Amid a global pandemic, and despite the fact that the 2020 cruise season was officially cancelled, the cruise industry still blights coastal communities in Italy.

This paper analyses one specific but illustrative case: the Costa Luminosa. It never made it back to Venice as scheduled, but might have. Therefore we share the concerns of the city of Savona.

In late February, due to concerns linked to Covid 19, the ship was turned away from ports midway through the Caribbean portion of its global voyage that began in Venice on January 5. Nonetheless the voyage continued, and more passengers boarded in Fort Laudedale, Florida on March 5 before setting sail for Europe. A detailed account of the cruise corporations' handling of the emergent pandemic situation is described in our March report, Ships in the Dark.

During the Atlantic crossing, a number of coronavirus cases developed on board while the global pandemic was declared. The Luminosa offloaded most of its stricken passengers in Marseille before docking in Savona on March 20. It has been docked in the city centre with its engine running continuously, adding an associated quantity of air pollution to ambient levels with multifaceted consequences upon which to deliberate.

The structure of this paper is based on a series of technical considerations by colleagues from Savona Porto Elettrico, a community group engaged in the problems associated with cruise traffic that has been trying to engage every level of public authority and institution in getting the ship moved out of the Savona harbour to a mooring further away from homes or out at sea.

This analysis is a reflection of the WahV approach to act local and think global.

I Background

The Mediterranean is the most popular global destination for coastal tourism, drawing in a third of all visitors worldwide. In this context, the cruise industry has grown faster than any other mode of tourism, doubling every decade since 1990. Prior to the Covid-19 outbreak, a record 30 million passengers were expected in 2020[1]. This massive expansion has taken place within a wider trend for the maritime sector, which has played a key role in globalisation. Maritime transport has tracked the growth of Gross Domestic Product (GDP), growing at a more rapid rate than both energy consumption and global population[2].

Shipping represents the most energy-efficient method to move bulk cargo, and carries 80% of global trade by volume, to which 94% of the world's ships are dedicated.[3] Considering the correlation between growth in demand and global trade, shipping transit is projected to increase fivefold by 2050 on 2010 levels.

The energy demand is met chiefly by fossil fuels. As such, shipping accounted for some 950 million tonnes of carbon dioxide (CO_2) emissions in 2012[4], similar in magnitude to Germany. Furthermore, marine fuels, as stipulated by the EU Sulphur in Liquid Fuel Directive (2016/802/EU) have a higher sulphur content than land-based transport modes. In the case of heavy fuel oil (HFO) it is 100x greater. Associated atmospheric emissions are substantial and influence air quality on a regional and national scale.

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[1] CLIA. (2010). **Cruise market overview.** Miami: Cruise Line International Association.

[2] Eskeland, G.S., Lindstad, H.E., 2016. **Environmental taxation of transport.** Int. J. Green Growth Dev. 2 (2), 51–86.

[3] UNCTAD, **Review of Maritime Transport**, United Nations Publication, New York and Geneva, 2017.

[4] Smith T. Jalkanen J. Anderson BA. Corbett JJ. Faber J. Hanayama S. O'Keeffe E, Parker S. Johansson L, Aldous L et al. ***Third IMO GHG Study 2014,*** International Maritime Organization, London, 2014.

