The business case for hybrid and electric technology

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Presentation & sponsor documents

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Page 15: Erno Tenhunen, Danfoss Editron
Page 20: Will Ayers, Elliott Bay Design
Page 25: Jon Diller, Spear Power Systems
Page 30: Corvus Energy corporate brochure
Page 43: Elliott Bay Design corporate brochure
Cecilie Larsen
Project Manager, Renewable Energy
Municipality of Ærø, Denmark
Email: cla@aeroekommune.dk
Fuel costs and energy efficiency
Battery prices dropping
Crew and maintenance
The business case

• Larger investment

• Reduced operational costs

• Return on investment far earlier than battery or ferry replacement
The business case for hybrid and electric technology

Monday 2 June

Halvard Hauso
Chief Commercial Officer Corvus Energy
Why Energy Storage makes sense

<table>
<thead>
<tr>
<th>Diesel Gen Set Size</th>
<th>Battery Size</th>
<th>Annual Fuel consumption</th>
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</thead>
<tbody>
<tr>
<td>Diesel RTG 450kW</td>
<td>No Battery</td>
<td>120,000 L</td>
</tr>
<tr>
<td>Hybrid Diesel-Battery RTG 50kW</td>
<td>80kWh</td>
<td>50,000 L</td>
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</tbody>
</table>

Corvus Energy
Pioneers on Maritime ESS

1st Zero Emission Tug
1 Zero emission ferry
1st OCV to use battery in DP3
1st Hybrid OSV
1st Hybrid Shuttle tanker
1st Offshore Drilling Rig
1st Hybrid Tug
1st Hybrid 1000+ Passenger Ro-Pax
1st hybrid Tanker
1st long range XLUUV
1st all-electric E-ROV
1st 1000+ Passenger Ro-Pax
350+ Projects

89 Car and Passenger ferries

20 Cruise and Yachts

56 Offshore and Subsea

39 Tugs/Workboat/Fishing

19 Merchant vessels

128 Port equipment and Shore stations

>2 500 000 operating hours

300+ MWh

>2 500 000 operating hours

300+ MWh
### Reported/Estimated savings per vessel type

<table>
<thead>
<tr>
<th>Car ferry</th>
<th>PSV</th>
<th>Fishing Vessel</th>
<th>Shuttle Tanker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully electric</td>
<td>Hybrid</td>
<td>Hybrid</td>
<td>Hybrid</td>
</tr>
<tr>
<td>80%</td>
<td>35-50%</td>
<td>50-75%</td>
<td>35-50%</td>
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<tr>
<td>100%</td>
<td>15-20%</td>
<td>20-25%</td>
<td>20-25%</td>
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<tr>
<td>95%</td>
<td>15-20%</td>
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<tr>
<td>95%</td>
<td>30-40%</td>
<td>30-40%</td>
<td>30-40%</td>
</tr>
</tbody>
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Corvus Energy
Corvus Product Comparison

**Corvus Blue Marlin**
- Offshore
- Rig/Topside
- Regeneration of energy

**Corvus Orca Energy**
- OSVs
- Ferries
- Port Cranes

**Corvus Dolphin Power**
- Light weight
- High Speed Vessels

**Corvus Moray Power**
- Regeneration of energy
  - Subsea Niche Product

**Corvus Dolphin Energy**
- Light weight
  - Long charge/discharge

**Corvus Moray Energy**
- Subsea energy bank
  - Subsea Niche Product

**Corvus Blue Whale**
- Cruise
- RoRo/RoPax
- Slow Charge/discharge
<table>
<thead>
<tr>
<th>Available technology</th>
<th>Near Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>E - Car Ferries</td>
<td>E – OSV</td>
</tr>
<tr>
<td>H - Car Ferries</td>
<td>H – Container Vessels</td>
</tr>
<tr>
<td>H - OSVs DP2</td>
<td>E- RoPax</td>
</tr>
<tr>
<td>H Tugs</td>
<td>E – Fast Ferry</td>
</tr>
<tr>
<td>H- Fishing Vessels</td>
<td>E- Tankers</td>
</tr>
<tr>
<td>H- Fishfarm Vessels</td>
<td>E – Fish farm vessels</td>
</tr>
<tr>
<td>H- Workboatds</td>
<td>E – Fast Ferry</td>
</tr>
<tr>
<td>H – RoPax/RoRo</td>
<td>H - Cruise Vessels</td>
</tr>
<tr>
<td>E - Sightseeing Vessel</td>
<td>E- Shiphandling Tug</td>
</tr>
<tr>
<td>H - Exploration Cruise</td>
<td></td>
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<tr>
<td>H - Fast Ferry</td>
<td></td>
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<tr>
<td>H - OSVs DP3</td>
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<tr>
<td>H- Cargo vessels</td>
<td></td>
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<tr>
<td>H- Harbour Tug</td>
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<tr>
<td>H- Shuttle Tankers</td>
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<tr>
<td>H - Chemical tankers</td>
<td></td>
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</tbody>
</table>
Thank You!
Hybrid power plant and propulsion systems for unmanned vessels

Erno Tenhunen
Director BU Marine, Danfoss Editron
New requirements for hybrid systems
Case unmanned vessel

