

PERSPECTIVE

Oil refining in Sicily: A critical perspective looking to the future

Abstract

Hosting close to half of Italy's oil refining capacity, Sicily is home to four petroleum refineries, one of which ended operations in 2014–2015. Following an updated outlook of Sicily's oil infrastructure, this study provides both a critical perspective as to where oil refining in Sicily currently stands and a substantial view into its near future. We conclude offering a clue on how the autonomous Sicily's government might act to face the consequences of the undergoing profound changes summarized herein.

1 | INTRODUCTION

Aptly called by a historian a “geopolitical oil rig,”¹ Sicily hosts in its east lands, next to the harbor towns of Milazzo, Augusta, Priolo, Melilli, Siracusa, and Gela, four large petroleum refineries, one of which (Gela) in 2015 ended to operate. Not all the oil refined in these large refineries originates though tankers sailing from oil-rich countries because Sicily also hosts several oil rigs and offshore platforms in the southeastern area of the island where the presence of oil was known since early nineteenth century.²

We briefly remind that an oil refinery's unit converts crude oil, through a series of physical and chemical processes such as distillation, and catalytic desulfurization and conversion (cracking, hydrocracking, etc) into valued fuels and petrochemical feedstock including liquefied petroleum gas (LPG), virgin naphtha, gasoline, jet fuel, diesel, and fuel oil.³ The crude oil is retrieved from the storage tanks, typically having a capacity of 80–150 thousand cubic meters, regularly filled through pipelines carrying crude oil either unloaded from a tanker or from oil wells.

Writing in the early 1980s, Dutch scholars were noting how “the island's geographical position is advantageous both for importing crude oil supplies and for the distribution of refined products to home and international market;”⁴ adding that “at the onset of the 'eighties, the European off refinery industry faced a serious overcapacity in distillation due to the decline of demand and late effects of investments made in

the early 'seventies. Closures and cut-backs will not be distributed evenly across Europe, but affect notably regions like Holland and Italy (in particular Sicily and Sardinia) whose refining capacity far exceeds their own demand.”⁴

Actually, as mentioned above, Sicily's refineries were built targeting Italy's (and not Sicily's) fuel market. Indeed, their capacity amounts to about half of Italy's overall oil refining capacity. Not only were existing refineries profitably working for decades after the above mentioned 1984 forecast, but in 1997 the capacity of Sicily's largest refinery in Priolo with a refining capacity of 11 million tonnes per year, was risen first to 12 and then to 16 million t/a.

In the late 1990s, the price of oil was very low, economy in Italy and Europe was flourishing and oil refining was by far the most important economic activity in Sicily.

Following the great financial crisis started in 2008, Italy's economy started an unprecedented decline. Between 2008 and 2013 unemployment doubled because national income fell by 9%, per capita income by 11%, and industrial production by 25%.⁵

Following the adoption of a common currency with Europe's main countries, Italy since 2002 no longer can devalue its currency to stimulate export, whereas low and declining salaries (“austerity”) enforced by governments to meet Maastricht's treaty requirements (State annual deficit lower than 3% of gross domestic product) caused a similarly unprecedented decline in internal demand. With internal demand so low, public and private investment dropped resulting in deflation.⁶

With regards to energy, the outcome has been a dramatic reduction in oil consumption, which dropped from 93.5 million tonnes in year 2000 to 57.4 million tonnes in 2014.⁷ Since then, it never recovered, regardless of widening the number of Italy's oil industry companies monitored in 2018, when Italy's consumption of oil amounted to 60.4 million tonnes.⁸ Under these circumstances, the aforementioned “serious overcapacity in distillation due to the decline of demand”⁴ readily materialized, and several refineries in Italy were closed, including one in Sicily's Gela.

Add to this that almost concomitantly, Italy (and Sicily) suddenly started to adopt wind power and solar photovoltaic

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to generate power on mass scale, to such an extent that several oil-burning thermoelectric plants were closed, including the 210 MW power plant built in Augusta in 1959 to supply power to eastern Sicily and to the new oil refineries.