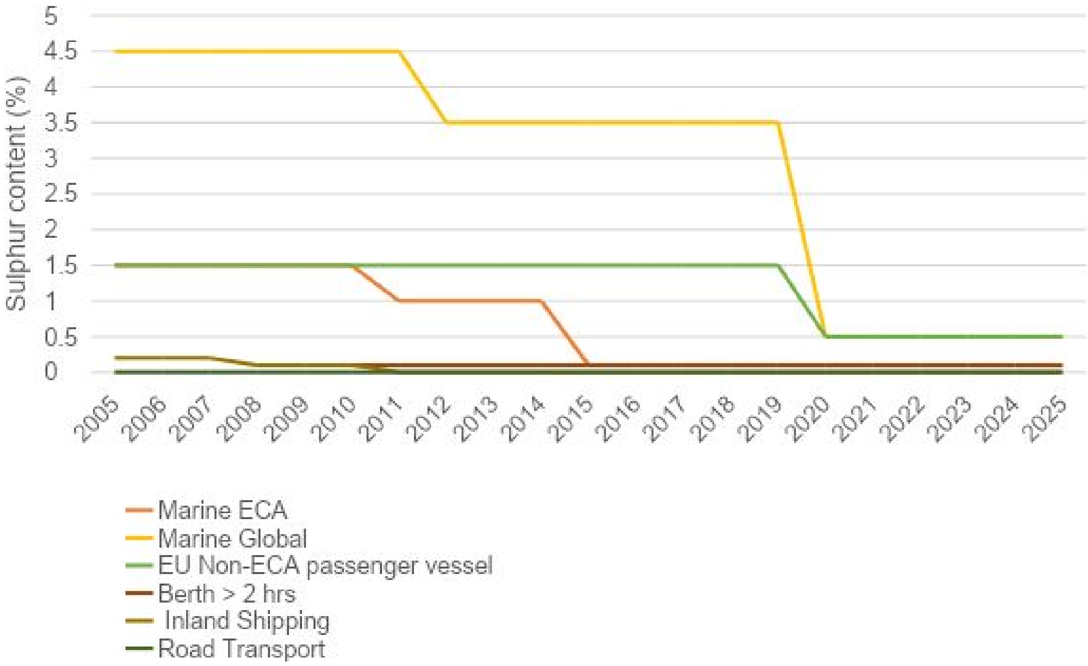

Figure 1 *EU Sulphur standards for marine and road transport*

Now, with the outbreak of Covid-19, fault lines in the business models have been exposed, numerous articles in both the mainstream media and scientific literature attest that "cruise ships are often settings for infectious diseases[5]", and projections for record growth have been slashed. Instead, with international tourism forecasted to fall by up to 80% this year, cruise ships and their crews are clustered in nautical limbo across the globe.

With many ships idling in ports around the world, the environmental costs continue to be borne by coastal communities, and by some metrics may be more severe overall than under regular scenarios. Savona, Italy, is a prime example.

[5] Moriarty LF, Plucinski MM, Marston BJ, et al. **Public Health Responses to COVID-19 Outbreaks on Cruise Ships — Worldwide, February–March 2020.** *MMWR Morb Mortal Wkly* Rep 202, 69, 347-352. DOI: http://dx.doi.org/10.15585/mmwr.mm6912e3

Figure 2 A flotilla of cruise ships of Manila harbour. Source: Reuters

II The Costa Luminosa in Savona

Using an analytical approach of triangulation to examine the environmental impact of a cruise ship in port, pollutant emissions are estimated, drawing from bottom-up activity-based methodologies and literature-based emission factors to explore both current and alternative scenarios. In addition, we consider what action needs to be taken today to mitigate the environmental impacts of the cruise industry in future.

As the cruise industry has expanded, so has its ecological footprint in coastal communities. Negative impacts of cruise ships are wide-ranging and well documented, from marine litter & hazardous wastewater to air and noise pollution. A particularly damaging practice is that of waste discharge, most intensely in the open sea.

Environmental impacts can also be considered within a wider context of social and economic progress. However, despite claims of prosperity brought by tourism in the free market, a study undertaken in Croatia revealed environmental costs of up to seven times the economic benefits for local communities[X]. In the Spring of 2020,

the most pertinent impacts are those associated with the cruise ship at berth, namely the combustion of marine fuel.

From a life cycle assessment (LCA) perspective, cruise tourism is most impactful in terms of climate change, with emissions attributed predominantly to fuel combustion during the use phase[6]. Energy is required for propulsion as well as ‘hotel’ functions, that on average account for 40% of total energy demand[7]. In port, cruise ships operate exclusively in ‘hotel mode’, whereby most of the power generated is used for hot water, lighting, air conditioning, as well as emergency systems. Main engines are switched off, while auxiliary engines and boilers sustain on-board operations.

