Methanol and Ethanol as Alternative Fuels for Shipping

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ABSTRACT

Over the past decade regulatory emission control has been adopted and even stricter emission reductions are being considered. In order to comply with the present and future regulations the ship owners and engine manufacturers are facing a difficult task. The shipping industry is presently offering multiple choices such as scrubbers and Selective Catalytic Reduction (SCR), dual fuel engines, Liquefied Natural Gas / Liquefied Petroleum Gas (LNG/LPG) powered engines, and lately the introduction of methanol and ethanol as alternative fuels. This work presents a short overview of the possible use of methanol and ethanol as alternative fuels in shipping. The first part of this work deals with physical properties of methanol and ethanol, production and availability, as well as advantages and disadvantages in comparison with other fuels. In the second part the cost perspective is presented together with the cost-benefit analysis, which is the most important aspect in the ship owner's decision whether to invest into the new alternative. Methanol and ethanol are not magical solutions, but rather another alternative which, from the cost perspective, offers a potential under certain circumstances. These circumstances are competitive prices in comparison to Marine Gas Oil (MGO) and time spent in Emission Control Area (ECA) which should be a large portion of the total sailing time. In this paper the scientific methodology was followed by using the method of compilation, the descriptive and the comparative methods.

KEY WORDS

methanol; ethanol; alternative fuel; emissions;

1. INTRODUCTION

The quest for economically sound and effective alternative energy, which can be competitive to fossil fuels and at the same time less harmful to the environment is constant these days. A flood of ideas is emerging into the marine market, almost on a monthly basis. Some of them are really promising and they might develop into effective solutions. However, all of them will need to pass a long transition, emerging from technological niches, meet the expectations of socio-technical regime and landscape developments, and in the end, compete with advanced technical solutions for the use of fossil fuels. Although the presence of pioneering enterprises of renewable energy use is growing, such as Sky-sail, Flettner rotor, Fuel cells, Photo-voltaic panels, ..., so far none of them represents an eminent threat to fossil fuels. Combined, they might have enough strength to compete with fossil fuels, but more technical research and development is required. More likely, passing mid-step with advanced conventional propulsion engines fuelled by Liquefied Natural Gas (LNG) or bio fuels is required before the next step. Recent engine development in MAN and Wartsila clearly marked this path. While LNG-powered vessels are already well proven, although they are still struggling to take their market share, the vessels powered by bio fuels are a novelty. The recently launched series of methanol-powered vessels have yet to prove the idea behind alternative fuels. After a period of operational experience lots of technical and safety queries will be solved, most probably influencing further decline in investment costs. Providing reasonable trend of methanol/ethanol price, this might establish another substitute for conventional fuel.

2. METHANOL AND ETHANOL AS FUELS

In the process of complying with low sulphur requirements, in addition to LNG, methanol and ethanol draw attention as alternatives to fossil fuels. Since 2006 the following projects have been in process or completed in order to test methanol as a fuel in the shipping industry:

– METHAPU 2006-2009
– Effship 2009-2013
– SPIRETH 2011-2014
– Methanol: the marine fuel of the future 2013-2015
– MethaShip 2014-2018
– Waterfront Shipping 2013-2016
– LeanShips 2015-2019

– proFLASH 2015, phase 1
– SUMMETH 2015

As a crown of all these projects MAN recently launched the first methanol-powered vessel [1]. Seven vessels of 50,000 deadweight (DWT) were built for "Waterfront Shipping Co.", "Mitsui", "Westfal-Larsen", and "Marinvest", powered by Main Engine - Liquid gas injection (ME-LGI) MAN engines. MAN has developed ME-LGI engine (on the base of Main Engine type-electronically controlled engine) for operation on Heavy Fuel Oil (HFO), Marine Diesel Oil (MDO), Marine Gas Oil (MGO) and methanol, [1]. Physical properties of methanol and ethanol in comparison with HFO/ MGO/ LNG, reveal a couple of disadvantages, as well as advantages. Methanol/ethanol densities are lower and therefore bigger storage tanks are required. Methanol has lower heating value which is about half that of HFO/MGO, meaning that twice as much fuel by weight must be stored to obtain the same energy. Lubricity is additional problem, since it is in direct relation to the life of machinery components (liner, piston rings). In addition, both methanol and ethanol are corrosive to some materials, so that the selection of proper material must be taken into consideration. However, from the environmental aspect, methanol and ethanol (when produced from renewable sources) are very competitive as they are clean-burning, do not contain sulphur, and can be produced from renewable feedstock. Nitrogen oxides (NO_x) level is low, in line with Tier III NO_x emission. It has been noted that while running on methanol, the engine efficiency is as high as or even higher than with fossil fuels. An important aspect is biodegradability, as they do not bio-accumulate, which is important in case of vessels collision or grounding. Both of them dissolve readily in water, and they are not rated as toxic to aquatic organisms. Methanol is widely used in chemical industry, and for that reason it is available globally. Although there are no terminals for bunkering vessels with methanol, it is considered that the infrastructure could be developed at a relatively low cost (in comparison to LNG) as current bunkering infrastructure needs only a minor modification to handle methanol.

