continuous power (3F)

Data center continous power is a specific mission critical application. It is especially designed for the use in data centers as emergency standby units. “Data centre continous power” offers an economic and customer friendly solution to comply to the Uptime Institute* Tier III and Tier IV standards.

Continuous/Prime/Grid stability power

Continuous + CHP (3A)

Continuous power applies to installations where one or several generator sets serve as utility. At constant or varying load, the number of generator set operating hours is unlimited. Typical application here is CHP.

Prime power (3B)

Prime power applies to installations where utility power is unavailable or unreliable. At varying load, the number of generator set operating hours is unlimited.

Grid stability power (3G)

Grid stability power is focused on providing additional short-term power to the grid (peak shaving). This application becomes relevant whenever renewable power sources like solar or wind are used that might not always be able to provide the full power demand for example during peak load times.

* The Uptime Institute is a pioneer in creating and operating knowledge communities for improving uptime effectiveness in data center facilities and information technology organizations.

A Only available for 50Hz markets

Rating definitions

OVERVIEW

Standby power		
Standby power (3D)	***mtu* Power Generation**	**ISO 8528-1 (ESP)**
Load	variable	variable
Load factor	**≤ 85 %**	≤ 70 %
10 % overload (ICXN)	no	not specified
Max. operating hours (per year)	**500 h**	200 h
Uptime compliant	Tier I & Tier II	not specified

Prime power for stationary emergency (3E)	***mtu* Power Generation**	**ISO 8528-1 (ESP)**
Load	variable	variable
Load factor	**≤ 85 %**	≤ 70 %
10 % overload (ICXN)	**yes**	not specified
Max. operating hours (per year)	**500 h**	200 h
Uptime compliant	Tier I & Tier II	not specified

Data center continuous power (3F)	***mtu* Power Generation**	**ISO 8528-1 (DCP)**
Load	continuous	continuous or variable
Load factor	≤ 100 %	≤ 100%
10 % overload (ICXN)	**yes**	not specified
Max. operating hours (per year)	unlimited [B]	unlimited
Uptime compliant	Tier I - Tier IV	not specified

Continuous/Prime/ Grid stability power		
Continuous power + CHP (3A)	***mtu* Power Generation**	**ISO 8528-1 (COP)**
Load	constant	constant
Load factor	≤ 100 %	≤ 100 %
10 % overload (ICXN)	Gas: no Diesel: **yes**	not specified
Max. operating hours (per year)	unlimited	unlimited

Prime power (3B)	***mtu* Power Generation**	**ISO 8528-1 (PRP)**
Load	variable	variable
Load factor	**≤ 75 %**	≤ 70 %
10 % overload (ICXN)	yes	yes
Max. operating hours (per year)	unlimited	unlimited

Grid stability power (3G)	***mtu* Power Generation**	**ISO 8528-1 (LTP)**
Load	continuous	continuous
Load factor	≤ 100 %	≤ 100%
10 % overload (ICXN)	Gas: no Diesel: **yes**	not specified
Max. operating hours (per year)	**1000 h; 500 h with 100% load w/o interruption**	500 h

A Only available for 50Hz markets
B Unlimited hours in data center application where a reliable grid/utility is present.

The next generation

NEW *mtu* SERIES 500 GAS GENERATOR SET

The new ***mtu*** Series 500 introduces natural gas generator sets to the 250-550 kWe power range. Available in 50 Hz and 60 Hz versions, these highly efficient units feature an optimized engine designed to greatly lower fuel costs, making them an ideal fit for a broad range of utility and industrial applications.

- **Fuel:** natural gas
- **Output:** 250, 360 and 550 kWe
- **Frequency:** 50 Hz and 60 Hz
- **Compliant** with industry codes and standards
- **Efficiency:** 3.1% more efficient than the previous Series 400 genset, best in class
- **Flexibility:** the ***mtu*** Module Control (MMC) automation system simplifies system control, integrates easily with diverse microgrids and creates a direct link to expert digital service support

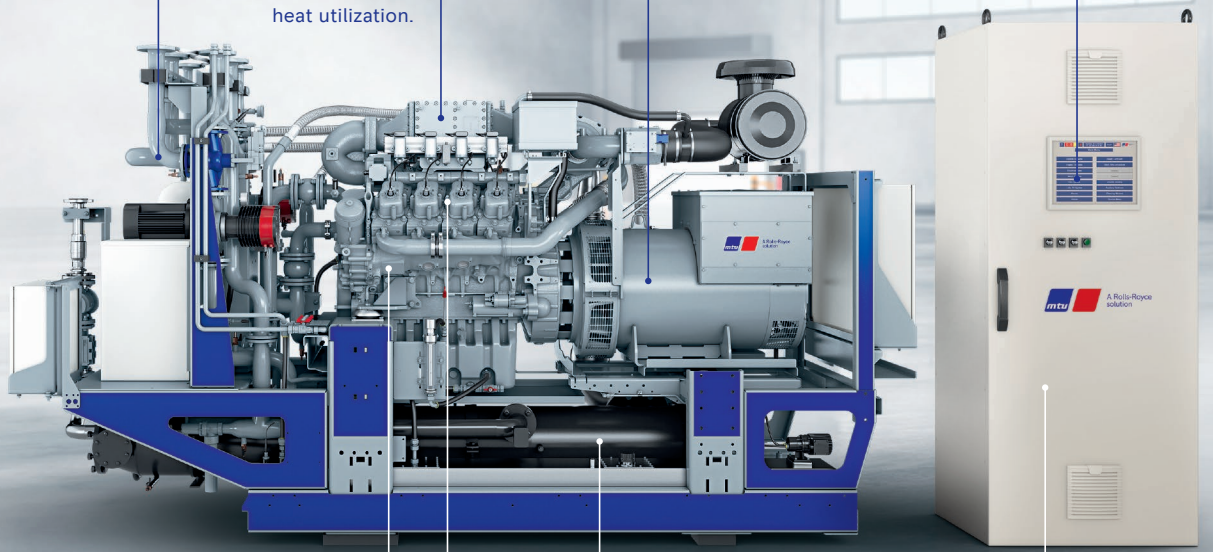
Depicted here is an *mtu* 8V500 genset in GC configuration with MMC. The standard scope of supply (GB configuration) comprises the engine, generator, base frame, fuel gas train and *mtu* Module Control automation system.

Flexible heat recovery unit (GR configuration)
This unit ensures highest thermal efficiencies for the jacket water, lube oil and coolant mixture.

Mixture cooler
The two-stage mixture cooler improves engine performance and heat utilization.

Generator
Optimally tailored to the engine, the generator provides best-in-class reliability and efficiency.

***mtu* Module Control (MMC)**
The ***mtu*** Module Control covers all important functions needed for controlling the whole system. It comes in a separate panel and is placed next to the genset.



Gas engine
Improved combustion technology increases engine efficiency and lowers fuel costs.

Ignition system
A microprocessor-controlled ignition system optimally adjusts the ignition time and ignition energy to the quality of the gas.

Exhaust heat recovery (GC configuration)
The exhaust heat recovery system with exhaust heat exchanger achieves highest thermal efficiencies in CHP systems. With the ***mtu*** 12V500 GS version, the exhaust heat exchanger is supplied separately.

Key features:
- Industrial PC with touch-screen colour display
- Monitors all system processes
- Logs all fault and status messages
- Integrates seamlessly with other controls
- Enables multi-module system networking
- Supports numerous protocols (e.g. Ethernet, Profbus DP)

Digital connectivity
The system can be equipped with a data logger providing access to our digital solutions, including remote monitoring, fast and reliable service support and, soon, further features such as predictive failure prevention and operational optimization.

The next generation

mtu SERIES 4000 NATURAL GAS GENERATOR SET

Operational flexibility
- Quick ramp-up and ramp-down plus a wide range of partial load operation make this product a perfect match for grid stabilization applications..
- Fulfills the highest emission standards.

30 % more power
- The new genset increases its performance by 30%, withstanding hot and humid conditions.
- Highly robust against derating.

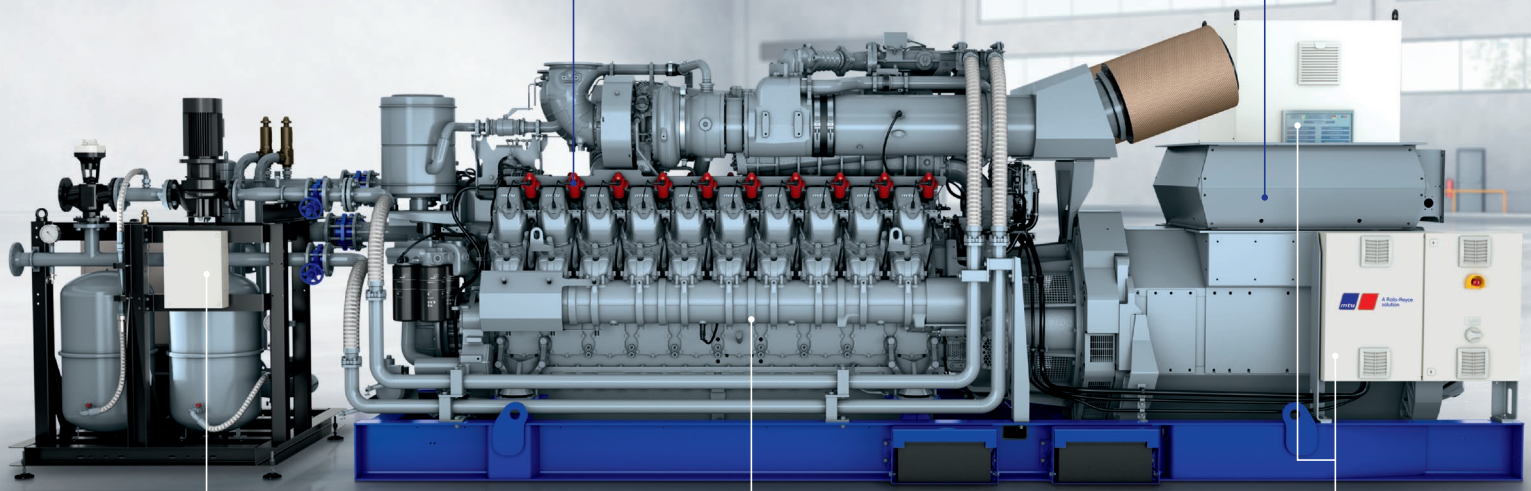
Low lifecycle costs
- Good serviceability
- Favorable maintenance intervals
- Reduced oil consumption
- No additional exchange of cylinder heads necessary before Life-Time (TBO)
- 84,000 oH lifetime to major overhaul (TBO)

Up to 44.4 % el. efficiency
- An advanced, proven Series 4000 engine optimized for natural gas operation. Its combustion chambers ensure top levels of efficiency in its performance category.

Ignition system
Ignition systems for individual cylinders allow for the most efficient level of operation for all cylinders, even with variable CH4 content. The ignition voltage display gives customers information on the state of the spark plugs.

Digitally connected
The system is equipped with a data logger providing access to digital *mtu* solutions, including remote monitoring, fast and reliable service support and – coming soon – further features such as predictive failure prevention and operational optimization.

Generator
Perfectly tuned to the engine and made by renowned manufacturers, the generator ensures a high level of reliability and optimum efficiency.



Heat Recovery Unit
Well proven design perfectly suits the genset and provides the basis for optimized auxiliary efficiencies. The unit is fully integrated in the automation concept and is both safe and certified (CE).

Knock detection
Cylinder-specific knock detection and regulation protect the engine from abnormal operating conditions, and guarantee safe operation even with natural gas containing low levels of methane.

Automation Systems MIP & MMC
Motor interface panel (MIP) with stand-alone *mtu* Module Control (MMC). The MMC provides all the functions necessary for controlling the system. All the auxiliary drives required for the CHP system can be operated from here. The integrated power circuitry minimizes the customer's need for cabling on site.

20 years of top performance. Now in the 4th generation.

mtu SERIES 4000 DIESEL GENERATOR SET

Key technical data	*mtu* S4000 G04	50Hz
Cylinder version	12V, 16V, 20V	
Power output/ frequency	12V: 2100 – 2300 kVA – 50Hz 16V: 2600 – 2850 kVA – 50Hz 20V: 3380 – 4000 kVA – 50Hz	
Ratings	Standby power, prime power, data center continuous power, prime power for stationary emergency	
Optimization	Fuel consumption optimized, emission optimized (NEA & Tier 2 compliant)	

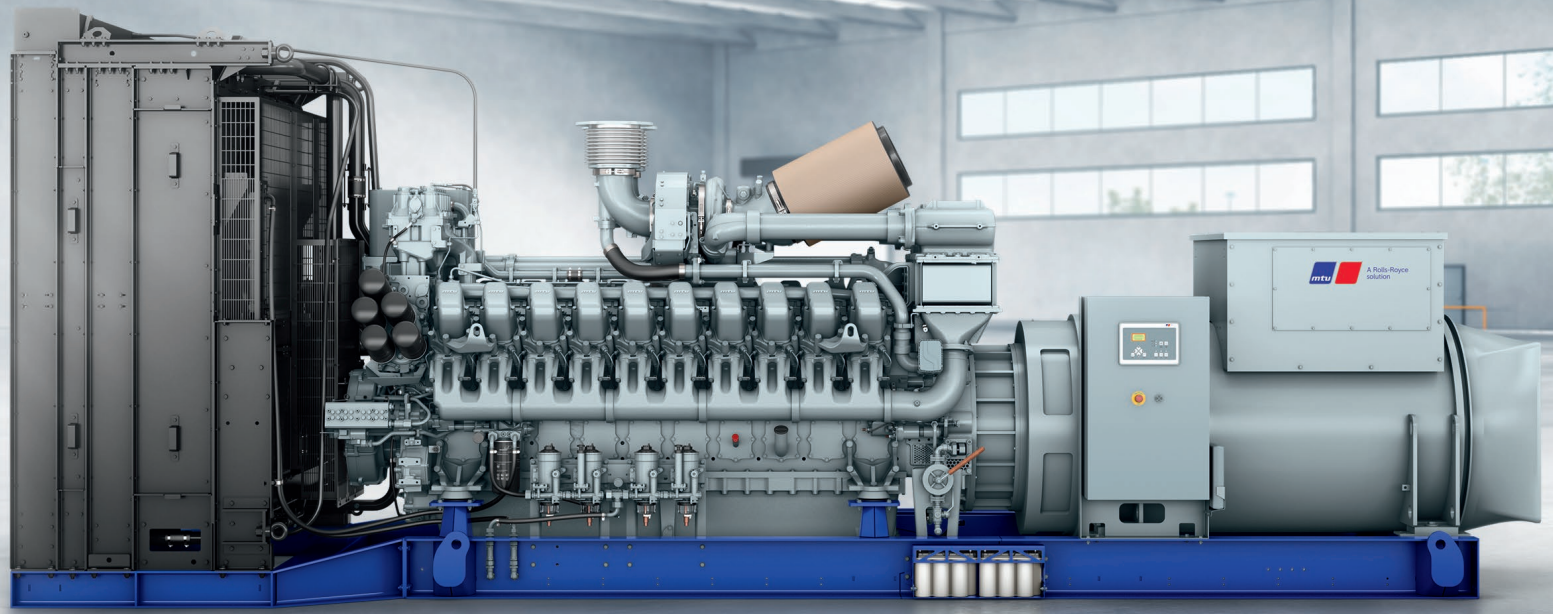
More available power
- Industry-leading load factors.
- More operating hours, compared to ISO 8528-1 requirements.

Highly robust against derating
- Even under rough ambient conditions.
- Engine Site Condition Management.

Excellent load acceptance
- Overachieving ISO 8528-5 performance class G3.
- Load steps with 1st load step > 50%.
- 100% block load acceptance (NFPA 110).

High-grade electricity
- Superior transient behavior.
- Protection for sensitive electrical infrastructure & IT equipment.
- Simplification of electrical infrastructure.

High power density
- Less investment in new installations.
- Easy retrofit and system integration.



mtu 20V4000 DS4000

Ready for a new perspective on dynamic UPS?

mtu KINETIC POWERPACK

Our ***mtu*** Kinetic PowerPack provides dynamic uninterruptible power supply through kinetic energy and is engineered to withstand the most demanding power supply challenges.

Lower TCO
— At medium and higher power ratings, ***mtu*** Kinetic PowerPacks are more cost-effective, reducing consumable electricity cost and maintenance.

Smaller footprint
— Its component count and monobloc structure give the ***mtu*** Kinetic PowerPacks a compact design, reducing its footprint to 40% of an equivalently rated static UPS system – making it the smallest in the market.

Units up to 3000 kVA
— The current-carrying capability of electronic components does not limit ***mtu*** Kinetic PowerPacks. Their perunit ratings are considerably more significant, leading to a much lower component count on higher power installations.

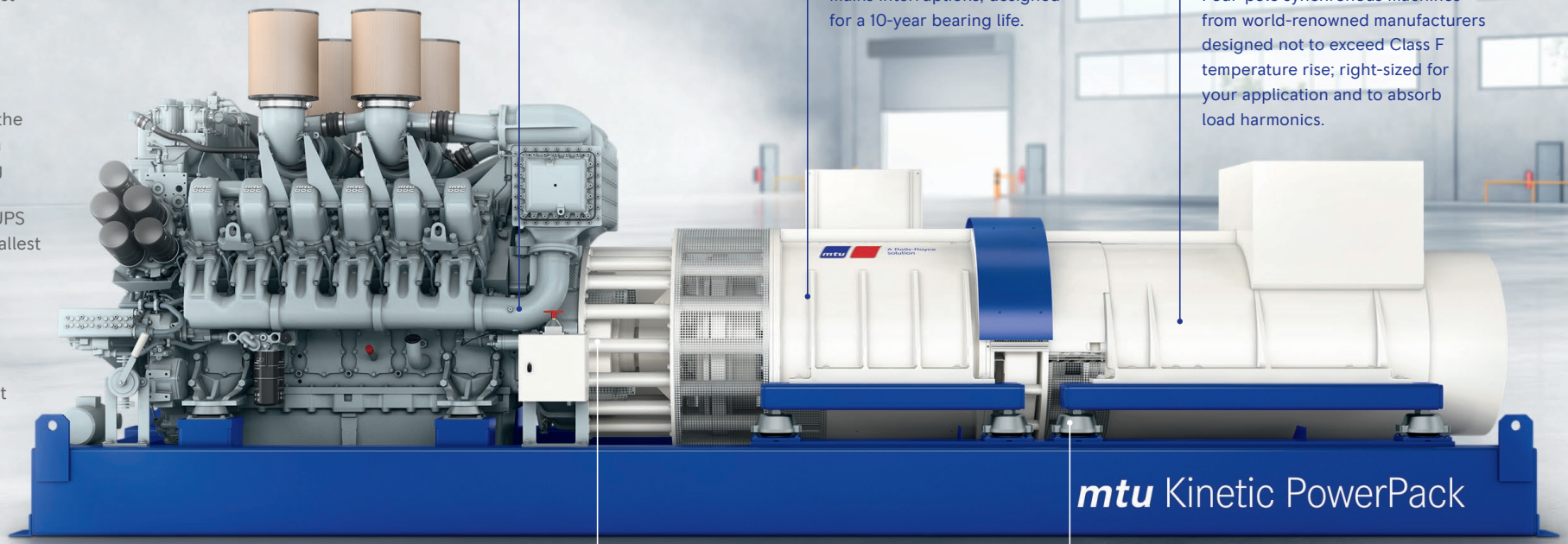
Optimal sustainability
— Static UPS systems require heavy batteries and generate chemical waste. Due to the kinetic energy storage unit's energy that is immediately available to generate power until the ***mtu*** diesel engine is activated, batteries belong to the past when using ***mtu*** Kinetic PowerPacks.

Medium voltage systems
— ***mtu*** Kinetic PowerPacks are the perfect solution for medium voltage critical loads or when more considerable distribution distances need to be covered.

***mtu* diesel engine**
Complying with the latest emissions standards; preheated; quick start and not running during conditioning mode pre-lubricated.

Kinetic energy module
Patented accu provides stored kinetic energy to ride through mains interruptions; designed for a 10-year bearing life.

Synchronous machine
Four-pole synchronous machines from world-renowned manufacturers designed not to exceed Class F temperature rise; right-sized for your application and to absorb load harmonics.

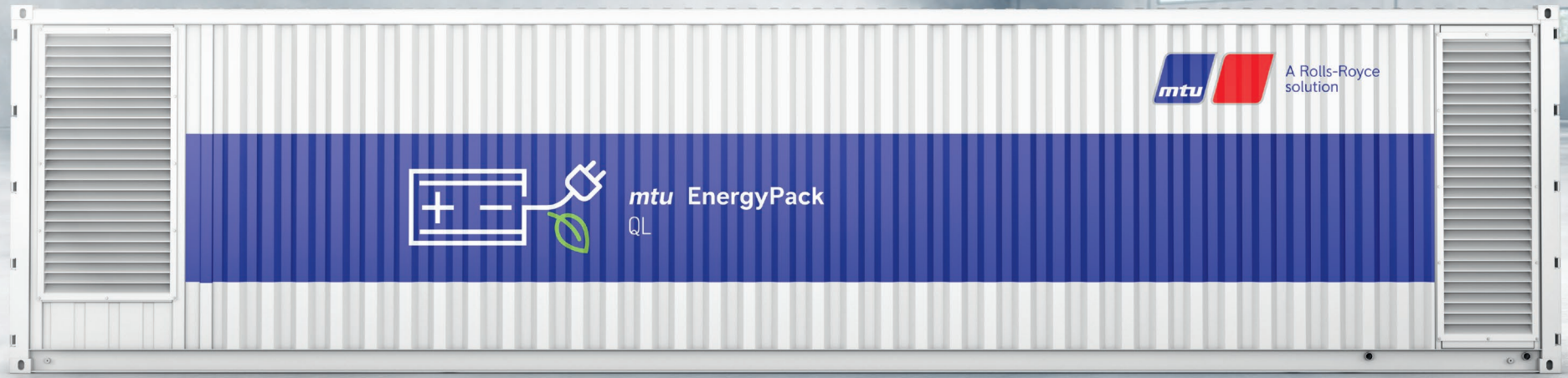


Electromagnetic clutch
The prime starter system consists of standard engine starting motors. The clutch is maintenance-free and guarantees the diesel engine to start at all times, thanks to the redundant start feature.

Vibration isolation
Thanks to the solid base frame with isolators between frame and equipment and direct floor installation, vibrations are reduced >97%.

The scalable all-in-one solution

mtu ENERGYPACK



Flexibility
- Factory tested plug-and-play design.
- Scalable in size.

Ultra-fast
- Immediate response.

High power density
- Compact system design.
- Small footprint.

Power control
- Condition monitoring.

Digital connectivity
- Various applications in combination with ***mtu*** Microgrid Controller.

Integrated solution
- Optimized system integration ability.
- Easy integration into Rolls-Royce Microgrid Solutions.

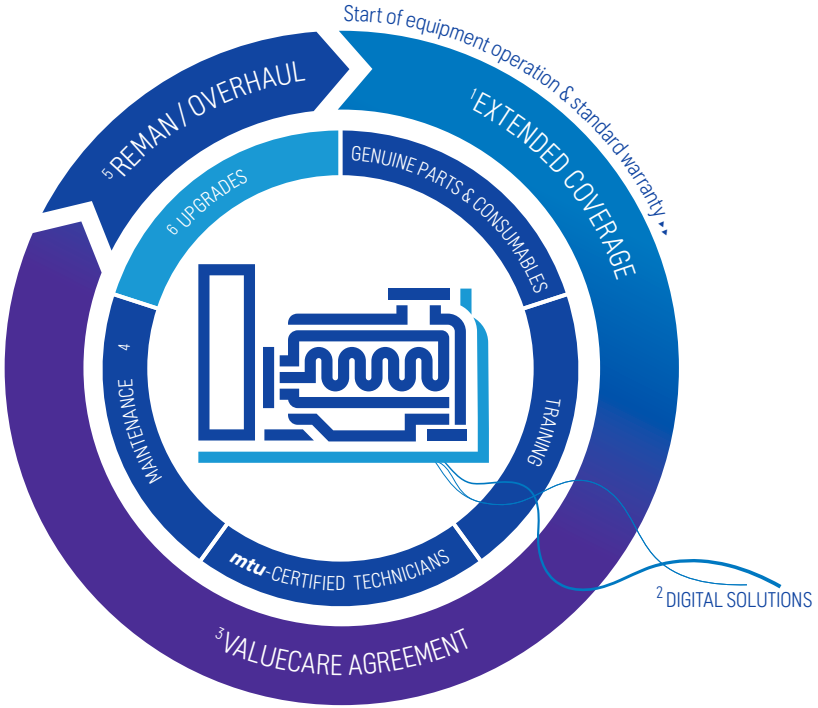
Safety features
- High safety & reliability.

Key technical data	*mtu* EnergyPack
Dimensions	QS (Enclosure) / QM (20ft.) / QL (40ft.)
Nominal power output	40 - 2,000 kVA
Nominal capacities	70 - 2,600 kWh
Application	Continuous, prime/peak, standby power, mission critical (on- & off-grid)
Nominal grid voltages	515 V (400 V with internal transformer)
Nominal round trip efficiency (w/o HVAC)	up to 90%
Grid frequency	50/60 Hz
Power factor range (cos ϕ)	0 ind. ...1 ... 0 cap

Service solutions

FOCUS ON YOUR OPERATIONS. LEAVE THE REST TO US.

You've got a tough job. With us as your partner, you'll get the power, performance and peace of mind to get it done right. Our digitally-enabled ValueCare Agreements make it easy to keep your business running smoothly and reduce total cost of ownership by maximizing uptime, optimizing lifecycle costs and helping you avoid equipment-related business disruptions through preventive maintenance.



1 Avoid the unexpected with added protection beyond the standard warranty.
2 Make better decisions faster with digitally-enhanced tools.
3 Maximize availability and optimize lifecycle costs with a ValueCare Agreement.
4 Improve system performance and extend equipment life with on-demand support.
5 Keep a good thing going with factory reman/overhaul solutions.
6 Maximize the value of your equipment with custom upgrades for changing needs.

Service solutions designed around your priorities

With tailored solutions to meet your needs, there is a ValueCare Agreement that is just right for you.

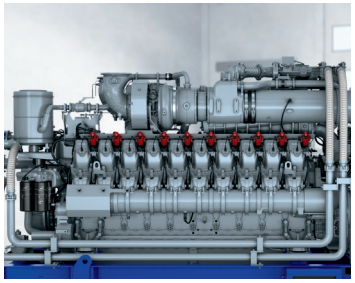
Bronze
Ensure parts availability and price stability

Silver
Eliminate unexpected maintenance costs

Gold
Maximize operational uptime

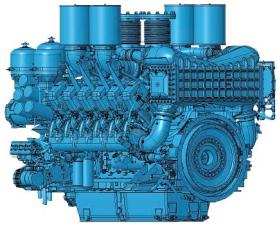
mtu Upgrade Solutions

We know that needs change over time, and that capital investments aren't for the short term. With upgrade solutions designed specifically for your ***mtu*** systems, you can get the most out of your equipment and extend its useful life.



L33 Efficiency Solution

The L33 Efficiency Solution is designed to extend the life of L61, L62 and L63 ***mtu*** Series 4000 gas systems. Through a cost-effective, sustainable system overhaul, the existing engine will be manufacturer-certified to the current status of an L33 remanufactured engine, achieving an electrical efficiency gain of about 1.4%. The upgrade also includes an alternator overhaul, new automation system and additional system enhancements. Best of all, it will fit onto the existing L61, L62 or L63 base frame, so no peripheral modifications are required.



Lifetime-Based Overhaul

Lifetime-Based Overhaul is our manufacturer-certified overhaul solution specifically designed for the needs of engines in standby power generation applications with low operating hours. This scheduled solution uses time as the key criteria and provides the same peace of mind as a traditional overhaul at a fraction of the cost. Only time worn components are replaced, which can be done onsite, eliminating the need for removal, transport and reinstallation that is typically required during an overhaul.