Renewable power generation on utility-scale in Sicily is actually so effective that during the first half of 2015, for the first time the zonal electricity price in Sicily decreased below the national wholesale price in Italy.⁹

This study provides both a critical perspective as to where oil refining in Sicily currently stands and a substantial view into its near future. We conclude offering a clue on how the autonomous Sicily's government might act to face the consequences of the undergoing profound changes summarized herein.

2 | SICILY'S OIL INFRASTRUCTURE

Purchased in 2018 by Algeria's national oil company, the 175 000 barrel-per-day Augusta refinery was the first refinery built in Sicily. Through depots in Augusta, Palermo, and Naples the refinery has supplied fuels and other oil-derived products across the Italian national territory since 1949. Due to lack of sufficient refining capacity, a rapidly developing economy and a young population, Algeria recently recorded a surge in refined fuel demand. For example, the country spent \$2.5 billion for fuel imports in 2017, namely three times more than the \$800 million paid in 2016.¹⁰

Entirely owned by a Russian company since 2013 another large refinery is located in Priolo. Its northern site operates since 1964 whereas the southern site started operations in 1975. Consisting of three production sites interconnected each other through a system of pipelines, one of which generates electricity burning fuel syngas produced from the gasification of the refinery TAR (asphalt) in a 549 MW power station, the refinery has a 16 million t/y refining capacity.¹¹ The plant produces large amounts of naphtha for the integrated production of olefins in the nearby petrochemical plant.

Located on the northeastern coast of Sicily and operated by a joint venture between Italy's and Kuwait's national oil companies, the 200 000 barrels per day Milazzo oil refinery is amid Italy's four largest refineries.¹² Comprising two crude distillation units, the plant specializes in the production of light fuels (gasoline, diesel, and kerosene). When it started, in 1961, the production of fuel oil for thermoelectric power plants was truly significant. In the early 1990s, the refinery units were updated to ensure a reduction of fuel oil production in favor of distillates of improved quality (lower sulfur content).¹³

Built in the early 1950s by Italy's national oil company, the Gela refinery had a refining capacity of 100 000 barrels/d, mostly refining heavy crude oil obtained from nearby fields offshore Sicily. In 2015, the refinery that was integrated with nearby petrochemical plant stopped operations.

An agreement was signed in late 2014 aiming to convert the latter refinery into a biorefinery designed for processing 750 000 tonnes of palm oil and its by-product palm fatty acid distillate, and 400 000 tonnes of nonedible waste (recycled used and frying oils and animal fats) as feedstocks to make biodiesel and green diesel fuel.¹⁴ The latter, added to conventional diesel fuel, determines a reduction of ultrafine particulate matter (<2.5 μm) reduction of up to 40% thanks to an increase of cetane number (>55), contributing to better combustion efficiency, acoustic comfort, and fuel efficiency.¹⁵

As mentioned above, Sicily hosts several oil (62 in 2016) and natural gas wells (44 in 2016), as well as offshore extraction platforms (3 in 2016) not distant from Sicily's southern shore.¹⁶ In 2016, the overall amount of oil extracted in Sicily approached 1 million tonnes, 679 000 t inland (from 5 different sites: Gela, Giaurone, Irminio, Ragusa, and S. Anna) and 278 000 t at sea.

To visualize how Sicily's refineries actually serve Italy's fuel needs, it is enough to learn that the amount of crude oil entering Sicily's refinery ports in 2016 amounted to 24.57 million tonnes (Table 1).¹⁶

Oil consumption in Italy literally collapsed to 57.3 million tonnes in 2014 from 93.5 million in 2000 (−39%, Figure 1).⁷

TABLE 1 Crude oil entering Sicily's four refinery ports (2010-2016)¹⁶ Data for year 2005 are included for comparison^a

Year	Augusta (10 ³ t)	Gela (10 ³ t)	Milazzo (10 ³ t)	Priolo (10 ³ t)	Total (10 ³ t)
2005					35 110
2010	11 320	2110	7760	7570	28 760
2011	9880	1730	8480	7000	27 090
2012	9875	720	7970	7440	26 005
2013	7820	305	7400	6510	22 035
2014	7160	125	7110	7010	21 405
2015	8180	0	8060	7230	23 470
2016	8180	0	8230	8160	24 570

^aRegione Siciliana, Assessorato regionale dell'energia e dei servizi di pubblica utilità, *Lavorazioni e consumi di prodotti petroliferi anno 2008*.

