

USING WIND POWER PROFITABLY

It is a simple fact: wind is cheaper than oil and the most economic source of energy on the high seas. And yet, shipping companies are not taking advantage of this attractive savings potential at present - for a simple reason: So far no sail system has been able to meet the requirements of today's maritime shipping industry.

Now for the first time, SkySails is offering a wind propulsion system based on large towing kites, which meets all these requirements.

Depending on the prevailing wind conditions, a ship's average annual fuel costs can be reduced by 10 to 35% by using the SkySails-System. Under optimal wind conditions, fuel consumption can temporarily be cut by up to 50%.

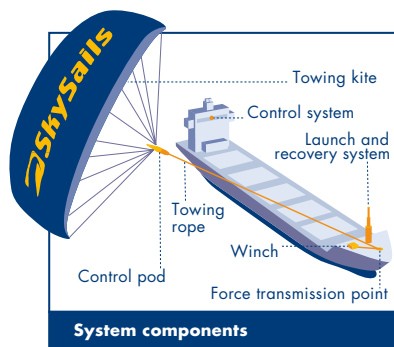
Virtually all existing cargo vessels and new builds can be retro- or outfitted with the SkySails auxiliary wind propulsion system.

The SkySails-System is used parallel to and for relief of the main engine, if wind conditions allow. The main engine's propulsion power remains fully available if required.

This dual propulsion solution offers the flexibility required to minimize operating costs. By using a SkySails-System foresighted shipping companies now have the opportunity to increase their competitiveness and yields!



**Simple fact:
wind is cheaper than oil**



THE SKYSAILS- TECHNOLOGY IN DETAIL

The SkySails-System consists of three simple main components: A towing kite with rope, a launch and recovery system, and a control system for automatic operation.

A multi-level security system and redundant components guarantee the highest possible safety during operation of the SkySails propulsion.

The optional weather routing system provides shipping companies with a means to guide their ships to their destinations on the most cost-effective routes and according to schedule.

TOWING KITE WITH ROPE

Instead of a traditional sail fitted to a mast, SkySails uses large towing kites for the propulsion of the ship. Their shape is comparable to that of a paraglider.

The towing kite is made of high-strength and weatherproof textiles. It is double-walled and fitted with chambers along its entire length as well as ports at the front end. A line tree defines the requested kite shape by spanning lines of different lengths between the pod and the towing kite. The profile of the towing kite is designed in such a way that optimal aerodynamic efficiency can be achieved.

Their double-wall profile gives the SkySails towing kites aerodynamic properties similar to the wing of an aircraft. Thus, the SkySails-System can operate not just downwind, but at courses of up to 50° to the wind as well.

Test results show that in practice, high propulsion power can be achieved on courses from 70 degrees onwards. The most efficient courses are those between 120 and 140 degrees.

In case of very strong winds, the power of the towing kite can be reduced by changing its position in the wind window (relative to the horizon), without having to minimize the towing kite area.



SkySails towing kite



A coupling mechanism connects the towing kite with the kite adapter attached to the launch and recovery mast.

Presently, SkySails is offering towing kites for cargo ships with kite areas of approx. 150 to 600m².

Force transmission

The specially-designed force transmission system of the SkySails propulsion transmits the tractive forces of the towing kite to the ship. The system is customized for each ship.

The force transmission system comprises the following components: towing rope, force transmission point and winch.

Towing rope

The tractive forces are transmitted to the ship via a highly tear-proof, synthetic rope.

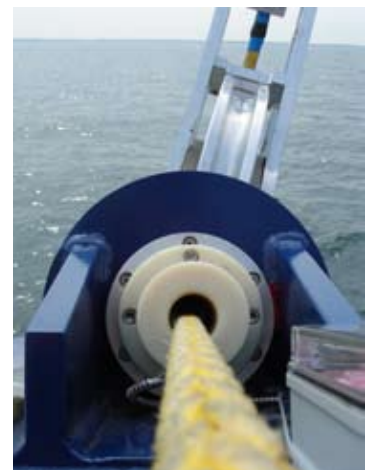
The energy supply of the control pod is ensured by means of a patented special cable integrated in the towing rope.

