Everllence B&W
two-stroke
marine engines

A leap in vessel energy efficiency advancement with engine-supported air lubrication

Contents

Executive summary

- The fastest way to decarbonise shipping is to burn less fuel.
- Less fuel means lower emissions, lower cost, and lower risk for shipowners.
- Efficiency is the only strategy that always pays under every credible future framework.

Introduction and regulatory developments

While the goal of shipping's decarbonisation is clear, the direct pathway remains unsettled. The International Maritime Organization has defined an ambition to reach net-zero emissions by or around 2050, but the mechanisms intended to guide this transition – particularly the mid-term measures shaping the Net-Zero Framework – remain under active discussion. This creates a paradox for decision-makers: long asset lifetimes demand clarity, while the regulatory architecture continues to evolve.

In this environment, a robust strategy cannot depend on a single fuel pathway or a predefined regulatory outcome. Instead, it must prioritise measures that deliver value across scenarios – technologies that reduce fuel consumption, lower exposure to fuel price volatility, and limit the total amount of energy requiring decarbonisation. In other words, the transition must begin with reducing the size of the problem itself.

From an engine designer's perspective, this places energy efficiency at the centre of the transition. Regardless of how fuels are regulated – whether through well-to-wake intensity limits, market-based mechanisms, or hybrid approaches – the absolute demand for energy will remain the dominant driver of both emissions and cost. Efficiency improvements are therefore not an alternative to the transition of fuel, but a prerequisite for making it feasible.

Engine-supported air lubrication (ESAL) (Fig. 1) represents a step change in this direction. By reducing the fuel required to deliver a given transport work, ESAL contributes directly to easing the green transition. At the same time, it represents a compelling business case for owners and operators, lowering fuel costs and reducing exposure to regulatory mechanisms such as the Energy Efficiency Design Index (EEDI), Carbon Intensity Indicator (CII), and FuelEU Maritime penalties where fuel greenhouse gas (GHG) intensity exceeds applicable limits. In this sense, ESAL aligns environmental performance with operational economics, making it valuable already under existing frameworks - independent of how the Net-Zero Framework ultimately materialises.

Everllence brings decades of experience in integrating engine and vessel systems to unlock such efficiencies. Solutions such as waste heat recovery and advanced power take-out configurations have long demonstrated how deeper integration of the propulsion plant can expand the efficiency potential of commercial vessels. More recently, wind-assisted propulsion and air lubrication systems have emerged as additional pathways to reduce energy demand even further. ESAL builds on these developments by combining principles known from both waste heat utilisation and air lubrication, rethinking how air is supplied and utilised to unlock efficiency gains that have historically been limited by auxiliary energy consumption, namely stand-alone compressors dedicated to hull air supply.

This paper examines the hydrodynamic principles, engine integration, and system-level effects of ESAL, and evaluates its contribution to reducing both fuel consumption and the cost of compliance. ESAL is not only a technology, but a strategic response to uncertainty in the regulatory landscape.

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The strategic relevance of ESAL, however, ultimately rests on its physical effect on the vessel. The reduction in fuel consumption is not achieved through abstraction, but through a direct reduction of hydrodynamic resistance and a more efficient utilisation of energy within the propulsion system. To understand both the magnitude and the boundaries of the savings, it is therefore necessary to examine how air lubrication alters the interaction between hull and water, and how integration with the main engine enables these benefits to be realised with reduced energy penalty, effectively maximising net energy savings. The following sections outline the principles of air lubrication and the specific mechanisms through which ESAL translates system integration into measurable and commercially relevant efficiency gains.

Principles of air lubrication

The biggest resistance to overcome for any commercial vessel is the friction between the hull and the water. By feeding air to the boundary layer, air lubrication systems (ALS) are showing promising reductions in this drag on the bottom shell.

Air lubrication systems exist in many different forms. However, the overall principle is the same: air is distributed to the boundary layer to reduce its density and thereby lower frictional resistance.

Experiments are still being carried out on the design of air release systems distributing the air along the vessel bottom. Several designs exist, including a single release band at the bow and several release bands along the bottom.

In configurations with a release band at the bow, the “air carpet” may not fully cover the flat part of the bottom area, particularly in sea states with some degree of vessel motion, although air lubrication systems differ.

As ALS-induced drag reduction affects only the flat bottom of the hull, the savings potential depends on the ratio of flat bottom area to the total wetted surface. In addition, the length-to-breadth ratio impacts the potential efficiency, as this ratio reflects how effectively the established air carpet is utilised. Furthermore, the draught of the vessel is directly related to the pressure at which the air needs to be released. All these parameters are illustrated and exemplified in Fig. 3 and Table 1.

Considering these three factors, the relative savings are generally highest for wide beam vessels with a relatively low draught and a high ratio of flat bottom area to total wetted surface, such as LNG carriers, container vessels, and ro-ro cargo vessels, depending on their specific dimensions. However, ALS can still play a substantial role for vessels with a relatively high design draught, as when operating, i.e., an ore carrier or large crude oil carrier in ballast, the flat part of the bottom constitutes a large share of the wetted surface.

