HEMPAGUARD - Evidence of performance gains

Mads Raun Bertelsen, Director of Solution Management, Marine, Hempel A/S
Diego Meseguer Yebra, R&D Director, Marine, Hempel A/S

Summary

Hempaguard offers superior performance against conventional antifouling coatings. This is based on its ability to minimize the hull frictional resistance by having (a) the smoothest surface out-of-dock, (b) the ability to stay smooth over time regardless of substrate and application conditions and (c) superior fouling prevention capability, especially when the vessel stays idle in aggressive waters. This paper summarizes the collective evidence for Hempaguard as the ultimate hull coating solution for an energy efficient hull with significant positive impact on CII and Vref for the purpose of EEXI. Hempaguard has shown the most compelling fuel saving potential based on a series of laboratory scale experiments and fluid dynamics research projects with external partners. The test results have been conclusively confirmed with actual performance monitoring data from various ship types in service.

1. Hempaguard performance in context of EEXI and CII

The fuel savings for Hempaguard have been established to:

a) 6-8% as an immediate **out-of-dock effect** compared to *any* conventional antifouling coating. This translates to 2-3% speed increase, thus EEXI is expected to be improved by 2-3%. Additional gain of estimated 2.5% can result from a full abrasive blasting of underwater hull Vs spot repair as surface preparation.
b) 20-22% as a **total efficiency gain** over in-service interval thanks to high out-of-dock gain and low speed loss over time (1.2% and 1.4% guaranteed for Hempaguard X8 and X7 respectively) compared to a *market average* conventional antifouling coating as measured based on ISO 19030 methodology. This translates to 20-22% reduction in CO_2 emissions, thus CII (AER) is expected to be improved by 20-22% over the in-service period. When compared to a *top-tier* conventional antifouling, total efficiency gain and CII improvement from Hempaguard is expected to be 9-12%.

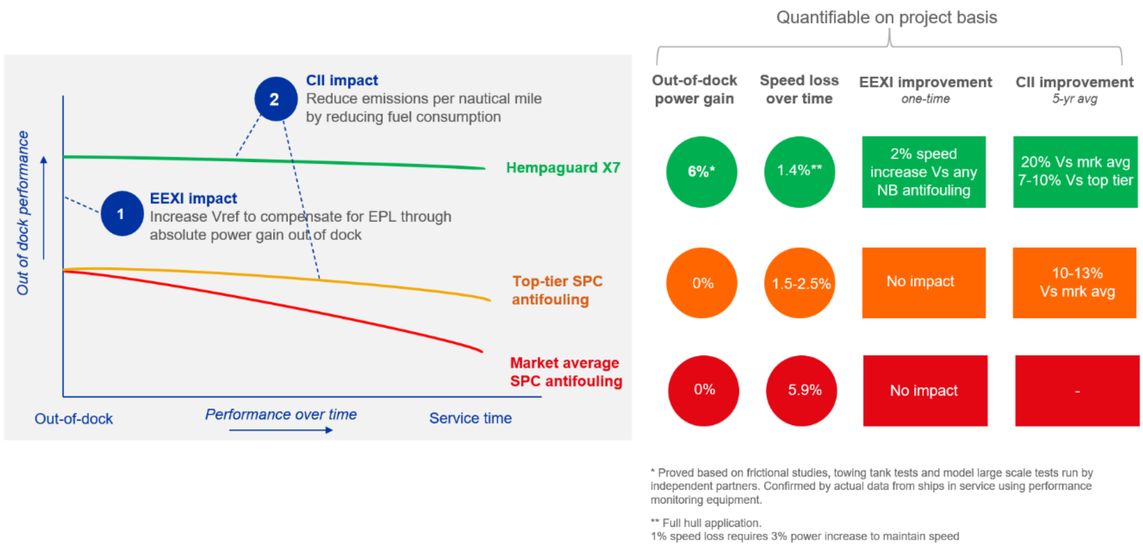


Figure 1: Impact of Hempaguard on fuel savings translated to CII and EEXI improvement compared to conventional AF

2. Evidence of performance

Hempaguard offers superior performance against conventional antifouling coatings. This is based on its ability to minimize the hull frictional resistance by having (a) the smoothest surface out-of-dock, (b) the ability to stay smooth over time regardless of substrate and application conditions and (c) superior fouling prevention capability, especially when the vessel stays idle in aggressive waters. The individual contributors to increased friction through water for a ship are explained below along with the results from measurements and tests of Hempaguard Vs conventional antifouling coatings.