Force transmission point (tow point)

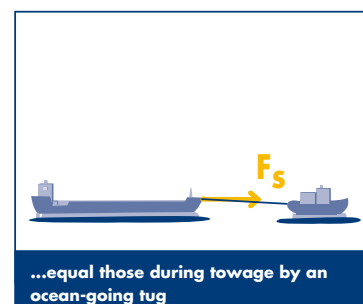
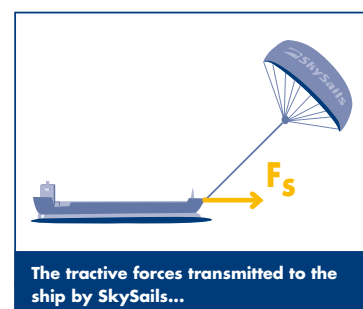
The "force transmission point" - also called "tow point" - is the point at which the towing rope of the kite is connected to the ship.

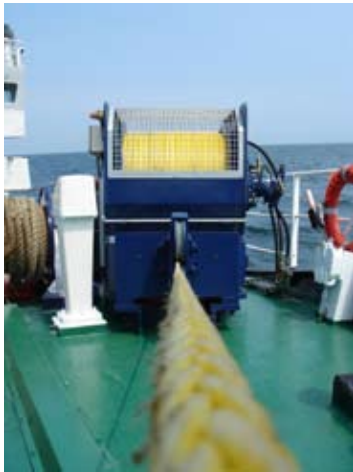
The tow point guarantees the optimal alignment of the kite's power for every course and wind direction.

The tractive force of the SkySails-System is directed to the bow area over the force transmission or tow point mounted on the foredeck. Generally the existing ship's structures are sufficiently dimensioned, since that is where the capstan and anchor windlass are also housed. The power transmitted by the SkySails-System is comparable to that of an ocean-going tug. An appropriate stability computation is made for each vessel prior to the installation of a SkySails propulsion.



Force transmission point





Winch

Winch

The SkySails towing kite is recovered and launched using a dynamically operating winch, which also serves as rope storage. The tractive force measurement is pre-installed in the winch. The winch speed is chosen so that the towing kite can be stabilized at any time.

LAUNCH AND RECOVERY SYSTEM

The launch and recovery system manages the automatic deployment and lowering of the towing kite and is installed on the forecastle. During launch a telescopic mast lifts the towing kite, which is reefed like an accordion, from its storage compartment. At sufficient height the towing kite then unfurls to its full size and can be launched. A winch releases the towing rope until operating altitude has been reached. The recovery process is performed in reverse order.

The entire launch and recovery procedure is carried out automatically and lasts approx. 10 - 20 mins each.

**Launch of the SkySails
towing kite**



STEERING SYSTEM

The steering system of the SkySails propulsion operates automatically. The towing kite can be aligned relative to wind direction, wind force, ship course and ship speed in order to achieve optimal propulsion power.

The steering system of the SkySails consists of the control pod and the control system.

Control pod

The functionality of the control pod is comparable to the pilot of a paraglider: It "pulls" to the left and right of the control lines, thereby modifying the aerodynamic profile of the towing kite and thus controlling its flight path. Both the mechanical control actuators as well as the electronics for the control of the kite are installed in the control pod.

The control pod features a modular layout and is the physical link between the towing kite and the towing rope. Its structure is optimized with regard to tensile strength and weight.



Control pod





Towing kite with control pod

The control pod has a streamlined casing which is waterproof and protects the electronic components against humidity and shocks. A chassis made out of carbon fiber composite material carries the casing, the electronic components, the gear mechanism and the motor.

Control system

The function of the control system is to steer the SkySails-System automatically. It is similar to the autopilot of an airplane in that data is collected via sensors and processed by the autopilot software. Subsequently, the software sends control commands to actuators in the system, e.g. to those of the control pod.

The control system comprises the following components:

SkySails on-board computer

The entire SkySails-System is managed using the SkySails on-board computer. A graphic user interface on the bridge informs those commanding the ship about the system's status and allows the system to be operated manually by inputting commands (launch, recovery and flight maneuvers, etc.).

Control pod computer

A computer in the control pod takes over the tasks of sensor signals processing, motor control, data communications and backup functions for the autopilot.



SkySails control panel on the bridge

Autopilot program / Kite maneuver control

The towing kite is controlled automatically at all times. The autopilot can also let the towing kite fly defined maneuvers automatically depending on the wind direction, wind strength and ship's speed or can hold the kite in a stable flight position. This is performed by an autopilot like those used in aerospace applications. The autopilot is integrated in the SkySails on-board computer.