An additional saving from ALS that is often overlooked is its positive impact on propeller loading, as reducing resistance directly reduces the thrust the propeller must deliver. Low-

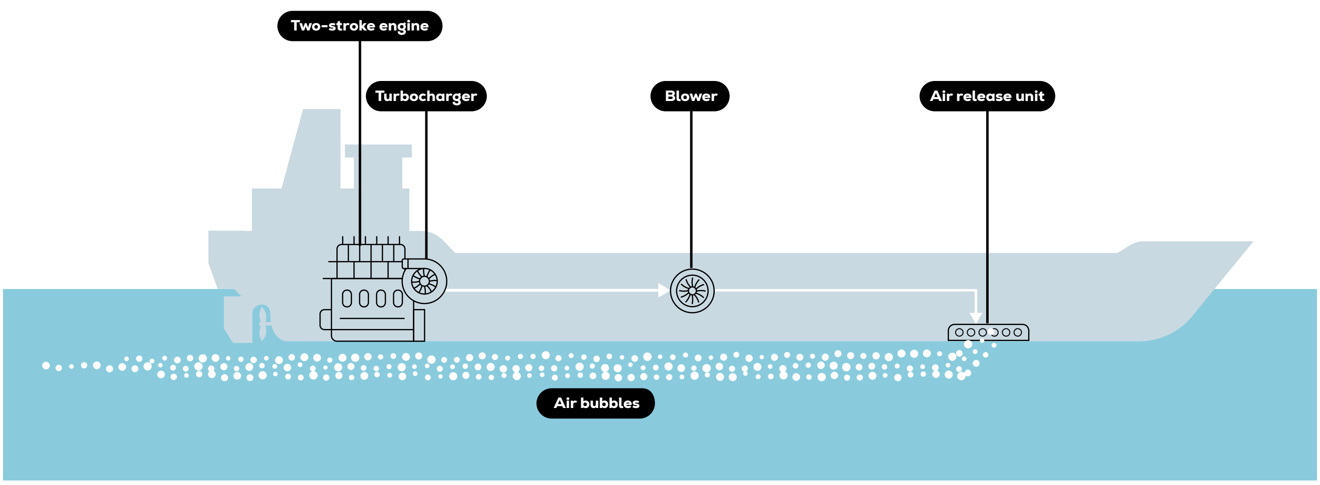


Fig. 1: General principles of engine-supported air lubrication

ering the loading of the propeller increases the propeller efficiency. Traditionally, propellers on bulkers and tankers are relatively higher loaded, as ballast conditions limit the maximum propeller diameter. Therefore, even if the relative reduction in skin friction is lower for such vessels, the relatively larger impact on propeller efficiency partially compensates for this.

In addition, it is important to recall that ALS reduces only the frictional resistance component, the residual “wave making” resistance is not reduced by a reduction in skin friction. As the vessel speed increases, the benefit of operating the ALS will be relatively smaller. Considering all the above factors, it is difficult to establish a general savings potential for ALS across all possible applications, and a case-by-case evaluation is necessary.

All hydrodynamic and performance savings presented in this paper represent Everllence's generic understanding of air lubrication technologies and do not reflect the results of any single air release methodology or specific manufacturer of air lubrication systems.

When utilising air lubrication, regardless of whether the air is supplied by compressors or by the main engine, the operating point of the propeller changes as the vessel resistance decreases for an unchanged ship speed.

When evaluated from a ship speed perspective, the impact of operating the ALS is as shown in Fig. 2, regardless of whether the ALS is supplied with air from compressors or from the main engine.

Depending on ship speed, the share of the flat bottom in the total wetted surface area, sea state, etc., Everllence’s experience shows that the gross savings achieved through ALS operation vary depending on the application, ship speed, load profile, draught and ALS.

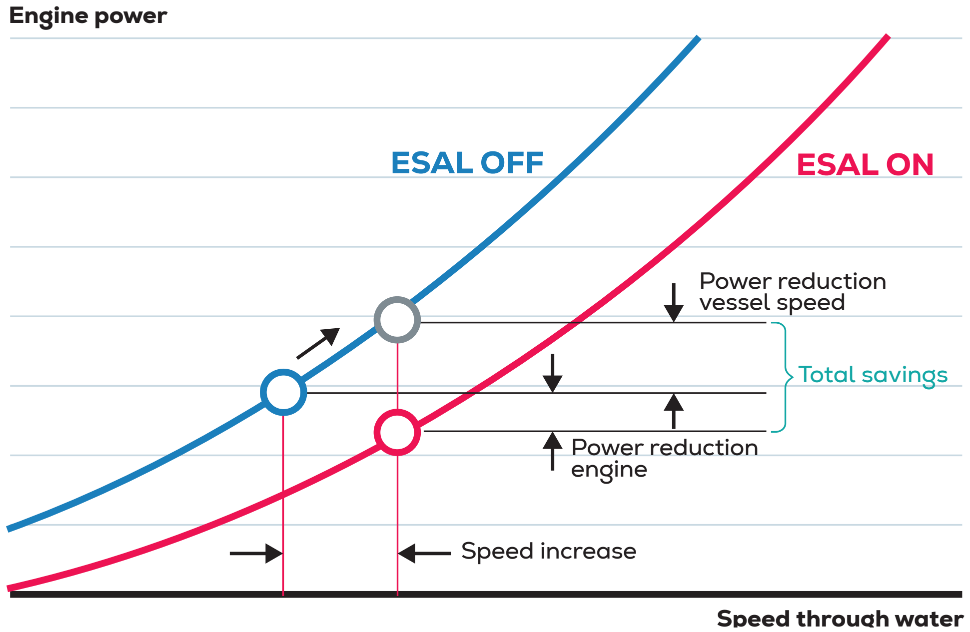


Fig. 2: When the ALS is activated, all other parameters being equal, including the engine speed setting, there are two main effects that contribute to the overall saving. First, the hull resistance is reduced, which increases the ship speed for the same engine speed setting. Second, the reduced thrust requirement lowers the engine power needed to maintain the engine speed. The increase in ship speed can be converted into additional savings if the main engine speed setting is reduced accordingly

Principles of engine-supported air lubrication (ESAL)

By allowing the main engine to supply the air required for the ALS, it is possible to substantially reduce the energy required to compress air and reduce the need for compressors installed onboard.