3. PRODUCTION AND AVAILABILITY

It is interesting that the initial interest for methanol use as fuel in transportation started in 1976, when lead in gasoline was banned. Full project was in place in California during 1980-1990 for conversion of gasoline vehicle to 85% methanol, [2]. The program was pretty successful, although the main reason for conversion was not environmental protection but methanol's low price and replacement of lead as octane booster. However, the program ended in 1993. It was the result of inadequate infrastructure, limited refineries capacity, and therefore increase of price which eventually equalized with the price of gasoline. Today, methanol is widely used in chemical industry, and the production capacity is constantly increasing. As per global market study worldwide, methanol demand increased by 23% [3] in the period from 2010 to 2012, mostly due to the Chinese demand growth. The majority of methanol production is from gas and coal by means of steam reformation. At the same time this is a non-renewable feedstock. Renewable production of methanol, or bio-methanol, uses wood biomass. An interesting technology was discovered in 2005 by Prof. George A. Olah [4] (University of South Carolina), as the recovery of carbon dioxide (CO_2) from the atmosphere for methanol production. A small plant in Iceland is using a similar process; CO_2 emissions from geothermal plant. The capacity of this plant is 50 million litres, [5]. Ethanol is mostly produced in the United States (US) and Brazil from crops containing sugar or starch. In Europe, ethanol is produced from wheat and sugar beets. Europe's production of ethanol is around 5% [6] of the worldwide production, and most probably it will stay at this level due to the European Union (EU) Parliament legislation, which limits the use of crop-based biofuels to 7%. [7]

4. EMISSION OF SO_X, NO_X, AND PARTICULATE MATTER

Both methanol and ethanol are relatively pure fuels, and do not contain sulphur. Laboratory emission level tests, with methanol as fuel, were performed on two types of engines; Wartsila Vasa 32 and Wartsila Sulzer Z40SMD. During the test on the Vasa 32 engine, NOx emission was recorded within 3 to 5 g/kWh [8], while for MGO at about 11.8 g/kWh [8]. Similar results were found during the test on Z40SMD engine. In comparison to HFO380, methanol particulate matter (PM) was reduced by 95% [8], CO_2 was found to be reduced by 7% [8], and sulphur oxides (SO_x) reduction was 99% [8] (small amount of SO_x was accounted for by diesel pilot ignition). Unfortunately, no similar testing was recorded for ethanol fuel. In *Figure 1*, CO_2 emission factor is presented for MDO, LNG, methanol and ethanol. From the environmental point of view, it is important to present a summary of greenhouse gas (GHG) emission for every kind of fuel. Namely, a part of CO_2 emissions are accounted for by the production and transport of fuel to the vessel. In literature this emission is named "Well-to-Tank", while the emission resulting from burning fuel on board is "Tank-to-Wake".