As per EU legislation, the sulphur content of fuel combusted in port is limited to 0.1 %, obliging vessels to utilise marine diesel/gas oil (MDO/MGO), or heavy fuel oil (HFO) with scrubbers.

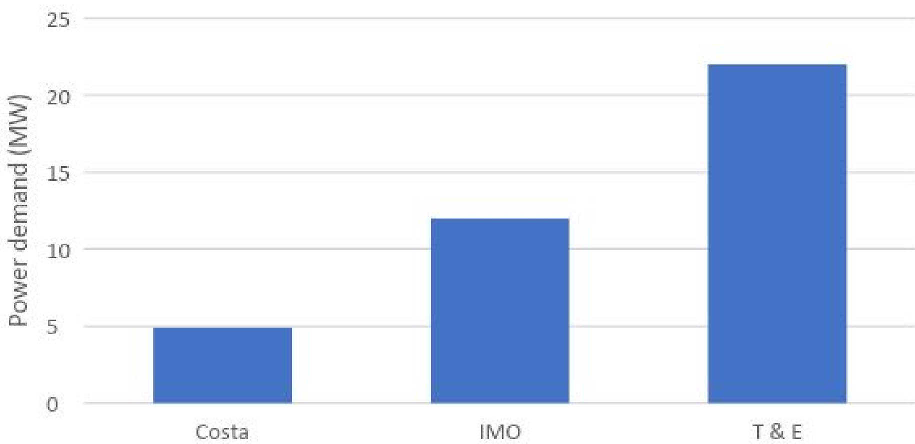

Figure 3 *Estimates of auxiliary engine load (MW) at berth*

[6] Farr R & Hall C, **A Life Cycle Assessment of the Environmental Impact of Cruise Holidays,** 2015, Conference: Contemporary Perspectives in Tourism and Hospitality Research: Policy, Practice and Performance, Brighton, UK

[7] Howitt OJ *et al, Energy Policy,* 2010, 38, 2552–2560

Estimates of power demand at berth are highly variable. However, it is noted that the estimate claimed by Costa (3.9 MW) is dwarfed by figures given by both the International Maritime Organisation (IMO) and environmental NGO Transport & Environment[8].

Bottom-up methods of ship emission rates during a specific operation phase can be estimated according to an emission factor (EF) with energy output or fuel consumption. EFs may be expressed as the mass of pollutant per unit of power (g/kWh), whilst energy output may be a function of engine power multiplied by a load factor.

Emissions calculation A

According to local authorities, the power engaged is one twentieth of its potential capacity and emits as much CO_2 "as 20 apartments".

As estimated by the Third IMO GHG Study, the engine load (auxiliary and boiler loads) of a cruise ship of capacity bin 60,000–99,999 at berth is approximately 11,980 kW. In Table 1, emission estimates for the Costa Luminosa are compared with those of a typical apartment.

Table 1 *Comparison of power, energy consumption and emission estimates between household and cruise ship fuel scenarios. Residential, maritime emission factors from Casasso A[9], Gilbert P et al,[10] respectively.*

		Typical apartment	Costa Luminosa
Capacity (kW)	Installed	25	64,000
	Engaged	25	3,900
Fuel		Natural Gas	MDO

[8] Transport & Environment, 2018, ***Roadmap to decarbonising European shipping***

[9] Casasso A et al, **Environmental and Economic Benefits from the Phase-out of Residential Oil Heating: A Study from the Aosta Valley Region (Italy)** *Sustainability* 2019, *11*, 3633; doi:10.3390/su11133633

[10] Gilbert P *et al*, *Journal of Cleaner Production,* 2018, 172, 855-866

Energy expended / 24hr (kWh)		135.5*	93,600
Operational fuel emission factor (g/kWh)	CO_2	233.6	524
	PM	0.000593	0.16
	NO_x	0.23709	14.8
Emissions / 24hr	CO_2 (t)	0.0308	49.0
	Ratio	1	1,594
	PM (g)	0.08	14,976
	Ratio	1	186,381
	NO_x (t)	0.00064	1.4
	Ratio	1	43,120

**normalised energy consumption based upon 1980 hrs (165 days * 12 hrs) of boiler utilisation*

We calculate that, on a 24hr basis, assuming central heating was engaged during the colder weeks, the Costa Luminosa may be emitting CO_2 emissions equivalent to around 1600 apartments, and particulate matter emissions equivalent to 186,000 apartments, if operating with MDO.