Data and control commands are transmitted to the control pod by means of a special cable integrated in the towing rope.

Launch and recovery process control

Managing the launch and recovery process consists of controlling the launch and recovery mast, winches and towing kite adapter. This automatic mechanism in the form of a PLC (Programmable Logic Controller) manages the entire launch and recovery process. The winch control is also handled by this PLC, which is accessed using RS 232 and 422 interfaces. The PLC can be operated using a control panel installed on the foredeck when the launch and recovery process is to be controlled manually.

Servo electronics control pod

The control pod's servo-electronics are used to control the pod actuators. Redundant systems are on hand for safety reasons.

Ship sensors

As a minimum, the following sensors must be installed on the ship for the SkySails-System:

- GPS
- Wind direction gauge
- Anemometer
- Rudder position
- Course

The ship's sensors that are normally found on board must comply with the NMEA standard (0183 or higher). Data are transmitted to the SkySails on-board computer via an RS 232 or RS 422.



Dynamic towing kite flight maneuvers



SkySails control panel



MS Beaufort on the Baltic Sea

SkySails provides the following supplementary sensors together with the system:

- Kite adapter sensors
- Tow point sensors
- Winch sensors

SAFETY SYSTEM

A multi-level security system and redundant components guarantee the highest possible safety during operation of the SkySails propulsion.

- The tractive force can be modified and reduced as needed by changing the relative position of the towing kite to the ship.
- The force vectors on the ship can be controlled by changing the direction of pull.
- The actively operating main winch automatically limits the maximum tractive force and has an integrated gusts and dynamic compensation feature.
- In case of overloading, the winch will automatically let out the towing kite.
- The towing kite has an emergency release feature for use in extreme situations.

ROUTING SYSTEM

The optional weather routing system provides shipping companies with a means to guide their ships to their destinations on the most cost-effective routes and according to schedule.

Experienced meteorologists do the weather routing in four steps:



Optimized routing system

Weather Forecast	First they determine what kind of performance can be generated with SkySails propulsion under the forecast weather conditions. Potential routes and speeds are then calculated.
Decision Model	Included in the decision model are the requirements set forth by the shipping company, such as the desired arrival time.
Performance Calculation	The data from the weather forecast and the decision model flow into the performance calculation. The optimal route is then computed based on the projected performance.
Recommended Route	Finally the recommended route is translated into waypoints and sent to the shipmaster.

Modern meteorological methods make precise three to five-day weather forecasting possible. Major weather systems and weather trends can be forecast for even longer periods. The routing system hence contributes significantly to system safety by means of projecting and preventing risk.

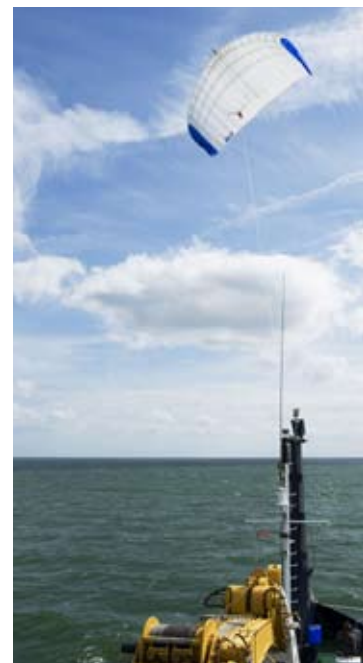
OPERATING CONDITIONS

The SkySails-System supplements the existing propulsion of a vessel and is used offshore, outside the 3-mile zone and traffic separation areas.

The SkySails-System is designed for operation in predominantly prevailing wind forces of 3 to 8 Beaufort at sea. The system can be recovered, but not launched, at wind forces below 3 Beaufort. At average wind forces of up to 10 Beaufort - and faster gusts corresponding to this wind intensity - the system can be recovered smoothly.

CLASSIFICATION

The main components of the SkySails-System are certified by type. The operation of the system is not limited by any regulations at present.



ADVANTAGES IN DETAIL

TECHNICAL ADVANTAGES IN DETAIL

High propulsion power

The technical possibilities resulting from the spatial separation of the ship and the "sail" or towing kite give SkySails an entirely new performance spectrum.

SkySails generate two to three times more propulsion power per square meter sail area than conventional sail propulsions.