- Unmanned vessels built today are mainly <100m LOA
- Typical power plant configuration is Full-Electric, Hybrid or Diesel-Electric
- Weight and space critical
- Is available onboard space adequate for all required equipment?
Novel technology (opening new possibilities for vessel design)

- Decentralized DC configuration
  - Installation into machinery space
  - Reduced system footprint
  - Reduced system weight
  - Light and compact component design

- Required robustness through ground breaking design
  - Less moving parts, no active air cooling
  - Novel permanent magnet technology
  - Protection based on simple ultra-rapid fuses
Importance of Energy efficiency in hybrids

- High equipment efficiency yields to high benefits:
  - Smaller battery installation
  - Smaller cooling equipment
  - Smaller charging infrastructure
  - Lower CO2 emissions

- Importance of real efficiency throughout the operational range vs. “nominal efficiency”
  - Efficiency remains high also in partial power
Conclusions

- Decentralized power system configuration solves major ship design issues
- Simplicity improves reliability
- System overall efficiency reduce CAPEX and OPEX
The Transition is Unique

- Not like sail to steam or steam to diesel
- No clear-cut replacement for diesel:
  - Battery Plug-In
  - Hydrogen
  - LNG
  - Methanol?? Ammonia??
  - CCS???
- Vessel type and operational profile
The Challenge

Lithium-Ion, 124kWh  

3 Gallons of Diesel, 124kWh

- Man overboard searches
- Nearby vessel in distress
- Disasters
- Electric utility outages
- Car ramp failure
- Shore plug failure
- Onboard battery issue
- Emergency drydock
- Scheduled shipyard periods
The Transition is Connected

- Solutions will be judged on the shore-side component:
  - Battery Plug-In, how are you producing the electricity?
  - Hydrogen, how are you producing it?
  - LNG, is bio-gas being used and to what extent?
- Short-haul vessels as the low hanging fruit.
  - Cost connections related to limited diesel engine use
  - Cost connections between vessel and vehicle electrification
  - Cost connections between plug-ins and renewables
Battery and Inverter Costs

- There are many studies showing projected price drops in both.

The Revolution in Renewables

- The Duck Curve and the other 20 hours per day
Considering Marine Battery Price

- **Critical** to capital decision making, thus gating green
- **Confusing** at the surface, in automotive and stationary contexts
- **Trends** drive timing, and we are out of time
Cost Drivers

Marine

ESS

Auto

$Bn 2020
Trends

$/kWh Marine vs ESS


ESS
Marine
Coming Impact

- NMC improvements 2022
- Protected anode 2025-2027
- Solid state 2028-2030
Energy Storage Systems
Product Overview
Corvus Energy - the maritime industry standard

Corvus Energy is the leading provider of energy storage systems for maritime, oil & gas, subsea and port applications. The team at Corvus Energy combines technological excellence in developing energy storage systems with what we like to call maritime DNA.

The company was founded in 2009, and we have been pioneering maritime Energy Storage System (ESS) deliveries ever since. Our long list of “firsts” include the famous car ferry Ampere, large passenger ferries, offshore service and support vessels, deep-sea vessels and other craft, all sailing with batteries from Corvus Energy.

With more than 300 deliveries aggregating more than 3 million hours of operation, Corvus Energy has the world’s largest installed base of maritime ESS’, and we pride ourselves in our premium knowledge on battery system safety, design, sizing and dimensioning.

The experience acquired from our systems in operation enables us to continuously improve our products and services, meet the highest standards of our customers and constantly push the boundaries of how energy storage systems are used to optimize energy consumption onboard ships, thereby reducing vessel emissions and operational costs.
Well proven, reliable products

We are proud to provide our customers with a complete range of maritime ESS with the highest level of safety and services in the maritime industry.

More than 50% of the world’s hybrid and zero-emission vessels are equipped with Corvus Energy Storage Systems. We have more than 300 MWh deployed in 300+ projects and more than 2,500,000 operating hours.

- Proven performance and technology powering the commercial maritime industry
- Patented safety system
- State-of-the-art monitoring system
- Extensive module-based service program
- Life cycle management and customer portal
- Second life and recycling

Advantages:
- Rapid return on investments
- Reduced fuel consumption
- Reduced emissions
- Reduced maintenance costs

Corvus Energy Product portfolio

The Corvus Energy product portfolio covers a range of ESS solutions suitable for various applications.

Emission savings and ROI are key driving factors for the implementation of Energy Storage Systems in the maritime industry.

As the requirements for every project is different, there is no “one-fits-all” when it comes to battery systems. Corvus Energy has therefore developed a wide range of products, ensuring that we can offer the most suitable solution to any application.

By working closely with our customers, we analyse the operational profile of the project and give advice on suitable Corvus Energy products that will fulfil the requirements of the application, ensuring smart and sustainable hybrid and all-electric solutions for any vessel.
Corvus Blue Whale

The Corvus Blue Whale Energy Storage System is a ground-breaking ESS specifically designed to meet the large energy requirements of emission free operation over longer periods of time.

The Corvus Blue Whale design is a result of the knowledge gained from having the largest global installed base of ESS solutions combined with our industry leading research and development capabilities.