Emissions calculation B

An algorithm was derived by Simonsen et al[11] to calculate fuel consumption in port based upon gross weight and number of berths:

$$\frac{Fuel_{tonne}}{hour} = e^{(-21.9+(2.8*\ln ln\,(GrossWgt))+(-1.15*\ln ln\,(berths)))}$$

For the Costa Luminosa (Gross tonnage = 92,600, capacity = 3760) this equals 1.923 tonnes/hour. Rather than utilising data on an individual boiler basis, one may take the average annual Italian household energy consumption, thus accounting for other household appliances.

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[11] Simonsen M, Walnum HJ, Gössling S, **Model for Estimation of Fuel Consumption of Cruise Ships,** *Energies* 2018, *11*, 1059

Table 2 A comparison of power, energy consumption and emission estimates between household and cruise ship fuel scenarios.

Emission factors from Third IMO GHG Study.

		Typical apartment	Costa Luminosa
Energy / Fuel Consumption		16 MWh / annum	1.923 tonnes / hr
Fuel		Natural Gas	MDO
Operational fuel emission factor	**CO_2**	233.6 g/kWh	3,206 kg/tonne fuel
	PM	0.000593 g/kWh	1.02 kg/tonne fuel
	NO_x	0.23709 g/kWh	36.12 kg/tonne fuel
Emissions / 24hr	**CO_2 (t)**	0.0102	147.96 t
	Ratio	1	14,449
	PM (g)	0.026	47,080
	Ratio	1	1,811,150
	NO_x (kg)	0.01	1,667
	Ratio	1	160,396

With this second calculation, the associated CO_2 and PM emissions are some 3 times greater than the power estimates provided by Costa Cruises, and may be regarded as being more accurate; the apartment estimations decrease, and thus the disparity between the two energy consumers increases.

III Implications

To compare emissions from domestic heating and other sources is common practice. However, it is crucial to discern between the by-products of fossil fuel combustion, namely toxic short-lived air pollutants such as particulate matter (PM) and long-lived climate pollutants such as CO_2, which predominantly impact human and planetary health, respectively.

Air pollution and global warming are indisputably interwoven. Many sources of air pollutants (predominantly related to fossil fuel extraction and combustion) also emit CO_2, whilst global warming intensifies meteorological conditions, influencing pollutant dispersion and accumulation.