2.1 Hempaguard provides a much smoother surface out of dock

It is well known that surface roughness on a ship influences its performance. Actual Average Hull Roughness (AHR) measurements on ships just out of dock confirm that Hempaguard provides a much smoother surface compared to conventional antifoulings. In a recent study by Hempel with a sample of 100 vessels, 86% of silicone projects are below 100 µm AHR compared to an average of 140-160 µm from conventional antifouling coatings. This has significant impact on fuel consumption: Townsin (1979) proposed an approximation that for every 10 µm increase in roughness there is a 0.7%-1% increase in fuel consumption.

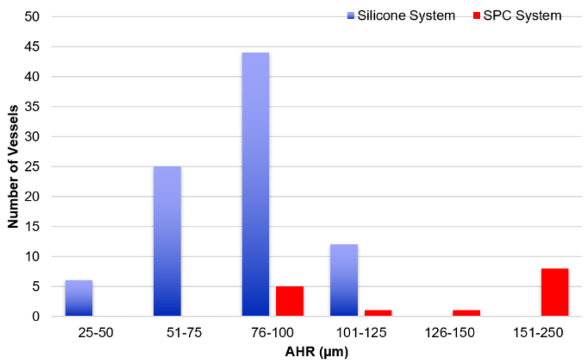


Figure 2: Real-life data from AHR measurements – sample of ~100 vessels including containerships, tankers and bulkers of different sizes.

2.2 Hempaguard will stay smooth over time

Contrary to conventional antifouling coatings which polish over time and generates a rougher surface, Hempaguard maintains its surface smoothness as shown in below figure. Conventional antifouling coatings generally show some initial smoothening effects when hull surface irregularities are smoothened out but the antifouling polishing process will cause roughness increase due to the leached layer formation.

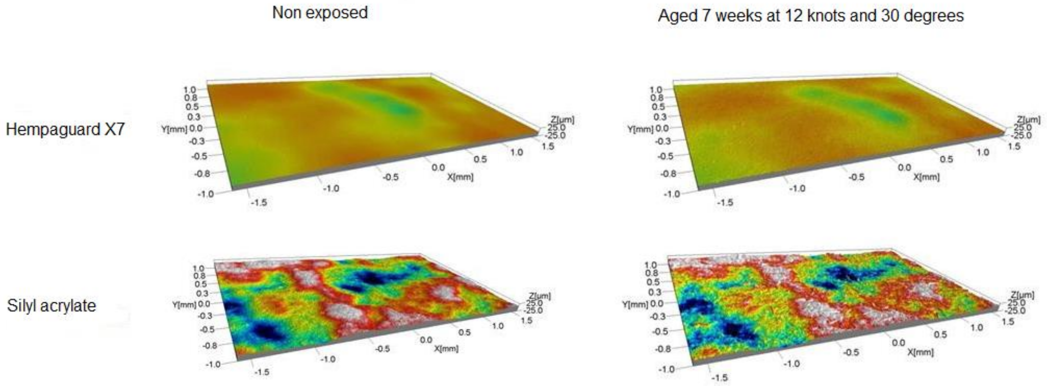


Figure 3: The surfaces of two coatings were measured when freshly applied and unexposed to sea water and compared after being exposed to sea water (30 degrees) for 7 weeks, at 12 knots. Hempaguard® stays smooth while the roughness of the silyl acrylate based antifouling coating is higher in the beginning and increased over time.