The Corvus Blue Whale ESS differs from other ESS technologies available in the market in that it is specifically designed for use in vessels like Cruise, Ro-Pax, Ro-Ro, Mega Yachts etc where the operational profiles caters for slow charge and discharge rates and a product that enables emission free sailing over longer periods of time and/or emission free port stays. The system has been developed with larger installations (>10MWh total system energy) in mind. Low weight and low total system volume have been key design criteria, resulting in a world leading energy density in a battery room with minimal service aisle requirements.

Applications

Blue Whale is ideal for applications that are in need of a large amount of energy at a cost effective kWh price. Typical vessel-types are:

- Cruise ships
- Ro-Ro/Pax
- Yacht
- Merchant
- Sightseeing/Workboats
- Inland Vessels

Features

- Low C-Rate – for slow charge and discharge
- Industry leading volumetric and gravimetric room energy density
- Designed for voltages up to 1140 VDC
- Low installation and commissioning time
- Very cost efficient for large installations
- Enhanced reliability with contained power connections
- Weight and volume reduced ~30% and ~50 % compared to Orca Energy
- Flexible and modularised design
- No service aisles required
- Passive single cell Thermal Runaway protection
- Scalable capacity and voltage according to vessel requirements
- Industry-proven Battery Management System (BMS)
- Remote monitoring capabilities
- Enhanced EMI immunity design for maritime environments

Performance Specifications

| C-Rate - Peak | 1C for 20 minutes |
| C-Rate - RMS | 0.7C |

System Specifications

| Single Module Size/Increments | 43 kWh / 80 VDC |
| Single Pack Range | 301-4816 kWh / 571 - 1142 VDC |
| Max Gravimetric Density - Room | ~110 Wh/kg | ~9.1 kg/kWh |
| Max Volumetric Density - Room | ~130 Wh/l |

Example Pack - 6 strings

| Energy | 3612 kWh |
| Voltage | Max: 1142 VDC | Nom: 1075 VDC | Min: 1008 VDC |
| Dimensions | Height: 2850 mm | Width: 1390 mm | Length: 10200 mm |
| Weight | 32870 kg |

Example System - 4 packs of 6 Strings

| Energy | 14,448 kWh |
| Voltage | Max: 1142 VDC | Nom: 1075 VDC | Min: 1008 VDC |
| Dimensions | Height: 2850 mm | Width: 5560 mm | Length: 10200 mm |
| Weight | 131480 kg |

Safety Specifications

- Thermal Runaway anti-propagation: Passive cell-level thermal runaway isolation with exhaust gas system
- Fire suppression recommended: Per SOLAS, class and Corvus recommendation
- Disconnect circuit: Hardware-based fail-safe for over temperature, over voltage
- Faults communicated: Over-voltage, under-voltage, over-temperature
- Short Circuit protection: Fuses included on the module and string level
- Emergency Stop Circuit: Hard-wired
- Ground Fault Detection: Integrated
- Disconnect Switchgear Rating: Full load

General Specifications

- Class Compliance: DNV GL, Lloyds Register, Bureau Veritas, ABS
- Type Approval: Lloyds Register and Bureau Veritas
- Ingress Protection: System: IP44
- Cooling: Forced air
- Vibration and Shock: IEC 61000-4, IEC60945, CISPR16-2-1
Corvus Orca Energy

The Orca Energy ESS represented a shift in the maritime industry when launched in 2016. No other Energy Storage System can compete with the installation count of the Orca Energy system. Outstanding results and the highest level of safety has set the new industry standard for maritime batteries.

When launched, Corvus Energy combined its industry leading research and development capabilities with several years of experience from having the largest global installed base of ESS solutions to build the industry’s safest, most reliable, high performing and cost effective maritime ESS.

Applications
Orca Energy is ideal for applications that are in need of both energy and a high amount of power, moving large amounts of energy at an inexpensive lifetime cost per kWh. Typical vessel-types are:
- Ferries
- Cruise ships
- Ro/Ro – Ro/Pax
- Yachts
- Offshore vessels
- Rigs
- Tugs
- Fishing vessels
- Merchant vessels
- Port cranes
- Shore charging
- Fish farms

Features
- High C-Rate, up to 6C peak
- Installed on 200+ vessels around the world
- Designed for voltages up to 1200 VDC
- Low installation and commissioning time
- Low life cycle cost
- Enhanced reliability with contained power connections
- Flexible and modularised design
- Passive single cell Thermal Runaway protection
- Scalable capacity and voltage according to vessel requirements
- Industry-proven Battery Management System (BMS)
- Remote monitoring capabilities
- Enhanced EMI immunity design for maritime environments

Corvus Energy safety innovations
Passive-Single - Cell-level Thermal Runaway (TR) Isolation
- True cell-level thermal runaway isolation
- TR does not propagate to neighboring cells
- Isolation NOT dependent on active cooling
Exceeds Class and Flag standards TR Gas venting
- Integrated thermal runaway gas exhaust system
- Easily vented to external atmosphere rather than the battery room

