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Revolutionizing the electrification of tugs – the next transformation in clean energy

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SYNOPSIS
New International Maritime Organization (IMO) GHG reduction regulations and subsequent expectations of tug owners and operators to meet those new targets are approaching. Tugs that are low and zero emissions will thus be preferred by their customers, and in many cases, required as the entire maritime supply chain demonstrates a commitment to climate action. Shift Clean Energy has introduced a revolutionary clean energy technology that will result in tug fleet owners and operators meeting tough new environmental laws, improve financial earnings and deliver high operational performance in an environment of exponentially growing marine vessel traffic. The paper gives a summary of Shift Clean Energy's game-changing model for tug electrification.

Introduction

Tug owners and operators are facing some of the greatest challenges the industry has ever faced. New laws and regulations to reduce greenhouse gas emissions and improve local air quality are forcing owners to abandon the use of conventional marine diesel power systems and adopt low-emission power systems.

Several technologies are vying to become the global standard including battery electric, hydrogen fuel cell, liquified natural gas (LNG), diesel hybrid and biodiesel fuels. The successful technology must meet tough new environmental requirements, have the best business case, meet and exceed performance and safety specifications and several additional critical factors.

Shift Clean Energy has introduced a revolutionary clean energy technology that will result in tug fleet owners and operators meeting tough new environmental laws, improve financial earnings and deliver high operational performance in an environment of exponentially growing marine vessel traffic.

The following technical paper provides:

- an overview of the emerging climate change policies and legislation driving massive changes in marine low-emission power system technologies;
- an overview and comparison of low-emission power system technologies under development, and
- a detailed overview of the industry-leading features of the Shift Clean Energy Electric Battery PwrSwäp which makes it the best solution for tug fleet owners and operators.

Achieving zero carbon operations and improved financial returns

In 2015, countries came together in Paris, France to sign the Paris Agreement which commits signatories to a goal to limit global warming to well below 2 degrees Celius, preferable to 1.5 degrees Celsius, compared to pre-industrial levels [1]. Since the creation of the Paris Agreement, 194 countries and the European Union have signed the Agreement. Many national signatories to the Paris Agreement have made significant commitments to reduce their greenhouse gas emissions and have released plans on how it will be achieved. A large and growing number of countries, including the UK and the European Union, have made commitments to achieve carbon neutrality by 2050, and a growing list of countries have committed to achieving carbon neutrality significantly sooner. It is prudent to anticipate that most countries will join this effort to commit to achieving carbon neutrality by 2050 or sooner. These commitments will impact across all industries, and in particular, the marine transportation industry which both is a major source of global greenhouse gas emissions and significantly impacts local air quality from using bunker and diesel fuels.

For the past several decades there has been a lot of talk about making changes and starting to do something about climate change in our industry. The time for talk in our industry ended several years ago and today tug fleet owners and managers need to make concrete changes to their fleets and operations to reduce emissions or face significant financial consequences. New regulations on greenhouse gas emissions from shipping means that fleet operators will need to begin modifying their existing

fleets to reduce their fleet greenhouse gas emissions and choose new emission-free technologies when replacing aging ships. This needs to be accomplished at the same time as maintaining the financial viability of our industry and responding to growing demand for our services as port traffic continues to grow exponentially.

The International Maritime Organization (IMO) has acknowledged the climate change challenge and taken action to create change. It marked 2021 as a decade of action in cutting greenhouse gas emissions from shipping with the first international mandatory measure to improve ship energy efficiency [2]. With IMO rules requiring that by 2050, greenhouse gas emissions will have to be 50% lower than 2018 levels, tug fleet and owners and operators must begin to make the transition to cleaner power sources [3]. It can reasonably be expected that these rules will be increasing toward a 70% reduction. In addition, new laws are being passed that require ports to reduce greenhouse gas emissions and improve air quality from port operations are further putting pressure on tug fleet owners and operators to act.