Service network

LOCAL SUPPORT. WORLDWIDE.

The most important part of your power system isn't a part at all—it's your local service team. With more than 1,200 service locations worldwide—backed by regional Parts Logistics Centers in Europe, Asia and America—you can count on responsive support by expert technicians, wherever work takes you. To find your local service partner, visit **www.mtu-solutions.com.**

Always on call, 24/7
Whether it's connecting you with a local service partner or assigning an urgent problem to a dedicated team of our experts, we're ready to assist you—wherever you are, whatever you need.

Europe, Middle East, Africa +49 7541 90-77777
Asia/Pacific +65 6860 9669
North and Latin America +1 248 560 8888
info@ps.rolls-royce.com

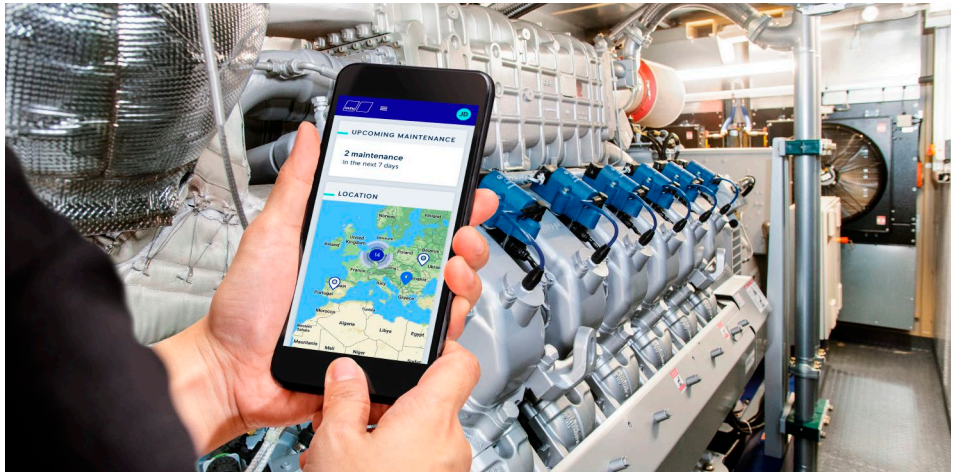
Digital solutions

HOW DIGITAL SOLUTIONS OPTIMIZE YOUR BUSINESS.

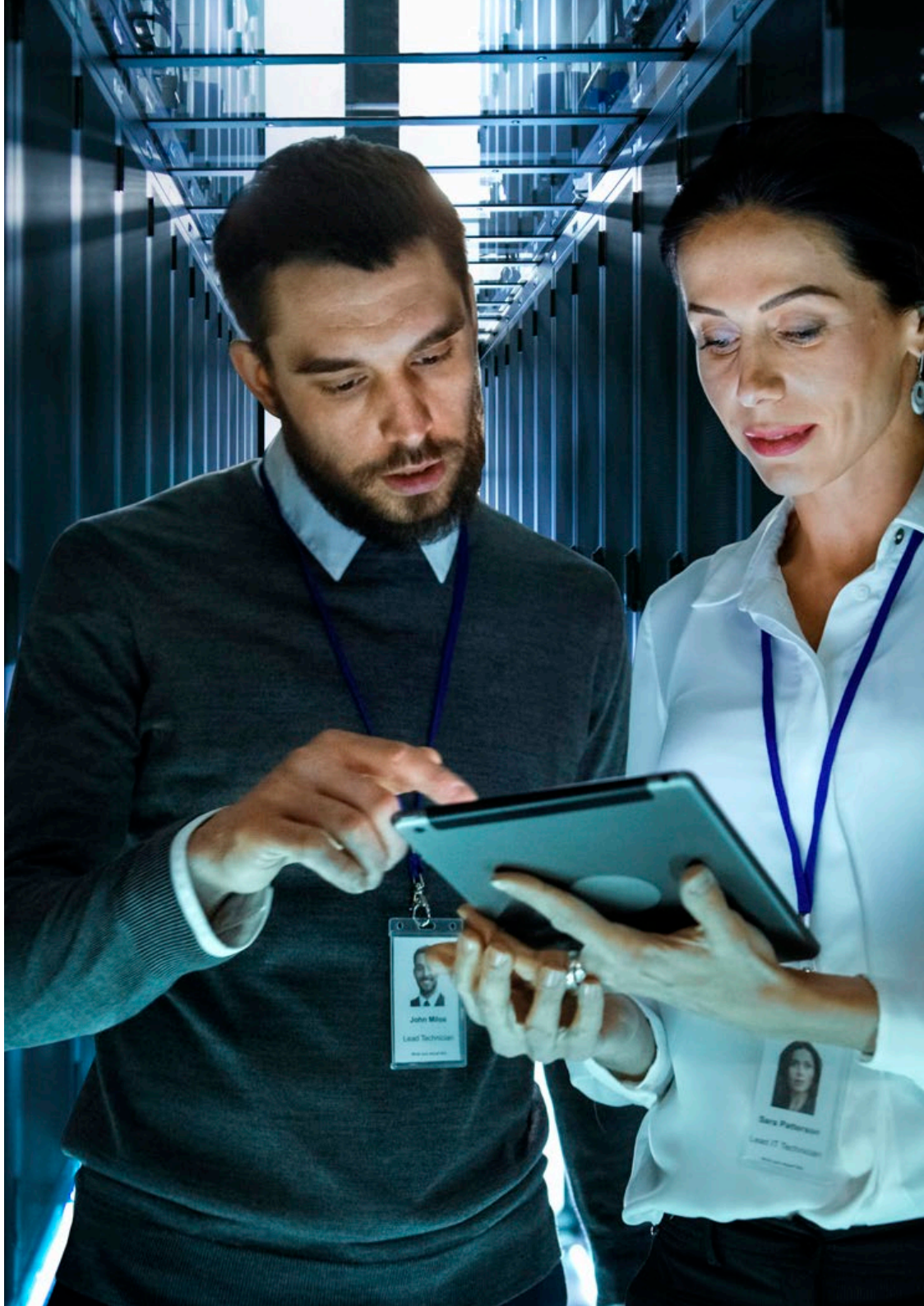
Streamline your service requirements.
We offer you the best possible service for your equipment by incorporating digitalization in a holistic approach. This helps improve our service to you and helps you operate your equipment more effectively.

Monitor and manage your equipment.
Our digital platform ***mtu*** Go! offers you the opportunity to analyze system data quickly, determine important action steps, and plan them optimally, either independently or together with our service department.

Maintain your data security.
We always adhere to the highest data privacy and security standards of our industry. Because we understand and value the trust you put in us by having us analyze your data to create the best possible service solutions for your equipment.



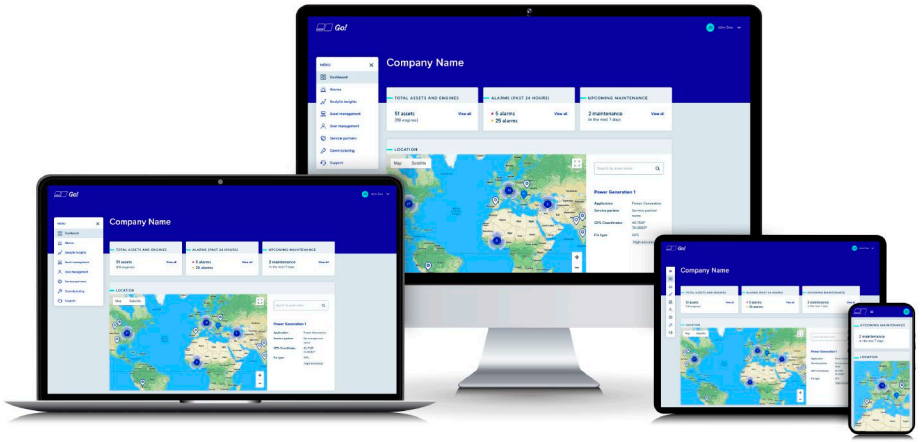
A connectivity device transmits vital equipment data in near real-time to your screen.



Digital solutions

DELIVERING ACTIONABLE INSIGHTS THROUGH DIGITAL SOLUTIONS.

mtu Go!



Connect all your equipment

Data collection from your plant, asset, system and engine

Connectivity is the basis for all the advantages of digitally supported service. Using our edge software connected to the control unit, you and your service network can monitor relevant deviations from the optimum conditions remotely. We offer several ways to collecting data, including the creation of interfaces to already existing data sets. In doing so, we always adhere to the highest data privacy and security standards of our industry.

Access your data

- Remote monitoring, available for individual assets, as well as complete plants worldwide
- Different device and software options ensure optimal connectivity
- Data privacy and security to the highest industry standards

Monitor your plant

Visualization of data for a quick and accurate overview of your plant

With the ***mtu*** Go! platform, predefined users, such as on-site technicians or managers, can view the system data and perform initial analyses by using diagnostic tools. By accessing the same information, your service network can provide fast support in handling alarms and planning necessary maintenance together with you. Open APIs allow you to interface directly to your existing dashboards or systems.

Keep track of your data

- All important data and alarms available at a glance for efficient plant monitoring
- Intuitive and clear design for easy operation
- Visual comparison of data using the diagnostic tools for initial analyses

Manage your plant

Digital solutions for your detailed data analysis on necessary actions

Supported by ***mtu*** Go! your Service Network is able to analyze all relevant data from your equipment and compare it with data sets from other systems. From this we together can proactively derive recommendations for action. In future, the analysis can be enriched with additional external data sets, such as environmental influences or time schedules. Cross-linking data will create new opportunities for optimizing business processes.

Learn from your data (under development)

- Algorithms for proactive early detection of deviations
- Troubleshooting based on large amounts of data with artificial intelligence
- Comparison with data outside own plant leads for faster knowledge transfer and optimum service tool for initial analyses

Standby power – diesel generator sets

STANDBY POWER (3D) – 50 HZ/1500 RPM.

	Power output [1]		Available voltages			Emissions						Certifications				Perform. class [2]		Uptime compl.		Housing		Engine type	Cooling variant [3]	Genset type
	kVA	kWe	380 - 415V (3 Phase)	6300 - 6600 kV (3 Phase)	10000 -11000 V (3 Phase)	Fuel consumption optimized	NOx emission optimized	NEA Singapore for ORDE	US EPA Tier 2 compliant	EU Nonroad Stage II compliant (97/68/EC)	EU Nonroad Stage IIIA compliant (97/68/EC)	ISO 8528	CE/IEC	NFPA 110	VDE-AR-N 4110 (German Grid Code)	ISO 8528-5 - G2	ISO 8528-5 - G3	Tier I & Tier II	Tier III & Tier IV	Enclosure	Container			
mtu 0080/0113 DS	56	45	x			x				x		x	x			x		x		x		F32 TM 1A	A2A	***mtu*** 4R0080 DS55
	67	53	x							x		x	x			x		x		x		NEF45 SM 1A	A2A	***mtu*** 4R0113 DS63
	82	66	x							x		x	x			x		x		x		NEF45 SM 2A	A2A	***mtu*** 4R0113 DS80
	90	72	x			x						x	x			x		x		x		NEF45 SM 5	A2A	***mtu*** 4R0113 DS94
mtu 1600 DS*	500	400	x			x		x			x	x	x	x		x	x	x		x		10V 1600 G70F	A2A	***mtu*** 10V1600 DS500
	540	432	x			x					x	x	x	x		x	x	x		x		10V 1600 G80F	A2A	***mtu*** 10V1600 DS540
	650	520	x			x		x				x	x	x		x	x	x		x		12V 1600 G70F	A2A	***mtu*** 12V1600 DS650
	720	576	x			x		x				x	x	x		x	x	x		x		12V 1600 G80F	A2A	***mtu*** 12V1600 DS720

* available soon, for detailed information please check website

Standby power – diesel generator sets

STANDBY POWER (3D) – 50 HZ/1500 RPM.

	Power output [1]		Available voltages			Emissions						Certifications				Perform. class [2]		Uptime compl.		Housing		Engine type	Cooling variant [3]	Genset type
	kVA	kWe	380 - 415V (3 Phase)	6300 - 6600 kV (3 Phase)	10000 -11000 V (3 Phase)	Fuel consumption optimized	NOx emission optimized	NEA Singapore for ORDE	US EPA Tier 2 compliant	EU Nonroad Stage II compliant (97/68/EC)	EU Nonroad Stage IIIA compliant (97/68/EC)	ISO 8528	CE/IEC	NFPA 110	VDE-AR-N 4110 (German Grid Code)	ISO 8528-5 - G2	ISO 8528-5 - G3	Tier I & Tier II	Tier III & Tier IV	Enclosure	Container			
mtu 2000 DS	825	660	x				x	x	x			x	x	x		x	x	x				12V 2000 G76F	A2A	***mtu*** 12V2000 DS825
	1010	800	x			x						x	x	x	x	x	x	x				12V 2000 G86F	A2A	***mtu*** 12V2000 DS1000
	1100	880	x				x	x	x			x	x	x	x	x	x	x				16V 2000 G76F	A2A	***mtu*** 16V2000 DS1100
	1250	1000	x			x						x	x	x	x	x	x	x				16V 2000 G86F	A2A	***mtu*** 16V2000 DS1250
	1400	1120	x			x						x	x	x	x	x	x	x				18V 2000 G76F	A2A	***mtu*** 18V2000 DS1400
	1100	880	x				x	x	x			x	x	x	x	x	x	x				16V 2000 G76F	W2A*	***mtu*** 16V2000 DS1100
	1250	1000	x			x						x	x	x	x	x	x	x				16V 2000 G86F	W2A*	***mtu*** 16V2000 DS1250
	1400	1120	x			sx						x	x	x	x	x	x	x				18V 2000 G76F	W2A*	***mtu*** 18V2000 DS1400
mtu 4000 DS	1780	1424	x		x	x		x				x	x	x	x	x	x	x				12V 4000 G74F	W2A	***mtu*** 12V4000 DS1650
	1880	1504	x		x	x		x				x	x	x	x	x	x	x				12V 4000 G74F	W2A	***mtu*** 12V4000 DS1750
	2080	1664	x		x	x		x				x	x	x	x	x	x	x				12V 4000 G84F	W2A	***mtu*** 12V4000 DS2000
	2300	1840	x		x	x		x	x			x	x	x	x [11]	x	x	x				12V 4000 G94F	W2A	***mtu*** 12V4000 DS2250
	2330	1864	x		x	x		x				x	x	x	x	x	x	x				16V 4000 G74F	W2A	***mtu*** 16V4000 DS2250
	2610	2088	x		x	x		x				x	x	x	x	x	x	x				16V 4000 G84F	W2A	***mtu*** 16V4000 DS2500
	2850	2240	x		x	x		x	x			x	x	x	x [11]	x	x	x				16V 4000 G94F	W2A	***mtu*** 16V4000 DS2750
	2800	2240	x		x	x		x				x	x	x	x	x	x	x				20V 4000 G64F	W2A	***mtu*** 20V4000 DS2750
	3200	2560	x		x	x		x				x	x	x	x	x	x	x				20V 4000 G74F	W2A	***mtu*** 20V4000 DS3100
	3410	2728	x		x	x		x				x	x	x	x	x	x	x				20V 4000 G84F	W2A	***mtu*** 20V4000 DS3300
	3730	2984		x [11]	x	x		x	x			x	x	x	x [11]	x	x	x				20V 4000 G94F	W2A	***mtu*** 20V4000 DS3600
	4000	3200		x [11]	x	x		x	x			x	x	x		x	x	x				20V 4000 G94LF	W2A	***mtu*** 20V4000 DS4000

* available soon, for detailed information please check website

Standby power – dynamic uninterruptible power supply systems

STANDBY POWER (3D) – 50 HZ/1500 RPM.

	Power output [1]				Available voltages		Emissions					Accu arrang.	Certifications				Perform. class [2]		Uptime compl.		Housing	
	no-break kVA	no-break kWe	short-break kVA	short-break kWe	low voltage 380 - 415V (3 Phase)	medium voltages 6 - 36 kV (3 Phase)	Fuel consumption optimized	NOx emission optimized	NEA Singapore for ORDE	US EPA Tier 2 compliant	EU Nonroad Stage II compliant (97/68/EC)		ISO 8528	CE/IEC	NFPA 110	VDE-AR-N 4110 (German Grid Code)	ISO 8528-5 - G3	ISO 8528-5 - G4	Tier I & Tier II	Tier III & Tier IV	Enclosure	Container
mtu KP5	250	200			x	x		x				single		x				x	x			x
	300	240			x	x		x				single		x				x	x			x
	400	320			x	x	x		x			single		x				x	x			x
	500	400			x	x	x					single		x				x	x			x
	630	504			x	x	x		x			single		x				x	x			x
	700	560			x	x	x					single		x				x	x			x
	900	720			x	x	x					single		x				x	x			x
	1000	800			x	x	x					single		x				x	x			x
	1250	1000			x	x	x		x			single		x				x	x			x
	1500	1200			x	x	x		x			single		x				x	x			x
	1650	1320	600	480	x	x	x		x			single		x				x	x			x
	1700	1360			x	x	x		x			single		x				x	x			x
	1875	1500	625	500	x	x	x		x			single		x				x	x			x
	2000	1600			x	x	x		x			single		x				x	x			x
	2250	1800			x	x	x		x			bi		x				x	x			x
	2500	2000			x	x	x		x			bi		x				x	x			x
	2750	2200			x	x	x		x			bi		x				x	x			x
mtu KP7	2250	1800			x	x	x		x			single		x				x	x			x
	2500	2000			x	x	x		x			single		x				x	x			x
	2750	2200			x	x	x		x			single		x				x	x			x

Standby power – diesel generator sets

STANDBY POWER (3D) – 60 HZ/1800 RPM.

	Power output [1]		Available voltages												Certifications				
	kWe	kVA	240 V Dedicated (1 Phase)	240 V Re-connectable (1 Phase)	208 V (3 Phase)	240 V (3 Phase)	380 V (3 Phase)	440 V (3 Phase)	480 V (3 Phase)	600 V (3 Phase)	4160 V (3 Phase)	12470 V (3 Phase)	13200 V (3 Phase)	13800 V (3 Phase)	ISO 8528	UL2200	NFPA 110	IBC 2015	IBC 2018
mtu 0096/0113 DS	30	37		x	x	x	x		x	x					x	x	x	x	
	40	50		x	x	x	x		x	x					x	x	x	x	
	50	62	x	x	x	x	x		x	x					x	x	x	x	
	60	75	x	x	x	x	x		x	x					x	x	x	x	
	80	100	x	x	x	x			x	x					x	x	x		
	100	125	x	x	x	x			x	x					x	x	x		
	125	156	x	x	x	x			x	x					x	x	x		
	150	187	x	x	x	x			x	x					x	x	x		
	180	225	x	x	x	x			x	x					x	x	x		
	200	250	x	x	x	x			x	x					x	x	x		
mtu 0120 DS	80	100	x	x	x	x	x		x	x					x	x	x		x
	100	125	x	x	x	x	x		x	x					x	x	x		x
	125	156	x	x	x	x	x		x	x					x	x	x		x
	150	187	x	x	x	x	x		x	x					x	x	x		x
	180	225	x	x	x	x	x		x	x					x	x	x		x
	200	250	x	x	x	x	x		x	x					x	x	x		x
mtu 0150/0225 DS	230	288		x	x	x	x		x	x					x	x	x		x
	230	288		x	x	x	x		x	x					x	x	x		x
	250	313		x	x	x	x		x	x					x	x	x		x
	250	313		x	x	x	x		x	x					x	x	x		x
	275	344			x	x	x		x	x					x	x	x		x
	275	344			x	x	x		x	x					x	x	x		x
	300	375			x	x	x		x	x					x	x	x		x
	300	375			x	x	x		x	x					x	x	x		x
	350	438			x	x	x		x	x					x	x	x		x
	350	438			x	x	x		x	x					x	x	x		x
	400	500			x	x	x		x	x					x	x	x		x
	400	500			x	x	x		x	x					x	x	x		x

	Emissions						Uptime compl.		Housing		Engine type	Cooling variant [3]	Genset type
	US EPA Tier 4	US EPA stat. EMERG Tier 3 (40 CF 60)	US EPA Nonroad Tier 3 compliant	US EPA stat. EMERG Tier 2 (40 CF 60)	US EPA Nonroad Tier 2 compliant	Fuel consumption optimized	Tier I & Tier II	Tier III & Tier IV	Enclosure	Container			
mtu 0096/0113 DS		x					x		x		3029 TFG89	TC only	***mtu*** 3R0096 DS30
		x					x		x		4045 TF280	TC only	***mtu*** 4R0113 DS40
		x					x		x		4045 TF280	TC only	***mtu*** 4R0113 DS50
		x					x		x		4045 HF280	A2A	***mtu*** 4R0113 DS60
		x					x		x		4045 HF285	A2A	***mtu*** 4R0113 DS80
		x					x		x		4045 HF285	A2A	***mtu*** 4R0113 DS100
		x					x		x		4045 HF285	A2A	***mtu*** 4R0113 DS125
		x					x		x		6068 HF285	A2A	***mtu*** 6R0113 DS150
		x					x		x		6068 HFG85	A2A	***mtu*** 6R0113 DS180
		x					x		x		6068 HFG85	A2A	***mtu*** 6R0113 DS200
mtu 0120 DS		x					x		x		OM924LA	A2A	***mtu*** 4R0120 DS80
		x					x		x		OM924LA	A2A	***mtu*** 4R0120 DS100
		x					x		x		OM924LA	A2A	***mtu*** 4R0120 DS125
		x					x		x		OM926LA	A2A	***mtu*** 6R0120 DS150
		x					x		x		OM926LA	A2A	***mtu*** 6R0120 DS180
		x					x		x		OM926LA	A2A	***mtu*** 6R0120 DS200
mtu 0150/0225 DS		x					x	x	x		6090 HF484	A2A	***mtu*** 6R0150 DS230
	x						x	x	x		6090 HFG06	A2A	***mtu*** 6R0150 DS230
		x					x	x	x		6090 HF484	A2A	***mtu*** 6R0150 DS250
	x						x	x	x		6090 HFG06	A2A	***mtu*** 6R0150 DS250
		x					x	x	x		6090 HF484	A2A	***mtu*** 6R0150 DS275
	x						x	x	x		6090 HFG06	A2A	***mtu*** 6R0150 DS275
		x					x	x	x		6090 HFG86	A2A	***mtu*** 6R0150 DS300
	x						x	x	x		6090 HFG06	A2A	***mtu*** 6R0150 DS300
		x					x	x	x		6135 HFG84	A2A	***mtu*** 6R0225 DS350
	x						x	x	x		6135 HFG06	A2A	***mtu*** 6R0225 DS350
		x					x	x	x		6135 HFG84	A2A	***mtu*** 6R0225 DS400
	x						x	x	x		6135 HFG06	A2A	***mtu*** 6R0225 DS400

Standby power – diesel generator sets

STANDBY POWER (3D) – 60 HZ/1800 RPM.

mtu 1600 DS

Power output [1]		Available voltages												Certifications				
kWe	kVA	240 V (Dedicated (1 Phase))	240 V (Re-connectable (1 Phase))	208 V (3 Phase)	240 V (3 Phase)	380 V (3 Phase)	440 V (3 Phase)	480 V (3 Phase)	600 V (3 Phase)	4160 V (3 Phase)	12470 V (3 Phase)	13200 V (3 Phase)	13800 V (3 Phase)	ISO 8528	UL2200	NFPA 110	IBC 2015	IBC 2018
450	563			x	x	x	x	x	x					x	x	x		x
500	625			x	x	x	x	x	x					x	x	x		x
550	688			x	x	x	x	x	x					x	x	x		x
600	750			x	x	x	x	x	x					x	x	x		x

Emissions							Uptime compl.		Housing		Engine type	Cooling variant [3]	Genset type
US EPA Tier 4	US EPA stat. EMERG Tier 3 (40 CF 60)	US EPA Nonroad Tier 3 compliant	US EPA stat. EMERG Tier 2 (40 CF 60)	US EPA Nonroad Tier 2 compliant	Fuel consumption optimized		Tier I & Tier II	Tier III & Tier IV	Enclosure	Container			
	x	x					x		x		10V 1600 G70S	A2A	***mtu*** 10V1600 DS450
			x	x			x		x		10V 1600 G80S	A2A	***mtu*** 10V1600 DS500
			x	x			x		x		12V 1600 G70S	A2A	***mtu*** 12V1600 DS550
			x	x			x		x		12V 1600 G80S	A2A	***mtu*** 12V1600 DS600

Standby power – diesel generator sets

STANDBY POWER (3D) – 60 HZ/1800 RPM.

	Power output [1]		Available voltages														Certifications			
	kWe	kVA	240 V Dedicated (1 Phase)	240 V Re-connectable (1 Phase)	208 V (3 Phase)	240 V (3 Phase)	380 V (3 Phase)	416 V (3 Phase)	440 V (3 Phase)	480 V (3 Phase)	600 V (3 Phase)	4160 V (3 Phase)	12470 V (3 Phase)	13200 V (3 Phase)	13800 V (3 Phase)	ISO 8528	UL2200	NFPA 110	IBC 2018
mtu 2000 DS	1000	1250			x	x	x			x	x	x				x	x	x	x
	1250	1562					x			x	x	x				x	x	x	x
	1250	1562					x			x	x	x				x	x	x	
mtu 4000 DS	1250	1562					x	x	x	x	x	x	x	x	x	x	x	x	x
	1500	1875					x	x	x	x	x	x	x	x	x	x	x	x	x
	1500	1875					x	x	x	x	x	x	x	x	x	x	x	x	x
	1750	2187					x	x	x	x	x	x	x	x	x	x	x	x	x
	1750	2187					x	x	x	x	x	x	x	x	x	x	x	x	x
	2000	2500					x	x	x	x	x	x	x	x	x	x	x	x	x
	2250	2812					x	x	x	x	x	x	x	x	x	x	x	x	x
	2500	3125					x	x	x	x	x	x	x	x	x	x	x	x	x
	2500	3125					x	x	x	x	x	x	x	x	x	x	x	x	x
	2800	3500					x	x	x	x	x	x	x	x	x	x	x	x	x
	3000	3750					x			x	x	x	x	x	x	x	x	x	x
	3250	4062								x	x	x	x	x	x	x	x	x	x

	Emissions					Uptime compl.		Housing		Engine type	Cooling variant [3]	Genset type
	US EPA stat. EMERG Tier 3 (40 CF 60)	US EPA Nonroad Tier 3 compliant	US EPA stat. EMERG Tier 2 (40 CF 60)	US EPA Nonroad Tier 2 compliant	Fuel consumption optimized	Tier I & Tier II	Tier III & Tier IV	Enclosure	Container			
mtu 2000 DS			x	x		x				16V 2000 G86S	W2A	***mtu*** 16V2000 DS1000
			x	x		x				16V 2000 G86S	W2A	***mtu*** 16V2000 DS1250
			x	x		x				18V 2000 G76S	A2A	***mtu*** 18V2000 DS1250
mtu 4000 DS			x	x		x				12V 4000 G74S	W2A	***mtu*** 12V4000 DS1250
			x	x		x				12V 4000 G74S	W2A	***mtu*** 12V4000 DS1500
			x			x				12V 4000 G75S	W2A	***mtu*** 12V4000 DS1500
			x	x		x				12V 4000 G84S	W2A	***mtu*** 12V4000 DS1750
			x			x				12V 4000 G85S	W2A	***mtu*** 12V4000 DS1750
			x	x		x				16V 4000 G74S	W2A	***mtu*** 16V4000 DS2000
			x	x		x				16V 4000 G84S	W2A	***mtu*** 16V4000 DS2250
			x	x		x				16V 4000 G94S	W2A	***mtu*** 16V4000 DS2500
			x	x		x				20V 4000 G64S	W2A	***mtu*** 20V4000 DS2500
			x	x		x				20V 4000 G74S	W2A	***mtu*** 20V4000 DS2800
			x	x		x				20V 4000 G94S	W2A	***mtu*** 20V4000 DS3000
			x	x		x				20V 4000 G94S	W2A	***mtu*** 20V4000 DS3250

Standby power – dynamic uninterruptible power supply systems

STANDBY POWER (3D) – 60 HZ/1800 RPM.

