

# Atmospheric and Economic Impact of LNG fueled Dredging. The Argentine Case

Impacto Atmosférico y Económico del uso de Dragas a GNL.  
El Caso de Argentina

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## Abstract

This paper takes a 2021 Argentine case to show the atmospheric and economic impacts of using LNG fueled dredgers in the second largest worldwide operation of its kind about to start in Rio de la Plata. From the emissions point of view, LNG (Liquified Natural Gas) would reduce 23%, mainly those (NO<sub>x</sub>, SO<sub>x</sub> and PM) affecting the coastal population health. The use of BioLNG would reduce 99% (60,000 Tons/yr), including as well the planetary impact of CO<sub>2</sub>. The economic impact is estimated in savings of 14% of Dredging Cost: 665 Million Dollars (MMUsd), over the 15 years of operation. The origin of these savings is 48% Operational (reduced fuel cost) and 52% external cost mainly due to the reduced impact in Public Health Budget.

**Key words:** Dredging, Marine LNG, Atmospheric Impact, Economic impact.

## Resumen

Este trabajo toma el caso de Argentina en 2021 para mostrar los impactos atmosféricos y económicos de usar GNL (Gas Natural Licuado) en la propulsión de dragas en la segunda mayor operación mundial de dragado a realizarse en el Rio de la Plata. Del punto de vista de las emisiones, el GNL las reduciría un 23%, actuando principalmente sobre las que afectan a la salud de las poblaciones costeras. El uso de BioGNL las reduce un 99% (60,000 Tons/a), incluyendo el efecto planetario del CO<sub>2</sub>. El impacto económico se estima en un ahorro del 14% del costo total del dragado (665 Millones de dólares) a lo largo de los 15 años de concesión. El 48% de este ahorro se debe a una reducción de costo de combustible y el 52% son ahorros de costos externos por el menor gasto necesario en la Salud Pública.

**Palabras claves:** Dragado, GNL Naval, Impacto Atmosférico, Impacto Económico.

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## Introduction

In November 2020, the Argentine government launched the bidding process for the new Dredging and Buoying Concession for the inland waterway on the Paraná and Rio de la Plata rivers up to where the latter empties into the Atlantic Ocean. This will make it possible to increase, and afterwards maintain, the width, depth and buoying of the waterways needed to allow some 6,000 ships to circulate with imports and exports from Argentina, Bolivia, Brazil, Paraguay and Uruguay. This is the second largest dredging operation of its kind at global level.

There is a worldwide trend to diminish the harmful effect of dredgers' atmospheric pollution, adopting LNG as fuel, for which reason this study analyzes the atmospheric and economic benefits of this energy transition solution.

## Cost of the Investment in Dredgers

Given that the specific approaches covered in this study relate to the construction of new, environmentally-friendly Trailing Suction Hopper Dredgers (TSHD), here we analyze some cases that assist in estimating the cost of these new constructions.

A ship-owner's first reaction, when thinking about reducing pollution and economizing on the operation by using LNG-fueled dredgers, is to convert his existing dredgers. However, this isn't convenient in the cases of aging vessels since such a conversion demands a very large investment – of the order of 30% of the value of a new dredger – and poses serious space limitations.

A case in point is the transformation to LNG carried out by Damen in 2018 on the *Samuel de Champlain* dredger, built in 2002, owned by the French company Dragages-Ports Eig for operation at the Port of Nantes-Saint Nazaire (*GIE DRAGAGES-PORTS, 2017*). The investment was of US\$ 25MM, equivalent to 29% of the construction of a new conventional unit, and was subsidized by the