The tethered flying SkySails can operate at altitudes between 100 and 300 m where stronger and more stable winds prevail.

At an altitude of 100m the average wind speed is between 10 and 20% higher than at an altitude of 10m, due to the absence of friction with the earth's and the water surface. Thus more than twice the amount of energy can be available at an altitude of 200m than at 10m - depending on the weather conditions.

A higher wind speed is particularly relevant, since for the calculation of the tractive power of the SkySails towing kite the wind speed is squared:

$$F(a) = c_l * \rho / 2 * v^2 * A$$

$F(a)$: Lifting force of the towing kite

c_l : Lift coefficient of the towing kite

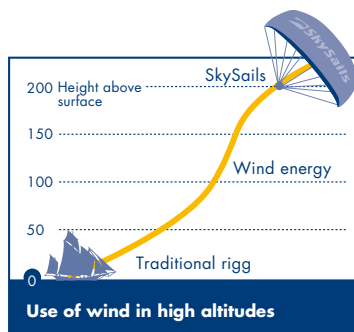
ρ : Density of the air

v : Velocity of the air

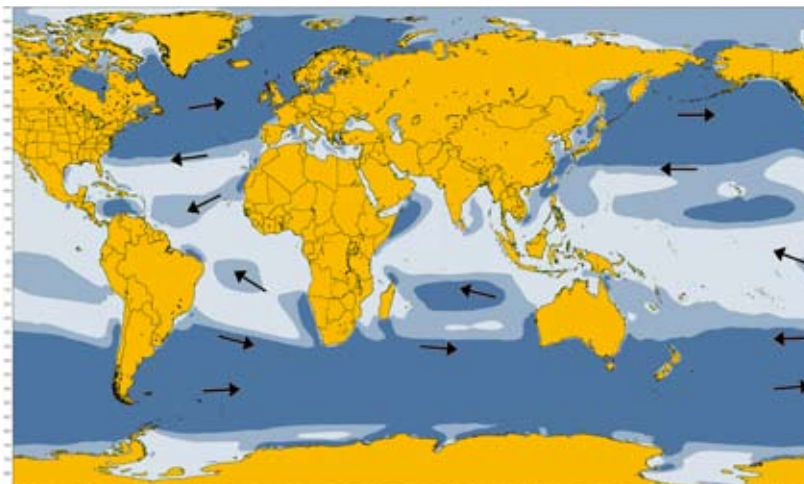
A : Surface area of the towing kite

There exists a quadratic relationship between the wind speed and the wind energy potential. A doubling of the wind velocity, for example, corresponds to a quadrupling of the tractive force of the SkySails-System.

A further significant technological advantage of the SkySails propulsion is the fact that the towing kite can be navigated "dynamically". This means








Dynamic flight of the towing kite



Worldwide average wind energy potential

powered by WetterWelt

Legend wind energy potential map:

-  land
-  high wind energy potential
-  medium wind energy potential
-  low wind energy potential
-  prevailing wind direction

that the autopilot can perform flight maneuvers with the towing kite such as the figure of eight in front of the ship. That way the wind speed at the towing kite is increased and the tractive forces rise accordingly:

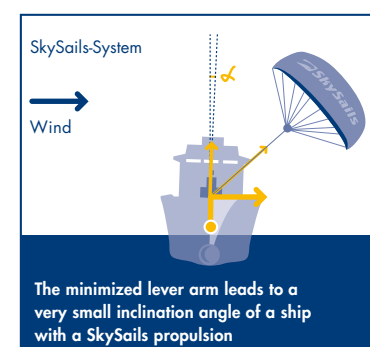
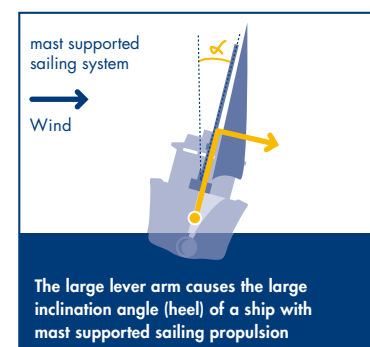
If, for example, the true wind velocity at the towing kite is 11.5 m/s during its static flight, the tractive forces generated by the kite increase by the factor 2.68 when changing to dynamic flight due to an apparent wind speed of 20 m/s at the kite. The tractive forces thus approximately treble.