While facing these new emission regulations, the tug industry continues to face significant financial pressure. Over the past several years the capital cost of vessels has been significantly increasing as demand for new ships of all types has pushed up costs at shipyards. Operating cost such as fuel, maintenance, insurance, harbour dues, berthage, and foreshore leases have also continued to steadily increase. In addition, the tug workforce is aging, and it is increasingly difficult to attract new workers to our sector which is putting pressure on wages and benefits. Tug fleet owners and operators are looking across all areas to reduce costs in order to remain financially viable.

It is abundantly clear that the selection of a new technology to meet emission IMO and port-specific emission requirements must also be affordable from both CAPEX and OPEX perspectives.

Emerging power system technology options

Tug owners and operators are being inundated with new technological solutions to help them meet new requirements to reduce and ultimately eliminate emissions from their operations. The following provides an overview of the major technologies under development and compares them across a range of critical factors for fleet owners and operators to consider when making long-term and potential expensive decisions.

Full-Cycle Electric Battery – Fit tugs with electric batteries sized to meet a full operational cycle (up to 14 hours) on a single charge, accommodate rapid recharging and diminishing performance resulting of rapid recharging. Electric motors must be sized to accommodate tug performance requirements and large battery mass. Rapid recharging stations require high electric energy demand, more complex cooling systems and other critical safety elements. Rapid battery recharging quickly degrades battery life requiring frequent and expensive battery replacement.

Shift Clean Energy Electric Battery PwrSwäp – Fit tugs with electric batteries sized to be rapidly swapped several times per operational cycle. Batteries are significantly smaller, and less massive, which can also reduce electric motor size and mass. Batteries are slow charged on shore improving the durability of the battery and requiring lower electric energy demand, smaller cooling systems and improved safety. Batteries, swapping and charging facilities owned by separate company requiring tug fleet owners to only pay for electricity and a service fee.

Hybrid Diesel Electric – Combines traditional diesel marine engines with batteries and electric motors, like hybrid automobiles. Improved emission performance, but limited reduction potential. More suitable as a bridging option.

Hydrogen Fuel Cell – Hydrogen fuel cell systems produce electricity from liquid or gaseous hydrogen. Liquid hydrogen storage on vessels requires specialized tanks to maintain storage temperatures lower than 20 degrees Kelvin [4] (-423 degrees F, -253 degrees C) and shore-based hydrogen storage and refueling systems. Emissions from hydrogen fuel cell operations include water and heat as well as boil off hydrogen to maintain temperature within the storage tank. Hydrogen bunkering, shore storage and handling requires special materials to avoid embrittling.

Liquified Natural Gas (LNG) – LNG-fueled tugs use a modified internal combustion engine and can also burn diesel fuel. LNG is stored on the vessel in special tanks to maintain 111 degrees Kelvin [5] (-260 degrees F, -162 degree C) as well as shore-based storage and refueling facilities. Emissions from LNG fueled vessels include hydrocarbons, nitrogen oxides, carbon monoxide and carbon dioxide. Unlike diesel fueled vessels, LNG fueled vessels produce no sulphur oxides or particulate.

Marine Biofuels – Marine biofuels systems use conventional diesel internal combustion engines. Biofuels are manufactured using sustainably produce organic material (cereal crops, forestry waste, municipal sewage and solid waste) in refineries in alongside conventional crudes. Biofuels produce significantly fewer particulates and generally no sulphur oxides; however, nitrogen oxides must be controlled. Biofuels are viewed as fossil fuel extenders and are unable to fully replace conventional crudes. Availability of marine-grade biofuels is limited, and most engine manufacturers do not warranty biofuels at this time.

The following table compares emerging tug low-emission energy technologies across a range of factors. Factors are ordered from left to right based on importance to fleet owners and operators. As can be seen on the table, the battery swap electric option best meets the financial, operational, and environmental performance requirements for tug fleet owners and operators today and to meet future requirements.