This means that in 2014, oil refined in Sicily contributed close to 40% (37.3%) to Italy's overall needs, showing evidence of the “geopolitical oil rig” definition of Sicily by the historian mentioned above.¹

The reduction in the amount of oil refined in Sicily between 2005 and 2016 (−30%) parallels that of Italy and explains why two refineries were sold to new owners, and one was shut down to be reconverted into a biorefinery.

All this happened during a period of time in which the number of internal combustion engine (ICE) vehicles in Italy reached (in 2016) the historic record number of 50 155 380 units (around 38 million cars, 6.6 million motorcycles, 98 000 buses and 4.6 million trucks, and delivery vehicles).¹⁷

Three years later, the number of battery electric vehicles sold in Italy in 2019 will cross the 10 000 units threshold, while across the world the figure has surpassed 5 million in a truly booming market driven by ever lower cost and larger availability of Li-ion batteries.¹⁸

It is therefore useful to ask what might happen to Sicily's oil refining infrastructure while the amount of low-cost electricity produced in Sicily from freely available solar and wind energy using today's low-cost photovoltaic (PV) and wind power technologies continues to grow.

3 | OIL, SOLAR ENERGY, BIOECONOMY

As put it by an anthropologist concluding a recent research on the long trajectory of petrochemical industrialization in southeastern Sicily “for Sicily's people, petroleum represents both a blessing and a curse.”¹⁹

Feeding and upholding modern society, oil “is crucial not only for driving the energy services of modern society, but also as basic feedstock for producing polymers.”²⁰ Out of the five conventional commodity thermoplastics (polypropylene, polyethylene, polyvinyl chloride, polystyrene, and polyethylene terephthalate), polyethylene is produced in Sicily at an industrial plant in Ragusa receiving the ethylene feedstock from a 400 000 t/a plant at Augusta petrochemical site. Petrochemical productions in Gela, which included that of polyethylene, ended in 2009.

From an economic viewpoint, Italy's 2018 consumption levels of refined oil barely exceeding 60 million tonnes (60.8 million),²¹ when the number of electric cars circulating in Italy merely exceeded 10 000 units and that of electric buses did not reach the 100 unit threshold, indicate that Sicily's refineries, with their refining capacity exceeding 45 million tonnes, may soon face issues of economic sustainability.