In the ESAL application, air is supplied by the turbocharger. The impact on engine specific fuel oil consumption (SFOC) varies with the engine load, see Figs. 4 and 5.

Two parameters are key for the engine to deliver air to an air lubrication system: airflow and pressure.

With the ESAL solution from Everllence, the engine control system (ECS) continuously monitors and regulates the airflow to ensure safe engine operation while delivering the required air supply. The ECS also controls a booster blower to ensure that the ALS receives the required airflow and pressure without exceeding limitations on the main engine. Typically, up to 10–15% of the scavenging air can be supplied to the ALS, depending on load and engine configuration.

The scavenge air pressure varies with engine load. However, across the range of two-stroke engine types, the scavenge air pressure is more or less constant from the smallest to the largest bore sizes.

The number of turbochargers installed on an engine can greatly affect the load range over which the scavenge air pressure can be maintained at a level that supports the ALS with minimal assistance from the booster blower. For 80-bore engines and larger, sequential turbocharging with more than one turbocharger enables turbocharger cut-out at lower loads. As a result, the scavenge air pressure can be kept within the ALS operating range.

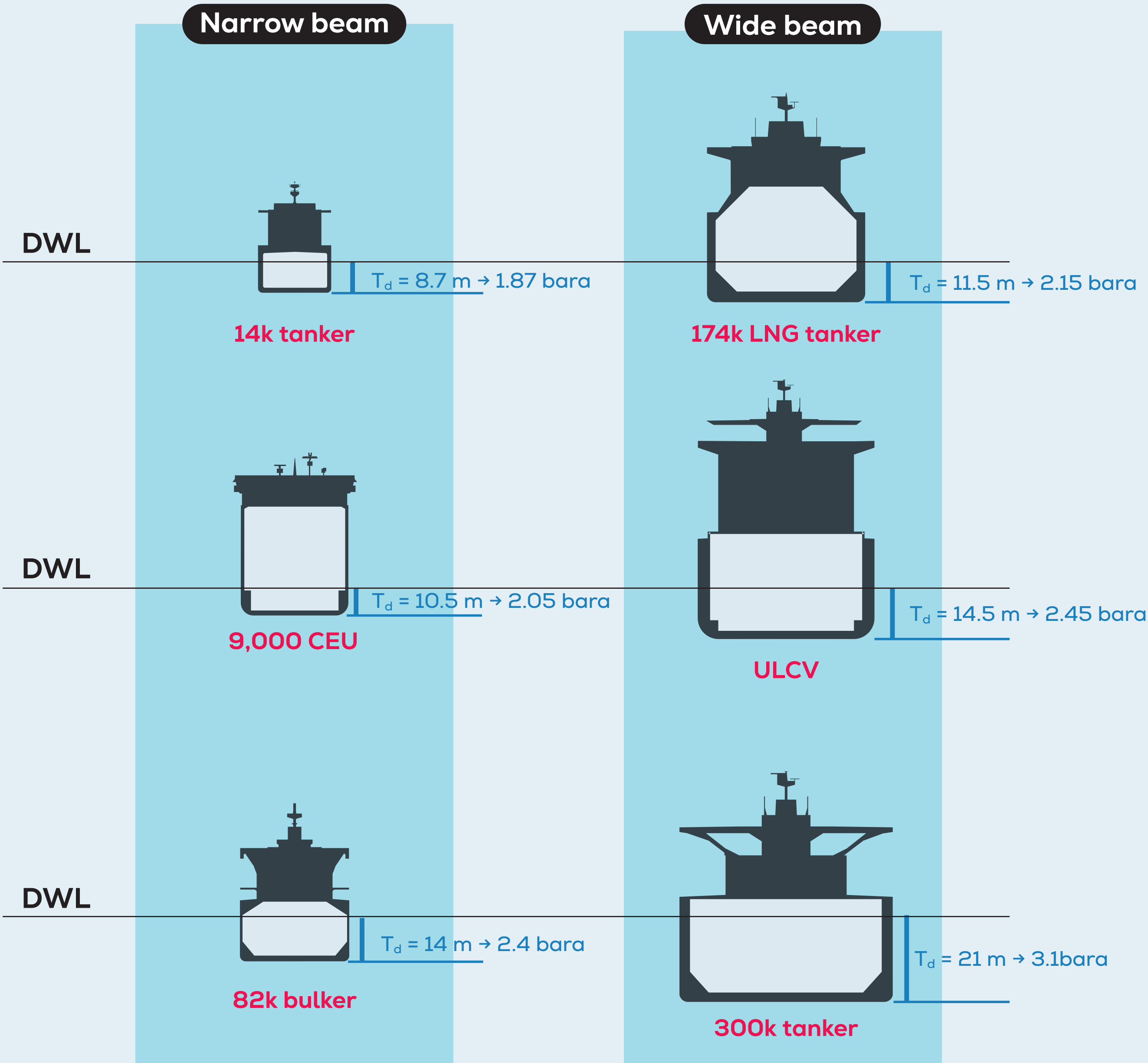


Fig. 3: Illustration of draught and beam for different ship types

	Design draught, Td [m]	Pressure at bottom [bara]	L/B ratio [-]	Flat bottom/wetted surface [-]
14k dwt chemical tanker	8.7	1.87	5.7	≈0.51
174k dwt LNGC	11.5	2.15	6.2	≈0.59
8,000 lm ro-ro cargo vessel	7.2	1.72	7.0	≈0.59
9,000 CEU	10.5	2.05	7.1	≈0.52
24k teu ULCV	14.5	2.45	6.3	≈0.65
82k dwt Kamsarmax bulker	14.0	2.4	7.2	≈0.52
300k VLCC	21	3.1	5.3	≈0.57