According to *Figure 1* "Tank-to-Wake" emissions for bio-fuels do not exist. The reason is the EU renewable energy Directive (2009/28/EC) which considers biomass-based fuels to be carbon neutral. Namely, the amount of CO_2 released during combustion on board is almost the same as amount used by the plant during growth. It could be noted that LNG has two different

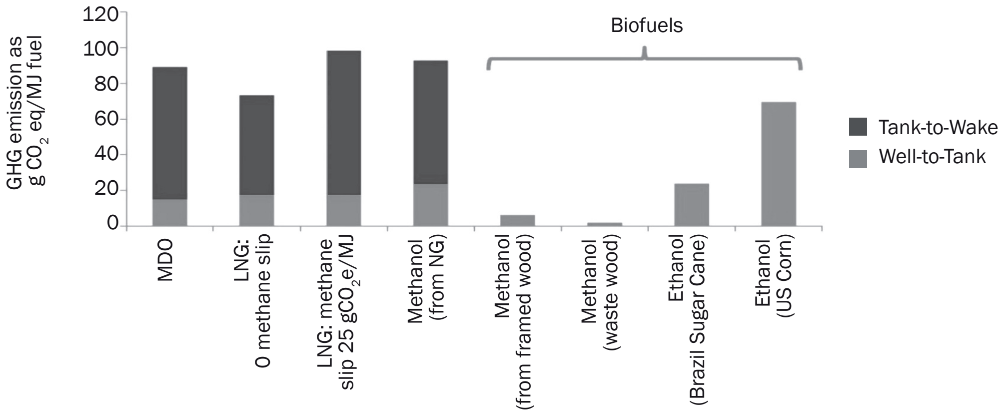

Figure 1 – Emissions for selected fuels [8]

combustion values; LNG with zero methane slip and LNG with methane slip (refers to unburned methane at low engine loads).

5. FUEL COST AND ECONOMIC ANALYSIS – EMSA STUDY

Comparative economic analysis can be accurate only for a short period of time due to unpredicted fluctuation of fuel prices over a prolonged period. It certainly does not help ship owners to make strategic decision ref. type of fuel to be used on the vessels. Any investment, whether in conversion or newbuilding requires thorough economic analysis which needs to result with reasonable payback time. In the European Maritime Safety Agency (EMSA) study three types of vessels were considered: Ro-Ro ferry, chemical tanker and cruise ship. Conventional types of fuels HFO/MGO were compared with LNG, methanol and ethanol. The analysis covered: the investment costs for each type of fuel, equipment operation, maintenance cost, and future fuel cost for each type of vessels. The last variable (fuel cost) is the most critical for calculation, as the final result depends entirely on the correct prediction of the future fuel cost. However, the EMSA study based the calculation on the scenarios of three cases for fuel cost presented in *Figure 2*.

Summarized results of payback time for different options are presented in *Table 1*. The base for comparison was a vessel running on conventional fuel: HFO outside Emission Control Area (ECA), and MGO in ECA, and without the installed scrubber.

In addition, the study took into consideration the period after 2020, when 0.5% global sulphur cap will take place. For this calculation, a price of 900 USD/t for 0.5% sulphur residual fuel cap was considered as comparator. Ro-Ro ferry operating 100% in the area with 0.5% sulphur fuel cap was taken as comparator. Based on this price *Table 2* presents the payback times.

Table 1 – Payback time (for average fuel price) [8]

Ship type and operating location	Payback time [years]							
	Retrofit				New build			
	HFO + Scrubber + SCR	LNG	Methanol	Ethanol	HFO + Scrubber + SCR	LNG	Methanol	Ethanol
Ferry 100% in ECA	2.2	3.8	3.1	Never	2.0	4.6	2.6	Never
Ferry 0% in ECA	NA	Never	Never	Never	NA	Never	Never	Never
Chem. Tanker 100% in ECA	1.7	3.0	2.4	Never	1.5	3.6	2.1	Never
Chem. Tanker 50% in ECA	3.4	7.5	21.2	Never	3.1	9.1	18.0	Never
Cruise ship 100% in ECA	2.3	3.6	2.9	Never	2.1	4.4	2.5	Never
Cruise ship 25% in ECA	9.0	36.2	Never	Never	8.2	44.2	Never	Never

Table 2 – Payback time after 2020 [8]

	0.5% fuel oil	HFO + scrubber + SCR	LNG	Methanol	Ethanol
Assumed fuel cost [USD/t]	900	711	931	412	737
Payback time new build	Comparator	3.0	7.5	6.2	Never
Payback time retrofit	Comparator	3.3	6.2	7.3	Never