Since the SkySails-System generates a significantly higher propulsion power per square meter sail area than conventional sail propulsions, it is possible to gain significant savings by using comparatively small sail areas. For comparison: The 109m long four-mast barque "Sea Cloud" has a sail area of 3,000m² in total. A cargo ship of the same length would be fitted optimally with a towing kite of 300 to 600m² in size.

Minimal heel

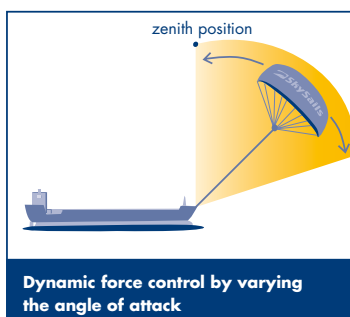
Unlike conventional forms of wind propulsion, the heeling caused by the SkySails-System is minimal and virtually negligible in terms of ship safety and operation.

The tractive forces of the SkySails towing kite are transmitted to the ship at deck level. The lever arm which causes the inclined position (heeling) of conventional sailing ships is thus shortened.



Improved behavior at sea

At sea the SkySails-System damps the waves because the uplifting forces of the towing kite effect a smoother slicing of the ship's hull into the wave.



Dynamic force control

The position of the SkySails towing kite in relation to the horizon can be varied for the integrated force control of the SkySails propulsion to ensure the ship's safety. If, for example, sudden, strong winds occur, the autopilot can position the towing kite in the neutral zenith position directly above the ship in max. 30 seconds. In this position the towing kite does not exert any force onto the ship and can thus be safely recovered even in the case of strong winds. In an extreme case, this may prevent collisions with ships violating the statutory minimum safety clearances.

Automatic operation

During operation of the system, an autopilot controls the towing kite. The launch and recovery procedure of the towing kite is carried out automatically as well.

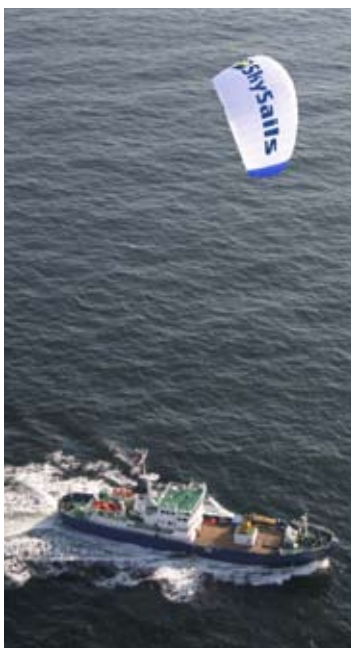
As the SkySails-System operates automatically, the ship's regular crew is adequate for operating the system and no additional personnel costs will arise.

Optimized routing system

The optional weather routing system provides shipping companies with a means to guide their ships to their destinations on the most cost-effective routes and according to schedule. The weather routing system is already available.

System for retrofitting

Due to the compact and universal design, virtually all seagoing cargo ships can be out- or retrofitted with the SkySails propulsion.



Towing kite in zenith position above the ship

The tractive force of the SkySails-System is directed to the bow area over the force transmission or tow point mounted on the foredeck. Generally the existing ship's structures are sufficiently dimensioned, since that is where the capstan and anchor windlass are also housed. The power transmitted by the SkySails-System is comparable to that of an ocean-going tug. An appropriate stability computation is made for each vessel prior to the installation of a SkySails propulsion.

Hybrid propulsion

The SkySails-System is used parallel to and for relief of the main engine, if wind conditions allow. The main engine's propulsion power remains fully available if required.

Marginal spatial requirements

Due to the spatial separation of the kite and the ship's hull, the reduction of the ship's effective area by the SkySails-System is economically irrelevant.

The textile towing kite is easy to stow when folded and requires very little space on board ship. A folded 160m² SkySails for example is only the size of a telephone booth.

In contrast to conventional sail propulsions the SkySails-System has no superstructures which may obstruct loading and unloading at harbors or navigating under bridges, since the towing kite is recovered as soon as the 3-mile zone is reached.

Improved ship safety

SkySails - as an alternative propulsion system - can also minimize the negative economic effects of engine malfunctions.

In the case of a total breakdown of the main engine, the SkySails-System can be used as emergency propulsion to reduce average risk.