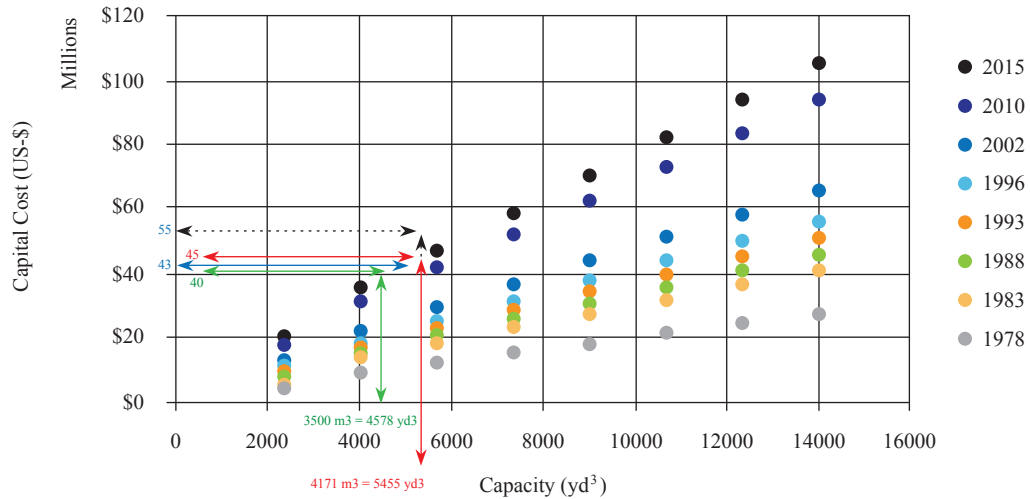
*European Commission's Innovation Fund through its Connecting Europe Facility.*

In order to estimate the costs of new Trailing Suction Hopper Dredgers, a chart is shown (Fig. 1) (*Wowtschuk, B. M. 2016*) which indicates the evolution of prices since 1978 as a function of hopper volume. The following cases are indicated on the chart:

1. The building of the dredger *Afonso de Albuquerque*, owned by Jan de Nul, concluded in 2019 at the *Keppel Singmarine* shipyards in Nantong, China, at a cost of US\$ 40MM. This value is 6% higher than that of a conventional dredger owing to the installation of a scrubber system to partially reduce exhaust gas emissions. This equipment has arrived for operation in Argentina (indicated in the color green in the chart).
2. Blue indicates the US\$ 43MM cost bid by IHC to the Uruguayan National Ports Administration for the dredger *21 de Julio*, with a 4,200 m<sup>3</sup> hopper, built in Europe. That international tender was canceled and bids sought for the construction of the dredger in Uruguay – which was very successfully carried out in 2017. The new IHC value with partly Uruguayan construction is indicated with a dotted blue line at US\$ 55MM.
3. Lastly, the red line indicates the “design dredger” of this study with a hopper volume of 4,171 m<sup>3</sup> which shows a value of US\$ 45MM (US\$ 10,800/m<sup>3</sup> of hopper).

In order to consider the extra cost of an LNG-powered dredger over a conventional one, the comparison is made with the case of the pushers (*Podetti R.E., 2021*) on the Paraguay-Paraná Waterway, for which an estimated extra cost of the order of 25% was arrived at. As the percentage cost of the motorization of a pusher is relatively higher than that of a dredger, the extra expense of LNG for the latter is considered to be 15%. In this way the designer LNG dredger in this paper is valued at US\$ 51.7MM (US\$ 12,400/m<sup>3</sup> of hopper).

Fig. 1. TSHD Cost Estimate.



Source: Bohdon Michael Wowtschuk, “Production and cost estimating for trailing suction hopper dredge,” Texas A&M University, Ocean Engineering Dept., 2016. Chart modified by the author.

## Dredging Concession in Argentina

The governmental information (ARGENTINA. HIDROVÍA FEDERAL) on the dredging operation under the current concession is analyzed in order to relate volumes dredged, hours worked,

fuel consumption and type of equipment. To do this, the statistics available on the national government’s official page were pored (Fig. 2) through, which initially led to the volumes dredged between 1995 and 2017, leading to an annual average of 28.6 million m<sup>3</sup>, representing 50% of

Fig. 2. Argentine Dredging Operation Data 2016-2017.