2.3 Hempaguard provides the smoothest surface regardless of substrate and application

In general, the substrate on which the coating is applied has an impact on the finish of the final coat. In Table 1 are the average roughness values from a series of coating applications. Independently of the surface roughness of the substrate Hempaguard will always provide the smoothest surface.

Type of coating	Lab conditions (ideal)	Dry docking – good substrate and application	Dry docking – poor substrate and application
Hempaguard	45 µm	up to 100 µm	up to 125 µm
Silicone based coating	50 µm	up to 110 µm	up to 135 µm
Top tier nano acrylate based coating	60 µm	up to 125 µm	up to 175 µm
Top tier silyl acrylate based coating	70 µm	up to 150 µm	up to 200 µm

Table 1: The average surface roughness values for various coating types generated from several coating applications

2.4 Hempaguard has significant frictional resistance reduction advantages compared to conventional antifouling paints

Hempaguard provides a much smoother surface which stays smooth over time regardless of substrate and application. However, the importance of the surface of the coating lies in its impact upon friction. A number of independent research institutes have run studies comparing the drag resistance of silicone-based coatings vs. traditional antifoulings. Some results are summarised below.

Source	Reduction in frictional coefficient (ΔC_f)	Remarks
Weinell et al. (2003)	6,1%	Rotary study (Couette). Smooth PVC
Candries et al. (2003)	3,5%	Rotary study. Smooth PVC
Schultz (2004)	3,0-3,8%	304SS
Candries and Atlar (2005)	5,3%	Smooth steel. Turbulent boundary layer measurements
Force Technology (2008)	1,4%	Towing tests. Smooth Aluminium panels

Table 2: Representative differences in friction coefficient when comparing clean fouling release coatings to self-polishing type ones. Silicone topcoats are reported to consistently decrease the drag resistance of a hull compared to eroding-type paints

2.4.1 Model ship towing tank tests

To further establish the beneficial characteristics of Hempaguard® towing tank tests using ship models were conducted in collaboration with Indian Institute of Technology Madras, India. The difference in effective power was calculated for a modified Hempaguard® coating and a top tier antifouling coating – see below. The average difference over the speed interval was established at 3.6%.

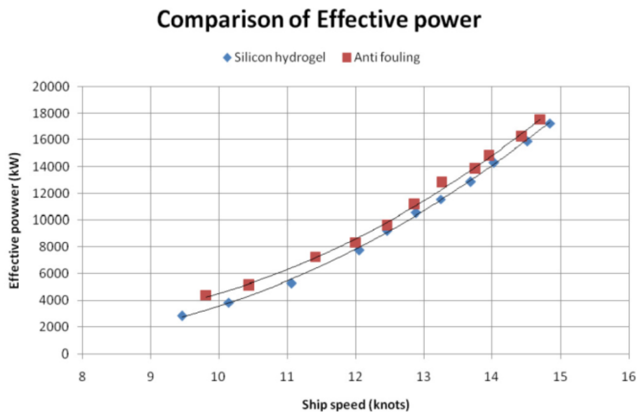


Figure 4: The effective power for the ship model test as a function of the ship speed giving a power reduction of 3.6% for the Hempaguard® equivalent coating compared to a top tier antifouling coating.

2.4.2 Rotating disk study

An experimental setting where a disk was rotating in sea water was built. Disks were coated with different fouling control coatings and the torque differences were measured. The torque differences were translated to frictional coefficients. Below figure shows the differences frictional coefficient as a function of substrate roughness for two coating systems. The difference is more pronounced as the substrate roughness increases.