Table 1: Overview of key parameters affecting the efficiency of ALS and ESAL for different ship types. The area of the flat bottom is estimated by $A_{bottom}=L\times B\times C_B$ and the wetted surface by Mumford's equations

Optimum application of ESAL

When combining the considerations regarding hydrodynamic savings and the impact on engine efficiency, it becomes evident that ALS and engine-based air supply are well suited to achieving maximum relative savings for vessel types characterised by a relatively low draught and high beam, including but not limited to LNG carriers, container vessels, and ro-ro cargo vessels.

Everllence's initial developments focus on two-stroke G95 and G80 engines, given the benefits provided by sequential turbocharging combined with economics of scale.

Throughout this paper, the effects of ESAL for two-stroke engines are illustrated on a New Panamax container vessel with a G95ME-C10 and a Post Panamax container vessel with a G80ME-C10 engine. Furthermore, the potential gains of applying ESAL on an LNG carrier with a G70ME-C10 engine are illustrated as well, even if not prioritised for initial development. Table 2 lists the three vessels examined.

For four-stroke engines, ESAL can also provide significant benefits, especially in a propulsion plant with several units, either in a diesel-electric or father-and-son configuration, as it is possible to maintain engine load and thereby pressure throughout the operational profile. Such solutions are currently being investigated.

Example vessel	New Panamax vessel	Post Panamax vessel	LNG carrier
Capacity	16,000 teu	8,000 teu	174k CBM
Engine type	8G95ME-C10	7G80ME-C10	2x5G70ME-C10
Power	45,000 kW	30,000 kW	2x12,500 kW
Design draught	15 m	13 m	11.5 m

Table 2: **Vessels for which ESAL have been evaluated: New Panamax and Post Panamax container vessels, and LNG carrier. The ESAL principles are largely unaffected by the engine dot number**