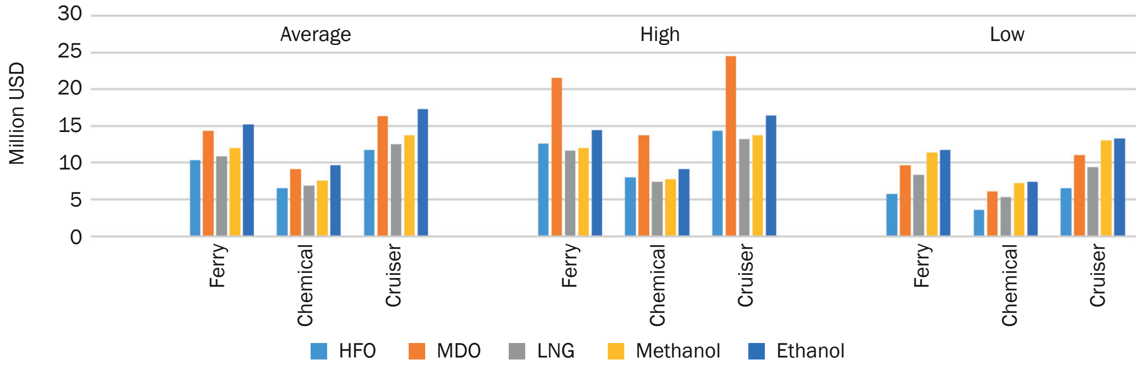

Figure 2 – Annual fuel costs for each ship type in million USD [8]

6. FUEL COST AND ECONOMIC ANALYSIS WITH FUEL PRICES IN 04/2018

Taking into consideration that fuel prices have changed since EMSA study (*Figure 3*), the new calculation was made, using the same methodology and the same sources for fuel prices (as a variable found to be most critical for calculation).

Based on fuel price findings in 04/2018, the calculation of annual fuel consumption is made following the methodology from the original study, so the results could be compared. Results are shown in *Figure 4*.

It is clear that fuel prices have changed significantly, and made a great change to annual fuel costs, when comparing the results from the EMSA study. Annual cost values are similar to those of low fuel cost scenario in the EMSA study, except for the ethanol cost. Such findings were expected, since the ethanol prices have decreased significantly. If compared to the average fuel cost from the EMSA study, all the values are much lower.

Following the same methodology, the payback times have been calculated for the retrofit, and the new-builds. The same cost for retrofitting the engine, and for the new build, as in the EMSA study have been taken into calculation. The results are shown in *Table 3*.

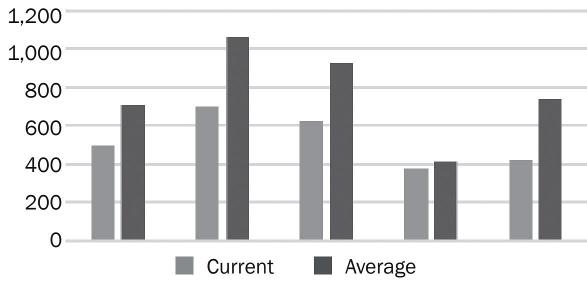

Figure 3 – Fuel prices in 04/2018 [USD/t] compared with average prices from EMSA study [9-11]

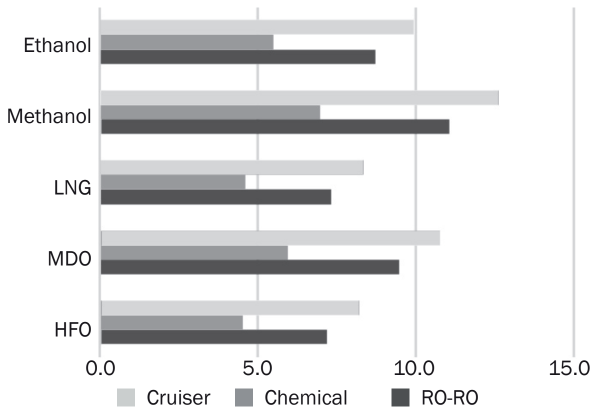

Figure 4 – Annual fuel cost for different fuel and ship types in million USD

Table 3 – Payback time using prices in 04/2018

Ship type and operating location	Payback time [years]							
	Retrofit				New build			
	HFO + Scrubber + SCR	LNG	Methanol	Ethanol	HFO + Scrubber + SCR	LNG	Methanol	Ethanol
Ferry 100% ECA	3.7	5.6	Never	8.7	3.3	6.8	Never	7.2
Ferry 0% in ECA	NA	Never	Never	Never	NA	Never	Never	Never
Chem. Tanker 100% in ECA	2.9	4.3	Never	6.7	2.7	5.4	Never	5.8
Chem. Tanker 50% in ECA	5.8	9.1	Never	Never	5.3	11.5	Never	Never
Cruise ship 100% in ECA	3.8	5.6	Never	8.8	3.4	6.9	Never	7.3
Cruise ship 25% in ECA	15.1	27.2	Never	Never	13.5	33.1	Never	Never