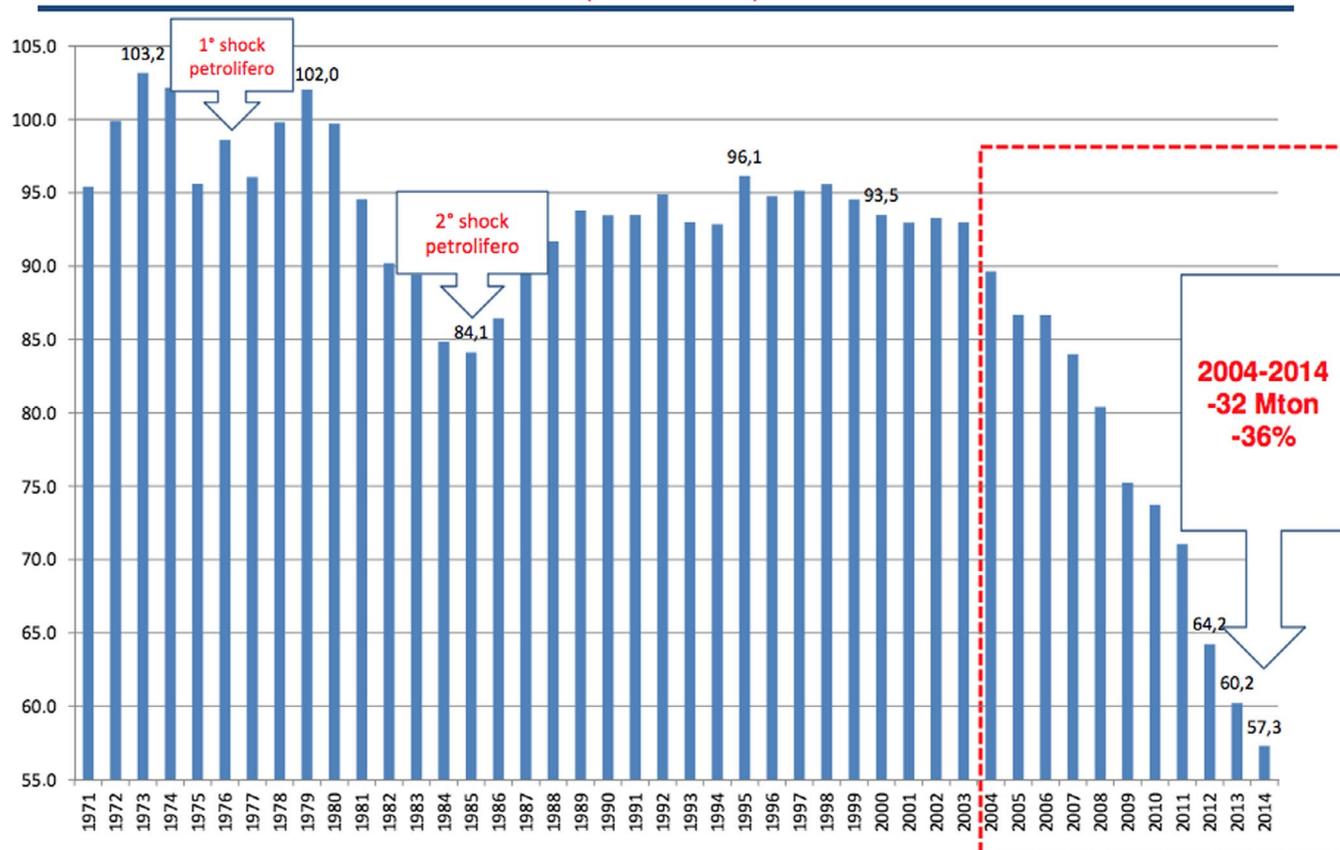


FIGURE 1 Oil consumption in Italy (1971-2014). [Image courtesy of R. Pistacchio, reproduced from Ref. ⁷, with kind permission]

FIGURE 2 Photovoltaic (*left*) and wind (*right*) power installed in Italy between 2012 and June 30, 2019. [Image adapted from Ref. 27, courtesy of Terna]



Furthermore, the forthcoming ban of nonbiodegradable plastic bags and other disposable single-use plastic objects in several countries and the booming bioplastics production in China, suggest a forthcoming drop in the global demand of conventional commodity thermoplastics, starting from polyethylene used for packaging and in agriculture.²²

We have shown in 2016 that wealth (the global gross domestic product, W_GDP) can be modeled as a power function of the global population (W_Pop), as shown in Equation (1)²³:

$$W_GDP = (0.0077 \pm 0.0008)W_Pop^{(4.69 \pm 0.06)} \quad (1)$$

Moreover, according to the latter study, the total energy consumption is linearly correlated with the global population.