DREDGERS CAPACITY, VOLUME DREDGED AND DIESEL OIL CONSUMPTION 2016 / 2107												
DREDGER		DREDGER VOLUME	TOTAL POWER	2016 (HIGH)			2017 (LOW)			2016+2017		
Name	No.	M3	HP	HOURS /YR		DO CONS.	HOURS /YR		DO CONS.	DO CONS.		
				Operat.	Std By	LITERS/YR	Operat.	Std By	LITERS/YR	LITERS		
				63%	18%	<% AT 100%HP	63%	18%	<% AT 100%HP			
Niña	1	3.400	7.415	5.928	564	5.132.318	4.832	618	4.222.100	9.354.418		
Alvar N. C. De Vaca	2	3.400	5.494	4.913	515	3.160.201	2.412	424	1.582.463	4.742.664		
Americo Vespucci	3	3.500	6.968	5.451	527	4.436.771	2.763	343	2.266.329	6.703.100		
James Ensor	4	3.600	9.849	4.557	739	5.339.538	66	29	83.272	5.422.810		
Manzanillo	5	4.000	16.268	-	-	-	3.164	423	6.075.101	6.075.101		
Sanderus	6	5.300	9.085	1.652	147	1.749.376	-	-	-	1.749.376		
Capitán Nuñez	7	6.000	13.708	6.980	468	11.083.404	3.067	833	5.153.410	16.236.814		
Pedro A. Cabral	8	14.000	21.386	1.616	314	4.148.206	-	-	-	4.148.206		
Niccolo Machiavelli	9		31.517	1.465	1.041	6.327.403	-	-	-	6.327.403		
TOTAL HS /YR				32.562	4.315		16.304	2.670				
TOTAL LIT. D.O. /YR				41.377.219			19.382.674			60.759.893	1	
TOTAL VOL DREDGED				53.122.000			29.445.000			82.567.000	2	
DO /M3				0,78			0,66			0,74	3 = 1/2	
AVERAGE DREDGER VOL.		4.171		DREDGING AVAILABLE VOLUME(M3) :							67.100	4
ANNUAL DREDGING VOLUME (M3) / DREDGING AVILABLE VOLUME: 1231												

Prepared by the author based on (WOWTSCHUK, B. M. 2016) and (ARGENTINA. HIDROVÍA FEDERAL)

the volume projected (*LATINOCONSULT, 2020*) for the following period. The dredgers employed were almost exclusively of the TSHD type.

Next, an analysis is performed of the years 2016 and 2017 (with available complete information), which additionally represent two different situations: that for 2016 was of very high dredging activity, while that for 2017 was almost equal to the average for the previous 23 years.

Seven dredgers in operation were taken into consideration along with two additional ones that arrived for operating in one season in 2016. They are all trailing dredgers save one, the *Niccolò Machiavelli* (9), which is a “cutter.”

D.O. Consumption was in each case calculated (*Wowschuk, B. M. 2016*) multiplying by parameter 0.1818, the following factors:

- The dredger’s total Power (HP)
- The dredgers’ annual Hours of Operation.
- The percentage of Equivalent Hours/day, at 100% of Power, during Operation.
- The dredgers’ annual Stand By Hours.
- The percentage of equivalent Hours/day, at 100% of Power, during Stand By.

The daily logs for each dredger (ARGENTINA. HIDROVÍA FEDERAL) yielded the Hours of Operation and Hours of Stand By, for each year analyzed.

In order to estimate the Equivalent Hours at 100% of power for each condition (Operation and Stand By), the values presented in Fig. 3 were employed.

Analyzing this information, the conclusion is that in this two-year period:

- Some 60.8 million liters of D.O. were consumed, and some 82.6 million m<sup>3</sup> were dredged, leading to a specific consumption ratio of **0.74 Liters D.O./m<sup>3</sup> dredged**.
- In order to achieve the 82.6MM m<sup>3</sup> dredged, dredgers with a total hopper capacity of 67,100 m<sup>3</sup> were on hand, making it possible

to propose a ratio of **1,231 m<sup>3</sup> dredged/m<sup>3</sup> available hopper**.

These parameters are highly useful in carrying out the projections for costs, consumption and necessary investments for the new stage.

Fig. 3. Equivalent Hours at 100% Power.

EQUIVALENT HOURS AT 100% POWER				
HP	OPERATION		STAND BY	
	HS/DAY	HS EQ.100%	HS/DAY	HS EQ.100%
100%	1	1,0	0	0,0
75%	18	13,5	3	2,3
10%	5	0,5	21	2,1
	24	15,0	24	4,4
		<b>63%</b>		<b>18%</b>

### Projection for Volume and Total Cost of Dredging and Buoying

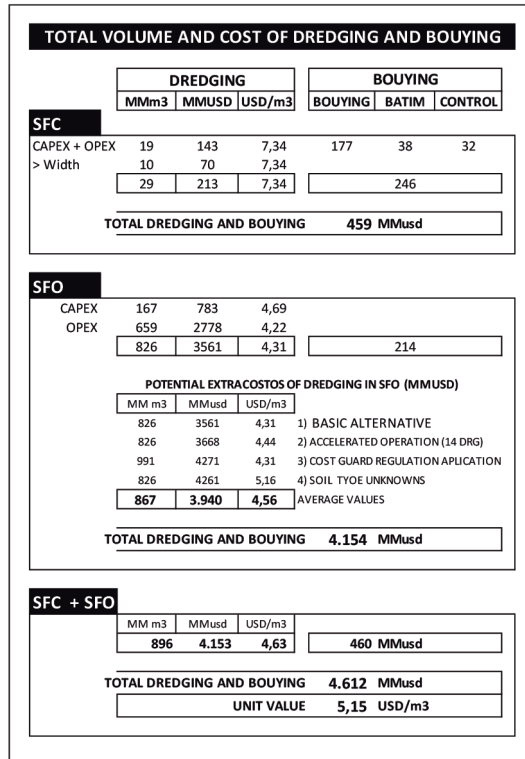
The basis adopted was a recent study (*LATINOCONSULT, 2020*), financed by a series of organizations that represent the interests of sectors which the new concession impacts on.