SKYSAILS-SYSTEMS FOR CARGO SHIPS

Currently, SkySails is offering towing kites for cargo vessels with an effective load* of between 8 and 32 tons. The scheduled product program comprises towing kite propulsion systems with an effective load* of up to 250 tons.

An effective tractive force of 8 tons by a SkySail corresponds to approx. 600 to 1,000 kW installed main engine power - depending on the ship's properties (propeller efficiency degree, resistance, etc.)

The following chart gives an overview of the dimensions of the SkySails propulsion on different ships:

SkySails-System	Available in	Design Load [t]	Effective Load* [t]	Exemplary vessel - type	Length [m]	Main propulsion [kW]	Speed at NCR** [kn]	Main propulsion thrust at NCR** [t]
SKS 160	2007	16	8	Buoy Tender	54	1,260	11	8.5
				Bulker	88	1,520	10.5	11
SKS 320	2008	32	16	Tanker	93	2,800	12	17
				Container Feeder	90	2,000	14	15
SKS 640	2009	64	32	MPP Heavy Lift	133	3,840	14	23
				Bulker	175	5,845	13.5	48
SKS 1280	2010	128	64	Bulker	175	5,845	13.5	48
				Cruise Ship	250	24,800	17/21	80

*: Tractive force of the system in the direction of the ship's course under SkySails standard conditions. Ship speed: 10kn, Wind speed: 25kn, True wind direction: 130°, SkySails flight mode: dynamic. Depending on the wind conditions on the routes traveled and the frequency of use of the SkySails-System, the average annual savings generally amount to between 10 and 35 %.

** : NCR (Nominal Continuous Rating) is the (revolution) speed to which the main engine is optimized.

Ideally, the effective load* specified for the towing kite should range between 70 and 150% of the thrust at NCR generated by the ship's main propulsion.



*Effective Load

The effective load of the SkySails propulsion indicates the maximum tractive force of the system in the direction of the ship's course under optimal conditions. The effective load is substantial when dimensioning the SkySails-System as it can be directly compared to the thrust required by the ship to reach its cruising speed.

Since ships differ in construction and operate on very diverse routes, it is difficult to make a general statement regarding the propulsion power of the SkySails-System. However, and in order to give an indication of the system's propulsion power, SkySails states its effective load under standard conditions. The system's power is determined for a clearly defined system status at a specified point in time. This system status is defined as follows:

SkySails standard conditions

System variable	Value
Wind speed	12.8 m/s (25 knots)
True wind direction	130°
Ship speed	5.1 m/s (10 knots)
Sea state	2
Propeller efficiency degree	0.6
Towing kite flight mode	dynamic

The SkySails' effective load under standard conditions is specified for an exemplary vessel which cruises at a speed of 10 knots at a true wind course of 130°. The wind speed is 25 knots, waves are up to 60 cm high, and the towing kite is maneuvered dynamically.

The determination of the system's propulsion power under standard conditions is based on field testing results and theoretical calculations.

INSTALLATION & SERVICE

SUPPLY INTERFACES

The majority of the SkySails-System components (winch, launch and recovery mast, and force transmission point) are installed on the foredeck on mounts welded to the ship's hull. The SkySails-System requires a connection to the ship's electronics and/or hydraulics on the foredeck. The control system with operating panel for navigation is installed on the bridge. In addition to a power supply, an appropriate interface to the ship's computer is needed in order to supply the system with the ship's data.

INSTALLATION & COMMISSIONING

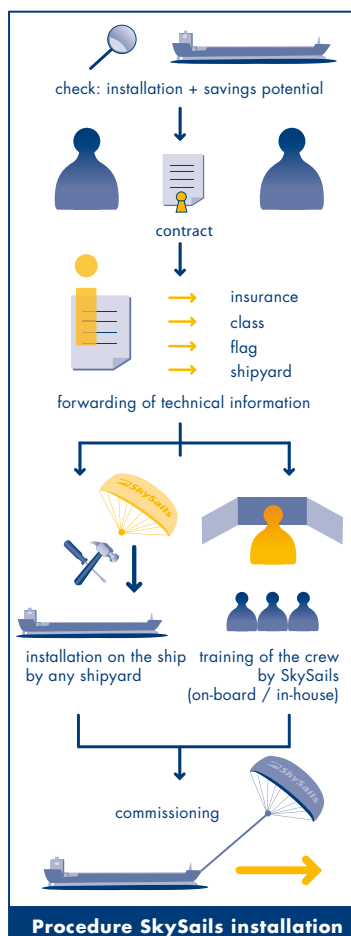
Virtually all existing cargo vessels and new builds can be retro- or outfitted with the SkySails auxiliary wind propulsion system.