At least in the short term, oil appears as a hardly replaceable energy source.²⁴ The relation above therefore says that, in order to keep pace with “natural” wealth and global population growth identified by the aforementioned model combining the competing dynamics of oil price, economic growth, and oil extraction costs, by year 2025 oil companies should make globally available an extra output of >11 million b/d even to keep the oil fraction in the energy mix at the current level around 33%, (or >32 million b/d to achieve the desirable threshold of 40% for the oil fraction in the energy mix).²³

Furthermore, said extra amount of oil should be of high energy returned per energy invested (EROI) in its extraction, and therefore of low cost. In this respect, the exceptional output of shale oil in North America has been almost entirely driven by debt, in its turn made possible by prolonged low or even negative interest rates. Now that the debt is maturing, several shale oil companies are exiting the market due to lack of profitability.²⁵

The inevitable outcome, when the unprofitable shale oil production will be over, is a new (and imminent)²⁶ rise in the

oil price which will make ever less convenient to refine oil faraway from its extraction wells, driving upwards the costs of fuels and making electric vehicles even more convenient than today.

In Italy too, driven by the widespread adoption of today's low-cost solar PV and wind energy, the electrification of the energy end uses, including electric vehicles (EVs) and building heating using heat pumps, is growing at fast pace. By June 2019, Italy hosted a 20.35 GW installed PV power and 10.6 GW of wind power.²⁷ Most of this power was installed in the course of the last decade (2008-2018) and, contrary to most forecasts, its growth (Figure 2) did not stop even after PV feed-in-tariff incentives were suddenly canceled by mid-2012.

Investigating the value of solar PV power in the Italian wholesale electricity market (IPEX), in 2014 we developed a model to simulate and predict the monthly average electricity prices in peak hours.²⁸

The merit-order effect of the PV generation in Italy thereby computed (around -2.9 €/MWh per each additional GWh of PV production), turned out to be in line with subsequent evolution of IPEX market prices, fully in line with wholesale electricity markets with significant PV penetration. This means that electric utilities, whose revenues and profits are negatively impacted by diminishing wholesale prices, are left with one of two options, both of which directly impact oil and natural gas industries.

One option is to increase sales of electricity to new customers such as the owners of battery EVs. Another is to increase their production of electricity generated at low cost from sunlight and wind, selling it on the day ahead wholesale electricity market competing with thermoelectric power plants now routinely producing at higher costs.

In both cases, the outcome of this new scenario we first called in 2008 “Helionomics”²⁹ is that electric utilities are

no longer partners (ie large customers) of oil companies, but rather competitors.

For example, by early 2018 Sicily hosted 1323 gas stations,³⁰ regularly refilling with diesel, gasoline, and LPG fuel more than 3.2 million cars, 650 000 motorcycles, 400 000 trucks, and 7400 buses.

Yet, in 2017 Italy's national electric company started to install EV charging points across the island. Investing €8.5 million (50% of which from taxpayer money from European EVA+ project),³¹ the company in partnership with other firms in Italy and abroad built a network of 200 public fast-charging stations in Italy and Austria. In late 2017, one such new 22 kW charging stations for EVs was installed in Augusta, the city hosting Sicily's first refinery and largest petrochemical plant.

To anticipate the impact of EV mass adoption on oil refining in Sicily it is instructive to review the case of Messina, a city in Sicily where a first electric fleet of 16 electric buses started operation in mid-2019. Alone, these buses allow the city's public transport company to save about 200 000 L of diesel fuel every year.³²

As the price of Li-ion battery plunges with production levels expanding at fast pace the oil-powered bus will be the first conventional vehicle whose production will stop in the next few years.³³ It is just a matter of time before all 7400 buses in Sicily and 98 000 in Italy will be replaced by electric buses.

Lithium-ion battery production increased from 65 GWh in 2015 to 180 GWh by 2019. Several new large battery factories are under construction across the world. A conservative estimate suggests that, in 5 years only, by 2023 the global capacity and output will exceed 1234 GWh (1.234 TWh).³⁴

When, after 250 000 km driving, the EV battery pack loses 10%-20% of its original capacity, it is reused for 10 years in stationary energy battery system applications,³⁵ through which intermittent renewable electricity is made even more reliable than electricity supplied by the grid.

Along with a proton exchange membrane (PEM) hydrogen fuel cell (with a 1000 kWh capacity) using solar H₂ produced with an alkaline electrolyzer via PV electricity only, a 600 kWh Li-ion battery pack is being installed in Sicily's Stromboli island fraction of Ginostra.