The information is presented in Fig.4 and separately analyzed for two geographical sectors: SFC (Santa Fe-Confluencia), to the north, and SFO (Santa Fe-Ocean) to the south; and for two main activities: Dredging and Buoying. At the end the information is unified to obtain median parameters that are easier to handle.

Adding the two sectors together (SFC + SFO), the following overall results are obtained: the total volume of 896 million m<sup>3</sup> to be dredged costs 4,153 million dollars (US\$ 4.63/m<sup>3</sup>). Adding the cost of buoy laying for both stretches, some 460 million dollars, a final overall cost of US\$ 4,612 million is reached, which corresponds to a final unit value of US\$ 5.15/m<sup>3</sup> of dredged material (buoying included).

The following table compares the volumes to be dredged in the projected fifteen years with 23 of the 25 years of the current concession for which reliable data were obtained.

Fig. 4. Dredging Cost.



It is seen that the projected dredging effort is somewhat larger than twice what was carried out up to now in annual averages.

As a reference for the evolution of dredging costs over recent years, the following chart presents the U.S. case (in 2018 dollars). The rise is accounted for by increases in fuel, higher environmental demands and the concentration of supply among

a few dredging companies, thus reducing real competition.

The following chart (Fig.5) shows the unit cost of dredging (Fritelli, J. 2019) at various U.S. ports and that which is projected for the River Plate. A good correlation with the dredged volume is observed.

### Unit Cost of Dredging with LNG

Fig. 6 details the impact of the use of LNG on the combined result of the Cost of Dredging and Buoying, highlighting the values that are modified with regard to the use of Diesel Oil.

The unit cost is broken down into five factors: Ships, Fuel, Crew + Maintenance, General Expenditures and Others. The table analyzes them separately using the data obtained previously and with parameters from the references (Wowschuk, B. M. 2016; LATINOCONSULT, 2020 and CIRIA, 2016).

A 7.5% reduction in the unit cost is seen, which translates into total savings of 321 million dollars. These would be the operational savings with LNG, which lead to greater competitiveness for Argentina's exports.

### Toxic Emissions in Dredging Operations

There is overwhelming scientific evidence with regard to the impact that the toxic emissions of ships, including dredgers, have on health and the

Fig. 5. Dredging Unit Cost.

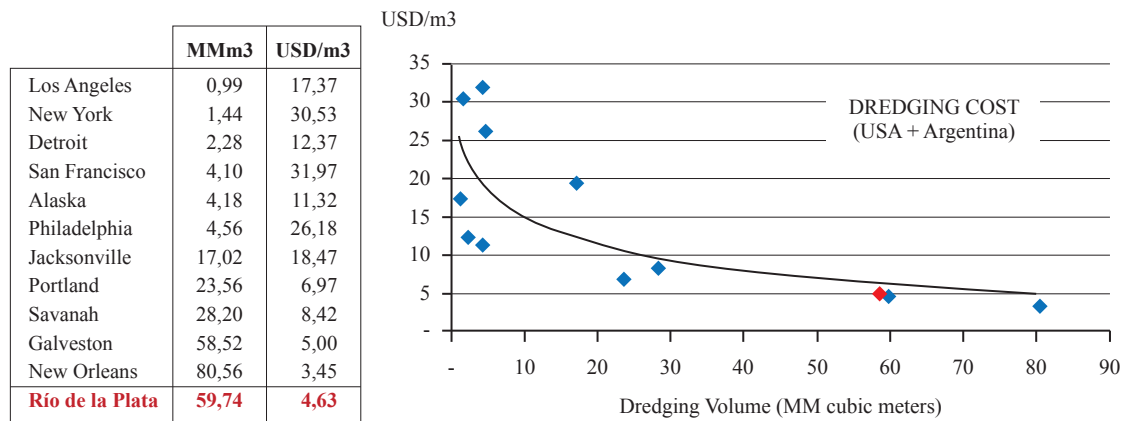


Fig. 6. Dredging Unit Cost Breakdown (LNG).