Technical Specifications

<table>
<thead>
<tr>
<th>Performance Specifications</th>
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<tbody>
<tr>
<td>C-Rate - Peak</td>
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<tr>
<td>C-Rate - RMS</td>
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<table>
<thead>
<tr>
<th>System Specifications</th>
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<tbody>
<tr>
<td>Single Module Size / Increments</td>
</tr>
<tr>
<td>Single Pack Range</td>
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<tr>
<td>Max Gravimetric Density - Pack</td>
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<td>Max Volumetric Density - Pack</td>
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<table>
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<tr>
<th>Example Packs</th>
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<tr>
<td>Energy</td>
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<tr>
<td>Voltage</td>
</tr>
<tr>
<td>Dimensions - Vertical Pack - 124 kWh</td>
</tr>
<tr>
<td>Dimensions - Horizontal Pack - 124 kWh</td>
</tr>
<tr>
<td>Dimensions - Tall Pack - 497 kWh</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Example System - 8 Vertical Packs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
</tr>
<tr>
<td>Voltage</td>
</tr>
<tr>
<td>Dimensions 8 x 124 kWh</td>
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<table>
<thead>
<tr>
<th>Safety Specifications</th>
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<tbody>
<tr>
<td>Thermal Runaway anti-propagation</td>
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<tr>
<td>Fire suppression recommended</td>
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<tr>
<td>Disconnect circuit</td>
</tr>
<tr>
<td>Short Circuit protection</td>
</tr>
<tr>
<td>Emergency stop circuit</td>
</tr>
<tr>
<td>Ground fault detection</td>
</tr>
<tr>
<td>Disconnect Switchgear Rating</td>
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<table>
<thead>
<tr>
<th>General Specifications</th>
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<tbody>
<tr>
<td>Class Compliance</td>
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<tr>
<td>Ingress Protection</td>
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<td>Cooling</td>
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<tr>
<td>Vibration and shock</td>
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<td>EMC</td>
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</table>
Corvus Dolphin Energy

The Dolphin Energy ESS is specifically designed for lightweight applications. Dolphin Energy combines outstanding energy density and a reasonable power density with the highest level of safety, setting new industry standard for maritime energy storage systems. The flexible design of the Dolphin Energy allows the system to be stacked in various directions enabling high space efficiency in compact installations.

Applications
Dolphin Energy is ideal for ships with long, slow charges and discharges where lightweight is essential. Typical vessels are:
- Tourist vessels
- Canal boats
- Cruise ships
- Sightseeing vessels
- Ferries

Features
- Low C-rate for slow charge and discharge
- Low weight
- Designed for voltages up to 1000 VDC
- Flexible installation
- Low life cycle cost
- Easy and safe plug and play connections
- Very flexible and modularised design
- Passive single cell Thermal Runaway protection
- Scalable capacity and voltage according to vessel requirements
- Industry-proven Battery Management System (BMS)
- Remote monitoring capabilities
- Enhanced EMI immunity design for maritime environments

Technical Specifications

Performance Specifications
- C-Rate - Peak (Discharge / Charge): 1.1C / 1.0C for 10 seconds
- C-Rate - RMS (Discharge / Charge): 0.5C / 0.4C

System Specifications
- Single Module Size / Increments: 11 kWh / 128 VDC
- Single Pack Range: 11-88 kWh / 128-1024 VDC
- Max Gravimetric Density - Pack: ~183 Wh/kg | 5.5 kg/kWh
- Max Volumetric Density - Pack: ~90-100 Wh/l

Example Pack - 7 Modules
- Energy: 77 kWh
- Voltage: Max 896 VDC | Nom: 805 VDC | Min: 672 VDC
- Dimensions (Vertical): Height: 2370 mm | Width: 654 mm | Depth: 500 mm | 420 kg

Example System - 4 Packs
- Energy: 308 kWh
- Voltage: Max 896 VDC | Nom: 805 VDC | Min: 672 VDC
- Dimensions - 4 x 77 kWh: Height: 2370 mm | Width: 2616 mm | Depth: 500 mm | 1680 kg

Safety Specifications
- Thermal Runaway anti-propagation: Passive cell-level thermal runaway isolation
- Fire suppression recommended: Per SOLAS, class and Corvus recommendation
- Disconnect circuit: Cell individual fail-safe for over-temperature and over-voltage
- Short Circuit protection: Fuses included on cell, module and pack level
- Emergency Stop Circuit: Hard-wired
- Ground Fault Detection: Integrated
- Disconnect Switchgear Rating: Full load

General Specifications
- Class Compliance: DNV GL, Lloyds Register, Bureau Veritas, ABS, RINA
- Type Approval: DNV GL (Pending)
- Ingress Protection: System: IP23
- Cooling: Forced air
- Vibration and Shock: UNT38.3, DNV 2.4
- EMC: IEC 60945-9

Corvus Energy safety innovations
Passive-Single - Cell-level Thermal Runaway (TR) isolation
- True cell-level thermal runaway isolation
- TR does not propagate to neighbouring cells
- Isolation NOT dependant on active cooling
Corvus Dolphin Power

The Dolphin Power ESS is specifically designed for lightweight applications. Dolphin Energy combines outstanding power density and a reasonable energy density with the highest level of safety, setting a new industry standard for maritime energy storage systems.

The flexible design of the Dolphin Power allows the system to be stacked in various directions enabling high space efficiency in compact installations. Dolphin Power is ideal for high-speed vessels that need to boost propulsion to reach max speed, or vessels that must recharge the batteries quickly and often.