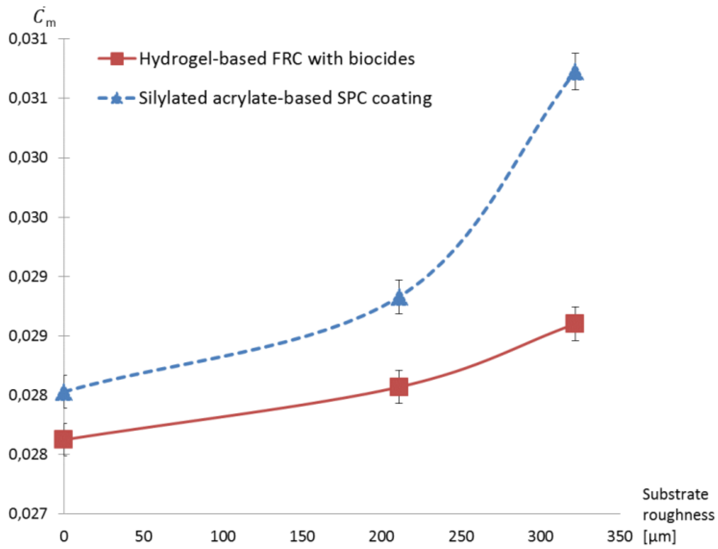


Figure 5: Showing the frictional coefficient as a function of the substrate roughness upon which two coating systems have been applied. Independently of the substrate roughness Hempaguard® (red line) and a silyl acrylate based antifouling coating (blue line) will always provide a smoother surface.

2.4.3 Large scale towing tank tests

In order to increase the accuracy of the frictional studies large scale tests were conducted at FORCE Technology's towing tank facilities by use of International Towing Tank Conference (ITTC) standards. 2.5 by 0.6 meter panels were coated and dragged at a speed of up to 7 meters per second. The skin friction coefficients for various coatings were calculated.

The fuel saving potential for the Hempaguard equivalent coating compared to conventional anti-fouling coatings as calculated by FORCE Technology are shown in below table. The average initial saving is 6%. The fuel saving potential is due to the smoother Hempaguard equivalent coating and the more beneficial interaction with water for the flat panel during towing tank test.

Ship type	Initial saving %
Aframax tanker	7.2
Bulk carrier	5.9
Container ship	6.5
Gas tanker	5.1
Ro-Ro/passenger	4.8
Supply vessel	3.5
VLCC	8.6

Table 3: The initial savings for the Hempaguard equivalent coating compared to conventional antifouling coatings for a series of ship types.

2.4.4 Frictional measurements in fouled condition

In order to test coatings fouling resistance, flat disks were immersed at Den Helder, the Netherlands for one month in order to expose the coatings to the marine fouling environment. The impact of the fouling upon drag resistance was calculated for the difference coatings. The appearance of the disks after being exposed to seawater for one month are shown in below figure.

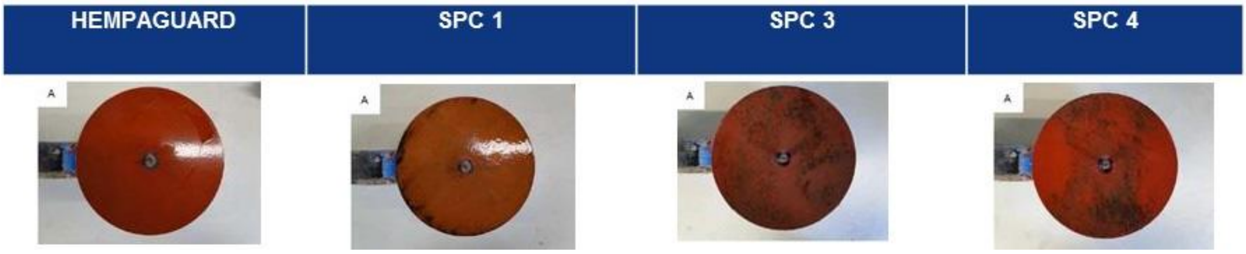


Figure 6: The appearance of Hempaguard® and three top tier conventional antifouling coatings after being exposed to the marine environment for one month.