Comparison of Low-Emission - Tug Fleet Power Supply Options							
	Operational Uptime	Technical Maturity	Capital Cost	Operating Cost	Safety	Tug Emissions	Technical Performance
Full Cycle Electric Battery							
Battery Swap							
Hybrid Diesel Electric							
Hydrogen Fuel Cell							
LNG							
Marine Biofuels							

Shift Clean Energy Storage System

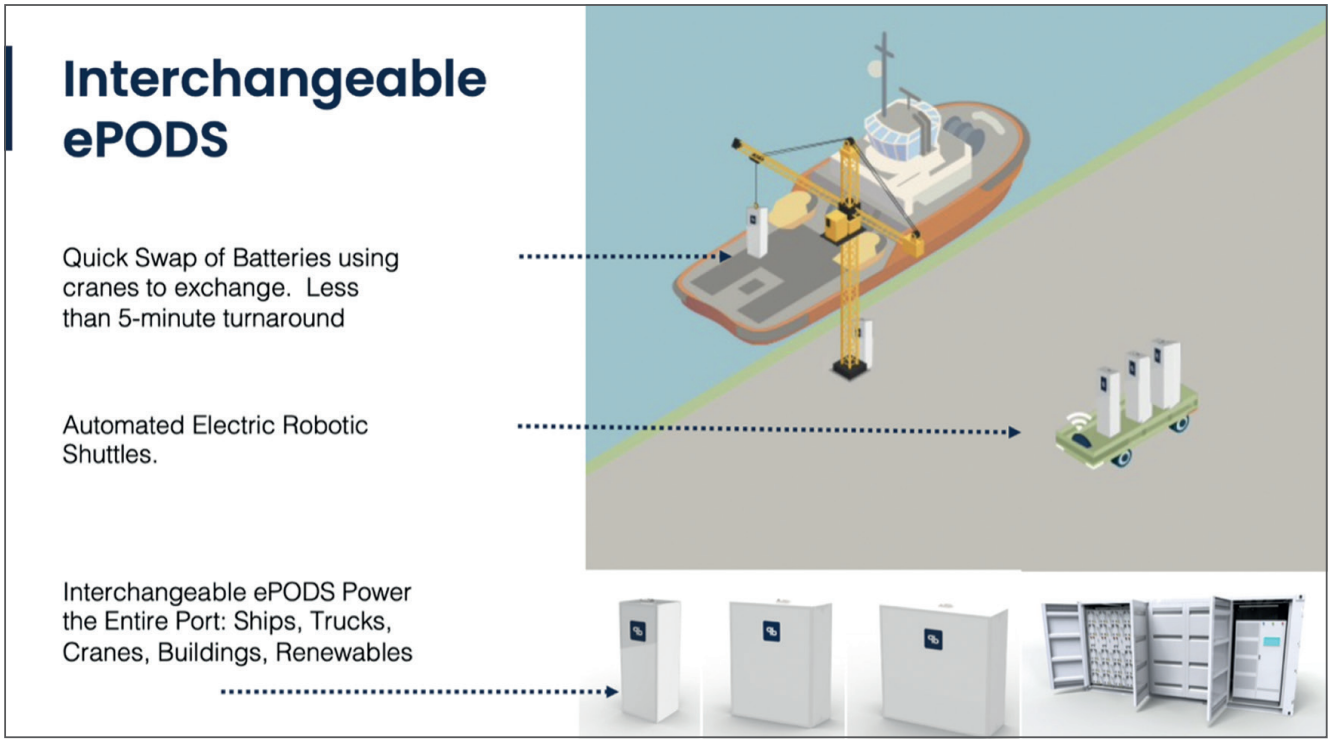
Shift Clean Energy has found a way to revolutionize energy storage systems (ESS) in the marine space to make the transition to zero and low emission operations not only feasible but provide real ROI to fleet operators. We are now offering a new model for tug electrification that removes the generally accepted 'limitations' of energy storage solutions such as size, weight, charging, and CAPEX.