	Power output [1]				Available voltages		Emissions					Accu arrang.	Certifications				Uptime compl.		Housing	
	no-break kVA	no-break kWe	short-break kVA	short-break kWe	low voltage 208 - 480V (3 Phase)	medium voltages 4 - 36 kV (3 Phase)	US EPA stationary EMERG Tier 3 (40 CF 60)	US Nonroad Tier 3 compliant	US EPA stationary EMERG Tier 2 (40 CF 60)	US Nonroad Tier 2 compliant	Fuel consumption optimized		ISO 8528	UL2200	NFPA 110	IBC 2012	Tier I & Tier II	Tier III & Tier IV	Enclosure	Container
mtu KP5	250	200			x	x					x	single			x		x			x
	300	240			x	x					x	single			x		x			x
	400	320			x	x					x	single			x		x			x
	500	400			x	x			x	x		single			x		x			x
	625	500			x	x			x	x		single			x		x			x
	800	640			x	x				x		single			x		x			x
	1000	800			x	x				x		single			x		x			x
	1250	1000			x	x				x		single			x		x			x
	1500	1200			x	x			x	x	x	single			x		x			x
	1700	1360			x	x			x	x	x	single			x		x			x
	1875	1500	1125	900	x	x			x	x	x	single			x		x			x
	2000	1600			x	x			x	x	x	single			x		x			x
	2000	1600	500	400	x	x			x	x	x	single			x		x			x
	2500	2000			x	x			x	x	x	bi			x		x			x
	3000	2400			x	x			x	x	x	bi			x		x			x
	3000	2400	300	240	x	x			x	x	x	bi			x		x			x
mtu KP7	2500	2000			x	x			x	x	x	single			x		x			x
	3000	2400			x	x			x	x	x	single			x		x			x
	3000	2400	300	240	x	x			x	x	x	single			x		x			x

Standby power – gas generator sets

STANDBY POWER (3D) – 60 HZ/1800 RPM.

Power output [1]		Available voltages											Emissions	Certifications				Fuel type		Housing		Engine type	Genset type
kWe	kVA	240 V Dedicated (1 Phase)	240 V Re-connectable (1 Phase)	208 V (3 Phase)	240 V (3 Phase)	380 V (3 Phase)	480 V (3 Phase)	600 V (3 Phase)	4160 V (3 Phase)	12470 V (3 Phase)	13200 V (3 Phase)	13800 V (3 Phase)	EPA Certified	ISO 8528	UL2200	NFPA 110	IBC 2018	Natural gas	Propane gas/ liquid propane	Enclosure	Container		
30	38	x	x	x	x	x	x	x					x	x	x	x	x	x		x		2.5L	***mtu*** 4R0063 GS30
40	50	x	x	x	x	x	x	x					x	x	x	x	x	x		x		2.5LT	***mtu*** 4R0063 GS40
50	63	x	x	x	x	x	x	x					x	x	x	x	x	x		x		6.2L	***mtu*** 8V0078 GS50
60	75	x	x	x	x	x	x	x					x	x	x	x	x	x		x		6.2L	***mtu*** 8V0078 GS60
70	88	x	x	x	x		x	x					x	x	x	x	x	x		x		6.8L	***mtu*** 10V0068 GS75
100	125	x	x	x	x		x	x					x	x	x	x	x	x		x		6.8LT	***mtu*** 10V0068 GS100
125	156	x	x	x	x		x	x					x	x	x	x	x	x		x		6.8LT CAC	***mtu*** 10V0068 GS125
150	187	x	x	x	x		x	x					x	x	x	x		x		x		8.1L CAC	***mtu*** 6R0135 GS150
200	250	x	x	x	x		x	x					x	x	x	x		x		x		11.1L CAC	***mtu*** 6R0185 GS200
260	325		x	x	x		x	x					x	x	x	x		x		x		14.6L CAC	***mtu*** 8V0183 GS260
350	437		x	x	x		x	x					x	x	x	x		x		x		18.3L CAC	***mtu*** 10V0183 GS350
400	500		x	x	x		x	x					x	x	x	x		x				21.9L CAC	***mtu*** 12V0183 GS400
500	625			x	x	x	x	x	x				x	x	x	x		x				31.8L CAC	***mtu*** 12V0265 GS500
550	688			x	x	x	x	x	x				x	x	x	x		x				31.8L CAC	***mtu*** 12V0265 GS550
600	750			x	x	x	x	x	x				x	x	x	x		x				31.8L CAC	***mtu*** 12V0265 GS600
650	813			x	x	x	x	x	x				x	x	x	x		x				31.8L CAC	***mtu*** 12V0265 GS650

mtu 0063 - 0265 GS/natural gas

Standby power – gas generator sets

STANDBY POWER (3D) – 60 HZ/1800 RPM.

mtu 0063 - 0183 GS/propane gas

Power output[1]		Available voltages											Emissions	Certifications				Fuel type		Housing		Engine type	Genset type
kWe	kVA	240 V Dedicated (1 Phase)	240 V Re-connectable (1 Phase)	208 V (3 Phase)	240 V (3 Phase)	380 V (3 Phase)	480 V (3 Phase)	600 V (3 Phase)	4160 V (3 Phase)	12470 V (3 Phase)	13200 V (3 Phase)	13800 V (3 Phase)	EPA Certified	ISO 8528	UL2200	NFPA 110	IBC 2018	Natural gas	Propane gas/ liquid propane	Enclosure	Container		
30	38	x	x	x	x	x	x	x					x	x	x	x	x		x	x		2.5L	***mtu*** 4R0063 GS30
40	50	x	x	x	x	x	x	x					x	x	x	x	x		x	x		2.5L	***mtu*** 4R0063 GS40
50	63	x	x	x	x	x	x	x					x	x	x	x	x		x	x		6.2L	***mtu*** 8V0078 GS50
60	75	x	x	x	x	x	x	x					x	x	x	x	x		x	x		6.2L	***mtu*** 8V0078 GS60
75	94	x	x	x	x		x	x					x	x	x	x	x		x	x		6.8L	***mtu*** 10V0068 GS75
100	125	x	x	x	x		x	x					x	x	x	x	x		x	x		6.8LT	***mtu*** 10V0068 GS100
125	156	x	x	x	x		x	x					x	x	x	x	x		x	x		6.8LT CAC	***mtu*** 10V0068 GS125
100	125	x	x	x	x		x	x					x	x	x	x			x	x		8.1L CAC	***mtu*** 6R0135 GS150
130	162	x	x	x	x		x	x					x	x	x	x			x	x		11.1L CAC	***mtu*** 6R0185 GS200
160	200		x	x	x		x	x					x	x	x	x			x	x		14.6L CAC	***mtu*** 8V0183 GS260
245	306		x	x	x		x	x					x	x	x	x			x	x		18.3L CAC	***mtu*** 10V0183 GS350
295	368		x	x	x		x	x					x	x	x	x			x	x		21.9L CAC	***mtu*** 12V0183 GS400
350	438			x	x	x	x	x	x				x	x	x	x			x			31.8L CAC	***mtu*** 12V0265 GS500
400	500			x	x	x	x	x	x				x	x	x	x			x			31.8L CAC	***mtu*** 12V0265 GS500

Standby power – diesel generator sets

PRIME POWER FOR STATIONARY EMERGENCY (3E) – 50 HZ/1500 RPM.

	Power output [1]		Available voltages								Emissions						Certifications				Perform. class [2]		Uptime compl.		Housing		Engine type	Cooling variant [3]	Genset type
	kVA	kWe	380 V (3 Phase)	400 V (3 Phase)	415 V (3 Phase)	6300 V (3 Phase)	6600 V (3 Phase)	10000 V (3 Phase)	10500 V (3 Phase)	11000 V (3 Phase)	Fuel consumption optimized	NOx emission optimized	NEA Singapore for ORDE	US EPA Tier 2 compliant	EU Nonroad Stage II compliant (97/68/EC)	EU Nonroad Stage IIIA compliant (97/68/EC)	ISO 8528	CE/IEC	NFPA 110	VDE-AR-N 4110 (German Grid Code)	ISO 8528-5 - G2	ISO 8528-5 - G3	Tier I & Tier II	Tier III & Tier IV	Enclosure	Container			
mtu 1600 DS*	450	360	x	x	x						x	x	x			x	x	x	x	x		x		x		10V 1600 G10F	A2A	***mtu*** 10V1600 DS500
	500	400	x	x	x						x	x	x			x	x	x	x	x		x		x		10V 1600 G20F	A2A	***mtu*** 10V1600 DS540
	590	472	x	x	x						x	x	x				x	x	x	x		x		x		12V 1600 G10F	A2A	***mtu*** 12V1600 DS650
	650	520	x	x	x						x	x	x				x	x	x	x		x		x		12V 1600 G20F	A2A	***mtu*** 12V1600 DS720
mtu 2000 DS	800	640	x	x	x						x	x	x	x			x	x	x	x	x	x	x				12V 2000 G26F	A2A	***mtu*** 12V2000 DS1000
	910	730	x	x	x						x	x	x	x			x	x	x	x	x	x	x				16V 2000 G16F	A2A	***mtu*** 16V2000 DS1000
	1000	800	x	x	x						x	x	x	x			x	x	x	x	x	x	x				16V 2000 G26F	A2A	***mtu*** 16V2000 DS1100
	1135	900	x	x	x						x	x	x	x			x	x	x	x	x	x	x				16V 2000 G36F	A2A	***mtu*** 16V2000 DS1250
	1250	1000	x	x	x						x	x	x	x			x	x	x	x	x	x	x				18V 2000 G26F	A2A	***mtu*** 18V2000 DS1400
	910	730	x	x	x						x	x	x	x			x	x	x	x	x	x	x				16V 2000 G16F	W2A*	***mtu*** 16V2000 DS1000
	1000	800	x	x	x						x	x	x	x			x	x	x	x	x	x	x				16V 2000 G26F	W2A*	***mtu*** 16V2000 DS1100
	1135	900	x	x	x						x	x	x	x			x	x	x	x	x	x	x				16V 2000 G36F	W2A*	***mtu*** 16V2000 DS1250
	1250	1000	x	x	x						x	x	x	x			x	x	x	x	x	x	x				18V 2000 G26F	W2A*	***mtu*** 18V2000 DS1400
mtu 4000 DS	1600	1280	x	x	x			x	x	x	x	x	x				x	x	x	x	x	x	x				12V 4000 G14F	W2A	***mtu*** 12V4000 DS1650
	1700	1360	x	x	x			x	x	x	x	x	x				x	x	x	x	x	x	x				12V 4000 G14F	W2A	***mtu*** 12V4000 DS1750
	1880	1504	x	x	x			x	x	x	x	x	x				x	x	x	x	x	x	x				12V 4000 G24F	W2A	***mtu*** 12V4000 DS2000
	2100	1680	x	x	x			x	x	x	x		x	x			x	x	x	x [11]	x	x	x				12V 4000 G34F	W2A	***mtu*** 12V4000 DS2250
	2160	1728	x	x	x			x	x	x	x	x	x				x	x	x	x	x	x	x				16V 4000 G14F	W2A	***mtu*** 16V4000 DS2250
	2360	1888	x	x	x			x	x	x	x	x	x				x	x	x	x	x	x	x				16V 4000 G24F	W2A	***mtu*** 16V4000 DS2500
	2600	2080	x	x	x			x	x	x	x		x	x			x	x	x	x [11]	x	x	x				16V 4000 G34F	W2A	***mtu*** 16V4000 DS2750
	2640	2112	x	x	x			x	x	x	x	x	x				x	x	x	x	x	x	x				20V 4000 G14F	W2A	***mtu*** 20V4000 DS2750
	2910	2328	x	x	x			x	x	x	x	x	x				x	x	x	x	x	x	x				20V 4000 G24F	W2A	***mtu*** 20V4000 DS3100
	3110	2488	x	x	x			x	x	x	x	x	x				x	x	x	x [11]	x	x	x				20V 4000 G34F	W2A	***mtu*** 20V4000 DS3300
	3630	2904					x [11]		x	x	x		x	x			x	x	x		x	x	x				20V 4000 G44LF	W2A	***mtu*** 20V4000 DS4000

* available soon, for detailed information please check website

Standby power – diesel generator sets

PRIME POWER FOR STATIONARY EMERGENCY (3E) – 60 HZ/1800 RPM.

	Power output [1]		Available voltages											Emissions					Certifications				Uptime compl.		Housing		Engine type	Cooling variant [3]	Genset type
	kWe	kVA	240 V	240 V	208 V	240 V	380 V	480 V	600 V	4160 V	12470 V	13200 V	13800 V	US EPA stationary EMERG Tier 3 (40 CF 60)	US EPA Nonroad Tier 3 compliant	US EPA stationary EMERG Tier 2 (40 CF 60)	US EPA Nonroad Tier 2 compliant	Fuel consumption optimized	ISO 8528	UL2200	NFPA 110	IBC 2012	Tier I & Tier II	Tier III & Tier IV	Enclosure	Container			
			Dedicated (1 Phase)	Re-connectable (1 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)																
mtu 1600 DS	450	563	x	x	x	x	x	x	x	x					x				x	x	x	x	x		x		10V 1600 G20S	A2A	***mtu*** 10V1600 DS500
	500	625	x	x	x	x	x	x	x	x					x				x	x	x	x	x		x		12V 1600 G10S	A2A	***mtu*** 12V1600 DS550
	550	688	x	x	x	x	x	x	x	x					x				x	x	x	x	x		x		12V 1600 G20S	A2A	***mtu*** 12V1600 DS600
mtu 2000 DS	900	1125			x	x	x	x	x	x					x				x	x	x	x	x				16V 2000 G26S	W2A	***mtu*** 16V2000 DS1000
	1125	1406					x	x	x	x					x				x	x	x	x	x		x		12V 4000 G14S	W2A	***mtu*** 12V4000 DS1250
	1400	1750					x	x	x	x					x				x	x	x	x	x		x		12V 4000 G14S	W2A	***mtu*** 12V4000 DS1500
	1600	2000					x	x	x	x					x				x	x	x	x	x		x		12V 4000 G24S	W2A	***mtu*** 12V4000 DS1750
mtu 4000 DS	1800	2250					x	x	x	x	x	x	x		x				x	x	x	x	x		x		16V 4000 G14S	W2A	***mtu*** 16V4000 DS2000
	2045	2556					x	x	x	x	x	x	x		x				x	x	x	x	x				16V 4000 G24S	W2A	***mtu*** 16V4000 DS2250
	2250	2813					x	x	x	x	x	x	x		x				x	x	x	x	x				20V 4000 G14S	W2A	***mtu*** 20V4000 DS2500
	2500	3125					x	x	x	x	x	x	x		x				x	x	x	x	x				20V 4000 G24S	W2A	***mtu*** 20V4000 DS2800
	2800	3500					x	x	x	x	x	x	x		x				x	x	x	x	x				20V 4000 G44S	W2A	***mtu*** 20V4000 DS3000

Standby power – diesel generator sets

DATA CENTER CONTINUOUS POWER (3F) – 50 HZ/1500 RPM.

	Power output [1]		Available voltages								Emissions						Certifications				Perform. class [2]		Uptime compl.		Housing		Engine type	Cooling variant [3]	Genset type
	kVA	kWe	380 V (3 Phase)	400 V (3 Phase)	415 V (3 Phase)	6300 V (3 Phase)	6600 V (3 Phase)	10000 V (3 Phase)	10500 V (3 Phase)	11000 V (3 Phase)	Fuel consumption optimized	NOx emission optimized	NEA Singapore for ORDE	US EPA Tier 2 compliant	EU Nonroad Stage II compliant (97/68/EC)	EU Nonroad Stage IIIA compliant (97/68/EC)	ISO 8528	CE/IEC	NFPA 110	VDE-AR-N 4110 (German Grid Code)	ISO 8528-5 - G2	ISO 8528-5 - G3	Tier I & Tier II	Tier III & Tier IV	Enclosure	Container			
mtu 1600 DS*	450	360	x	x	x						x	x	x			x	x	x	x	x	x	x	x	x		10V 1600 G10F	A2A	***mtu*** 10V1600 DS500
	500	400	x	x	x						x	x	x			x	x	x	x	x	x	x	x	x		10V 1600 G20F	A2A	***mtu*** 10V1600 DS540
	590	472	x	x	x						x	x	x				x	x	x	x	x	x	x	x		12V 1600 G10F	A2A	***mtu*** 12V1600 DS650
	650	520	x	x	x						x	x	x				x	x	x	x	x	x	x	x		12V 1600 G20F	A2A	***mtu*** 12V1600 DS720
mtu 2000 DS	1000	800	x	x	x						x	x	x	x			x	x	x	x	x	x	x	x		16V 2000 G26F	A2A	***mtu*** 16V2000 DS1100
	1250	1000	x	x	x						x	x	x	x			x	x	x	x	x	x	x	x		18V 2000 G26F	A2A	***mtu*** 18V2000 DS1400
	1000	800	x	x	x						x	x	x	x			x	x	x	x	x	x	x	x		16V 2000 G26F	W2A*	***mtu*** 16V2000 DS1100
	1250	1000	x	x	x						x	x	x	x			x	x	x	x	x	x	x	x		18V 2000 G26F	W2A*	***mtu*** 18V2000 DS1400
mtu 4000 DS	1600	1280	x	x	x			x	x	x	x	x	x				x	x	x	x	x	x	x	x		12V 4000 G14F	W2A	***mtu*** 12V4000 DS1650
	1700	1360	x	x	x			x	x	x	x	x	x				x	x	x	x	x	x	x	x		12V 4000 G14F	W2A	***mtu*** 12V4000 DS1750
	1880	1504	x	x	x			x	x	x	x	x	x				x	x	x	x	x	x	x	x		12V 4000 G24F	W2A	***mtu*** 12V4000 DS2000
	2100	1680	x	x	x		x[11]	x[13]			x		x	x			x	x	x	x	x	x	x	x		12V 4000 G34F	W2A	***mtu*** 12V4000 DS2250
	2160	1728	x	x	x			x	x	x	x	x	x				x	x	x	x	x	x	x	x		16V 4000 G14F	W2A	***mtu*** 16V4000 DS2250
	2360	1888	x	x	x			x	x	x	x	x	x				x	x	x	x	x	x	x	x		16V 4000 G24F	W2A	***mtu*** 16V4000 DS2500
	2600	2080	x	x	x		x[11]	x[13]			x		x	x			x	x	x	x	x	x	x	x		16V 4000 G34F	W2A	***mtu*** 16V4000 DS2750
	2640	2112	x	x	x			x	x	x	x	x	x				x	x	x	x	x	x	x	x		20V 4000 G14F	W2A	***mtu*** 20V4000 DS2750
	2910	2328	x	x	x			x	x	x	x	x	x				x	x	x	x	x	x	x	x		20V 4000 G24F	W2A	***mtu*** 20V4000 DS3100
	3110	2488	x	x	x			x	x	x	x	x	x				x	x	x	x	x	x	x	x		20V 4000 G34F	W2A	***mtu*** 20V4000 DS3300
	3390	2712					x[11]	x[13]	x[11]	x	x		x	x			x	x	x	x	x	x	x	x		20V 4000 G44F	W2A	***mtu*** 20V4000 DS3600
	3630	2904					x[11]		x[11]	x	x		x	x			x	x	x	x	x	x	x	x		20V 4000 G44LF	W2A	***mtu*** 20V4000 DS4000

* available soon, for detailed information please check website

Standby power – dynamic uninterruptible power supply systems

DATA CENTER CONTINUOUS POWER (3F) – 50 HZ/1500 RPM.

	Power output [1]				Available voltages		Emissions					Accu arrang.	Certifications				Perform. class [2]		Uptime compl.		Housing	
	no-break kVA	no-break kWe	short-break kVA	short-break kWe	low voltage 380 - 415V (3 Phase)	medium voltages 6 - 36 kV (3 Phase)	Fuel consumption optimized	NOx emission optimized	NEA Singapore for ORDE	US EPA Tier 2 compliant	EU Nonroad Stage II compliant (97/68/EC)		ISO 8528	CE/IEC	NFPA 110	VDE-AR-N 4110 (German Grid Code)	ISO 8528-5 - G3	ISO 8528-5 - G4	Tier I & Tier II	Tier III & Tier IV	Enclosure	Container
mtu KP5	400	400			x	x	x	x	x			single		x	x			x	x	x		x
	480	384			x	x	x	x	x			single		x	x			x	x	x		x
	630	504			x	x	x	x	x			single		x	x			x	x	x		x
	1250	1000			x	x	x	x	x			single		x	x			x	x	x		x
	1500	1200			x	x	x	x	x			single		x	x			x	x	x		x
	1650	1320	600	480	x	x	x	x	x			single		x	x			x	x	x		x
	1700	1360			x	x	x	x	x			single		x	x			x	x	x		x
	1875	1500	625	500	x	x	x	x	x			single		x	x			x	x	x		x
	2000	1600			x	x	x	x	x			single		x	x			x	x	x		x
	2200	1760			x	x	x	x	x			bi		x	x			x	x	x		x
	2500	2000			x	x	x	x	x			bi		x	x			x	x	x		x
	2750	2200			x	x	x	x	x			bi		x	x			x	x	x		x
mtu KP7	2250	1800			x	x	x	x	x			single		x	x			x	x	x		x
	2500	2000			x	x	x	x	x			single		x	x			x	x	x		x
	2750	2200			x	x	x	x	x			single		x	x			x	x	x		x

Standby power – diesel generator sets

DATA CENTER CONTINUOUS POWER (3F) – 60 HZ/1800 RPM.

	Power output [1]		Available voltages													Emissions				
	kWe	kVA	240 V Dedicated (1 Phase)	240 V Re-connectable (1 Phase)	208 V (3 Phase)	240 V (3 Phase)	380 V (3 Phase)	416 V (3 Phase)	440 V (3 Phase)	480 V (3 Phase)	600 V (3 Phase)	4160 V (3 Phase)	12470 V (3 Phase)	13200 V (3 Phase)	13800 V (3 Phase)	US EPA stationary EMERG Tier 3 (40 CF 60)	US EPA Nonroad Tier 3 compliant	US EPA stationary EMERG Tier 2 (40 CF 60)	US EPA Nonroad Tier 2 compliant	Fuel consumption optimized
mtu 2000 DS	900	1125			x	x	x			x	x	x						x	x	x
mtu 4000 DS	1135	1419					x	x	x	x	x	x	x	x	x			x	x	x
	1350	1688					x	x	x	x	x	x	x	x	x			x	x	
	1400	1750					x	x	x	x	x	x	x	x	x			x	x	x
	1600	2000					x	x	x	x	x	x	x	x	x			x	x	
	1600	2000					x	x	x	x	x	x	x	x	x			x	x	x
	1825	2281					x	x	x	x	x	x	x	x	x			x	x	x
	2045	2556					x	x	x	x	x	x	x	x	x			x	x	x
	2275	2843					x	x	x	x	x	x	x	x	x			x	x	x
	2500	3125					x	x	x	x	x	x	x	x	x			x	x	x
	2800	3500					x	x	x	x	x	x	x	x	x			x	x	x

	Certifications				Uptime compl.		Housing		Engine type	Cooling variant [3]	Genset type
	ISO 8528	UL2200	NFPA 110	IBC 2012	Tier I & Tier II	Tier III & Tier IV	Enclosure	Container			
mtu 2000 DS	x	x	x	x	x	x			16V 2000 G26S	W2A	***mtu*** 16V2000 DS1000
mtu 4000 DS	x	x	x	x	x	x			12V 4000 G14S	W2A	***mtu*** 12V4000 DS1250
	x	x	x	x	x	x			12V 4000 G15S	W2A	***mtu*** 12V4000 DS1500
	x	x	x	x	x	x			12V 4000 G14S	W2A	***mtu*** 12V4000 DS1500
	x	x	x	x	x	x			12V 4000 G25S	W2A	***mtu*** 12V4000 DS1750
	x	x	x	x	x	x			12V 4000 G24S	W2A	***mtu*** 12V4000 DS1750
	x	x	x	x	x	x			16V 4000 G14S	W2A	***mtu*** 16V4000 DS2000
	x	x	x	x	x	x			16V 4000 G24S	W2A	***mtu*** 16V4000 DS2250
	x	x	x	x	x	x			20V 4000 G14S	W2A	***mtu*** 20V4000 DS2500
	x	x	x	x	x	x			20V 4000 G24S	W2A	***mtu*** 20V4000 DS2800
	x	x	x	x	x	x			20V 4000 G44S	W2A	***mtu*** 20V4000 DS3000

Standby power – dynamic uninterruptible power supply systems

DATA CENTER CONTINUOUS POWER (3F) – 60 HZ/1800 RPM.

	Power output [1]				Available voltages		Emissions					Accu arrang.	Certifications				Uptime compl.		Housing	
	no-break kVA	no-break kWe	short-break kVA	short-break kWe	low voltage 208 - 480V (3 Phase)	medium voltages 4 - 36 kV (3 Phase)	US EPA stationary EMERG Tier 3 (40 CF 60)	US Nonroad Tier 3 compliant	US EPA stationary EMERG Tier 2 (40 CF 60)	US Nonroad Tier 2 compliant	Fuel consumption optimized		ISO 8528	UL2200	NFPA 110	IBC 2012	Tier I & Tier II	Tier III & Tier IV	Enclosure	Container
mtu KP5	500	400			x	x			x	x		single			x		x	x		x
	625	500			x	x			x	x		single			x		x	x		x
	1500	1200			x	x			x	x	x	single			x		x	x		x
	1700	1360			x	x			x	x	x	single			x		x	x		x
	1875	1500	1125	900	x	x			x	x	x	single			x		x	x		x
	2000	1600			x	x			x	x	x	single			x		x	x		x
	2000	1600	500	400	x	x			x	x	x	bi			x		x	x		x
	2500	2000			x	x			x	x	x	bi			x		x	x		x
	3000	2400			x	x			x	x	x	bi			x		x	x		x
mtu KP7	2500	2000			x	x			x	x	x	single			x		x	x		x
	3000	2400			x	x			x	x	x	single			x		x	x		x

Continuous/prime/grid stability power – diesel generator sets

CONTINUOUS POWER + CHP (3A) – 50 HZ/1500 RPM.

mtu 2000 DS

Power output [1]		Available voltages								Emissions						Certifications				Perform. class [2]		Uptime compl.		Housing		Engine type	Cooling variant [3]	Genset type
kVA	kWe	380 V (3 Phase)	400 V (3 Phase)	415 V (3 Phase)	6300 V (3 Phase)	6600 V (3 Phase)	10000 V (3 Phase)	10500 V (3 Phase)	11000 V (3 Phase)	Fuel consumption optimized	NOx emission optimized	NEA Singapore for ORDE	US EPA Tier 2 compliant	EU Nonroad Stage II compliant (97/68/EC)	EU Nonroad Stage IIIA compliant (97/68/EC)	ISO 8528	CE/IEC	NFPA 110	VDE-AR-N 4110 (German Grid Code)	ISO 8528-5 - G2	ISO 8528-5 - G3	Tier I & Tier II	Tier III & Tier IV	Enclosure	Container			
750	600	x	x	x						x						x	x	x	x	x	x	x	x			12V 2000 B26F	A2A	***mtu*** 12V2000 DS1000
800	640	x	x	x						x						x	x	x	x	x	x	x	x			16V 2000 B26F	A2A	***mtu*** 16V2000 DS1250
1000	800	x	x	x						x						x	x	x	x	x	x	x	x			18V 2000 B26F	A2A	***mtu*** 18V2000 DS1400
800	640	x	x	x						x						x	x	x	x	x	x	x	x			16V 2000 B26F	W2A*	***mtu*** 16V2000 DS1250
1000	800	x	x	x						x						x	x	x	x	x	x	x	x			18V 2000 B26F	W2A*	***mtu*** 18V2000 DS1400

* available soon, for detailed information please check website

Continuous/prime/grid stability power – gas generator sets

CONTINUOUS POWER + CHP (3A) – 50 HZ (NO_X 500 MG/NM^3 @ 5% O_2 DRY).