After the coatings were exposed to the marine environment the drag measurements were performed again using the same procedure as described in the procedures for rotating disks in their non-fouled condition, i.e. torque measurements converted to friction coefficient via the Granville procedure which were further translated into full scale power increase for different ship types by the ResPro software developed by FORCE Technology. The results from the rotating disks, both in fouled and in non-fouled conditions are summarized in below figure and exemplified for an Aframax tanker.

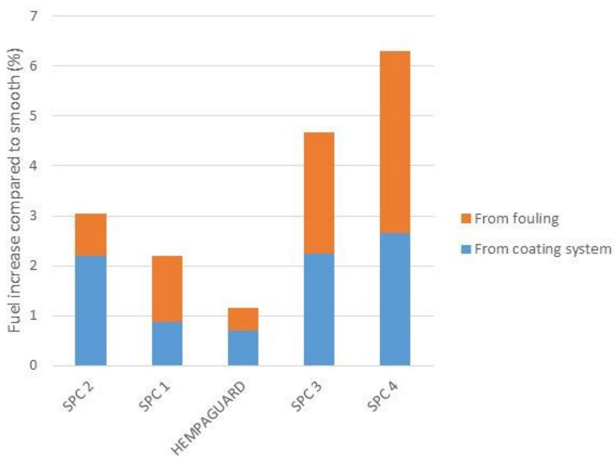


Figure 7: Showing the contribution upon fuel increase compared to a hydrodynamically smooth hull for a series of hull coatings, Hempaguard® and four top tier conventional antifouling coatings. Hempaguard® outperform all other coatings by way of being the smoothest and the most resistant to becoming fouled once exposed to the marine environment.

2.5 Hull performance monitoring of ships in service

The real impact of Hempaguard's outstanding performance is best evaluated for ships in service using on board monitoring equipment. Performance of hull coatings is measured as a combination of two performance indicators:

(1) Out-of-dock performance

It is the indicator of the absolute performance in the initial period after dry docking. Hulls are considered to be free from fouling and with limited mechanical damage. Refers to the performance during the first 10-12 months in service – power usage is compared at identical speed. Below is a typical example of a comparison between two sister Suezmax vessels with shaft power meters and with similar trade. Vessel A is fully blasted and coated with Hempaguard while vessel B is spot blasted and coated with a conventional antifouling coating. Power usage is compared at 13 knots. Actual data for first 10 months show 15% savings for the vessels coated with Hempaguard.