Rapid battery pod swapping technology

The foundation of the Shift is the installation of battery pods that can be swapped with fresh batteries in less than three minutes using a crane. Swapping can be completed multiple times over a vessel's operating cycle. The diagram below shows the ease of the system from both a vessel layout and shore-based systems.

This system provides several important advantages over other power system options, including:

- ***Battery Pod Location*** – Our safety rating allows us the flexibility of placement, including outside the traditional battery room, leaving room below deck for other critical systems. The machinery space A60-rated pods can be positioned vertically or horizontally in a variety of spaces, depending on tug design. Battery pods are in the optimal position for quick access.
- ***Smaller and More Efficient Electric Motors*** – The electric motors replacing marine diesel engines are typically smaller, quieter and require less maintenance resulting in better performance and higher operational up time.
- ***Smaller and More Efficient Battery Power System*** – Because battery pods are rapidly swapped as needed



during the operational cycle, battery pods are significantly smaller and less massive than battery systems designed to last an entire operating cycle. This improves vessel performance and reduces energy consumption.

- ***Minimal Downtime for Battery Swapping*** – Tugs being refueled with liquid or gaseous fuels face extended refueling times. This results in lost operational time and higher crew costs. With the Shift batteries taking only three minutes to be changed, the tug
- ***Improved Battery Life Reducing Cost*** – Batteries are slow-charged in a central location. Slow charging batteries significantly increases the number of life-time battery charging cycles compared to rapid charging batteries. Batteries last longer, reducing the service fee to the tug fleet owner and reduces waste. There is also no need to tie up tugs to a charging location and attach high-voltage cables.
- ***Highest Battery Safety Performance*** – Shift batteries are designed to eliminate the possibility of a thermal runaway event. In addition, Shift batteries can be dropped or punctured without the possibility of igniting.
- ***Future Proof Regulatory Compliance*** – By being emission free today, electric tugs will meet all future emission requirements. The same cannot be said for energy sources which continue to release greenhouse gas emissions.
- ***Integration with Electrified Ports*** – As ports become fully electrified to reduce emissions across all facets of port operations, the PwrSwäp system completely integrates with port power systems.

Maximizing ROI for tug owners and operators

Shift has brought a new power system financial model to the marketplace for tug owners. Traditionally, tug fleet owners have been required to borrow and capitalize vessel power system conversions or pay significantly higher upfront costs for expensive new power systems when ordering new vessels.