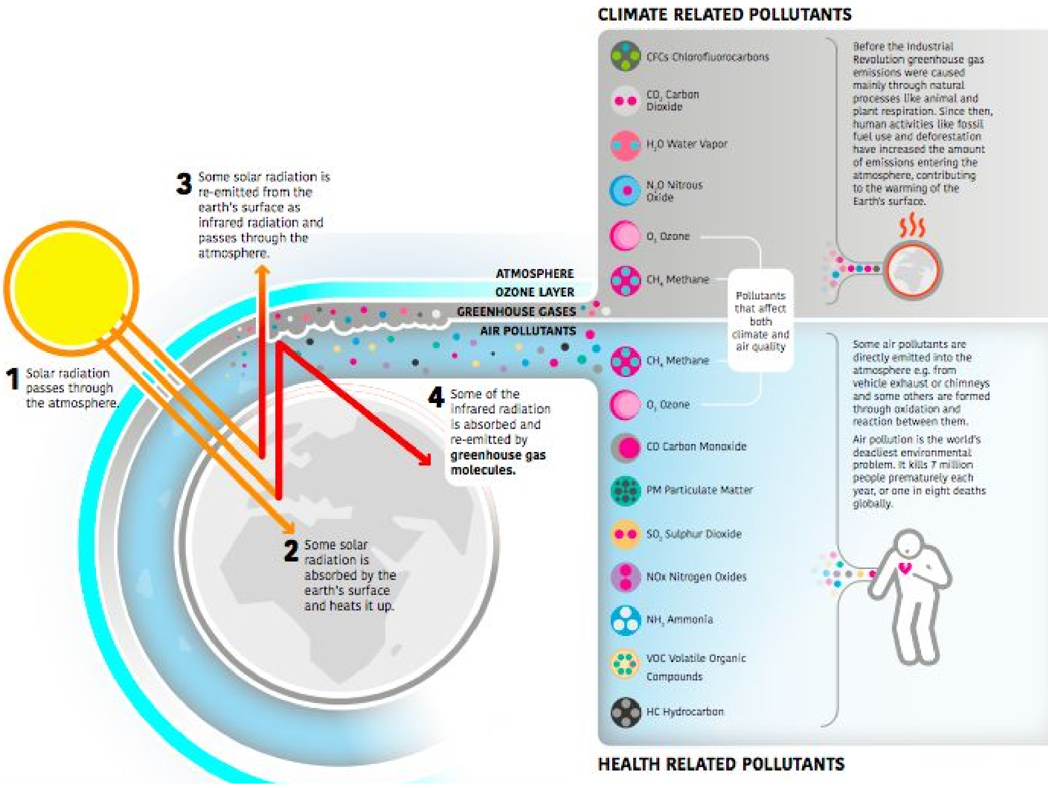


Figure 4 *The interaction between air pollution and climate change. Source: iSCAPE*

Thus, air quality tangibly ties the health of people and planet together. Yet, climate and health related pollutants may have diverse physicochemical characteristics, with equally diverse impacts and distributions in space and time.

Take $PM_{2.5}$, recognized as the most damaging pollutant in terms of human health. In Italy, the major pollutant emissions source is residential and commercial energy use. It typically has a lifetime of days.