Applications
Dolphin Power is ideal for vessels where light weight is essential but where high charge or discharge power is also required. Typical vessels are:
- Fast ferries
- Ferries
- Yachts
- Tourist vessels
- Cruise ships
- Sightseeing vessels

Features
- High C-Rate, up to 4,4C peak
- Low weight
- Designed for voltages up to 1000 VDC
- Flexible installation
- Low life cycle cost
- Easy and safe plug and play connections
- Very flexible and modularised design
- Passive single cell Thermal Runaway protection
- Scalable capacity and voltage according to vessel requirements
- Industry-proven Battery Management System (BMS)
- Remote monitoring capabilities
- Enhanced EMI immunity design for maritime environments

Technical Specifications

### Performance Specifications
- **C-Rate - Peak (Discharge / Charge)**: 4.4C / 2.0C for 10 seconds
- **C-Rate - RMS (Discharge / Charge)**: 2.2C / 1.6C

### System Specifications
- **Single Module Size / Increments**: 7.8 kWh / 128 VDC
- **Single Pack Range**: 7.8-62.4 kWh / 128-1024 VDC
- **Max Gravimetric Density - Pack**: ~130 Wh/kg | 7.7 kg/kWh
- **Max Volumetric Density - Pack**: ~75 Wh/l

### Example Pack - 7 Modules
- **Energy**: 54.6 kWh
- **Voltage**: Max: 896 VDC | Nom: 805 VDC | Min: 672 VDC
- **Dimensions**: Height: 2370 mm | Width: 654 mm | Depth: 500 mm | 420 kg

### Example System - 4 Packs
- **Energy**: 218.4 kWh
- **Voltage**: Max: 896 VDC | Nom: 805 VDC | Min: 672 VDC
- **Dimensions - 4 x 54.6 kWh**: Height: 2370 mm | Width: 2616 mm | Depth: 500 mm | 1680 kg

### Safety Specifications
- **Thermal Runaway Anti-Propagation**: Passive cell-level thermal runaway isolation
- **Fire Suppression**: Per SOLAS, class and Corvus recommendation
- **Disconnect Circuit**: Cell individual fail-safe for over-temperatur and over-voltage
- **Short Circuit Protection**: Fuses included on cell, module and pack level
- **Emergency Stop Circuit**: Hard-wired
- **Ground Fault Detection**: Integrated
- **Disconnect Switchgear Rating**: Full load

### General Specifications
- **Class Compliance**: DNV GL, Lloyd’s Register, Bureau Veritas, ABS, RINA
- **Type Approval**: DNV GL (Pending)
- **Ingress Protection**: System: IP23
- **Cooling**: Forced air
- **Vibration and Shock**: IEC 60068-2.7"
Corvus Moray Power

The Moray Power is a highly advanced battery system for demanding subsea environments. The customer has a unique possibility to customize the product for the required application.

This Energy Storage System is ideal for systems performing active heave compensation, buffer stations or high power rated actuators.

Applications
Corvus Moray Power is ideal for subsea applications where tailor made energy storage systems is needed and regeneration of energy into the battery is expected.

Features
- High C-rate, up to 1.1C peak
- Low weight
- Designed for voltages up to 900 VDC
- Easy and safe plug and play connections
- Low life cycle cost
- Very low self discharge for long term energy storage operations
- Very flexible and modularised design
- Passive single cell Thermal Runaway protection
- Scalable capacity and voltage according to requirements
- Industry-proven Battery Management System (BMS)
- Remote monitoring capabilities
- Enhanced EMI immunity design for maritime environments

Technical Specifications

<table>
<thead>
<tr>
<th>Performance Specifications</th>
<th>Corvus Moray Power</th>
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<tr>
<td>C-Rate - Peak</td>
<td>1.1C for 10 seconds</td>
</tr>
<tr>
<td>C-Rate - RMS</td>
<td>0.55C</td>
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<thead>
<tr>
<th>Operational Specifications</th>
<th>Corvus Moray Power</th>
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<tbody>
<tr>
<td>Single Module Size / Increments</td>
<td>1.3 kWh / 8 VDC</td>
</tr>
<tr>
<td>Single Pack Range</td>
<td>5.3-165 kWh / 32-900 VDC</td>
</tr>
<tr>
<td>Max Gravimetric Density - Pack</td>
<td>~ 145 Wh/kg</td>
</tr>
<tr>
<td>Max Volumetric Density - Pack</td>
<td>~ 135 Wh/l</td>
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<thead>
<tr>
<th>Example Pack - 24 Modules</th>
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<tr>
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<td>Passive cell-level thermal runaway isolation</td>
</tr>
<tr>
<td>Fire Suppression</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Disconnect Circuit</td>
<td>Cell individual fail-safe for over-temperatur and over-voltage</td>
</tr>
<tr>
<td>Short Circuit Protection</td>
<td>Fuses included on cell, module and pack level</td>
</tr>
<tr>
<td>Emergency Stop Circuit</td>
<td>Hard-wired</td>
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<tr>
<td>Ground Fault Detection</td>
<td>Integrated</td>
</tr>
<tr>
<td>Disconnect Switchgear Rating</td>
<td>Full load</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>General Specifications</th>
<th>Corvus Moray Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class Compliance</td>
<td>DNV GL, Lloyd’s Register, Bureau Veritas, ABS, RINA</td>
</tr>
<tr>
<td>Type Approval</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Ingress Protection</td>
<td>System: IP23</td>
</tr>
<tr>
<td>Cooling</td>
<td>Passive</td>
</tr>
<tr>
<td>Vibration and Shock</td>
<td>UNT38.3, DNV 2.4</td>
</tr>
<tr>
<td>EMC</td>
<td>IEC60945-9</td>
</tr>
</tbody>
</table>
The Corvus Moray Energy is a highly advanced battery system for demanding subsea environments. The customer has a unique possibility to customize the product for the required application.