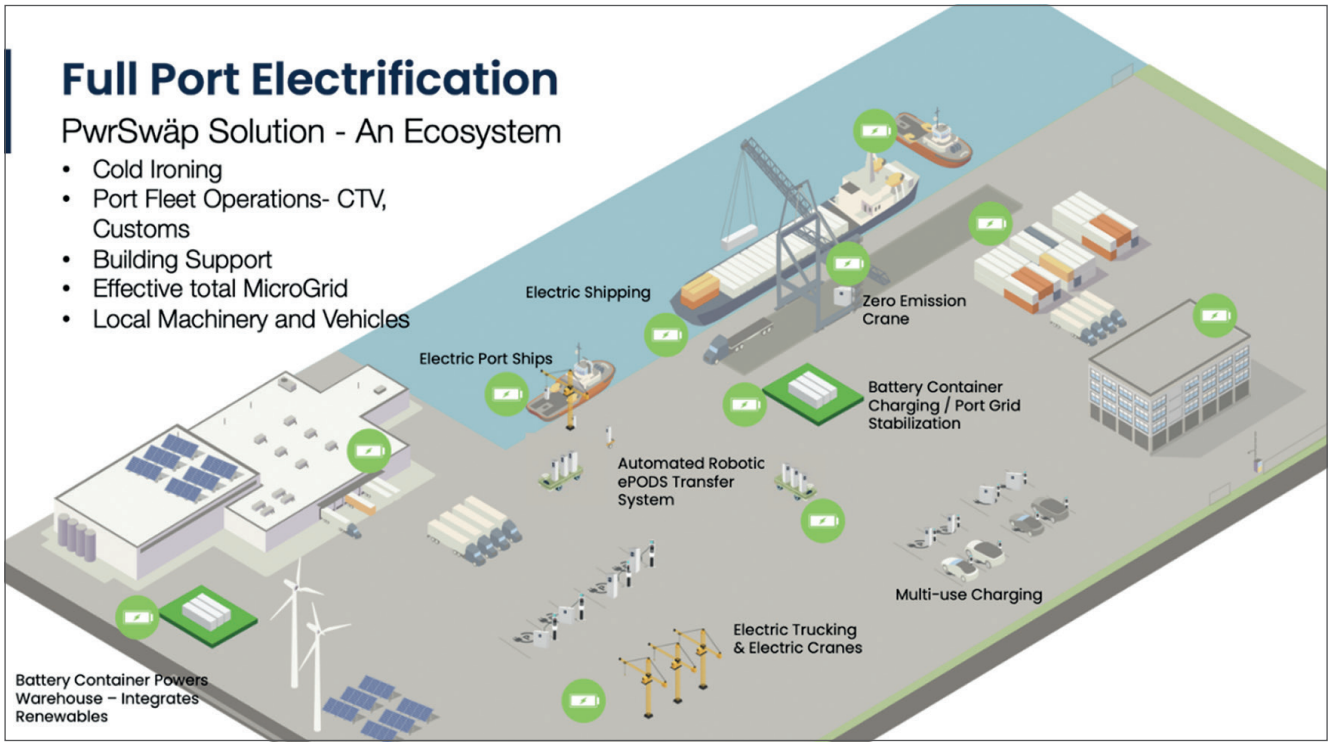
With Shift, tug fleet owners do not purchase or maintain the battery pods or shore-based facilities to change out and recharge battery pods. Instead, tug fleet owners only pay for the energy consumed and a monthly service fee. Shift owns and maintains the battery pods ensuring that vessels are always using batteries that are within optimal operating parameters. Most importantly, tug fleet owners do not need to borrow or capitalize for these systems, freeing up balance sheets for other important investments.

Shift and its practical pay-as-you-go PwrSwäp service gives customers clean energy with more reliability but with less risk. Customers save money from day one, while meeting climate action goals through electrification.

The right choice for tug owners and operators

Shift Clean Energy has developed the industry leading electric tug system which produces superior financial returns while meeting current and future emission regulations:

- Shift is taking action on climate change now by providing customers with a reliable, affordable way to electrify and reduce GHG because reliance on fossil fuels, including in the maritime industry, is causing climate change
- Shift is a pioneer in delivering zero emissions solutions to the maritime industry, empowering customers to address climate change by using our safe energy storage systems to electrify.
- Shift is a practical solution that empowers customers to Shift 2 Clean Energy. Shift brings together proven technologies and provides something no one else has: our pay-as-you-go PwrSwäp ecosystem.



• PwrSwäp delivers energy when and where you need it.
  - Shift builds the batteries and charging infrastructure to fit what the customer needs, where the customer needs it.
  - Our PwrSwäp system can power ports, terminals, inland sea short sea shipping vessels, and other industrial sites and even isolated communities.
  - Shift empowers customers to meet corporate and IMO climate action goals through electrification.

Conclusion

Shift's new system will be an exciting new opportunity for the tug industry when it comes to achieving environmental and efficiency goals. For tug owners and operators that want to move towards IMO targets and position themselves as zero emissions leaders, the PlanB solution is the winning one.

References

[1] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[2] https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Technical and Operational Measures/Resolution MEPC.203%2862%29.pdf
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