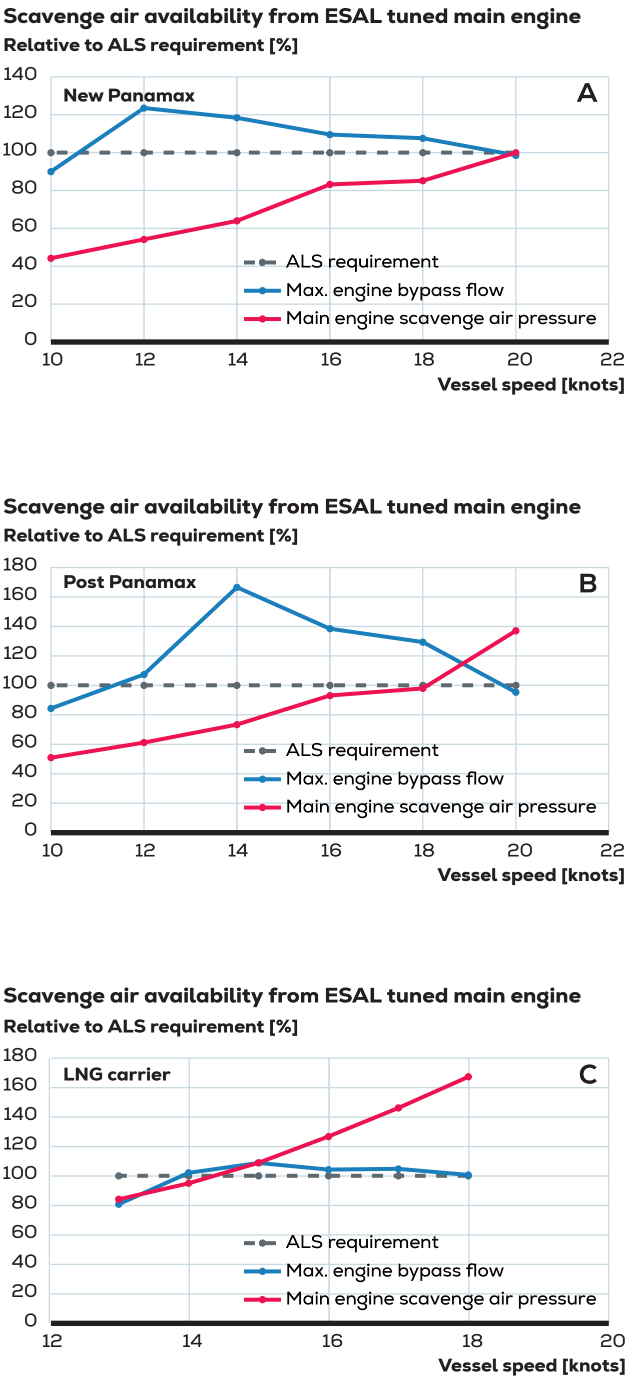


Fig. 4: Illustration of scavenge air pressure and airflow available from the main engine with ESAL for a) New Panamax, b) Post Panamax container vessels, and c) LNG carrier, engine load including PTO load. Please notice that due to the lower draught of the Post Panamax vessel and LNG carrier, the pressure of the scavenge air is sufficient in a wider speed range

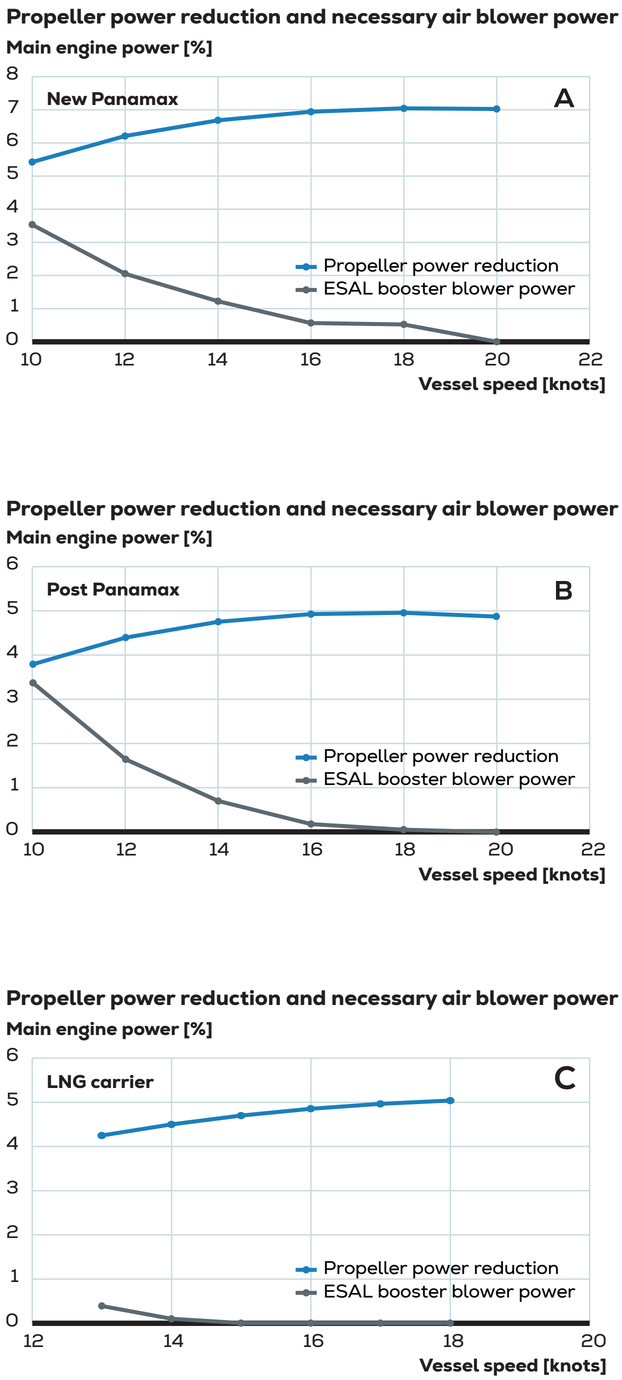


Fig. 5: Reduction of propeller power by applying air lubrication for a) New Panamax, b) Post Panamax container vessels, and c) LNG carrier.

ESAL impact on engine and net-savings

Fig. 4 illustrates the airflow and pressure required by an ALS - averaging Everllence's experience with different systems – relative to the main engine air available.

The airflow available on a New Panamax vessel is sufficient for an air lubrication system. However, at the design draught, the air pressure must be boosted by an electric blower at lower engine loads. If the vessel operates in lighter conditions, the range without the need for booster blower support increases.

In general, it is beneficial to combine ESAL with a shaft generator. This ensures that the electrical load onboard, including the power for an ESAL blower, is covered by the main engine, as well as maintains the main engine load as high as possible at lower ship speeds, to keep up airflow and pressure.

Fig. 5 illustrates the propeller power reduction attained by operating the air lubrication system.