This Energy Storage System is ideal for subsea energy banks for long-term power supply with very low self discharge rated actuators.

**Applications**

Corvus Moray Energy is ideal for subsea applications where tailor made energy storage systems is needed and high energy density combined with low discharge rates are required.

**Features**

- Low C-rate for slow charge and discharge
- Low weight
- Designed for voltages up to 900 VDC
- Easy and safe plug and play connections
- Low life cycle cost
- Very low self discharge for long term energy storage operations
- Very flexible and modularised design
- Passive single cell Thermal Runaway protection
- Scalable capacity and voltage according to vessel requirements
- Industry-proven Battery Management System (BMS)
- Remote monitoring capabilities
- Enhanced EMI immunity design for maritime environments

### Technical Specifications

**Performance Specifications**

<table>
<thead>
<tr>
<th>C-rate - Peak</th>
<th>0.77C for 10 seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-rate - RMS</td>
<td>0.20C</td>
</tr>
</tbody>
</table>

**Operational Specifications**

| Single Module Size / Increments | 1.85 kWh / 8.0 VDC |
| Single Pack Range               | 75-233 kWh / 32-900 VDC |
| Max Gravimetric Density - Pack  | ~ 200 Wh/kg | 5 kg/kWh |
| Max Volumetric Density - Pack   | ~ 190 Wh/l |

**Example Pack - 24 Modules**

| Energy          | 45 kWh      |
| Voltage         | Max: 192 VDC | Nom: 173 VDC | Min: 144 VDC |
| Dimensions      | Height: 2400 mm | Diameter: 360 mm | 230 kg |

**Safety Specifications**

| Thermal Runaway Anti-Propagation | Passive cell-level thermal runaway isolation |
| Fire Suppression                | Not applicable |
| Disconnect Circuit              | Cell individual fail-safe for over-temperature and over-voltage |
| Short Circuit Protection        | Fuses included on cell, module and pack level |
| Emergency Stop Circuit          | Hard-wired |
| Ground Fault Detection          | Integrated |
| Disconnect Switchgear Rating    | Full load |

**General Specifications**

| Class Compliance | DNV GL, Lloyds Register, Bureau Veritas, ABS, RINA |
| Type Approval    | Not applicable |
| Ingress Protection | System: IP23 |
| Cooling          | Passive |
| Vibration and Shock | UNT38.3, DNV 2.4 |
| EMC              | IEC60945-9 |
Corvus Blue Marlin

The Blue Marlin is a unique ESS where Corvus Energy has combined its industry leading research with the development capabilities and knowledge gained from having the largest global installed base of energy storage systems solutions. The result is a new cutting edge ESS with performance nearing a capacitor with improved energy density.

The Corvus Blue Marlin is designed for use in any application when in need of short peaks of high power. It has industry-leading design with no manual connections, enhanced reliability and the highest level of safety.

Applications
- Offshore drilling platforms
- Semi-submersible rigs
- Jack-ups
- Drilling vessels

Features
- Highest C-rate in the industry, 550C peak
- Very long life and minimal self-discharge
- Designed for voltages up to 1094 VDC
- Low installation and commissioning time
- Low life cycle cost
- Enhanced reliability with contained power connections
- Very flexible and modularised design
- Passive single cell Thermal Runaway protection
- Scalable capacity and voltage according to vessel requirements
- Industry-proven Battery Management System (BMS)
- Remote monitoring capabilities
- Enhanced EMI immunity design for maritime environments

Technical Specifications

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</tr>
<tr>
<td>C-Rate - RMS</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>System Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Module Size / Increments</td>
</tr>
<tr>
<td>Single Pack Example</td>
</tr>
<tr>
<td>Max Gravimetric Density - Pack</td>
</tr>
<tr>
<td>Max Volumetric Density - Pack</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Example Pack - 7 Modules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power, Peak and RMS</td>
</tr>
<tr>
<td>Energy</td>
</tr>
<tr>
<td>Voltage</td>
</tr>
<tr>
<td>Dimensions</td>
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<table>
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</tbody>
</table>
Corvus Energy Services

Corvus Energy Storage Systems (ESS) are estimated for a certain lifespan, measured in years after energized. This estimated lifespan is based on a mutually agreed load profile prior to delivery as specified in the Battery System Specification.

Corvus Energy provides a range of aftermarket services – from commissioning, all through the battery lifetime, to decommissioning and recycling.

We offer tailor-made service agreements to each customer’s specific needs, covering the entire lifecycle of the product. With our monitoring services, we can help you ensure improved performance, productivity gains as well as maximized lifetime for your ESS installation.

Life Cycle Service Program

Corvus provides for all installations a Life Cycle Service Program commencing after the Customer Acceptance Test (CAT).

With this service program, Corvus will be able to provide Customers with non-binding performance improvement proposals and vessel-specific information on usage, to help ensure that the energy storage system is operated in accordance to load profiles agreed in the Battery System Specification.