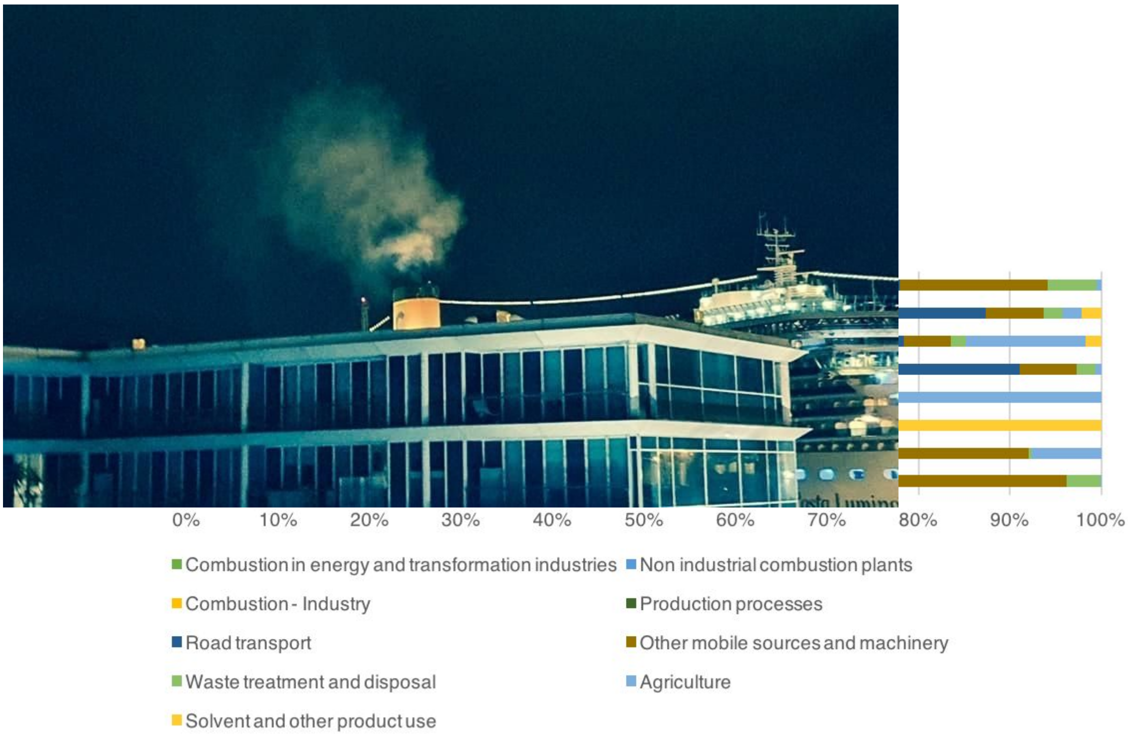


Figure 5 *Contribution to Italian emissions from the main source sectors, 2018*

In Italy, 77% of premature deaths attributable to air pollution may be due to $PM_{2.5}$ exposure. This is a public health concern first and foremost, with the highest impact localized at the emission sources, yet with long-range transport capacity.

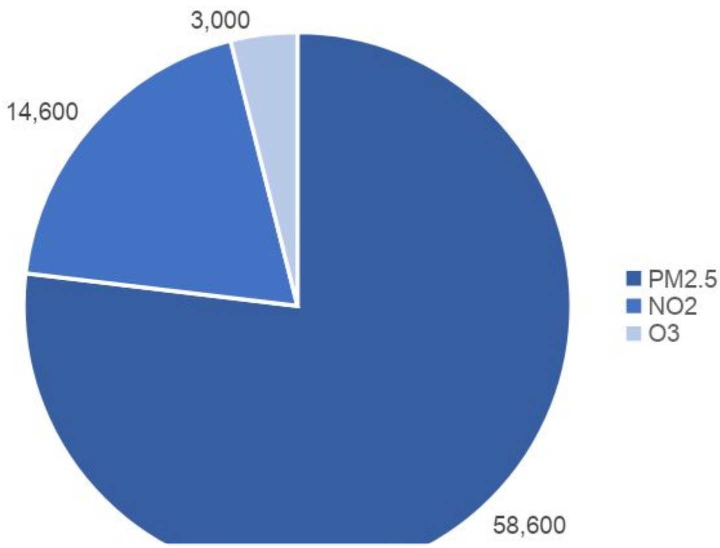
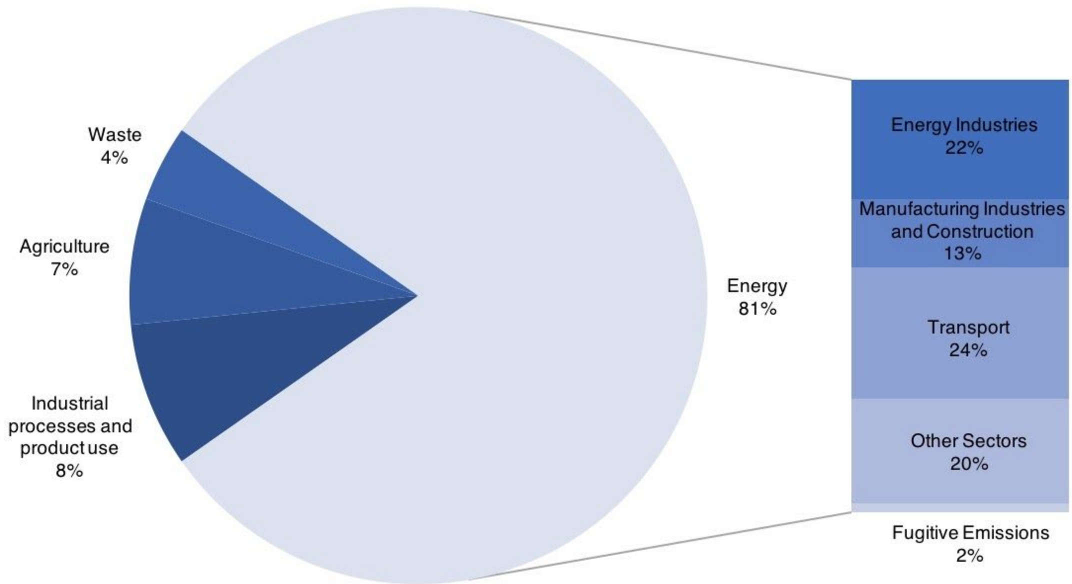