All energy originates from a nearby 170 kW PV park whose first 100 kW portion was installed in Stromboli's Ginostra as early as of 2004 (Figure 3).³⁶

However, the obsolete lead-ion batteries installed in 2004 quickly deteriorated leaving no other option than to burn diesel fuel in the generator set. For years, diesel fuel has been brought to this area of the island using a helicopter (Figure 3).

Now, the entire electrical load will be met at low cost using the PV-battery-hydrogen hybrid system affording high-quality electricity at a levelized cost of electricity (LCOE) of 0.78 €/kWh, compared to 0.94 and 1.02 €/kWh for the system with only battery and only hydrogen, respectively.³⁷



FIGURE 3 An helicopter (*top*) has been regularly used to bring diesel fuel to the diesel-fueled power generator of the Ginostra village, after the lead-ion batteries coupled to the original 100 kW PV station built in 2004 (*bottom*) quickly went out of use. [Images adapted from: www.remote-euproject.eu, with kind permission]

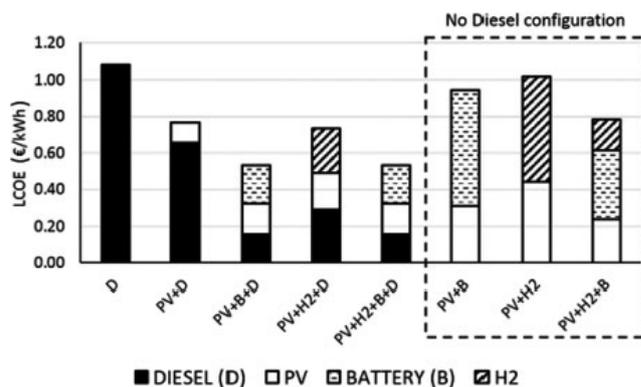


FIGURE 4 LCOE for the different configurations of the stand-alone system to power the village of Ginostra, in the Stromboli island (D = Diesel; PV = photovoltaic; B = battery; H₂ = hydrogen). [Image retrieved from Ref. 37, with kind permission]

With its uniquely high energy density (40 kWh/kg), indeed, hydrogen can nicely meet the seasonal energy demand peak due to tourism when the number of people hosted in Ginostra goes from a few units during winter to several hundreds during summer.

In terms of LCOE, the combination of PV, battery, and diesel generator is still the most convenient (Figure 4). Yet,

with solar hydrogen generated by splitting collected rainwater, no delivery of diesel fuel will ever be needed, making the method the most suited to power entire islands not only in Sicily, but actually across the world's seas.³⁸

Solar PV generation plus storage in energy storage systems is feasible and convenient not only in remote areas. Numerous large installations (storage >100 MWh and PV parks exceeding 50 MW of power) already exist across the world, whose exceptional performance in balancing and regulating the grid has allowed to almost entirely displace natural gas thermolectric generators previously used.³⁹

In brief, after more than a decade of skepticism concerning renewable energy, and solar PV in particular,⁴⁰ today's electric utilities are fully aware of the synergistic and beneficial effects on energy production costs due to the concomitant expansion of battery EV adoption and growth of the PV energy generation, reflecting the greater and beneficial impact of the PV generation with increasing electricity demand.⁴¹

It is instructive, in this respect, to learn that one large petrochemical company based in Sicily's Augusta petrochemical site has purchased a fleet of 40 modern EVs replacing 40 diesel fuel-powered passenger cars, and it also installed two external charging points (adding to 15 within the site) available to external customers to recharge their own EVs.⁴² Electricity, indeed, is self-generated by the company burning natural gas abundantly available at the site.