	Fuel type			Output						Energy input [9]	Efficiency			Methane number [10]	NOx raw gas @5% O_2 dry		Options							Engine type	Genset type
	Ambient condition	Natural gas	Biogas, sewage gas, landfill gas	Electr. [6] kW_{el}	Therm. [7] kW_{th}	Exhaust [8] kW_{th} (°C)	Reference temp. for exhaust gas heat (°C)	Low Temp. kW_{th} (°C)	Mixture cooling water temp. (°C)	kW	Electr. n_{el} (%)	Therm. n_{th} (%)	Total n_{tot} (%)	Reference	500 mg/Nm^3	250 mg/Nm^3	400V alternator	415V alternator	6300V alternator	10500V alternator	11000V alternator	120s FAST Start	Heat recovery unit		
mtu 400 GS	ISO	x		182	126	143	120	23	70	506	36,0	53,2	89,1	70	x		x						x	L9	***mtu*** 6R400 GS
	ISO	x		192	106	149	120	29	50	534	36,0	47,8	83,7	70	x		x						x	L9	***mtu*** 6R400 GS
	ISO	x		202	109	154	120	36	40	560	36,1	47,0	83,0	70	x		x						x	L9	***mtu*** 6R400 GS
	ISO	x		221	120	134	120	17	40	558	39,6	45,5	85,1	80	x		x						x	Z5	***mtu*** 6R400 GS
	ISO	x		357	235	256	120	38	70	952	37,5	51,6	89,1	70	x		x						x	L9	***mtu*** 12V400 GS
	ISO	x		370	194	263	120	52	50	988	37,4	46,3	83,7	70	x		x						x	L9	***mtu*** 12V400 GS
	ISO	x		390	233	241	120	28	40	995	39,2	47,6	86,8	70	x		x						x	Z6	***mtu*** 12V400 GS
	ISO	x		420	247	257	120	31	40	1064	39,5	47,4	86,8	80	x		x						x	Z6	***mtu*** 12V400 GS
	ISO		x	221	130	132	120	17	40	559	39,5	46,9	86,4	120	x		x						x	Z8	***mtu*** 6R400 GS
	ISO		x	370	190	235	120	48	50	943	39,2	45,1	84,3	120	x		x						x	L8	***mtu*** 12V400 GS
	ISO		x	400	245	262	120	29	40	1015	39,4	50,0	89,4	120	x		x						x	Z7	***mtu*** 12V400 GS
	Cogeneration module 100°/80°C heating water circuit																								
	ISO	x		166	114	130	120	13	80	465	35,7	52,5	88,2	70	x	x	x						x	LH9	***mtu*** 6R400 GS
	ISO	x		323	206	250	120	25	80	879	36,7	51,9	88,6	70	x		x						x	LH9	***mtu*** 12V400 GS
	ISO	x		352	182	267	120	49	50	954	36,9	47,1	84,0	70	x		x						x	LH9	***mtu*** 12V400 GS
	ISO	x		420	239	269	120	36	40	1068	39,3	47,6	86,9	80	x		x						x	ZH6	***mtu*** 12V400 GS
mtu 500 GS	ISO	x		250	131	129	120	26	38	598	41,8	43,4	85,2	80	x	x	x						x	E406-ct80	***mtu*** 6RA500 GS
	ISO	x		360	188	193	120	31	38	846	42,6	45,0	87,6	80	x	x	x						x	E408-ct80	***mtu*** 8VA500 GS
	ISO	x		499	263	271	120	46	38	1188	42,1	45,0	87,1	80	x	x	x						x	E412-ct80	***mtu*** 12VA500 GS
	ISO	x		550	287	290	120	51	38	1290	42,6	44,8	87,4	80	x	x	x						x	E412-ct80	***mtu*** 12VA500 GS

Continuous/prime/grid stability power – gas generator sets

CONTINUOUS POWER + CHP (3A) – 50 HZ (NO_X 500 MG/NM^3 @ 5% O_2 DRY).

Fuel type			Output						Energy input [9]	Efficiency		
Ambient condition	Natural gas	Biogas, sewage gas, landfill gas	Electr. [6] kW_{el}	Therm. [7] kW_{th}	Exhaust [8] kW_{th} (°C)	Reference temp. for exhaust gas heat (°C)	Low Temp. kW_{th} (°C)	Mixture cooling water temp. (°C)	kW	Electr. n_{el} (%)	Therm. n_{th} (%)	Total n_{tot} (%)
ISO	x		776	414	422	120	47	40	1832	42,4	45,6	88,0
ISO	x		854	422	435	120	51	43	1967	43,4	43,6	87,0
ISO	x		999	522	490	120	68	43	2258	44,2	44,8	89,1
ISO	x		1013	530	494	120	69	43	2287	44,3	44,8	89,1
ISO	x		1286	703	650	120	90	40	2949	43,6	45,9	89,5
ISO	x		1521	788	742	120	115	43	3443	44,2	44,4	88,6
ISO	x		1712	1015	825	120	127	40	3979	43,0	46,3	89,3
ISO	x		2028	1060	995	120	145	43	4583	44,3	44,8	89,1
ISO	x		2145	1196	1078	120	142	40	4985	43,0	45,6	88,6
ISO	x		2538	1241	1212	120	176	43	5751	44,1	42,7	86,8
ISO	x		2540	1241	1212	120	176	43	5751	44,2	42,7	86,8
ISO		x	776	390	396	120	74	40	1806	43,0	43,5	86,5
ISO		x	800	401	402	180	78	40	1861	43,0	43,1	86,1
ISO		x	1169	586	602	120	103	40	2716	43,0	43,8	86,8
ISO		x	1560	825	800	120	133	40	3616	43,1	45,0	88,1
ISO		x	1950	1030	1046	120	97	40	4493	43,4	46,2	89,6

Methane number [10]	NOx raw gas @5% O_2 dry		Options							Engine type	Genset type
Reference	500 mg/Nm^3	250 mg/Nm^3	400V alternator	415V alternator	6300V alternator	10500V alternator	11000V alternator	120s FAST Start	Heat recovery unit		
70	x	x	x						x	L33	***mtu*** 8V4000 GS
70	x	x	x	x	x	x	x		x	L64	***mtu*** 8V4000 GS
72	x	x	x	x	x	x	x		x	L64FNER	***mtu*** 8V4000 GS
72	x	x	x	x	x	x	x		x	L64FNER	***mtu*** 8V4000 GS
80	x	x	x	x	x	x	x		x	L33	***mtu*** 12V4000 GS
72	x	x	x	x	x	x	x		x	L64FNER	***mtu*** 12V4000 GS
80	x	x	x	x	x	x	x		x	L33	***mtu*** 16V4000 GS
72	x	x	x	x	x	x	x	x	x	L64FNER	***mtu*** 16V4000 GS
80	x	x	x	x	x	x	x		x	L33	***mtu*** 20V4000 GS
80	x	x	x	x	x	x	x	x	x	L64FNER	***mtu*** 20V4000 GS
80	x	x	x	x	x	x	x		x	L64	***mtu*** 20V4000 GS
120	x		x						x	L32FB	***mtu*** 8V4000 GS
120	x		x						x	L32FB	***mtu*** 8V4000 GS
120	x	x	x	x	x	x	x		x	L32FB	***mtu*** 12V4000 GS
120	x	x	x	x	x	x	x		x	L32FB	***mtu*** 16V4000 GS
120	x		x	x	x	x	x		x	L32FB	***mtu*** 20V4000 GS

Continuous/prime/grid stability power – gas generator sets

CONTINUOUS POWER + CHP (3A) – 50 HZ (NO_X 500 MG/NM^3 @ 5% O_2 DRY).

Fuel type			Output						Energy input [9]	Efficiency		
Ambient condition	Natural gas	Biogas, sewage gas, landfill gas	Electr. [6] kW_{el}	Therm. [7] kW_{th}	Exhaust [8] kW_{th}	Reference temp. for exhaust gas heat (°C)	Low Temp. kW_{th} (°C)	Mixture cooling water temp. (°C)	kW	Electr. n_{el} (%)	Therm. n_{th} (%)	Total n_{tot} (%)
H&H	x		776	460	420	120	32	53	1853	41,9	47,5	89,4
H&H	x		999	595	476	120	50	58	2300	43,4	46,6	90,0
H&H	x		1169	680	624	120	58	53	2732	42,8	47,7	90,5
H&H	x		1521	849	717	120	79	58	3428	44,4	45,7	90,1
H&H	x		1560	954	802	120	79	53	3661	42,6	48,0	90,6
H&H	x		1948	1068	1101	120	78	53	4577	42,6	47,3	89,9
H&H	x		2028	1173	974	120	93	58	4622	43,9	46,5	90,3
H&H	x		2540	1441	1243	120	150	58	5781	43,9	46,4	90,4
H&H		x	776	430	424	120	67	53	1854	41,9	46,0	87,9
H&H		x	1169	636	631	120	90	53	2755	42,4	46,0	88,4
H&H		x	1560	877	815	120	119	53	3652	42,7	46,4	89,1
H&H		x	1950	1039	1044	120	84	53	4576	42,6	45,5	88,1
LM	x		1560	951	937	120	99	53	3848	40,5	49,1	89,6
LM	x		1948	1180	1181	120	99	53	4812	40,5	49,1	89,6

H&H = Hot & Humid, LM = Low Methan

Methane number [10]	NOx raw gas @5% O_2 dry		Options							Engine type	Genset type
Reference	500 mg/Nm^3	250 mg/Nm^3	400V alternator	415V alternator	6300V alternator	10500V alternator	11000V alternator	120s FAST Start	Heat recovery unit		
80	x	x	x						x	L32	***mtu*** 8V4000 GS
80	x	x	x	x	x	x	x		x	L64FNER	***mtu*** 8V4000 GS
80	x	x	x	x	x	x	x		x	L32	***mtu*** 12V4000 GS
80	x	x	x	x	x	x	x		x	L64FNER	***mtu*** 12V4000 GS
80	x	x	x	x	x	x	x		x	L32	***mtu*** 16V4000 GS
80	x	x	x	x	x	x	x		x	L32	***mtu*** 20V4000 GS
80	x	x	x	x	x	x	x		x	L64FNER	***mtu*** 16V4000 GS
80	x	x	x	x	x	x	x		x	L64FNER	***mtu*** 20V4000 GS
120	x		x						x	L32FB	***mtu*** 8V4000 GS
120	x	x	x	x	x	x	x		x	L32FB	***mtu*** 12V4000 GS
120	x	x	x	x	x	x	x		x	L32FB	***mtu*** 16V4000 GS
120	x		x	x	x	x	x		x	L32FB	***mtu*** 20V4000 GS
60	x		x	x	x	x	x			L32ER	***mtu*** 16V4000 GS
60	x		x	x	x	x	x			L32ER	***mtu*** 20V4000 GS

Continuous/prime/grid stability power – gas generator sets

CONTINUOUS POWER + CHP (3A) – 60 HZ (NO_X 500 MG/NM^3 @ 5% O_2 DRY).

	Fuel type			Output						Energy input [9]	Efficiency		
	Ambient condition	Natural gas	Biogas, sewage gas, landfill gas	Electr. [6] kW_{el}	Therm. [7] kW_{th}	Exhaust [8] kW_{th}	Reference temp. for exhaust gas heat (°C)	Low Temp. kW_{th}	Mixture cooling water temp. (°C)	kW	Electr. n_{el} (%)	Therm. n_{th} (%)	Total n_{tot} (%)
mtu 400 GS	ISO		x	349	212	282	180		70	951	36,8	49,6	88,6
mtu 500 GS*	ISO	x		250	143	144	120	21	38	618	40,5	46,4	86,9
	ISO	x		360	189	211	120	33	38	882	40,8	45,4	86,2
	ISO	x		550	304	325	120	51	38	1359	40,5	46,3	86,8

	Methane number [10]	NOx raw gas				Options							Engine type	Genset type
	Reference	500 mg/Nm^3 @5%O^2 dry	1 g/bhp-hr	250 mg/Nm^3 @5%O^2 dry	0,5 g/bhp-hr	480V alternator	600V alternator	4160V alternator	12470V alternator	13200/13800V altern.	120s FAST Start	Heat recovery unit		
mtu 400 GS	120	x	x			x						x	Z7	***mtu*** 12V400 GS
mtu 500 GS*	80		x		x	x						x	E406-ct80	***mtu*** 6RA500 GS
	80		x		x	x						x	E408-ct80	***mtu*** 8VA500 GS
	80		x		x	x						x	E412-ct80	***mtu*** 12VA500 GS

* available soon, for detailed information please check website

Continuous/prime/grid stability power – gas generator sets

CONTINUOUS POWER + CHP (3A) – 60 HZ (NO_X 500 MG/NM^3 @ 5% O_2 DRY).

Fuel type			Output						Energy input [9]	Efficiency		
Ambient condition	Natural gas	Biogas, sewage gas, landfill gas	Electr. [6] kW_{el}	Therm. [7] kW_{th}	Exhaust [8] kW_{th}	Reference temp. for exhaust gas heat (°C)	Low Temp. kW_{th}	Mixture cooling water temp. (°C)	kW	Electr. n_{el} (%)	Therm. n_{th} (%)	Total n_{tot} (%)
ISO	x		842	452	448	120	49	40	1993	42,2	45,2	87,4
ISO	x		997	540	494	120	69	43	2287	43,6	45,2	88,8
ISO	x		1272	675	659	120	88	43	2974	42,8	44,9	87,6
ISO	x		1506	800	742	120	115	43	3456	43,6	44,6	88,2
ISO	x		1705	974	821	120	113	40	3991	42,7	45,0	87,7
ISO	x		2014	1072	995	120	145	43	4583	43,9	45,1	89,0
ISO	x		2129	1208	1077	120	142	40	4985	42,7	45,8	88,5
ISO	x		2519	1368	1236	120	211	43	5781	43,6	45,0	88,6
ISO		x	764	388	321	180	74	40	1806	42,3	39,3	81,6
ISO		x	1152	581	488	180	103	40	2716	42,5	39,4	81,9
ISO		x	1549	638	652	180	313	40	3616	42,8	35,7	78,5
ISO		x	1934	745	873	180	373	40	4493	43,0	36,0	79,1
H&H	x		764	454	420	120	32	53	1853	41,2	47,2	88,4
H&H	x		997	614	480	120	51	58	2329	42,8	47,0	89,8
H&H	x		1155	642	638	120	43	53	2747	42,0	46,6	88,6
H&H	x		1506	861	717	120	79	58	3428	43,9	46,0	90,0
H&H	x		1549	901	805	120	76	53	3651	42,4	46,7	89,2
H&H	x		1934	1046	1101	120	78	53	4577	42,3	46,9	89,2
H&H	x		2014	1185	974	120	93	58	4622	43,6	46,7	90,3
H&H	x		2519	1454	1243	120	150	58	5781	43,6	46,6	90,2
H&H		x	764	427	349	180	67	53	1854	41,2	41,9	83,1
H&H		x	1155	647	519	180	90	53	2755	41,9	42,3	84,2
H&H		x	1549	677	671	180	330	53	3652	42,4	46,0	88,4
H&H		x	1934	775	856	180	425	53	4576	42,3	35,6	77,9
LM	x		1547	932	937	120	84	53	3848	40,2	48,6	88,8
LM	x		1934	1154	1181	120	99	53	4812	40,2	48,5	88,7

H&H = Hot & Humid, LM = Low Methan

Methane number [10]	NOx raw gas				Options							Engine type	Genset type
Reference	500 mg/Nm^3 @5%O^2 dry	1 g/bhp-hr	250 mg/Nm^3 @5%O^2 dry	0,5 g/bhp-hr	480V alternator	600V alternator	4160V alternator	12470V alternator	13200/13800V altern.	120s FAST Start	Heat recovery unit		
80	x	x	*	*	x	x					*	L33	***mtu*** 8V4000 GS
72	x	x	x	x	x						*	L64FNER	***mtu*** 8V4000 GS
80	x	x	*	*	x	x	x	x	x		*	L33	***mtu*** 12V4000 GS
72	x	x	x	x	x	x	x	x	x		*	L64FNER	***mtu*** 12V4000 GS
80	x	x	*	*	x	x	x	x	x		*	L33	***mtu*** 16V4000 GS
72	x	x	x	x	x	x	x	x	x		*	L64FNER	***mtu*** 16V4000 GS
80	x	x	*	*	x	x	x	x	x		*	L33	***mtu*** 20V4000 GS
72	x	x	x	x	x	x	x	x	x		*	L64FNER	***mtu*** 20V4000 GS
120	x	x			x	x					*	L32FB	***mtu*** 8V4000 GS
120	x	x	x		x	x	x	x	x		*	L32FB	***mtu*** 12V4000 GS
120	x	x	x		x	x	x	x	x		*	L32FB	***mtu*** 16V4000 GS
120	x	x			x	x	x	x	x		*	L32FB	***mtu*** 20V4000 GS
80	x	x	*	*	x	x					*	L32	***mtu*** 8V4000 GS
80	x	x	x	x	x						*	L64FNER	***mtu*** 8V4000 GS
80	x	x	*	*	x	x	x	x	x		*	L32	***mtu*** 12V4000 GS
80	x	x	x	x	x	x	x	x	x		*	L64FNER	***mtu*** 12V4000 GS
80	x	x	*	*	x	x	x	x	x		*	L32	***mtu*** 16V4000 GS
80	x	x	*	*	x	x	x	x	x		*	L32	***mtu*** 20V4000 GS
80	x	x	x	x	x	x	x	x	x		*	L64FNER	***mtu*** 16V4000 GS
80	x	x	x	x	x	x	x	x	x		*	L64FNER	***mtu*** 20V4000 GS
120	x	x			x	x					*	L32FB	***mtu*** 8V4000 GS
120	x	x	x		x	x	x	x	x		*	L32FB	***mtu*** 12V4000 GS
120	x	x	x		x	x	x	x	x		*	L32FB	***mtu*** 16V4000 GS
120	x	x			x	x	x	x	x		*	L32FB	***mtu*** 20V4000 GS
60	x	x			x	x	x	x	x		*	L32ER	***mtu*** 16V4000 GS
60	x	x			x	x	x	x	x		*	L32ER	***mtu*** 20V4000 GS

* on request

Continuous/prime/grid stability power – diesel generator sets

PRIME POWER (3B) – 50 HZ/1500 RPM.

	Power output [1]		Available voltages			Emissions					
	25°C kVA	25°C kWe	380 - 415V (3 Phase)	6300 - 6600 kV (3 Phase)	10000 -11000 V (3 Phase)	Fuel consumption optimized	NOx emission optimized	NEA Singapore for ORDE	US EPA Tier 2 compliant	EU Nonroad Stage II compliant (97/68/EC)	EU Nonroad Stage IIIA compliant (97/68/EC)
mtu 0080/0113 DS	50	40	x							x	
	60	48	x							x	
	75	60	x							x	
	84	67	x			x					
mtu 1600 DS*	450	360	x			x	x	x			x
	500	400	x			x	x	x			x
	590	472	x			x	x	x			
	650	520	x			x	x	x			

* available soon, for detailed information please check website

	Certifications				Perform. class [2]		Uptime compl.		Housing		Engine type	Cooling variant [3]	Genset type
	ISO 8528	CE/IEC	NFPA 110	VDE-AR-N 4110 (German Grid Code)	ISO 8528-5 - G2	ISO 8528-5 - G3	Tier I & Tier II	Tier III & Tier IV	Enclosure	Container			
mtu 0080/0113 DS	x	x			x		x				F32 TM 1A	A2A	***mtu*** 4R0080 DS55
	x	x			x		x				NEF45 SM 1A	A2A	***mtu*** 4R0113 DS63
	x	x			x		x				NEF45 SM 2A	A2A	***mtu*** 4R0113 DS80
	x	x			x		x				NEF45 SM 5	A2A	***mtu*** 4R0113 DS94
mtu 1600 DS*	x	x	x		x	x	x		x		10V 1600 G10F	A2A	***mtu*** 10V1600 DS500
	x	x	x		x	x	x		x		10V 1600 G20F	A2A	***mtu*** 10V1600 DS540
	x	x	x		x	x	x		x		12V 1600 G10F	A2A	***mtu*** 12V1600 DS650
	x	x	x		x	x	x		x		12V 1600 G20F	A2A	***mtu*** 12V1600 DS720

Continuous/prime/grid stability power – diesel generator sets

PRIME POWER (3B) – 50 HZ/1500 RPM.

	Power output [1]		Available voltages			Emissions						Certifications				Perform. class [2]		Uptime compl.		Housing		Engine type	Cooling variant [3]	Genset type
	kVA	kWe	380 - 415V (3 Phase)	6300 - 6600 kV (3 Phase)	10000 -11000 V (3 Phase)	Fuel consumption optimized	NOx emission optimized	NEA Singapore for ORDE	US EPA Tier 2 compliant	EU Nonroad Stage II compliant (97/68/EC)	EU Nonroad Stage IIIA compliant (97/68/EC)	ISO 8528	CE/IEC	NFPA 110	VDE-AR-N 4110 (German Grid Code)	ISO 8528-5 - G2	ISO 8528-5 - G3	Tier I & Tier II	Tier III & Tier IV	Enclosure	Container			
mtu 2000 DS	800	640	x			x	x	x	x			x	x	x	x	x	x	x				12V 2000 G26F	A2A	***mtu*** 12V2000 DS1000
	910	730	x			x	x	x	x			x	x	x	x	x	x	x				16V 2000 G16F	A2A	***mtu*** 16V2000 DS1000
	1000	800	x			x	x	x	x			x	x	x	x	x	x	x				16V 2000 G26F	A2A	***mtu*** 16V2000 DS1100
	1135	900	x			x	x	x	x			x	x	x	x	x	x	x				16V 2000 G36F	A2A	***mtu*** 16V2000 DS1250
	1250	1000	x			x	x	x	x			x	x	x	x	x	x	x				18V 2000 G26F	A2A	***mtu*** 18V2000 DS1400
	910	730	x			x	x	x	x			x	x	x	x	x	x	x				16V 2000 G16F	W2A*	***mtu*** 16V2000 DS1000
	1000	800	x			x	x	x	x			x	x	x	x	x	x	x				16V 2000 G26F	W2A*	***mtu*** 16V2000 DS1100
	1135	900	x			x	x	x	x			x	x	x	x	x	x	x				16V 2000 G36F	W2A*	***mtu*** 16V2000 DS1250
	1250	1000	x			x	x	x	x			x	x	x	x	x	x	x				18V 2000 G26F	W2A*	***mtu*** 18V2000 DS1400
mtu 4000 DS	1600	1280	x		x	x	x	x				x	x	x	x	x	x	x				12V 4000 G14F	W2A	***mtu*** 12V4000 DS1650
	1700	1360	x		x	x	x	x				x	x	x	x	x	x	x				12V 4000 G14F	W2A	***mtu*** 12V4000 DS1750
	1880	1504	x		x	x	x	x				x	x	x	x	x	x	x				12V 4000 G24F	W2A	***mtu*** 12V4000 DS2000
	2160	1728	x		x	x	x	x				x	x	x	x	x	x	x				16V 4000 G14F	W2A	***mtu*** 16V4000 DS2250
	2360	1888	x		x	x	x	x				x	x	x	x	x	x	x				16V 4000 G24F	W2A	***mtu*** 16V4000 DS2500
	2640	2112	x		x	x	x	x				x	x	x	x	x	x	x				20V 4000 G14F	W2A	***mtu*** 20V4000 DS2750
	2910	2328	x		x	x	x	x				x	x	x	x	x	x	x				20V 4000 G24F	W2A	***mtu*** 20V4000 DS3100
	3110	2488	x		x	x	x	x				x	x	x	x	x	x	x				20V 4000 G34F	W2A	***mtu*** 20V4000 DS3300
	3390	2712		x [11]	x	x		x	x			x	x	x	x [11]	x	x	x				20V 4000 G44F	W2A	***mtu*** 20V4000 DS3600

* available soon, for detailed information please check website

Continuous/prime/grid stability power – diesel generator sets

PRIME POWER (3B) – 50 HZ/1500 RPM – NORTH AND LATIN AMERICA

	Power output [1]		Available voltages									Emissions					
	kVA	kWe	220 V (1 Phase)	220 V (3 Phase)	380 V (3 Phase)	400 V (3 Phase)	415 V (3 Phase)	3300 V (3 Phase)	10000 V (3 Phase)	10500 V (3 Phase)	11000 V (3 Phase)	Fuel consumption optimized	NOx emission optimized	NEA Singapore for ORDE	US EPA Tier 2 compliant	EU Nonroad Stage II compliant (97/68/EC)	EU Nonroad Stage IIIA compliant (97/68/EC)
mtu 0096 DS	34	27	x	x	x	x	x					x					
	44	35	x	x	x	x	x					x					
	55	44	x	x	x	x	x					x					
mtu 1600 DS	450	360			x	x	x					x	x				
	500	400			x	x	x					x	x				
	590	472			x	x	x					x	x				
	650	520			x	x	x					x	x				
mtu 2000 DS	1250	1000			x	x	x	x				x					

	Certifications				Perform. class [2]		Uptime compl.		Housing		Engine type	Cooling variant [3]	Genset type
	ISO 8528	CE/IEC	NFPA 110	VDE-AR-N 4110 (German Grid Code)	ISO 8528-5 - G2	ISO 8528-5 - G3	Tier I & Tier II	Tier III & Tier IV	Enclosure	Container			
mtu 0096 DS	x		x		x		x				3029 TFG89	TC only	***mtu*** 3R0096 DS34
	x		x		x		x				4045 TF280	TC only	***mtu*** 3R0096 DS44
	x		x		x		x				4045 HF280	TC only	***mtu*** 3R0096 DS55
mtu 1600 DS	x		x		x		x				10V 1600 G10F	A2A	***mtu*** 10V1600 DS500
	x		x		x		x				10V 1600 G20F	A2A	***mtu*** 10V1600 DS550
	x		x		x		x				12V 1600 G10F	A2A	***mtu*** 12V1600 DS650
	x		x		x		x				12V 1600 G20F	A2A	***mtu*** 12V1600 DS715
mtu 2000 DS	x		x		x	x	x				18V 2000 G26F	A2A	***mtu*** 18V2000 DS1400

Continuous/prime/grid stability power – diesel generator sets

PRIME POWER (3B) – 60 HZ/1800 RPM.