However, the extraction of scavenge air from the main engine results in a minor fuel penalty. By reducing the airflow through the cylinder, different countermeasures are needed to keep operating temperatures within acceptable limits, thereby negatively affecting the engine SFOC, see Fig. 6. When evaluating the overall SFOC impact of operating ESAL, it is important to consider the impact of the reduced engine load resulting from the reduced drag and unloading of the propeller. At relatively high engine loads,

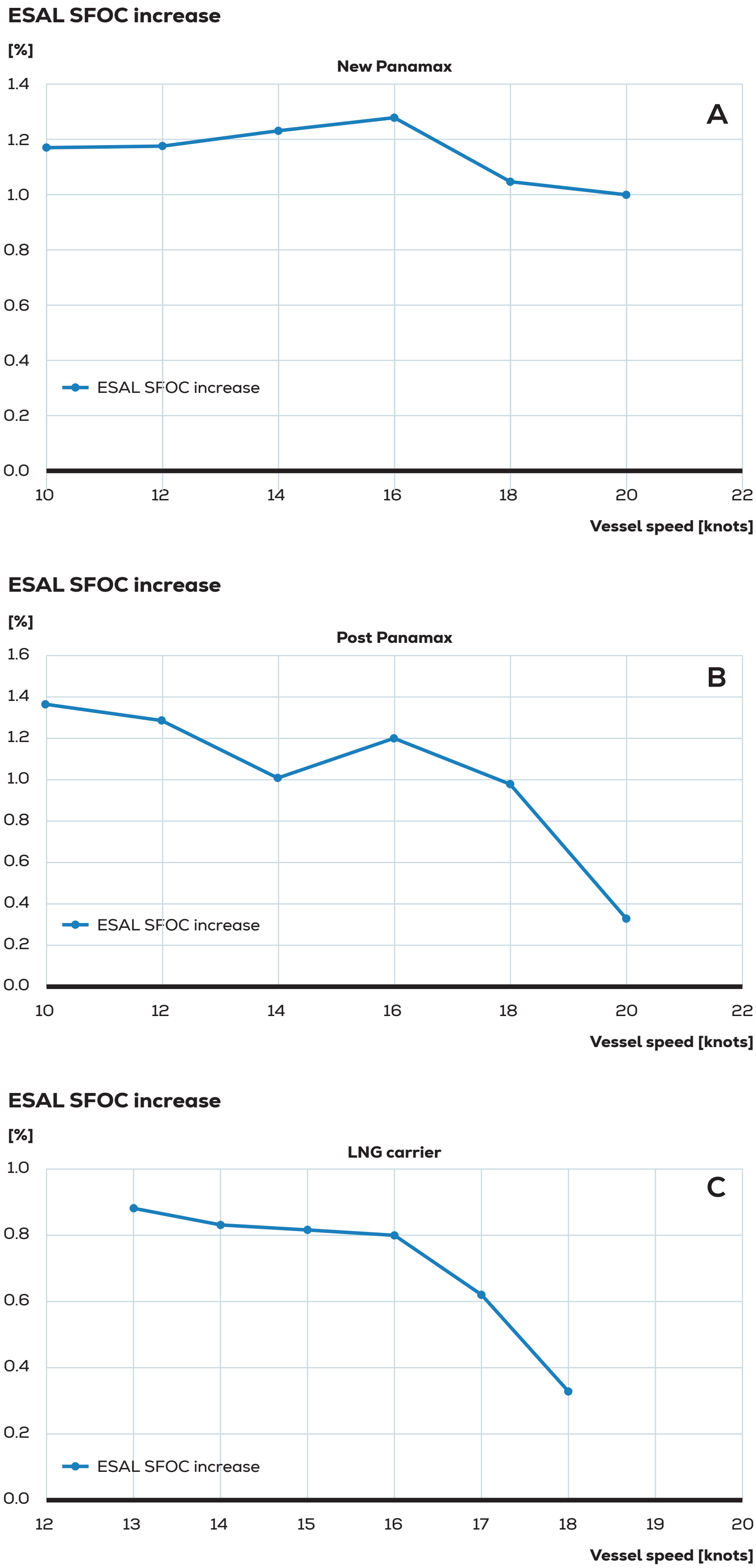
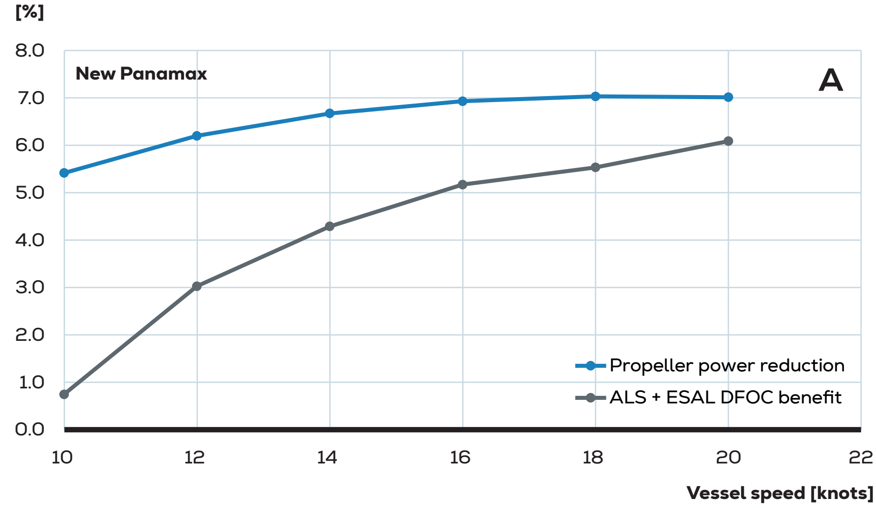


Fig. 6: Illustration of engine SFOC penalty by operating ESAL as a function of ship speed for a) New Panamax, b) Post Panamax container vessel, and c) LNG carrier, including impact of load change on main engine by operating the air lubrication system. The knuckle point for a) and b) is the result of cutting out a turbocharger at lower loads