The Life Cycle Service Program includes:

- 24/7 technical support – operated by skilled Corvus Services Engineers
- Support on alarms and incidents handling according to agreed SLA standards
- Required QHSE and incident handling training programs for vessel crew and other resources
- A secure Vessel Information Portal with restricted access and personal credentials
- Continuously monitor and report battery condition in a Power BI application in the portal
- ESS specific documentation and logs are accessible through the Vessel Information Portal
- Inventory list of spares and online spares requests
- Alternative options for battery End of Life/recycling
- Annual expert based advisory report on system usage and performance to achieve estimated life span
24/7 Technical support

Corvus offer 24/7 technical support – operated by skilled Services Engineers.
Our on-duty engineers are trained to assess a failure situation, respond with technical support to perform root-cause analysis and remote advisory on incidents mitigation according to agreed SLA standards.
When an incident arises a service ticket will be initiated forming a unique reference for the technical support issue and tracking of history.
A Corvus Energy engineer will be dispatched to the vessel if needed, within a predefined, agreed time-frame to restore the equipment performance.

Spare Parts

Regular maintenance is key to ensuring the operational safety of your equipment, and to reduce maintenance costs.
The availability of the right spare parts also contributes to operational readiness by avoiding the risk of delays.
Combining the use of quality spare parts from an original equipment manufacturer with continuous monitoring and smart maintenance planning can bring considerable benefits for the lifecycle of an installation.
Corvus offers global inventory management services including local storage of spare parts provided by a Corvus service partner when required for safe operations. We always provide lists of recommended spare parts for each delivery.

Training

Corvus Energy offers a range of training options – both required QHSE and incident handling training programs for vessel crew and other recourses, and tailor made training courses for customers and partners.

Required QHSE training courses:
- Introduction to Corvus Energy Storage Systems (ESS)
- Troubleshooting and maintenance for end-users
- Incidents handling and procedures
- Duration 1 to 2 days. Available on different locations

Advisory services

Corvus Energy holds an unparalleled Maritime DNA and understanding of how energy storage may be utilized in maritime applications. Our unrivalled ESS install base has accumulated more than 2 500 000 operational hours in total.
Based on this vast experience with maritime ESS, from design to operational lifetime, we provide a wide range of advisory services:

- Comparing the battery system usage with predefined operational design targets as set out in the Battery System Specifications, identifying potential deviations from agreed usage.
- Providing expert based reports to vessel owners with all relevant and vital data recorded. - Reports will discuss any usage or conditions that deviate from the agreed profile, and how to mitigate such deviations
- Propose solutions if actions are needed to achieve an estimated life span
- Consultancy towards design companies, system integrators, shipyards, and shipowners
- Battery sizing and lifetime calculations
- Vessel Energy optimization.
- ESS integration and system integration
- Retrofitting (installing ESS on older vessels)

Recycling services

The transition to a fossil-free economy has led to large investments in renewable energy technologies around the world. This includes Maritime Energy Storage Systems (ESS), Electric Vehicles, solar panels and wind turbines amongst others.

Cobalt and Lithium are minerals central to the development and production of these solutions. The demand for minerals is continuously increasing. Cobalt and Lithium may be recycled by extracting the minerals from products and infrastructure that is no longer in use. This will help meet the environmental milestones as decided by the Paris Agreement and 2030 Agenda for Sustainable Development.

As a supplier of Lithium-ion batteries, Corvus Energy takes environmental responsibility seriously and recycling services is an important part of our strategy in its entity. Our main goal is to maintain the sustainable lifecycle of the battery from design all the way through its first and second life to end recycling.
Established in 1988, Elliott Bay Design Group (EBDG) is an employee-owned firm with offices in Seattle, New Orleans, Ketchikan and New York. We offer an array of services including naval architecture, marine engineering and production support to owners, operators and shipyards across the country.

Our mission is to help our clients provide safe and efficient transportation of people and cargo with minimal impact on the environment. In doing so, we seek the best combination of service, quality and innovation to meet the needs of each client.

As a full-service firm, we apply multiple disciplines to our designs, providing clients with comprehensive solutions that meet their goals and objectives. To support this broad-ranging approach, we maintain an extensive technical library of the current USCG, ABS, SOLAS and IMO publications. In addition, EBDG facilitates its clients’ desires to incorporate environmental best practices in the design, construction, operation and eventual disposal of maritime vessels.
offices

EBDG headquarters is located in Seattle’s historic Ballard community. Our facility provides a safe and efficient space that fosters a collaborative work environment while providing room for the needs of our growing staff. In addition to Seattle, EBDG has offices in New Orleans, Ketchikan and New York. The New Orleans office, established in 2006, has grown to become one of the most valued regional vessel support firms on the Gulf Coast. EBDG’s Ketchikan office, opened in 2013, serves as our base of operations within the state. From this locale, EBDG supports clients operating within Alaska and provides a regional resource for quick reaction field engineering. Our most recent expansion to New York strengthens client access and relationship management on the East Coast and is a springboard for future growth.