DREDGING AND BOUYING UNIT COST (w/LNG)				
USD/m <sup>3</sup>	ITEM	MMm <sup>3</sup>	MMUSD	
			15 YEARS	
15,4%	<b>0,74</b> VESSELS			
14,6%	0,70 DREDGERS			
0,8%	0,04 BOUY SETTERS	896	37	(7u x 15years x 0,35 MMUSD/u-yr)
9,2%	<b>0,44</b> FUEL			
7,7%	0,37 DREDGERS			
1,5%	0,07 BOUY SETTERS	896	63	(7u x 15years x 0,6 MMUSD/u-yr)
37,3%	<b>1,79</b> CREW AND MAINTENANCE			
34,8%	1,67 DREDGERS			
2,5%	0,12 BOUY SETTERS	896	105	(7u x 15years x 1MMUSD/u-yr)
35,4%	<b>1,70</b> GENERALES			OTHER OPERATING AND GENERAL COSTS AND BENEFIT
33,3%	1,60 DREDGERS			0
2,1%	0,10 BOUY SETTERS	896	89	(7u x 15years x 0,85MMUSD/u-yr)
2,7%	<b>0,13</b> OTHERS			Buoys, Signals, Batimery, Control Administration
100%	<b>4,80</b> USD/m <sup>3</sup> TOTAL	896	4291	
	<b>-7,5%</b> Cost Reduction by the uso of LNG			
	<b>-321</b> MMUSD is the projected Saving with LNG			
90%	4,34 DREDGERS			
6,9%	0,33 BOUY SETTERS			
2,7%	0,13 OTHERS			
	4,80 USD/m <sup>3</sup>			

environment, particularly when traffic is intense and contiguous to areas near rivers where there is high population density.

It's interesting to note the corporate position which some global dredging firms are adopting with regard to the issue of pollution, even beyond the minimum regulatory obligations which some consider to be excessively permissive, given the extremely serious worldwide environmental situation. In order to reflect this, the following paragraph is quoted:

*“With more than 1,100 dredging vessels worldwide, of which about half are trailing suction hopper dredgers, DEME believes that dredging companies can contribute to the call of the International Maritime Organization (IMO) for improvements in energy efficiency.*

*The industry should not wait for policies and regulations to rethink the fuel efficiency performance of their dredging vessels, but should achieve sustainable growth by*

*improving energy efficiency with regard to carbon emissions.*

*Energy objectives at DEME are quantified through an increase in efficiency of 7% by 2022 compared to 2011.” (J.B de Cuyper, 2014)*

At present, the replacement of Diesel Oil by Liquid Natural Gas (LNG) on trailing dredgers appears as the most convenient transitional option, for the following reasons:

- The current (and projected) cost of LNG is much lower than that of refined Diesel Oil and this difference is on the rise. *The Netherlands Expert Group for Sustainable Transport and Logistics* poses price differentials which on average are of 50% in favor of LNG.
- LNG very strongly reduces emissions that are harmful to health (NO<sub>x</sub>, SO<sub>x</sub> and PM).
- It permits being mixed with biogas to thus also reduce CO<sub>2</sub> emissions, up to total decarbonization.
- The technology is already tested and widely available on the maritime market with successful applications to new dredgers as well as to others converted from D.O. to LNG.

Nevertheless, to overcome dredgers' specific operational challenges, special designs became necessary that would make it possible to overcome the limitations of the dual (LNG/D.O.) engines applied to dredging (*W. Shi et al., 2015*). The success of these designs is reflected in the rising percentage of new constructions of LNG-powered dredges.

In the majority of cases, it is necessary to build a new dredger since the large cost of conversion to LNG (of the order of 30% of a new one) isn't justified in the case of vessels nearing the end of their useful life – which will cause a large part of the fleet to be out of commission earlier than had initially been contemplated.

### Unit Cost of Dredging with LNG

The harm to the environment and to health, caused by the toxic emissions of ships in general, is

proportional to three factors: Nearness to population, Type of fuel used and Volume consumed.