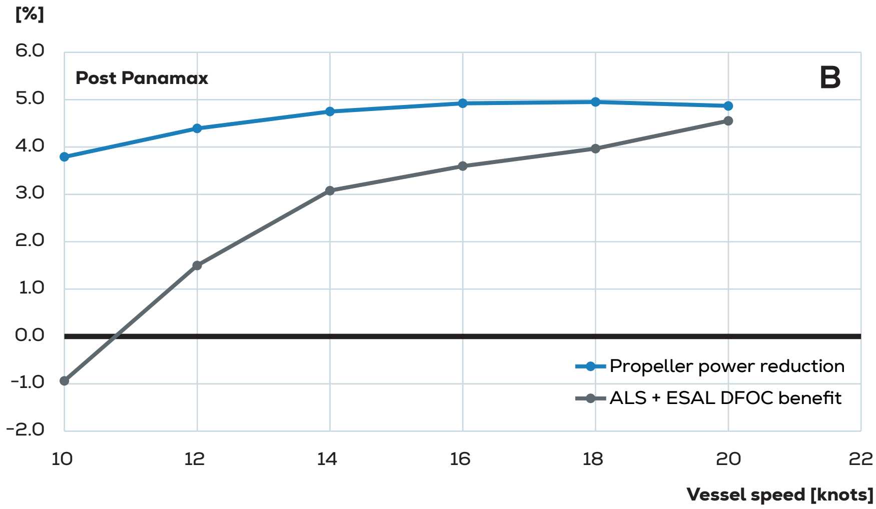
the SFOC reduction from reducing the engine load can almost level out the penalty of ESAL.

Naturally, applying ESAL cannot eliminate the gap between the current gross and net savings across the full speed range. Fig. 7 indicates that at high ship speeds and engine loads, ESAL can deliver net savings close to the gross propeller power reduction. However, the actual savings depend on the operational profile, as the difference between net and gross savings increases with decreasing speed, and varies with the vessel draught.

Gross and net savings on daily fuel oil consumption (DFOC)



Gross and net savings on daily fuel oil consumption



Gross and net savings on daily fuel oil consumption

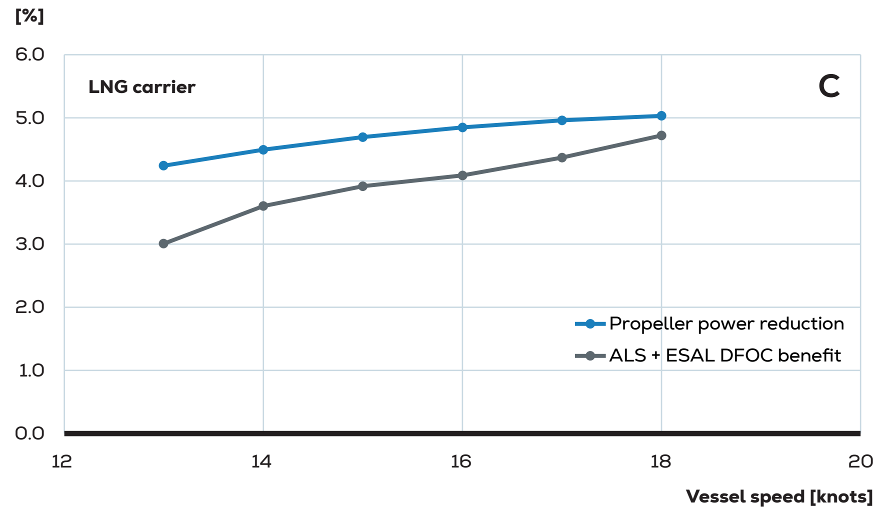


Fig. 7: Gross and net savings of air lubrication with ESAL as a function of ship speed for a) New Panamax, b) Post Panamax container vessel, and c) LNG carrier at design draught. The lower design draughts of b) and c) improve the relative saving by ESAL at part loads

Operational experience of ESAL

Everllence is releasing ESAL following extensive and successful testing on test bed and on two vessels with different configurations of the system, particularly regarding the integration of the booster blower. Testing has been performed in global operation.

These tests have focused on confirming three key aspects of ESAL:

- Proof of concept for ALS with air supplied from the main engine and validation of pressure losses from the engine room to the foreship for release of air
- Optimisation of the balance between air supply and engine penalty
- Thermal loads on combustion chamber components

The tests have been successful in both demonstrating the savings calculated above and verifying that pressure losses are not prohibitive to the operation of the system.

The temperatures of the combustion chamber components are not unaffected by the operation of ESAL, as the reduced scavenging reduces the flow of relatively cold air through the cylinder. However, the temperatures do not exceed the design criteria. Nevertheless, the impact on component lifetime still awaits further service experience.

Fig. 8: Wake with ESAL active

While we wait

While clarity on the final design of IMO's mid-term measures is still pending, the direction of travel is sufficiently defined to guide investment decisions. The increasing emphasis on well-to-wake GHG intensity, combined with mechanisms for compliance and trading, will ultimately translate into a cost signal on emissions, either explicitly through penalties or implicitly through fuel selection.

As an efficiency-improving measure, ESAL does not reduce the GHG fuel intensity (GFI) of the fuel itself. However, it directly reduces the total amount of fuel required to deliver the same transport work. As a consequence, the absolute magnitude of any penalty linked to fuel consumption is reduced proportionally. For FuelEU Maritime, a lower fuel consumption reduces the total penalty exposure when operating above GHG intensity limits. Within regional emission pricing mechanisms such as the EU ETS, reduced fuel consumption translates directly into lower operating costs.