	Power output [1]		Available voltages												Emissions					Certifications				Uptime compl.		Housing		Engine type	Cooling variant [3]	Genset type
	kWe	kVA	240 V	240 V	208 V	240 V	380 V	440 V	480 V	600 V	4160 V	12470 V	13200 V	13800 V	US EPA stationary EMERG Tier 3 (40 CF 60)	US EPA Nonroad Tier 3 compliant	US EPA stationary EMERG Tier 2 (40 CF 60)	US EPA Nonroad Tier 2 compliant	Fuel consumption optimized	ISO 8528	UL2200	NFPA 110	IBC 2012	Tier I & Tier II	Tier III & Tier IV	Enclosure	Container			
			Dedicated (1 Phase)	Re-connectable (1 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)																
mtu 0096/0113 DS	27	33	x	x	x	x	x		x	x					x					x	x	x	x	x		x		3029 TFG89	TC only	***mtu*** 3R0096 DS30
	40	50		x	x	x	x		x	x					x					x	x	x	x	x		x		4045 TF280	TC only	***mtu*** 4R0113 DS40
	45	56	x	x	x	x	x		x	x					x					x	x	x	x	x		x		4045 TF280	TC only	***mtu*** 4R0113 DS50
	55	68	x	x	x	x	x		x	x					x					x	x	x	x	x		x		4045 HF280	A2A	***mtu*** 4R0113 DS60
	80	100	x	x	x	x			x	x					x					x	x	x		x		x		4045 HF285	A2A	***mtu*** 4R0113 DS80
	90	113	x	x	x	x			x	x					x					x	x	x		x		x		4045 HF285	A2A	***mtu*** 4R0113 DS100
	111	139	x	x	x	x			x	x					x					x	x	x		x		x		4045 HF285	A2A	***mtu*** 4R0113 DS125
	135	169	x	x	x	x			x	x					x					x	x	x		x		x		6068 HF285	A2A	***mtu*** 6R0113 DS150
	180	225	C/F	C/F	x	x			x	x					x					x	x	x		x		x		6068 HFG85	A2A	***mtu*** 6R0113 DS180
	210	263		x	x	x			x	x					x					x	x	x		x		x		6090 HF484	A2A	***mtu*** 6R0150 DS230
	230	288			x	x			x	x					x					x	x	x		x		x		6090 HF484	A2A	***mtu*** 6R0150 DS250
	250	313			x	x			x	x					x					x	x	x		x		x		6090 HF484	A2A	***mtu*** 6R0150 DS275
mtu 0120 DS	72	90	x	x	x	x	x		x	x					x					x	x	x	x	x		x		4R 924 G10S	A2A	***mtu*** 4R0120 DS80
	90	113	x	x	x	x	x		x	x					x					x	x	x	x	x		x		4R 924 G20S	A2A	***mtu*** 4R0120 DS100
	111	139	x	x	x	x	x		x	x					x					x	x	x	x	x		x		4R 924 G20S	A2A	***mtu*** 4R0120 DS125
	135	169	x	x	x	x	x		x	x					x					x	x	x	x	x		x		6R 926 G10S	A2A	***mtu*** 6R0120 DS150
	163	204	x	x	x	x	x		x	x					x					x	x	x	x	x		x		6R 926 G20S	A2A	***mtu*** 6R0120 DS180
	180	225	x	x	x	x	x		x	x					x					x	x	x	x	x		x		6R 926 G30S	A2A	***mtu*** 6R0120 DS200

Continuous/prime/grid stability power – diesel generator sets

PRIME POWER (3B) – 60 HZ/1800 RPM.

	Power output [1]		Available voltages												Emissions					Certifications				Uptime compl.		Housing		Engine type	Cooling variant [3]	Genset type
	kWe	kVA	240 V	240 V	208 V	240 V	380 V	440 V	480 V	600 V	4160 V	12470 V	13200 V	13800 V	US EPA stationary EMERG Tier 3 (40 CF 60)	US EPA Nonroad Tier 3 compliant	US EPA stationary EMERG Tier 2 (40 CF 60)	US EPA Nonroad Tier 2 compliant	Fuel consumption optimized	ISO 8528	UL2200	NFPA 110	IBC 2012	Tier I & Tier II	Tier III & Tier IV	Enclosure	Container			
			Dedicated (1 Phase)	Re-connectable (1 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)	(3 Phase)																
mtu 1600 DS	400	500			x	x	x	x	x	x					x					x	x	x	x	x		x		10V 1600 G10S	A2A	***mtu*** 10V1600 DS450
	450	563			x	x	x	x	x	x								x		x	x	x	x	x		x		10V 1600 G20S	A2A	***mtu*** 10V1600 DS500
	500	625			x	x	x	x	x	x								x		x	x	x	x	x		x		12V 1600 G10S	A2A	***mtu*** 12V1600 DS550
	550	687			x	x	x	x	x	x								x		x	x	x	x	x		x		12V 1600 G20S	A2A	***mtu*** 12V1600 DS600
mtu 2000 DS	900	1125			x	x	x		x	x	x						x	x		x	x	x	x	x				16V 2000 G26S	W2A	***mtu*** 16V2000 DS1000
	1000	1250					x		x	x	x								x	x	x	x	x	x				18V 2000 B76	A2A	***mtu*** 18V2000 DS1250
mtu 4000 DS	1125	1406					x		x	x	x						x			x	x	x	x	x		x		12V 4000 G14S	W2A	***mtu*** 12V4000 DS1250
	1400	1750					x		x	x	x						x			x	x	x	x	x		x		12V 4000 G14S	W2A	***mtu*** 12V4000 DS1500
	1600	2000					x		x	x	x						x			x	x	x	x	x		x		12V 4000 G24S	W2A	***mtu*** 12V4000 DS1750
	1800	2250					x		x	x	x	x	x	x			x			x	x	x	x	x		x		16V 4000 G14S	W2A	***mtu*** 16V4000 DS2000
	2045	2556					x		x	x	x	x	x	x			x			x	x	x	x	x				16V 4000 G24S	W2A	***mtu*** 16V4000 DS2250
	2250	2812					x		x	x	x	x	x	x			x			x	x	x	x	x				20V 4000 G14S	W2A	***mtu*** 20V4000 DS2500
	2500	3125					x		x	x	x	x	x	x			x			x	x	x	x	x				20V 4000 G24S	W2A	***mtu*** 20V4000 DS2800
	2800	3500					x		x	x	x	x	x	x			x			x	x	x	x	x				20V 4000 G44S	W2A	***mtu*** 20V4000 DS3000

Continuous/prime/grid stability power – gas generator sets

PRIME POWER (3B) – 60 HZ/1800 RPM.

Power output [1]		Available voltages											Emissions
kWe	kVA	240 V Dedicated (1 Phase)	240 V Re-connectable (1 Phase)	208 V (3 Phase)	240 V (3 Phase)	380 V (3 Phase)	480 V (3 Phase)	600 V (3 Phase)	4160 V (3 Phase)	12470 V (3 Phase)	13200 V (3 Phase)	13800 V (3 Phase)	EPA certified
130	162	x	x	x	x		x	x					x
175	218	x	x	x	x		x	x					x
235	293		x	x	x		x	x					x
300	375		x	x	x		x	x					x
355	443		x	x	x		x	x					x

Certifications				Fuel type		Housing		Engine type	Genset type
ISO 8528	UL2200	NFPA 110	IBC 2012	Natural gas	Propane gas	Enclosure	Container		
x	x	x		x		x		8.1L CAC	***mtu*** 6R0135 GS150
x	x	x		x		x		11.1L CAC	***mtu*** 6R0185 GS200
x	x	x		x		x		14.6L CAC	***mtu*** 8V0183 GS260
x	x	x		x		x		18.3L CAC	***mtu*** 10V0183 GS350
x	x	x		x		x		21.9L CAC	***mtu*** 12V0183 GS400

Continuous/prime/grid stability power – diesel generator sets

GRID STABILITY POWER (3G) – 50 HZ/1500 RPM.

	Power output [1]		Available voltages								Emissions					
	kVA	kWe	380 V (3 Phase)	400 V (3 Phase)	415 V (3 Phase)	6300 V (3 Phase)	6600 V (3 Phase)	10000 V (3 Phase)	10500 V (3 Phase)	11000 V (3 Phase)	Fuel consumption optimized	NOx emission optimized	NEA Singapore for ORDE	US EPA Tier 2 compliant	EU Nonroad Stage II compliant (97/68/EC)	EU Nonroad Stage IIIA compliant (97/68/EC)
mtu 2000 DS	1000	800	x	x	x						x	x	x	x		
	1250	1000	x	x	x						x	x	x	x		
	1000	800	x	x	x						x	x	x	x		
	1250	1000	x	x	x						x	x	x	x		
mtu 4000 DS	1600	1280	x	x	x			x	x	x	x	x	x			
	1700	1360	x	x	x			x	x	x	x	x	x			
	1880	1504	x	x	x			x	x	x	x	x	x			
	2160	1728	x	x	x			x	x	x	x	x	x			
	2360	1888	x	x	x			x	x	x	x	x	x			
	2640	2112	x	x	x			x	x	x	x	x	x			
	2910	2328	x	x	x			x	x	x	x	x	x			
	3110	2488	x	x	x			x	x	x	x	x	x			

	Certifications				Perform. class [2]		Uptime compl.		Housing		Engine type	Cooling variant [3]	Genset type
	ISO 8528	CE/IEC	NFPA 110	VDE-AR-N 4110 (German Grid Code)	ISO 8528-5 - G2	ISO 8528-5 - G3	Tier I & Tier II	Tier III & Tier IV	Enclosure	Comtainer			
mtu 2000 DS	x	x	x	x	x	x	x	x			16V 2000 G26F	A2A	***mtu*** 16V2000 DS1100
	x	x	x	x	x	x	x	x			18V 2000 G26F	A2A	***mtu*** 18V2000 DS1400
	x	x	x	x	x	x	x	x			16V 2000 G26F	W2A*	***mtu*** 16V2000 DS1100
	x	x	x	x	x	x	x	x			18V 2000 G26F	W2A*	***mtu*** 18V2000 DS1400
mtu 4000 DS	x	x	x	x	x	x	x				12V 4000 G14F	W2A	***mtu*** 12V4000 DS1650
	x	x	x	x	x	x	x				12V 4000 G14F	W2A	***mtu*** 12V4000 DS1750
	x	x	x	x	x	x	x				12V 4000 G24F	W2A	***mtu*** 12V4000 DS2000
	x	x	x	x	x	x	x				16V 4000 G14F	W2A	***mtu*** 16V4000 DS2250
	x	x	x	x	x	x	x				16V 4000 G24F	W2A	***mtu*** 16V4000 DS2500
	x	x	x	x	x	x	x				20V 4000 G14F	W2A	***mtu*** 20V4000 DS2750
	x	x	x	x	x	x	x				20V 4000 G24F	W2A	***mtu*** 20V4000 DS3100
	x	x	x	x	x	x	x				20V 4000 G34F	W2A	***mtu*** 20V4000 DS3300

* available soon, for detailed information please check website

Diesel generator sets

ENCLOSURES – 50 HZ/1500 RPM.

	Dimensions			Noise level [4] Standard		Fuel tank (option)	Genset type
	Length (mm)	Width (mm)	Height (mm)	Level 1 (dBA @ 7m)	Level 2 (dBA @ 7m)	Capacity (l)	
mtu 0080/0113 DS	2100	957	1349	60,0	–	100	***mtu*** 4R0080 DS45
	2300	1050	1458	59,3	–	130	***mtu*** 4R0080 DS55
	2750	1100	1760	61,2	–	288	***mtu*** 4R0113 DS63
	2750	1100	1760	61,3	–	288	***mtu*** 4R0113 DS80
	2750	1100	1760	61,5	–	288	***mtu*** 4R0113 DS94
mtu 0120 DS	2750	1100	1760	C/F	–	288	***mtu*** 4R0120 DS90
	2750	1100	1760	C/F	–	288	***mtu*** 4R0120 DS110
	2750	1100	1760	C/F	–	288	***mtu*** 4R0120 DS140
	C/F	C/F	C/F	C/F	–	C/F	***mtu*** 6R0120 DS175
	C/F	C/F	C/F	C/F	–	C/F	***mtu*** 6R0120 DS200
	C/F	C/F	C/F	C/F	–	C/F	***mtu*** 6R0120 DS235
	C/F	C/F	C/F	C/F	–	C/F	***mtu*** 6R0120 DS250
mtu 1600 DS*	5400	2140	2852	70	75	800	***mtu*** 10V1600 DS500
	5400	2140	2852	70	75	800	***mtu*** 10V1600 DS540
	5400	2140	2852	70	75	800	***mtu*** 12V1600 DS650
	5400	2140	2852	70	75	800	***mtu*** 12V1600 DS720

* available soon, for detailed information please check website

Diesel generator sets

ENCLOSURES – 60 HZ/1800 RPM.

	Prime power			Standby power			Certifications				Genset type
	Level 1 (dBA @ 7m)	Level 2 (dBA @ 7m)	Level 3 (dBA @ 7m)	Level 1 (dBA @ 7m)	Level 2 (dBA @ 7m)	Level 3 (dBA @ 7m)	UL 2200	CSA	ISO 9001:2008	IBC 2012/OSHPD	
mtu 0060/0113 DS	79,2	72,4	69,6	79,2	72,4	69,6	x	x	x	x	***mtu*** 4R0060 DS30
	84,2	76,7	70,8	84,2	76,7	70,8	x	x	x	x	***mtu*** 4R0113 DS35
	84,3	77,0	71,0	84,3	77,0	71,0	x	x	x	x	***mtu*** 4R0113 DS40
	84,6	76,7	71,5	84,6	76,7	71,5	x	x	x	x	***mtu*** 4R0113 DS50
	83,9	77,2	73,4	83,9	77,2	73,4	x	x	x	x	***mtu*** 4R0113 DS60
	78,9	75,2	70,9	78,9	75,2	70,9	x	x	x	x	***mtu*** 4R0113 DS80
	79,0	74,9	70,9	78,9	75,2	70,9	x	x	x	x	***mtu*** 4R0113 DS100
	82,5	81,8	71,9	82,8	81,7	72,0	x	x	x	x	***mtu*** 4R0113 DS125
	84,3	82,9	73,1	84,5	83,0	73,4	x	x	x	x	***mtu*** 6R0113 DS150
	85,1	83,0	73,9	85,1	83,0	73,9	x	x	x	x	***mtu*** 6R0113 DS180
mtu 0120 DS	82,0	81,7	73,6	82,2	81,5	73,7	x	x	x	x	***mtu*** 4R0120 DS80
	82,1	81,8	74,1	82,2	81,3	74,4	x	x	x	x	***mtu*** 4R0120 DS100
	82,7	81,8	74,4	82,2	81,8	74,5	x	x	x	x	***mtu*** 4R0120 DS125
	91,1	88,7	72,5	91,2	88,4	72,8	x	x	x	x	***mtu*** 6R0120 DS150
	91,1	88,7	72,7	91,2	88,7	73,0	x	x	x	x	***mtu*** 6R0120 DS180
	91,1	88,7	73,0	91,2	88,7	73,1	x	x	x	x	***mtu*** 6R0120 DS200

Diesel generator sets

ENCLOSURES – 60 HZ/1800 RPM.

	Prime power			Standby power			Certifications				Genset type
	Level 1 (dBA @ 7m)	Level 2 (dBA @ 7m)	Level 3 (dBA @ 7m)	Level 1 (dBA @ 7m)	Level 2 (dBA @ 7m)	Level 3 (dBA @ 7m)	UL 2200	CSA	ISO 9001:2008	IBC 2012/OSHPD	
mtu 1600 DS	88,0	79,7	73,9	88,5	80,5	74,1	x	x	x	x	***mtu*** 6R0150 DS230
	88,5	80,5	74,1	88,6	80,1	74,6	x	x	x	x	***mtu*** 6R0150 DS250
	88,6	80,1	74,6	88,3	80,6	74,3	x	x	x	x	***mtu*** 6R0150 DS275
	N/A	N/A	N/A	90,3	81,9	75,1	x	x	x	x	***mtu*** 6R0150 DS300
	N/A	N/A	N/A	89,5	80,9	75,6	x	x	x	x	***mtu*** 6R0225 DS350 [12)]
	N/A	N/A	N/A	90,1	81,1	76,2	x	x	x	x	***mtu*** 6R0225 DS350 [12)]
	N/A	N/A	N/A	89,9	81,6	76,5	x	x	x	x	***mtu*** 6R0225 DS350
	N/A	N/A	N/A	91,0	82,1	75,5	x	x	x	x	***mtu*** 6R0225 DS400
	90,7	86,0	74,0	91,0	86,5	74,5	x	x	x	x	***mtu*** 10V1600 DS450
	91,0	86,5	74,5	91,0	86,6	74,9	x	x	x	x	***mtu*** 10V1600 DS500
	92,8	88,0	81,0	92,9	88,0	81,2	x	x	x	x	***mtu*** 12V1600 DS550
	92,9	88,0	81,2	92,8	89,0	81,5	x	x	x	x	***mtu*** 12V1600 DS600
mtu 2000 DS	95,0	87,0	75,2	95,0	87,0	75,2	x	x	x	x	***mtu*** 12V2000 DS750
	94,0	87,0	75,2	94,0	87,0	75,2	x	x	x	x	***mtu*** 12V2000 DS800
	92,0	86,0	74,7	92,0	86,4	74,7	x	x	x	x	***mtu*** 16V2000 DS1000
	N/A	N/A	N/A	93,0	86,0	75,0	x	x	x	x	***mtu*** 16V2000 DS1250

Diesel generator sets

POWER MODULES[14] - 50/60 HZ – EUROPE, AFRICA, ASIA AND AUSTRALIA

mtu 4000 DS

Power output[1]		Available voltages				Emissions		Noise level	Dimensions			
kWe	kVA	280 V	400 V	480 V	600 V	Fuel consumption optimized	US EPA Nonroad Tier 2 compliant	dBA @ 1m	Size	Length (mm)	Width (mm)	Height (mm)
1531	1914		x			x		99	40ft HC	12192	2438	2896
1807	2259			x		x		103	40ft HC	12192	2438	2896
1836	2295		x			x		99	40ft HC	12192	2438	2896
2109	2636			x		x		103	40ft HC	12192	2438	2896
2048	2560		x			x		99	40ft HC	12192	2438	2896
2321	2901			x		x		105	40ft HC	12192	2438	2896
1888	2360			x		x		[11]	40ft HC	12192	2438	2896
1440	1800			x		x		[11]	40ft HC	12192	2438	2896

Frequency		Application			Certifications			Engine type	Cooling variant[3]	Genset type
Hz	50/60Hz switchable	Continuous power	Prime power	Standby power	ISO 8528	NFPA 110	CSC certification			
50	x	x			x		x	16V 4000 B24F	W2A	***mtu*** 16V4000 DS2560
60	x	x			x		x	16V 4000 B24S	W2A	***mtu*** 16V4000 DS2560
50	x		x		x		x	16V 4000 G24F	W2A	***mtu*** 16V4000 DS2560
60	x		x		x		x	16V 4000 G24S	W2A	***mtu*** 16V4000 DS2560
50	x			x	x		x	16V 4000 G84F	W2A	***mtu*** 16V4000 DS2560
60	x			x	x		x	16V 4000 G84S	W2A	***mtu*** 16V4000 DS2560
60			x		x		x	16V 4000 G24S	Tabletop radiator	Caribic configuration
60		x			x		x	16V 4000 B24S	Tabletop radiator	Caribic configuration

Gas generator sets – continuous/prime/grid stability power

POWER MODULES - 50/60 HZ.

Power output [1]	Available voltages		Emissions	Dimensions				Frequency		Application	Engine type	Fuel type	Genset type
kWe	400 V	480 V	NOx<500 mg/Nm³ NOx<250 mg/Nm³	Size	Length (mm)	Width (mm)	Height (mm)	50 Hz	60 Hz	Continuous power		NG = Natural gas NNG = Non-natural Gas (biogas/ sewage/landfill)	
Power application													
762 - 1013	x		x	40ft HC	12203	2438	2896	x		x	L32/L33/L64/L64FNER	NG/NNG	***mtu*** 8V4000 GS
1151 - 1523	x	x	x	40ft HC	12203	2438	2896	x	x	x	L32/L33/L64/L64FNER	NG/NNG	***mtu*** 12V4000 GS
1537 - 2030	x		x	40ft HC	12203	2438	2896	x		x	L32/L33/L64/L64FNER	NG/NNG	***mtu*** 16V4000 GS
1948 - 2535	x		x	40ft HC	12203	2438	2896	x		x	L32/L33/L64/L64FNER	NG/NNG	***mtu*** 20V4000 GS
CHP application													
180 - 220	x	x	x	30+	12203	2438	2896	x	x	x	L/Z	NG/NNG	***mtu*** 6R400 GS
				40ft HC	9000	3000	3000						
245 - 420	x	x	x	31+	12203	2438	2896	x	x	x	L/Z	NG/NNG	***mtu*** 12V400 GS
				40ft HC	9000	3000	3000						
762 - 1013	x		x	40+	12203	3200	3200	x		x	L32/L33/L64/L64FNER	NG/NNG	***mtu*** 8V4000 GS
1151 - 1523	x		x	40+	12203	3200	3200	x		x	L32/L33/L64/L64FNER	NG/NNG	***mtu*** 12V4000 GS
1537 - 2030	x		x	47+	14200	3200	3200	x		x	L32/L33/L64/L64FNER	NG/NNG	***mtu*** 16V4000 GS
1948 - 2535	x		x	47+	14200	3200	3200	x		x	L32/L33/L64/L64FNER	NG/NNG	***mtu*** 20V4000 GS

mtu EnergyPack

BATTERY STORAGE.

Nominal capacity	Nominal apparent power	C-Rates [15]	Nominal power factor	Frequency
kWh_{nom}	kVA_{nom}	C	λ_{nom}	Hz
up to 600	40 - 400	0.5 / 1 / 2	-1 to 1	50/60
300 - 800	300 - 800	0.5 / 1 / 2	-1 to 1	50/60
500 - 2,200	300 - 2,000	0.5 / 1 / 2	-1 to 1	50/60

Overall dimensions [16]				Certifications		Battery storage type
Size	Length (mm)	Width (mm)	Height (mm)	UL	CE	
Enclosure	3.000	2.230	2.400	on request	x	***mtu*** EnergyPack QS
20ft. HC	6.096	2.438	2.896	on request	x	***mtu*** EnergyPack QM
40ft. HC	12.192	2.438	2.896	on request	x	***mtu*** EnergyPack QL

Classification for data center continuous power

ACCORDING TO THE UPTIME INSTITUTE.

Tier I
Tier I is composed of a single path for power and cooling distribution, without redundant components.

Tier II
Tier II is composed of a single path for power and cooling distribution, with redundant components.

Tier III
Tier III is composed of multiple active power and cooling distribution paths, but only one active path has redundant components and is concurrently maintainable.

Tier IV
Tier IV is composed of multiple active power and cooling distribution paths, has redundant components and is fault tolerant.

	Tier I	Tier II	Tier III	Tier IV
Delivery paths	One	One	One active + one passive	Two active
Redundant components	No	Yes	Yes (for active path)	Yes (for two active path)
Simultaneously maintainable	No	No	Yes	Yes
Fault tolerance (single event)	No	No	No	Yes
Compartmentalisation	No	No	No	Yes
Suitable ***mtu*** power generation application	Standby power (3D) Prime power for stationary emergency (3E) Prime power (3B) Grid stability power (3G)		Data center continuous power (3F) Continuous power (3A)	

For complete definition see http://uptimeinstitute.com/

Conversion table

NUMBERS TO BACK YOU UP.

1 kW	= 1.360 PS	g	= 9.80665 m/s^2
1 kW	= 1.341 bhp	Л	= 3.14159
1 bhp	= 1.014 PS	e	= 2.71828
1 oz	= 28.35 g		
1 lb	= 453.59 g	1 lb	= 16 oz
1 short ton	= 907.18 kg	1 short ton	= 2000 lbs
1 lb/bhp	= 447.3 g/PSh	1 ft lb	= 1.356 Nm
1 lb/bhp	= 608.3 g/kWh	1 ft/min	= 0.00508 m/s
1 gal/bhp (US)	= 4264 g/kWh	pDiesel	= 0.83 kg/l
1 kWh	= 860 kcal	1 lb/sqin	= 0.069 bar (1 psi)
1 cal	= 4.187 J	1 mm Hg	= 1.333 mbar (133.3 Pa)
1 BTU	= 1.055 kJ	1 mm H_2O	= 0.0981 mbar (9.81 Pa)
1 inch	= 2.540 cm	T (K)	= t (°C) + 273.15
1 sq. inch	= 6.542 cm^2	t (°C)	= 5/9 x (t (°F) -32)
1 cu. inch	= 16.387 cm^3	t (°C)	= 5/4 x t (°R)
1 foot	= 3.048 dm	1 foot	= 12 inches
1 sq. foot	= 9.290 dm^2	1 yard	= 3 feet
1 mile	= 1.609 km	1 mile	= 5280 feet
1 naut. mile	= 1.853 km	1 naut. mile	= 6080 feet
1 UK Gallon	= 4.546 l	1 US Barrel	= 0.159 m^3
1 US Gallon	= 3.785 l		= 42 US Gallons
Energy:	1 J = 1 Ws = 1 VAs = 1 Nm		
Power:	1 W = 1 VA = 1 Nm/s		
Force:	1 N = 1 kgm/s^2		
Pressure:	1 Pa = 1 N/m^2 (1 bar = 10^5 Pa)		
MEP (bar)	$= \frac{P_{cyl}(kW) \times 1200}{n(1/min) \times V_{cyl}(l)}$		
Torque (Nm)	$= \frac{P_{ges}(kW) \times 30000}{n(1/min) \times \pi}$		

FOOTNOTES.

A Only available for 50Hz markets
B Unlimited hours in data center application where a reliable grid/utility is present.

Application descriptions, e.g. load factor, applies to *mtu* powered equipment.

(1) Power output based on 400V, fuel consumption opt. emission level and standard or optional generator. For arrangements with other emissions, voltages and/or optional generators, ratings may vary. Series 4000 without cooling package.

(2) Ambient conditions and load application acc. to ISO 8528

(3) Cooling variants:
A2A: air-to-air charge air cooling (TD)
W2A: water-to-air charge air cooling (TB)

(4) Sound levels in accordance with European Noise Directive (2000/14/EC), for further information on acoustic data see datasheets

(5) Power available up to 25°C intake air temperature / 100m site altitude above sea level

(6) Rated power at nominal voltage, power factor = 1,0 and nominal frequency

(7) Heat output from engine cooling with tolerance of ± 8%

(8) Heat output from exhaust with tolerance of ± 8%

(9) Performance data in accordance with ISO 3046/I-2002 with tolerance of 5%

(10) Referenced methane number

(11) Availability on request

(12) Single-phase units only

(13) Availability on request only for VDE-AR-N 4110

(14) Datacenter configuration available level

15) C-Rate availability dependend on requested capacity-power combination

16) Transformer can be within shown dimensions or additional, dependend on requested capacity-power combination. For details please submit request.

* available soon, for detailed information please check website

50Hz – Power available up to:
Standard:
Site altitude above sea level: 400 m
Intake air temperature: 40° C

NOx emission optimized:
Site altitude above sea level: 100 m
Intake air temperature: 25° C

NEA Singapore:
Site altitude above sea level: 100 m
Intake air temperature: 40° C

60Hz – Power available up to:
Standard:
Site altitude above sea level: 400 m
Intake air temperature: 25° C

Available power for battery storage solutions:
Standard:
Site altitude above sea level: 2000 m
Ambient temperature: -20°C to 40°C

C/F: Consult factory

D: Lambda = 1 with 2-way-catalyst

L: Leanburn with single stage intercooling

Z: Leanburn with two stage intercooling

Cooling variants:
A2A: air-to-air charge air cooling (TD)
W2A: water-to-air charge air cooling (TB)

Subject to change. | 16120643 | Edition 01/21 | ESM 2021-03 | Printed in Germany on chlorine-free bleached paper.

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mtu Grid EnergyPack
Battery Energy Storage Solution
TECHNICAL DESCRIPTION

A Rolls-Royce solution

Table of Contents

1 Introduction

Rolls-Royce Solutions America Inc. is a system integrator of smart plug-and-play and grid scale energy storage solutions. The ***mtu*** EnergyPack QS, QM, and QL systems are turnkey systems, whereas the ***mtu*** Grid EnergyPack is an integrated Battery Energy Storage System (BESS). Both types of systems are equipped with ***mtu*** EnergetIQ Manager, an integrated micro-grid and energy management system.