Figure 6 *Premature deaths attributable to PM2.5, NO2 and O3 exposure in Italy, 2016. Source: EEA.*

CO_2, meanwhile, the gas with the greatest climate forcing impact, represents predominantly a planetary health threat. In Italy, as elsewhere, the greatest source is the energy sector, within which transport is the major source. Once emitted, CO_2 has a lifetime of around a century in the stratosphere, which is well mixed.



Atmospheric CO_2 concentration are likely to increase as the century progresses. Current policies are projected to reduce baseline emissions and result in 3°C warming above pre-industrial levels. Alongside biodiversity loss, climate change as measured by CO_2 ppm is a prominent driver of climate breakdown, which has global consequences.

It is pertinent to note that with regards to both national air pollutant and greenhouse gas emission inventories, contributions from international shipping and aviation are *currently excluded*. If international shipping were to be a country, it would be the sixth largest in terms of CO_2 emissions[12]. In Europe, shipping contributes to 18% of both NO_x and SO_x emissions, and 11% of $PM_{2.5}$, and with projected global trade, total shipping emissions are expected to quadruple from 1990 to 2050[13].

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[12] Balcombe, P *et al*, *Energy Conversion and Management*, 2019, 182, 72-88

[13] T. W. P. Smith *et al, Third IMO Greenhouse Gas Study 2014* (International Maritime Organization, 2014)

__Table 3__ A comparison of per capita energy consumption between quarantine and business-as-usual scenarios.

		Quarantine conditions	Normal conditions
Engaged power kW		3,900	4,900
Occupancy		100	3,760
Port call duration (hr)		24	10
Energy expended (kWh)	**per day**	93,600	49,000
	pro capita	936	13.0
	pro capita / hr	39	1.3

Per capita electricity consumption in Italy is estimated at 4,715 kWh in 2018, corresponding to 12.9 kWh/day (0.54 kWh/hr). It seems that the evaluation of electricity consumption for both cruise ship worker and general citizen in this framework may be underestimated. According to the IMO, normal berth power demand would, in line with quarantine levels of crew, correspond to 2890 kWh per capita per day, a value ~ 223 times that of an average citizen. Still, the magnitude of consumption disparity is stark.

IV Thoughts

Iif the power engaged at berth per ship is so low (4.9 MW) under normal circumstances, the motivations behind the Savona Port Authority's opposition to shore power connections -- that power requirements would be too high -- are difficult to justify.

Shore power is indeed a mature technology with high potential to abate local air pollution[14]. The role of international regulation (e.g. adoption of Emission Control Areas) is critical for wider implementation, in addition to correctly balanced economic incentives and political will.

The advantage of large ships are categorically not economies of scale (a capacity to fit more passengers per unit of volume), but quite the opposite - more attractions for

[14] UK Department for Transport (DfT) , 2019, ***Reducing the Maritime Sector's Contribution to Climate Change and Air Pollution*****,** Dr. Tristan Smith (UCL/UMAS), Chester Lewis (E4tech), Jasper Faber (CE Delft), Cavin Wilson (Frontier Economics) and Kat Deyes (Frontier Economics),

the accommodated passengers. Life on the ship is designed not only to satisfy a diverse range of customers, but to capture, through innovation, higher spending levels on board[15].

Since the Savona Porto Elettrico group began applying pressure on local authorities, the Mayor has expressed a desire to extend air quality monitoring capacity. However, the existing evidence is already comprehensive and concrete. The data undeniable, numbers of avoidable deaths well documented.

Other Italian ports afflicted by stalled cruise ships at the time of writing are Ancona, Naples, Civitavecchia and Genoa. In the UK there are 5 ships in the port of Southampton. There are also ships in German ports, Spain etc.

Jack Wright, 30th May 2020

[15] Núñez-Cacho P *et al, Heliyon,* 2019, 5, e01280.