clients

EBDG is privileged to have worked with a range of clients, both large and small, from private owners and operators to public agencies, shipyards and consultants. Our scope of projects range from new construction to vessel modification and repair. Whether performing a stability analysis or designing a complete vessel, we strive to provide each client with the best professional service possible. Our dedicated team brings a focus on service and professionalism to every project; we are passionate about our work and committed to our clients’ success.
EBDG’s growing team includes architects, engineers, designers and support personnel. The strength of EBDG lies with the depth and experience of our staff. Our senior engineers are variously registered in the states of Alaska, California, Louisiana, Michigan, North Carolina, New York, Oregon, Texas, Virginia and Washington. They are supported by bright, innovative engineers as well as some of the industry’s most talented marine designers. Their combination of extensive hands-on experience in vessel operation, combined with a thorough working knowledge of shipyard construction practices and extensive analytic capabilities, enables EBDG to solve the toughest marine-related engineering challenges.

industry involvement

EBDG strives to be a valuable resource for its clients and the industry by remaining actively involved in issues and organizations concerning all segments of the marine transportation sector. Membership in professional organizations, regulatory committees, commercial clubs and trade organizations, on both a staff and corporate level, keeps EBDG informed of the issues impacting the ever-changing maritime environment.

**EBDG organizational affiliations include:**

- American Bureau of Shipping
- American Society of Mechanical Engineers
- American Waterways Operators
- Canadian Ferry Association
- Interferry
- International Association of Drilling Contractors
- National Fire Protection Agency
- National Research Council Transportation Research Board
- Northwest Fishing Association
- Offshore Marine Services Association
- Passenger Vessel Association
- Propeller Club
- Puget Sound Maritime Historical Society
- Royal Institute of Naval Architects
- Society of Naval Architects & Marine Engineers
- Society of Port Engineers
- Washington Maritime Blue
- Worldwide Ferry Safety Committee
key market experience

Barges
EBDG’s portfolio of barge designs range in size and capacity, from shallow-draft river service to bunkering, ocean towing and ATBs. We have various specialized designs such as multi-cargo, hazardous cargo, specialty equipment deck barges and multiple LNG barges for both bunkering and transport. EBDG supports its customers in the design and integration of onboard systems, including vapor control and recovery, inerting, cargo transfer and blending, and ballasting.

Ferries
As the recognized national leader in vehicle ferry design, we have designed more ferries than any other firm in the United States. We are intimately familiar with the needs of a ferry to be both economical to operate and attractive and comfortable to the riding public. EBDG provides its clients with a wide-range of ferry design and engineering services including repowerings and mid-life refurbishments, structural, motions and stability analysis, efficiency studies, transportation and environmental studies, capital budgets and security improvements as well as incident response, construction liaison services, bid support, and contract negotiation assistance.

Fishing Vessels
EBDG’s history of supporting fishing vessel owners and operators dates back to the 1950s. Our firm has proudly served this vital sector with a number of vessel projects encompassing a wide array of engineering services. We have provided technical support and on-site inspection services for owners, shipyards, vendors, and financial institutions.

Floating Structures
EBDG has significant experience working with floating marine structures including drydocks, floating surface collectors, caissons, bridges, and breakwaters. Our depth of expertise ranges from basic design using regulatory formulas to first principle analysis using advanced finite element analysis (FEA) techniques to include the effects of damage and corrosion. We remain current with applicable regulatory criteria and operational aspects of drydocks.
key market experience, cont.

Oilfield Vessels
EBDG is actively involved in providing vessel engineering design expertise for the offshore industry. Our clients include oil companies, shipyards, operators, contractors, service companies and suppliers. We have performed concept through detailed engineering of hull structures, marine systems, and specialized equipment. In addition to new design, our team is frequently called upon to provide plans for modifications and conversions of existing vessels.

Passenger Vessels
EBDG’s engineering team are specialists in passenger vessel design. We design exciting vessels that attract customers while paying close attention to operational and long term maintenance costs. In addition to our many successful ferry projects, EBDG also provides technical services for other passenger vessel types – cruise ships, casino boats, and excursion vessels. We have designed sailing ships, stern paddlewheel vessels, high-speed planing hulls, and robust landing craft.

Research Vessels
EBDG’s innovative thinking and vast experience make us the firm of choice to design and engineer a research vessel ideally suited to adapt to the needs of the science community. Our clients have included the University of Connecticut, the Bermuda Biological Research Station, the US Army Corps of Engineers, the National Oceanographic and Atmospheric Administration, and Cape Fear Community College. On their behalf, we have applied a variety of tools to develop hulls with good seakeeping, safe working decks, innovative hybrid propulsion systems, and strong working deck gear. Our skills give the scientists a platform they can depend upon.

Tugs & Towboats
EBDG designs innovative, efficient tugs and towboats including coastal towing, ship escort, ship docking, and emergency response vessels, among others. To meet the specific operational needs of operators, vendors, and test facilities, we stay abreast of the latest performance research, equipment development, and environmental challenges. Our design portfolio includes more than 50 different tugboats, ranging from small harbor tugs to deep sea salvage tugs. In addition to new designs, we offer broad experience in repowering, tonnage reduction and modification projects.

Workboats & Specialty Vessels
At EBDG, we have the expertise to undertake one-of-a-kind design projects. We understand that these unique projects require specialized management as well as innovative design and equipment approaches. Among the various workboat types in our project portfolio are lightering support vessels, landing craft, fireboats, patrol and pilot boats.
contact information

Seattle
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