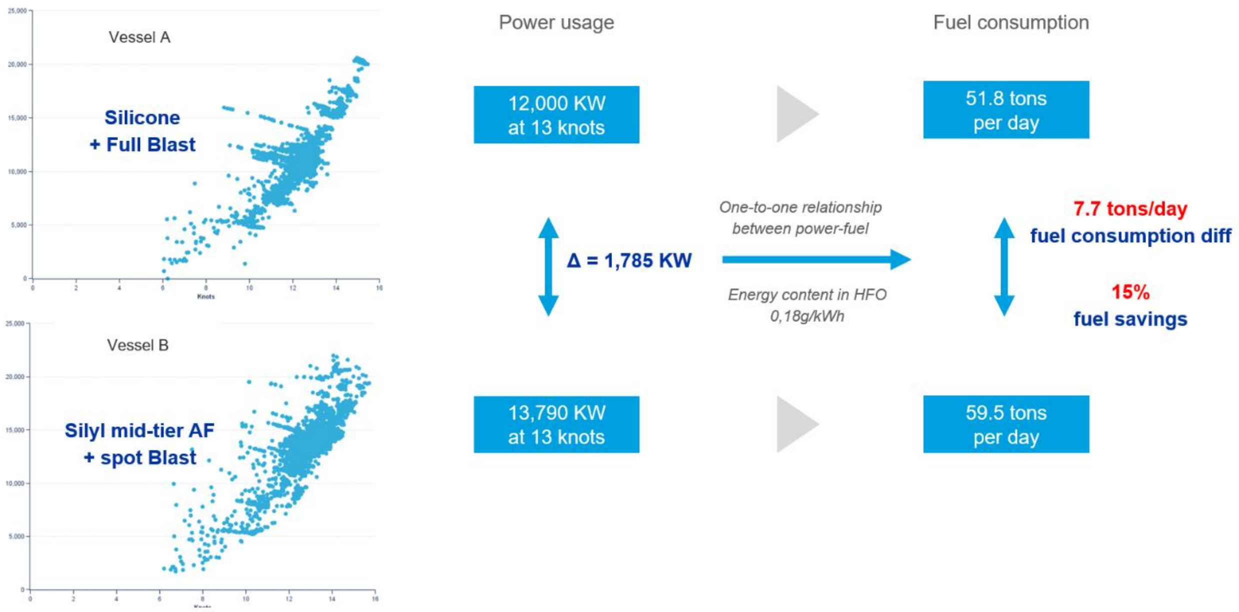
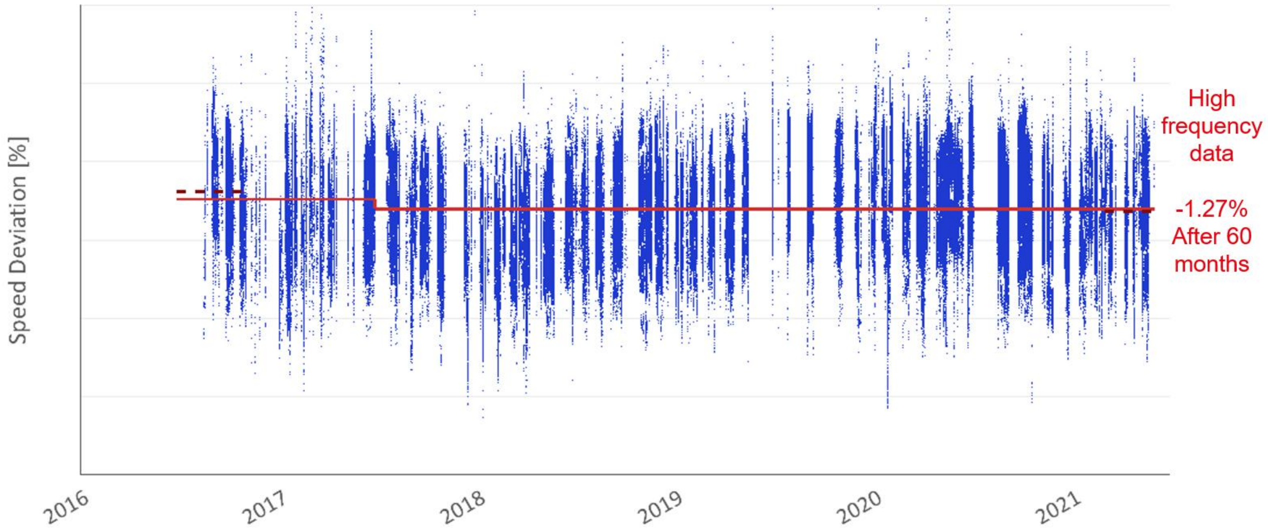


Figure 8: Out of dock performance example – 2 sister vessels with similar trade, different hull coating and surface preparation

(2) Performance over time

It is the indicator that measures performance changes over time based on ISO 19030. The first year in service constitutes the baseline to which the remaining time in service is compared to showing the relative performance drop over time. The % deviation of each data point is measured against reference speed power curves.

The plots below show typical examples of the speed changes in percentage (speed loss %) caused by fouling on the hull and propeller for Hempaguard Vs Silyl methacrylate antifoulings (Fig. 9) and for Hempaguard on Figure 10 and 11. The speed loss % is a measure on how the speed of a ship changes given a fixed power output. The more fouling is accumulate on the hull the slower the speed of the ship for a given power output.