The results have shown that with 04/2018 prices scenario methane has no financial benefit and ethanol might be profitable, both opposite to the EMSA study results. This is the direct impact of fuel price change with ethanol found to be much cheaper at the moment. In such circumstances it might be considered a profitable fuel for ships also, especially the ones that sail through ECA.

7. ECONOMIC ANALYSIS – DNV GL AND MAN STUDY

The quest for conventional fuel alternatives continues, and for that reason it is not surprising that many ship owners either search or order cost-benefit analyses for alternative fuels. Recently, Det Norske Veritas Germanischer Lloyd (DNV GL) and MAN [12] published an analysis for 75,000 DWT product tanker which is supposed to operate on the route North America and Northern Europe: Houston-Ventspils-Rotterdam-Houston. The calculated distance of the route is 11,700 nautical miles, including 37% inside the Emission Control Area / Sulphur Emission Control Area (ECA/SECA). The task of the analysis was to investigate different fuel options and present cost-benefit for each option, taking care of the incoming new worldwide regulation for 0.5% sulphur in 2020. The fuel variants are presented in *Table 4*.

For calculation purposes the fuel price scenario was derived from fuel price trend from 2012 to 2015. Two possibilities were used: high-price scenario (mid 2014 – Brent oil 100-110 USD/barrel; 1 barrel=158.987 litres) and low-price scenario (mid 2015 – 50 USD/barrel). For each option the Capital Expense (CAPEX) has been calculated and no wonder that the most expensive was found to be for LNG option, due to high tank price. However, LNG and LPG prove to be in either price scenario the attractive options, although in the low-price scenario they are less attractive. Methanol does not give a positive result, which is in alignment with EMSA study. The conclusion is: methanol can be financially attractive only if the price is reduced by 18-20% below the MGO price (historical period 2011-2012). *Figure 5* presents the results of the study.

8. CONCLUSION

Today's shipping market, even after a long period, does not show signs of recovery, and the additional investment in conversions to be, which is inevitable by 2020, will cause turmoil among many ship owners. In addition to the decision what type of vessel to build, there is dilemma which fuel to use for powering

Table 4 – Fuel variants used in the analysis [12]

Option	Inside ECA	Outside ECA 2018-2019	Outside ECA 2020
Reference	MGO	HFO	LSFO 0.5%
LNG	LNG	LNG	LNG
LPG	LPG	LPG	LPG
Methanol	Methanol	Methanol	Methanol
LNG/HFO	LNG	HFO	LSFO 0.5%
LPG/HFO	LPG	HFO	LSFO 0.5%
Methanol/HFO	Methanol	HFO	LSFO 0.5%
ULSFO 0.1%	ULSFO 0.1%	ULSFO 0.1%	ULSFO 0.1%