Installation can be made in the shipyard of choice or in a port that has an adequate crane system. The ship can remain in the water during installation.

In line with the installation process, the client first provides SkySails with all the needed information and records pertaining to the ship onto which the SkySails-System is to be installed. This involves the information requested in the Ship Data Questionnaire. The responsible SkySails technical project manager also inspects the ship together with the client to examine the installation options on board.

Based on this information SkySails then prepares the required records for the insurance company, the classification society and the installing shipyard. With the aid of these records, the client can then request bids and proposals from shipyards for installing the SkySails-System and inform his insurance company and classification society about the integration of the system.

The SkySails-System is then installed on the vessel under the direction of the SkySails technical project manager at the shipyard designated by the client.



The components are installed in three steps:

1. Prepare the mounts and foundations for the launch and recovery mast, winch and force transmission point; make the openings for the wiring and hydraulic lines; construct the storage compartment for the towing kite. Reinforcement of the foredeck may be required. Commonly, the ship's structure in this area is however already designed with adequate stability, since this is where the anchor windlass is housed.
2. Install the components, launch and recovery mast, winch and force transmission point on the foredeck mounts. Install the control panel on the bridge.
3. Lay the electrical and hydraulic lines and connect the system components. Wind the towing rope onto the winch. Stow the towing kite and control pod in the storage compartment.

As desired or needed, each of the individual installation steps can be performed independently, at different times and at different locations. This, for example, allows using extended docking times for loading and offloading to install the SkySails-System.

A total of 3 x 2 consecutive workdays are required for installing the SkySails-System. If necessary, a few more days may be required for work on the electric system, which however can be completed while the ship is at sea.

The costs of the installation work are handled directly between the shipyard and the client.

Once the installation is complete, a function check of the components fitted on the ship is conducted in port. The function of the entire SkySails-System is tested during subsequent sea trials. Following that the seller then provides the buyer with a record of delivery verifying that the system is in proper working order.



Installation telescopic mast



Installation winch



Installation force transmission point

CUSTOM-TAILORED SERVICES

SERVICE AND MAINTENANCE

With the exception of the control system and the textile-based components (towing kite, towing rope), all components of the SkySails-System can be serviced by technically qualified staff, e.g. ship-based machinists. These services can be carried out offshore when the SkySails-System is not in use, but also at a harbor or dock yard.

System components requiring specific know-how are serviced by SkySails' specialists. If required they can be requested at any harbor in the world.

SkySails guarantees a high availability of replacement parts. For example, all wearing parts are held in stock and can be delivered to the international airport located nearest to the harbor where the ship lies at anchor within 36 hours.

SKYSAILS CREW TRAINING

SkySails offers shipping companies custom training and instruction to ensure crews are optimally prepared to use the SkySails-System efficiently and safely. This training program comprises both theoretical instruction and hands-on training.

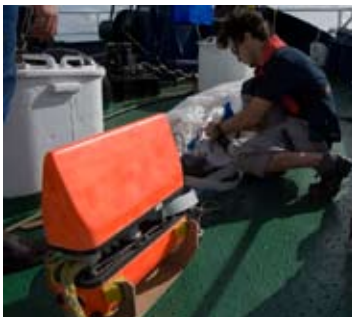
SkySails Basic Training

The two-day SkySails Basic Training program teaches the theoretical principles underlying how SkySails is employed. In addition to the fundamentals of SkySails technology and aerodynamics, this instruction focuses on imparting an understanding of how to utilize the SkySails-System during maritime operations, including systems control, monitoring, stability, maneuver performance and deployment conditions, as well as the legal principles governing its use.

SkySails Basic Training is available at SkySails in Hamburg or can be conducted by mobile SkySails trainers at a location of your choice.