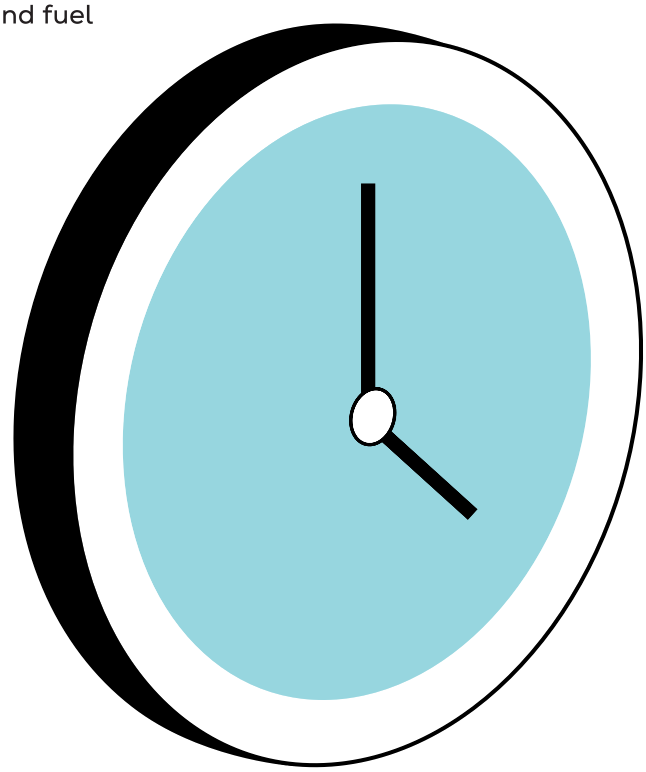
This mechanism is straightforward but important. Less fuel consumed leads directly to lower absolute emissions, lower compliance costs, and lower exposure to volatility in both fuel prices and regulatory cost.

The regulatory treatment of other efficiency-related technologies, however, highlights an important asymmetry. For wind propulsion systems, defined by the IMO as technologies that directly transfer mechanical propulsion forces to the ship's structure, the energy contribution is assigned a zero emission intensity. For technologies that reduce the required propulsion power, such as air lubrication systems and ESAL, no equivalent adjustment is currently foreseen. This means that the value of ESAL is primarily captured through reduced fuel consumption and reduced costs, rather than through a direct accounting advantage within GFI metrics.

The commercial effect of ESAL is therefore twofold: an immediate reduction in fuel consumption and a corresponding reduction in exposure to regulatory costs. The precise magnitude of these effects depends on the vessel type, operating profile, and fuel selection.

Preliminary evaluations indicate that the direct operating expenditure savings from fuel reduction may be moderate when viewed in isolation. Their full significance emerges when fuel savings are assessed together with fuel price, compliance costs, and the long operating life of the vessel.

Pending final regulatory clarification, the economic logic nevertheless remains clear. If a technology reduces fuel consumption, it also reduces the scale of both emissions and compliance costs. In that respect, ESAL already creates value under existing and foreseeable regulatory conditions.



Conclusions and perspectives

The maritime transition will not be decided by regulation alone. It will be determined by which solutions create credible value under real operating conditions, across vessel types, fuel pathways, and investment horizons.

From that perspective, the role of energy efficiency is fundamental. The most robust way to reduce emissions, lower operating costs, and ease the transition to low- and near-zero GHG fuels is to reduce the amount of energy required in the first place. Efficiency is therefore not a secondary measure alongside fuel transition. It is the condition that makes the fuel transition more practical, more scalable, and more affordable.

ESAL illustrates this clearly. By combining hydrodynamic savings with deeper integration between the engine and the vessel, it turns air lubrication into a more effective and commercially relevant efficiency measure. The overall vessel efficiency improves significantly with the application of ESAL, improving vessel efficiency up to 6%, considering typical operational profiles. This improvement reflects both the reduction in auxiliary power demand and the more efficient utilisation of energy within the propulsion system. The result is not only a lower fuel consumption, but a direct reduction in emissions, regulatory costs, and exposure to future uncertainty.

The overall vessel efficiency improves significantly with the application of ESAL, improving vessel efficiency up to 6%, considering typical operational profiles.

This is the broader perspective in which ESAL should be understood. It is not merely an add-on technology, and it does not depend on a single regulatory outcome. It is a practical response to a structural challenge in shipping: how to decarbonise while maintaining competitiveness and operational flexibility.

From a system perspective, efficiency improvements such as ESAL also reduce the scale of the challenge ahead. Every percentage point of fuel saved lowers the demand for low- and near-zero GHG fuels, easing pressure on supply chains, infrastructure development, and overall transition costs. In this way, efficiency does not compete with the fuel transition but makes it more attainable.

As additional vessel-specific calculations and operational data become available, the case for ESAL will be further strengthened.

Everllence's position is therefore clear. The maritime energy transition must begin with reducing energy demand. Solutions that improve efficiency today will retain their value under any credible future framework. ESAL represents such a solution: practical, scalable, and ready to deliver value now while supporting the long-term ambition of net-zero shipping.

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