- The Nearness of the contaminating ship to cities is critical, above all for the health of the most vulnerable populations (children and the aged).
- The Type of fuel consumed causes the specific levels of emissions to vary. Fuel Oil is much more contaminating than Diesel Oil, which in turn is much more contaminating than LNG, which in turn emits more CO<sub>2</sub> than biogas.
- The Volume of the harmful emissions generated by ships is proportional to the volume of fuel consumed.

In the case of dredgers and buoy layers, which we are concerned with here, we are in one of the worst situations, since the three factors pointed out combine negatively:

- They operate near the country's largest coastal population centers (metropolitan Buenos Aires-Santa Fe).
- Because of the age of the vessels used under the current concession, in certain cases, the

type of fuel is highly contaminating, to which is added a low energy efficiency, this being another factor in the rise in emissions.

- By the high operating intensity of the dredgers and buoy layers, their fuel consumption levels, and therefore those of toxic emissions, are very high.

### Volume of Consumption of Diesel Oil

In order to estimate the volume of fuel during the new concession, current consumption was taken and adjusted in proportion to the volume of dredging.

In Fig. 7 we see that this operation implies a consumption of the order of 52,300 m<sup>3</sup> of D.O. yearly by the 17-vessels fleet of the new concession. As a reference, it is pointed out that this is 77% of the volume currently consumed by river transport on the Paraguay-Paraná Waterway (Podetti R.e., 2021).

### Volume of Emissions

Fig. 8 presents the Emissions Factor associated with Diesel Oil and LNG for each of the four toxic

Fig. 7. Projected Annual Fuel Consumption of Dredging and Bouying.

PROJECTED ANNUAL DIESEL CONSUMPTION				
	Qty of Vessels	LITERS OF DIESEL /YR		
		1 VESSEL	FLEET	
BOUY SETTERS	7	1.200.000	8.400.000	0,74 L/m <sup>3</sup> x 59,7 MMm <sup>3</sup> /a
DREDGERS	10	4.396.142	43.961.425	
			<b>52.361.425</b>	
			=	
			<b>52.361</b>	Annual Consumption

Fig. 8. Projected Annual Emissions of Dredging and Bouying.

PROJECTED ANNUAL EMISSIONS OF DREDGING AND BOUYING							
Emission	EMISSION FACTOR Tons / Thous of Diesel (m <sup>3</sup> )		EMISSIONS ( Tons/Yr) for the projected DO Vol of: 52,36 Th m <sup>3</sup> D.O/y		EMISSIONS REDUCTION w/LNG (Tons/year)		Emission
	D.O	LNG	D.O	LNG	D.O - LNG		
CO <sub>2</sub>	1106	863	57922	45179	12743	22%	CO <sub>2</sub>
NO <sub>x</sub>	22,14	2,51	1159	131	1028	89%	NO <sub>x</sub>
SO <sub>x</sub>	0,74	0	39	0	39	100%	SO <sub>x</sub>
PM <sub>10</sub>	0,52	0,15	27	8	19	71%	PM <sub>10</sub>
			<b>59147</b>		<b>13829</b>		

emissions considered. Applying these factors to the annual 52,361 m<sup>3</sup> of consumption leads to the annual figure for toxic tons for each case.

Lastly, through the difference, the last column shows the improvement in tons and percentages, clearly demonstrating that the largest percentage improvements are obtained with regard to the emissions that are harmful to health (NO<sub>x</sub>, SO<sub>x</sub> and PM), and are much more moderate in relation to CO<sub>2</sub>, which impacts on global warming. To eliminate these CO<sub>2</sub> emissions, LNG can be gradually replaced, over the coming years, by BioLNG, as the production of the latter increases in volume and it thus also becomes available for maritime use.

These reduction percentages are somewhat conservative when compared to other, similar studies on the industry (*Gabriel, J., 2016*) which indicate the following reductions: 25% for CO<sub>2</sub>, 85% for NO<sub>x</sub>, 99% for SO<sub>x</sub> and 99% for PM.

#### Economic Assessment of the Damage caused by Toxic Emissions

In a just society, to every crime there corresponds a proportional penalty, which usually has an economic valuation commensurate with the cost of the damage generated. Something similar should occur with contamination, understood as environmental social harm. In Europe, where consciousness over this subject is high and rising, systems of economic penalization of pollution are already in existence. In Argentina (and in many other countries), environmental damages remain unpunished, and very often the problem generated – and therefore its economic impact – are denied.