The ***mtu*** EnergyPack QS, QM and QL are non-UL systems, suitable for both on-grid and off-grid applications in the 100 kilowatt to multi megawatt power range. The ***mtu*** Grid EnergyPack is an on-grid energy storage solution with UL certified components which is suitable for 10 megawatt to several hundred megawatt power range. This document will focus on the ***mtu*** Grid EnergyPack system.

The key benefits of the ***mtu*** Grid EnergyPack are:

- An integrated microgrid and energy management system, the ***mtu*** EnergetIQ Manager, controls the entire generation system. This includes management of batteries, diesel generators, gas generators, PV systems, wind turbines, and deferrable loads.
- Cloud data storage solution for system performance analysis and optimization
- Pre-engineered battery rack, power conversion system, HVAC, and control software based on pre-selected and tested components from leading manufacturers with extensive track record and worldwide service network
- Energy storage based on lithium-ion phosphate (LFP) battery technology that offers high performance and low maintenance
- Highly standardized and modular for economic design
- Tailoring of base units for project specific power and capacity needs
- Scaling of base units to any project size
- Ultrafast (ms) response and 100 % instantaneous load acceptance

Together, ***mtu*** Grid EnergyPack and ***mtu*** EnergetIQ Manager perform the following important functions:

- **Energy storage**: The ***mtu*** Grid EnergyPack stores excess energy from Distributed Energy Resources (DER) and other generation sources in the grid and makes energy available for later use at any time (for example, peak shaving, load shifting, etc.).
- **Frequency regulation and power balancing:** The ***mtu*** EnergetIQ Manager controls the entire microgrid and ensures an instantaneous active and reactive balance between load and generation. The system stabilizes the frequency of the microgrid independently and is impervious to changes in load or changes from other generation systems.
- **Reactive power and voltage regulation:** The power electronics of the ***mtu*** Grid EnergyPack contribute to the voltage regulation of the grid, performing proper management of the reactive power circulating in the grid.
- **Spinning reserve:** The ***mtu*** Grid EnergyPack and ***mtu*** EnergetIQ Manager manage and control spinning reserve requirements of the total energy system. It automatically switches generation components and the battery system on and off based on pre-defined parameters.
- **Increasing reliability:** The ***mtu*** Grid EnergyPack is grid-forming and has black-start capability to resume network operation after an outage or fault. Multiple ***mtu*** Grid EnergyPack units can

be operated in parallel with each other and in parallel with other generation systems to increase system reliability and redundancy.

- **Performance optimization of generation and distribution systems:** The combination of the above functionalities enables the integration of large shares of renewable energy, lowers the cost of conventional energy generation systems, and provides high quality and reliable power in on-grid and off-grid applications.

In addition, Rolls Royce Solutions America Inc. advises and supports customers throughout the design, installation, and operational phases of the systems. Ongoing support includes:

- Overall system evaluation and design support from project development through project close
- Detailed hardware and software engineering including integration of existing power generation units
- Delivery and commissioning of energy storage solutions
- Training of local operators and maintenance staff
- Remote technical support and monitoring during operations

2 Product description

2.1 General description

The ***mtu*** Grid EnergyPack is grid-forming and/or grid-following, with fully automatic operation and black-start capability. The ***mtu*** EnergetIQ Manager monitors and manages all generation units in the grid (for example, diesel generators, PV systems, deferrable load, etc.) via the respective interfaces.

All generation components and the grid can be monitored and controlled locally as well as remotely via the user-friendly human-machine-interface (HMI). Set points P, Q, and cos-phi can be set flexibly. Also, various BESS diagnostic information can be made available via the HMI.

For details, please refer to the document ***mtu*** EnergetIQ Manager.

2.2 Basic system configurations

The ***mtu*** Grid EnergyPack BESS consists of four main components. These are a battery system, an Energy Storage System (ESS) controller, a Power Conversion System (PCS) with MV transformer, and switchgear.

Three basic system configurations are available for the ***mtu*** Grid EnergyPack system: Grid EnergyPack1, Grid EnergyPack05, and Grid EnergyPack025. These configurations are described in Table 1 and pictured in Figures 1, 2 and 3.

Basic System Configurations

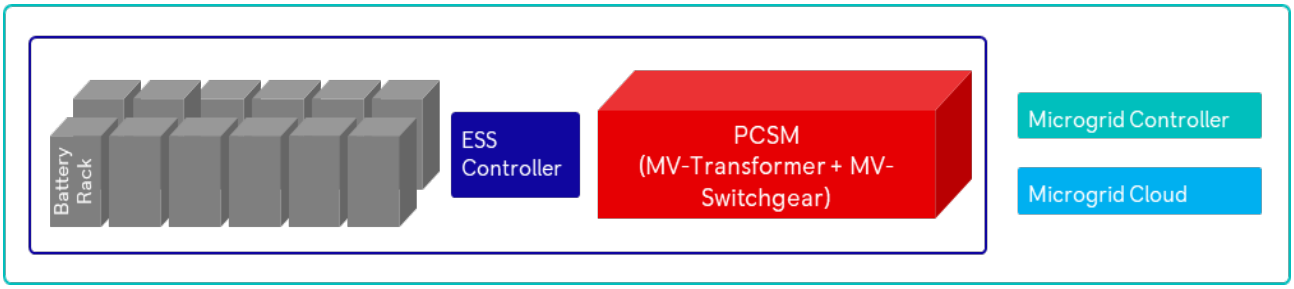

Figure 1: Basic system configuration for Grid EnergyPack1

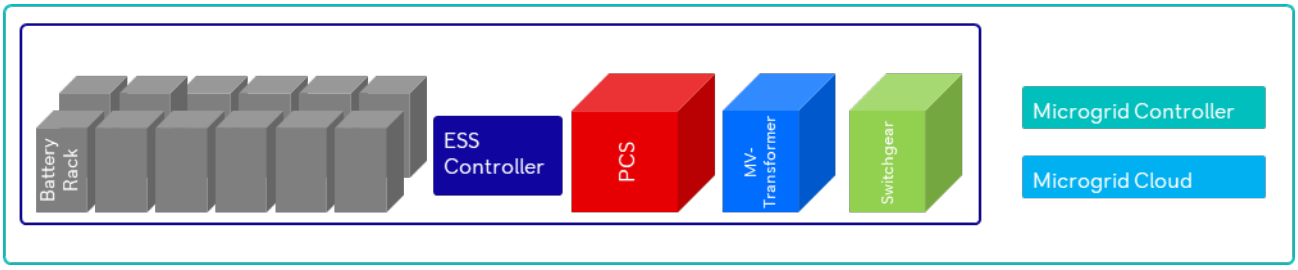

Figure 2: Basic system configuration for Grid EnergyPack05 and Grid EnergyPack1

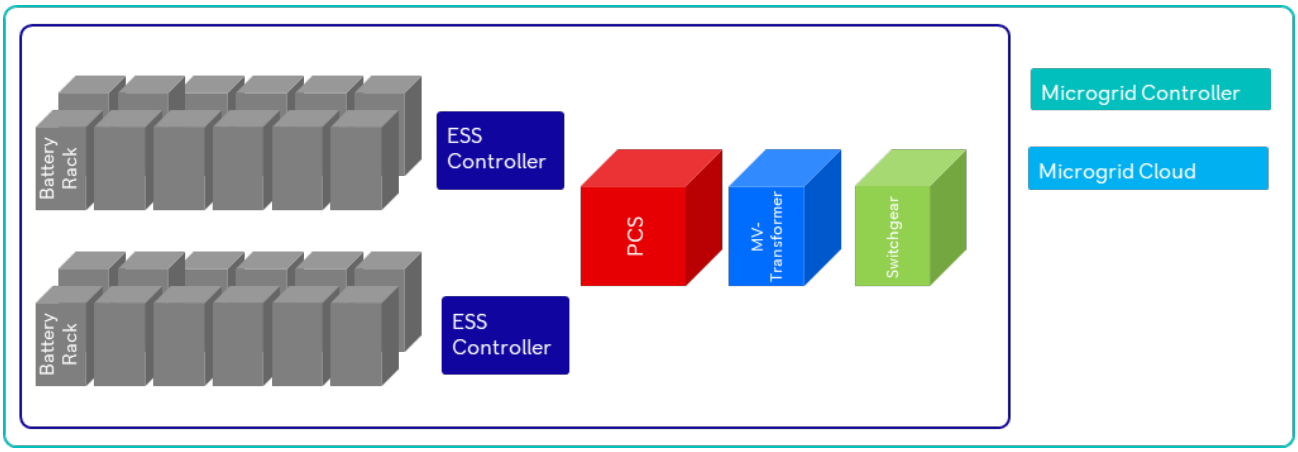

Figure 3: Basic system configuration for Grid EnergyPack025

Example of mtu Grid EnergyPack system basic configurations

System name	Grid EnergyPack025	Grid EnergyPack05	Grid EnergyPack1
System C-rate	0.25	0.5	1
Used battery C-rate	0.5	0.5	1
Quantity of 372.7 kWh battery racks	24	12	12
Total capacity of batteries (kWh)	8,944.8	4,472.4	4,472.4
Quantity of ESS-controllers (1 per 12 battery racks)	2	1	1
PCS type	Multi PCSK	PCSK Frame 2	PCSK Frame 4/PCSM
AC output power kW @ 104 °F	2,195	2,195	4,390/4,200
Operating grid voltage VAC	690V	690V	690V/34.5kV
DC voltage range VDC	976 – 1,500V	976 – 1,500V	976 – 1,500V

Table 1: Example of *mtu* Grid EnergyPack system basic configurations

2.3 Footprint

In Figures 4, 5, and 6 footprints of basic system configurations are illustrated.

Footprint of *mtu* Grid EnergyPack05 and Grid EnergyPack1 basic system (PCSK)

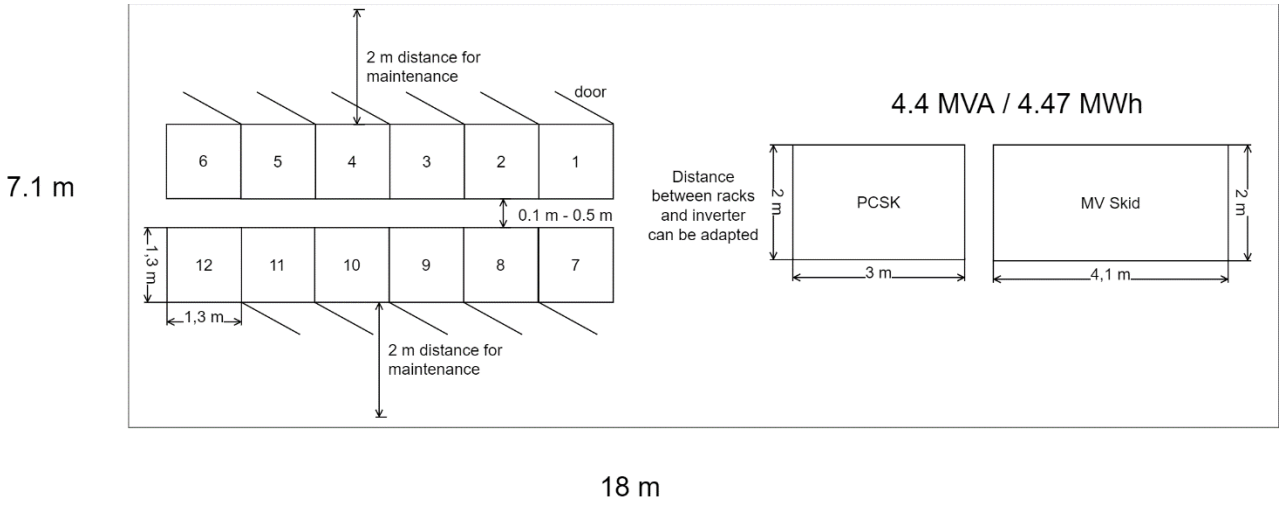

Figure 4: Footprint of *mtu* Grid EnergyPack05 and Grid EnergyPack1 basic system (PCSK)

Footprint of *mtu* Grid EnergyPack1 basic system (PCSM)

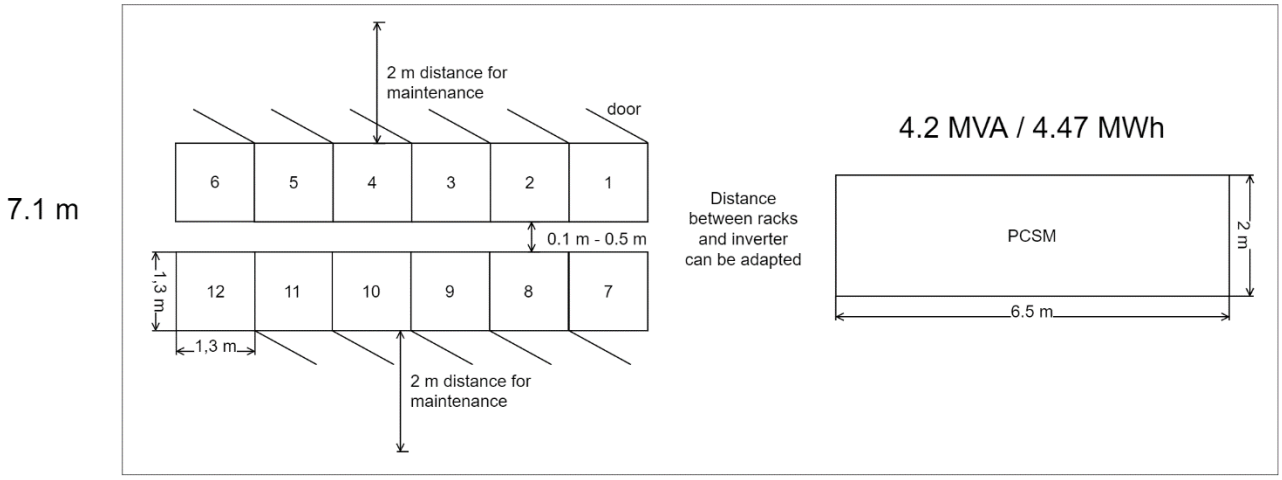

Figure 5: Footprint of *mtu* Grid EnergyPack1 basic system (PCSM)

Footprint of *mtu* Grid EnergyPack025 basic system (PCSK)

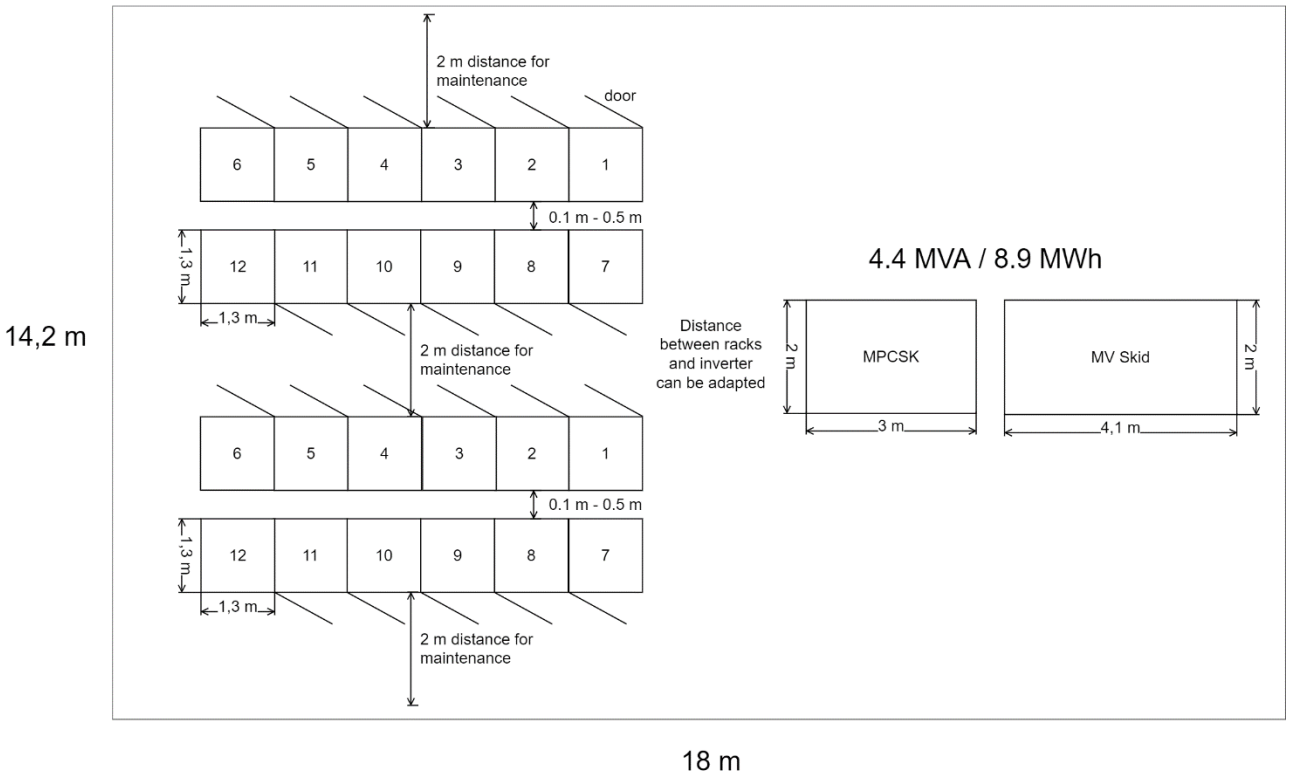

Figure 6: Footprint of *mtu* Grid EnergyPack025 basic system (PCSK)

3 Battery system

3.1 General description

The battery system uses a 280Ah Outdoor Liquid Cooling Rack. Its main components are a chiller, a control box, eight battery modules, and a fire protection set as shown in Figure 7 below. The battery's cathode material is lithium-ion phosphate, one of the safest materials for this purpose. It will not release oxygen during a thermal runaway.

Batteries are available with 0.5C and 1C. The battery cell and battery rack are UL9540A tested. See General battery rack characteristics below for a list of battery rack characteristics.

Battery Module

Figure 7: Battery Module

General battery rack characteristics

Battery type: LFP battery rack					
No.	**Item**		**Specification**		**Remarks**
	C-RATE		1C	0.5C	
1	CONFIGURATION		1P416S		
2	RATED ENERGY		372.7kWh		
3	RATED VOLTAGE		1,331.2VDC		
4	VOLTAGE RANGE		1,164.8~1,497.6VDC		
5	CHARGING CURRENT	Rated	280A	140A	
		Maximum	320A	160A	Up to 1 min
6	DISCHARGING CURRENT	Rated	280A	140A	
		Maximum	320A	160A	Up to 1 min
7	OPERATING TEMPERATURE	Charge	-22~122 °F		
		Discharge	-22~122 °F		
8	AUXILIARY POWER SUPPLY	Voltage range	187-264V AC	176-264V AC	50/60Hz
		Power	Heating-2,250W		
			Cooling-3,650W	1,250W	77 °F
9	OPERATING ENVIRONMENT REQUIREMENTS	Storage humidity	RH ≤ 85%		No condensing
		Storage temperature	-40~140 °F		
		Application altitude	≤ 2,000m		
10	GENERAL PARAMETERS	Size	2,280mm (H) * 1,300m m (W) * 1,300mm (D)		
		Weight	7,720 lbs		
		IP level	IP65		
		Cooling mode	Liquid cooling		
		Communication agreement	CAN		
		Power connection	Fast plug		
		Communication connection	Fast plug		
		AUX power connection	Fast plug		
		Coolant	50% Ethylene glycol aqueous solution		

General battery rack characteristics

Battery type: LFP battery rack				
11	CERTIFICATIONS & STANDARDS	Cell	UN38.3	
			UL1973	
			UL9540A	
			IEC62619	
		Rack	UL1973	
			IEC62619	
			IEC62477-1	
			UL9540A	
			IEC61000-6-2/-4	

Table 2: General battery rack characteristics

3.2 Battery aging

For an illustrated simulation with the following assumptions, the charge/discharge profiles are shown in Figure 8 below. The aging profile is illustrated in Figure 9.

- 2 cycles per day
- Average charge/discharge rate of 0.65C (For example, a 100 MWh system charging/discharging with 65 megawatts on average)
- Relaxation at 50% state of charge
- Average upper state of charge level of 66%
- Average lower state of charge level of 34%.
- Assuming a 530 MWh project

C-rate and state of charge profiles

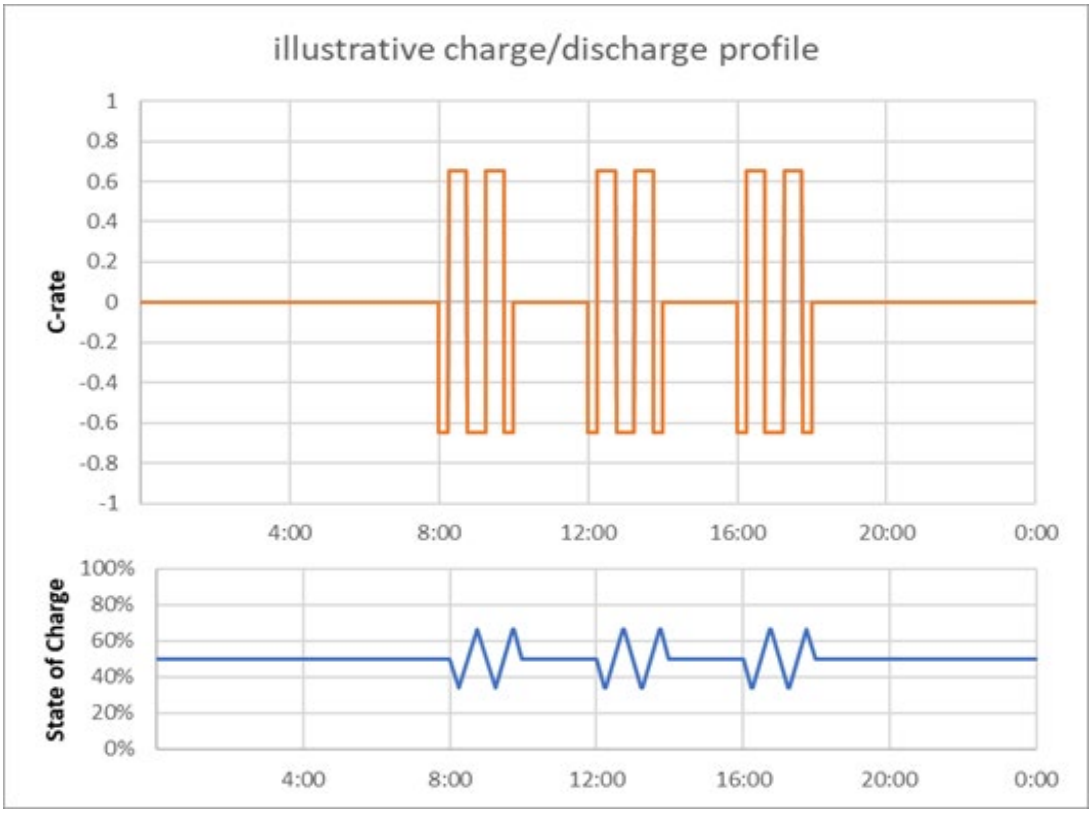

Figure 8: C-rate and state of charge profiles

Aging profile of the battery system

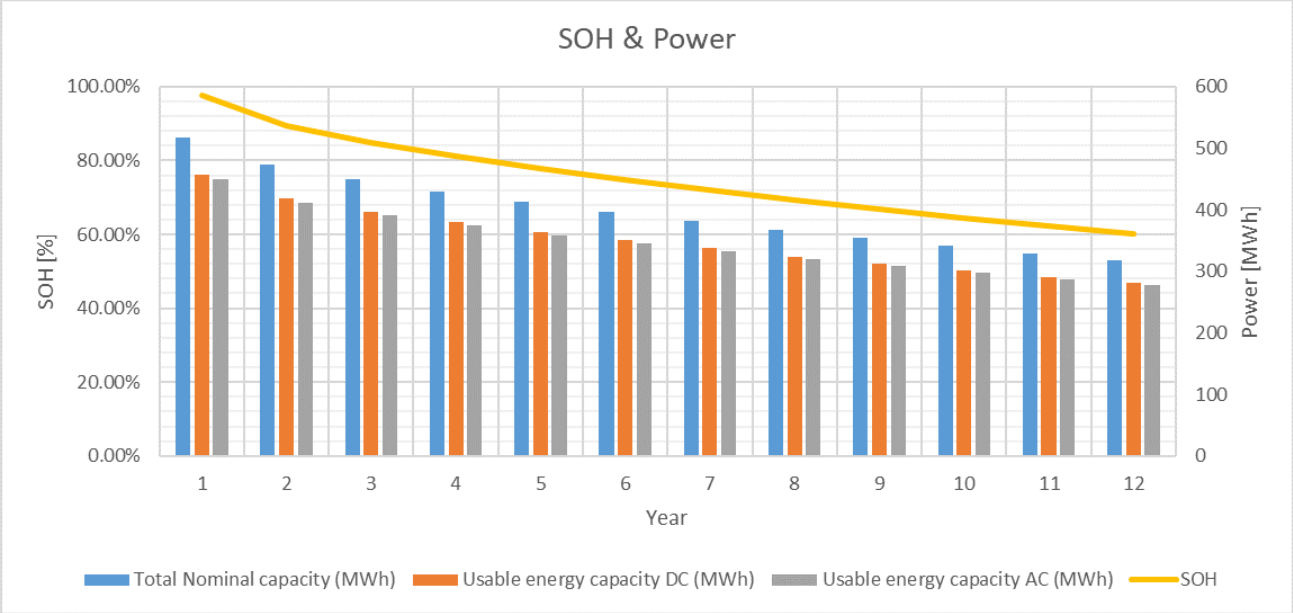

Figure 9: Aging profile of the battery system

3.3 Operating limits

The batteries can charge and discharge at constant power (1C) between 32 °F and 122 °F and from 2% and 94% state of charge. Above 94% the charge power, and below 2% the discharge power, will be reduced to keep the voltage constant (CV charging: constant voltage charging). These limits are graphically illustrated in Figure 10.