Installation and service on the MS "Beaufort"

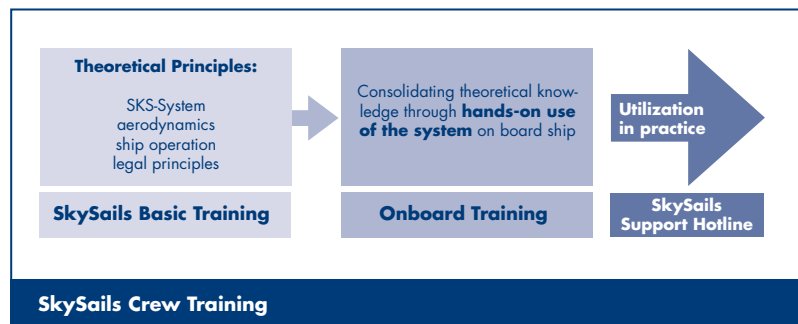


SkySails training facilities in Hamburg-Harburg

Onboard Training

Onboard Training reinforces the theoretical knowledge acquired during SkySails Basic Training and develops skills in the on-hand use of SkySails propulsion.

This practical Onboard Training is offered aboard the SkySails training ship "Beaufort" or on board the customer's vessel.



Onboard Training on the SkySails training vessel MS "Beaufort"

SKYPROFIT – THE CONVENIENT WAY TO MEASURE SAVINGS

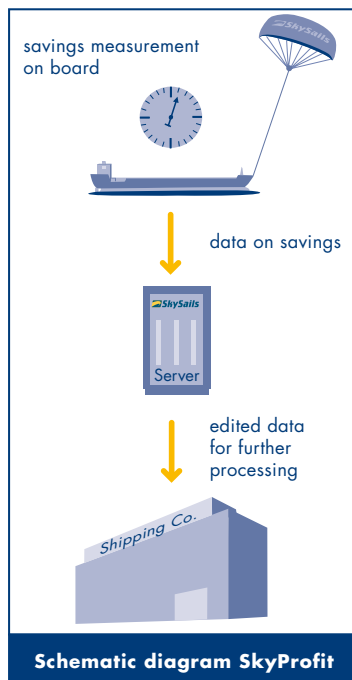
Clear standards for a secure investment

The SkyProfit savings measurement system lets any shipping company profit from an investment in SkySails propulsion – even when not acting as the charterer itself.

Since gauging fuel savings generated by the SkySails-System is as reliable as it is easy, shipping companies can now bill charterers for the saved fuel either in full or in part.

As an alternative, shipping companies can charge higher charter rates for ships outfitted with the SkySails-System in light of how their reduced operating costs can be fully documented.





Convenient and reliable savings measurement

SkyProfit measures the fuel savings generated by the SkySails-System right on board the vessel, processes the information and forwards it to the shipping company.

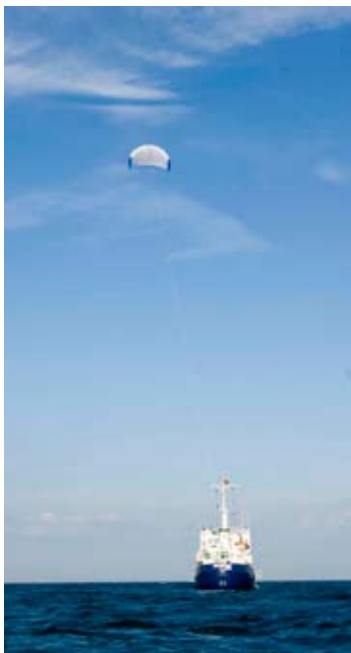
The SkyProfit savings measurement system determines the SkySails' tractive force, the ship's speed and fuel consumption while SkySails propulsion is in use. From this the system computes the savings data, which may be accessed at any time through the SkySails-System's user interface on board the vessel. The following information can be displayed:

- Current tractive force, fuel consumption and savings (in tons of oil and euros)
- Average savings (in tons of oil and euros) during any given interval (e.g. the last 3 journeys or the past half-year)
- Total savings since commissioning the SkySails-System (in tons of oil and euros)

A non-manipulative process using secure measuring units and data storage systems tracks and records the data.

SkyProfit encrypts and transmits the savings data to a central server at SkySails. Here the data is prepared for further processing at the shipping company. You may choose to have the data sent from there by e-mail, fax or online using a secure web interface to the shipping company, the charterer and/or the owner. The data can be provided in either real-time via satellite or at regular intervals, such as monthly or quarterly.

This savings data forms the basis for allocating the profits generated by using SkySails propulsion among the contracting partners.



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