4 | OUTLOOK AND CONCLUSIONS

“For historical and geographical reasons linked to the position of the island in the Mediterranean sea,” concluded his SuNEC 2013 invited lecture on the end of the culture of oil novelist, playwright and screenwriter Cappellani, “the dominant energy culture and Sicily are closely interconnected.”⁴³

That a “dominant energy culture” existed for decades in most world's countries and regions, including Sicily, is testified by the impressive achievements with electric vehicles and renewable energy of China. While in most world's countries, cities, and companies were (and still are) carrying out “experimental trials” with electric buses, China had already replaced 400 000 diesel-powered buses with battery electric buses, displacing consumption of around 177 000 barrels per day of diesel fuel.³³

At the same time, the country installed over 174 GW of PV capacity and over 184 GW of wind power, generating 177.5 TWh of electricity from sunlight and 366 TWh from wind only in the course of 2018.⁴⁴

Concluding in 2015 one of the first studies on the impact of the forthcoming mass adoption of EVs on the power market in the presence of significant photovoltaic generation, we were writing that “as the solar revolution continues with

electrification of transportation now slowly, but inexorably, taking place, governments in both developed and developing nations should wisely continue to encourage the adoption of electric mobility through a number of well-known incentives (tax breaks, free parking, free access to reserved areas etc).”⁴¹

“The outcomes for their countries” we added “will be... eminently advantageous from an economic viewpoint. Incentives will be rapidly repaid by the fall of hydrocarbon imports, as well as by the fast reduction in electricity costs as the impact of PV generation on the power market is synergistically magnified by a growing electricity demand.”⁴¹

This *economic* advantage will now drive mass adoption of EVs in Europe, regardless of lacking Li-ion battery plants and the limited number of EV models made available until the end of 2019 by automotive manufacturers based in Europe. Early signs of change became evident in the first half of 2019, when the number of EVs sold in France (21 006) and in Germany (31 059) approached for the very first time the 2% share of the total new car market.

Italy will follow shortly as a large number of new EV passenger car is due to reach the marketplace in 2020 and 2021 after two decades of postponements and announcements. Automotive manufacturers beyond China, indeed, have no other option to avoid to be brought out of business likewise to what happened to most solar cell and PV module manufacturers based in Europe.

A similar shift will happen with bioplastics manufacturing (whose current production levels amount to less than 1% of total plastics market)⁴⁵ in which India, and not only China, will play a pivotal role in rapidly expanding production by quick advances in both process (chemical and biochemical process) and product innovation.²²

Under these global, but “closely interconnected” conditions emphasized by Cappellani,⁴³ oil refining in Sicily will undergo its second major, and this time conclusive change, as the only oil fuel needed will be highly refined “jet fuel” used to power airplanes.

Even ships, indeed, are undergoing rapid electrification, first with battery-electric ferries already in operation in Norway and Denmark, and then with hydrogen fuel cell ships adding to hydrogen-powered trains already deployed in Germany.¹⁸

At the end of 2019, a search using the “oil in Sicily” query in an academic online search engine will return only a few articles,⁴⁶ with most of the scientific articles retrieved dealing with olive oil or with citrus essential oils, both of which are manufactured on large scale in Sicily.

Starting in the late 1940s, the newly formed Sicily's autonomous governments following the 1946 special autonomy statute, largely supported the creation of a large oil refining industry in the island.¹

Similarly, entering the third decade of the 21st century, tomorrow's Sicily's governments are called to guide and support the transition of Sicily's economy from oil refining

and petroleum-based chemistry to solar energy and biobased productions.²⁹

If they will be successful, the fate of Sicily's large oil refineries will be different from that occurred to Sicily's large sulfur mines, all of which, with the rapid emergence of the oil industry in the 1950s, quickly became an historic heritage of the past.

KEYWORDS

bioplastics, electric vehicle, energy transition, oil refining, sicily

ACKNOWLEDGMENTS

This article is dedicated to Ottavio Cappellani, eminent writer and novelist, on the occasion of his 50th birthday. Thanks to Alberto Pierobon, Sicily's vice President for energy and public services, for appointing one of us (MP) as one of his renewable energy advisors. We thank Nello Anastasio for making available on Flickr under CC BY-NC 2.0 license a photograph of a Sicily's refinery near Augusta. The photograph of the photovoltaic park in Sicily is courtesy of Manni Energy. Both pictures were used herein for producing the Table of Contents image.

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