Discharge and charge operating limits of the battery system

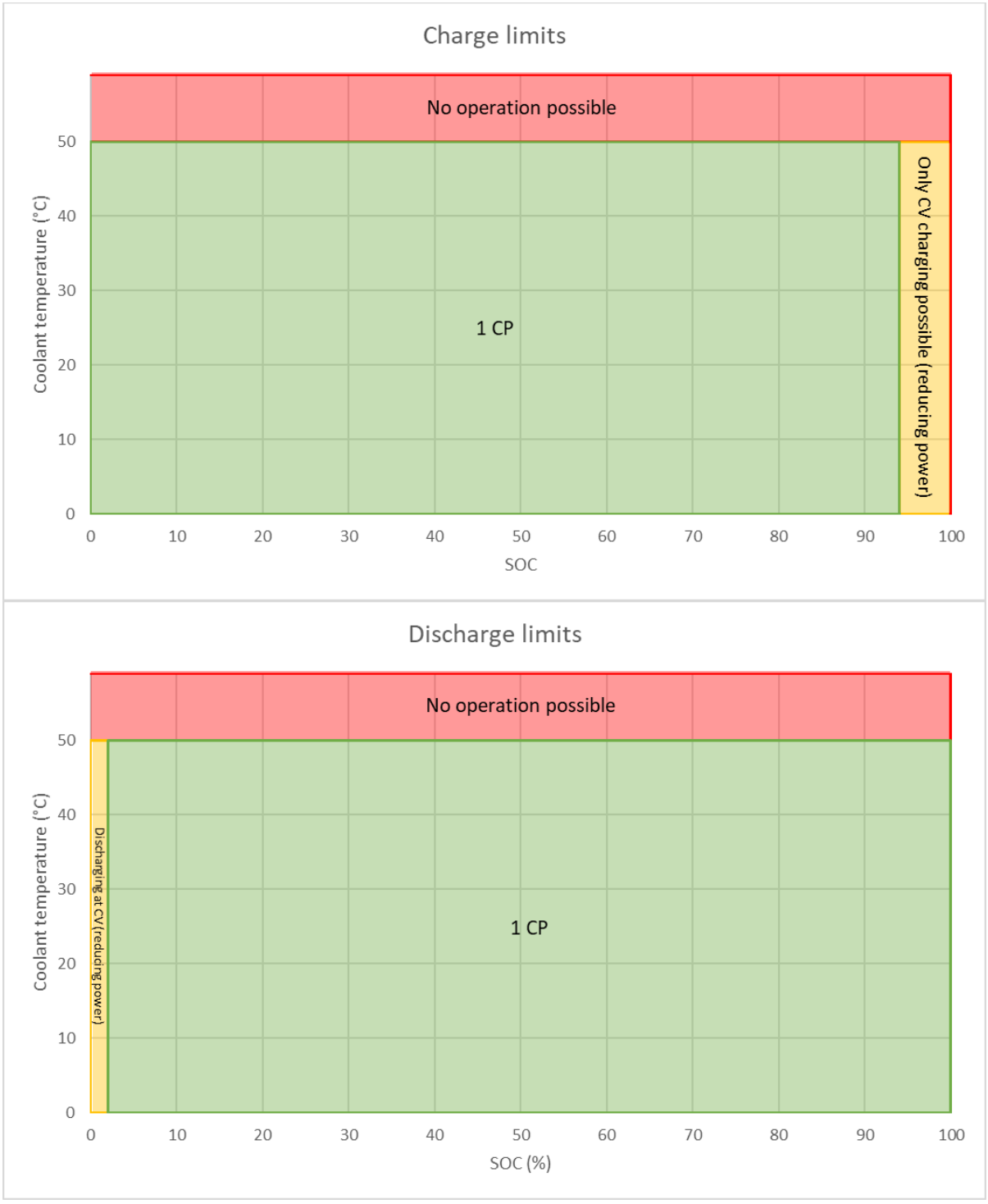

Figure 10: Discharge and charge operating limits of the battery system

4 Power conversion system

4.1 General description

The Power Conversion System (PCS) is a four-quadrant power converter and has a lifetime supply of 40 GW in several power node configurations worldwide.

The PCS design is optimized for energy storage applications, considering technical and economical parameters for the reliable operation of a complete energy storage solution. Inside the power converter, the LC filter is tailored for the power module. It corrects for the sinusoidal shape of the voltage and reduces the level of harmonics at the grid connection point.

The PCS is equipped with a low-voltage motorized circuit breaker for line-side separation. All component suppliers are ISO 9001 and ISO 14001 certified.

Table 3 and Table 4 list general specifications of the Medium Voltage PCS 34.5 kV.

Table 5 and Table 6 list general specifications of the Medium Voltage Multi PCS 34.5 kV.

Table 7 and Table 8 list general specifications of the Low Voltage PCS 690 V.

Medium voltage PCS datasheet

Common features medium voltage PCS		FP4010M	FP4200M
AC	Maximum AC output power (kW) @ 105 °F	4010	4200
	Operating grid frequency (Hz)	60Hz	
	Current harmonic distortion (THDi)	< 3% per IEEE519	
	Power factor (cosine phi) [1]	See Figure 11	
	Reactive power compensation	Four quadrant operation	
DC	DC voltage ripple	< 3%	
	Maximum DC continuous current (A)	4,590	4,590
	Battery technology	All type of batteries (BMS required)	
	Dimensions [WxDxH] (m)	6.5 x 2 x 2.2	
	Weight (lbs)	30,865	30,865
	Type of ventilation	Forced air cooling	
Environment	Degree of protection	NEMA 3R/IP55	
	Permissible ambient temperature	-31 °F to +140 °F, >122 °F/Active power derating	
	Relative humidity	4% to 100% non-condensing	
	Maximum altitude (above sea level)	2,000m/>2,000m power derating (maximum 4,000m)	
Control interface	Communication protocol	Modbus TCP	
	Power plant controller	Optional. Third party SCADA systems supported.	
	Keyed ON/OFF switch	Standard	
Protections	Ground fault protection	Insulation monitoring device	
	Humidity control	Active heating	
	General AC protection & disconnect	Circuit breaker	
	General DC protection & disconnect	DC switch-disconnectors [3]	
	Overvoltage protection	Type 2 protection for AC and DC (optionally, Type 1+2)	

Medium voltage PCS datasheet

Common features medium voltage PCS		FP4010M	FP4200M
Certifications & standards	Safety	UL 1741 / CSA 22.2 No.107.1-16	
	Utility interconnected [4]	IEEE 1547:2018/UL 1741 SB	
Notes	[1] Consult P-Q charts available: Q(kVAr) = √(S(kVA)2-P(kW)2). [2] Readings taken 1 meter from the back of the unit. [3] Battery short circuit disconnection must be done on the battery side. [4] Consult the factory for other applicable standards/grid codes.		

Table 3: Medium voltage PCS datasheet

Medium voltage PCS datasheet, Part 2

34.5 kV			
References		FP4010M	FP4200M
AC	AC output power (kVA/kW) @ 105 °F [1]	4,010	4,200
	AC output power (kVA/kW) @ 122 °F [1]	3,720	4,075
	Operating grid voltage (VAC)	34.5 kV ±10%	
	DC voltage range	976V – 1,500V	
DC	Maximum DC voltage	1,500V	
Efficiency	Efficiency (maximum) (η) (including MV transformer)	97.75%	97.80%
Notes	[1] Values at 1.00·Vac nom and cosϕ = 1. [2] Consult factory for charging mode and derating curves.		

Table 4: Medium voltage multi-PCS datasheet, Part 2

Medium voltage multi-PCS datasheet

Common features medium voltage multi-PCS		FP4200M2
AC	Maximum AC output power (kW) @ 105 °F	4,200
	Operating grid frequency (Hz)	60Hz
	Current harmonic distortion (THDi)	< 3% per IEEE519
	Reactive power compensation	Four quadrant operation
DC	DC voltage ripple	< 3%
	Maximum DC continuous current (A)	4,590
	Battery technology	All type of batteries (BMS required)
	Number of separate DC inputs	2
	Dimensions [WxDxH] (m)	3 x 2 x 2.2
	Weight (lbs)	30,865
	Type of ventilation	Forced air cooling
Environment	Degree of protection	NEMA 3R/IP55
	Permissible ambient temperature	-31 °F to +140 °F, >122 °F/Active power derating
	Relative humidity	4% to 100% non-condensing
	Maximum altitude (above sea level)	2,000m/>2,000m power derating (maximum 4,000m)
Control interface	Communication protocol	Modbus TCP
	Power plant controller	Optional. Third party SCADA systems supported.
	Keyed ON/OFF switch	Standard
Protections	Ground fault protection	Insulation monitoring device
	Humidity Control	Active heating
	General AC protection & disconnect	Circuit breaker
	General DC protection & disconnect	DC switch-disconnectors [3]
	Overvoltage protection	Type 2 protection for AC and DC (optionally, Type 1+2)

Table 5: Medium voltage multi-PCS datasheet

Medium voltage multi-PCS datasheet, Part 2

34.5 kV		
References		**FP4200M2**
AC	AC output power (kVA/kW) @ 105 °F [1]	4,200
	AC output power (kVA/kW) @ 122° F [1]	3,900
	Operating grid voltage (VAC)	34.5 kV ± 10%
DC	DC voltage range [2]	934V – 1,500V
	Maximum DC voltage	1,500V
Efficiency	Efficiency (maximum) (η)	97.80%
Notes	[1] Values at 1.00·Vac nom and cosϕ = 1. Consult factory for charging mode and derating curves. [2] Consult factory for derating curves	

Table 6: Medium voltage multi-PCS datasheet, Part 2

Low voltage PCS datasheet

Common features low voltage PCS		Frame 2	Frame 4
AC	Max. AC output current (A) @ 40 °C	1,837	3,674
	Operating grid frequency (Hz)	50/60 Hz	
	Current harmonic distortion (THDi)	< 3% per IEEE519	
	Power factor (cosine phi)[1]	See Figure 11	
	Reactive power compensation	Four quadrant operation	
DC	DC voltage ripple	< 3%	
	Maximum DC continuous current (A)	2,295	4,590
	Battery technology	All type of batteries (BMS required)	
	Dimensions [WxDxH] (m)	3 x 2 x 2.2	
	Weight (lbs)	11,464	11,464
	Type of ventilation	Forced air cooling	
Environment	Degree of protection	NEMA 3R/IP55	
	Permissible ambient temperature	-31 °F to +140 °F, >122 °F/Active power derating	
	Relative humidity	4% to 100% non-condensing	
	Maximum altitude (above sea level)	2,000m/>2,000m power derating (maximum 4,000m)	
Control interface	Communication protocol	Modbus TCP	
	Power plant controller	Optional. Third party SCADA systems supported.	
	Keyed ON/OFF switch	Standard	
Protections	Ground fault protection	Insulation monitoring device	
	Humidity control	Active heating	
	General AC protection & disconnect	Circuit breaker	
	General DC protection & disconnect	DC switch-disconnectors[3]	
	Overvoltage protection	Type 2 protection for AC and DC (optionally, Type 1+2)	

Low voltage PCS datasheet

Common features low voltage PCS		Frame 2	Frame 4
Certifications & standards	Safety	UL 1741 / CSA 22.2 No.107.1-16 / IEC 62109-1 / IEC 62109-2	
	Utility interconnected[4]	IEEE 1547:2018 / UL 1741 SB/ IEC 62116:2014	
Notes	[1] Consult P-Q charts available: Q(kVAr) = √(S(kVA)2-P(kW)2). [2] Readings taken 1 meter from the back of the unit. [3] Battery short circuit disconnection has to be done on the battery side. [4] Consult factory for other applicable standards/grid codes.		

Table 7: Low voltage PCS datasheet

Low voltage PCS datasheet, Part 2

690 V		Frame 2	Frame 4
References		FP2195K	FP4390K
AC	AC output power (kVA/kW) @ 40 °C [1]	2,195	4,390
	AC output power (kVA/kW) @ 50 °C [1]	2,035	4,075
	Operating grid voltage (VAC)	690V ± 10%	
	DC voltage range	976V – 1,500V	
DC	Maximum DC voltage	1,500V	
Efficiency	Efficiency (maximum) (η)	98.84%	98.93%
Notes	[1] Values at 1.00·Vac nom and cosϕ = 1. [2] Consult factory for charging mode and derating curves.		

Table 8: Low voltage PCS datasheet, Part 2

4.2 Power factor

The inverter dimensioning considers the highest possible efficiency at all operating points and a wide range of the cos phi. Depending on the mains voltage and the state of charge of the BESS, this may result in minor restrictions in the provision of reactive power in the boundary area of the permissible operating range, as seen in Figure 11.

If required, the power conversion system can be oversized to meet the full cos phi circle (i.e., Cos ϕ = 1) at any condition.

Cos Phi for 10% overvoltage, nominal voltage and 10% undervoltage

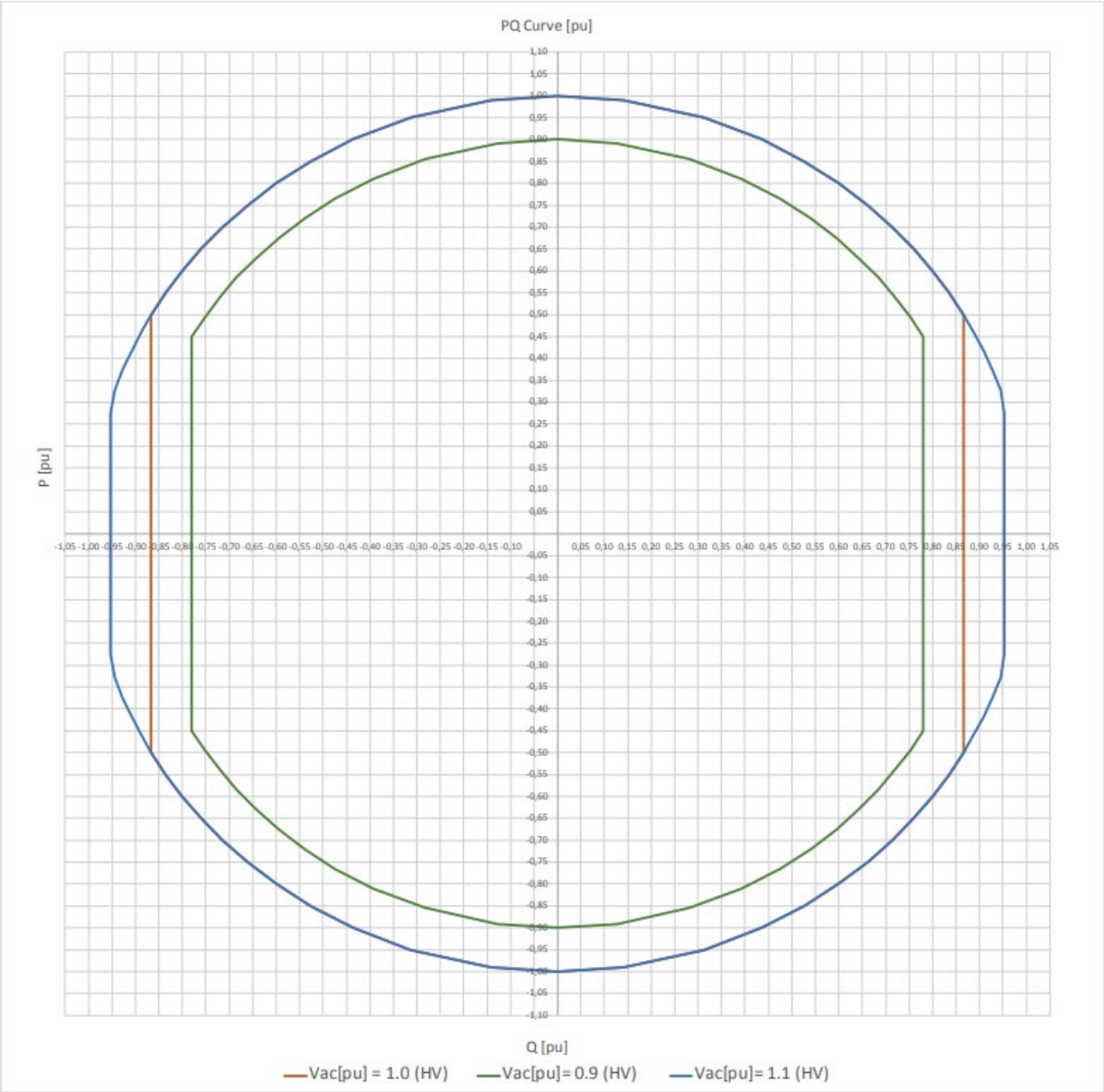

Figure 11: Cos Phi for 10% overvoltage, nominal voltage and 10% undervoltage

4.3 Power derating curves

Preliminary power derating curves due to DC-voltage

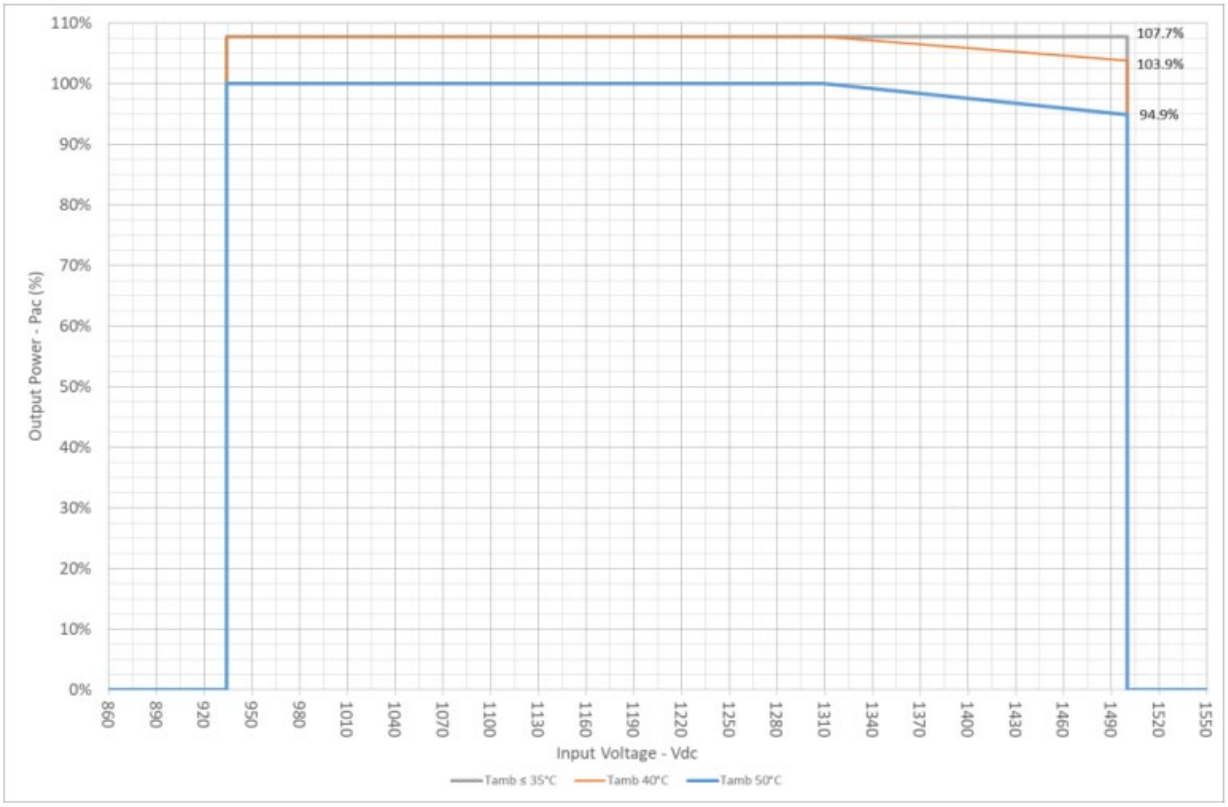

Figure 12: Preliminary power derating curve for Power Factor > 0.85

Power derating curves due to altitude and temperature

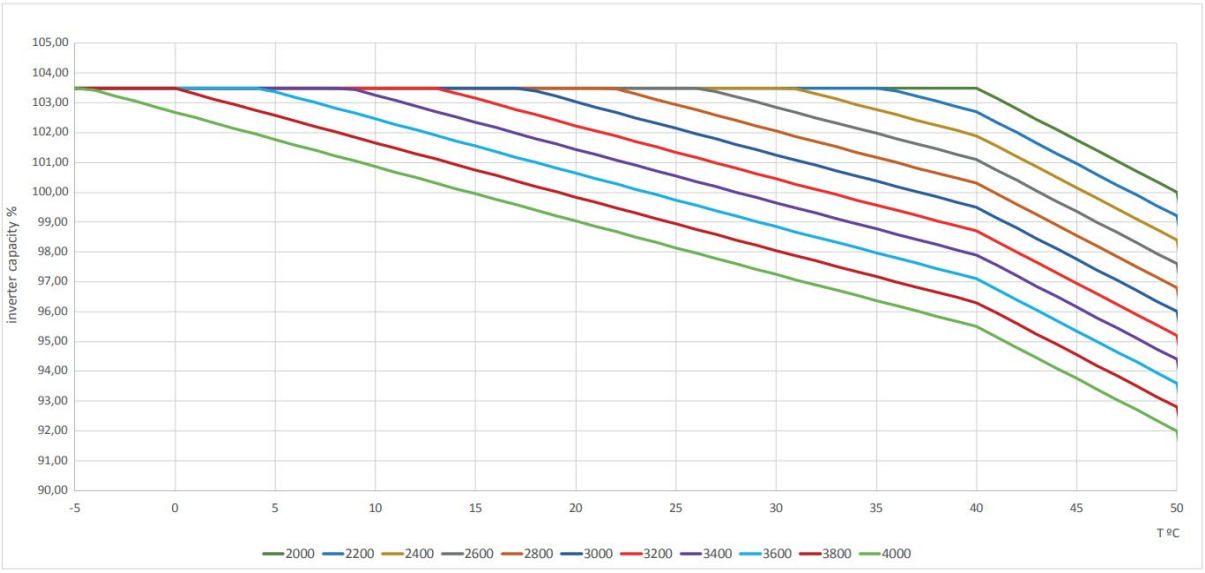

Figure 13: Power derating curves due to altitude and temperature (2000 m – 4000 m)

Preliminary power derating curve for 0.85 ≥ Power Factor ≥ 0.5

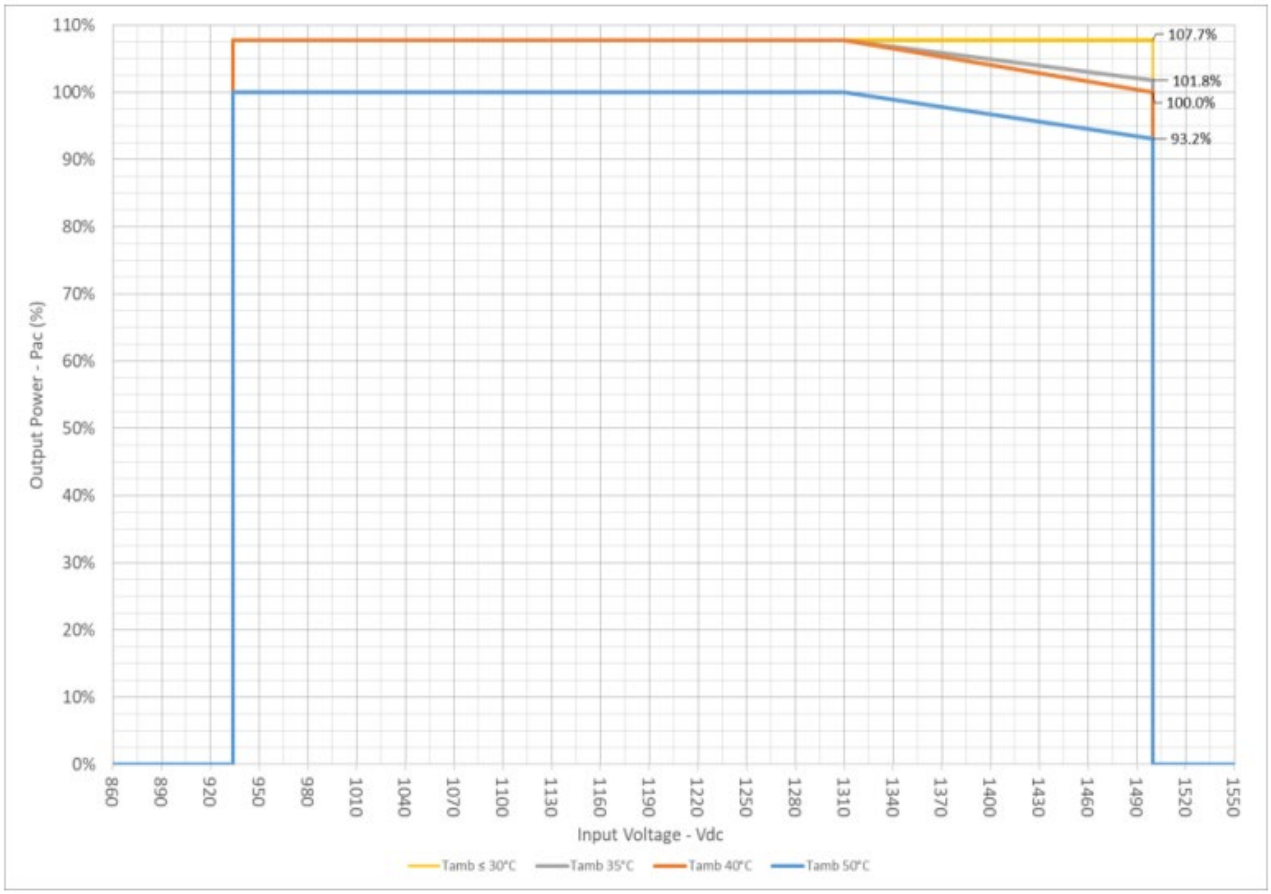

Figure 14: Preliminary power derating curve for 0.85 ≥ Power Factor ≥ 0.5

4.4 Power conversion system layout

The different areas of the PCS are listed in Table 9, and a complete PCS is shown in Figure 15.

Components of the PCS

AC termination area	Converter area	DC termination area	Control area
• Grid connection • Connection for auxiliary loads	• AC circuit breaker • Converter/power module	• Battery system DC terminal	• Control panel (user cabinet, control keypad) • Main control cabinet • DC power supply (24 V)

Table 9: Components of the PCS

Power conversion system

Figure 15: Power conversion system

4.5 Electrical protection

The PCS is protected against thermal overload. Insulating monitoring ground fault detection is provided and EMC requirements meet IEC 61000. The following additional protective functions are provided:

- DC overvoltage
- DC undervoltage
- DC overcurrent
- AC overvoltage
- AC undervoltage
- AC overcurrent
- Over and underfrequency
- Anti-islanding
- Battery protection
- Internal fault (over temperature, logic failure, etc.)

4.6 Ring network with PCSK and MV-Skid

In Figure 16, an example of a ring network system for the connection of battery strings to the grid is shown. The number of possible basic systems is dependent on the basic system used and the MV/LV voltage. For a Grid EnergyPack1 with a LV-Voltage of 690 VAC and an MV-Voltage of 34.5 kV, a maximum of eight systems may be used in the ring network.

Ring network system example

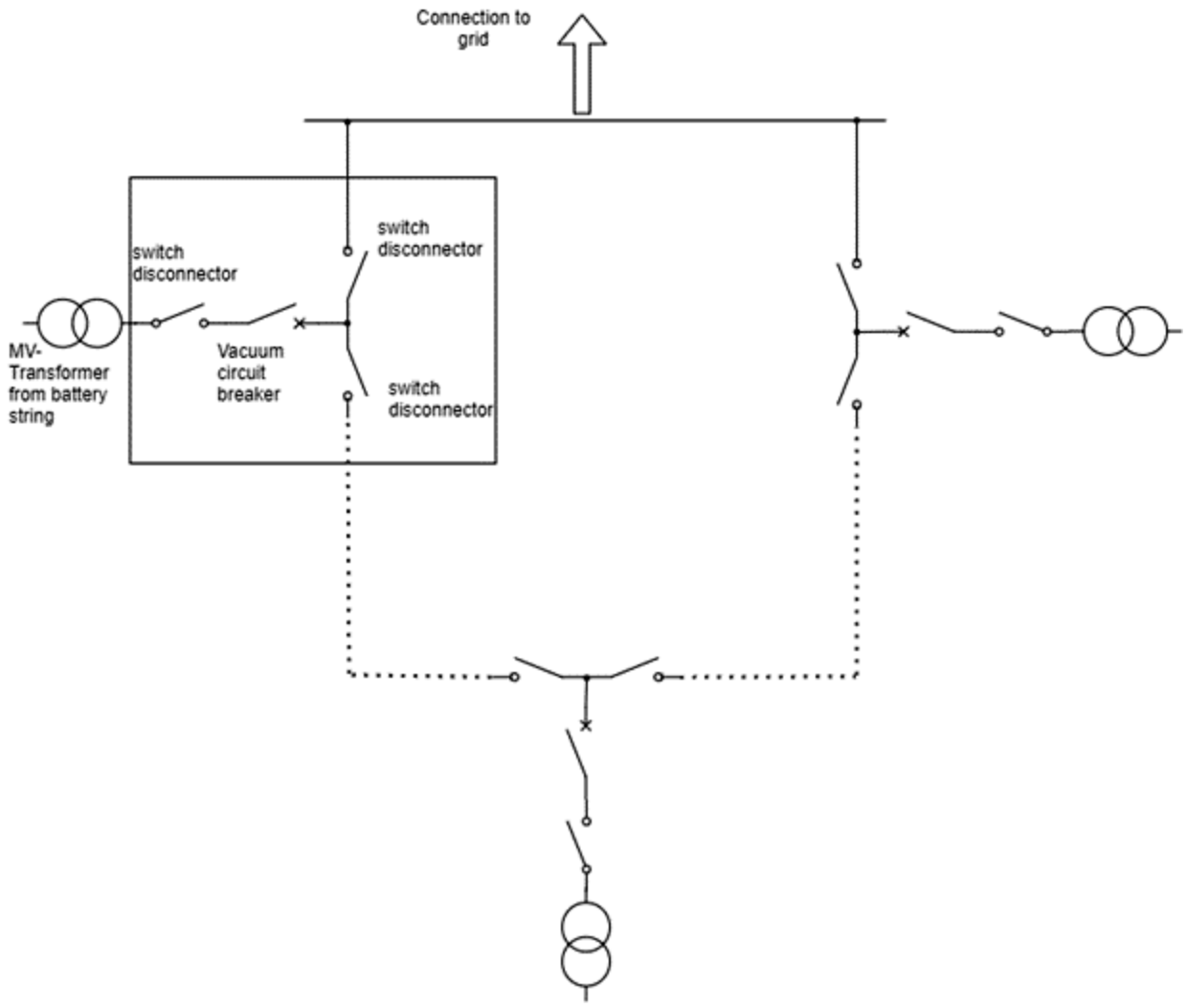

Figure 16: Ring network system example

5 Communication

Each Battery Rack (BR) has one Battery Management Unit (BMU). All the BRs connected in parallel communicate with the Module Battery Management System (MBMU) via the Control Area Network (CAN).