The toxic emissions of dredgers and buoy tenders generate environmental damages with social costs that are not contemplated by the government and much less so by the concession holder, so that they are termed “external costs.” This name seeks to differentiate them from the “internal” costs (fuel, personnel, repairs, etc.) which a ship-owner knows and seeks to minimize since he must pay a price for them.

The environmental costs of ships’ emissions remain hidden, yet are very real. **They are generated costlessly by the ship-owner, but are paid by the contaminated population**, without charging them to the party causing them. This represents an unfair subsidy that fosters the continuation of costless contamination. In Europe, on the other hand, a fairer policy is already beginning to be applied, summarized in the phrase, he who does it, pays for it. This process seeks to “internalize” external costs; in other words, have the ship-owners shoulder the costs of the damage through higher taxes on contaminating fuels or, even better, by investing on more environmentally-friendly ships, etc.

#### External Costs of Dredging in Argentina

Below we analyze “Argentine external costs” – those that are caused by these vessels’ toxic emissions and that increase expenditure on public health because of illnesses and deaths. To which are added the economic losses through damage to infrastructure, harvests and biodiversity, as in the case of the acid rain generated by these harmful emissions.

Since no regional study on the valuation of these damages has been found, the results of European studies (*CE DELFT, 2011*) are extrapolated. This analysis was performed for the Waterway (*Podetti R.e., 2021*) and is applied to the case of dredging and buoying, being presented in the following table (Fig.9).

The first line shows the tons of toxic emissions and then the unit external cost for each toxic ton (extrapolating from the European case). It can be seen that particulate matter generates a relatively higher external cost per ton, mainly by being responsible for cardiorespiratory diseases, cancer and deaths among the coastal population.

The conclusion is that, if the current permission to pollute through the use of Diesel Oil in dredging and buoy laying is maintained, we Argentine would pay some US\$ 391MM for the damages which the dredging concessionaire causes all of us as a society, at a pace of US\$ 26MM/yr. If, instead,



Fig. 9. Projected Annual External Costs of Dredging and Bouying.

PROJECTED ANNUAL EXTERNAL COSTS				
	PM	NOx	SOx	TOTAL
EMISSIONS VOLUME W/DIESEL (Tons/Yr)	27	1.160	39	
UNIT EXTERNAL COST (Usd/Ton)	71.560	20.265	16.133	
TOTAL EXTERNAL COST (MM Usd/yr)	1,93	23,51	0,63	26 MMUsd/yr
			15 years	391 MMUsd
EMISSIONS VOLUME W/LNG (Tons/Yr)	8	131	-	
UNIT EXTERNAL COST (Usd/Ton)	71.560	20.265	16.133	
TOTAL EXTERNAL COST (MM Usd/yr)	0,57	2,65	-	3 MMUsd/yr
			15 years	23 MMUsd/yr
			15 years	343 MMUsd

the use of LNG were implemented, this cost would be appreciably diminished to only US\$ 3MM/yr, i.e. to only 11%.

These results coincide by 95% with those obtained when employing the method proposed (MERK, O. 2014) in the OECD’s International Transport Forum for ship emissions in port. To this end, the results are related as a function of per capita GDP and the size of the affected coastal populations.

In a way, allowing the use of Diesel Oil is a kind of US\$ 391MM subsidy that the Argentine government awards the concession holder, which neither seems very convenient for the country nor is necessary for the company, which faces a large US\$ 4.6 billion business. In addition, in this way the greatest incentive to cease polluting is lost.

### External Costs of Dredging on the Planet

Another aspect which seems remote, but is equally important, is that of the assessment of the “planetary external cost,” that is to say the cost related to the climate change that affects all of humanity (current and, above all, future) because of the global warming generated by greenhouse gases, the principal representative of which is CO<sub>2</sub>.

Fig. 10 (CE DELFT, 2011) shows the projection for the external cost caused by CO<sub>2</sub> (euros/ton-CO<sub>2</sub>). Located in the center, between the curves for the two most probable scenarios and for the concession

period (2022-2037), is the median value of 80 euros/t-CO<sub>2</sub> (US\$ 96/t-CO<sub>2</sub>). The product of this parameter by the previously calculated volume of CO<sub>2</sub> emitted by D.O.-powered dredgers and buoy tenders (57,922 t-CO<sub>2</sub>/yr) leads to an annual cost of US\$ 5.6MM, which over the 15 years means **US\$ 84MM**.