Speed deviation of an LNG tanker with shaft power and datalogger installed – 60 months service, no cleanings

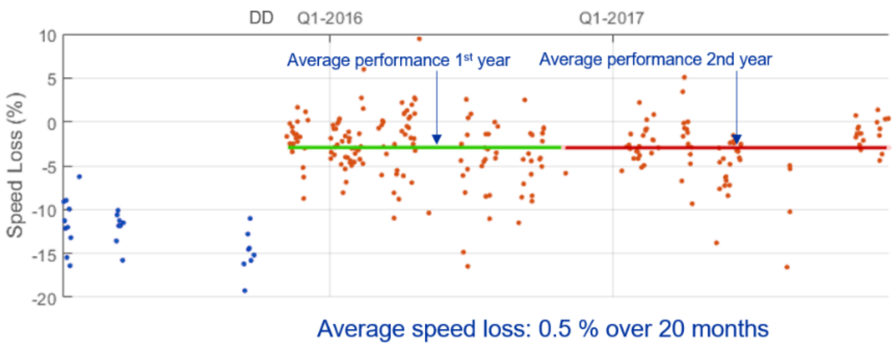


Figure 10: Speed index as a function of time due to hull fouling for a Tanker vessel (VLCC) in service for 3 years

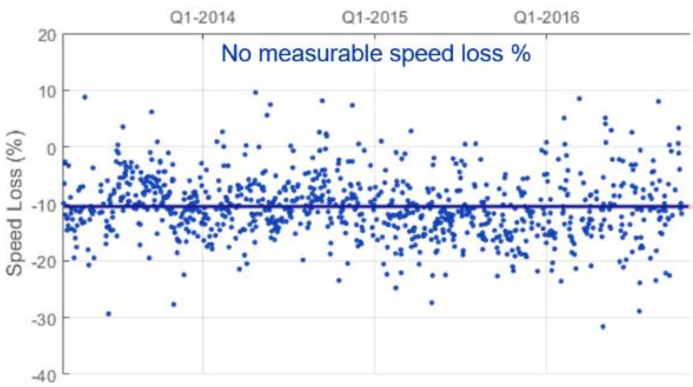


Figure 11: Speed index as a function of time due to hull fouling for a Containership in service for 4 years

2.6 Summary

To summarize, the results from the frictional studies using rotating disks (fouled and non-fouled), towing tank tests and model large scale tests prove the following Vs traditional self-polishing antifouling:

- Hempaguard has the smoothest surface from day one in service with average initial fuel saving of 6%)
- Hempaguard will stay smooth over time
- Hempaguard is the most resistant towards fouling accumulation helping the maintenance of its smoothness during its entire service life

Data from onboard performance monitoring for a series of ships in service confirm the reliability of the laboratory results and towing tank tests. Based on above evidence, Hempaguard is considered as the most energy efficient hull coating available in the market and the most cost-efficient retrofit technology available to improve fuel savings.

References

1) Paint and Coating Industry, 30, 8, 20-23, 2014
2) Granville, P., Drag-characterization method for arbitrarily rough surfaces by means of rotating disks., J. Fluids Eng., 104, 373–377, 1982.
3) Candries, M. and Atlar, M. Experimental investigation of the turbulent boundary layer of surfaces coated with marine antifoulings, Journal of Fluids Engineering, 127 (2), 219–232, 2005
4) Candries M., Atlar M., Mesbahi E. and Pazouki K., The measurement of the drag characteristics of tin-free self-polishing co-polymers and fouling release coatings using a rotor apparatus, Biofouling, 19 (supplement), 27–36, 2003
5) Schultz M. P., Frictional resistance of antifouling coating systems, Journal of Fluids Engineering, 126, 1039–1047, 2004
6) Schultz M. P. (2007) Effects of coating roughness and biofouling on ship resistance and powering, Biofouling, 23(5), p. 331-341
7) Townsin, R. L. (1979) The economic consequences of fouling and roughness, Marine Fouling Seminar, London
8) Weinell C.E., Olsen K.N., Christoffersen M.W. and Kiil S., Experimental study of drag resistance using a laboratory scale rotary set-up, Biofouling, 19 (supplement), 45–51, 2003