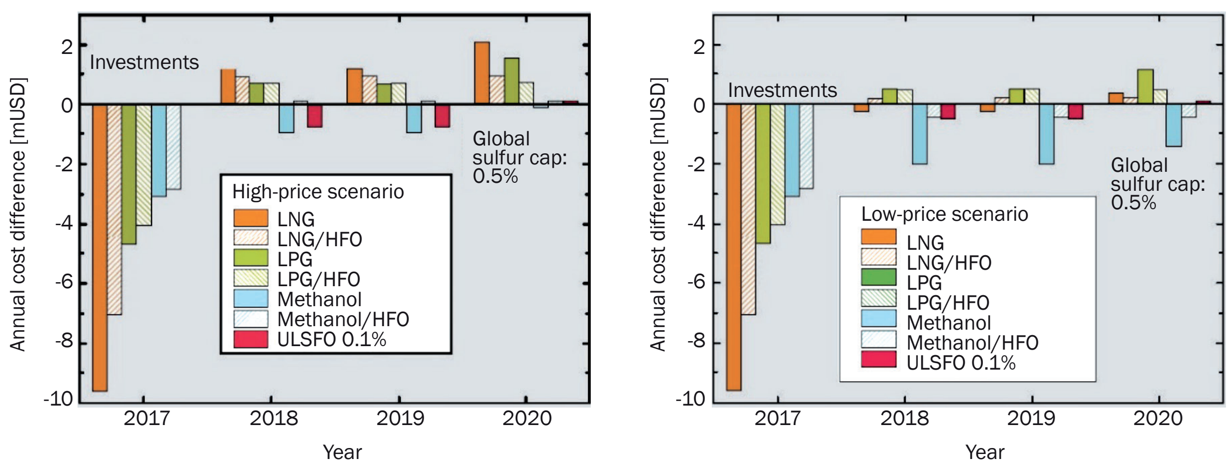

Figure 5 – Annual cost differences for the various fuel variants, based on two fuel price scenarios [12]

the vessel in order to have the most economic result during the vessel lifetime. The present market is offering a couple of choices with its advantages and disadvantages. Choosing the proper option is entirely up to the owner, based on thorough market research and fuel prices trend prediction. The recent commissioning of seven new chemical tankers with dual fuel methanol engines by "Waterfront Shipping" should, after a long-term operational experience, build confidence in methanol as fuel. Unfortunately, for ethanol there is no project in prospective, although there is a long-term experience in heavy duty engines in land transport. In addition, long-term operational experience might help to lower costs for conversion as the first generation of methanol vessels were built with additional safety precautions for obvious reasons. It remains to be seen whether methanol will take its share of the shipping market, following LNG-powered vessels. Both previously presented economic analyses consider methanol as economically sound option under certain circumstances. Taking into consideration the fuel prices in 04/2018 the results of calculations in this paper are found to be different. Diversity of options will certainly offer fuel spectrum with a range of advantages and disadvantages. Taking into consideration that those new generations of engines are capable of burning multiple kind of fuels, a new opportunity for ship owners is arising; vessels which can use multiple fuels are certainly having advantages by choosing the most economic fuel in a certain region. This is technically feasible and for some ship owners already a reality. However, choosing a proper option will remain a complex task for ship owners, as one has to consider the installation costs, present and future fuel costs, availability, safety, environment impact, as well as compliance with new regulations.

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METANOL I ETANOL KAO ALTERNATIVNA GORIVA U POMORSTVU

SAŽETAK

Tijekom proteklog desetljeća usvojena je regulatorna kontrola emisija, a razmatraju se i još oštrija smanjenja emisija. Kako bi udovoljili sadašnjim i budućim propisima, vlasnici i proizvođači motora suočavaju se s teškim zadatkom. Brodarska industrija trenutno nudi višestruke izbore kao što su 'skraberi' i selektivna katalitička redukcija (SCR), motori s mogućnošću uporabe dvostrukog goriva, pogonski motori na ukapljeni prirodni plin / ukapljeni naftni plin (LNG / LPG) te u posljednje vrijeme uvođenje metanola i etanola kao alternativnih goriva. Ovaj rad predstavlja kratak pregled moguće uporabe metanola i etanola kao alternativnih goriva u pomorstvu. Prvi dio rada bavi se fizikalnim svojstvima metanola i etanola, proizvodnjom i raspoloživošću, kao i prednostima i nedostacima u usporedbi s drugim gorivima. U drugom dijelu prikazana je troškovna perspektiva zajedno s analizom troškova i koristi, što je najvažniji aspekt u odluci vlasnika broda da li će ulagati u novu alternativu. Metanol i etanol nisu čarobna rješenja, već druga alternativa koja iz perspektive troškova pruža potencijal u određenim okolnostima. Ove okolnosti su konkurentne cijene u odnosu na brodsko plinsko ulje (MGO) i vrijeme provedeno u području nadzora emisija (ECA) koje bi trebalo biti velik dio ukupnog vremena plovidbe. U ovom je radu znanstvena metodologija praćena metodom kompilacije, deskriptivnom metodom i komparativnom metodom.

KLJUČNE RIJEČI

metanol; etanol; alternativno gorivo; emisija;

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