The MBMU is responsible for detecting any abnormality and controlling the battery racks when necessary. It is placed in the control cabinet with the Ethernet Module (ETH). The ETH communicates with the PCS and the Energy Storage System (ESS) controller via Modbus/TCP. The control cabinet is placed in the housing of the ESS controller.

The communication block diagram is shown in Figure 17 below.

Communication block diagram of Grid EnergyPack system

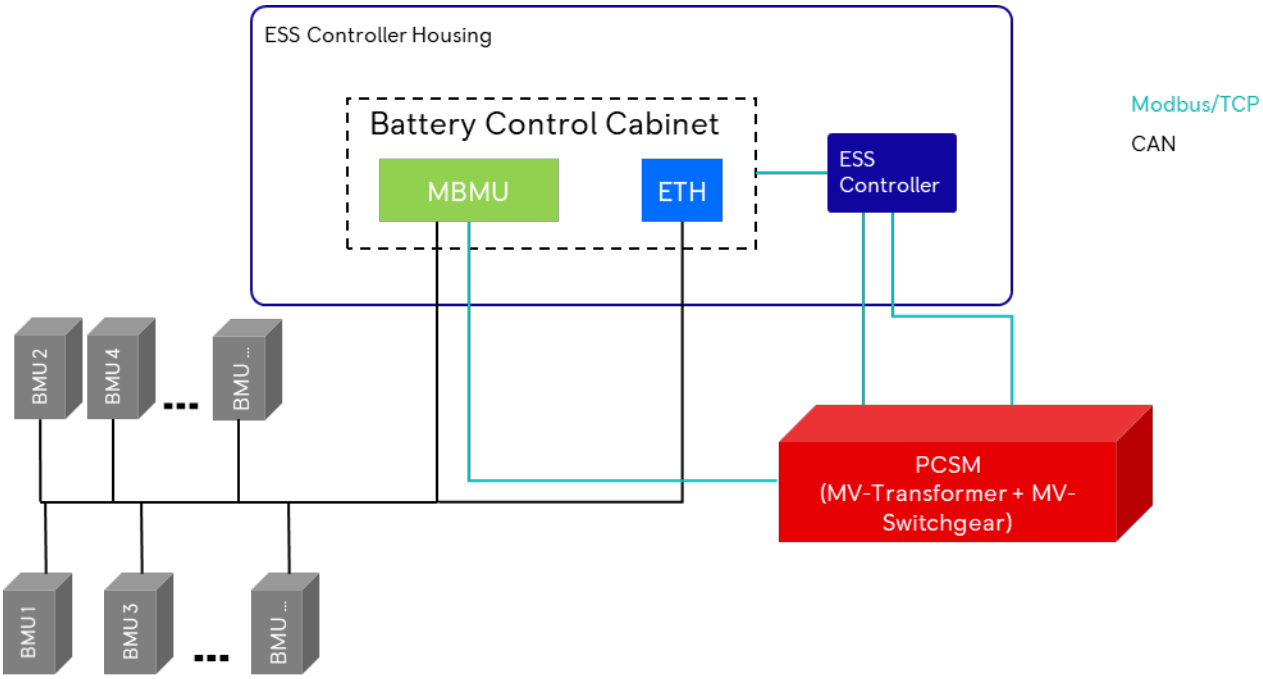

Figure 17: Communication block diagram of Grid EnergyPack system

Whether there are one or multiple Grid EnergyPack BESS in a project, only one ***mtu*** EnergetIQ Manager is required to control the entire system. Figure 18 illustrates a project consisting of four Grid EnergyPack BESS.

Project with four Grid EnergyPack BESS

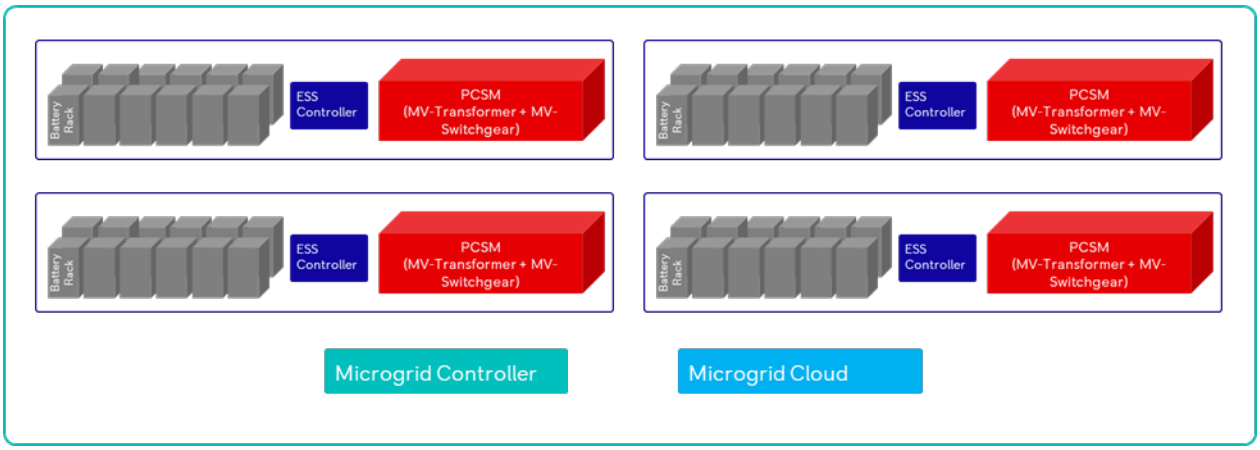

Figure 18: Project with four Grid EnergyPack BESS

6 Revisions

Rev.	Date	Changes	Compiled by		Reviewed by	
			Dept.	Name	Dept.	Name
0	06/15/2022	First draft Grid EnergyPack documentation	SPHS	Shashank Shinde		

Power Generation

DESIGNING MICROGRIDS FOR EFFICIENCY AND RESILIENCY

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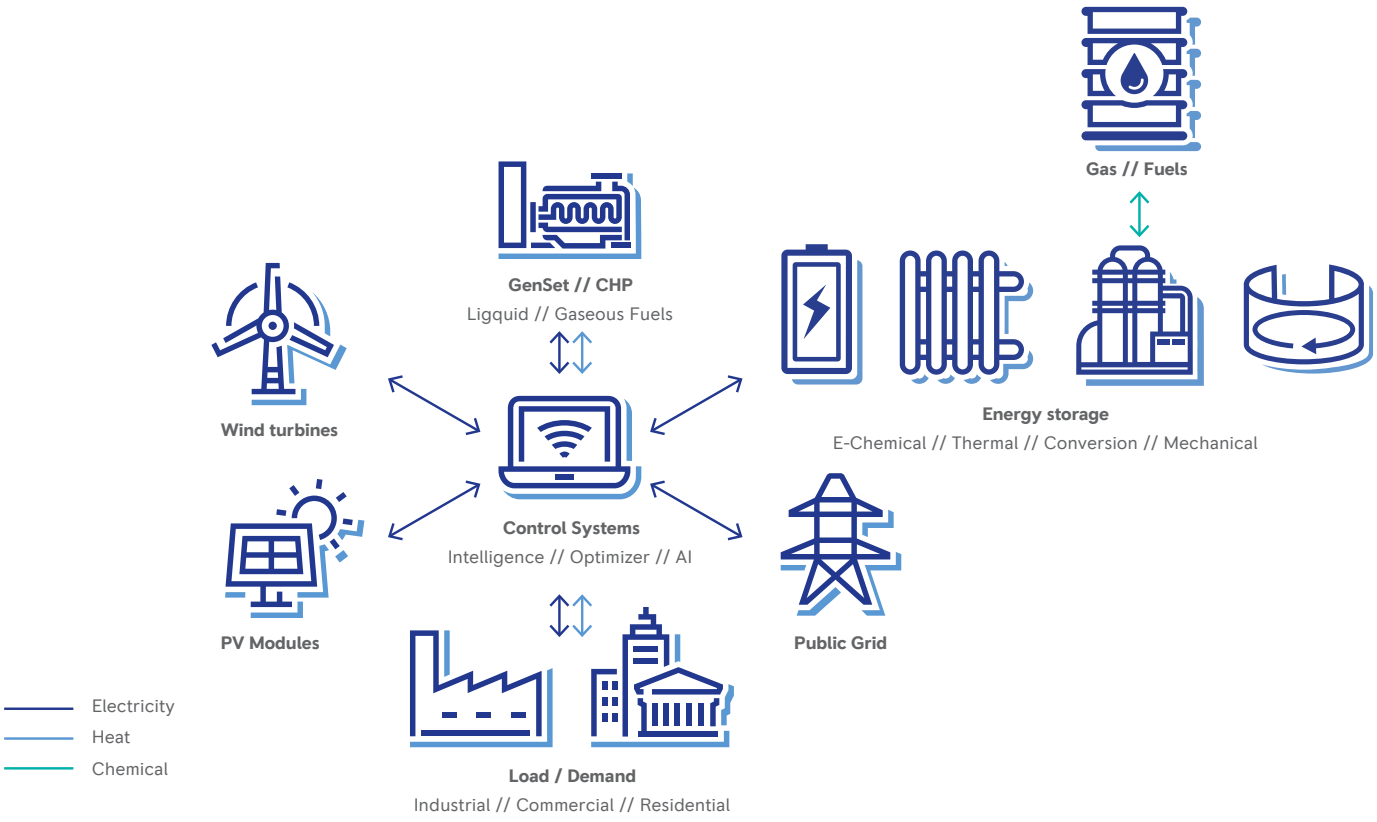
For decades, mission-critical facilities have depended on centralized power plants owned and operated by utilities. However, the traditional model is changing. Intelligent distributed generation systems, in the form of microgrids, are providing much-needed stability to an aging power grid.

A facility's energy demand is key to the design of a microgrid system. To ensure efficiency and resiliency, microgrids combine different components to meet a given demand, while optimizing costs.

Key components

By combining different components, a microgrid can be tailored to every customer need, providing the ideal technical and economical solution. These systems are designed to satisfy an electrical and/or thermal energy demand that is traditionally supported by the natural gas or electric utility provider. A microgrid most commonly operates in island mode, but it also can be connected to the grid.



Distributed energy resources

These include conventional resources, like natural gas or diesel generators, that convert fuel mechanically to make electricity and thermal energy as well as renewable systems, like solar and wind, that utilize natural resources.

Energy storage

Energy is held in reserve to be dispatched as needed to supplement other distributed assets. Systems include electrochemical (BESS), mechanical (flywheels), thermal (hot water) and energy conversion. This energy can come from the overproduction of renewables, or it can be stored/charged when energy is cheaper for use at times of peak cost.

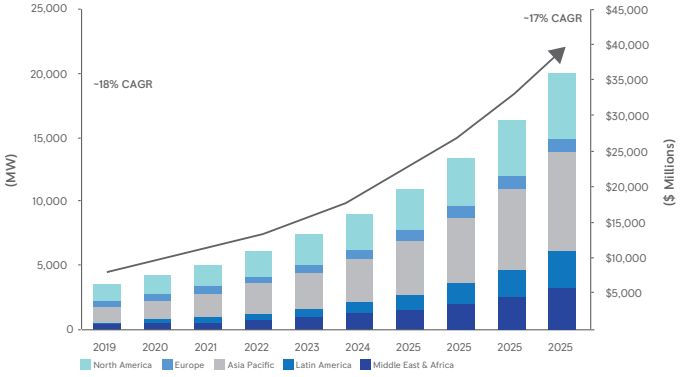
Control systems

Intelligent controls are used to optimize the available assets to provide the lowest cost of electricity by automatically dispatching supply to the most efficient resource. For example, shutting down one generator when two are running at the highest load factor to increase fuel efficiency. Control systems can operate with or without dynamic control (smart grids).

A successful microgrid solution provides modularity, scalability, energy dispatchability, power management and balancing of resources. Whether off-grid or on-grid, these powerful and reliable distributed energy generation systems can provide high performance under any site condition.

Global demand for new solutions

The energy world is undergoing a transformation. Various factors are driving growth in energy demand, and encouraging the development of flexible, sustainable, cost-effective energy solutions like microgrids. As a result, microgrid capacity and revenue continues to rise all over the world.



Source: Navigant Research

World Markets: 2019 - 2028

Benefits of microgrids and energy storage

By combining renewable power generation, power storage and conventional power generation to meet energy demands, microgrids can provide cost savings, reliability and sustainability.

Energy cost optimization
- Electricity cost reduction
- Fuel and O&M cost reductions
- Independence from electricity price development

Access to power
- Access to electricity in remote areas
- Increase of industrial load despite grid limitations
- EV charging in urban areas

Quality and security of supply
- Backup during power outages
- Voltage and frequency stabilization
- Reduction of fuel dependence

Positive environmental impact
- Increased energy use from PV & wind: reduced carbon footprint
- Incentives, tax benefits, fines avoidance
- Reputation

New revenue streams
- Revenues from grid services and energy markets
- Improved marketability of renewable energy

Implementation challenges

Every microgrid is different. To deliver the right energy mix for a facility's needs, several key parameters must be considered in the design stage.

Reliable and economical operation
- High penetration levels of intermittent generation in stand-alone mode of operation

Schedule and dispatch of units
- Supply and demand uncertainty and determination of appropriate levels of reserves

Demand Side Management (DSM)
- Design appropriate DSM schemes to allow customers to react to the grid needs and drives supply

Distribution Level Protection
- Re-engineering of DLP schemes to account for bidirectional power flows

Market/business models design
- New models to allow competitive participation of intermittent energy sources driven by fuel savings

Plug and play development
- Market and control mechanisms that exhibit P&P Feature to allow for seamless integration over time

Voltage/frequency control
- Development of control techniques to account for the increase in Power-Electronics-Interfaced DG

Grid code
- Addressing grid compliance issues for the grid connection of microgrids

Market conditions for distributed generation

Economic growth and population growth are increasing the demand for power. Increased pressure to decarbonize, and growing demand for more flexible, sustainable, cost-effective energy solutions are guiding governments and industry away from traditional energy sources like coal and gas, and toward renewable energies such as solar and wind power.

Four trends are transforming the energy world, triggering demand for new solutions:

Globalization
- Increased mobility and energy needs
- Higher level of price competition
- Urbanization

Decarbonization
- Decentralization
- Energy transition
- Increase of fluctuating renewable sources
- Environmental awareness

Electrification
- Rising electricity demand
- Increasing power need
- Environmental awareness
- Sector coupling

Digitalization
- New business models
- Increased computing performance
- High data volume and energy need for services

Costly consequences

Systems must be in place to ensure power to communities in extreme conditions. An outdated and overstressed grid has made the network more susceptible to outages. For example, in July 2019, with only 45 minutes of notice, Con Edison had to shut down power to New York City residents when a section of its system reached a maximum capacity of 12,063 MW. In Northern California, PG&E has been proactively shutting down power through rolling blackouts to avoid the risk of fire during high-risk times of the year.

In 2019, a weather/climate event caused more than $1 billion in damages 14 different times. Total costs for that year was $45 billion. In 2020, wildfires in California and the Pacific Northwest have destroyed power transmission infrastructures, disrupted public services and caused massive financial losses. Also in 2020, a storm in Iowa cut power to more than 400,000 people. Estimated damages due to lost crops are $3.7 billion, along with $82 million in home damages. For data centers, it costs nearly $9,000 every minute an outage occurs. And healthcare facilities can average nearly $700,000 per outage.

New solutions are needed

The increase in non-dispatchable renewable generation in the form of grid-scale wind and solar has added to the overall instability of the grid. Solar power, wind power and other renewable energy sources offer key benefits, but there are some drawbacks as they are dependent on weather and time-of-day, can suffer output fluctuations, and often require major capital investment. A smart microgrid uses storage and/or complementary generation technologies to optimize the use of renewables.

Upgrades to the grid are becoming more and more important due to the overall age of the transmission and distribution network. The U.S. Department of Energy (DOE) reports that 70% of power transformers are 25 years of age or older, 60% of circuit breakers are 30 years or older, and 70% of transmission lines are 25 years or older. The average age of the country's 40,000 miles of transmission lines is 52 years. The need for reliable, independent access to power has never been greater.

Customers, key benefits and configurations

Power

Examples: grid system operators, utilities, independent power producers
Key benefits: new revenue streams, energy cost optimization
Typical configuration:

Commercial

Examples: offices, retail, warehouses, data centers, infrastructure, transport, hotels, restaurants
Key benefits: energy cost optimization, secure and reliable power supply, access to power
Typical configuration:

Industry

Examples: agriculture, manufacturing, mining, commodities
Key benefits: energy cost optimization, CO2 avoidance
Typical configuration:

Communities

Examples: remote communities, urban district/town solutions
Key benefits: energy cost optimization, access to power, CO2 avoidance
Typical configuration:

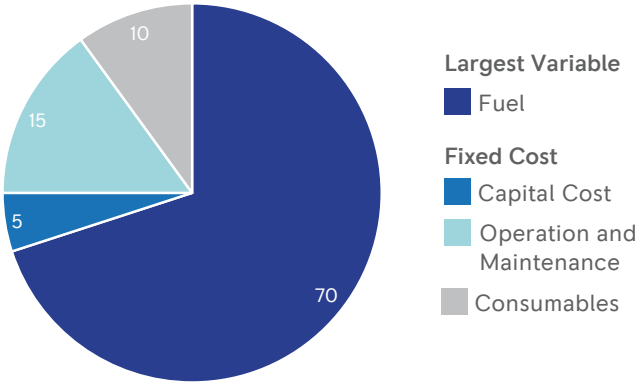
Public

Examples: military base, healthcare, institutional, education
Key benefits: energy cost optimization, quality and service of supply
Typical configuration:

Design factors for efficiency and resiliency

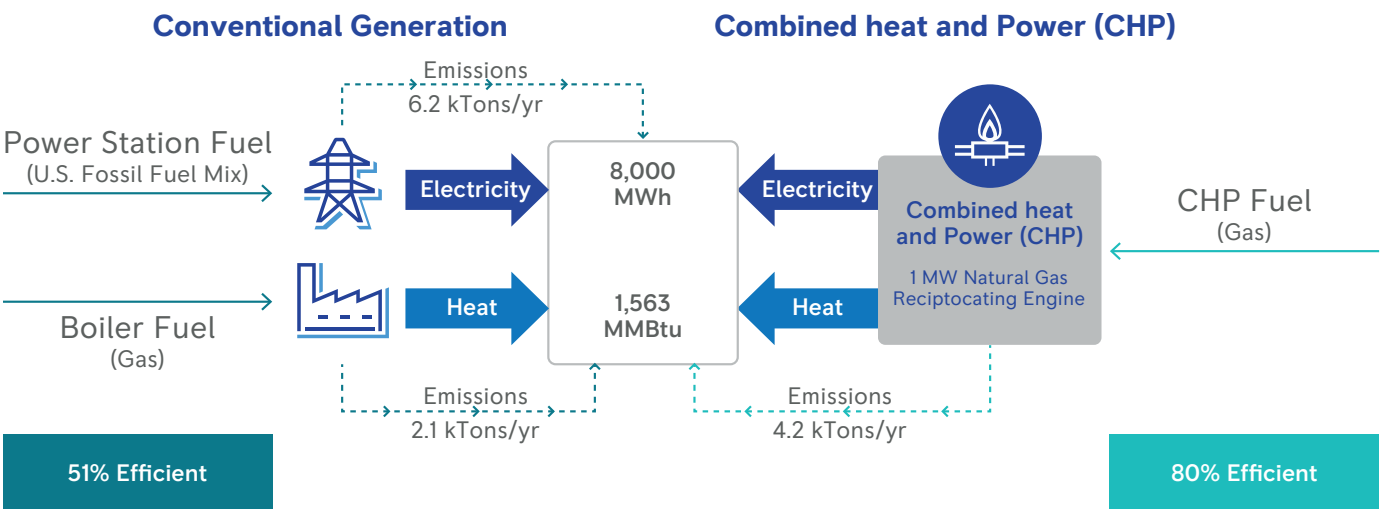
In a true microgrid application, the load or energy demand is key to the design of the energy system. Designing to efficiency and resiliency means balancing these assets with the cost of operation, space available, fuel resources, and government regulations.

Lifecycle costs for distributed generation system



A power generation project is a large investment. However, upfront and other fixed costs are just a small part of the total lifecycle costs. Fuel accounts for up to 70 percent of lifecycle costs. By utilizing renewable energy sources and battery storage, a microgrid can lower fuel consumption, reducing overall operating costs while ensuring the availability of reserve power.

Distributed generation systems generally lower operating costs compared to conventional power generation techniques. Properly deploying distributed generation systems requires an analysis of the existing thermal and electrical systems, ensuing the selection of building systems that are critical to continuous operation.



Secondary fuel costs

Many microgrids use a combined heat and power (CHP) module, which can produce both electric energy and heat energy from the same fuel, thereby nearly doubling overall efficiency. Higher operating efficiencies enable CHP systems to consume less fuel while generating the same amount of power and useful thermal energy as separate heat and power systems. Compared to conventional electricity and heat generation, CHP modules reduce carbon emissions by approximately 50 percent.

The challenge in maximizing the efficiency of a cogeneration application is matching the demand for the heat byproduct with the demand for electricity. If demand for electricity is greater than demand for the heat product, then excess heat must be exhausted to a radiator or water-cooling tower, thus efficiency suffers. If demand for heat exceeds generator output (light electrical demand or high heat demand), then it will need to be scaled back to match the heat output of the generator or the process, augmented with heat from a boiler.

The perfect balance

When designing a microgrid system for any application, it is important to choose the right combination of components to balance resiliency with efficiency.

Fuel availability and emissions regulations

With a widespread distribution network, natural gas is often used for North American microgrid systems. In Latin America, where pipeline natural gas might not be available, other options are often considered. Emissions rules can limit fuel types. For example, diesel may only be used in some areas for standby and with a limited run time of 100 hours or less annually.

Wind

Strength: No fuel requirement

Solar

Strength: No fuel requirement

Gas (CHP)

Strength: Opportunity to use biogas
Weaknesses: Gas pipeline or storage required, emissions controls required in certain areas

Diesel

Weaknesses: Fuel transport/storage, high CO2 emissions, high NOx emissions, limited run hours

Energy storage

Strength: Enables integration of renewables, increase flexibility of genset

Grid connection and permitting

Each individual utility creates a set of rules that govern the process and costs of operating in parallel with its transmission and distribution system. Even when electricity is kept behind the meter, the costs and time needed to properly operate in grid parallel add additional unforeseen costs to projects. Exporting excess energy is even more costly and difficult. Analysis must be performed on how any distributed energy system will affect a relationship with the utility provider.

Wind

Strengths: No carbon emissions, federal and local incentives
Weaknesses: Not dispatchable, visual and noise pollution, capital cost

Solar

Strengths: No carbon emissions, federal and local incentives
Weakness: Large space required (greenfield sites)

Gas (CHP)

Strengths: Opportunity to use biogas, dispatchable

Diesel

Strength: Dispatchable
Weaknesses: High CO2 emissions, high NOx emissions, limited run hours

Energy storage

Strength: Federal and local incentives

Ambient conditions and plant operations
Facility load or demand will drive the size and shape of the microgrid. It is important to analyze each site individually even if the loads and designs are similar, as location affects local regulations. In addition, ambient conditions, such as high altitude and high temperature, will affect how the distributed energy resources will perform. Local codes and standards are one of the main early drivers for the design of a microgrid.

Wind
Weakness: Dependent on weather conditions

Solar
Strengths: Retrofittable, e.g. on buildings
Weakness: Dependent on weather conditions and time of day

Gas (CHP)
Strengths: Power heat and cooling, efficient, economic continuous operation

Diesel
Strength: Fast start time (<20 seconds)
Weaknesses: High operating and maintenance costs

Energy storage
Strengths: Flexible use for various applications, low operation and maintenance cost
Weakness: Battery capacity degrades over time

Applications

Example #1:
Industrial Facility – Southeast USA

Site details
- Industrial demand response project
- Industrial process with high peak electrical loads

Challenges
- Control peak demand to reach goal of $100,000 monthly reduction in energy bill
- Microgrid controller to optimize all distributed generation assets

Solutions
- 3 x 16V4000 natural gas generators (6MW)
- 3 x 2MW/2MWh – 6MWh ***mtu*** Energy Pack
- 18.7 MW of PV
- Projected $1 million annual savings

Example #2:
Granjas Carroll de Mexico – Puebla, Mexico

Site details
- New pork processing facility for one of the leading producers in Mexico
- Continuous power project

Challenges
- Complete independent off-grid solution
- Customized automation system for plant control and remote operation
- Accommodate extension for heat recovery and use of biogas in future

Solutions
- 4 x 20V4000 natural gas generators
- 1 x 16V4000 diesel generator
- 9.7 MWel power output
- The first off-grid solution of its kind for Rolls-Royce Power Systems in the Americas

Microgrid Validation Center

Every microgrid is unique. Modeling real-world applications can ensure a microgrid and its control system is designed optimally. ***mtu*** Microgrid Validation Centers offer highly flexible simulation and testing capability. Equipped with diesel and co-generation standby generator sets, solar panels, ***mtu*** EnergyPack battery storage and integrated ***mtu*** automation system, the self-sustaining Validation Centers can simulate a wide range of conditions, including off-grid operation. Located in Aiken, South Carolina and Friedrichshafen, Germany, they are effective proving grounds for customers to apply a software model to just about any real-world installation.

Conclusion

Power security for mission critical facilities has traditionally been limited to a coal-fired central power plant that supplies electricity through a transmission and distribution system with on-site standby generators for selected loads, but trends are changing.

End users are paying more attention to how they design and purchase their power systems. Intelligent distributed generation systems in the forms of microgrids increase security and efficiency by offering a wide selection of power generation and storage sources, providing maximum control for facility managers, and reducing reliance on utilities.

Rolls-Royce provides world-class power solutions and complete lifecycle support under our product and solution brand ***mtu***. Through digitalization and electrification, we strive to develop drive and power generation solutions that are even cleaner and smarter and thus provide answers to the challenges posed by the rapidly growing societal demands for energy and mobility. We deliver and service comprehensive, powerful and reliable systems, based on both gas and diesel engines, as well as electrified hybrid systems. These clean and technologically advanced solutions serve our customers in the marine and infrastructure sectors worldwide.