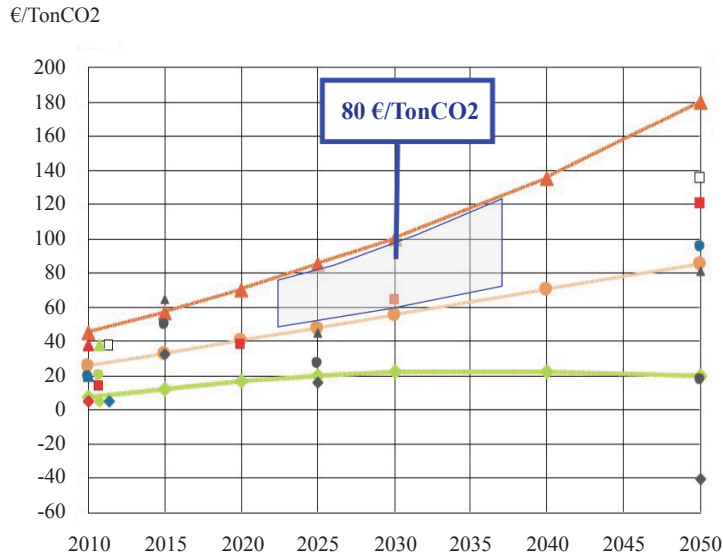
Another way to evaluate the economic cost of this planetary harm caused by CO<sub>2</sub> emissions is derived from the very recent “carbon market,” which is an indicator of the price paid by those companies that emit CO<sub>2</sub> to those with activities that have a negative CO<sub>2</sub> balance.

This is a new type of market, which “compensates” those projects that make the biggest efforts in favor of the planet, through the sale and purchase of carbon bonds.

According to the study published by The Economist, the carbon market price (2007) applied to river navigation (PIANC, 2010) is the equivalent of an additional cost of US\$ 0.15/L of Diesel Oil as a penalty for the emission of CO<sub>2</sub>.

Applying this to the projected consumption by dredgers and buoy layers under the new concession (52.3 million L D.O./yr), detailed above, leads to a cost of US\$ 8MM/yr., or **US\$ 120MM** in total, which the company operating the concession ought to pay on the carbon market to compensate for the generated pollution.

Fig. 10. Projected Planetary External Costs.



Taking the average between the two monetary assessments, it can be estimated that, using D.O., the future dredging concessionaire on the River Plate will generate a planetary damage with effects on climate change with a value of the order of **US\$ 102MM**, which could be initially reduced by 22% with the use of LNG, and by almost 100% with an increasing use of biogas in propelling the dredgers and buoy layers.

Total External Costs

The following table (Fig.11) summarizes the external costs detailed above:

In sum, the total external cost which the concession holder would generate if it were allowed to continue using Diesel would be of US\$ 493MM, 79% of which (US\$ 391MM) would be a hidden subsidy – which Argentines all pay together – issued to the dredging company, for it to continue polluting us for free.

If, instead, the concessionaire were to use LNG, this external cost (mainly social expenditure on health) to Argentina (hidden subsidy) would be reduced by 88%.

Lastly, the use of LNG under the concession allows savings in social expenditures of **US\$ 344MM**

Fig. 11. Summary of External Costs of Dredging and Bouying.

SUMMARY OF EXTERNAL COST OF DREDGING				
	DIESEL		REDUCTION W/	
	MMUSD	MMUSD/y	LNG	BIOGAS
EXTERNAL LOCAL COST (PM10, Sox, Nox)>> HEALTH	391 79%	26	88%	99%
EXTERNAL PLANETARY COST (CO2) >> CLIMATE CHANGE	102 21%	7	22%	100%
<b>TOTAL EXTERNAL COST</b>	<b>493</b>	<b>33</b>	<b>74%</b>	<b>99%</b>

(88% of 391), and avoids many deaths, protecting our health and that of the planet.

## Conclusions

The use of LNG (and even better bioLNG) to fuel the dredging operations in Argentina would impact in the health of local population and global climate change in a very positive way. But it would also save public funds and operational costs to the operators. Taking the above presented results, there would be large savings in operation and external costs. They are estimated in **US\$ 665MM**, close to 14% of total Dredging Cost along the 15 years of concession.

For these reasons, the author has proposed the Argentine government to include a simple but powerful clause in the international tender under preparation. This clause sets a limit to the maximum admissible volume of emissions, and on top of that, proposes a method to prize the bidders that guarantee lower emission levels. A heavy monetary penalty is proposed in case of contamination.

A similar clause is proposed to promote the construction of new dredgers in Argentine shipyards.

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